7. キャパシティアセスメント

7.1　2018年～2019年

August 2019
JICA Expert Team

The Project for Introduction of Hybrid Power Generation System in Pacific Island Countries
July 2018～ June 2019 Training Evaluation
(Kosrae・FSM)

1. Executive Summary

To achieve the project purpose for FSM in the project of the introduction of the Hybrid Power Generation System, two main outputs [1. Enhancement of an appropriate and economical system for O&M of Diesel Generators (DGs) and 2. Establishment of a methodology for appropriate planning and O&M of Renewable Energy (RE)] are required.

As activities for these two outputs, training on basic knowledge of DG's and RE was provided in the above period.

2. Trainer List

No.	JCC Meeting		Core Trainer Name	Position	Comments
	JCC1	JCC2			
1) Operation and Maintenance of Diesel Engine Generators					
1	●	●	Robert Taualupe	Operations Manager (Electrical)	
2	●	●	Ronald Albert	Supervisor of Operator (Mechanical)	
3		●	Careston Alokoa	Power Plant Operator	
2) Plan for introduction of hybrid power generation systems					
1	●	●	Electrical Engineer		
2	●		Energy Efficiency Officer		
3	●	●	Customer Service Head, Admin. & Training Officer		
4	●	●	Operations Manager		
5			Customer Service Supervisor		
3) Operation and Maintenance of Renewable Energy generation system					
1	●	●	Robert Taualupe	Operations Manager	
2	●		Tolenoa Joe	Energy Efficiency Officer	
3	●	●	Gifford Sigrah	Distribution Foreman	
4		●	Ronnie George	Lineman-2	

3. Results

The training evaluation result for each task is shown in below tables. The Achievement evaluation of the trainers is the result of the discussion and judgment between the Experts Team members based in the average result of the level tests done in Fiji, second the active participation demonstrated during the training and third in the speed in knowledge acquisition during the practical training.

● **DEG Training (Micronesia・Kosrae)**	**Project Counterparts (Core trainers)**			**Other training participants**		
Name	Robert Taualupe	Ronald D. Albert	Careston Alokao	Hairom Livaie	Gerrado Protacio	
	Operation manager	PS operator	PS operator	Customer services	Electrical engineer	
(1) Operation & Maintenance of DG						
Operation of DG						
1) Can start-up/stop engines	3	2		2		
2) Can control DG according to the grid load	3	1		1		
3) Can trouble shoot the plant in case of faults	3	1		2		
4) Can Black start procedures	3	1		2		
5) Can check parameters of the DG in operation (temperature, pressure, voltage, frequency, etc.)	3	1		2		
6) Can measure and calculate specific fuel consumption	3	2		1		
7) Can explain the concept of Economic Dispatch Control (EDC)	2	1		1		
8) Can manage operation (running hours, selection of DG, numbers of units, maintenance schedule, etc.)	3	1		1		
9) Any other specific ability to be mentioned						
Average	2.9	1.3		1.5		
Maintenance of DG						
1) Can plan maintenance schedule (spare parts, staff, arrangements, etc.)	3	1		2		
2) Can plan maintenance of equipment of the power house (overhead crane, boiler, incinerator, etc.)	3	1		2		
3) Can plan and coordinate daily, weekly, monthly maintenance works	3	1		1		
4) Can supervise periodical maintenance works(daily, weekly, monthly)	3	1		2		
5) Can trouble shoot the plant in case of faults	3	1		2		
6) Can manage the planning for overhaul works	3	1		1		
7) Can supervise overhaul works (use of special tools, measurement equipment, etc.)	3	1		1		
8) Any other specific ability to be mentioned						
Average	3.00	1.00		1.57		
Training of Operation and maintenance of DG (20/Aug～27/Aug/2018)	Operation manager	PS operator				
Attendance days	6	6	—	—	—	
Mechanical Check Test	4	5	—	—	—	
Electrical Check Test		6	—	—	—	
Average	4	5.5	—	—	—	
Disel Power Generation Facility Overhaul Training in Kumejima (27/Sep～22/Oct/2018)		PS operator	PS operator			
1st Check Test	—	5	4	—	—	
2nd Check Test	—	8	7	—	—	
Average	—	6.5	5.5	—	—	
Training of Operation and maintenance of DG (18/Feb～25/Feb/2019)		PS operator	PS operator			
Attendance days	—	6	6	—	—	
Mechanical 1st Check Test	—	4	3	—	—	
Mechanical 2st Check Test	—	6	5	—	—	
Electrical 1st Check Test	—	5	2	—	—	
Electrical 2st Check Test	—	9	4	—	—	
Average	—	6	3.5	—	—	
Evaluation results (Max 10)	4	6	4.5			
Remarks, (JICA Expert team opinion) 3 : Well Done 2: Achieved 1 : One further step 0 : unachieved	2/Good knowledge of DG's	2/ Good participation in the training. Experienced in maintenance	2/ Good participation in the training. Experienced in maintenance			

● **RE Training (Micronesia・Kosrae)**	**Project Counterparts (Core trainers)Nov.2018**					**Other training participants**	
Name	Gerrado Protacio	Hairom Livaie	Robert Taualupe	Gifford Sigrah	Ronnie George	Toleona Joe	Ronald D. Albert
Item	Electrical engineer	Customer services	Operation manager	Distribution foreman	Lineman	Energy develop officer	PS operator
(2) Planning, Operation & Maintenance of RE generation system							
Grid integration of RE							
1) Knowledge of the issues in RE integration (frequency, voltage etc.)	3	2	3	1		2	
2) Can explain the difference of short-term and long-term output fluctuation of RE and their effect on grid operation	2	3	2	1		2	
3) Can calculate the maximum capacity of RE for grid-interconnection, in consideration of the effect of frequency fluctuation (short term fluctuation)	1	2	2	1		3	
4) Can calculate the maximum capacity of RE for grid-interconnection, in consideration the effect of demand fluctuation (long term fluctuation) without battery storage system	1	2	2	1		3	
5) Can derive the optimum capacity of RE, in consideration of the total generation cost	1	3	2	1		3	
6) Can plan solar home systems, and mega solar facilities	1	2	2	1		2	
7) Knowledge of kind of solar panels, batteries, inverters, etc.(characteristics and frequent uses)	2	2	2	1		3	
8) Knowledge of RE grid interconnection guideline	2	2	2	1		2	
9) Any other specific ability to be mentioned							
Personal Average	1.6	2.3	2.1	1.0	#DIV/0!		
Operation & Maintenance of RE (PV)							
1) Can establish maintenance schedule and checklist	2	2	3	1		3	
2) Can conduct periodical maintenance works	2	2	3	1		3	
3) Can conduct troubleshooting in case of faults	2	2	2	1		2	
4) Can use measuring instruments for maintenance works	3	2	3	1		2	
5) Any other specific ability to be mentioned							
Average	2.3	2.0	2.8	1.0	#DIV/0!		
Training of Operation and maintenance of RE (24/Jul～31/Jul/2018)				Distribution foreman			PS operator
Attendance days	—	—	—	5	—	—	5
RE Check Test	—	—	—	1	—	—	8
Average	—	—	—	1	—	—	8
Training of Operation and maintenance of RE (22/Jan～30/Jun/2019)	Electrical engineer		Operation manager				
Attendance days	6	—	6	—	—	—	—
RE Check Test	6	—	6	—	—	—	—
RE Check Test	9	—	6	—	—	—	—
Average	7.5	—	6	—	—	—	—
Evaluation results (Max 10)	7.5	—	6	1	—	—	8
Remarks,（JICA Expert team opinion） 3：Well Done 2: Achieved 1：One further step 0：unachieved	2/ Good knowledge of RE		2/ Good knowledge of RE	1/ Need more training			1/ Need more training

O&M for Diesel Engine Generators / YEAR GOAL ACHIEVEMENT Sheet / Kosrae (2019)

	Core trainers			**Other training participants**		
Name	Robert Taualupe	Ronald D. Albert	Careston Alokoa	Gerrado Protacio	Hairom Livaie	
General Evaluation (2019)	3	2	2	1	1	

【Score Standard】3P：Well Done / 2P: Achieved / １P：One further step / ０P：unachieved

FY2018 (Basic knowledge learning)						
・Understanding of Diesel Generators type, structure, operation principle and characteristic.	3	2	2	2		
・Understanding of mechanical devices on Diesel power generation. Purpose, type, characteristics etc. of each device.	3	2	2	1		
・Understanding of electrical components on Diesel power generation. Purpose, type, characteristics etc. of each electrical panels, etc.	3	2	2	2		
・Diesel engine performance curve, efficiency during operation, heat balance diagram, etc.	2	1	1	1		
・Operation and control method of diesel power generation facilities (governor free, automatic control devices, etc.)	2	1	1	1		
・Diesel generator Economical load distribution operation (EDC technology (basic knowledge・application))	2	1	1	1		
・Operation supervisory monitoring method	2	1	1	1		
・Proper maintenance of the diesel generation facility・(Electrical and Mechanical) Maintenance method (disassembly inspection item, cycle etc)	2	2	2	2		
・Inspection after disassembly inspection	2	2	2	2		
・Safety work training	2	2	2	2		
***CP acquire the basic knowledge of DG power generation facility. (Composition, operation and maintenance)**	2	2	2	2		
points	25	18	18	17	0	0
Full mark	22	22	22	22	22	22
score	114%	82%	82%	77%	0%	0%

※Total evaluation is made if the trainer has participate in more than 2 (two) trainings.

Grid Integration of RE Generation Systems / Year Goal Achievement Level Sheet / Kosrae (2019)

	Core trainers			**Other training participants**		
Name	Gerrado Protacio	Robert Taualupe	Casey Freddy	Gifford Sigrah	Ronald D. Albert	Hairom Livaie
General Evaluation (2019)	2	2	-	0	0	1

【Scoring Standard】3P：Well Done / 2P: Achieved / １P：Nearly achieved / ０P：Much room for impovement

FY 2018 (Acquisition of Basic Knowledge)						
・Impact on the power quality caused by implementation of RE.	2	2	-	1	1	2
・Basic knowledge of allowable amount of RE. (algebraic method, HOMER software)	1	1	-	0	0	1
・Basic knowledge of Hybrid systems	2	2	-	1	1	2
***CP will acquire the basic knowledge of Hybrid power generation.**			-			
Points	5	5	-	2	2	5
Full mark	8	8	-	8	8	8
Score	63%	63%	-	25%	25%	63%

※Total evaluation is made if the trainer has participate in more than 2 (two) trainings.

RE Operation and Maintenance Training /Goal Achievement Level Sheet / Kosrae (2019)

	Core trainers			**Other training participants**		
Name	Robert Taualupe	Gifford Sigrah	Ronnie George	Ronald D. Albert		
General Evaluation (2019)	2	2	-	2		

【Scoring Standard】3P：Well Done / 2P: Achieved / １P：Nearly achieved / ０P：Much room for impovement

FY 2018 (Acquisition of Basic Knowledge)						
・Understanding of the types, structure, operation principle and characteristic of the solar cell.	2	2	-	2		
・Role of peripheral equipment of solar power facilities (connection box, PCS, distribution board, etc.)	2	1	-	1		
・How to process and utilize photovoltaic power generation measurement system (solar radiation intensity, total output power etc.)	1	1	-	1		
・Plan and installation method of solar array (practical exercise)	2	1	-	1		
・Summary from Plan to implementation of solar power system.	2	1	-	1		
・Economic study.	1	0	-	0		
・Appropriate maintenance of solar power generation system. Maintenance method (inspection item, cycle etc).	2	2	-	2		
・Inspection after installation (IV checker, open circuit voltage, insulation resistance measurement, etc.)	2	2	-	2		
・Training on working safely	2	2	-	2		
***CP will acquire the basic knowledge of solar power generation facilities. (Composition, operation and maintenance)**	2	2	-	2		
Points	18	14	0	14	0	
Full mark	18	18	18	18	18	
Score	100%	78%	0%	78%	0%	

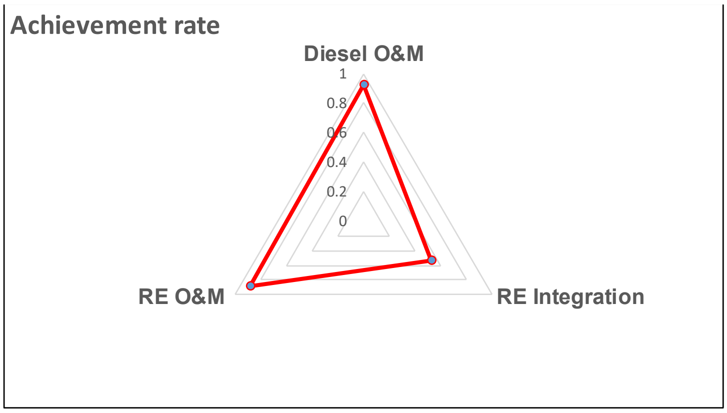
※Total evaluation is made if the trainer has participate in more than 2 (two) trainings.

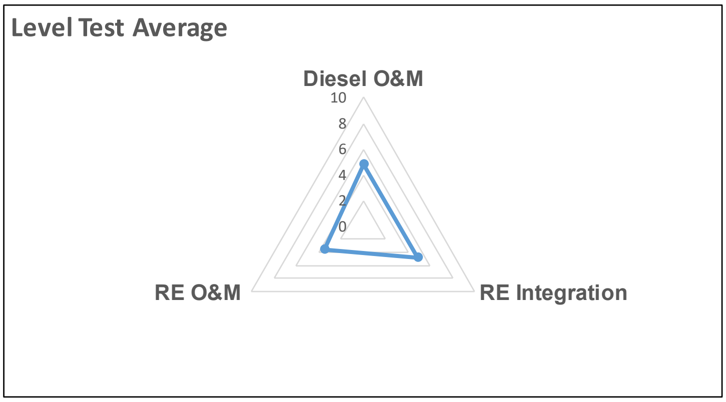
Diesel O&M		
Name	Test points	Achievement
Robert Taualupe	4.00	113.6%
Ronald D. Albert	6.00	81.8%
Careston Alokoa	4.50	81.8%
Average	4.83	92.4%

RE Integration		
Name	Test points	Achievement
Gerrado Protacio	7.50	62.5%
Hairom Livaie	–	62.5%
Robert Taualupe	6.00	62.5%
Gifford Sigrah	1.00	25.0%
Ronnie George	–	–
Average	4.83	53.1%

RE O&M		
Name	Test points	Achievement
Robert Taualupe	6.00	100.0%
Gifford Sigrah	1.00	77.8%
Ronnie George	–	–
Average	3.50	88.9%

KUA average	Test points	Achievement
Diesel O&M	4.83	92.4%
RE Integration	4.83	53.1%
RE O&M	3.50	88.9%





End

7.2　2019年～2020年

August 2020
JICA Expert Team

The Project for Introduction of Hybrid Power Generation System in Pacific Island Countries
July 2019 to June 2020 / Training Evaluation
(Kosrae / FSM)

1. Executive Summary

In order to achieve the purpose of "Introduction of hybrid power generation systems in Pic's" project, two main outputs "1. Enhancement of appropriate and economical system for O&M of Diesel Generators (DG's)," and "2. Establishment of the methodology for appropriate planning and O&M of Renewable Energy (RE)" are required.

As activities for these two outputs, following the training on basic knowledge of DG's and RE provided in FY 2018, the following training was provided in FY 2019.

- **Enhancement of appropriate and economical system for O&M of Diesel Generators (DG's)**

Training focused mainly in hands-on training such us measuring of fuel consumption rate, maximum explosion pressure (Pmax), vibration etc., also inspection of circuit breaker, measurement of the current and insulation resistance of auxiliary equipment to verify the operating state of the DG facility was conducted.

In the training for performing OH, training on using various measuring instruments provided by the JICA expert team was conducted. Necessary verification of spare parts (dimension), meters (pressure, temperature) in boards, conditions of circuit breakers, etc. and record of the measurement results using the necessary sheets was performed.

As a result of the training, it appears that the core trainers (Mr. Robert, Mr. Ronald) were able to achieve about 87% of the training objectives based on the tests conducted on-site and the findings from the expert team members.

The team of experts advises to KUA to regularly use the measuring instruments in order to increase the skill of the personnel, which will result in an efficient operation and maintenance of the entire power plant.

- **Establishment of the methodology for appropriate planning and O&M of Renewable Energy (RE)**

Training focused on hands-on training was conducted to verify the actual operating status in FSM's PV facilities, training such as IV curve measurement and verification of strings connections using equipment provided by the JICA expert team, also reparation works, update of inspection check sheet and manual of O&M was conducted.

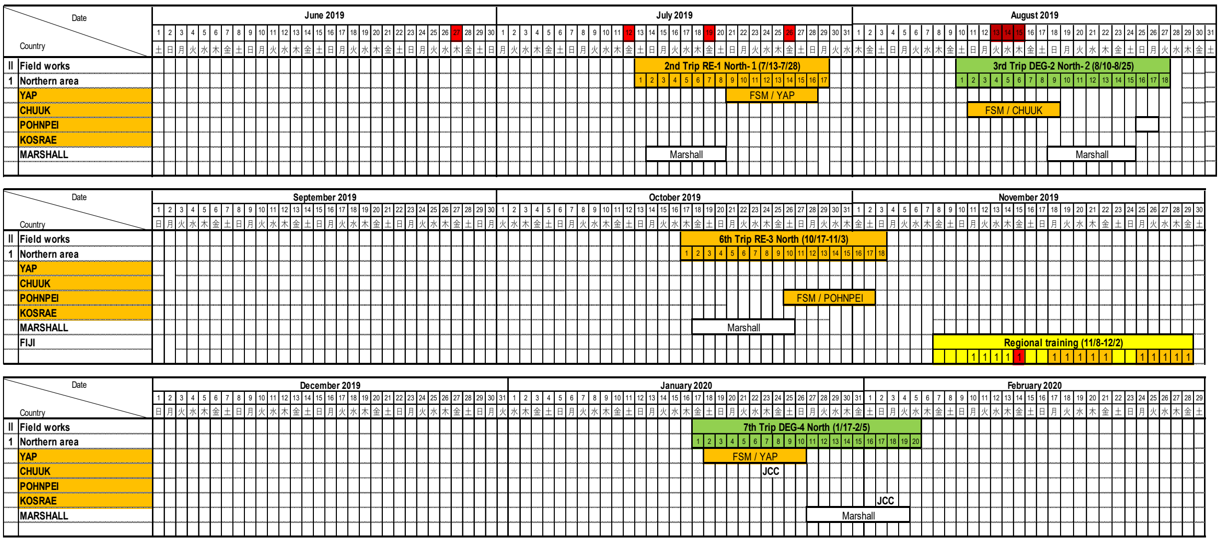
As a result of the training, it appears that the core trainers for RE were able to achieve about 76% of the training objectives based on the tests conducted on-site and the findings from the team members.

JICA expert team think that the core trainer for DG's and RE O&M Mr. Robert, has good knowledge, experience and skills to play a central role in KUA. So, the expert team request him to share his knowledge and skills to Mr. Gerardo and Mr. Casey, who are the core trainer for planning of RE integration.

Since PV performance ratio for 2019 had dropped from the baseline in 2016 (61%⇒54%), it is necessary for KUA to strength inspection and maintenance works of PV's facilities, for this reason, the expert team is planning to monitor the performance ratio value of those facilities and also conduct training focusing on troubleshooting. Also, expert team is planning to share cases studies on the integration of renewable energy in Okinawa.

2.Training schedule

The Introduction of Hybrid Power Generation System in Pacific Island Countries (2nd Phase) SCHEDULE



3. Core Trainers (Set in JCC meeting)

No.	JCC Meeting			Core Trainer Name	Position	Comments
	JCC1	JCC2	JCC3			
1) Operation and Maintenance of Diesel Engine Generators						
1	●	●	●	Robert Taualupe	Operations Manager (Electrical)	
2	●	●	●	Ronald Albert	Supervisor of Operator (Mechanical)	
3		●	●	Careston Alokoa	Power Plant Operator	
2) Plan for introduction of hybrid power generation systems						
1	●	●	●	Gerardo Protacio	Electrical Engineer	
2	●			Tolenoa Joe	Energy Efficiency Officer	
3	●	●		Hairom Livaie	Customer Service Head, Admin. & Training Officer	
4	●	●	●	Robert Taualupe	Operations Manager	
5			●	Casey Freddy	Customer Service Supervisor	

3) Operation and Maintenance of Renewable Energy generation system						
1	●	●	●	Robert Taualupe	Operations Manager	
2	●			Tolenoa Joe	Energy Efficiency Officer	
3	●	●	●	Gifford Sigrah	Distribution Foreman	
4		●	●	Ronnie George	Lineman-2	

4. 2019 to 2020 KUA counterparts training evaluation

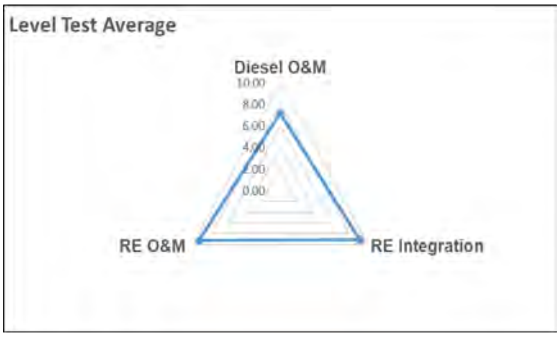
Training contents	
1. DG	*CP have the capacity to perform disassembly inspection, verification of spare parts condition and measurement of operation parameters (Pmax, fuel consumption rate, etc.) Writing of inspection record sheets.
2. RE integration	*CP will acquire more detailed knowledge regarding to Hybrid power generation.
3. RE O&M	*CP will have the capacity to perform implementation plan, operation training in-house, maintenance planning, inspection, and prepare, manage, and analyze work reports.

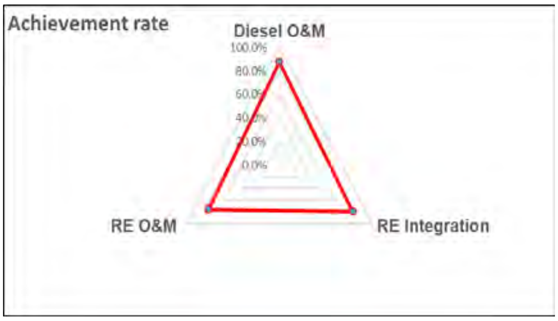
Results

The training evaluation result for each task is shown in below tables.

The Achievement evaluation of the trainers is the result of the discussion and judgment between the Experts Team members based first in the average result of the level tests done in FSM and Fiji regional training, second the active participation demonstrated during the training and third in the speed in knowledge acquisition during the practical training.

Diesel O&M		
Name	Test points	Achievement
Robert Taualupe	7.50	94.4%
Ronald D. Albert	7.33	83.3%
Careston Alokoa	6.50	83.3%
Average	7.11	87.0%
RE Integration		
Name	Test points	Achievement
Gerrado Protacio	9.00	92.9%
Robert Taualupe	9.33	92.9%
Casey Freddy	-	0.0%
Gifford Sigrah	-	50.0%
Ronnie George	-	-
Average	9.17	78.6%
RE O&M		
Name	Test points	Achievement
Robert Taualupe	9.33	83.3%
Gifford Sigrah	-	66.7%
Ronnie George	-	0.0%
Average	9.33	75.0%
KUA average	Test points	Achievement
Diesel O&M	7.11	87.0%
RE Integration	9.17	78.6%
RE O&M	9.33	75.0%





● **DEG Training (Micronesia・Kosrae)**	**Project Counterparts (Core trainers)**			**Other training participants**	
Name Skill	Robert Taualupe	Ronald D. Albert	Careston Alokoa	Hairom Livaie	Gerrado Protacio
	Operation manager	PS operator	PS operator	Customer services	Electrical engineer
(1) Operation & Maintenance of DG					
Operation of DG					
1) Can start-up/stop engines	3	2		2	
2) Can control DG according to the grid load	3	1		1	
3) Can trouble shoot the plant in case of faults	3	1		2	
4) Can Black start procedures	3	1		2	
5) Can check parameters of the DG in operation (temperature, pressure, voltage, frequency, etc.)	3	1		2	
6) Can measure and calculate specific fuel consumption	3	2		1	
7) Can explain the concept of Economic Dispatch Control (EDC)	2	1		1	
8) Can manage operation (running hours, selection of DG, numbers of units, maintenance schedule, etc.)	3	1		1	
9) Any other specific ability to be mentioned					
Average	2.9	1.3		1.5	
Maintenance of DG					
1) Can plan maintenance schedule (spare parts, staff, arrangements, etc.)	3	1		2	
2) Can plan maintenance of equipment of the power house (overhead crane, boiler, incinerator, etc.)	3	1		2	
3) Can plan and coordinate daily, weekly, monthly maintenance works	3	1		1	
4) Can supervise periodical maintenance works(daily, weekly, monthly)	3	1		2	
5) Can trouble shoot the plant in case of faults	3	1		2	
6) Can manage the planning for overhaul works	3	1		1	
7) Can supervise overhaul works (use of special tools, measurement equipment, etc.)	3	1		1	
8) Any other specific ability to be mentioned					
Average	3.00	1.00		1.57	
Training of Operation and maintenance of DG (Aug 12～16, 2019)					
Attendance days (max 5 days)	-				
Mechanical Check Test	-	7	8		
Electrical Check Test	-	6	6		
Average	-	6.5	7	#DIV/0!	#DIV/0!
Training of Operation and maintenance of DG (Jan 20～24, 2019)					
Attendance days (max 5 days)			-	-	-
Mechanical Check Test	-	9	6	-	-
Electrical Check Test	-	8	6	-	-
Average	-	8.5	6	-	-
Regional Training of DG in FIJI (November 18 ～November 22, 2019)					
Attendance days (max 5 days)	5	5	-	-	-
Check Test	7.5	7	-	-	-
Average	7.5	7	-	-	-
Evaluation results (Max 10)	7.5	7.33	6.5	-	-
Remarks, (JICA Expert team opinion) 3: Well Done 2: Achieved 1: One further step 0: unachieved	3/High knowledge in DG's	2/Good participation in the training. Experienced in electrical maintenance	2/Good participation in the training. Experienced in electrical maintenance		

※Total evaluation is made if the trainer has participate in more than 2 (two) trainings

● RE Training (Micronesia・Kosrae)	Core trainers （※+RE O&M)					Other training participants		
Name Skill	Gerrado Protacio	Robert Taualupe ※	Casey Freddy	Gifford Sigrah※	Ronnie George※	Toleona Joe	Ronald D. Albert	Hairom Livaie
	Electrical engineer	Operation manager	Energy Efficiency Officer	Distribution foreman	Lineman-2	Energy develop officer	PS operator	Customer services
(2) Planning, Operation & Maintenance of RE generation system								
Grid integration of RE								
1) Knowledge of the issues in RE integration (frequency, voltage etc.)	3	3		1		2		2
2) Can explain the difference of short-term and long-term output fluctuation of RE and their effect on grid operation	2	2		1		2		3
3) Can calculate the maximum capacity of RE for grid-interconnection, in consideration of the effect of frequency fluctuation (short term fluctuation)	1	2		1		3		2
4) Can calculate the maximum capacity of RE for grid-interconnection, in consideration the effect of demand fluctuation (long term fluctuation) without battery storage system	1	2		1		3		2
5) Can derive the optimum capacity of RE, in consideration of the total generation cost	1	2		1		3		3
6) Can plan solar home systems, and mega solar facilities	1	2		1		2		2
7) Knowledge of kind of solar panels, batteries, inverters, etc.(characteristics and frequent uses)	2	2		1		3		2
8) Knowledge of RE grid interconnection guideline	2	2		1		2		2
9) Any other specific ability to be mentioned								
Personal Average	1.6	2.1	-	1.0	-	2.5		2.3
Operation & Maintenance of RE (PV)								
1) Can establish maintenance schedule and checklist	2	3		1		3		2
2) Can conduct periodical maintenance works	2	3		1		3		2
3) Can conduct troubleshooting in case of faults	2	2		1		2		2
4) Can use measuring instruments for maintenance works	3	3		1		2		2
5) Any other specific ability to be mentioned								
Average	2.3	2.8	-	1.0		2.5		2.0
Training of Operation and maintenance of RE (July 22～26, 2019) ・Yap								
Attendance days								
RE Check Test	8	9						
Average	8	9						
Training of Operation and maintenance of RE (October 28～Nov 1, 2019) ・Pohnpei								
Attendance days								
RE Check Test	10	10						
Average	10	10						
Regional Training of DG in FIJI (November 25 ～November 29, 2019)								
Attendance days (max 5 days)		5		5				
Level Test		9		4				
Average		9		4				
Evaluation result (Max 10)	9	9.33	-	-	-	-	-	-
Remarks, (JICA Expert team opinion) 3 : Well Done 2: Achieved 1 : One further step 0 : unachieved	2/ good participation in the traininng. Fast acquisition of knowledges.	2/ good participation in the traininng. Fast acquisition of knowledges.		1/ Need more participation in the training				

※Total evaluation is made if the trainer has participate in more than 2 (two) trainings.

O&M for Diesel Engine Generators / YEAR GOAL ACHIEVEMENT Sheet / Kosrae (2019)

	Core trainers			Other training participants		
Name	Robert Taualupe	Ronald D. Albert	Careston Alokoa	Gerrado Protacio	Hairom Livaie	
General Evaluation (2019)	3	2	2	1	1	

【Score Standard】 3P：Well Done / 2P: Achieved / １P：One further step / ０P：unachieved

FY2018 (Basic knowledge learning)						
・Understanding of Diesel Generators type, structure, operation principle and characteristic.	3	2	2	2		
・Understanding of mechanical devices on Diesel power generation. Purpose, type, characteristics etc. of each device.	3	2	2	1		
・Understanding of electrical components on Diesel power generation. Purpose, type, characteristics etc. of each electrical panels, etc.	3	2	2	2		
・Diesel engine performance curve, efficiency during operation, heat balance diagram, etc.	2	1	1	1		
・Operation and control method of diesel power generation facilities (governor free, automatic control devices, etc.)	2	1	1	1		
・Diesel generator Economical load distribution operation (EDC technology (basic knowledge・application))	2	1	1	1		
・Operation supervisory monitoring method	2	1	1	1		
・Proper maintenance of the diesel generation facility・(Electrical and Mechanical) Maintenance method (disassembly inspection item, cycle etc)	2	2	2	2		
・Inspection after disassembly inspection	2	2	2	2		
・Safety work training	2	2	2	2		
***CP acquire the basic knowledge of DG power generation facility. (Composition, operation and maintenance)**	2	2	2	2		
points	25	18	18	17	0	0
Full mark	22	22	22	22	22	22
score	114%	82%	82%	77%	0%	0%

FY2019 (Use of inspection tools (OJT・Teoubleshooting))						
・Review of 2018 training, comprehension test, complementary training.	2	2	2	-	-	-
・Calculation of fuel consumption rate, measurement of operation parameters of diesel engine, etc.	2	2	2	-	-	-
・Inspection of each section of diesel generators, troubleshooting.（mechanical and electrical OJT）	2	2	2	-	-	-
・Handling of mechanical measuring equipment（OJT）	2	2	1	-	-	-
・Handling of electrical measuring equipment（OJT）	1	1	2	-	-	-
・Verification, modification, addition of notes in the maintenance manual(electrical / mechanical)	2	1	1	-	-	-
・Mechanical and electrical fault case introduction	2	2	2	-	-	-
・Maintenance works report writing, keeping and supervision	2	1	1	-	-	-
***CP have the capacity to perform disassembly inspection, verification of spare parts condition and mesurement of operation parameters(Pmax, fuel consumption rate, etc.) Writing of inspection record**	2	2	2	-	-	-
points	17	15	15	0	0	0
Full mark	18	18	18	18	18	18
score	94%	83%	83%	0%	0%	0%

※Total evaluation is made if the trainer has participate in more than 2 (two) trainings.

Grid Integration of RE Generation Systems / Year Goal Achievement Level Sheet / Kosrae (2019)

	Core trainers			Other training participants		
Name	Gerrado Protacio	Robert Taualupe	Casey Freddy	Gifford Sigrah	Ronald D. Albert	Hairom Livaie
General Evaluation (2019)	2	2	-	0	0	1

【Scoring Standard】 3P：Well Done / 2P: Achieved / １P：Nearly achieved / ０P：Much room for impovement

FY 2018 (Acquisition of Basic Knowledge)						
・Impact on the power quality caused by implementation of RE.	2	2	-	1	1	2
・Basic knowledge of allowable amount of RE. (algebraic method, HOMER software)	1	1	-	0	0	1
・Basic knowledge of Hybrid systems	2	2	-	1	1	2
***CP will acquire the basic knowledge of Hybrid power generation.**			-			
Points	5	5	-	2	2	5
Full mark	8	8	-	8	8	8
Score	63%	63%	-	25%	25%	63%

Fiscal 2019 (Understanding of implementation plan of Hybrid system)						
・Review of 2018 training, comprehension test, supplemental training.	2	2	-			
・ Understanding of the permissible amount of renewable energy connected into the system. (algebraic method)	1	1	-			
・Control of Hybrid power generation system.（DG low load operation/PV output）	2	2	-			
・System simulation overview.	2	2	-			
・Outline and practice of HOMER software	2	2	-			
・Outline of performance ratio	2	2	-			
***CP will acquire more detailed knowlwdge regarding to Hybrid power generation.**	2	2	-			
Points	13	13	0	0	0	0
Full mark	14	14	14	14	14	14
Score	93%	93%	0%	0%	0%	0%

※Total evaluation is made if the trainer has participate in more than 2 (two) trainings.

RE Operation and Maintenance Training /Goal Achievement Level Sheet / Kosrae (2019)

	Core trainers			Other training participants		
Name	Robert Taualupe	Gifford Sigrah	Ronnie George	Ronald D. Albert		
General Evaluation (2019)	2	2	-	2		

【Scoring Standard 】3P：Well Done / 2P: Achieved / １P：Nearly achieved / ０P：Much room for impovement

FY 2018 (Acquisition of Basic Knowledge)						
・Understanding of the types, structure, operation principle and characteristic of the solar cell.	2	2	-	2		
・Role of peripheral equipment of solar power facilities (connection box, PCS, distribution board, etc.)	2	1	-	1		
・How to process and utilize photovoltaic power generation measurement system (solar radiation intensity, total output power etc.)	1	1	-	1		
・Plan and installation method of solar array (practical exercise)	2	1	-	1		
・Summary from Plan to implementation of solar power system.	2	1	-	1		
・Economic study.	1	0	-	0		
・Appropriate maintenance of solar power generation system. Maintenance method (inspection item, cycle etc).	2	2	-	2		
・Inspection after installation (IV checker, open circuit voltage, insulation resistance measurement, etc.)	2	2	-	2		
・Training on working safely	2	2	-	2		
***CP will acquire the basic knowledge of solar power generation facilities. (Composition, operation and maintenance)**	2	2	-	2		
Points	18	14	0	14	0	
Full mark	18	18	18	18	18	
Score	100%	78%	0%	78%	0%	

Fiscal 2019 (Understanding of implementation plan and operation method)						
・Review of 2018 training, comprehension test, supplemental training.	2	2	-	-	-	-
・Preparation of the maintenance check sheet	2	1	-	-	-	-
・Implementation and compilation of facility inspections using check sheets	2	2	-	-	-	-
・ Measurement equipment operation practice (string tracer, cell line checker, insulation resistance meter)	2	2	-	-	-	-
・Troubleshooting (breakage between modules, influence of shadow, etc.)	2	1	-	-	-	-
・Fault case introduction.	2	1	-	-	-	-
・Verification, modification, addition of content, etc. of the maintenance and operation manual.	1	1	-	-	-	-
・Preparation of reports on operation and maintenance work as well as their storage and management.	1	1	-	-	-	-
***CP will have the capacity to perform implementation plan, operation training in-house, maintenance planning, inspection, and prepare, manage, and analyze work reports.**	1	1	-	-	-	-
Points	15	12	0	0	0	0
Full mark	18	18	18	18	18	18
Score	83%	67%	0%	0%	0%	0%

※Total evaluation is made if the trainer has participate in more than 2 (two) trainings.

End

7.3　2020年～2021年

June 2021
JICA Expert Team

The Project for Introduction of Hybrid Power Generation System in Pacific Island Countries
July 2020 to June 2021 / Training Evaluation (Draft)
(Kosrae / FSM)

1. Executive Summary

In order to achieve the objectives of the Project for Introduction of Hybrid Power Generation System in Pacific Island Countries, two main outputs "1. Enhancement of an appropriate and economical system for O&M of Diesel Generators (DG's)," and "2. Establishment of a methodology for appropriate planning and O&M of Renewable Energy (RE)" are required.

Since the JICA expert team could not conduct the necessary activities for these two outputs on site due to the Covid-19 pandemic, 12 online training sessions (6 for output 1 and 6 for output 2), 2 meetings to facilitate manual revision and other technical support through Facebook and email correspondence was provided.

Following the training on DG O&M and RE integration and PV facility O&M provided on site in 2019, the following online training was provided from June 2020 to June 2021.

2. Training Contents

2.1 Enhancement of an appropriate and economical system for O&M of Diesel Generators (DG's)

The first 2 online training sessions were a review of the lectures previously provided on site by the JICA expert team. From the third training session, new topics on the maintenance of DG's and auxiliary devices such as fuel storage tanks, turbocharger, heat exchangers were covered.

For overhaul works, videos on the maintenance of generators, circuit breakers, cylinder heads, pistons, main bearing, fuel injection valve, etc. were shown.

For operation of the power plant, lectures on operation analysis, planning the addition of DG's according to the power reserve, specific fuel consumption, improvement plan, preparation for periodic inspection, and blackout restoration procedures were conducted.

Also, the expert team assigned the main counterparts' homework such as monthly measurement of SFC, maximum explosion pressure (Pmax), vibration, preparation of OH schedule, and revision of the maintenance manual according to KUA standards.

As a result of the June 2020～June 2021 training, it appears that the core trainers Mr. Robert Taualupe was able to achieve about 76.7% of the training objectives based on the summary tests conducted in June 2021, the evaluation of the generation manager and also findings from the expert team members. JICA expert team could not evaluate Mr. Ronald Albert and Mr. Careston Alokoa due they not presented the summary test.

The JICA expert team advises the DG counterparts to participate more actively in the training sessions and in the revision of the DG O&M manual in order to improve their knowledge and skill which will result in a more efficient operation and maintenance of the entire power plant.

Training No./ Date		DG O&M / Online Training Content
1	6/18/20	1. Basic knowledge of DG (each utility system) 2. Daily inspection of DG's, Pmax measurement, exhaust gas temperature verification and FO rack adjustment 3. Description of electrical drawings (Single-line, three-line, sequence diagram) 4. Fuel consumption calculation exercise
2	7/29/20	1. Use of measuring instruments for mechanical side (Vernier calipers, micrometer, dial gauge) 2. Use of measuring instruments for electrical side (RTD, TC, pressure gauge) 3. Power plant operation 4. Power plant improvement progress 5. Revision of DG O&M manual
3	9/23/20	1. Safety 2. Basic knowledge of DG 3. DG maintenance: DK26 Daihatsu engine Cylinder head, starting valve maintenance video. 4. Periodic mechanical inspection 5. Power plant improvement progress 6. Fuel tank inspection 7. Specific fuel consumption measurement
4	10/21/20	1. Revision of the O&M manual 2. DG maintenance: DK26 Daihatsu engine - Fuel oil injection nozzle, pump, piston and connecting rod, main bearing maintenance video. 3. Turbocharger maintenance video 4. Periodic mechanical inspection 5. Power plant improvement progress
5	1/27/21	1. Daily inspection 2. Generator inspection 3. Preparation of a Remote Island Power Plant Periodic Inspection Plant 4. Power plant improvement progress 5. Specific fuel consumption measurement
6	5/26/21	1. Circuit breaker inspection 2. Nondestructive Testing (Penetrant Testing, Magnetic Particle Testing) 3. Blackout restoration procedure 4. Heat exchanger 5. Power plant improvement progress 6. Specific fuel consumption measurement
7	7/16/21	1st DG O&M Revision Training
8		2nd DG O&M Revision Training

2.2 Establishment of a methodology for appropriate planning and O&M of Renewable Energy (RE)

As with the training for DG O&M, online training was provided in replacement of hands-on training on site. Following the review of past lectures, the content of the training included the follow:

- RE integration

Review of previous lectures, case study on initiatives in Okinawa to disseminate RE, grid interconnection and operation (grid code, flow of grid interconnection, output control, etc.), output and frequency fluctuation mitigation control (ΔP & ΔF control)

- RE (PV facilities) integration and O&M

For operation, training on verifying the actual operating status of PV facilities, including an overview and summary of how to measure performance ratio, confirmation and evaluation of the current condition, and PV power generation cost calculation, was conducted.

For maintenance, lectures on configuration of PV systems, patrol inspection, daily and periodic inspections, update of inspection check sheet, future maintenance system, schedule, and budget were done.

The other main component of the RE training was focused on basic knowledge for preparing and updating of the manual for RE integration and O&M.

As a result of the training, it appears that the core trainers for RE integration, Mr. Gerardo Protacio, Mr. Robert Taualupe and Mr. Casey Freddy were able to achieve in average about 69% of the training objectives. And for RE O&M, Mr. Robert Taualupe achieved 67.3% of the training objectives. Both results are based on the summary tests conducted in June 2021, evaluation by the generation manager, and also findings from the expert team members.

Unfortunately, expert team could not evaluate two core trainers for RE O&M, first Mr. Ronnie George due he not presented the summary test and also Mr. Gifford Sigrah that never attended the training.

PV facilities are subject to evaluation by performance ratio, so the JICA expert team requests the sharing of performance ratio measurements of PV facilities so expert team can monitor and advise accordingly. The JICA expert team has requested for these data to be submitted every month, but they have not been submitted since march.

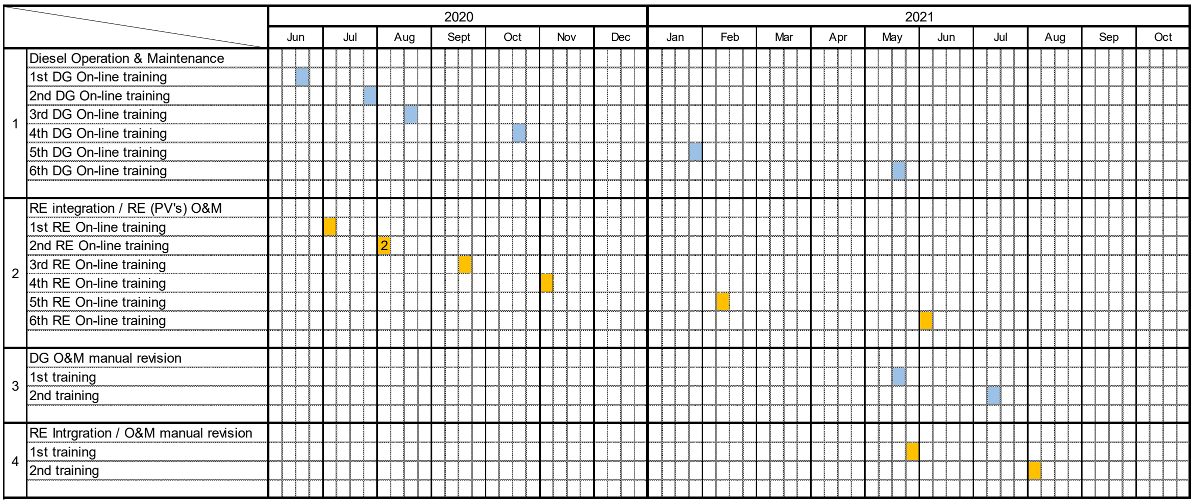
The expert team advises the RE counterparts to participate actively in the revision of the RE integration and O&M manual in order to increase the knowledge and skill which will result in the efficient operation and maintenance of all facilities in Tuvalu.

Training No. / Date		Training content
1	7/1/20	1. Basic knowledge of Hybrid power generation system (HPGS) technology 2. Explanation of performance ratio 3. Basic knowledge on preparation and updating of RE integration manual 4. Q&A on PV maintenance
2	8/6/20	1. Basics of preparing and updating manual 1 ・ Explanation of facility system configuration, O&M ・ Patrol inspection, daily inspection, and periodic inspection ・ Inspection check sheet preparation and recording (method, frequency, etc.) 2. Basic knowledge for preparing and updating the RE integration manual. ・ Frequency fluctuation (system constant, algebraic method) 3. Performance ratio. ・ Overview and summary of measurement method ・ Confirmation, evaluation, and verification of the current situation 4. O&M manual revision. Requested revision of Chapter 1

3	9/3/20	1. Basic knowledge for formulating and updating the RE integration manual. ・ Review questions 2. Basics of formulating and updating RE O&M manual ・ Review questions 3. PV facility inspection ・ Power generation cost exercise 4. Performance ratio
4	11/11/20	1. RE O&M manual revision (Chapter 1) 2. Performance ratio 3. RE grid interconnection and operation (system stabilization method) ・ Output fluctuation mitigation control (ΔP control) ・ Frequency fluctuation mitigation control (ΔF control) 4. Example of initiatives in Okinawa to disseminate RE ・ Yonaguni Hybrid System 5. Explanation of Plan of Operation (PO) 6. Future maintenance system and budget
5	2/18/21	1. Performance ratio ・ How to acquire solar radiation data (using NASA site) 2. Discussion on manual revision 3. Grid interconnection and operation of RE ・ Grid code (interconnection requirement) ・ Flow of grid interconnection ・ Operation (output control) *Case study 4. Future Maintenance System and Budget ・ Maintenance system ・ Maintenance budget ・ Assistance from other donors
6	6/11/21	1. Example of initiatives in Okinawa to disseminate RE ・ Abu Mega Solar facility ・ Ogimi Wind Power facility (demonstration research facility) ・ Control of power fluctuation (ΔP & ΔF control) 2. Future maintenance system and budget 3. Future maintenance schedule plan
7	5/24/21	1st DG O&M Revision Training
8	7/27/21	2nd DG O&M Revision Training

3. Training schedule

The Introduction of Hybrid Power Generation System in Pacific Island Countries / FSM Kosrae / On-Line Remote Training Schedule (2020～2021)



		2020							2021									
		Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
1	Diesel Operation & Maintenance																	
	1st DG On-line training	■																
	2nd DG On-line training		■															
	3rd DG On-line training			■														
	4th DG On-line training					■												
	5th DG On-line training								■									
	6th DG On-line training												■					
2	RE integration / RE (PV's) O&M																	
	1st RE On-line training		■															
	2nd RE On-line training			2														
	3rd RE On-line training				■													
	4th RE On-line training						■											
	5th RE On-line training									■								
	6th RE On-line training													■				
3	DG O&M manual revision																	
	1st training												■					
	2nd training														■			
4	RE Intrgration / O&M manual revision																	
	1st training												■					
	2nd training															■		

3. Core Trainers

No.	Core Trainer Name	Position	Comments
1) Operation and Maintenance of Diesel Engine Generators			
1	Robert Taualupe	Operation manager	
2	Ronald D. Albert	SV of operator	
3	Careston Alokoa	PS operator	
2) Plan for introduction of hybrid power generation systems			
1	Gerardo Protacio	Electrical engineer	
2	Robert Taualupe	Operation manager	
3	Casey Freddy	Energy efficiency officer	
3) Operation and Maintenance of Renewable Energy generation system			
1	Robert Taualupe	Operation manager	
2	Gifford Sigrah	Distribution foreman	
3	Ronnie George	Lineman	

4. FY2020 KUA counterparts training evaluation

Training content	
1. DG	・Review of 2020 training ・Handling of mechanical and electrical measuring equipment ・Inspection, troubleshooting of each part of diesel generator ・Update of power plant maintenance manual *CPs have the capacity to perform disassembly inspection, verification of spare parts condition, and measurement of operation parameters (Pmax, fuel consumption rate, etc.)
2. RE integration	・Review of 2020 training ・RE grid interconnection and operation method ・Examples of initiatives in Okinawa to disseminate renewable energy ・Use of storage battery in power systems ・PV system design ・Data measurement for performance ratio calculation ・Update of RE integration manual *CPs will acquire more detailed knowledge on RE integration
3. RE O&M	・Review of 2020 training ・Operation and maintenance of PV system. ・Inspection check sheet revision and use ・Practice in the use of measurement equipment (String Tracer, Cell Line Checker, insulation resistance tester) ・Revision of PV system O&M manual *CPs will have the capacity to perform maintenance planning, inspection, and prepare, manage, and analyze work reports

Results

See following Core trainers' evaluation check sheet and annual training objectives achievement rate graphs.

June 2020 ～June 2021 / DG Core trainer evaluation result sheet

● **DG O&M Training（FSM / KUA）**	**Project Counterparts　(Core trainers)**				
Name Skill	Robert Taualupe	Ronald D. Albert	Careston Alokoa		
	Operation manager	SV of operator	PS operator		
Ⅰ.Attitude to training (max.25 points =10)					
1. Remote training participation (5 times)	3	5	2		
2. JICA Expert team (Attitude during the web training)	7	6	6		
3. Manager evaluation	10	8.6	8		
subtotal	20	19.6	16.2		
evaluation	8.0	7.8	6.5		
Ⅱ.Test (max.20 points=10)					
4. 2020 Summary test	8	N/A	N/A		
Ⅲ.Target skill (Plan)	**(Results)**				
・Review of 2019's training, comprehension test,	Included in the 2020 summary test				
・Disassembly inspection, troubleshooting of each part of diesel generator. Continuation of training on electrical and mechanical OJT	Not carried out in site. It was done by remote training via videos.				
・Handling of mechanical measuring equipment（OJT)	Not carried out in site. It was done by remote training via videos.				
・Handling of electrical measuring equipment（OJT)	Not carried out in site. It was done by remote training via videos.				
・Trouble shooting	Remote trainings				
・Update of power plant maintenance manual.	In process yet				
・Verification, modification, addition of notes in the maintenance manual(electrical / mechanical)	In process				
・Improvements in power station	In process				
Evaluation from JICA Expert Team	7.00	6.00	6.00		
General evaluation	**2.3**	-	-		
Remarks,（JICA Expert team opinion) 3:Well Done 2: Achieved 1:One further step 0:unachieved	Good participation to the training	Good attendance to the training. Need more active participation	Need more attendance to the training and more active participation		
Comments ※1 Possibility of no attendance to the training due to works priority. ※2 No presentation of answer to the summary test. (Others reason) ※Total evaluation is made if the trainer has participate in more than 2 (two) trainings and presented the test					

June 2020 ～June 2021 / RE Integration Core trainer evaluation result sheet

● RE Integration Training（FSM / KUA）	Project Counterparts（Core trainers）				
Name	Gerardo Protacio	Robert Taualupe	Casey Freddy		
Skill	Electrical engineer	Operation manager	Energy Efficiency Officer		
Ⅰ.Attitude to training (max.25 points=10)					
1. Remote training participation (5 times)	3	4	2		
2. JICA Expert team (Attitude during the web training)	7	6	6		
3. Manager evaluation	9.4	10.0	2.2		
subtotal	19.4	20	10.2		
evaluation	7.8	8.0	4.1		
Ⅱ.Test					
4. 2020 Summary test	10.0	7.5	6.0		
Ⅲ.Target skill (Plan)	**(Results)**				
・Review of 2019 training, comprehension test, supplemental training.	Included in the 2020 summary test				
・Practice using HOMER software.	In process				
・Update of hybrid power generation planning manual.	In process				
・Renewable energy introduction roadmap planning method(1).	In process				
・Renewable energy grid interconnection and operation method(1).	In process				
・Examples of initiatives in Okinawa related to the spreading of renewable energy(1).	Done in on-line training				
・Use of storage battery in power system(1).	Done in on-line training				
・PV system design(1).	Next year				
・Data measurement related to performance ratio calculation	Done in on-line training				
Evaluation from JICA Expert Team	7.00	6.00	6.00		
General evaluation	**2.48**	**2.15**	**1.61**		
Remarks,（JICA Expert team opinion） 3：Well Done 2：Achieved 1：One further step 0：unachieved	Good participation during the training	Good participation during the training	Need more active participation and attendance		
Comments ※1 Possibility of no attendance to the training due to works priority. ※2 No presentation of answer to the summary test. (Others reason) ※Total evaluation is made if the trainer has participate in more than 2 (two) trainings and presented the test					

June 2020 ～June 2021 / RE O&M Core trainer evaluation result sheet

● DG O&M Training（FSM / KUA)	**Project Counterparts　　(Core trainers)**				
Name / Skill	Robert Taualupe	Gifford Sigrah	Ronnie George		
	Operation manager	Distribution foreman	Lineman		
Ⅰ.Attitude to training (max.15 points=10)					
1. Remote training participation (5 times)	4	0	4		
2. JICA Expert team (Attitude during the web training)	6	6	6		
3. Manager evaluation	N/A	N/A	N/A		
subtotal	10	6	10		
evaluation	6.7	4.0	6.7		
Ⅱ.Test					
5. 2020 Summary test	7.5	N/A	N/A		
Ⅲ.Target skill (Plan)	**(Results)**				
・Review of 2019 training, comprehension test, supplemental training.	Included in the 2020 summary test				
・Operation and maintenance of PV system.	Done in on-line training				
・Revision of PV system operation manual.	In prosess				
・Analysis of PV equipment operation efficiency improvement (current situation, economic efficiency, planning (understand master plan)	Done in on-line training / Verification of performance ratio measurement values.				
・Check sheet revision	Done in on-line training				
・Operation and maintenance of existing PV system (use of check sheet)	Done in on-line training / Verification of check sheets.				
・Measurement equipment operation practice (string tracer, cell line checker, insulation resistance meter)	Done in on-line training / Verification of performance ratio measurement values.				
Evaluation from JICA Expert Team	6.00	0.00	0.00		
General evaluation	**2.02**	-	-		
Remarks,（JICA Expert team opinion) 3: Well Done 2: Achieved 1: One further step 0: unachieved	Good participation during the training	Confirm as core trainer.	Not presented the summary test		

Comments
※1 Possibility of no attendance to the training due to works priority.
※2 No presentation of answer to the summary test. (Others reason)
※Total evaluation is made if the trainer has participate in more than 2 (two) trainings and presented the test

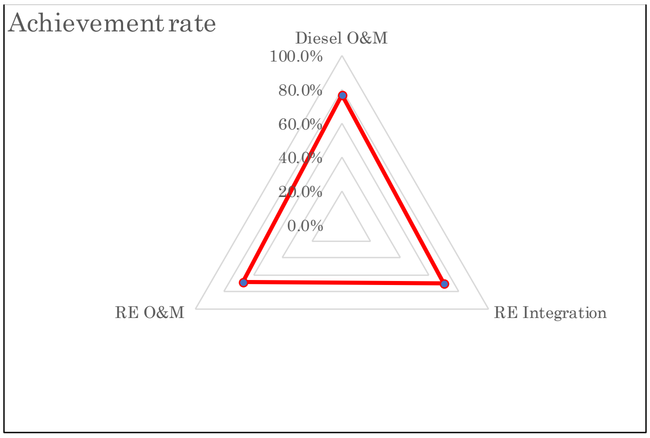
➢ June 2020 to June 2021 Summary

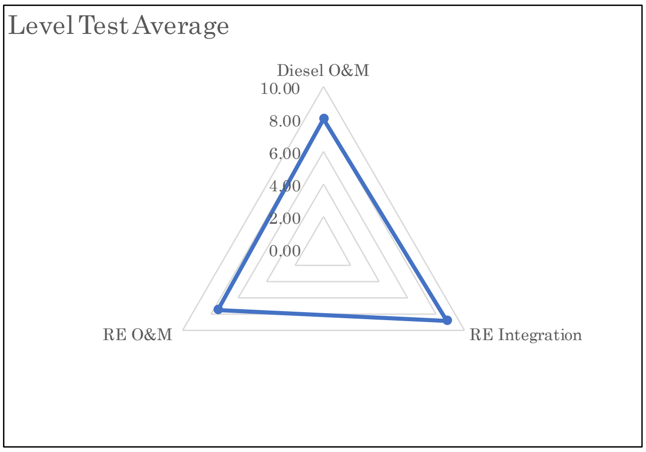
Diesel O&M		
Name	Test points	Achievement
Robert Taualupe	8.00	76.7%
Ronald D. Albert	N/A	N/A
Careston Alokoa	N/A	N/A
Average	8.00	76.7%

RE Integration		
Name	Test points	Achievement
Gerardo Protacio	10.00	82.7%
Robert Taualupe	7.50	71.7%
Casey Freddy	6.00	53.7%
Average	8.75	69.3%

RE O&M		
Name	Test points	Achievement
Robert Taualupe	7.50	67.3%
Gifford Sigrah	N/A	N/A
Ronnie George	N/A	N/A
Average	7.50	67.3%

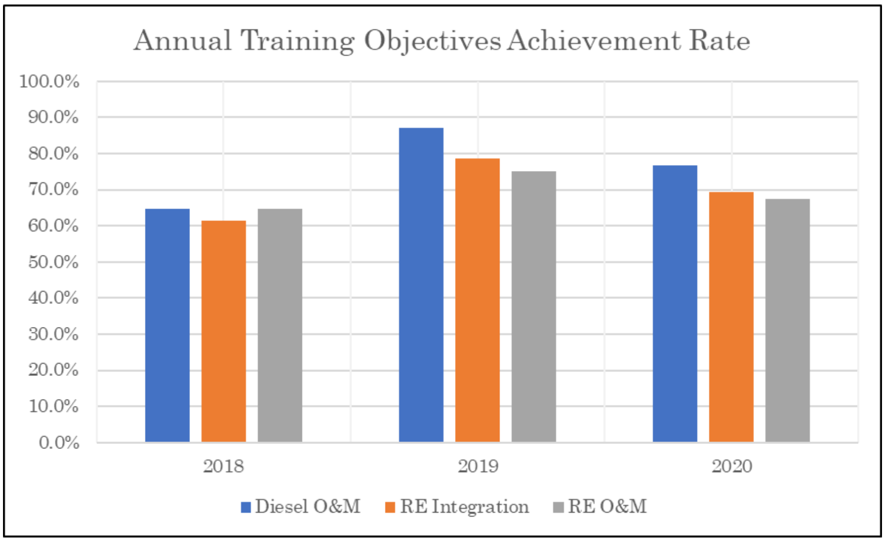
KUA average	Test points	Achievement
Diesel O&M	8.00	76.7%
RE Integration	8.75	69.3%
RE O&M	7.50	67.3%





➢ Annual training objectives achievement

KUA average	2018	2019	2020
Diesel O&M	64.6%	87.0%	76.7%
RE Integration	61.3%	78.6%	69.3%
RE O&M	64.6%	75.0%	67.3%



End

7.4　2021年～2022年

November 2022
JICA Expert Team

The Project for Introduction of Hybrid Power Generation System in Pacific Island Countries
July 2021 to June 2022 / Training Evaluation
(Kosrae / FSM)

1. Executive Summary

To achieve the project purpose for FSM in the project of the introduction of the Hybrid Power Generation System, two main outputs [1. Enhancement of an appropriate and economical system for O&M of Diesel Generators (DGs) and 2. Establishment of a methodology for appropriate planning and O&M of Renewable Energy (RE)] are required.

From July 2021 to June 2022, due to the COVID-19 pandemic, the JICA Expert Team was unable to conduct the necessary activities for these two outputs on-site, so three online training sessions (two for DG and one for RE outputs), and four meetings were provided to support the revision of the manuals. Additionally, in November 2021, KUA core trainers have participated in the 2nd Regional Online Training for DG and RE delivered by Fijian trainers.

2. Training Contents

2.1 Enhancement of an appropriate and economical System for O&M of Diesel Generators (DG)

Since the JICA expert team was unable to travel to FSM during this period to conduct the necessary hands-on trainings, online trainings focusing on fuel consumption monitoring, improving knowledge on DG configuration, troubleshooting, and reviewing the DG O&M manual were provided. The contents of the trainings are detailed in the below table.

The result of the DG trainings in the period July 2021 to June 2022, has shown that Mr. Robert Taualupe was able to achieve 70% of the training objectives based on the rate of attendance to the online trainings, the test carried out after the 2nd Regional Online Training and the evaluations by his manager and the JICA Expert Team. Mr. Ronald Albert has followed with an achievement rate of 63%, and unfortunately, Mr. Tedrick Joseph could not be evaluated because he has not submitted the summary test due to his work priority.

An important activity in this period was the revision of the DG O&M manual, but the core trainers of KUA have not made significant progress on this task, so that they will need to work hard to complete the revision by the end of this year.

The Expert Team advises to the core trainers to participate more actively in the revision of the manual which will help in the efficient operation and maintenance of KUA DG power plant.

Training Date		**DG O&M Online Training contents**
1	7/15/21	1. DG Maintenance Manual Revision

2	9/30/21	1. FSM. DG Manual updating schedule 20210802 rev1 2. Governor Fundamentals ver1 3. Heat Balance rev 03 4. Basics of Relays 5. Basics of Sequence Control 6. FSM. Improvement Plan Report 7. Others (SFC, OH)
3	11/15/21 ～ 11/24/21	2nd Online Regional Training for Operation and Maintenance of DGs.
4	5/30/22	1. OH (Turbocharger) 2. Troubleshooting case study 3. Revision of O&M Manual 4. Specific fuel consumption 5. Power plant improvement plan

2.2 Establishment of a methodology for appropriate planning and O&M of Renewable Energy (RE)

As with DG O&M training, for RE integration, online trainings have been delivered instead of on-site trainings, focusing on the acquisition of knowledge about Grid interconnection and system operation (grid interconnection code, grid interconnection flow, output control, and others related topics).

For RE O&M topics, the online training was focused on verifying the current operating status of the PV facilities through the monthly calculation of the performance ratio (PR), and the review of the Hybrid power generation system integration and O&M manual according to the standards used by KUA.

The result of the RE integration training in the period July 2021 to June 2022, has shown that Mr. Gerardo Protacio was able to achieve 85.6% of the training objectives based on the rate of attendance to the online trainings, the test carried out after the 2nd Regional Online Training and the evaluations by his manager and the JICA Expert Team. Unfortunately, Mr. Robert Taualupe could not be evaluated because he has not submitted the summary test due to his work priority.

For RE O&M training, the JICA Expert Team could not evaluate the RE core trainers because they have not submitted the summary test after the second regional training, also for their low attendance rate to the online trainings.

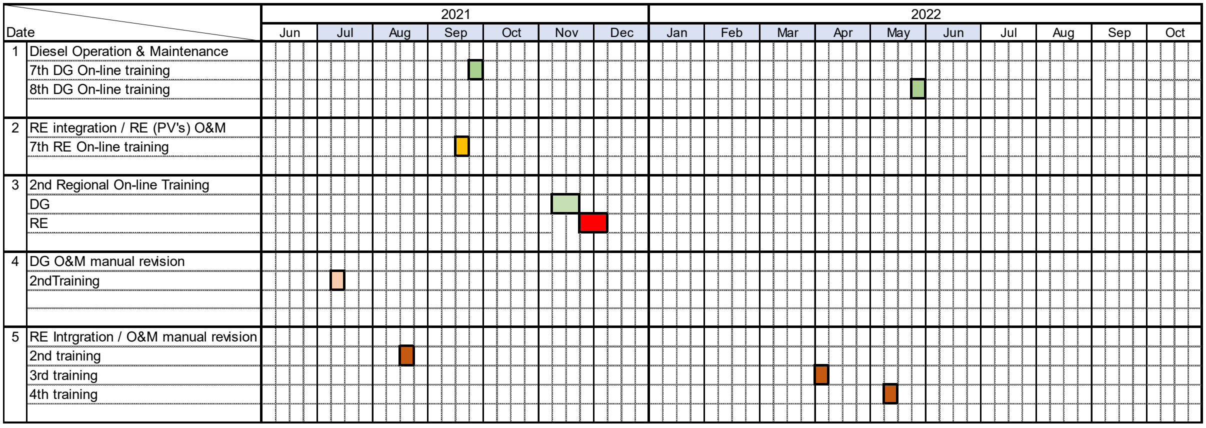
This time, to outline the level of KUA core trainers in the objectives achievement rate, the JICA Expert Team has conducted the evaluation considering only the attendance rate to the trainings and the evaluation by the general manager and the JICA expert team. The result showed to Mr. Robert Taualupe with 65% of achievement rate.

Training Date		RE Online Training contents
1	8/23/21	1. 2nd RE Manual Revision Meeting

2	9/21/21	1. RE Manual Revision Training 2. Performance ratio 3. Discussion on facility inspection ・PV inspection records ・Advice and discussion on inspection work ・Review of PV inspection methods 4. Future maintenance system for O&M ・Establishment of maintenance system and personnel plan
3	11/29/21 ～ 12/9/21	1. 2nd Online Regional Training for Integration of RE, Operation and Maintenance of PV facilities.
4	4/1/22	1. 3rd RE Manual Revision Meeting
5	5/16/22	2. 4th RE Manual Revision Meeting

3. July 2021 to June 2022 Training schedule

The Introduction of Hybrid Power Generation System in Pacific Island Countries / Kosrae / Online Remote Training Schedule (2021～2022)



4. Core Trainers

No.	Core Trainer Name	Position	Comments
1) Operation and Maintenance of Diesel Engine Generators			
1	Robert Taualupe	Operations manager	
2	Ronald D. Albert	SV of operator	
3	Tedrick Joseph	Power plant operator	
2) Plan for introduction of hybrid power generation systems			
1	Gerardo Protacio	Electrical engineer	
2	Robert Taualupe	Operations manager	
3	Casey Freddy	Customer service supervisor	
3) Operation and Maintenance of Renewable Energy generation system			
1	Robert Taualupe	Operations manager	
2	Gifford Sigrah	Distribution foreman	
3	Ronnie George	Lineman-2	

DG Remote training attendance record

Date / Name / Org.			2021										2022	Attend. Rate %
			O&M -2	7th	2nd Online Regional Training								8th	
			7/15	9/30	11/15	11/16	11/17	11/18	11/19	11/22	11/23	11/24	5/30	
Core trainers	Robert Taualupe	KUA	1	1	1	1		1		1			1	63.6%
	Ronald D. Albert	KUA			1	1	1						1	36.4%
	Tedrick Joseph	KUA		1	1	1		1					1	45.5%

🟨 Remote training
🟦 Manual Revision

RE Remote training attendance record

Date / Name / Org.			2021											2022		Attend. Rate %
			O&M -2	7th	2nd Online Regional Training									O&M -3	O&M -4	
			8/23	9/21	11/29	11/30	12/1	12/2	12/3	12/6	12/7	12/8	12/9	4/1	5/16	
Core Trainer	Gerardo Protacio	KUA	1	1	1	1	1	1	1	1	1	1	1	1	1	100%
	Robert Taualupe	KUA		1	1	1	1	1	1	1		1				62%
	Casey Freddy	KUA		1												8%
	Gifford Sigrah	KUA				1	1	1	1	1						38%
	Ronnie George	KUA					1	1	1	1	1	1	1			54%

🟨 Remote training
🟦 Manual Revision

5. KUA core trainers training evaluation

The training contents for the 3 task is shown in below table.

Training contents	
1. DG	・Review of past trainings ・Basics on DGs operation and control system ・Auxiliary devices of diesel generators ・Inspection, troubleshooting of diesel generator ・Update of power plant maintenance manual. *CP have the capacity to perform disassembly inspection, verification of spare parts condition and measurement of operation parameters through the OH works (Pmax, fuel consumption rate, etc.)
2. RE integration	・Review of 2020 trainings ・Renewable energy grid interconnection and operation method. ・Examples of initiatives in Okinawa related to the spreading of renewable energy. ・Use of storage battery in power system. ・Grid code. ・Data measurement related to performance ratio calculation. ・Update of hybrid power generation planning manual. *CP will acquire more detailed knowledge regarding to the implementation of Hybrid power generation.

3. RE O&M	・Review of past trainings ・Operation and maintenance method of PV system. ・Inspection check sheet revision and use. ・Revision of PV system O&M manual. ・Establishment of maintenance system and personnel plan *CP will have the capacity to perform maintenance planning, inspection, and prepare, manage, and analyze work reports.

Results

Below training evaluation sheet shown the punctuation of each task core trainer according to the attendance rate to the online trainings, the summary test after the 2nd Regional Online training and the evaluations by managers and the JICA Expert Team.

The KUA overall evaluation result is shown in the summary.

July 2021 ～June 2022 / DG Core trainer evaluation result sheet

● DG O&M Training (KUA)	Project Counterparts (Core trainers)				
Name Skill	Robert Taualupe	Ronald D. Albert	Tedrick Joseph		
	Operation manager	SV of operator	P/Plant Operator		
Ⅰ.Attitude to training (max. 31 points =10)					
1. Remote training participation (3 times)	3.0	1.0	1.0		
2.Participation in the 2nd Regional Training (8 days)	4.0	3.0	3.0		
3.JICA Expert team (willingness to learn)	6.0	5.0	5.0		
4. Manager evaluation	7.8	6.0	6.8		
subtotal	20.8	15	15.8		
evaluation	6.7	4.8	5.1		
Ⅱ.Test (max.20 points=10)					
4. 2021 Summary test	8.0	8.0	-		
Ⅲ.Target skill (Plan)	**(Results)**				
・Review of 2020's training, comprehension test, complementary training.	Included in the 2021 summary test				
・OH works / Disassembly inspection, troubleshooting of each part of diesel generator. Continuation of training on electrical and mechanical OJT	Not carried out in site. It was done by remote training via videos.				
・Handling of mechanical measuring equipment（OJT)	Not carried out in site. It was done by remote training via videos.				
・Handling of electrical measuring equipment（OJT)	Not carried out in site. It was done by remote training via videos.				
・Trouble shooting	Online trainings				
・Update of power plant maintenance manual.	In process yet				
・Verification, modification, addition of notes in the maintenance manual(electrical / mechanical)	In process				
・Improvements in power station	In process				
Evaluation from JICA Expert Team	6.0	6.0	6.0		
General evaluation (max10)	**7.0**	**6.3**	(5.5)		
Comments ※1 No attendance to the training due to works priority. ※2 No presentation of answer to the summary test. (Others reason) ※Total evaluation is made if the trainer has participate in the regional training and presented the test.	Need more active participation and response to the JICA experts request.	Need more active participation in the trainings.	Need more active participation in the trainings ※2		

July 2021 ～June 2022 / RE Integration Core trainer evaluation result sheet

● **RE Integration Training (KUA)**	**Project Counterparts (Core trainers)**				
Name	Gerardo Protacio	Robert Taualupe	Casey Freddy		
Skill	Electrical engineer	Operation manager	Energy Efficiency Officer		
Ⅰ.Attitude to training (max.33 points=10)					
1. Remote training participation (4 times)	4.0	1.0	1		
2.Participation in the 2nd Regional Training (9 days)	9.0	7.0	-		
3.JICA Expert team (willingness to learn)	8.0	7.0	-		
4. Manager evaluation	7.6	9.0	-		
subtotal	28.6	24	1		
evaluation	8.7	7.3	0.3		
Ⅱ.Test					
4. 2021 Summary test	9.0	-	-		
Ⅲ.Target skill (Plan)	**(Results)**				
・ Review of 2020's training, comprehension test, supplemental training.	Included in the 2021 summary test				
・Renewable energy grid interconnection and operation method.	In process				
・ Examples of initiatives in Okinawa related to the spreading of renewable energy.	On-line training				
・Use of storage battery in power system.	On-line training				
・Grid code.	On-line training				
・Data measurement related to performance ratio calculation.	In process				
・Update of hybrid power generation operation and maintenance manual	In process				
Evaluation from JICA Expert Team	8.00	7.00	-		
General evaluation	**8.56**	(7.1)	-		
Comments ※1 No attendance to the training due to works priority. ※2 No presentation of answer to the summary test. (Others reason) ※Total evaluation is made if the trainer has participate in the regional training and presented the test.	Very good willingness to learn.	Need attendance and actively participation to the trainings※1			

July 2021 ～June 2022 / RE O&M Core trainer evaluation result sheet

● **RE O&M Training (KUA)**	**Project Counterparts**			**(Core trainers)**	
Name / Skill	Robert Taualupe	Gifford Sigrah	Ronnie George		
	Operation manager	Distribution foreman	Lineman		
Ⅰ.Attitude to training (max.33 points=10)					
1. Remote training participation (4 times)	1.0	-	-		
2.Participation in the 2nd Regional Training (9 days)	7.0	5.0	7.0		
3.JICA Expert team (willingness to learn)	6.0	5.0	6.0		
4. Manager evaluation	9.0	-	-		
subtotal	23	-	13		
evaluation	7.0	-	3.9		
Ⅱ.Test					
5. 2021 Summary test	-	-	-		
Ⅲ.Target skill (Plan)	**(Results)**				
・Review of 2020 training, comprehension test, supplemental training.	Included in the 2021 summary test				
・Operation and maintenance of PV system.	Online training				
・Revision of PV systemO&M manual.	In prosess				
・Analysis of PV equipment operation efficiency improvement (current situation, economic efficiency, planning (understand master plan)	Online training / Verification of performance ratio measurement values.				
・Inspection check sheet revision and use.	Online training				
・Operation and maintenance of existing PV system (use of check sheet)	Online training / Verification of check sheets.				
・Establishment of maintenance system and personnel plan					
Evaluation from JICA Expert Team	6.00	5.00	-		
General evaluation	**(6.5)**	**-**	**-**		
Comments ※1 No attendance to the training due to works priority. ※2 No presentation of answer to the summary test. (Others reason) ※Total evaluation is made if the trainer has participate in the regional training and presented the test.	Need more attendance and actively participation to the training ※1	Need more attendance and actively participation to the training ※1	※1, ※2		

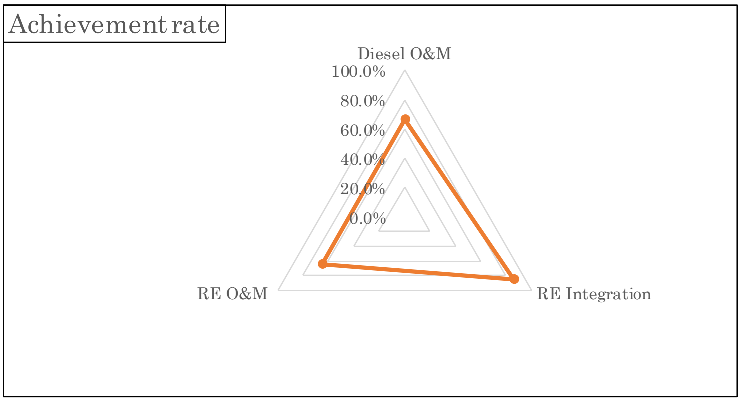
➢ Summary

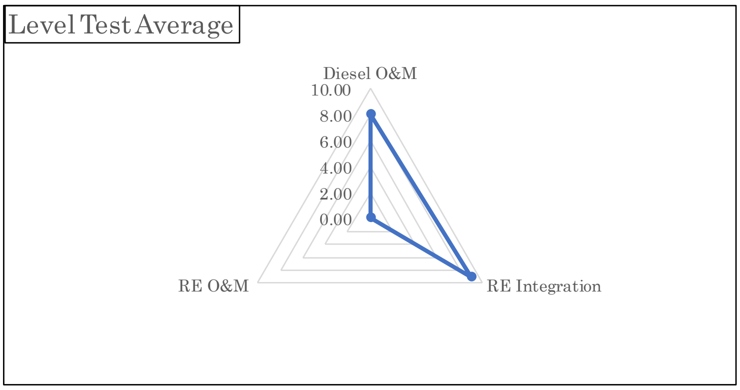
Diesel O&M		
Name	Test points	Achievement
Robert Taualupe	8.0	70.0%
Ronald D. Albert	8.0	63.0%
Tedrick Joseph	-	(55%)
Average	8.0	66.5%

RE Integration		
Name	Test points	Achievement
Gerardo Protacio	9.0	85.6%
Robert Taualupe	-	(71%)
Average	9.0	85.6%

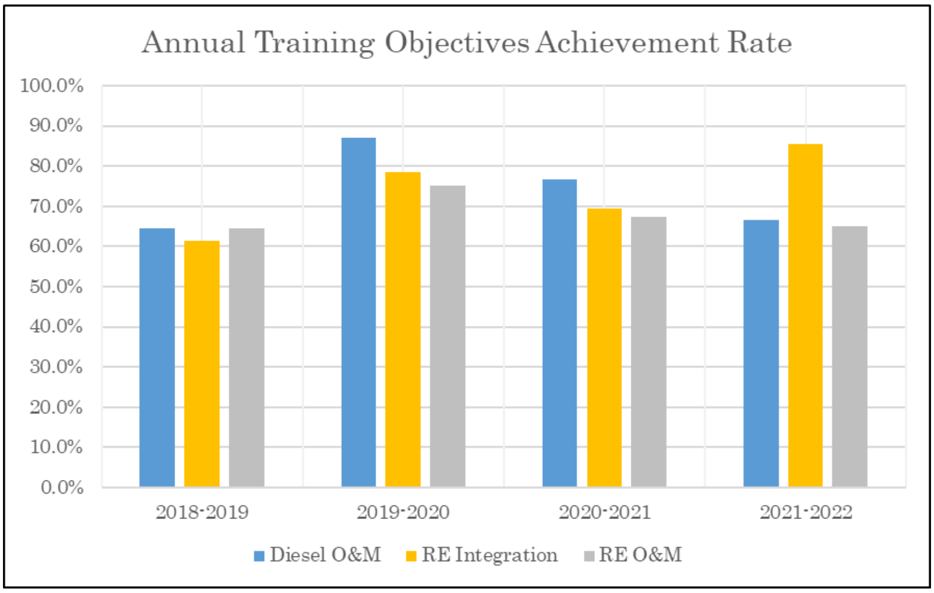
RE O&M		
Name	Test points	Achievement
Robert Taualupe	-	(65%)
Gifford Sigrah	-	-
Ronnie George	-	-
Average	0.00	65.0%

KUA average	Test points	Achievement
Diesel O&M	8.00	66.5%
RE Integration	9.00	85.6%
RE O&M	0.00	65.0%





KUA average	2018-2019	2019-2020	2020-2021	2021-2022
Diesel O&M	64.6%	87.0%	76.7%	66.5%
RE Integration	61.3%	78.6%	69.3%	85.6%
RE O&M	64.6%	75.0%	67.3%	65.0%



From above result, we can observe as follow

① DGs O&M Training

Since 2020, the impact of Covid-19 seems to be one of the causes that lead to a lower motivation of DG core trainers to attend the online trainings, which resulted in a decrease of about 10% in the objective achievement rate compared to the previous period.

For the remainder period of the project, the JICA Expert Team would like that the DG core trainers would make a little more effort to participate in the trainings and complete the requested tasks, such as the revision of the DG O&M manual, which is the only way to get a deeper communication to improve the knowledge acquired so far.

② RE Integration Training

During the evaluation period 2021 to 2022, there was an increase of about 16% in the rate of achievement of the training objectives, since Mr. Gerardo Protacio did a very good job. For the remainder period of the project, the JICA Expert Team expects him to complete the revision of the manual on RE integration including methods and system operation, that is one main topics in this task.

③ RE O&M Training

Same as DG core trainers, a lower motivation to attend the online trainings conducted to a little drop of 2% in the achievement rate of the training objectives.

For the remainder of the project, the JICA Expert Team would like to see a little more effort of the KUA RE core trainers to accomplish the tasks set forth such as the revision of the RE O&M manual and the preparation of the future maintenance plan that it is very important for efficient operation of PV facilities.

End

7.5　2022年～2023年

June 2023
JICA Expert Team

The Project for Introduction of Hybrid Power Generation System in Pacific Island Countries
July 2022 to April 2023 / Training Evaluation
(Kosrae / FSM)

1. Executive Summary

To achieve the project purpose for FSM in the project of the introduction of the Hybrid Power Generation System, two main outputs [1. Enhancement of an appropriate and economical system for O&M of Diesel Generators (DGs) and 2. Establishment of a methodology for appropriate planning and O&M of Renewable Energy (RE)] are required.

As a result of the continuous COVID-19 pandemic since 2020, the JICA Expert Team was unable to conduct the necessary on-site activities, so online training lectures and meetings to support the revision of the DG O&M and RE integration O&M manuals have been provided.

From January 2023, the expert team resumed the travel to Kosrae and conducted DG and RE training on the site for separate. Additionally, in February 2023, the main counterparts of FSM have participated in the 3rd Regional Training for DG and RE, conducted by Fijian trainers in Lautoka training center, Fiji.

2. Training Contents

2.1 Enhancement of an appropriate and economical System for O&M of Diesel Generators (DGs)

Since the JICA expert team was unable to travel to FSM during this period to conduct the necessary hands-on trainings, online trainings were conducted focusing on fuel consumption monitoring, improving knowledge on DG configuration, troubleshooting, and reviewing the DG O&M manual. The contents of the trainings are detailed in the below table.

The result of the DG trainings from July 2022 to April 2023 has showed that Mr. Robert Taualupe was able to achieve 85% of the training objectives based on the training attendance rate, the test during the on-site training in January, and the evaluations by his manager and the JICA expert team. Mr. Ronald Albert and Mr. Tedrick Joseph followed with an achievement rate of 70%, including the test result of the 3rd Regional Training in Fiji.

Training No./ Date		DG O&M Training contents
1	13/Sept/2022	**9th DG remote training and follow up.** ・Overview of the training ・Revision of O&M Manual ・Specific fuel consumption measurement status ・Power plant improvement status ・Confirm status of OH (Data update) ・Troubleshooting ・Others
2	1/Dec/2022	**3rd Follow up for Manual Revision (DG) (Online)** ・DG O&M Manual Revision

3	24-30/Jan/2023	**6th DG On site training** ・Confirmation of the unit condition of power plant ・Repair of fuel flow meter ・Hands-on training in the use of measurement instruments ・Fuel injector valve maintenance ・Check status of improvement plan ・Inspection on Battery, VCB, RTD, TC Pmax, exhaust, temperature, Pump centering, ・O&M revision work progress check
4	13-17/Feb/2023	**3rd Regional Training for DG O&M in Fiji** ・Safety ・Preparation for OH ・Operation of PS in EFL ・Measurement before starting OH ・OH works ・Restoration ・Commissioning ・Measurement Instruments ・Documentation

2.2 Establishment of a methodology for appropriate planning and O&M of Renewable Energy (RE)

The 8th RE remote training (July 2022), two online trainings for RE manual revision support (September and December 2022) and the 6th RE On site training have been provided (March 2023). In addition, the 3rd Regional Training in Fiji has been implemented in February 2023. The contents of the trainings are detailed in the below table.

For the RE O&M online training, the contents focused on the verification of the current operating status of the PV systems through the monthly calculation of the performance ratio (PR), as well as the review of the hybrid power generation system integration and O&M manual according to the KUA standard and conditions.

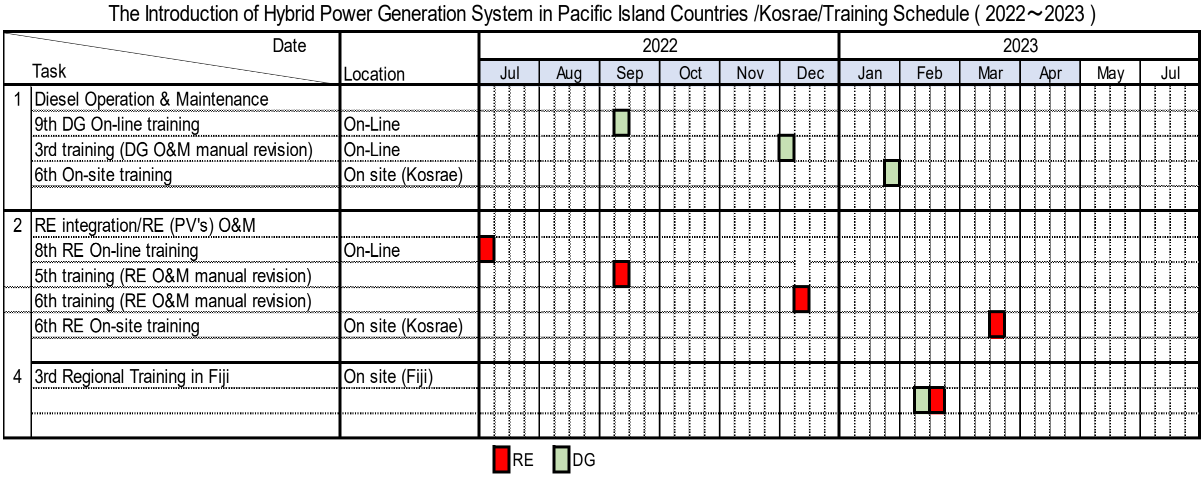
The evaluation result of the RE integration training from July 2022 to April 2023, showed that Mr. Gerardo Protacio was able to achieve about 90.0% of the training objectives based on the trainings attendance rate, the test conducted after the 3rd Regional Training, the test during the on-site training in March and the evaluations by his manager and the JICA Expert team.

Mr. Robert Taualupe scored 74.0% for the RE Integration training and 79% for the RE O&M training, a slightly lower percentage due to work priorities. Unfortunately, the JICA expert team was not able to evaluate Mr. Casey Freddy due to the low attendance rate in the trainings. The two counterparts for RE O&M, Mr. Gifford Sigrah and Mr. Ronnie George, also scored low for the same reason.

Training No. / Date		RE Training contents
1	7/July/2022	**8th RE remote training and follow up** ・Orientation ・Performance ratio ・RE Manual Revision Training (Chapter 1) ・RE integration planning lecture ・RE Manual Revision Training (Chapter 2) ・Future maintenance system and budget for O&M ・Discussion on facility inspection

2	12/Sep/2022	**5th Follow up for Manual Revision (RE) (Online)** ・RE integration / O&M Manual Revision
3	2/Dec/2022	**6th Follow up for Manual Revision (RE) (Online)** ・RE integration / O&M Manual Revision
4	21-27/March/2023	**5th RE On site training** ・Confirm site conditions & Check the inspection record data ・Checking the storage status of equipment (provided) ・PV facility inspection practical training (Open-circuit voltage measurement, Insulation resistance measurement, Inspection using string tracer and cell line checker ・Visual inspection using check sheet ・Maintenance (grass cutting, panel cleaning) ・PV facility inspection practical training (Measurement data evaluation) ・Revision of the RE Manual (RE Integration Planning, RE O&M) ・Preparation of the future maintenance plan (RE O&M) ・Lecture in Renewable Energy Integration Plan
5	20-24/Feb/2023	**3rd Regional Training for RE integration・PV O&M in Fiji** ・DOE presentation(Case study of LaKaRo PV project) ・RE integration & planning(RE development plan in Fiji, (PV and Hydro), Homer software, NCC experiences in RE integration or Grid operation, ・Operation and Maintenance of PV facilities (Measurement of I-V in Lautoka PV, Drawing up of I-V curve and explanation of the curve, Inspection, budget, SCADA system, etc.) ・Site visit (Inspection to Nadi Police Station PV facility / NCC)

3. July 2021 to June 2022 Training schedule



The Introduction of Hybrid Power Generation System in Pacific Island Countries /Kosrae/Training Schedule (2022～2023)

Task		Location	2022 Jul	Aug	Sep	Oct	Nov	Dec	2023 Jan	Feb	Mar	Apr	May	Jul
1	Diesel Operation & Maintenance													
	9th DG On-line training	On-Line			🟩									
	3rd training (DG O&M manual revision)	On-Line						🟩						
	6th On-site training	On site (Kosrae)							🟩					
2	RE integration/RE (PV's) O&M													
	8th RE On-line training	On-Line	🟥											
	5th training (RE O&M manual revision)				🟥									
	6th training (RE O&M manual revision)							🟥						
	6th RE On-site training	On site (Kosrae)									🟥			
4	3rd Regional Training in Fiji	On site (Fiji)												
										🟩🟥				

🟥RE 🟩DG

4. Core Trainers

No.	Core Trainer Name	Position	Comments
1) Operation and Maintenance of Diesel Engine Generators			
1	Robert Taualupe	Operations manager	
2	Ronald D. Albert	SV of operator	
3	Tedrick Joseph	Mechanic	
2) Plan for introduction of hybrid power generation systems			

1	Gerardo Protacio	Electrical engineer	
2	Robert Taualupe	Operations manager	
3	Casey Freddy	Customer service supervisor	
3) Operation and Maintenance of Renewable Energy generation system			
1	Robert Taualupe	Operations manager	
2	Gifford Sigrah	Distribution foreman	
3	Ronnie George	Lineman-2	

DG training attendance record

Date / Name / Org.			2022		2023		Attend. Rate %
			8th On-Line	3rd Manual Revision On-Line	6th DG On site training (for North area) On site (Kosrae)	3rd Regional Training in Fiji	
			9/13	12/1	2023/1/24-30	2023/2/13-17	
Core Trainer	Robert Taualupe	KUA	1	1	1		75.0%
	Ronald D. Albert	KUA	1	1	1	1	100.0%
	Tedrick Joseph	KUA	1	1	1	1	100.0%

RE Integration , O&M training attendance record

Date / Name / Org.			2022			2023		Attend. Rate %
			8th On-Line	5th Manual Revision On-Line	6th Manual Revision On-Line	3rd Regional Training in Fiji	6th RE On site training (for North area) On site (Kosrae)	
			7/7	9/12	12/2	2023/2/20-24	2023/3/21-27	
Core Trainer	Gerardo Protacio	KUA	1	1	1	1	1	100.0%
	Robert Taualupe	KUA	1		1		1	60.0%
	Casey Freddy	KUA	1				1	40.0%
	Gifford Sigrah	KUA					1	20.0%
	Ronnie George	KUA					1	20.0%

5. KUA counterparts training evaluation

The training contents for the 3 task is shown in below table.

Training contents	
1. DG	・Review of 2021 trainings ・Disassembly inspection, troubleshooting of each part of diesel generator. (Continuation of training on electrical and mechanical OJT) ・Completion of the operation and maintenance manual of DG's power generation. (electrical / mechanical) ・Performing of comprehensive test of the regional training. * CP have the knowledge and skill necessary to train staff of the power station.
2. RE	・Review of 2021 trainings

Integration	・Renewable energy grid interconnection and operation method. Grid code. ・Data measurement related to performance ratio calculation. ・Update of hybrid power generation planning manual. *CP will acquire more detailed knowledge regarding to the implementation of Hybrid power generation.
3. RE O&M	・Review of past trainings ・Operation and maintenance method of PV system. ・Inspection check sheet revision and use. ・Revision of PV system O&M manual. ・Establishment of the future maintenance system plan *CP will have the capacity to perform maintenance planning, inspection, and prepare, manage, and analyze work reports.

Results

The JICA expert team has established a criterion for designating key counterparts as core trainers and awarding them with an electronic certificate. The criterion is to pass the overall capacity assessment with a score of more than 70%.

Below training evaluation sheet shown the punctuation of each task main counterpart according to the attendance rate to the online / onsite trainings, the summary test after the 3rd Regional Online training / onsite training, and the evaluations by the manager and the JICA Expert team.

The result shows that for DG O&M Mr. Robert Taualupe, Mr. Ronald Albert and Mr. Tedrick Joseph have been approved as a DG core trainer through the evaluation by JICA Expert team.

For RE integration Mr. Gerardo Protacio and Mr. Robert Taualupe were approved and for RE O&M only Mr. Robert Taualupe was approved.

The overall evaluation result of KUA is shown in the summary.

July 2022 ～April 2023 / DG Core trainer evaluation sheet

● **DG O&M Training (KUA)**	**Project Counterparts (Core trainers)**				
Name	Robert Taualupe	Ronald D. Albert	Tedrick Joseph		
Skill	Operation manager	SV of operator	P/Plant Operator		
Ⅰ.Attitude to training (max. 30 points =10)					
1. training participation (4 times)	7.5	10.0	10.0		
8th DG remote training	✓	✓	✓		
3rd Manual Revision (On-Line)	✓	✓	✓		
6th DG On site training (5days)	✓	✓	✓		
3rd Regional Training (5 days)	※	✓	✓		
2.JICA Expert team (willingness to learn)	8.0	7.0	7.0		
3. Manager evaluation	9.0	6.8※2	6.8		
subtotal	24.5	23.8	23.8		
evaluation	8.2	7.9	7.9		
Ⅱ.Test (max.points=10)					
1. 3rd Regional Training Summary test	※	6.9	7.5		
2. On-site training in January	9.3	6.3	5.6		
Ⅲ.Target skill (Plan)	**(Results)**				
・Review of 2021's training	Verifications during Hands-on training in January 2023 and February regional training in Fiji.				
・Disassembly inspection, troubleshooting of each part of diesel generator. (Continuation of training on electrical and mechanical OJT)	Hands-on training in January and regional training in February 2023				
・Completion of the operation and maintenance manual of DG's power generation. (electrical / mechanical)	Completed				
・Performing of comprehensive test of the regional training.	Carried out in Kosrae last January and Fiji after DG O&M training.				
Evaluation from JICA Expert Team	8.0	7.0	7.0		
General evaluation (max10)	**8.5**	**7.0**	**7.0**		
Comments ※1 No attendance to the training due to works priority. ※2 Due to GM not evaluate, the JICA team adopted the same value that Tedrick.	Good active participation and response to the JICA experts request.	Good participation to the JICA trainings.	Good participation to the JICA trainings.		

July 2022 ～April 2023 / RE Integration Core trainer evaluation sheet

● **RE Integration Training (KUA)**	**Project Counterparts (Core trainers)**				
Name / Skill	Gerardo Protacio	Robert Taualupe	Casey Freddy		
	Electrical engineer	Operation manager	Assistant GM		
Ⅰ.Attitude to training (max.30 points=10)					
1. training participation	10.0	6.0	4.0		
8th RE remote training	✓	✓	✓		
5th Manual Revision (On-Line)	✓	absent	absent		
6th Manual Revision (On-Line)	✓	✓	absent		
5th RE On site training (5days)	✓	absent	absent		
3rd Regional Training (4 days)	✓	✓	absent		
2.JICA Expert team (willingness to learn)	9.0	6.0	-		
3. Manager evaluation	7.6	7.8	N/A		
subtotal	26.6	19.8	4		
evaluation	8.9	6.6	1.3		
Ⅱ.Test (max.points=10)					
1. 3rd Regional Training Summary test	10.0	※1	※1		
2. On-site training in January	9.15	9.5	※1		
Ⅲ.Target skill (Plan)	**(Results)**				
・Review of 2021 trainings	During on-line trainings				
・Renewable energy grid interconnection and operation method. Grid code.	On-line training and regional training				
・Data measurement related to performance ratio calculation.	In every On-line, on-site trainings				
・Update of hybrid power generation planning manual.	Completed				
Evaluation from JICA Expert Team	8.00	6.00	-		
General evaluation	**9.0**	**7.4**	**※2**		
Comments ※1 No attendance to the training due to works priority. ※2 Not possible evaluation due to poor attendance rate.	Very good willingness to learn.	Good attendance rate, need more active participation to the task.	Poor attendance rate to the trainings		

July 2022 ～April 2023 / RE O&M Core trainer evaluation sheet

● **RE O&M Training（KUA)**	**Project Counterparts (Core trainers)**				
Name / Skill	Robert Taualupe	Gifford Sigrah	Ronnie George		
	Operation manager	Distribution foreman	Lineman-2		
Ⅰ.Attitude to training (max.30 points=10)					
1. training participation	6.0	2.0	2.0		
8th RE remote training	✓	absent	absent		
5th Manual Revision (On-Line)	absent	absent	absent		
6th Manual Revision (On-Line)	✓	absent	absent		
6th RE On site training (5days)	✓	✓	✓		
3rd Regional Training	absent	absent	absent		
2.JICA Expert team (willingness to learn)	8.0	7.0	6.0		
3. Manager evaluation	7.8	N/A	N/A		
subtotal	21.8	9.0	8.0		
evaluation	7.3	3.0	2.7		
Ⅱ.Test (max.points=10)					
1. 3rd Regional Training Summary test	-	-	-		
2.On-site training	9.5	9.3	5.0		
Ⅲ.Target skill (Plan)	**(Results)**				
・Review of 2021 training	Verifications during Hands-on training in January				
・Operation and maintenance method of PV system.	On-line、on-site training				
・Inspection check sheet revision and use.	In use				
・Revision of PV system O&M manual.	Completed after 2 follow up meeting.				
・Establishment of the future maintenance system plan	In preparation / need check				
Evaluation from JICA Expert Team	7.00	6.00	6.00		
General evaluation	**7.9**	**6.1**	**4.6**		
Comments ※1 No attendance to the training due to works priority.	Good attendance rate but poor participation to the task.	Poor participation to the trainings	Poor participation to the trainings		

➢ Summary

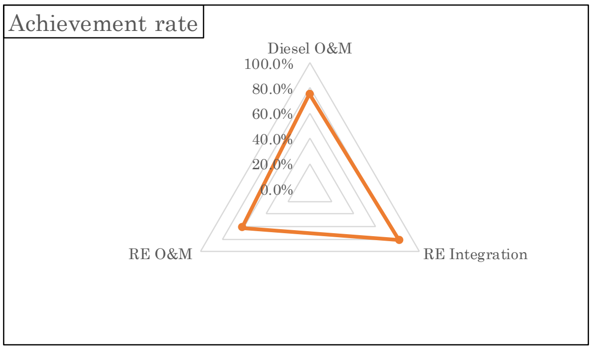
2022～2023 KUA counterparts training evaluation

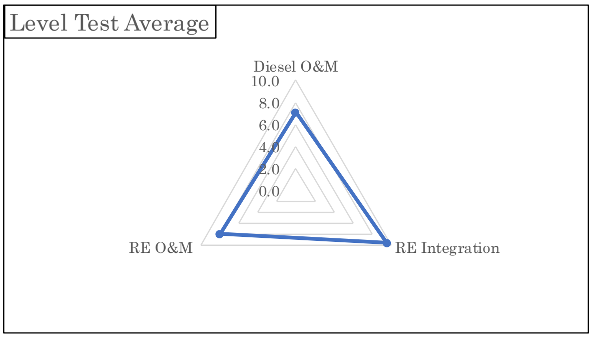
Diesel O&M		
Name	Test points	Achievement
Robert Taualupe	9.3	85.0%
Ronald D. Albert	6.3	70.0%
Tedrick Joseph	5.6	70.0%
Average	7.1	75.0%

RE Integration		
Name	Test points	Achievement
Gerardo Protacio	9.6	90.0%
Robert Taualupe	9.5	74.0%
Average	9.6	82.0%

RE O&M		
Name	Test points	Achievement
Robert Taualupe	9.50	79.0%
Gifford Sigrah	9.30	61.0%
Ronnie George	5.00	46.0%
Average	7.93	62.0%

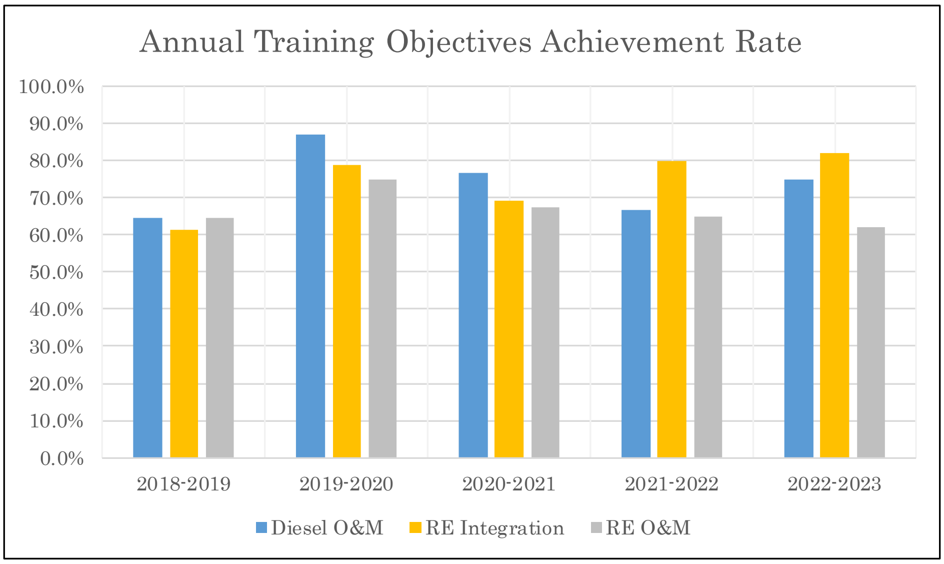
KUA average	Test points	Achievement
Diesel O&M	7.1	75.0%
RE Integration	9.6	82.0%
RE O&M	7.9	62.0%





Annual Training Objectives Achievement rate

KUA average	2018-2019	2019-2020	2020-2021	2021-2022	2022-2023
Diesel O&M	64.6%	87.0%	76.7%	66.5%	75.0%
RE Integration	61.3%	78.6%	69.3%	80.0%	82.0%
RE O&M	64.6%	75.0%	67.3%	65.0%	62.0%



From above result, we can observe as follow.

① DGs O&M Training

During this evaluation period, the only two opportunities for hands-on training were the on-site training in January and the 3rd Regional Training, in Fiji, where the two participants from KUA were able to increase their knowledge and skills through practice and exchange with participants from other PICs. The evaluation result was an increase of 8.5 points in the achievement rate of the training objectives compared with the previous period. The core trainers of this task attended the online trainings almost without fail and also scored well in the tests conducted, so the JICA Expert team would like to see the DG core trainers try to complete the requested task, which is the future maintenance plan, that is an important guide to maintain a continued reliable and affordable power supply in Kosrae.

② RE Integration

The very good active participation of Mr. Gerardo Protacio and Mr. Robert Taualupe increased the training objective achievement rate by 2 points compared to the previous year. The JICA expert team recognizes that Mr. Gerardo has made good efforts to complete the RE integration manual with the grid code for RE, which is a difficult subject to prepare. The JICA expert team would like KUA to continue to revise and update the contents, which is very important for the implementation of RE power generation in Kosrae.

③ RE O&M

Due to the influence of COVID-19, the JICA Expert team could not provide the necessary hands-on training on PV system maintenance, and in addition, two of the main RE counterparts did not participate in the online trainings and the regional training in Fiji, they only attended the on-site training in last March. This was the main reason for KUA not being able to maintain the same average of the training objectives achievement rate as the previous year, which was 3 points higher than the current period at 62%.

As the number of PV installations in Kosrae increases, it will be necessary for KUA to increase the number of PV maintenance personnel and to assign Mr. Robert Taualupe to train these new members as he is the only core trainer approved by JICA Experts team.

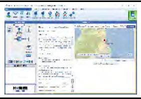
End

8. 供与機材実績

8.1　機材リスト

8.1 機材リスト(コスラエ)

No.	機材名称	数量	供与目的／必要性	備考
DG 供与機材				
1	Fuel flow meter Nitto Seiko BRC20-2-P4	4	正確な燃費を測定するため 燃料流量計	
2	Digital Pressure Calibrator Baker Hughes DPI800S	1	DG 計装機器の維持管理 圧力測定校正器	
3	Digital multimeter YOKOKAWA TY710	1	DG 計装機器の維持管理 マルチテスター	
4	Digital thermometer TOKOKAWA TX1001	1	DG 計装機器の維持管理 デジタル温度計	
5	Instrumentation signal measurement / Generator YOKOKAWA CA150	1	DG 計装機器の維持管理 計装信号測定・発生装置	
6	Ohm meter YOKOKAWA MY600	1	DG 計装機器の維持管理 絶縁抵抗計	
7	Air compressor kit Baker Hughes PV211	1	DG 計装機器の維持管理 空気圧加圧ポンプキット	
8	Air hose 1 m × 2　1.5 m × 1	1	DG 計装機器の維持管理 エアーホース	
9	Various types of fittings (1/8, 1/4, 3/8, 1/2, 3/4, 1)	1	DG 計装機器の維持管理 各種継手類	
10	Battery HiTester HIOKI BT3554	1	蓄電池設備の運転状況を診断 バッテリーテスター	
11	Clamp on AC/DC HiTester HIOKI 3285	1	蓄電池設備の運転状況を診断 クランプオンハイテスタ	
12	Radiation thermometer HIOKI FT3701	1	蓄電池設備の運転状況を診断 赤外線放射温度測定器	
13	Battery hydrometer	1	蓄電池設備の運転状況を診断 バッテリー液比重計	
14	Vibration measuring instrument TASCO TA415EB	1	DG 設備の運転状況を診断 振動計	
RE 供与機材				
15	Pyranometer & thermometer Togami Electric Mfg SPST-A-F2	1	PV 設備の運転状況を診断 日射・温度計	
16	String Tracer(I -V curve tracer) Togami Electric Mfg SPST-A2A-Y1	1	PV 設備の運転状況を診断 ｽﾄﾘﾝｸﾞ異常検知機器	

17	Cell Line Checker Togami Electric Mfg SPLC-A-Y1	1	PV 設備の運転状況を診断 故障ﾓｼﾞｭｰﾙ特定機器	
18	HOMER PRO HOMER Software	1	RE 設備の効果的な導入計画の立案 シミュレーションソフト	
19	Insulation Tester HIOKI IR4053-11	1	PV 設備の運転状況を診断 絶縁抵抗計	
20	Thermographic Camera Fluke TiS55	1	PV 設備の運転状況を診断 サーモグラフィ（温度監視）	
21	Digital Multimeter HIOKI DT4254	1	PV 設備の運転状況を診断 マルチテスター	

8.2　受領書

For Equipment based on R/D (which requested from government of the Federated States of Micronesia)

CERTIFICATE OF RECEIPT

PROJECT TITLE: INTRODUCTION OF HYBRID POWER GENERATION SYSTEM IN PICS

This is to certify that the equipment listed below for the above mentioned project have been received properly as of June 2018 to Kosrae Utilities Authority (KUA) from Japan International Cooperation Agency (JICA) Micronesia Office.

	Name of equipment	Model #	Quantity	Date of handover
1.	Type BR Oil Meter	BR20-2	6	

Sign:
Name: Mr. Fred Skilling
Title: General Manager
Organisation: Kosrae Utilities Authority
Place: Kosrae Utilities Authority
Date: 06/ 21 /2018

CERTIFICATE OF HANDOVER

To: Okinawa Enetech Co., Inc

Re: The Project for Introduction of Hybrid Power Generation System in Pacific Island Countries

This certificate of handover is to certify that the equipment in the attached list, which shall be utilized for the [The Project for Introduction of Hybrid Power Generation System in Pacific Island Countries], have been handed over properly to [Kosrae Utilities Authority], as of below date.

■Attached: List of Equipment

No.	Name of equipment	Model	Quantity	Manufacturing company
1	Pyranometer & thermometer	SPST-A-F2	1	Tagami Electgric Mfg.Co.,Ltd
2	StringTracer(I -V curve tracer)	SPST-A2A-Yl	1	
3	Cell Line Checker (Fault module detector)	SPLC-A-Yl	1	

(Signature)

Mr.Gifford Sigrah GIFFORD SIGRAH

~~Distribution Foreman~~

Kosrae Utilities Authority

Date 7/30/2018

※受領書：Kosrae
KUA(1台)

CERTIFICATE OF HANDOVER

To: Okinawa Enetech Co., Inc
Re: The Project for Introduction of Hybrid Power Generation System in Pacific Island Countries

This certificate of handover is to certify that the equipment in the attached list, which shall be utilized for the [The Project for Introduction of Hybrid Power Generation System in Pacific Island Countries], have been handed over properly to [Kosrae Utilities Authority], as of below date.

■Attached: List of Equipment

No.	Name of equipment	Model	Quantity	Manufacturing company
1	HOMER PRO	Standard permanent license	1set	HOMER Energy LCC

(Signature)
Mr. Robert Taualupe
Operation Manager
Kosrae Utilities Authority

Date 01/08/19

CERTIFICATE OF HANDOVER

To: JICA Micronesia Office

Re: The Project for Introduction of Hybrid Power Generation System in Pacific Island Countries

This certificate of handover is to certify that the equipment in the attached list, which shall be utilized for the [The Project for Introduction of Hybrid Power Generation System in Pacific Island Countries], have been handed over properly to [CHUUK PUBLIC UTILY CORPORAITION (CPUC)], as of below date.

- Attached: List of Equipment

No.	Equipment name	Model	Qty.	Manufacturer
1	Battery HiTester	BT3554	1	HIOKI
2	Clamp on AC/DC HiTester	3285	1	
3	Radiation thermometer	FT3701	1	
4	Battery hydrometer	-	1	-
5	Vibration measuring instrument	TA415EB	1	TASCO
6	Thermographic Camera	TiS55	1	Fluke
7	Digital Multimeter	DT4254	1	HIOKI
8	Mower	MEM428	1	Makita
9	High pressure washer	JCE-1408UDX	1	KOSHIN

The parties acknowledge and agree that this CERTIFICATE OF HANDOVER may be executed by electronic signature, which is considered as an original signature for all purposes and has the same force and effect as an original signature. "Electronic signature" includes faxed versions of an original signature or electronically scanned and transmitted versions (e.g., via pdf) of an original signature

(Signature)____________________
Kembo Mida
Chief Executive Officer
Chuuk Public Utility Corporation (CPUC)
Chuuk, Micronesia

Date 9/19/2022

Equipment List

No.	Name of equipment	Model	Qty	Manufacturer	Comments
1	BATTERY HiTESTER	BT3554	1	HIOKI	 960g・W199×H132×D60.6 ㎜
2	CLAMP ON AC/DC HiTESTER	3285	1	HIOKI	 540g・W62×H260×D39㎜
3	Radiation thermometer	FT3701	1	HIOKI	 256g・W48×H172×D119㎜
4	Battery hydrometer	-	1	-	 230g・W200×H78×D54㎜
5	Vibration measuring instrument	TA415EB	1	TASCO	 55g・W150×H22×D18㎜
6	Thermographic Camera	TiS55	1	Fluke	 2270g・W101×H267×D145㎜
7	Digital Multimeter	DT4254	1	HIOKI	 390g・W84×H52×D174㎜
8	Mower	MEM428	1	Makita	 5.2kg・W595×H1770×D370㎜

9	High pressure washer	JCE-1408UDX	1	KOSHIN	 31kg・W585×H775×D960㎜

End

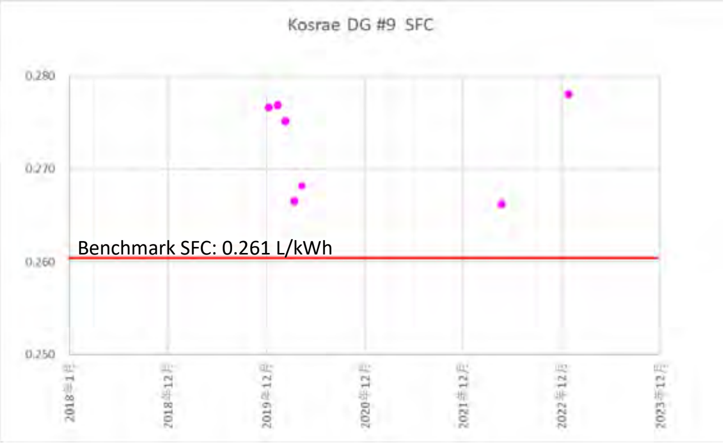
9. 燃料消費率
パフォーマンスレシオ値

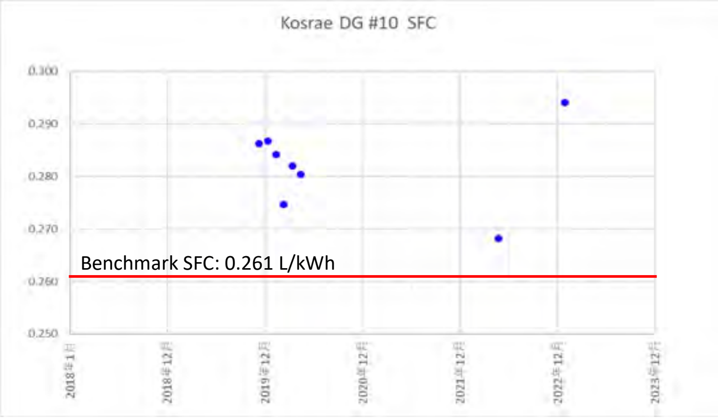
9.1　燃料消費率

コスラエの燃料消費率記録

コスラエ（FSM）の PDM に設定されたアウトプット 1-2『パイロット DG の燃料消費率が測定される』について下記表に記録を示す。

DATE	Fuel Consumption rate [L/kWh]	
	Unit #9	Unit #10
2019/12/1	—	0.286
2020/1/1	0.277	0.287
2020/2/1	0.277	0.284
2020/3/1	0.275	0.275
2020/4/1	0.267	0.282
2020/5/1	0.268	0.280
2022/5/20	0.266	0.268
2023/1/24	0.278	0.294
2023/1/25	0.279	0.295
2023/1/26	0.280	0.293
2023/1/27	0.270	0.292





プロジェクト期間中での発電所の年間燃料消費率の結果は以下の表に示す。

No	Description	Unit	2017	2018	2019	2020	2021	2022
1	Diesel Power Generation	kWh	6,016,055	5,723,512	6,434,030	6,846,007	6,584,895	6,529,217
2	Annual Total Fuel Consumption	Gal	448,929	447,019	468,045	490,968	490,490	485,427
		Litres	1,699,394	1,692,164	1,771,757	1,858,530	1,856,721	1,837,555
3	**SFC**	**L/kWh**	**0.282**	**0.296**	**0.275**	**0.271**	**0.282**	**0.281**

総合評価

コスラエのユニットでは、9 号機、10 号機とも燃料高圧管から燃料漏れが発生しているため、燃料消費率ベンチマーク 0.261 L/kWh にはほぼ届かない。2023 年中に Top OH を実施予定のため、OH 前後で燃料消費率を測定し比較することで、OH による燃料消費率の向上が確認できる。

以上

9.2　パフォーマンスレシオ値

コスラエPV設備（PEC Fund PV）

基本情報

設備名称	PEC Fund PV	外観写真	
導入年	2015年		
容量(kW)	200kW		
ドナー名			
管理者	KUA		

パフォーマンスレシオ(ベースライン:66%)

2020年	1月	2月	3月	4月	5月	6月	7月	8月	9月	10月	11月	12月	平均
	72.4	68.2	73.5	77.7	76	-	-	33.7	-	-	-	-	66.92
2021年	1月	2月	3月	4月	5月	6月	7月	8月	9月	10月	11月	12月	平均
	-	-	-	77.7	79.8	79.4	80.8	57.9	77.3	71.1	59.6	50	70.4
2022年	1月	2月	3月	4月	5月	6月	7月	8月	9月	10月	11月	12月	平均
	69.6	72.2	73.2	78.8	74.4	48.5	73.2	67.3	64.3	62.9	63.7	71.5	68.3
2023年	1月	2月	3月	4月	5月	6月	7月	8月	9月	10月	11月	12月	平均
	64.2	65.3	74.4	72.9	55.4	-	-	-	-	-	-	-	66.44

メモ

Baseline Perfomance Ratio =66%

（別添資料）
1. プロジェクト対象設備のパフォーマンスレシオ値比較表（ベース値、各月計測値、計測値年平均）
2. パフォーマンスレシオ計測値評価表（コスラエ）

コスラエPV設備（EU PV）

基本情報			
設備名称	EU PV	外観写真	 
導入年	2015年		
容量(kW)	100kW		
ドナー名			
管理者	KUA		

パフォーマンスレシオ(ベースライン:56%)													
2020年	1月	2月	3月	4月	5月	6月	7月	8月	9月	10月	11月	12月	平均
	53.4	54	60.6	56.1	54.7	57.2	59.1	59.8	59.8	58.4	56.2	50.7	56.67
2021年	1月	2月	3月	4月	5月	6月	7月	8月	9月	10月	11月	12月	平均
	-	-	-	56.8	53.7	52.7	51.1	59.3	55.4	54.8	57.3	23.9	51.67
2022年	1月	2月	3月	4月	5月	6月	7月	8月	9月	10月	11月	12月	平均
	55.6	53.6	55.4	-	53.5	55.5	52.8	54.5	59.1	58.2	61.4	58.5	56.19
2023年	1月	2月	3月	4月	5月	6月	7月	8月	9月	10月	11月	12月	平均
	61.2	-	44.4	58.9	58.3	-	-	-	-	-	-	-	55.7

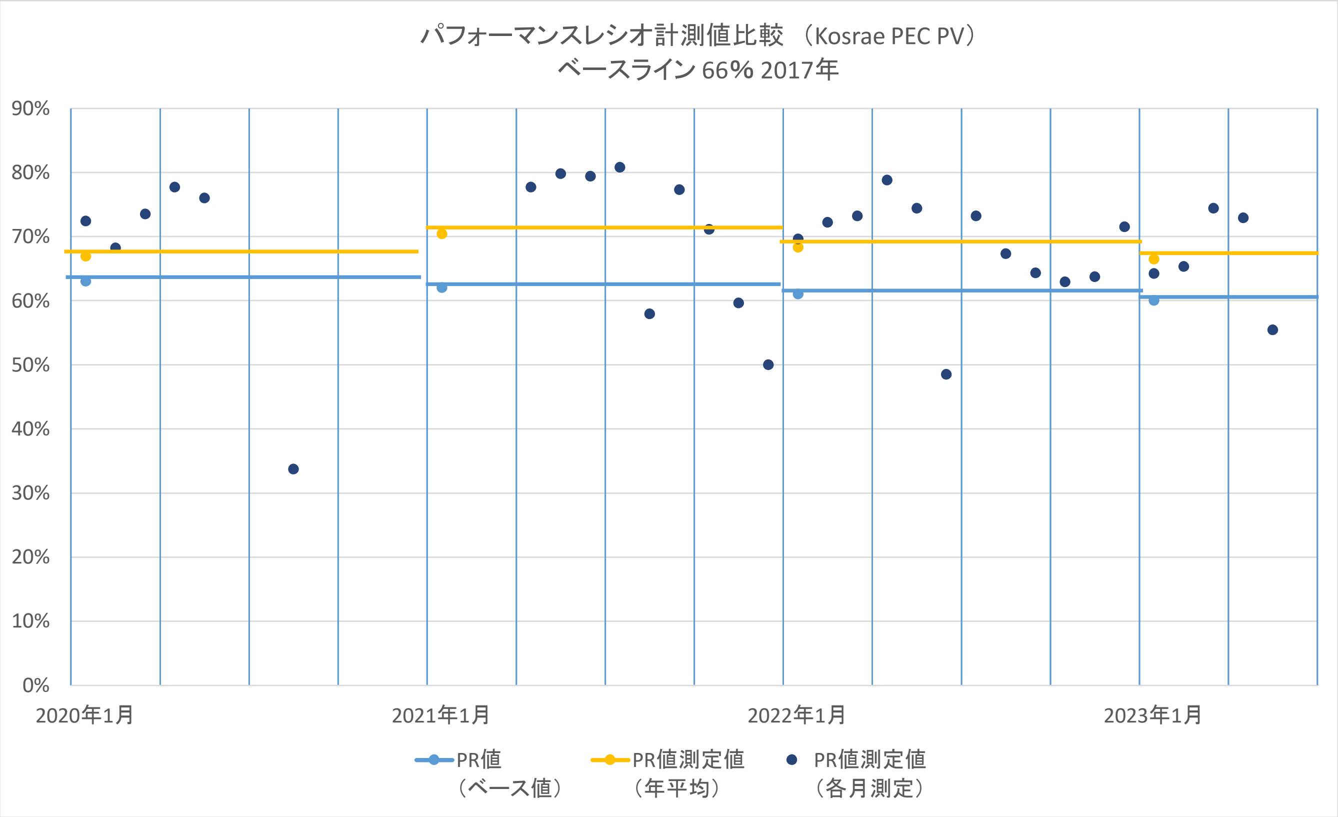
メモ

Baseline Perfomance Ratio =56%

（別添資料）
1. プロジェクト対象設備のパフォーマンスレシオ値比較表（ベース値、各月計測値、計測値年平均）
2. パフォーマンスレシオ計測値評価表（コスラエ）

パフォーマンスレシオ計測値比較（Kosrae PEC PV）

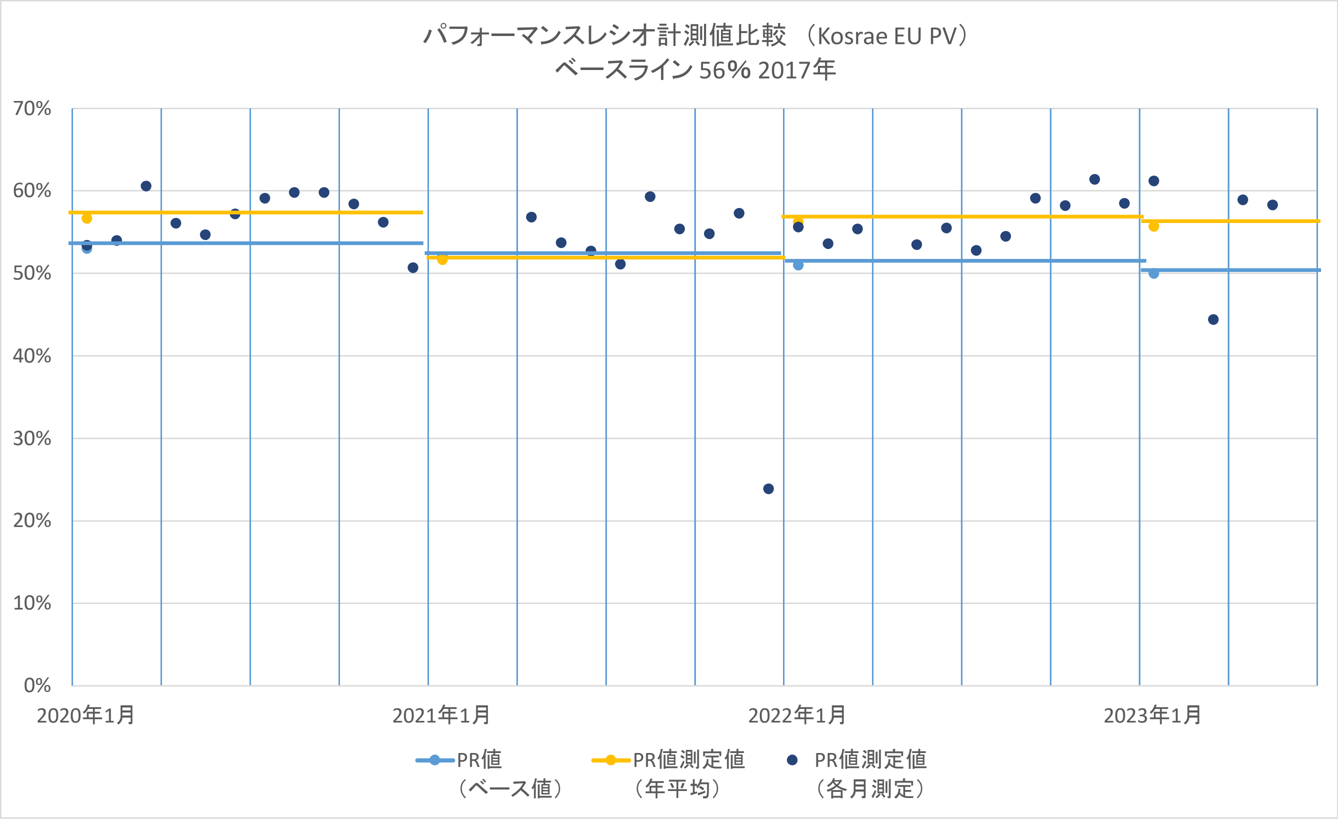
	PR値（ベース値）	PR値測定値（年平均）	PR値測定値（各月測定）
2020年1月	63%	66.9%	72.4%
2020年2月			68.2%
2020年3月			73.5%
2020年4月			77.7%
2020年5月			76.0%
2020年6月			
2020年7月			
2020年8月			33.7%
2020年9月			
2020年10月			
2020年11月			
2020年12月			
2021年1月	62%	70.4%	
2021年2月			
2021年3月			
2021年4月			77.7%
2021年5月			79.8%
2021年6月			79.4%
2021年7月			80.8%
2021年8月			57.9%
2021年9月			77.3%
2021年10月			71.1%
2021年11月			59.6%
2021年12月			50.0%
2022年1月	61%	68%	69.6%
2022年2月			72.2%
2022年3月			73.2%
2022年4月			78.8%
2022年5月			74.4%
2022年6月			48.5%
2022年7月			73.2%
2022年8月			67.3%
2022年9月			64.3%
2022年10月			62.9%
2022年11月			63.7%
2022年12月			71.5%
2023年1月	60%	66%	64.2%
2023年2月			65.3%
2023年3月			74.4%
2023年4月			72.9%
2023年5月			55.4%
2023年6月			



※PR値（ベース値）について、2017年を基準として1%/年の効率低下を想定し許容する。（例：6年間で6%の低下を許容する。）

パフォーマンスレシオ計測値比較（Kosrae EU PV）

	PR値（ベース値）	PR値測定値（年平均）	PR値測定値（各月測定）
2020年1月	53%	56.7%	53.4%
2020年2月			54.0%
2020年3月			60.6%
2020年4月			56.1%
2020年5月			54.7%
2020年6月			57.2%
2020年7月			59.1%
2020年8月			59.8%
2020年9月			59.8%
2020年10月			58.4%
2020年11月			56.2%
2020年12月			50.7%
2021年1月	52%	51.7%	
2021年2月			
2021年3月			
2021年4月			56.8%
2021年5月			53.7%
2021年6月			52.7%
2021年7月			51.1%
2021年8月			59.3%
2021年9月			55.4%
2021年10月			54.8%
2021年11月			57.3%
2021年12月			23.9%
2022年1月	51%	56%	55.6%
2022年2月			53.6%
2022年3月			55.4%
2022年4月			
2022年5月			53.5%
2022年6月			55.5%
2022年7月			52.8%
2022年8月			54.5%
2022年9月			59.1%
2022年10月			58.2%
2022年11月			61.4%
2022年12月			58.5%
2023年1月	50%	56%	61.2%
2023年2月			
2023年3月			44.4%
2023年4月			58.9%
2023年5月			58.3%
2023年6月			



※PR値（ベース値）について、2017年を基準として1%/年の効率低下を想定し許容する。（例：6年間で6%の低下を許容する。）

2023年6月末 現在

［JICAハイブリッド］パフォーマンスレシオ計測値評価表（コスラエ）

	パフォーマンスレシオ計測値評価											
国名	PJ対象施設	ベースライン（2017年）	2020		2021		2022		2023		妥当性の根拠（許容値）	計測値評価、計測値が低い理由など
			計測値年平均	許容値	計測値年平均	許容値	計測値年平均	許容値	測定値年平均	許容値		
コスラエ	PEC	66%	66.92%	63%	70.40%	62%	68.30%	61%	66.44%	60%	1%/年の効率低下を想定し許容する。（6年間運用では、6%の低下を許容する）	（測定値評価） ・計測値について、ベース値66%に対して、2020年～2021年6月までは年間平均値が67%～70%の間で推移しており、良い状態で運用できていると考える。 ・2020円6月～2021年3月まで計測値データがないことから、期間の状態については不明であるが、この期間前後はベース値より高い数値を維持している。 ・2020年8月の数値が極端に低下しているが、前後月の数値も低下が継続しているか不明であり、PR計測値のみで設備の不具合や劣化の原因と判断することは難しい、外的要因（太陽光の遮断など）も考えられるので、今後の計測時にこのような計測値がでた際は、数値を再確認してほしい。 （現在の運用値が低い理由など） ・2023年5月は、PCS（インバータ）の故障により数値が下がっている。現地CPにおいて原因究明できているため復旧対応後は、計測値も回復することが予想される。PCS（インバータ）故障前のPR値は72.9%(2023年4月)、74.4%(2023年3月)であり、ベースライン以上の値を維持している。
	EU	56%	56.67%	53%	51.67%	52%	56.19%	51%	55.70%	50%		（測定値評価） ・計測値について、ベース値56%に対して、年間平均値が52～57%で推移しており、ほぼベース値に近い良い状態で運用できていると考える。 ・2021年12月の数値が極端に低下しているが、前後月の計測値はベース値に近いことから、PR計測値のみで設備の不具合や劣化の原因と判断することは難しい、外的要因（太陽光の遮断など）も考えられるので、今後の計測時にこのような計測値がでた際は、数値を再確認してほしい。。

（別添資料）
1. パフォーマンスレシオ計測値 （2020年1月～2023年6月 設備毎の毎月計測値）
2. プロジェクト対象設備のパフォーマンスレシオ値比較表（ベース値、各月計測値、計測値年平均比較）

10. 運用改善計画

Improvement plan works progress report sheet（ Kosrae / FSM ）											
フェーズ		フェーズ 1	フェーズ 2								
No.		1	2	3	4	5	6	7	8	9	10
場所		現地	遠隔								現地
年		2017	2020				2021			2022	2023
確認月日		11/27 北-1 渡航	6/24 第 1 回	7/30 第 2 回	8/25 第 3 回	10/20 第 4 回	1/26 第 5 回	5/26 第 6 回	9/7 第 7 回	5/30 第 8 回	1/30 北-6 渡航
No.											
Power station building											
1	Reparation of the building	○	未	完了							
2	Cleaning and order	○	未	完了							
3	Concrete ceiling	○	未	完了							
Electrical Devices											
1	Cable pit covering	○	未	未	未	未		未	未	済	
2	Generator washing	○	未	未	未	未		未	未	OH 時(#8#6)	#9#10#11 の運用のため、必要無し
3	Cable pit covering	○	未	未	未	未		未	未	2022/6/1 実施予定	未実施
4	Inspection of relays in units #5 and #6(87 · 51 G).	○	未	未	未	未		未	未	完了#4#6#8	#9#10#11 の運用のため、必要無し
5	Internal cleaning of electrical boards	○	未	未	未	未		未	未	完了	
Mechanical devices											
1	Fuel flow meter installation	○	未	完了							
2	Stage installation	○	未	未	未	未		未	未		#9#10#11 の運用のため、必要無し
3	Tidy up	○	未	完了							
Operation / Maintenance / Management											
1	Implementation of SCADA system		未	未	未	未	未	未	未	未	WB プロジェクト計画
2	Report and records of troubles and fix results in the power plant.		未	未	未	未	未	未	未	完了	
3	Spare parts account record book.		未	未	未	未	未	未	未	完了	
4	Implementation of daily patrol.		未	未	未	未	未	未	未	完了	
5	Worker’s safety gears		未	未	未	未	未	未	未	完了	
6	Organizing drawings		未	未	未	未	未	未	未	未	完了
7	Updating of drawings (as commissioned)		未	未	未	未	未	未	未	未	完了
8	Cleaning of solar panels								未	未	完了
9	Record of PEC fund PV facility (generation data)										
10	Record of PEC fund PV facility (curtailment data)										

June 2023
JICA Expert Team

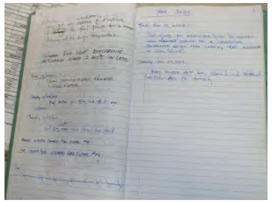
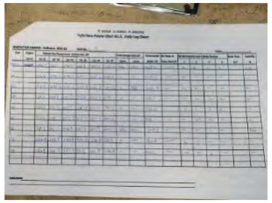
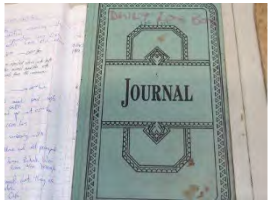
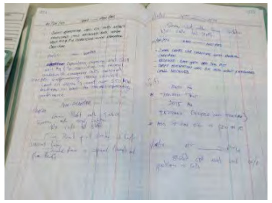
Improvement plan works progress report sheet (Kosrae)

Improvement Plan	**Progress status**	**Completion**
Powerhouse		
1. Old building Power house is deteriorating. Some places should be repaired. Safe operation  	・Reason for not implementation : ・Expected implementation schedule:	**OK**
2. Cleaning and order Old machines are scattered inside of the power plant. Risk: Operators and maintenance staff works security.  	・Reason for not implementation : ・Expected implementation schedule:  	**OK**
3. Concrete ceiling Part of the concrete ceiling inside of the control room seems to be peeling off. Risk: ・The concrete falls off and hit the operator's head. ・Possibility that the electric equipment is damaged. If these units will be operated as an emergency power generation facility, from the security point of view of the operators, it is better to fix it with implementation of net or mortar finishing.	・Reason for not implementation : ・Expected implementation schedule:	**OK**

Improvement Plan	Progress status	Completion
Mechanical		
1. Fuel flow meter installation Installed electronic fuel flowmeters are not working since the monitoring PC does not work. Risk: Fuel efficiency of the unit is unable to be calculated and maintenance work can't be set if fuel efficiency is bad. (please send flowmeter specification and quotation) Replacement of fuel flow that show in site the amount used. ※installed in Unit #11Caterpillar (2019install600kW) for both outbound and return. ※Flow meter for Unit #9 was installed due to existing failure.	・Reason for not implementation : ・Expected implementation schedule:  	Unit #8, #11(WB), #9 **OK**
2. Stage installation Establishment of a stage with fence for safe inspection that allows to check around the cylinder head on both side of the engine.   	・Reason for not implementation : #8 only　Planning Other units are unnecessary due to their low height. ※The current operation is Unit#9,#10,#11, so installation would not be necessary. ・Expected implementation schedule:	**Pending**
3. Tidy up Maintenance tools are scattered inside of the power plant. Risk: Emergency repair can be delayed due to arrange tools and equipments ・Separate common tools and special tools used in OH works. Putting them in order and arrange one set for each unit.  	・Reason for not implementation : ・Expected implementation schedule: Tools are organized in the new building. 	**OK**

Improvement Plan	Progress status	Completion
Electrical		
1. Cable pit The cable pit inside of the control room was not installed the cover. Risk: ・Operators can fall into the pit. ・Short-circuit accidents can be caused by small animals entering into the electric board through the open pit or biting cables. ※Close the pit with a cover made by veneer or steel. 	・Reason for not implementation : ・Expected implementation schedule:	**Pending**
2. Generator cleaning Dust and moisture enter inside of the all generator through the air intake. Dirt and rust in the stator and rotor wad observed. The same as for the exciter. Risk: The generator coil can cause fire.(heavy trouble trip ※Open the cover of the stop machine (about once every 3 months) and wipe as much as possible with a waste cloth (as a vacuum cleaner is considered, but it is dangerous from the viewpoint of fire) ※Cleaning completed. Filter under consideration.	・Reason for not implementation : ・Expected implementation schedule: 	**cancelled**
3. Opening curing The high-voltage cable rising from the pit inside of the circuit breaker panel of the unit #8 has an aperture. In addition, there are some apertures in the high-voltage cable rising from the pit to the generator of the unit #8 Risk: Power supply troubles due to a short circuit accident can be caused by small animals entering to electrical boards. ※Close the pit with a cover made by veneer or steel.	・Reason for not implementation : ・Expected implementation schedule: 	**Pending**

Improvement Plan	Progress status	Completion
4. Organization of electric boards. Since Unit #4 and #6 have been installed for over 20 years, it is concerned the installed relays do not work (87 · 51 G). Risk: Malfunction of the relays can cause burning of the power generation facility or electrical shock accidents. ※We recommend to check and confirm the operation of the protection relays(unit testing) or replace. (Japanese standard for replacement of protection relays is recommended less than 15 years)  	・Reason for not implementation : #6, #4, #8 OK during installation of new Daihatsu engines.	**Cancelled**
	・Expected implementation schedule: ※ Since the current operation is Unit#9,#10,#11, it is not expected to require replacement.	
5. Cleaning Dust inside of the circuit breaker of the unit #8 and rust on the breaker, withdrawal wheel, etc. are observed. Same conditions the units #4 and #6. Risk The circuit breaker could not open in case of any alarm. In that case, it damages the engine and electric shock accident may occur. ※1)Check the normal operation of the circuit breaker. 2)In case of malfunction, replacement is recommended.	・Reason for not implementation :  	**OK**
	・Expected implementation schedule:	

Operation & Maintenance Management	Reason for not implementation / Expected implementation schedule
1. For operation is better if the operator of the power plant can know on time outputs from IPP, Hydro and PV generation system. Introduction of SCADA system is recommended.	Contract is scheduled to be signed this year.(2022 WB)
2.Record of troubles in the power plant and fix results in the power plant. It gives you reference to plan special maintenance works.	Share reports of troubles  
3. Spare parts account record book. Reduce cost of spare parts in maintenance knowing the stock.	Prepare account record book.
4. Implementation of daily patrol. To know if there is not fault in the power generation facility.	Using the Logbook    
5. Wearing of safety helmets, work clothes, safety shoes, glasses etc. is desirable for workers.	Share picture  

6. Facility as constructed drawings and modifications drawings, specifications, diagrams etc. are not in order. (Caterpillar engines) Risk: Power plant managers and technical personnel cannot grasp the whole facility electrical and mechanical composition of the plant and it takes time to resolve problems in case of emergency. After completion of construction of the new power plant, claim the drawings and manuals of the facility as built and keep these in determined office inside of the power station. Take care of feedback small and big remodeling or changes in mechanical or electrical composition into the drawings.	All in Robert-san office.  
7. We could not see the approval drawings for the new units #10 and #11. Risk: It can be different from what KUA was planned. In the construction of new mechanical or electrical facility as well as modification works, it is necessary to confirm the drawings and hold meetings with the contractor to verify the contents and the progress of the works.	Completed, All in Robert-san office.
8. Dry grasses were observed on the PV panels of PEC PV. It can be affected to efficiency of PV generation. We will provide a maintenance check sheet for PV system. 	Cleaned in May
9. Generation data of PEC PV was lack partially. Data especially 10min and hour one is just stored the latest of 40days on the ftp server. Please save data once a month and it will be utilized for calculation of generation fluctuation and simulation of hybrid system.	Confirm to Gerard-san
10. We cannot confirm curtailment of PEC PV generation from the data. Please keep the operation log for PEC PV even after installation of timer for automatic curtailment to match operation and data.	Confirm to Gerard-san

11. マニュアルおよび将来業務計画書

11.1　DGマニュアルおよび将来業務計画書
(O&M)

11.1.1 DG 改訂マニュアル(O&M)

Diesel Generation
Operation and Maintenance Manual

Kosrae Utilities Authority

June 2023

(Signature)__________________________
Approved by
Fred Skilling
General Manager
Kosrae Utilities Authority (KUA)
Date 30 June 2023

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Diesel Generation
Operation and Maintenance Manual

1. SAFETY

Kosrae Utilities Authority

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1. Introduction

01 Safety of life shall outweigh all other considerations.

02 It is the intent of the KUA to provide a safe and healthy work environment for all employees have the knowledge, skills, and equipment to perform their jobs safely.

03 These rules shall be strictly adhered to. Negligence, carelessness or unsafe work practices shall not be tolerated. It is not practical to describe in detail all safe work practices necessary steps operation of the KUA.

04 No work is ever to be considered so important or urgent that the necessary steps cannot be taken to do safely.

05 All employees are responsible for seeing that all applicable safe work practices are followed in the performance of the job. Each employee has the additional responsibility of assisting in the safeguarding of others.

06 An employee shall not use intoxicants or drugs while on duty, report for duty while under the influence of toxicants or drugs or be relieved by another employee known To be under the influence of toxicants or drugs. If an employee's physician has prescribed drugs or medication that will limit the employee's ability to perform certain Jobs, the employee shall inform the supervisor of that effect.

07 Each employee shall challenge any carelessness or unsafe work practices and, if the employee believes it necessary in the intent of safety, shall advise the person in charge.

1.1 Safety first

This section sets out the safety rules to be observed at all times by all persons engaged in works on power station, or electrical supply facilities. Its objectives are to ensure

a. The safety of each individual
b. The safety of his workmates
c. The safety of the public and the environment
d. The safety of the power generation equipment and property

At all times, in all places, care shall be exercised, and undivided attention given to the work in hand.

Where there is any doubt about what is to be done the Team Leader in charge shall be consulted before starting the job. No work shall commenced until all doubts have been clarified.

1.2 General instruction for safety work planning

All work shall be planned in a safe manner prior to execution and the following steps needs to be followed.

a. Is the responsibility of the operation manager to physically identify the switch number to be operated, identify and mitigate all hazards, prepare a work plan, and draw a scope of work, identifying material and required manpower.
b. It is responsibility of the Team Leader to ensure that all members of the team have thoroughly understood the work to be carried out prior to the commencement of the work.
c. For all unplanned work the person in charge at the time shall be responsible for identifying and

controlling all safety issues conducting a job site safety assessment.

d. Take 5

1. Stop, Step back, Observe
2. Walkthrough the task
3. Identify all potential and existing Hazards
4. Control & Communicate
5. Safety Complete Task

2. Safety equipment & personal protection

All personal protective equipment, safety equipment and tools & equipment shall be maintained in good condition and shall be audited on a month basis by the supervisor.

2.1 Use of tools and equipment

The company shall provide the necessary tools and safety equipment for the use and safety of its employees. Each person shall satisfy himself that the tools and equipment to be used by him are in good working order.

Any tool or equipment found defective or expired shall not be used but shall be tagged and returned for repair, testing or replacement.

In case of test equipment, these shall be handed over to the relevant Leader who shall organize prompt repair, testing and re- certification for replacement.

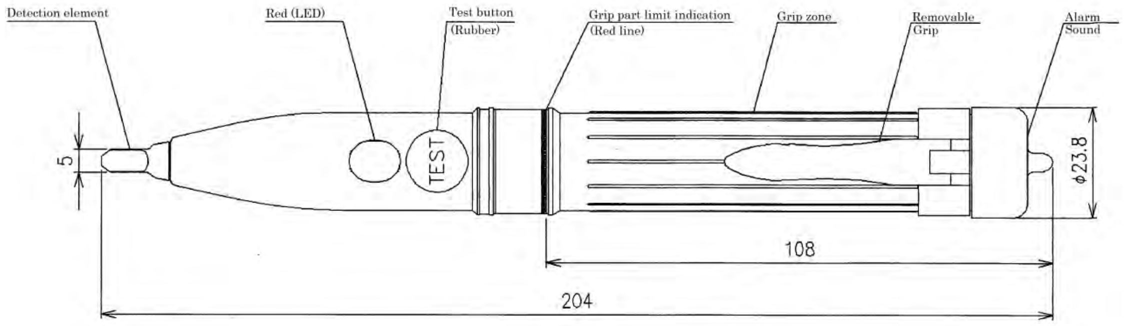
Each person shall be responsible for using and maintaining the tools and equipment in a proper and approved manner.

A request for any device which will add to safe working shall always receive proper consideration.

2.1.1 Safety Equipment

a. Electroscope

1. Intended Use ➢ Used to verify that a device, equipment, circuit, etc. does not have a charge.
2. Range of use ➢ When verifying that a device, equipment, circuit, etc. has been de-energized. ➢ When you need to verify that a device, equipment, circuit, etc. does not have a charge. ➢ When you need to verify whether or not a support structure, accessory parts, other equipment has a charge.
3. Checks before measuring ➢ Check the specifications for the electroscope; verify that the voltage used is (AC 80-7,000V); and verify operation indicator, etc. with voltage. ➢ Verify that there are no irregularities in appearance/construction (cracks, chips, etc.). ➢ If the electroscope is dirty, wipe the filth off with a dry cloth. ➢ Press the test button to verify that the sound and light signals change from intermittent (low voltage) to continuous (high voltage)



4. Measurement method

- For measuring high voltage
  Wear protective equipment (high voltage insulated gloves, rubber boots) for safety.
- For measuring low voltage
  Wear low voltage rubber gloves when there is risk of touching an energized part and when danger can be expected such as in damp places.
- Firmly grip around the center of the grip part such that your hand stays inside the grip part limit indication (red) and be sure to touch the item to be measured with the detection element at the tip.
- When measuring from over the sheathing of an insulated wire, use as shown in Figure A. If you make contact as shown in Figure B, the initial voltage will be high resulting in an incorrect reading.

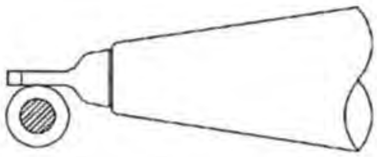


Fig. A (OK)

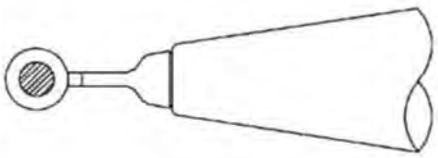
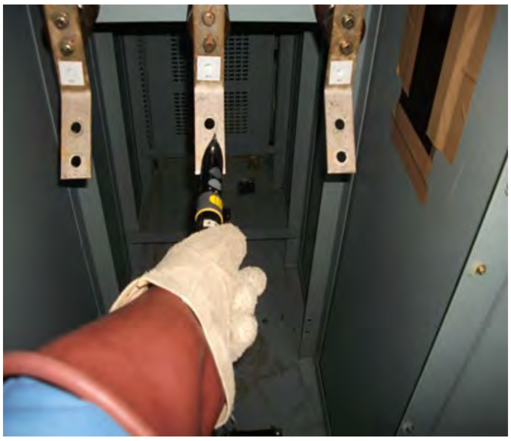


Fig. B (NG)

5. Caution when taking measurements

- Do not operate outside the specified voltage.
- ②Do not use in heavy rain or put in water.
- ③Do not by any means grip outside the grip part when taking measurements.
- ④The initial voltage may change in places where there is influence from other voltage or depending on the way the electroscope is gripped or applied.
- ⑤The voltage reading will change if gripping such that you are pinching the end of the grip part and result in an incorrect reading.
- ⑥It does not work with direct current.
- ⑦When taking measurements on ungrounded metal conduit and metal cases, readings may be triggered by induction voltage.



b. Short Circuit Grounding (Temporary earthing device)

1. Intended Use

- Mounted on a deenergized circuit to prevent disasters while working due to unintended energization, contact with other energized circuits, induction from other energized circuits, etc.

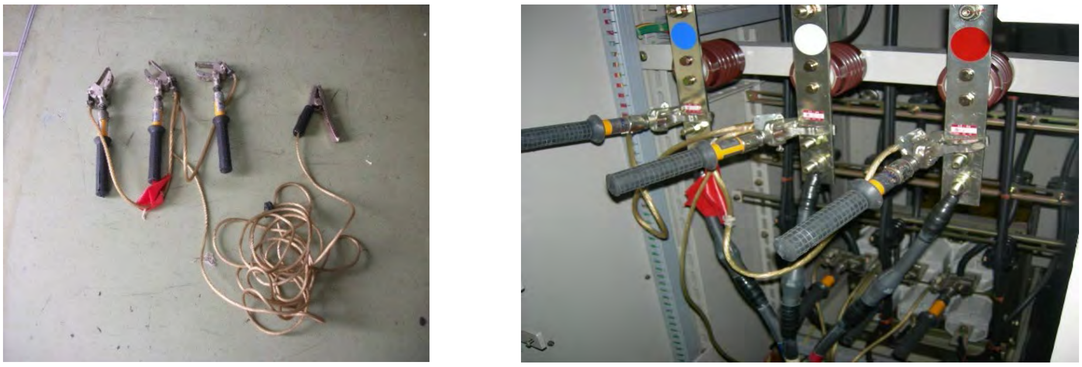
2. Range of use

- Use when partially or entirely deenergizing a circuit to perform work.
- When danger is expected due to induction voltage.

3. Precautions for use

- Verify that the circuit has been deenergized with electroscope prior to the mounting of short circuit grounding device.
- As a general rule, the short circuit grounding apparatus should be mounted on the load side closest to the point where the circuit is opened. After installing the ground rod, connect to the de-energized circuit, and when removing, remove the ground rod last. (Verify the applicable circuit voltage and the allowable current.)
- When the short circuit ground apparatus has been mounted, place a display tag in its place.
- Thoroughly inspect the short circuit grounding apparatus prior to mounting. (Inspect each wire and clip to ensure there are no cracks, impingement, or breaks in the cable.)
- Be sure to remove before transmission.

* Wear high voltage rubber gloves when working for safety.



2.1.2 Personal protection

- **Safety harness**

  All workers shall use the safety harness when working in high places, and elevating platform.

  Safety harness shall be used with the appropriate anchor strap, shall be maintained in safe working condition and shall be examined periodically to ensure good performance.

- **Ascending and descending at heights**

  When climbing up and down significant heights, the correct safety harness shall be used such that at any point of time the worker shall be connected via harness to a safety location.

- **Arc blast suit**

Intended Use

- ➢ Arc blast zones shall be demarcated and appropriate Arc Flash PPE such as arc blast suits shall be worn by the authorized person at all times while operating High voltage equipment to prevent electric shock from the arms, shoulders and also from the back .

Range of use

- ➢ Worn when performing live line work.
- ➢ Used to protect high voltage lines from interfering buildings, trees, etc. as needed.
- ➢ Worn when working near energized parts, and it is deemed dangerous.

Precautions for use

- ➢ Inspect for damage before use.
- ➢ Be sure that there are no protruding parts near the chest area when worn.
- ➢ Wear such that the rubber gloves overlap the sleeves, and do not roll up the cuffs.
- ➢ Do not dry with the heat of fire.
- ➢ Be sure that it is not damaged by the termination of power lines, etc.
- ➢ Avoid piling other materials, etc. on top of it when transporting

- **Rubber Insulating gloves**

Appropriate insulating gloves shall be worn for primary protection when handling electrical equipment to prevent electrical shock from the hand.

Over–gloves shall also be worn over insulating gloves for mechanical protection at all times.

High voltage (HV) insulating gloves together with over gloves shall be worn only as secondary protection when they are used for handling earth stick, fuse puller when running conductors under live high voltage.

The appropriate gloves shall be used at all times.

<u>Use and Care of Rubber Gloves</u>

a) The use of rubber gloves shall be in accordance with the following table:

Class of Gloves	Maximum Use Voltage (V)
0	1,000
1	7,500
2	17,000
3	26,500
4	36,000

b) Voltage shall be considered to be phase to phase

c) When the use of rubber gloves is required, they shall be put on before the employee comes within falling or reaching distance (in any event not less than 5 feet) of unprotected energized circuits or apparatus or those which may become energized and shall not be remove until the employee is entirely out of falling.

Minimum distances between protector gauntlet and cuff of rubber glove.

Class of Rubber Glove	Minimum Distance (m)
0	1”
1	1”
2	2”
3	3”
4	4”

Rubber Insulating Equipment Test Intervals:

Type of Equipment	When to Test
Rubber insulating line hose	Upon indication that insulating value is suspect
Rubber Insulating covers	Upon indication that insulating value is suspect
Rubber insulating blankets	Before first issue and every 12 months thereafter
Rubber insulating gloves	Before first issue and every 6 months thereafter
Rubber insulating sleeves	Before first issue and every 12 months thereafter

Rubber Insulating Equipment Voltage Requirements

Class of Equipment	Maximum Use Voltage (ac rms)	Retest Voltage (ac rms)	Retest Voltage (dc avg)
0	1,000	5,000	20,000
1	7,500	10,000	40,000
2	17,000	20,000	50,000
3	26,500	30,000	60,000
4	36,000	40,000	70,000

Range of use

- Worn when performing live line work and working near energized parts.
- Worn when operating energized switchgear outdoors in the rain.
- Worn when performing electroscope measurements, measurements, phase detection, high voltage cut-out, etc.
- Worn where there are electrical shock hazards such as when performing tasks such as equipment operation and short circuit grounding within a switchboard (or equivalent indoor space).
- Worn during wet or stormy weather, working on or within falling or reaching distance of any conductor or equipment which may be or may become energized at any voltage.
- Required by supervision.
- Making statiscope tests on cables.
- Operating manually controlled air-break switches.

Precautions for use

- Be sure to perform air test before use.
- Do not use with cuffs rolled up.
- Avoid piling other materials and tools on top of them to prevent damage when transporting.
- In order to prevent mechanical damage, wear protective gloves over the rubber-insulated gloves.

- **Boots and Mats**

Worn to prevent soles from being a part of the energization path.

Range of use

- Worn when performing live line work and working near energized parts.
- Worn when operating energized switchgear outdoors in the rain.
- Worn when performing electroscope measurements, measurements, phase detection, high voltage cut-out, etc.
- Worn where there are electrical shock hazards such as when performing tasks such as equipment operation and short circuit grounding within a switchboard (or equivalent indoor space).

Precautions for use

- Inspect for damage before use.
- Be sure to perform test each six month.
- Do not use with cuffs rolled up.
- Avoid piling other materials and tools on top of them to prevent damage when transporting.

- **Electrical safety helmet**

Worn mainly to protect the head from electric shock and mechanical shock.

Intended Use

- Prevents or mitigates the danger of flying or falling objects from above.
- Worn to prevent the danger of electric shock to the head

Range of use

- Wearing of safety helmet is compulsory where overhead and ground work is done, in the power station, substation, at Workshop shops switchyard and power poles.

- ➢ Worn when working with the head near an energized part.

Precautions for use

- ➢ Inspect for damage before use.
- ➢ Firmly tighten the chin strap when worn
- ➢ For electrical use the voltage shall not exceed 7,000V

No.	Notes
①	Hard shell that covers the head
② ③	Part which holds the helmet on the head and absorbs shock from impact
④ ⑤	Part which prevents the helmet from sliding and falling off
⑥	Part made of Styrofoam, etc. which absorbs impact *Not a packaging material

- **Insulating protective covers**
  - ➢ Insulating protective covers for used on live conductors shall be used for safety on low and high voltage lines.
  - ➢ On each job, before use, the covers shall be inspected for cuts, weak spots or other damage and if they are damaged they shall not be used.
  - ➢ When not being used insulating covers shall be stored in the containers or compartments provided. No tools or equipment shall be placed in these containers or compartments
  - ➢ They shall be handed in for testing at six monthly intervals by the responsible section head.

- **Clothing**

  Every worker while working shall wear appropriate clothing approved by the company. The team leader shall ensure this is followed. Personnel working at the power plant shall wear appropriate personal protective equipment & clothing. These include but are not limited to overall, hard hat with strap, safety boots, safety glasses, ear muff and gloves.

  Where there is exposure to electric shock or arc flash hazards, affected employees shall wear approved fire retardant (FR) apparel.

  Clothing made from the following types of fabrics, either alone or in blends, is prohibited:

acetate, nylon, polyester, rayon.
Personal headsets and earphones shall not be used while operating a company vehicle, nor shall they be worn while on the job.

- **Hair**
  Keep hair short and tidy. Long hair shall be kept under a tight fitting cap or net.
  Employees shall be required to weara hair net if the supervisor deems hair length to be hazard around moving machinery.

- **Ring & wrist watches**
  Do not wear ring or wrist watches, keys, watch chains, or bands when working on a moving equipment, near live conductors, on machine jobs as they add to potential hazardous.

- **Eye protection**
  Only approved eye protection that is good condition shall be worn.
  Appropriate safety glasses, googles or face shield shall be worn in areas where small flying fragments, dust, splashing hot metals, intense light or liquid can be encountered.

- **Ear protection**
  Ear protection shall be worn in areas where loud, or high frequency operations are carried out, eg. Use of high speed saws, generators, pneumatic hammer, grinders, etc.

- **Lung and body protection**
  Respirators, face mask and suitable aprons shall be worn where dangerous fume, excesive dust and heat may cause a safety hazard.

- **Good house keeping**
  - Keep gangways and corridor clear
  - Keep work area neat and tidy at all times
  - Keep tools in proper places
  - Clean floors from hazardous agents
  - Dispose scrap properly an correctly

- **Hand lifting**
  Use correct lifting techniques and equipment. Limit the average load to below 20 kg per person using the appropriate lifting device.

- **Machine tools**
  Ensure guards or safety device or securely placed in the right position. Use the machine tools for designated purpose only. Keep machine tools clean and maintain regularly. Familiarize yourself with machine tools function.

- **Working overhead**
  Secure all loose materials. Wear hard hats and protective boots. Barricade the working area where possible. Movement of personnel within the working area shall be strictly controlled.

- **Cranes and lifting equipment**
  - ✓ Familiarize yourself with the operation and controls of the crane.
  - ✓ Keep clear from the crane load
  - ✓ The stabilizer on the crane shall be fully extended and deployed prior to lifting any weight.
  - ✓ Secure and balance load with appropriate lifting equipment.
  - ✓ Use standard signals.
  - ✓ Use crane within designed limitation.(SWL safe working load)
  - ✓ Crane boom shall not be used to pull weight horizontally.
- **Entrances and exit**
  - ✓ Mark all exits clearly with location plan.
  - ✓ Entrances and exits shall be kept clear at all times.
  - ✓ Secure and lock all doors and gates in positive position.
- **Demarcation**
  At the power station, substation, at workshop and switchyard there are clearly identified lines portraying red for danger, amber for caution and green as safe area of work. These identified areas shall serve as notice where all staff use prudent judgment.

3. Periodic inspection standard of safety & protective equipment

3.1 Target protective equipment

1) Electrical safety helmet
2) Rubber-insulated gloves
3) Rubber-insulated sleeves
4) Insulated clothes
5) Insulated boots

3.2 Inspection method

Be sure to perform inspection to prevent disaster.

1) Types of inspection
   There are voluntary periodic inspections and daily inspections.

Ⅰ. Periodic inspection

A voltage resistance inspection is performed once every 6 months to verify insulation performance.

Table 1　Classification of periodical inspection (Japanese Standard)

Items subject to testing	Test standard		
	Test resistance value (New)	Test voltage value (voluntary periodic inspection)	Test Time
Electrical safety helmet	AC 20,000V	AC 10,000V	1 min (no more than 3 mins)
Rubber-insulated gloves DC1,500V class	AC 12,000V	AC　6,000V	1 min (no more than 3mins)
Rubber-insulated gloves AC 3,000V class	AC 12,000V	AC　6,000V	1 min (no more than 3 mins)
Rubber-insulated gloves AC 3,000V class	AC 20,000V	AC 10,000V	1 min (no more than 3 mins)
Rubber-insulated sleeves	AC 20,000V	AC 10,000V	1 min (no more than 3 mins)
Insulated clothes	AC 20,000V	AC 10,000V	1 min (no more than 3 mins)
Electrical boots	AC 20,000V	AC 10,000V	1 min (no more than 3 mins)

Ⅱ. Daily inspection

Inspect for deterioration and damage before using that day.

* Main things to look for and precautions

(For rubber products)

・Ensure that there are no punctures, cuts, cracks, foreign matter impeded in the surface, etc.

・Ensure that there is no bulging due to oil, grease, or other solvents.

・For rubber gloves in particular, check for rolled up cuffs and for pin holes by checking for air leaks.

(For synthetic resin products)

・Ensure that there are no fractures or cracks.

・Ensure that there are no conductive plates or tape attached.

・Ensure that there are no obvious scratches and that no filth is on the equipment.

(For metal products)

・Check for damage, cracks, corrosion, meshing, effectiveness of safety equipment.

- Record of inspection results and measures

Immediately enter inspection results in the record table. Promptly replace items judged to be defective and take measures such as repair.

4. Electric shock

Electrocution, also referred to as electric shock, occurs when electric current flows through the body. In addition, electric shock, can induce various symptoms including simply sensing current, shock which brings about pain, and further, death from ventricular fibrillation.

(1)　Risk factors of electric shock

Risks as the result of electric shock are mainly determined by the following factors.

① The magnitude of the energizing current (the magnitude of the current that flowed through the body)
② Energizing time (the time the current flowed through the body)
③ Energizing path (which part of the body the current flowed through)
④ Current type (AC, DC)
⑤ Frequency and waveform

Therefore, the longer current flows though vital parts of the body, the more hazardous it is, and it has no direct relation to the magnitude of voltage.

(2) Magnitude of the current and the body's response

(A) Sensed current

When the energizing current is gradually increased, the minimum current that the human body can notice with the senses is called the sensed current.

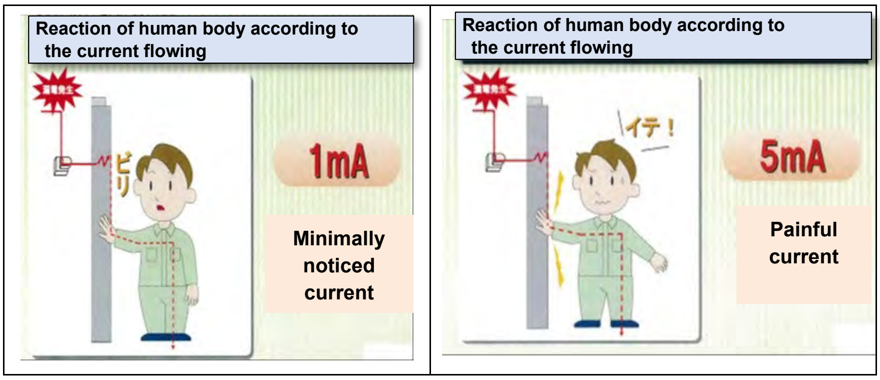


Fig.1 Current flowing through the body and the body’s reaction (Japanese Standard)

(B) Let-go threshold current and let-go current

If the energizing current is further increased, there is no direct abnormality to life, but the muscles in the energizing path cramp, and the nerves become paralyzed preventing you from moving freely and removing yourself from the energized part. If this condition persists for a long time, it may become difficult to breathe resulting in loss of consciousness or death from suffocation. The current where freedom of movement is lost is called let-go threshold current, and current where freedom of movement is not lost is called let-go current.

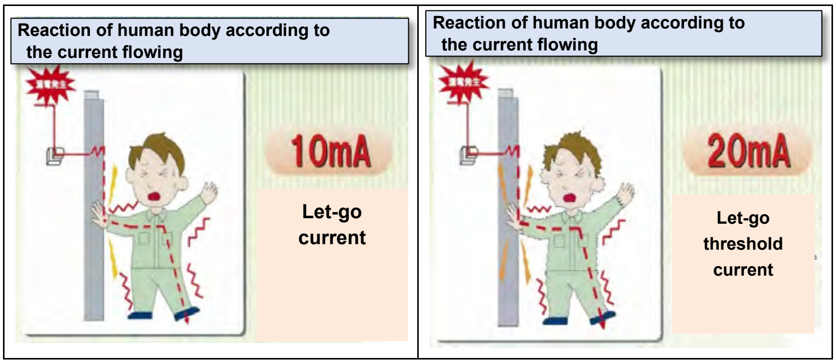


Fig.2 Current flowing through body and the body’s reaction (Japanese Standard)

(C) Ventricular fibrillation current

If the energizing current is increased further, the current flowing through the heart will also increase. When a large amount of current flows through the heart, it disrupts the hearts rhythm from its regular beats to quivers resulting in the loss of its blood circulation function and death within a few minutes. Such current is called ventricular fibrillation current, and this value varies greatly depending on duration and energizing path. This value cannot be derived by measurements of the human body performed by humans, so it is an estimation based on the results of experiments performed by many researchers on various animals and electrical accidents. According to the IEC (International Electrotechnical Commission), ventricular fibrillation current in 100 mA for 0.5 second, 50 mA for 1 second, and 40 mA for 3 seconds.

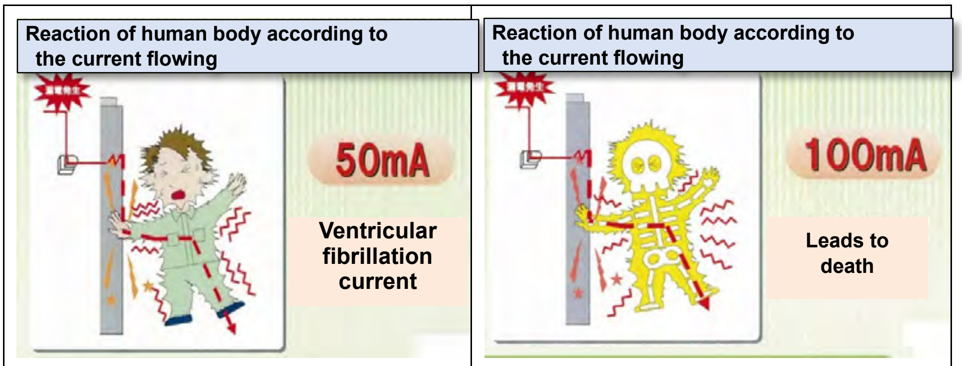


Fig. 4 Electrical shock hazards at various values of current

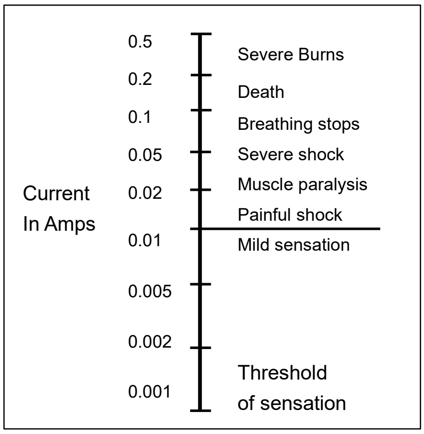


Fig.3 Current flowing through body and the body's reaction (Japanese Standard)

5. Short circuit

A short circuit is generally a large current exceeding the rated current resulting in the burnout of the sheathing of insulated electric wires, transformers, breakers, etc. This is one type of fault which occurs when contact is made due to failures and handling errors where the electric resistance between electric circuits is very low or nonexistent. In this case, an abnormally large current called short circuit current flows. That is, in Figure 5, during normal operation, the current flowing through the motor passes from one end of the transformer secondary winding through the wire and the motor winding and returns to the other end of the transformer secondary winding, and the current is I = V/R amperes. However, when the wire sheathing is damaged due to a failure, etc., and points a and b are short-circuited, the short circuit current "I" becomes very large because the resistance of the electric circuit becomes almost zero, and it can be from a few thousands of amperes, and depending on the case, it can be as much as tens of thousands of amperes.

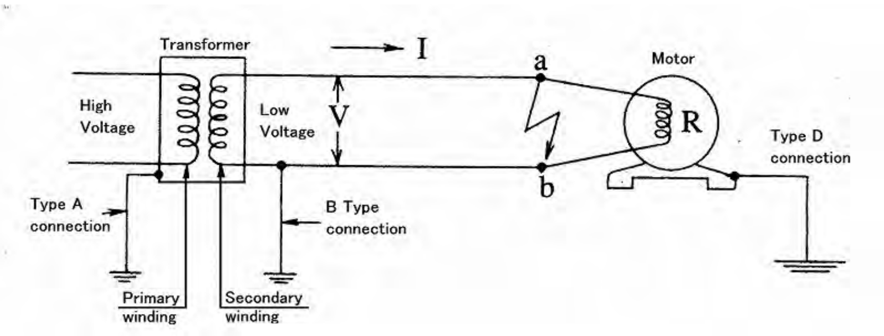


Fig.5 Short Circuit example

- Disaster due to short circuit and countermeasures

Since electric wires, etc. with a capacity suitable for the size of the load are generally used, if a large current flows due to a short circuit, it causes melting of the electric wire, burning of the insulating coating, etc., or major accidents and disasters such as explosion of a circuit breaker containing oil installed along the circuit. In addition, severe arcs often occur at the same time as a short circuit, which may cause electrical burns.

Such a short circuit may be caused by deterioration or damage of an insulation coating of an insulated wire or a cab tire cable, or by short-circuiting the terminals accidentally with the tip of a screwdriver when replacing a fuse of a switch. In addition, when an electric motor is overloaded or operated in an open phase condition (one of the three phases is disconnected), excess current flows through the windings and burns them, and may result in a short-circuit accident.

However, it is important that electric devices such as electric motors are operated in a normal state always ignoring the insulation state of electrical wiring, switches, connecting devices, etc.

On the other hand, it is important not to cause a short circuit accident, but in the event of an abnormal condition in which a short circuit or other excess current flows, it is important to be able to break the electrical circuit immediately. To do this, it is necessary to provide a short circuit or overcurrent circuit breaker having the appropriate breaking capacity within reach of distribution boards, electrical equipment, etc.

6. Ground Fault

Electric shock due to a ground fault generally refers to a current flowing through the human body to the earth like b shown in Figure 6 where the insulation between the circuit and the earth abnormally lowers, and the two become connected through an arc or a conductor. When this occurs, a hazardous voltage appears or a current flows outside the circuit or equipment. This phenomenon is also commonly referred to as "electric leakage," and the current flowing there is referred to as ground fault current or leakage current.

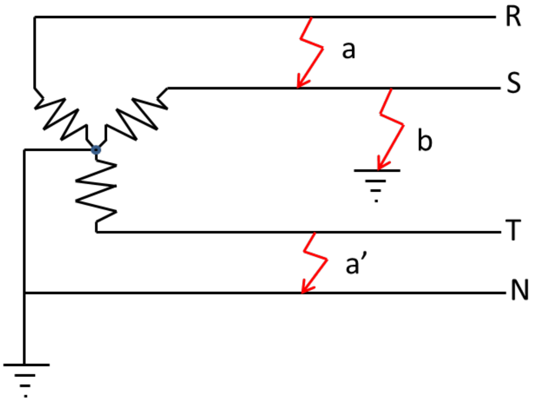


Fig.6 Ground fault

- Disaster due to ground fault and countermeasures

If a ground fault occurs in an electrical circuit, it often causes electric shock and damage to power facilities. For example, if the insulation of a transformer or an electric motor deteriorates or is damaged and a ground fault current flows through their metal cases, a voltage is generated in the cases, so if a person touches them, it will result in an electric shock. Therefore, the outer cases of equipment are grounded, and the earth leakage circuit breaker is installed in dangerous low voltage circuits.

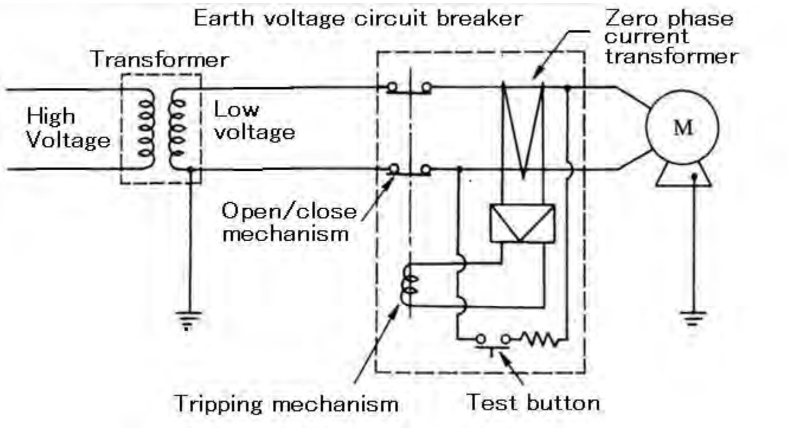


Fig.7 Construction of the earth leakage circuit breaker

In addition, if a ground fault occurs on a single line of the electrical circuit for power facilities such as transmission and distribution lines, depending on the magnitude of the ground capacitance of the circuit and the grounding method of the power supply, etc., a considerable ground fault current will occur causing intermittent arcing ground, or high-frequency electric oscillation occurs, which may cause abnormal voltage. As a result, there is a risk of melting the wire at the ground fault point or damaging the insulator and thereby lead to an interphase short circuit fault. In addition, when a ground fault current occurs, induction voltage, harmful to lines with weak current, which approaches due to the electromagnetic induction action is generated, which may cause noise on telephone lines and communication trouble on the telegraph lines. Therefore, in practice, ground fault relays are installed to quickly remove ground faults.

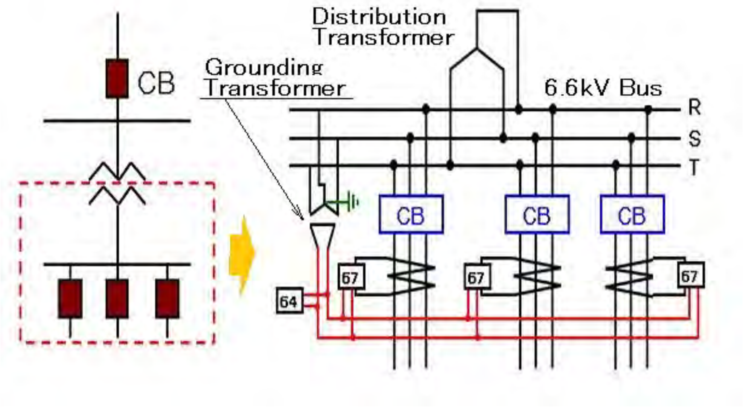


Fig.8 Ground fault relay circuit diagram

Ground fault direction relays (67) and ground fault overvoltage relays (64) are used to protect distribution lines from ground faults.

67 operates at a current and voltage of the fetch setting value or more. Zero phase voltage is taken from the ground fault relay circuit diagram and grounding transformer (voltage generated when a ground fault occurs), and the current is taken out by the zero phase current transformer (current which flows only during a ground fault). Then it operates at a voltage and current of the setting value or more. In addition, 64 monitor only the voltage, and if a zero phase voltage over a certain value is generated, it acts as a ground overvoltage. When operating under the conditions of 67 + 64, the circuit breaker is opened to eliminate power outage and faults on distribution lines.

7. Approach limit

Electric shock due to low voltage is caused by direct contact of a part of the human body with an energized part. However, with high voltage or higher, if the human body comes close to an energized part within a limit, even if it does not come into direct contact with the energized part, the air insulation will be broken causing a flashover, and the person will incur an electric shock. Since flashovers are mainly determined by the magnitude of the voltage of the energized part and approach distance, when approaching an energized part, you are not allowed to come within the flashover distance. Therefore, as the approach limit for live line work or work in close proximity of a live line at transmission lines, power plants, etc., a distance which includes the flashover distance corresponding to the voltage considering the work space of a worker and the dimensions of tools in his/her hand must be kept.

- Approach limit distance

KUA stipulates that when using equipment for live wire work for work on an extra high-voltage energized circuit, the body, etc. must keep the approach limit distance corresponding to voltage of the energized circuit shown in Table . "Approach limit distance" means the shortest straight-line distance between a worker's body or the part of a conductor actually handled by a worker such as a metal tool or material and an extra high voltage energized circuit. The voltage of the electric circuit at that time must not only take into account normal voltage but also abnormal voltage (lightning surge and switching surge) generated in the electric circuit.

Energized circuit voltage (kV) Phase to Phase	Minimum working and clear and clear hot stick distance in ft and ins	Remarks
2.1 to 15	2 ft 0 in.	
15.1 to 35	2 ft 4 in	
35.1 to 46	2 ft 6 in.	
46.1 to 72.5	3 ft 0 in.	
72.6 to 121	3 ft 4 in.	
138 to 145	3 ft 6 in.	
161 to 169	3 ft 8 in.	
230 to 242	5 ft 0 in.	
345 to 362	7 ft 0 in.	
500 to 552	11 ft 0 in.	
700 to 765	15 ft 0 in.	

- Separation distance

When using a mobile crane or the like in a place close to a transmission line or the like, the separation distance between a boom or a wire rope and the transmission/distribution line to be maintained according to the voltage of the electric circuit is shown above.
Cranes must stay a minimum distance from lines as follows:

- 10 feet for lines rated up to 50kV
- An additional 0.4 inch for each 1 kV above 50 kV

Clearances for unqualified workers

Unqualified workers and anything they are carrying or using (such as tools, pipes, window washing equipment, or construction materials) must maintain a seperation of at least 10 ft from bare, energized conductors.
An unqualified worker is anyone not familiar with the hazards of working around our equipment. This definition should be applied to anyone not involved in the high voltage electrical industry.

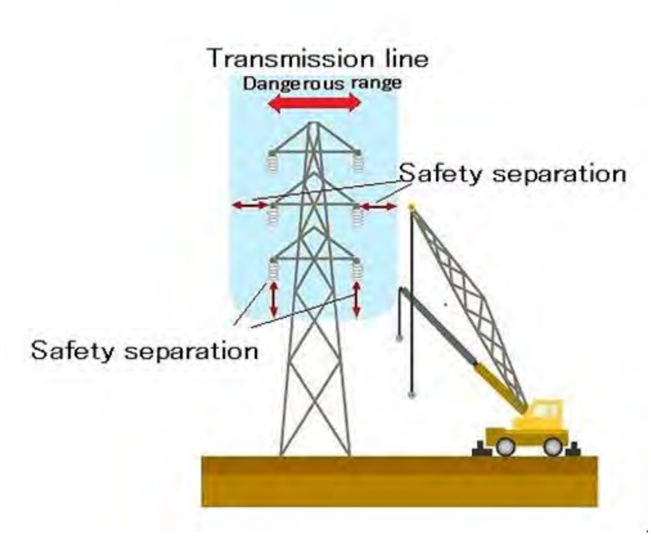


Fig.9 Separation distance from transmission tower

Nominal voltage	Separation distance (m)
100/200/240/415(V)	1.0
3.3/6.6(kV)	1.2
11(kV)	2.0
22	2.0
33	2.0
66	2.2
77	2.4
110	3.0
154	4.0
187	4.6

Table 3 Separation distance (JS)

8. Electric insulation

8.1 Conductor and insulator

Among materials, there are good electric conductors (copper, aluminum, iron, etc.), nonconductors which hardly conduct electricity (also known as insulators, such as air, porcelain, rubber, vinyl), and semiconductors with intermediate properties (silicon, selenium, germanium, etc.).

Good conductors such as copper are used for windings of distribution lines, electric motors, and transformers; synthetic resins such as rubber and vinyl for insulation of electric wires; and insulators such as porcelain are used for supporting power lines. In addition, semiconductors are widely used as electronic parts exhibiting special performance such as transistors and diodes.

8.2 Electric insulators

In order to use electricity safely and properly, it is important to prevent electricity from leaking to parts other than the electric circuit, and in electric wiring and electric appliances, it is essential to insulate between electric wires and between electric wires and the ground with an insulator.

These are called electric insulators, and electric insulation is extremely important to prevent accidents caused by electricity.

As a property of insulators, the extent to which electricity is not allowed to flow is expressed by the term insulation resistance, and MΩ is normally used as the unit. If the insulator is damaged and the insulation resistance decreases, a ground fault or a short circuit fault will occur causing electric shock and fire.

In addition, for live line work or work in close proximity of a live line, when a worker touches an energized part, it will cause an electric shock, so it is necessary to insulate the hands and feet of workers and energized parts with protective equipment and wear made of insulation.

8.3 Insulation deterioration and heat-resistant classification of insulators

Insulation deteriorates due to the following causes, and the insulation resistance decreases.

A) Electrical factors such as abnormally high voltage
B) Mechanical factors such as vibration and shock
C) Natural environmental factors such as sunlight
D) Thermal factors such as rise in temperature

The maximum temperature that can be used for insulation such as rubber and plastics which are often used as insulators of electric wires and electrical equipment in terms of insulation deterioration is decided depending on the type of insulation. This is called a heat-resistant classification and is divided into six types as shown in Table .

Table 4 Heat-resistant classification of insulation (Japanese Standard)

Type	Allowed maximum Temperature [℃]	Type of insulators	Use
Y	90	Cotton, silk, paper, etc.	Low voltage equipment
A	105	Materials above impregnated with varnish or immersed in oil	Ordinary rotating machines, transformer
E	120	Polyurethane resin, epoxy resin, melamine resin type, etc.	Large capacity and ordinary equipment
B	130	Mica, glass fiber, etc. used with adhesives	High voltage equipment
F	155	Those using the above material and silicone alkyd resin adhesive	High voltage equipment
H	180	Uses the above materials and adhesives such as silicone resin	Dry type transformer, etc.

(Prepared with reference to JIS C4003)

Table 5 Insulation resistance value of low-voltage circuit (Japanese Standard)
(Article 58 of the Ministry of Electricity Engineers Ordinance)

Classification of voltage used for circuits		Insulation resistance value
Not exceeding 300 V	In the case where the voltage to ground (voltage between the electric wire and the earth in a grounded circuit and the voltage between the electric wires in an ungrounded circuit) is 150 V or less	0. 1 MΩ
	Other cases	0. 2 MΩ
Items exceeding 300 V		0. 5 MΩ

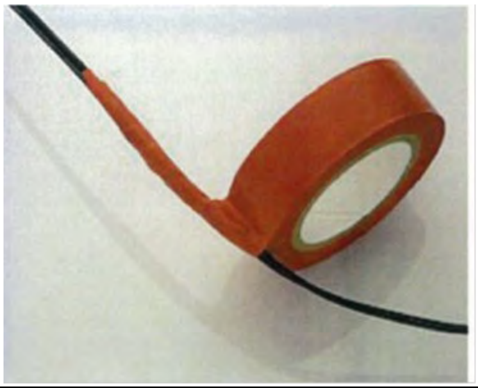
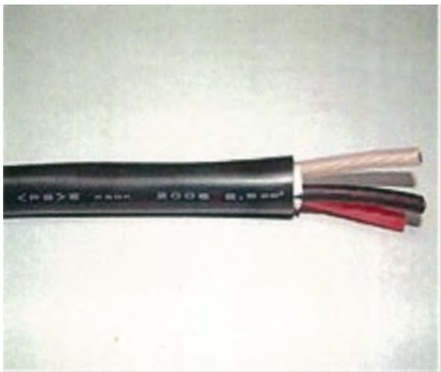
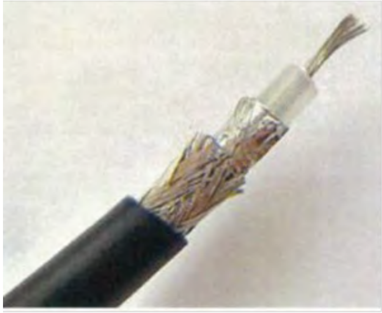
8.4 Maintenance

It is important that the maintenance of electrical equipment, etc. is performed regularly and properly so that insulation resistance does not decrease. Apart from cases recognized through visual inspection, insulation resistance deterioration is generally determined through insulation resistance measurements and voltage tolerance tests.

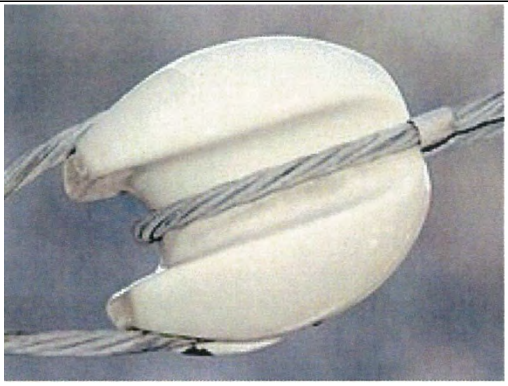
The visual inspection examines damage, cracks, presence of dust adhesion, etc. In addition, the insulation resistance of insulated circuits such as wires and cables must be measured using an insulation resistance tester and must be at least the value in Table 4 for each circuit that can be separated by switchgear or overcurrent breaker.

Reference case 1

Insulator is a generic term for substances that do not conduct electricity or heat well.

Ⅰ. Vinyl insulation tape.	Ⅱ. Three-core transmission cable. Each core wire is sheathed with insulation of a different color, and the whole is sheathed for protection.
	
Ⅲ. Mineral-insulated copper-clad cable. The core is composed of two copper wires.	Ⅳ. Coaxial cables are composed of an inner conductor insulated by a dielectric insulator, and all insulated by a metallic shield.
	

Reference case 2

Ⅴ. Ceramic insulator for 10 kV	Ⅵ. Ball insulator
	

9. Attachment

- List of existing SAFETY items

No.	Name	Qty.	Comments

1	Safety boots		
2			
3			
4			
5			
6			
7			

- Safety items to arrange

No.	Name	Qty.	Comments
1	Helmet		
2			For mechanics and electricians
3	Safety glasses		
4			
5			
6			
7			

End

Diesel Generation
Operation and Maintenance Manual

2. Basic of Diesel Power Generation

Kosrae Utilities Authority

INDEX

1. Overview of Diesel Power Generation Facilities

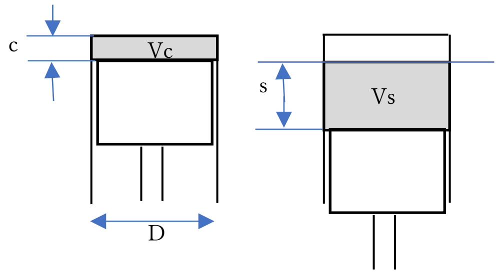
1-1 Basic knowledge of diesel engine

1) Terms and units

Terms		meanings	SI Unit	Conventional unit
Pressure		Force applied to unit area	MPa	Kgf/cm^2
Capacity (Volume)		$1\mathrm{m}^3 = 1000\ell$、$1\ell = 1000cc$	m^3	ℓ、cc
Discharge amount		Capacity per hour (for water pump etc.)	m^3/h	m^3/h
RPM		Number of revolutions per minute	Min^{-1}	rpm
Torque		The product of the force required to turn in the direction of rotation and the length of the bar	Nm	Kgf-m
Output	Horsepower	Percentage to workload of 75 kgf-m per second （1PS：75 kgf・m/sec）	kW	PS(HP)
	Electric power	1PS＝0.735kW	kW	W、kW
Fuel consumption		Fuel consumption per hour (When expressed in kg, it multiplies the specific gravity)	m^3/h	ℓ/Hr
Specific fuel consumption		Fuel consumption per horsepower per hour	g/kW・h	g/PS・Hr

2) Main related formula

(1) Compression ratio



$$\text{Compression ratio} = 1 + \frac{\mathrm{Vc} + \mathrm{Vs}}{\mathrm{Vc}} = 1 + \frac{\mathrm{Vc}}{\mathrm{Vs}}$$

$$\mathrm{Vc} = \text{Top clearance capacity} = \frac{\pi}{4}\mathrm{D}^2 \times \mathrm{C}$$

$$\mathrm{Vs} = \text{Stroke volume} = \frac{\pi}{4}\mathrm{D}^2 \times \mathrm{S}$$

(Adding top clearance volume, such as pre-combustion chamber volume, to pore volume)

* As the top clearance volume (Vc) increases, the compression ratio decreases.

Table 1 Compression ratio of different engines

Type of Machine	Diesel	Gasoline	Kerosene
Compression ratio	11～20	6～11	4.5～7

(2) Total exhaust amount (Total stroke volume)

$$\text{Total exhaust amount } (\ell) = \frac{\pi}{4}\mathrm{D}^2 \times \mathrm{S} \times \mathrm{N} \times \frac{1}{1000}$$

D：Cylinder internal diameter (cm) ; S：Piston stroke(cm)

N：Number of cylinders

(3) Thermal efficiency

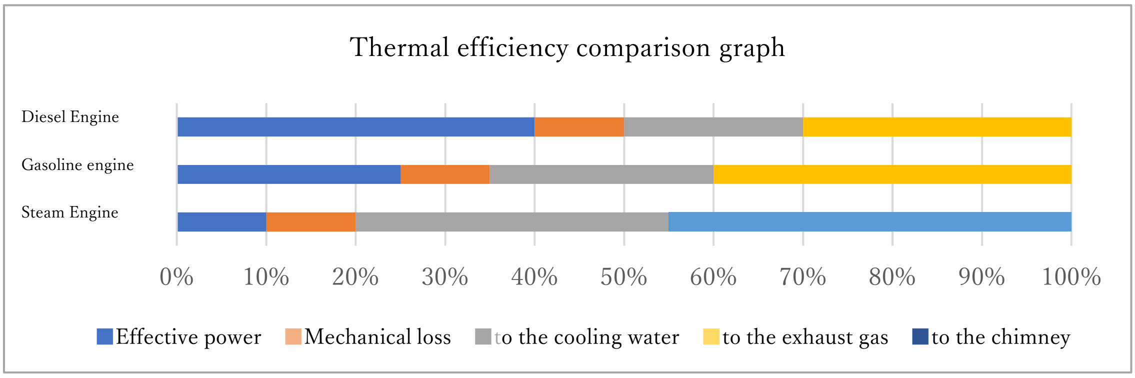
$$\text{Thermal efficiency}\left(\%\right) = \frac{\text{Brake horsepower} \times 4500 \times 60}{\text{1hour fuel consumption}\left(\text{kg}\right) \times \text{Calories(Kcal)} \times 427} \times 100$$

4500kgf-m/min ＝ 1 Workload per horsepower

427kgf-m ＝ 1Kcal of workload

Table 2 Thermal efficiency of different engines

Types of prime movement	Diesel engine	Gasoline engine	Gas engine	Gas turbine	Steam engine	Steam turbine
Thermal efficiency (%)	35～45	20～26	20～35	15～18	10～16	18～24



Graph 1. Comparison of thermal components of different engines

1-2 Basic knowledge of diesel generator facilities

1) Characteristics of diesel generation facilities

(1) Easy to handle and reliable start.

The diesel engine can start and stop more easily than other prime movers, and it is easy to automate. Also, the diesel engine takes about 30 to 60 seconds to start power generation and can be reduced to 5 to 10 seconds when necessary.

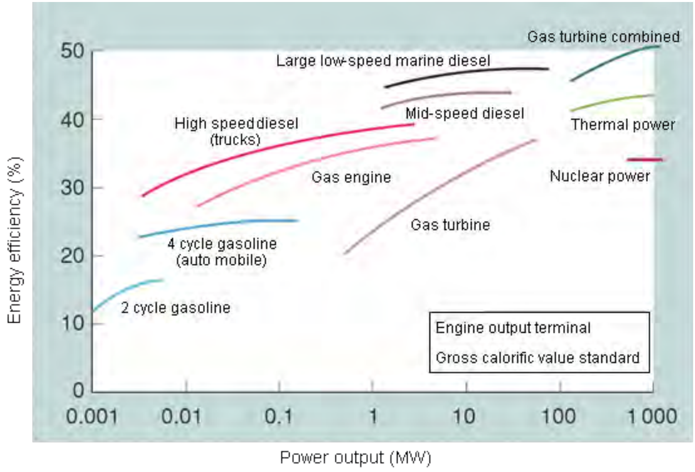
(2) Low cost and short construction period

Most diesel engines come small and lightweight with a short manufacturing period which allows for shortening construction period, and machinery costs are also low. These are the biggest benefits of diesel engines, and they have advanced to be medium to high-speed spec and downsized in recent years. In contrast, steam power systems and nuclear power systems involve many components, and thus a longer construction period.

(3) Economical due to high thermal efficiency

Diesel engines have the highest thermal efficiency compared to others such as gasoline engines and gas turbines, they consume less fuel and are economical. The following figure shows a comparison of thermal efficiency of various engines.

Steam power generation is too large to introduce in remote islands, therefore internal combustion engines are the mainstream, especially diesel power generators with high thermal efficiency.



Graph 2. Energy efficiency of various engines
(Source：Mitsubishi Heavy Industries publications
「Diesel・gas engine kouritsuka he no torikumi VOL.45 NO.1」: 2008)

(4) Fuel handling is easy and safety benefits

Diesel engines can operate on relatively safe heavy oil which has a higher flash point and thus provides safety benefits for fuel handling, storage, and transport. Diesel power generators use marine diesel fuel, and larger generators can run on heavy fuel oil, and they are easy to handle.

Trivial info:

Risk of fuel : A comparison of risk of various fuels is shown below.

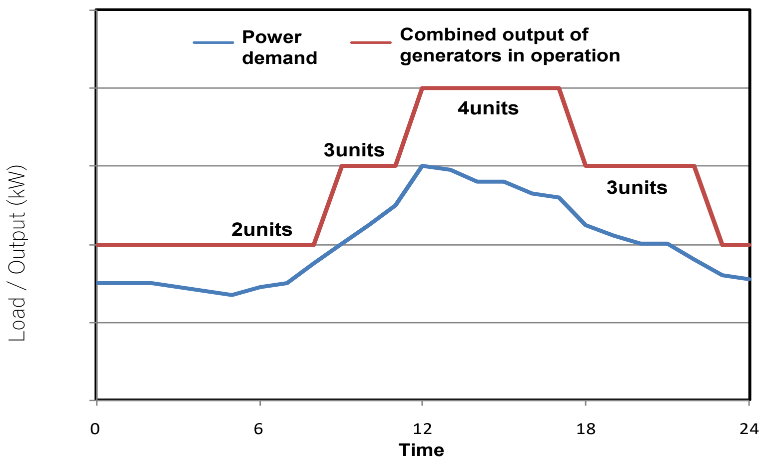
Risk **High** → **Low**

Gasoline ＞ Kerosene / light oil ＞ Heavy oil

(5) Efficient operation and secured stable power output.

Diesel power generators can be operated effectively by selecting the appropriate number of units to be operated based on the power demand. Also, they can be the backup source of other generators in case of maintenance or unexpected failures so that uninterrupted power supply is secured.

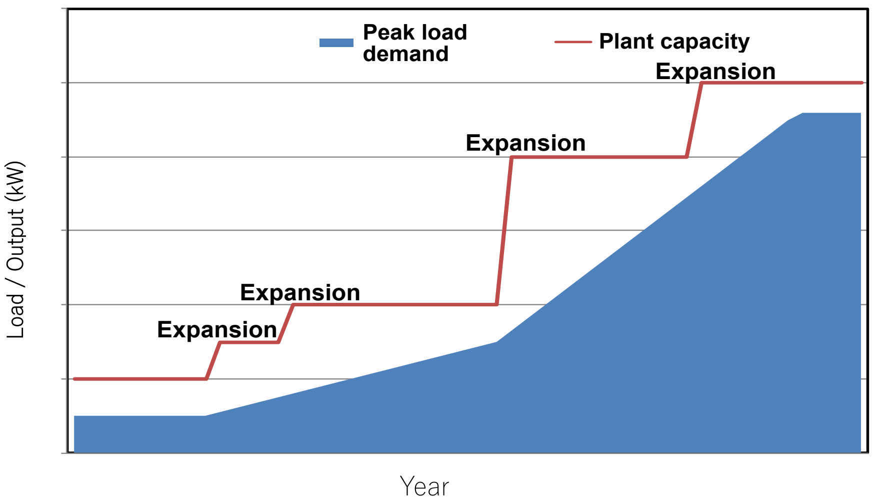
The number of operating units is controlled according to the load level to avoid inefficient low load operation. For the facilities of remote islands, the maximum output level of each generator is designed to contain a margin against the peak load to accommodate the load change in case of maintenance or failures.



Graph 3. Efficient operation of diesel generators

(6) Stepwise expansion is possible.

Energy conversion efficiency per unit of diesel generators remains the same even if planned capacity is dispatched by multiple units. That means, a power plant can expand its capacity by adding machines step by step according to the power demand increase. Therefore, excessive facility investments can be avoided.



Graph 4. Expansion of diesel generators

2) Disadvantages of diesel generation facilities

(1) Loud noise

Noises generated from diesel engines include intake sound, exhaust sound, mechanical sound, and explosion sound. The intake sound can be absorbed by a suitable filter, and the exhaust sound can be absorbed by a silencer (muffler), but mechanical sound and combustion sound cannot be suppressed.

Since the noise level is about 100 to 110 dB (A-scale) within 1.0m distance from the engine, preventative measures for those noise from leaking outside is necessary.

(2) Heavy vibration

Since the diesel engine is a prime mover that drives the generator by changing the reciprocating motion of the piston due to the combustion explosion to a circular motion, the angular velocity of the motion is not constant. Therefore, depending on the number of cylinders, vibration due to unbalanced force is generated. Since the crankshaft of the engine has elasticity, it generates torsional vibration due to fluctuation of torque.

To prevent these vibrations from affecting others, the foundation can be enlarged, and a vibration isolating common bed can be laid.

(3) Requires large amount of cooling water. (*In case of use the cooling water.)

In general, the amount of cooling water required by the engine is 30 to 40 liters / PS-h, and in 400 kW (500 kVA) power generation facilities, about 20 tons/h (330litres/minute) of cooling water per hour is required.

In the case of main power source, the required amount of cooling water is larger, so it is necessary to adopt a method such as providing a cooling tower and circulating cooling water.

3) Types of diesel generation facilities

Diesel power generation equipment are generally classified into two types, normal use, and emergency use, and classified into stationary type and mobile type according to the type of installation.

(1) Emergency diesel generator

Many diesel generators are installed as a source of security and emergency power for buildings, broadcasting / communication facilities, water and sewage pumping stations, hospitals, airports, steel mills, chemical plants, etc.

(2) Stationary diesel generator

Regardless of whether it is a normal or emergency type, the majority of diesel power generation facilities are fixed to a certain place on a foundation and used.

(3) Mobile diesel generator

For civil engineering, construction, and road works or communication facilities, portable diesel power generation equipment is manufactured. Since they are portable, they must be compact and light weight, and most have a capacity of 200 kVA or less. There are also mobile type trailers and other onboard type. In Japan these are subject to the application of mobile power generation equipment under the Electricity Business Law.

*Classification by rotational speed

According to engine speed, they are classified into high-speed engines, medium-speed engines, and low-speed engines as shown in the following table. Recently, the speed of engines with a considerably large cylinder diameter have also increased, so they are also classified according to piston speed as shown in the table below.

Table 3 Classification of engines according to rotational speed

Type	Rotational speed (min^{-1})	Piston speed (m/s)
High-speed	$1500\mathrm{min}^{-1}$ or more	10m/s or more
Medium speed	500～under $1500\mathrm{min}^{-1}$	7～10m/s
Low speed	Under $500\mathrm{min}^{-1}$	Under 7m/s

Recommended Rotational Speed Limits (for 60-Hz)

Class A Engine		Class B Engine		Class C Engine	
Specified Output (kW)	Max. Rotational Speed (rpm)	Specified Output (kW)	Max. Rotational Speed (rpm)	Specified Output (kW)	Max. Rotational Speed (rpm)
200 or less	1800	300 & less	1800	850 & less	1800
200 to 500	1200	300 to 800	1200	850 to 1200	1200
500 to 1000	900	800 to 2000	900	1200 to 2800	1200
1000 to 2000	720	2000 more	720	1200 to 2800	900
2000 more	514			2800 more	720

4) Composition of diesel generation facilities

The composition of diesel power generation facilities differs depending on their output, installation conditions, use conditions, and fuel conditions, but they are mainly composed of the following devices.

(1) Diesel engine main body, governor, supercharger, starting / stopping device, measuring device, block, etc.

(2) AC generator main body, exciter

(3) Distribution board, generator control board (transformer board, automatic starting board, remote monitoring control board) etc.

(4) Fuel oil related: fuel oil reservoir tank, transport pump, daily or service fuel oil tank, etc.

(5) Lubricating oil related: lubricating oil tank, lubricating oil cooler, priming pump, (heater), etc.

(6) Cooling water related: cooling water tank, cooling tower, radiator, etc.

(7) Starting device related: pneumatic air tank, air compressor, control panel, etc.
Electric start-up battery, charger, etc.

(8) Exhaust related: muffler, exhaust pipe, spark arrester, etc.

(9) Accessory: exhaust fan, lifting equipment, etc.

2. Overview of Diesel engine and accessory devices

1) Operating principle of diesel engines

There are two kinds of configuration in internal combustion engine – 4 cycle and 2 cycle engines. These systems reciprocate steps including intake, compression, combustion/ expansion and exhaust, and this process is referred to one cycle. An action or the distance of a piston moving between top dead center (TDC) and the bottom is called a stroke. With that said, it takes 2 strokes to rotate a crankshaft once, and 4 strokes to rotate twice. 4 cycle engine repeats 4 strokes for every 2 revolutions of crankshaft while 2 cycle engine has 2 strokes for every revolution.

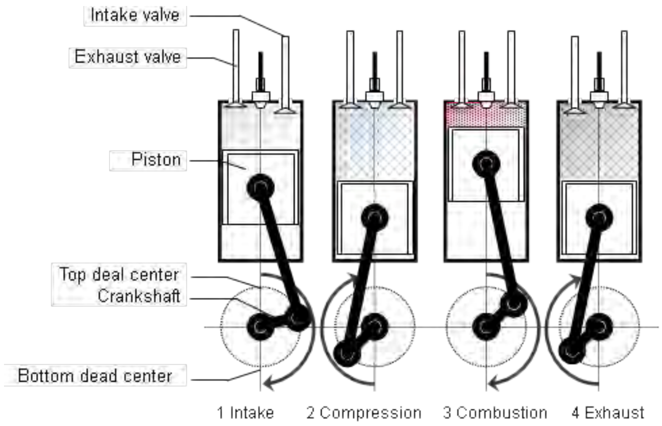


Figure 3. Operating principle 4 cycle (stroke) engine figure

S – piston stroke
Vc – clearance volume
Vd – displaced (swept) volume
p0 – atmospheric pressure
W – work
TDC – top dead center
BDC – bottom dead center
IV – inlet valve
EV – exhaust valve
IVO – inlet valve opening
IVC – inlet valve closing
EVO – exhaust valve opening
EVC – exhaust valve closing
IGN (INJ) – ignition (injection)

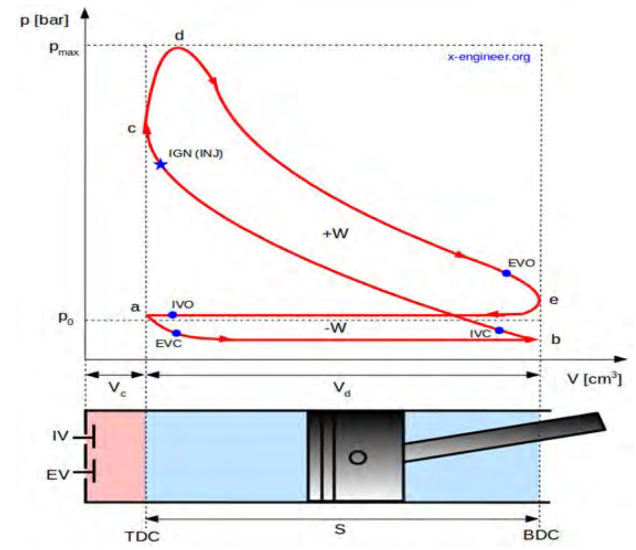


Figure 4. Diesel Engine P-V curve
(https://x-engineer.org/automotive-engineering/internal-combustion-engines/ice-components-systems/pressure-volume-pv-diagram-work-ice/)

(1) Intake stroke

As a piston approaches the top dead center (TDC), the intake valve opens up, and as the piston is pushed down to the bottom dead center (BDC), air pressure in a cylinder decreases and more air comes in through the intake valve until the piston reaches the BDC. This whole process is called the intake process.

Gasoline engines use a fuel-air mixture and gas engines use a mixture of air and fuel gas during the intake process.

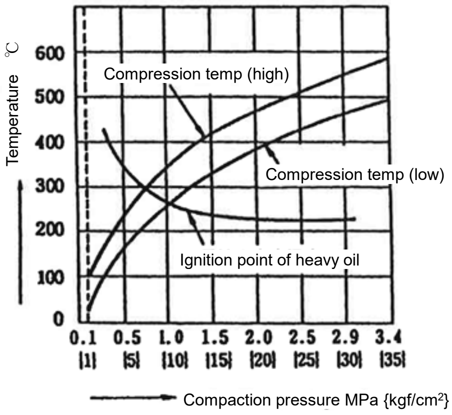
*Top dead center is the position of a piston when it is farthest from the crankshaft.

*Bottom dead center is the position of a piston when it is nearest to the crankshaft.

(2) Compression stroke

As the piston approaches the top dead center again, both intake and exhaust valves are closed for the air inside of the cylinder to be compressed. During the compression stroke, pressure level near the top dead center increases to about 2.9～4.4MPa (30～45kgf/cm$^{2)}$ and temperature rises to about 450℃～600℃. Fuel self-ignites at around 200℃, so it can be easily ignited to combust at this temperature. Thus, fuel injection from the injection valve near top dead center into the cylinder can cause an explosive combustion. This process is called the compression stroke. Since the compression temperature (as well as the compression pressure) in a gasoline engine is too low to self-ignite, an electric spark ignition method is applied.

The following figure shows the relationship of compression pressure which is caused by rapid air compression and compression temperature.



Graph 5. Relationship of air compression pressure and temperature
(Source：Japan Engine Generator Association "Jikayo hatsuden setsubi senmon gijutsusha text")

(3) Expansion stroke

Due to the explosion or combustion of fuel, suddenly increased pressure in the combustion chamber pushes the piston to the bottom dead center with 4.9～5.9MPa (50～60kgf/cm^2) of force for a non-supercharged engine and 7.8～12.7MPa (80～130kgf/cm^2) for a supercharged engine. This combustion continues until the fuel injection stops. As the piston is pushed down, the increase of stroke volume in the cylinder keeps the pressure level at 4.9～7.8MPa (50～80kgf/cm^2). After fuel injection ends, due to the expansion of fuel gas, the pressure decreases along with piston's descent until it reaches the bottom dead center. Then the crankshaft rotates, and the engine gains the power. This process is called the expansion stroke.

(4) Exhaust stroke

When the piston approaches the bottom dead center, the exhaust valve opens up which releases combustion gas to the outside, and as the piston ascends from the bottom to top, the remaining gas in the cylinder is exhausted and the piston reaches the top dead center. This process is called the exhaust stroke.

2) Structure of diesel engine

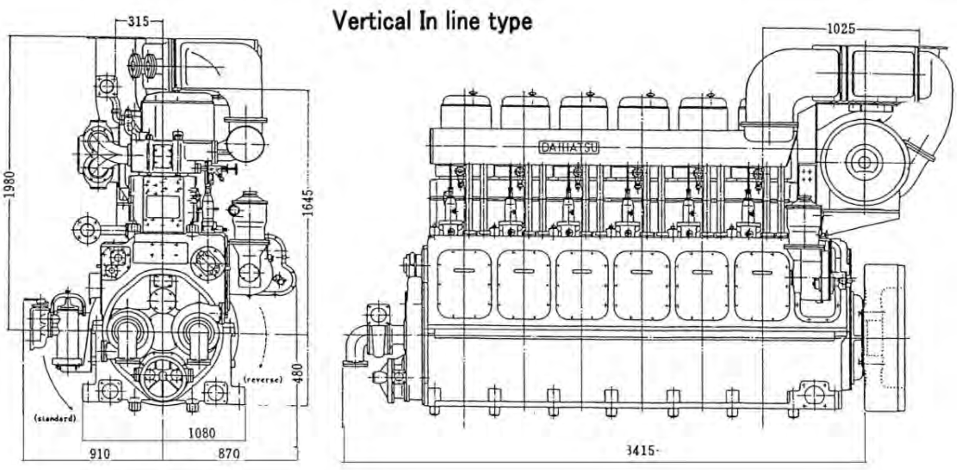
(1) Vertical-type and horizontal-type (In-Line type)

Vertical term in diesel engine is not referred to a shaft of electric machines, but the direction of cylinders. Therefore, a vertical engine has a horizontal shaft.

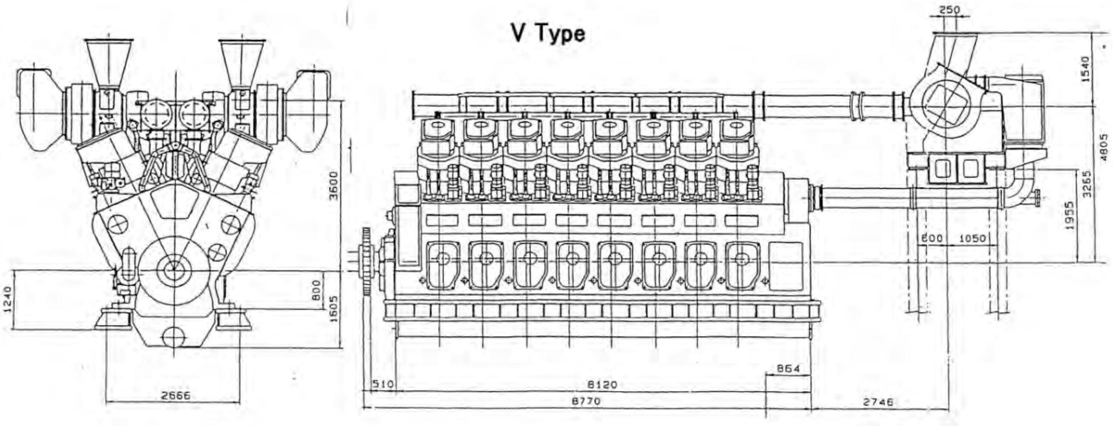
(2) Arrangements of cylinders

Engines with cylinders arranged in line are called a vertical inline engines, and other engines are arranged in a V-shape, W-shape, or horizontally opposed. Generally, the most popular engines are considered to the vertical inline type unless specified in manufacture's specification sheet. Figure 3 shows different arrangements of cylinders, and the vertical in line and V engines are commonly used in diesel power generators.

Figure 4 and 5 shows a cross section of vertical in line and V engine.



Vertical In line type



V Type

No	Name
1-1	Engine body
1-2	Cylinder block
2	Piston
3	Crankshaft
4	Crank pin metal
5	Cylinder head
6	Cylinder liner

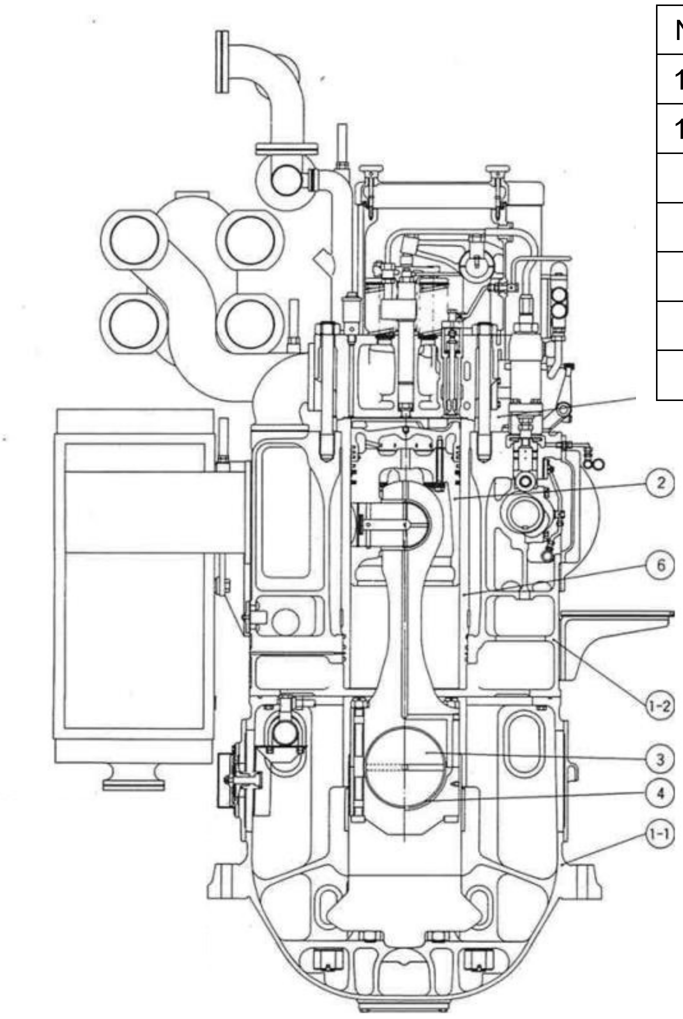


Figure 2. Vertical in Line Type diesel engine

(Source: Iwamitsu Tatomi "Shin denki series genba no diesel hatsuden gijutsu")

3) Characteristics of diesel engine

(1) Thermal efficiency

The thermal efficiency of the diesel engine is excellent compared with other prime movers using thermal power. For example, the thermal efficiency of a 10,000 kW class diesel engine is over 40%, and this value is equivalent to that of a new 100,000 kW class thermal power plant.

Table 3 shows comparison of thermal efficiency of various thermal power generation facilities

Table 4.　Comparison of thermal efficiency

Type of power generation	Generation capacity (kW)	Thermal efficiency (%)
・4 cycle diesel engines	300～10000	37～45
・Condensing steam turbine (reheating type)	85000～125000	35～40
・Gas turbine (free piston / gas turbine)	6000	32～33

Thermal efficiency is the net power generation efficiency with the lower heating value at the transmission end as a reference minus the power consumption of the necessary auxiliary equipment.

In addition, all of them have a power generation capacity of about 5000 kW or less, and Table 5 shows a similar comparison of the power generation when heavy fuel oil is used.

Table 5. Comparison of the power generation end using heavy oil

・Steam engine	9～19%
・Steam turbine	～25%
・Gas turbine	～25%
・Piston free・gas turbine	～33%
・4 cycle diesel engine	35～40%

The thermal balance of the diesel engine is about 35 to 40% of the supplied heat quantity as engine output, and the remaining is mechanical loss of the engine, exhaust loss, and cooling loss.

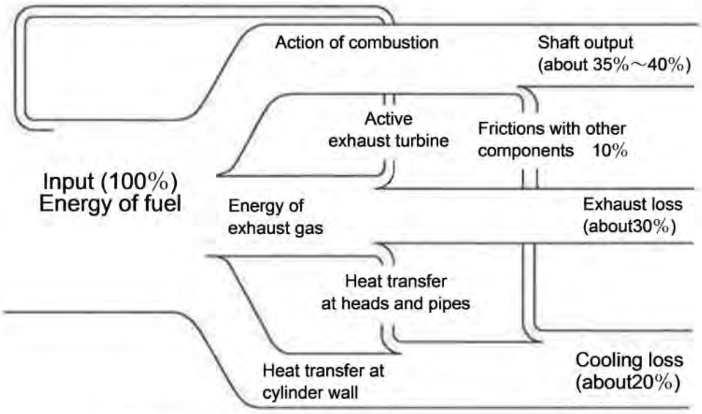


Figure 3. Energy balance of general combustion
(Source: Hidenori Tasaka 「Nainen kikan dai ni ban」 2005)

(2) The role of supercharger

The output of the internal combustion engine is nearly proportional to the amount of fuel injected. However, in order to completely burn this fuel and convert it to effective work, a certain amount or more of air corresponding to the amount of fuel must be fed in.

The more air is fed into the cylinder, the more fuel can be combusted, so the output of the engine will increase. This act of increasing the amount of combustion air and thus increasing the output is called supercharging.

A turbocharger which is driven by exhaust gas is one method for supercharging. That is, a turbine is rotated by using the energy of the exhaust gas of the diesel engine, and the intake air is compressed by the force produced and sent into the cylinder.

By using a turbocharger, the output of the engine is increased, and by further adding an air cooler, it can be increased to about three times the output of engines without a supercharger. It is expected that this will be further improved by future technology improvements. However, there is a tendency for noise to increase by about 4 to 6 phons.

(3)Governor

As described above, one of the factors limiting the output of the engine is the amount of air fed into the cylinder, but actually it is the amount of fuel oil injected into the cylinder which determines the output of the engine.

Therefore, unless the amount of fuel oil is changed in correspondence with to the load fluctuation, the rotational speed of the engine fluctuates significantly rendering it inoperable. For this reason, the governor detects the change in the engine speed and immediately adjusts the amount of fuel injected by the fuel pump such that it can always rotate at a constant rotational speed.

There are mechanical and hydraulic governors, and recently, electronic governors are being used. The mechanical governor is balanced by centrifugal weight and a spring, and speed change due to load fluctuation is detected as a change in the angle of the weight, and it is directly applied to the fuel injection pump to keep the speed constant.

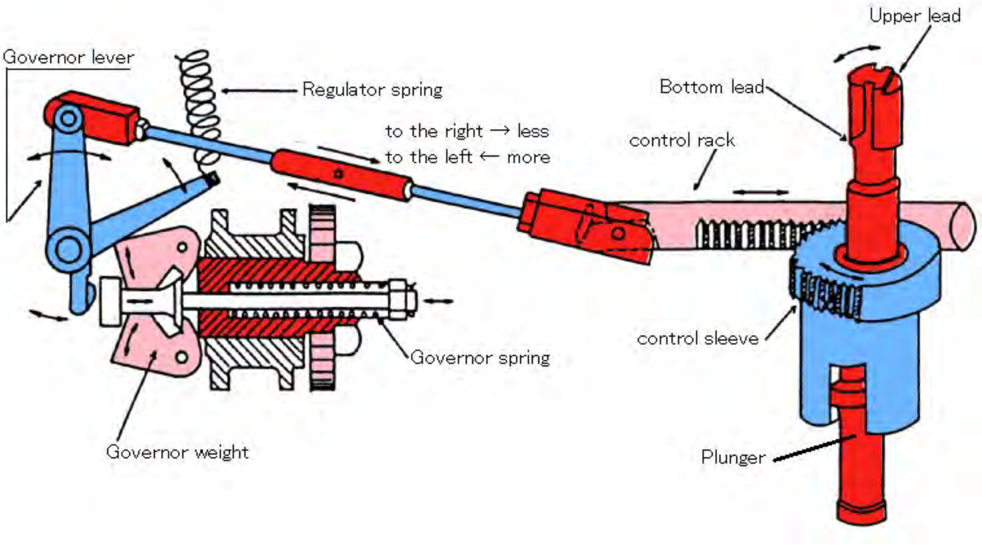


Figure 4.　Mechanical Governor

As the rotational speed increases, the flyweights spreads outward due to centrifugal force, pushing up the speeder spring with the toes of the flyweight.

In conjunction with that, the speeder rod is pulled upward. The control rack of the fuel injection pump is pulled by the lever connected to the speeder rod to decrease the amount of fuel and in turn, the rotational speed.

In this way, the rotational speed is kept constant by balancing the flyweight and the speeder spring with centrifugal force.

With the hydraulic governor, the change in the angle of the weight is increased by the hydraulic spool valve, and the turbo cylinder causes the fuel injection pump to act.

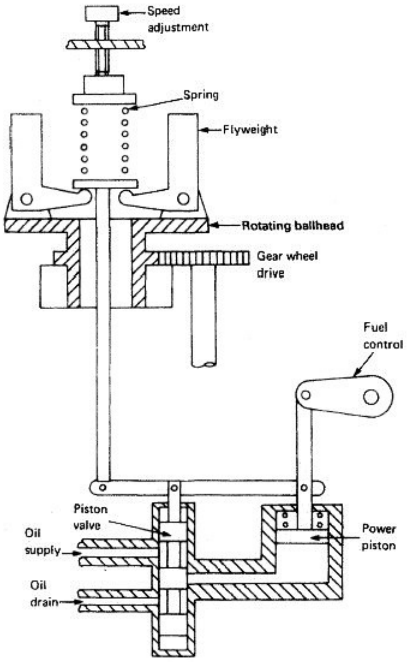


Figure 5 Hydraulic governor

(Source: http://www.machineryspaces.com/governor.html)

・Governor characteristic

To express the characteristics of the governor, it is generally expressed as a percentage of frequency change when the load changes from 0 to 100%. This is called the speed droop. From the definition, it is expressed by the following equation.

$$\delta = \frac{f0 - f}{f} \times 100$$

δ: Droop%

f 0: Frequency when load is 0%

f: Frequency when load is 100%

（Calculation example）

What happens to the frequency when the rated output of a 1200 kW diesel generator is running alone at full load at 60 Hz and the load drops to 1000 kW?

However, the droop is 4%, and the governor characteristic is linear.

$$f0 = 60\left(1 + \frac{4}{100}\right) = 62.4$$

Since the governor characteristic is linear, the frequency when the load drops to 1000 kW can be calculated as follows.

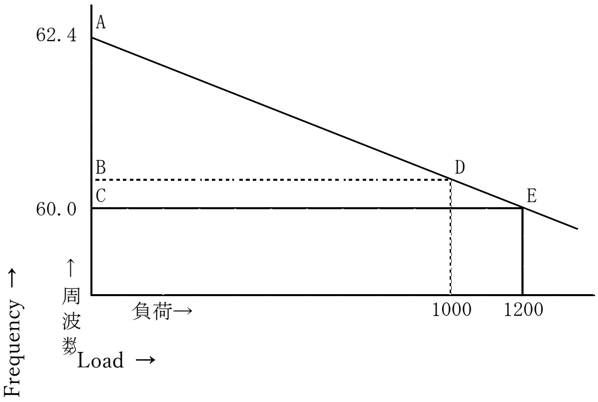
$$CE : BD = AC : AB$$

$$\overline{AB} = \frac{\overline{BD}\cdot\overline{AC}}{\overline{CE}}$$

$$= \frac{1000\times 2.4}{1200}$$

$$= 2$$

$$B = 62.4 - 2 = 60.4$$



That is, if the load decreases to 1000 kW, the frequency will be 60.4 Hz.

$$\%\ \text{Speed Droop} = \frac{\text{Speed @ Zero Load} - \text{Speed @ Full Load}}{\text{Speed @ Full Load}}$$

(4) Fuel oil System

1) Fuel system flow

The fuel is sent to the cylinder via the following path: fuel oil service tank → fuel oil filter → fuel pump → fuel injection pump. The amount of fuel supplied is adjusted by detecting the change in the rotational speed of the engine with the governor, operating the fuel regulating shaft, and adjusting the effective stroke of the fuel pump plunger.

Generally, diesel oil is used in high-speed diesel engines, and marine diesel fuel is used in medium- and low-speed diesel engines.

In medium- and low-speed large capacity diesel engines used for normal power generation operation, in many cases, B-class or heavy fuel oil is used to reduce fuel cost.

When used as an emergency engine, since the annual operation time is very short (at most about 100 hours), fuel should be chosen giving more priority to start ability over economy.

Cases of using heavy fuel oil is limited to regular power generation operation, but in such cases, it is necessary to switch to better quality oil when starting and stopping. Also, since it has a higher viscosity than marine diesel fuel, a fuel heater and an oil purifier are required.

2) Types of fuel oil

The fuel used for diesel engines is as follows according to JIS standard.

JIS standard excerpt

Table 4. Types of diesel fuels

Type \ item	Flash point ℃	Viscosity cSt	Residual carbon content%	Sulfur content mass%	Main applications
Diesel oil	Over 50	Over 2.7(30℃)	Under 0.1	Under 0.001	・Automobile ・For internal combustion engines
Marine diesel fuel	Over 60	Under 20(50℃)	Under 4.0	Under 2.0	・For internal combustion engines(small)
B class Heavy oil	Over 60	Under 50(50℃)	Under 8.0	Under 3.0	・For internal combustion engines
Heavy fuel oil	Over 70	Under 400(50℃)	—	—	・For internal combustion engines(large)

The requirements for fuel are good combustibility and less harmful byproducts of combustion.

3) Fuel tank

The specified quantity by the Fire Services Act is as follows.

Class 2 petroleum

(Diesel oil, etc. with a flash point of 21°C or higher and lower than 70°C) → 264 gals

Class 3 petroleum

(Diesel oil etc. with flash point of 70°C or over and less than 200°C) → 528 gals

If it is necessary to store it beyond the specified quantity, a permission application is required, and it will be treated as a general handling plant.

In such case, there will be constraints on building facilities, etc., and a chief managing director will be posted. For diesel engines for normal operations, a storage tank for storing fuel oil is required for long-term operation or for some reserve.

Eg.

- Island far from the mainland have 100 days' worth
- Island near to the mainland have 30 days' worth

4) Specific fuel consumption

It shows how many grams of fuel the engine consumes per horsepower per hour.

$$\text{Specific fuel consumption } b = \frac{V \times 60 \times 60}{t \times PS} \times \text{specific gravity } (g/PS \cdot Hr)$$

V : Measurement volume (cc) PS : horsepower t : Consumption time (sec)

specific gravity : Diesel oil≒0.82~0.83 A class fuel oil≒0.84~0.86

B class fuel oil≒0.9~0.94 C class fuel oil≒0.96~0.98

For generator diesel engines, it is generally expressed as follows.

$$\text{Specific fuel consumption } b\ (\ell/kWh) = \frac{\text{Fuel consumption}}{\text{Generated electric power}}$$

Therefore, the fuel consumption is as follows.

Fuel consumption Q （ℓ/h） ＝ Specific fuel consumption×Generated electric power

（Calculation example）

How much is the fuel consumption per hour if the diesel power generation output was 1,000 kW and the specific fuel consumption was 0.25 l / kWh

$$Q = 0.25 \times 1{,}000 = 250\ell/h \text{ (66 gal/h)}$$

FUEL CONSUMPTION IN 24 HRS:

W = w x kW x 24÷1000

Were :

w = fuel consumption rate, kg/kW h

W = total fuel consumed per day in tonnes.

1 tonne = 1000kg

5) Performance of diesel engines (performance curve)

Scale of output and torque of diesel engines vary with their purpose of use, so the fuel consumption rates, and other performance factors are different with each engine. The performance is not identical even between the engines of same manufacture and model with same manufactured date, since it depends on the frequency of use and method of maintenance. Figure 4-1 and figure4-2 show performance curves of diesel engines with about 18kW of rated output scale.

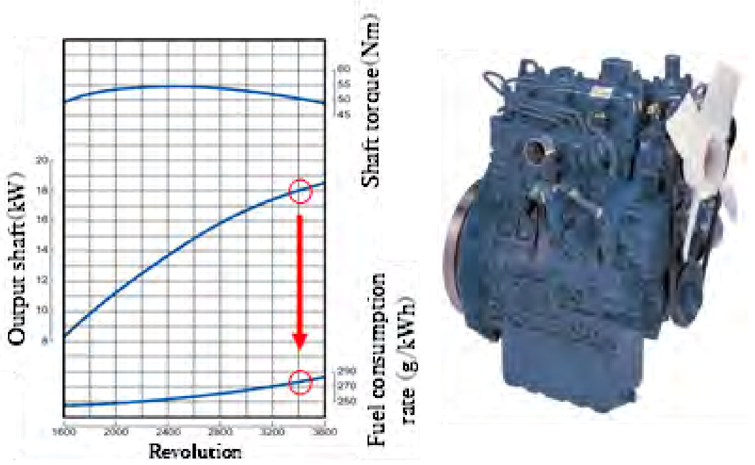


Figure 5. performance curve and appearance of a diesel engine #1

(Source: Kubota Corporation Catalog)

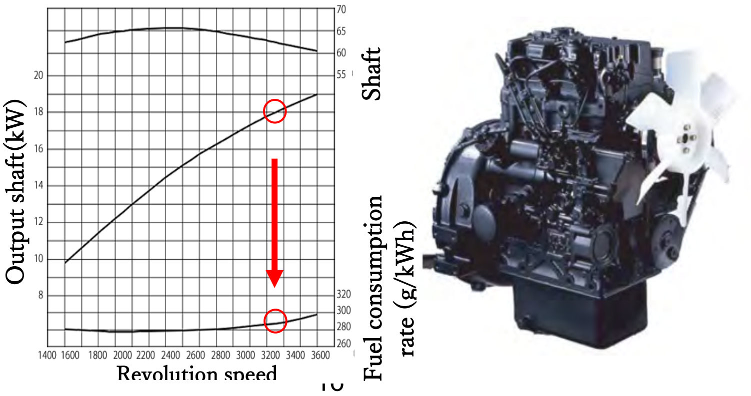


Figure 6. Performance curve and appearance of a diesel engine #2
(Source: Shibaura IHI Co. catalog)

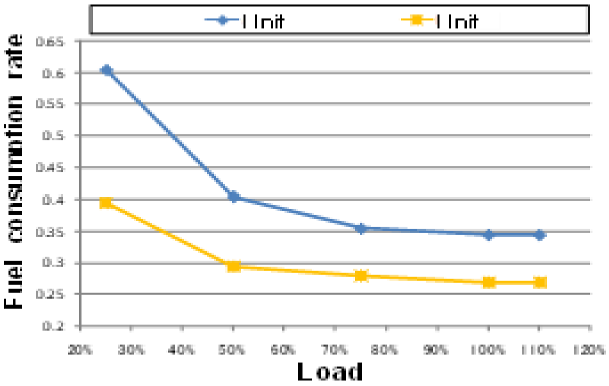
Above graph indicates shaft torque (Nm), shaft output (kW) and fuel consumption ratio from the top. In comparing the fuel efficiency of those two graphs, the engine #1 records about 280g/kWh and engine #2 shows about 290 g/kWh at the same output scale of 18kW. This implies although receiving the same level of output with similar generators, their use of fuel is different.

Since the performance of diesel engines are different with each unit, it is important for the power plants with multiple units to employ the “economic load dispatching,” which minimize the fuel cost based on the principle of equal incremental fuel cost.

6) Mechanism of lower performance in low load operation

Generally, diesel engines perform the best around rated output level and the worst around the low load range. Figure 5-1shows comparison of fuel consumption rate in two generators (unit A: rate output 100kW, unit B: rated output 350kW) used in Japan’s remote islands. This indicates that both of diesel generators function most efficiently around the rated output range and worsen as the load factor decreases.

This section explains the mechanism of performance deterioration as well as fuel consumption increase during the low load operation.

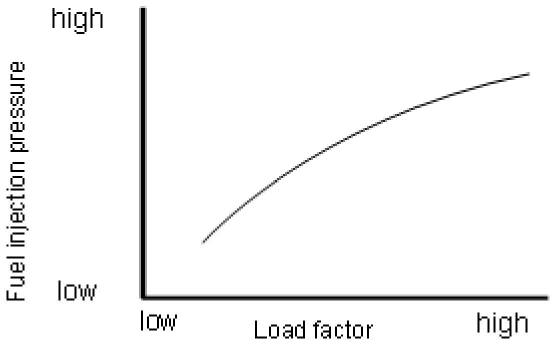


Graph 6. Fuel efficiency and load factor in diesel engines

When operating with low load factor, a primary phenomenon can be seen in diesel engine is the incomplete combustion, a poor burning of fuel-air mixture in the cylinder. A portion of fuel oil turning into soot is released as black smoke or white fume (liquid smoke), the fuel itself is discharged by the imperfect combustion. If the injected fuel doesn’t convert fully into heat energy, necessary output can’t be attained, thus more fuel needs to be supplied. This is the cause of increase in fuel consumption ratio.

One of the reasons of incomplete combustion is that decreased amount of air charge in cylinders associated with low pressure during the air intake. This leads to the decline of compression pressure as well as compression temperature, thus it becomes difficult for fuel to ignite and combust.

Another reason is that injection pressure delivered through fuel pump to the nozzle decreases during low load operation as shown in figure 5-2. Therefore, the diameter of fuel particle sprayed from the valve becomes large and unevenly distributed fuel cannot combust in time (image of incomplete combustion in figure5-3. The effort to maintain the appropriate spraying process in low load operation can lead to later increase of fuel pressure during high load factor range and cause excessive burden on the injection pump and valves by contrast.



Graph 7.　Load factor and fuel injection pressure

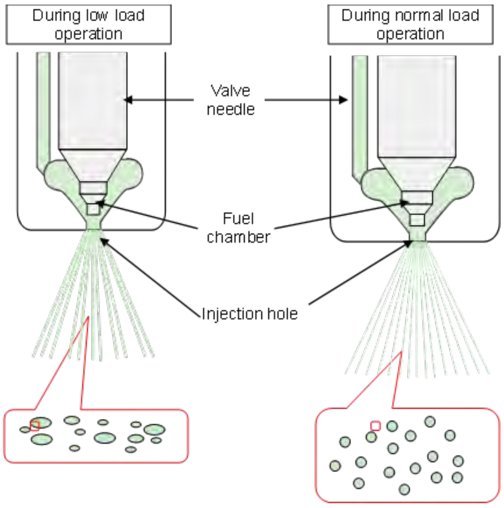


Figure 7.　Image of fuel distribution in different injection pressure

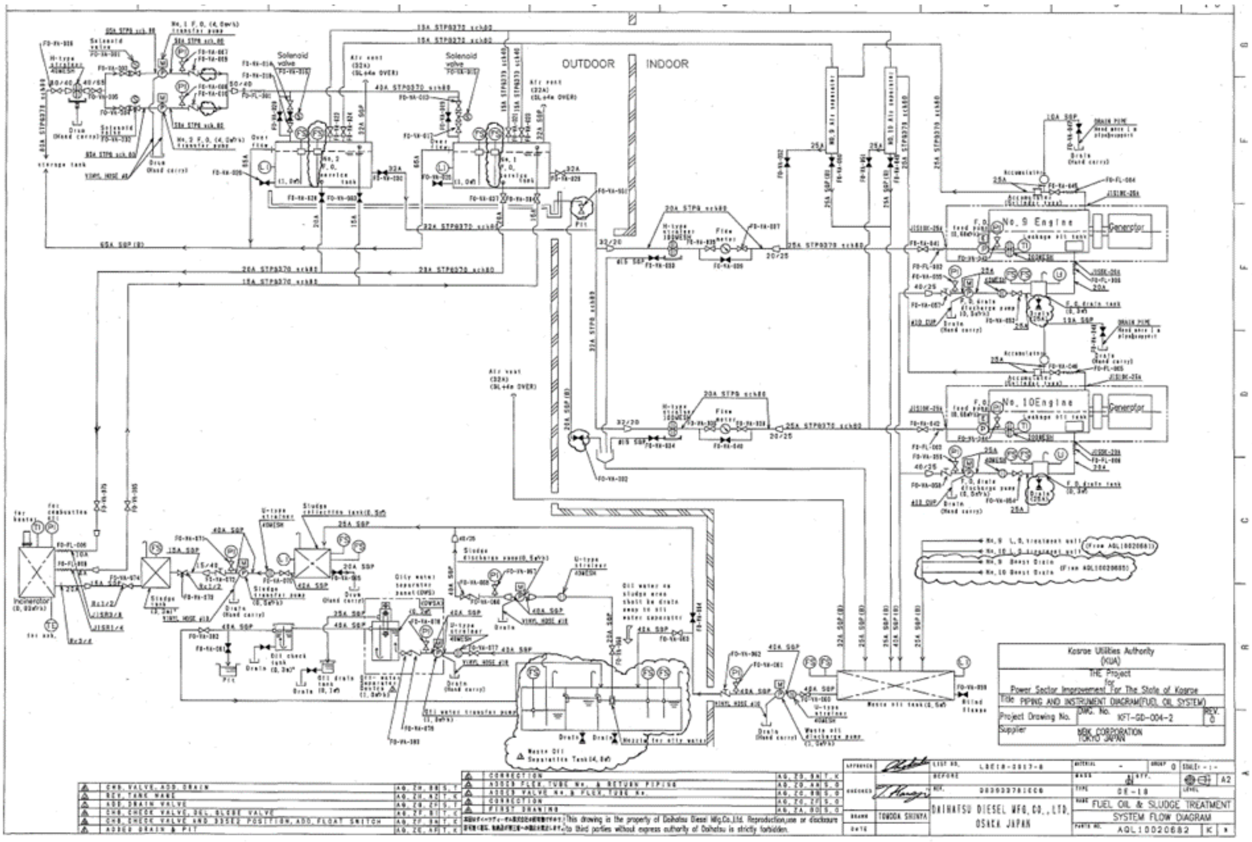


Fig.7 Fuel Oil System

(5) Lubricant oil system

1) Lubricating oil system flow

In general, the lubricating oil of the engine flows from the tank, is pressurized by the lubricating oil pump, passing through the oil filter and intercooler before being injected to various parts of the engine as shown in the figure below.

2) Role of lubricating oil

The piston of the diesel engine always operates while being exposed to high temperature and high pressure, and the crankpin, piston pin, main bearing, etc. continue the rotational movement under impulsive pressure.

Lubricating oil is required to provide the appropriate oil film to prevent wear on such sliding parts, to improve mechanical efficiency, and remove heat from the heat-generating parts to prevent excessive temperature rise.

3) Lubricant consumption

The amount of lubricating oil used in a diesel engine is the sum of the amount burned with fuel oil during operation and the amount lost as mist gas vapor. The amount used is generally as shown in the table below.

Table 5. Amount of Lubricant oil of different DG's

Type of engine	Lubricant consumption rate (g/PS-h)
High-speed small capacity engine	2.0～3.0
Medium-speed medium capacity engine	1.5～2.0
Medium-speed large capacity engine	1.2～1.5
Low-speed large capacity engine	1.2～1.5

Specific lube oil consumption is obtained as follows

$$\text{Specific lube oil consumption} = \frac{\text{Lubricating oil consumption(L)} \times \text{specific gravity(g/ml)}}{\text{Generated electric power(kWh)}} \times 1000$$

<u>Calculation of Engine BSOC:</u>

Gal/hr = <u>Engine bhp x Load Factor (%) x BSOC (lb/bhp-hr)</u>

<u>Density of Oil</u>

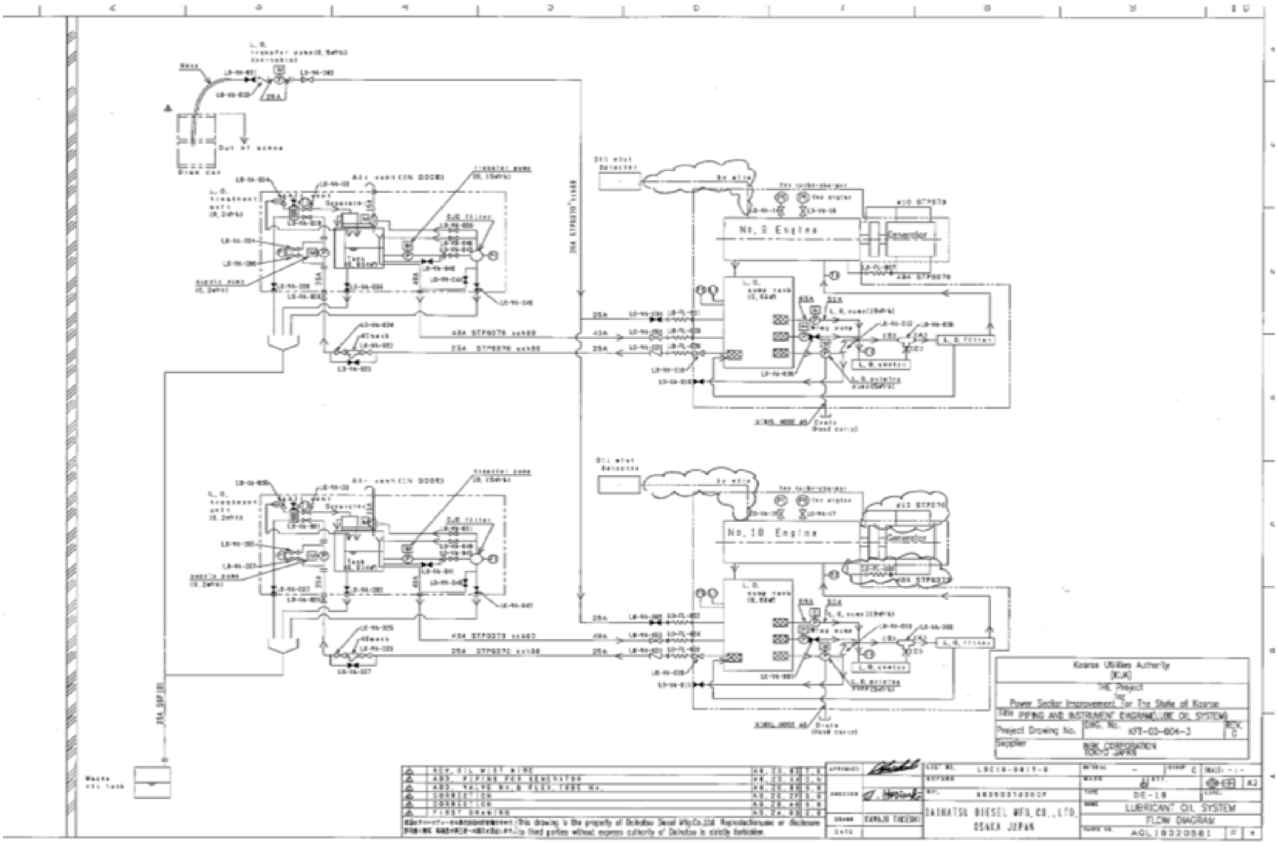


Figure 8. Lubricating oil system

(6) Cooling water system

1) Cooling system flow

Cooling water is generally used for the cooling system of the engine. There are 2 methods in general. The primary cooling method directly cools the engine's main body using only one system, and the secondary cooling method divides the engine's main body and each heat exchanger into two systems (Large engines have a tertiary cooling method).

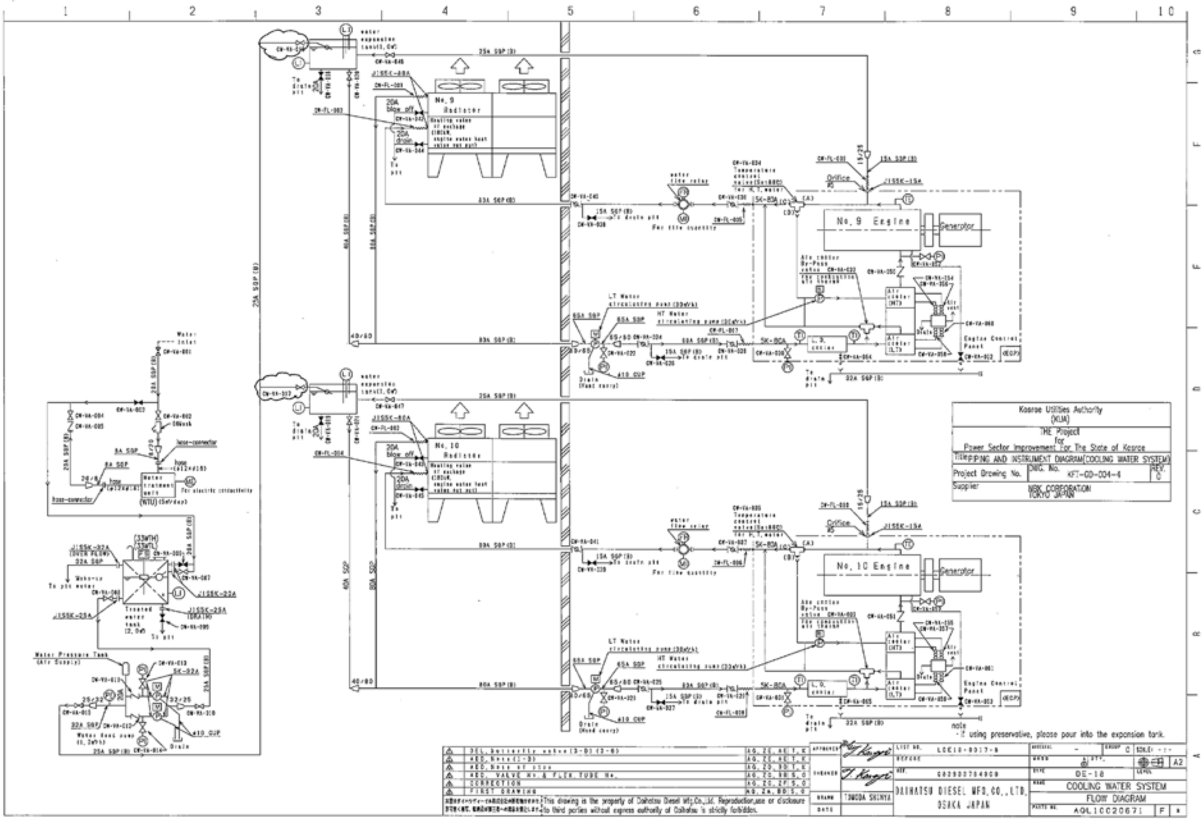


Figure 9. Cooling water system

2) Role of cooling water

In the combustion stroke of the diesel engine, the inside of the cylinder, etc. is exposed to combustion gas exceeding 1000°C. For that reason, in order to maintain the effectiveness of lubricating oil and prevent material deformation, high temperature parts must be cooled.

3) Purpose of adopting secondary cooling water system

Although equipment costs are slightly more expensive for engines for normal operations, secondary cooling systems are often adopted for the following benefits.

(a) Since the cooling water of the engine body can always be kept at a constant temperature, corrosion in the combustion system due to the sulfur oxide in the exhaust gas is reduced.

(b) Since the engine body is indirectly cooled by the secondary cooling, the quality of the secondary cooling water can be selected relatively freely. (Seawater can also be used)

(c) It is easy to prevent corrosion of the engine body and take measures against freezing during cold days.

(7) Air system

1) Air system flow

As shown in the figure, the starting air system requires an air compressor and an air tank. The air compressor is driven by an electric motor, and a method for automatically filling air with a pressure switch (PS) provided in the air tank is used.

The maximum pressure of the starting air is about 150psi, and normally it begins to fill at 100psi and issues a warning at 120psi.

2) Air start system

For the air starting method, air compressed by an air compressor is stored in an air tank, and when starting, by feeding this air into the cylinder through a distributing valve and a starting valve of the engine, the piston is pushed down, and this is sequentially repeated to start the engine.

There is also another method where the air starter is rotated by compressed air to rotate the flywheel to start the engine.

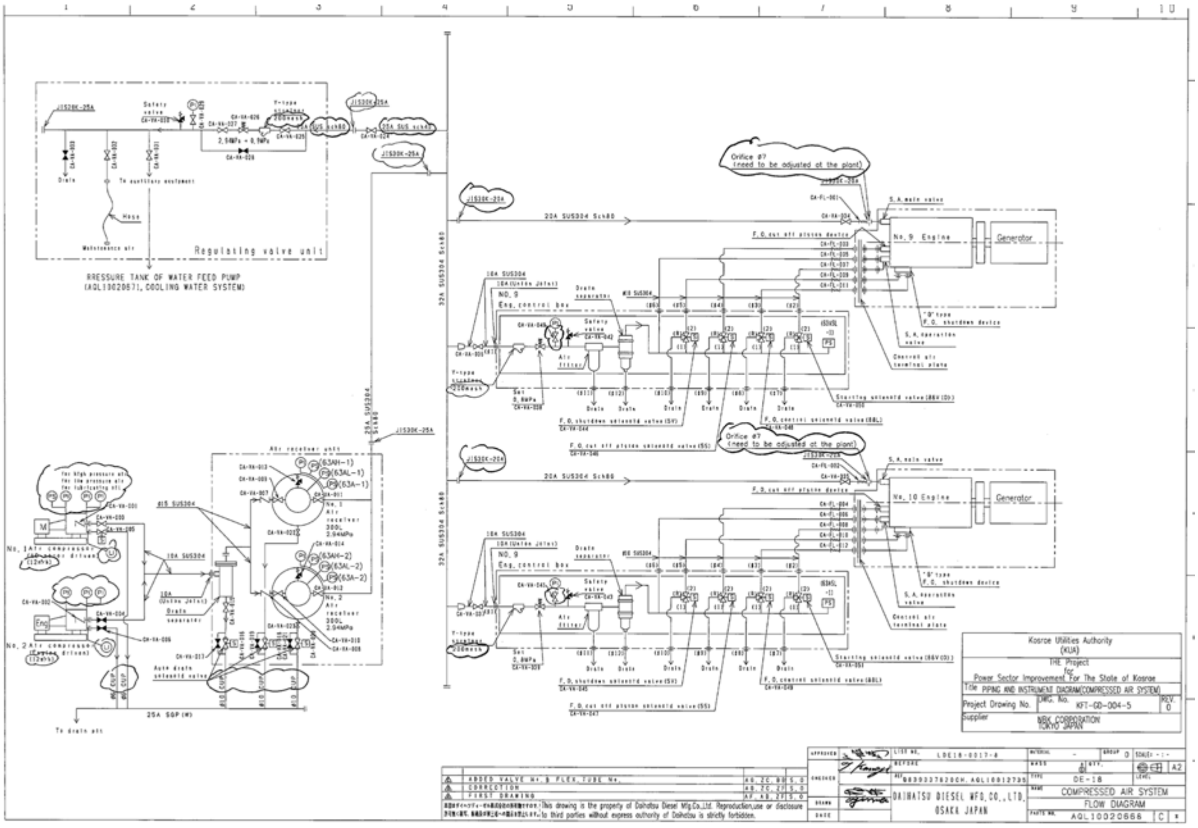


Figure 10. Air system

* Another method is an electric starting method (rotating the cell motor with a battery).

(8) Exhaust gas system

As shown in the figure, the exhaust device includes an exhaust pipe, elastic pipes, a muffler, etc. The exhaust pipe diameter is selected so that the engine outlet back pressure is usually .3psi (2.5kPa) or less. Noise pollution issues must be considered in selecting mufflers.

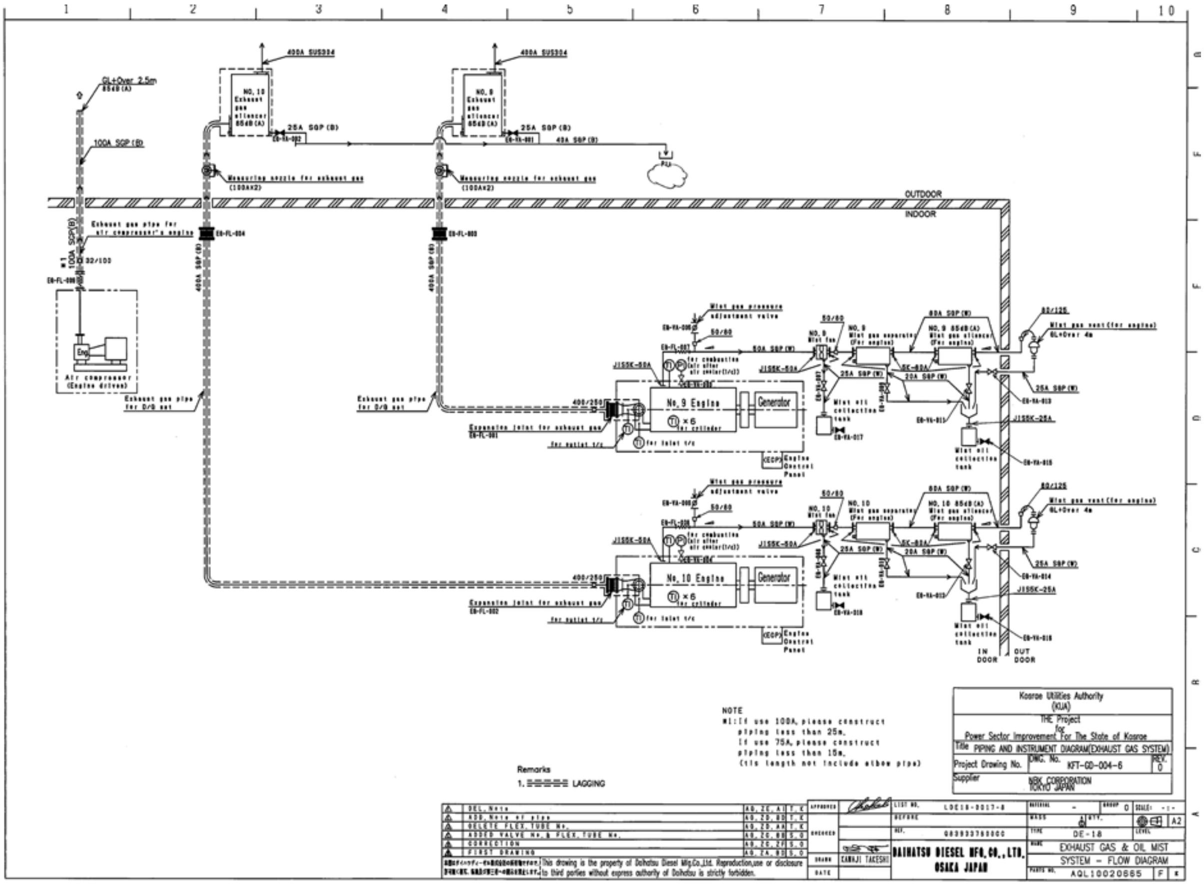


Figure 11. Exhaust gas system

(9) Ventilation system

For ventilation of the engine room, the following considerations are required.

・Amount of air required for combustion of engine fuel

・The amount of ventilation necessary to mitigate the rise in room temperature

・Amount of ventilation required for hygiene.

End

Diesel Generation
Operation and Maintenance Manual

3. Main Equipment of Diesel Generation
3.1 Main Equipment of Diesel Generation (Mechanical Devices)

Kosrae Utilities Authority

INDEX

Main composition of diesel engine

Diesel engines vary in construction according to their use, but their basic principles are all the same, and they are also composed of roughly similar parts. The composition can roughly be divided into the following.

① Engine body
② Moving engine parts
③ Valve train
④ Lubrication system
⑤ Cooling system
⑥ Fuel system
⑦ Governor
⑧ Starter
⑨ Supercharger

1-1 Engine body

The engine body consists of cylinders, cylinder liners, cylinder heads and combustion chamber.

1) Cylinder

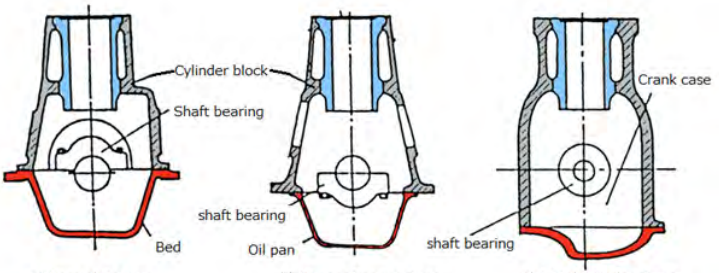
In general, the cylinder block includes the crankcase, but in other cases the cylinders and a crankcase are built separately. The cylinder liners, crankshaft, and cam shaft are attached on the inside; and the cylinder head is attached on top, an oil pan, or a base plate, etc. is attached to the bottom part to make up the engine body. In addition, there are cylinder blocks with the main lubricating oil pipe and cooling water pipes built in, and others with the intake manifold as an integrated structure to increase rigidity.

There are mainly three types of cylinder construction as shown in the figure below.

a) Base plate type:
Crankshaft and main bearing are mounted on the engine head (base plate).

b) Hanger Bearing Type:
Hung from the main bearing on the cylinder block with the oil pan attached to the bottom part.

c) Metal cylinder shape:
The crankcase is elongated, and the crankshaft and main bearing are inserted from the end surface. Generally used in small single cylinder engines.



a) Base plate type b) Hanger Bearing Type c) Metal cylinder shape

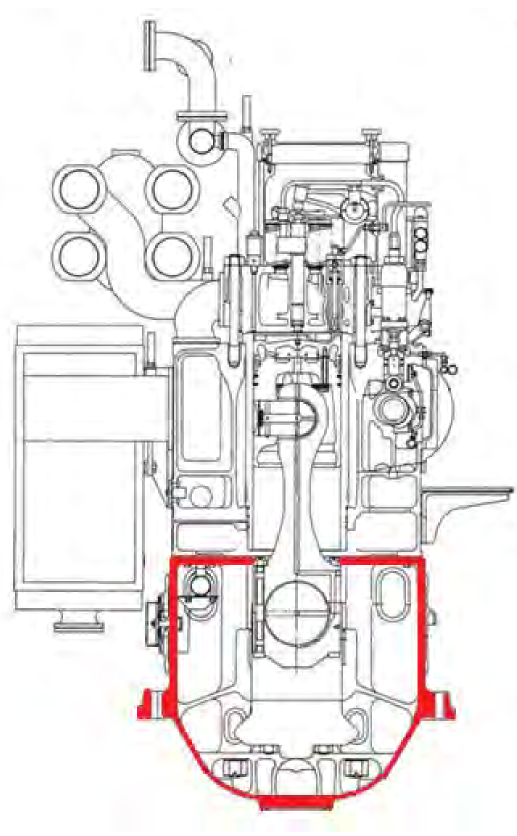


Figure 1. Types of cylinder construction　（Daihatsu DK）

2) Cylinder Liner

It has a hollow cylindrical shape also referred to as cylinder, and the piston reciprocates to compress the air and combust the fuel to generate thermal energy. Made of special cast iron which can withstand high temperature and high pressure, and special treatments such as hard porous chrome plating, tuft ride, etc. are applied to the internal surface

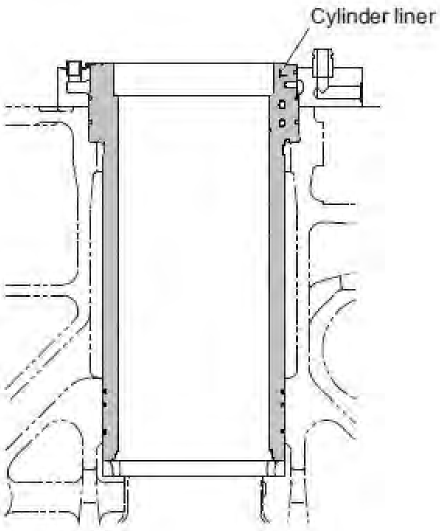


Figure 2. Cylinder liner

3) Cylinder Head

The cylinder head is made of cast iron, attached to the upper part of the cylinder, and forms the combustion chamber with the cylinder head, cylinder liner, and piston.

In addition to intake valves, exhaust valves, intake valve seats, exhaust valve seats, fuel injection valves, air-start actuating valves, etc. are provided on the bottom surface of the cylinder head. Inside of the cylinder head, in addition to the intake/exhaust port and valve guide, since there is a water channel designed to cool the heat generated in the combustion chamber, so it has a complicated construction. Furthermore, the upper part of the cylinder head is a valve arm chamber that houses valve actuating mechanisms such as a valve arm support base, a valve spring, a valve arm and the like.

There are some types of cylinder heads which are independent for each cylinder and others that integrate several cylinders or all cylinders.

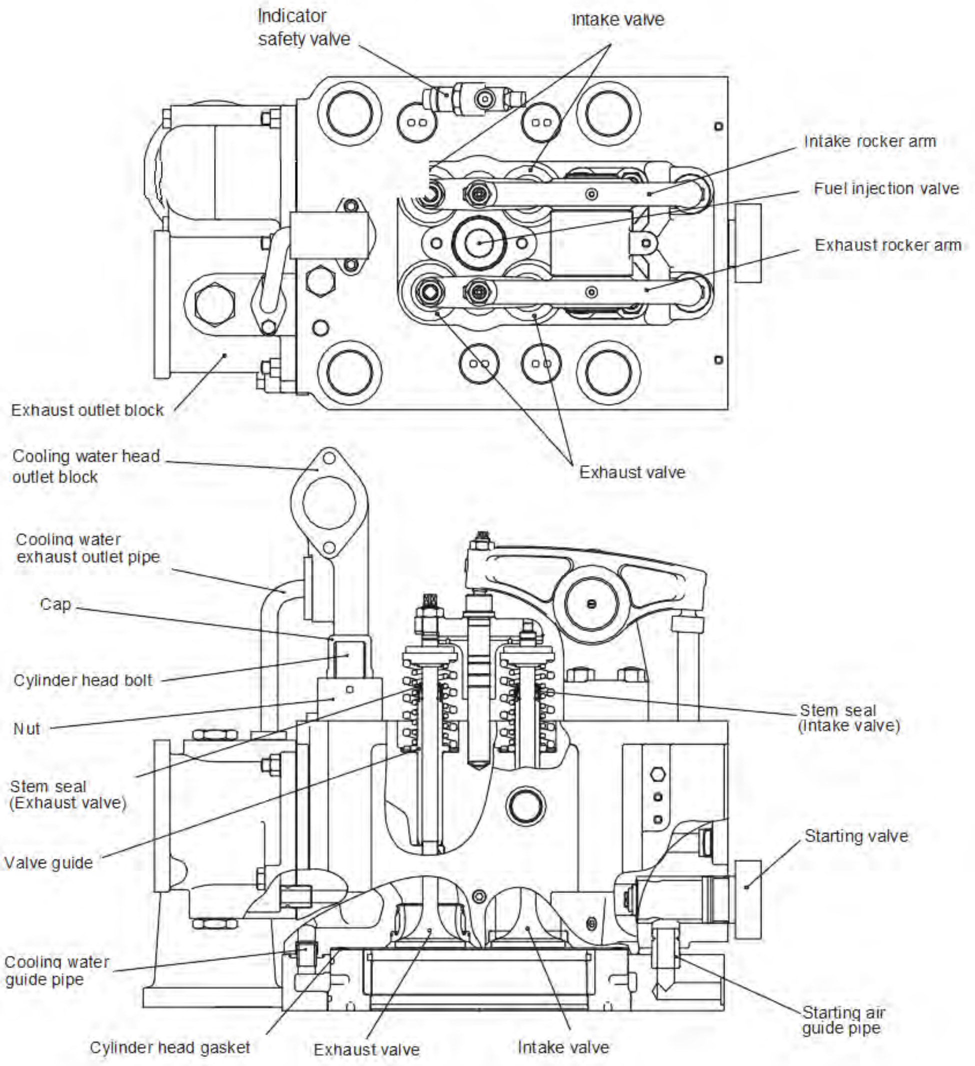


Figure 3. Cylinder head composition

1-2 Moving engine parts

The moving parts of the engine consist of the crankshaft, main bearing, thrust metal, pistons, connecting rods as shown in the figure below.

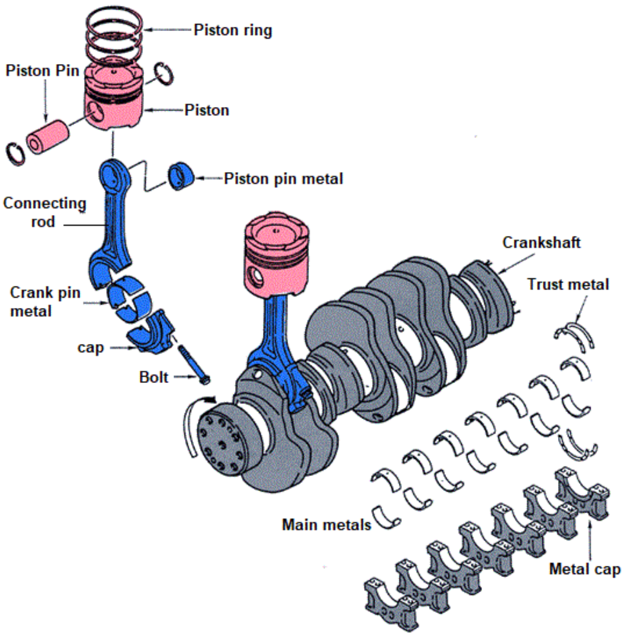


Figure 4. Moving parts components

1) Crankshaft

The reciprocating motion of the piston is changed to a rotational motion via a connecting rod, and a rotational force is transmitted from the shaft end to the other end. A crank journal which rotates and is supported by the main bearing, a crank pin parallel to the crank journal, and a crank arm which connects the crank pin and the crank journal.

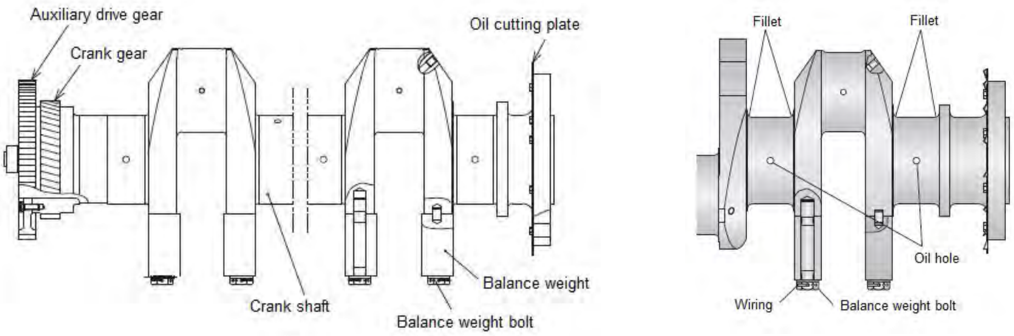


Figure 5. Crankshaft parts / Crank journal

Balancing weights are added to the crank arm as necessary to balance rotation. The material is a forged product of a special steel such as carbon steel, nickel chrome molybdenum steel, etc. with sufficient toughness, and the pin and journal are induction hardened and then polished.

2) Main bearing, main bearing metal, thrust bearing

The main bearing is a housing part precision bored with a main bearing cap and reinforcement work on the boss reinforced with a rib so as to give sufficient rigidity to the partition part of the crankcase and supports the crankshaft through the main bearing metal.

The position of the main bearing cap is determined by knock pins on inlay type or serration type so that the mating faces do not shift.

The main bearing metal is housed in the main bearing housing and supports the journal portion of the crankshaft to smoothly rotate the bearings. At present, bearings are generally the thin type. For the bearing metal, white metal (tin lead alloy), kermet metal (copper lead alloy), aluminum metal (aluminum tin alloy), etc. are often used as shown in the figure below.

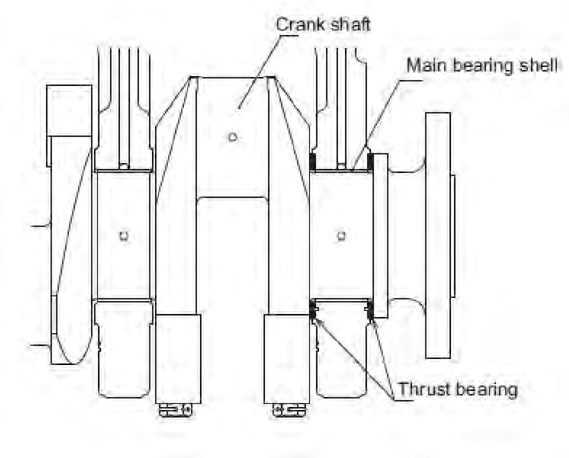
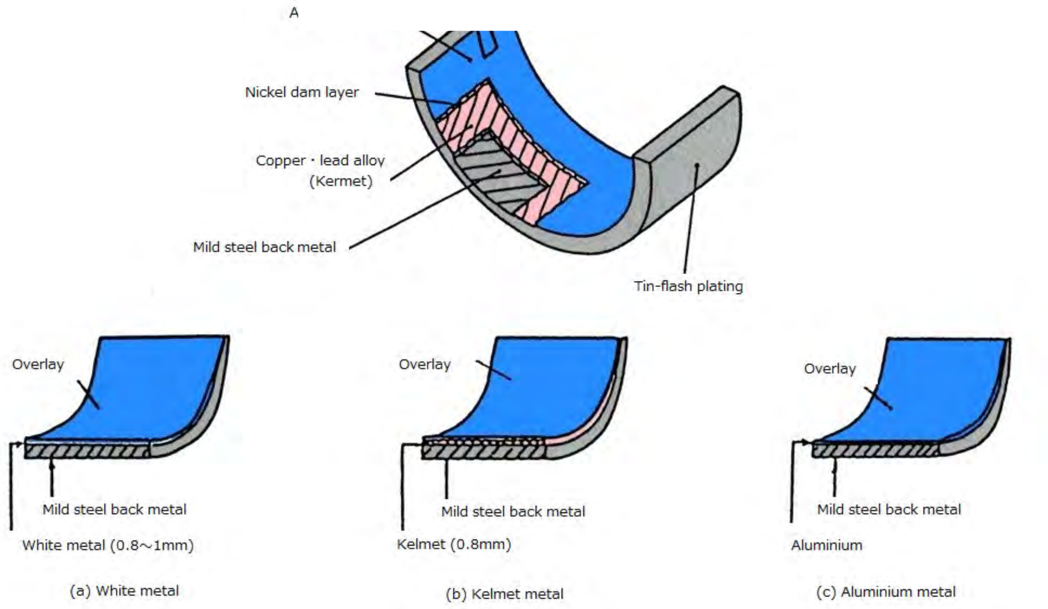


Figure 6. Thrust bearing



(a) White metal (b) Kelmet metal (c) Aluminium metal

Figure 7. Types of bearings

Thrust bearings are bearings which receive the force for the crankshaft to move in the axial direction and are normally provided to receiving the thrust force generated by the inclination angle of the engine seat so that a large thrust force does not act on the crankshaft. In general, thrust bearings use semicircular metal assembled on top of each other, but some are made integrated with main bearing metal.

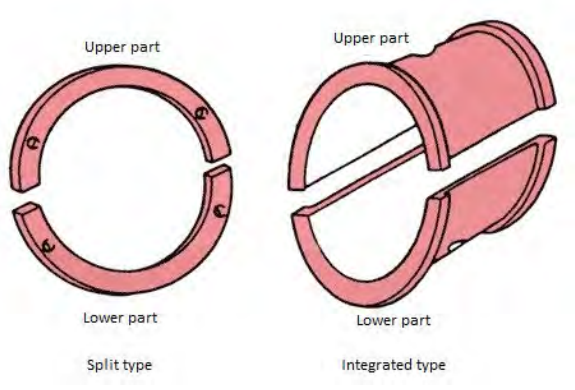


Figure 8. Types of thrust bearing

3) Connecting rod

The connecting rod consists of a small end connected to the piston pin, a large end connected to the crankpin, and a rod connecting the big end and the small end portion. The small end is connected to the piston, and the big end is connected to the crank shaft to convert the reciprocating motion of the piston to the crankshaft to a rotational motion. Also, the connecting rod receives the largest fluctuating load (repetition of compression and tension) among the engine parts. Because heat and vibration are also added by the bending action, for medium and high-speed engines, forging material (carbon steel forging steel: nickel chrome steel etc.) having an I-shaped cross section is used, and heat treatment is performed after forging to provide sufficient strength. In low-speed engines, many are made by free forging. An example of the shape and configuration of the connecting rod for medium and high speed engines is shown in the figure below.

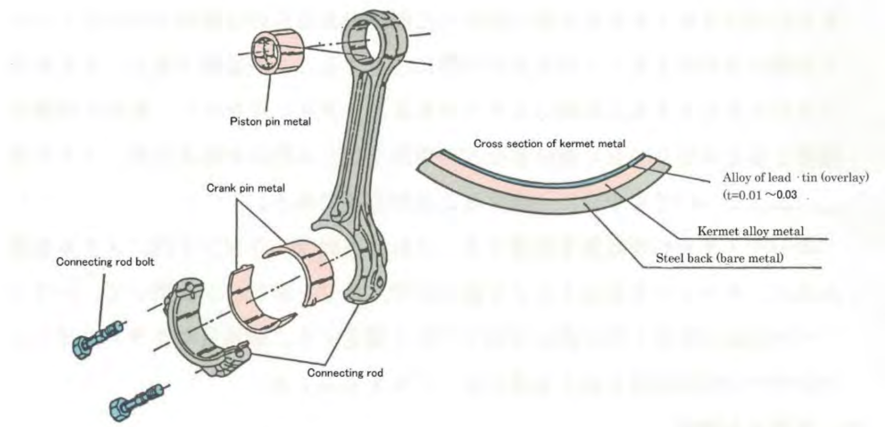


Figure 9. Connecting rod

Since the connecting rod bolt is also the part subjected to the most severe repetitive stress, a tough material such as nickel chrome steel or chrome molybdenum steel is used.

A piston pin metal (bush) made of phosphor bronze is inserted into the small end of the connecting rod, and it receives the explosion pressure generated at the top surface of the piston via the piston pin.

The big end is connected to the crankpin part, and the crankpin is held with thin-wall precision metal split in two (crankpin metal), and they are tightened together by the connecting rod bolt.

Crankpin metal is welded or sintered with a copper lead alloy (Kelmet) to the steel back metal, and Kelmet metal overlaid with tin-lead alloy on the surface is often used.

The connecting rod bolt is the most important bolt in the engine, and its tightening is very important, so it's always tightened with the specified tightening torque. The large end of the connecting rod is divided obliquely as shown in the above figure, and it is divided horizontally. As a recent trend, the medium and high speed/high supercharged engines use the diagonal large end because the crankpin diameter is made thick, making it possible to withdraw the piston during maintenance. In addition, there are some with holes at the center of the rod for lubricating oil of the piston pin and for cooling the piston.

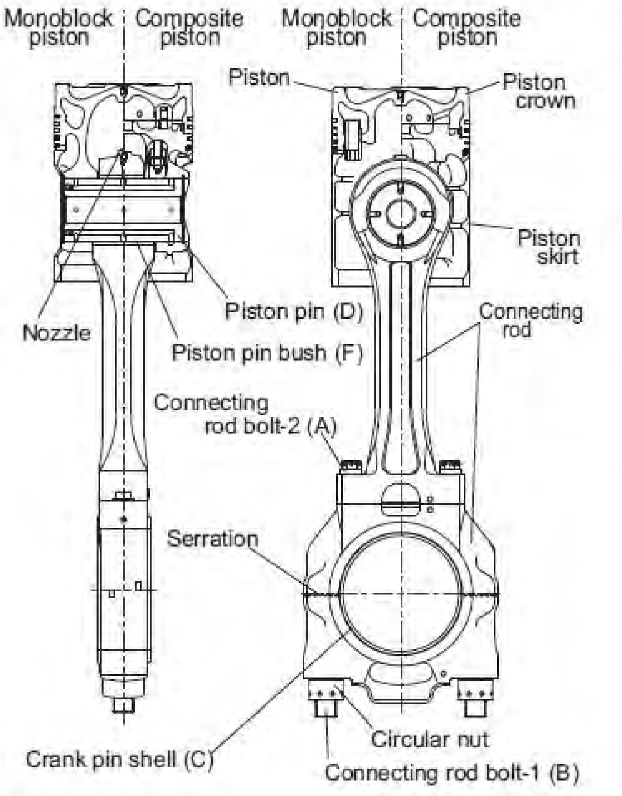


Figure 10. Piston and connecting rod parts (Daihatsu DK)

4) Piston

The piston is divided into a cylinder head, a cylinder liner, a piston head forming a part of the combustion chamber, ring lands on which the ring is mounted, a piston pin boss for supporting the piston pin, and a skirt for supporting the side pressure applied to the piston.

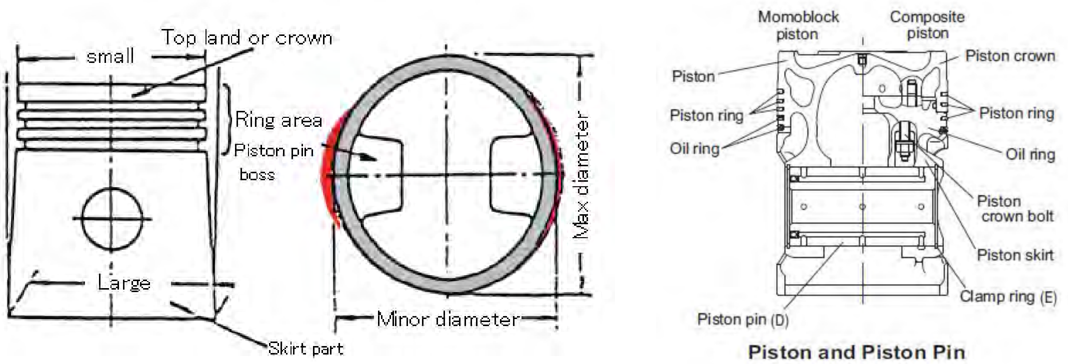


Figure 11. Parts of the piston

To make the engine small, lightweight, high-power output, the pistons were changed from the conventional cast iron to a light aluminum alloy, and a forced cooling method using lubricating oil from the inside of the piston was adopted as a measure to reduce the heat load at the top of the piston.

As a method, in addition to oil jet from the upper end of the connecting rod, a method of cooling by a fixed jet provided in the cylinder block has recently become mainstream. In addition, in order to reduce the loss caused by the reciprocating movement of the piston, the number of piston rings have been reduced from the conventional combination of 3 to 4 compression rings and 1 to 2 oil rings to one compression ring and one oil ring, and this has been put to practical use in small engines. In high-speed engines, the recent trend is that many have two compression rings and one oil ring. Further, in order to keep the amount of lubricating oil consumption low under this ring configuration, some have been designed to raise the surface pressure of the oil ring or to give the side of the piston a special shape, and those where gap is strictly managed in combining the piston and the liner. Other measures have also been taken such as reduction of lubricating oil consumption, special processing for high speed and high output, special treatment, etc.

Since the top surface of the piston is exposed to high pressure of around 100 kg./㎠ and high heat of about 2,000℃, in order to withstand high pressure and high inertia mass as well as to reduce inertial mass, pistons made of a special aluminum alloy which is light and has good thermal conductivity are generally used. A ring carrier is cast in the top ring groove to prevent wear of the ring groove. To improve the initial fitting, some have tin plating or graphite coating on the surface. Recently, thin cast iron pistons (One-piece ductile cast iron piston) are also in practical use.

5) Piston ring

The compression ring has two roles: pressure tight action and heat transfer action. First of all, it has the function of maintaining airtightness so that the piston generates red hot air capable of combusting fuel near the top dead center of the compression process, preventing the next explosive combustion gas pressure escaping, and ensuring that most of the combustion heat received at the top of the piston is transferred to the cylinder liner wall via the piston ring, and further, having the cooling water absorb it.

The role of the oil ring is to scrape off the lubricating oil scattered on the inner surface of the cylinder liner during the reciprocating motion of the piston to prevent excessive lubricating oil from entering the combustion chamber.

Special cast iron excellent in wear resistance is used in piston rings. In addition, in order to prevent wear, there are piston rings where the sliding surface of the ring is plated with hard chrome, and to reduce wear of the ring grooves, the sliding surface and the top and bottom surfaces of the ring are also chrome plated (also known as three-surface chrome plated ring). And recently, many rings which are soft plated on the sliding surface to improve the initial fitting are used, and high-speed engines which adopt steel piston rings are increasing.

The shape of the fitting part of the piston ring also varies, and each engine manufacturer uses its own combination according to the specifications of the engine.

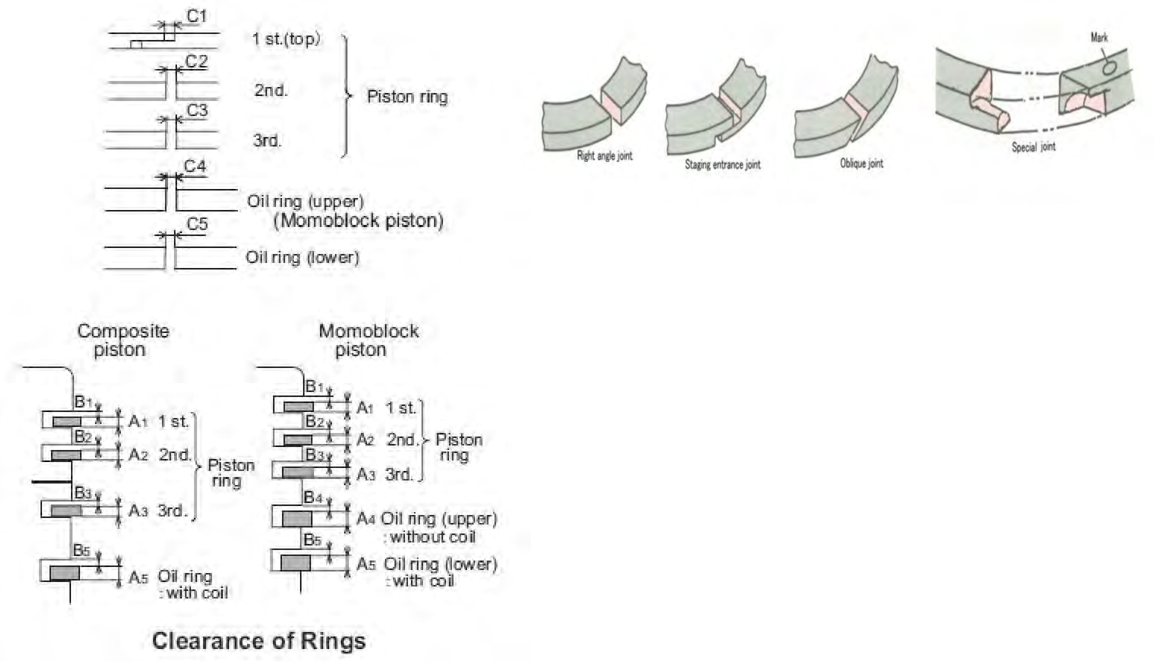


Figure 12. Piston rings types and clearances

Recently there are many high-speed engines which use an expansion ring containing a coil spring and one oil ring to reduce the friction loss with the liner.

6) Piston pin

The piston pin transfers the pressure of the combustion gas received at the top surface of the piston to the crankshaft through the connecting rod. For this reason, since bending and high bearing pressure act on the piston pin, a very tough material which can increase the surface hardness must be used to increase its rigidity. In general, it is used after being tempered or a special steel which has been tempered is used. The mounting on the piston adopts a floating type, that is, a method in which the piston pin is not fixed to the piston or to the connecting rod, and can freely rotate during operation. There is no bearing metal in the pin hole of the piston and the bearing metal is generally used only at the small end of the connecting rod. Circlips or snap rings are used at both ends of the piston pin so that the piston pin does not slip out of the piston hole. Also, in large engines, there are some which use piston pin lids, etc. to prevent the piston pin from slipping out.

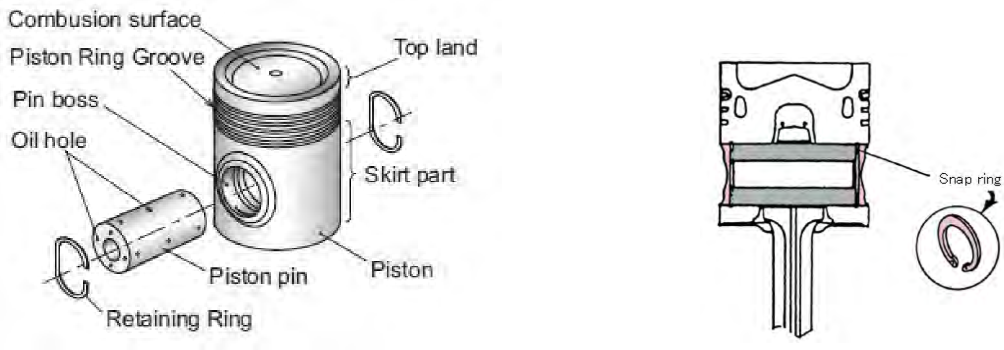


Figure 13.　Piston parts

7) Flywheel

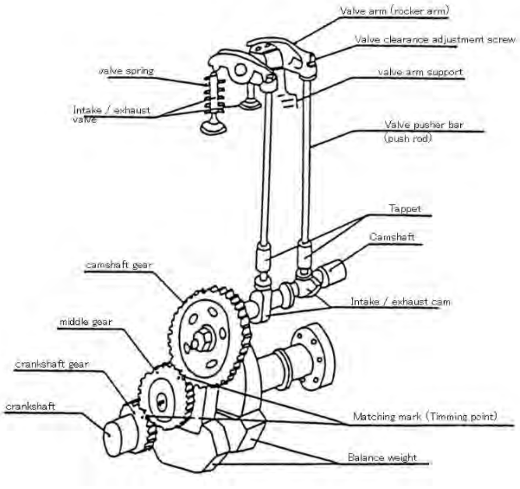
The four-cycle diesel engine performs four steps of intake, compression, expansion, and exhaust while the crankshaft rotates twice. That is, two rotation cycle of the flywheel completes one cycle. Among these four steps, only the expansion stroke gives rotational energy to the engine. In the other three steps, since the rotational force of the crankshaft has to be applied to the other moving parts, the rotational forces of the crankshaft are not the same, and the rotational torque varies from moment to moment. Therefore, attaching the flywheel to the end of the crankshaft, absorbing the extra energy of the combustion stroke in the flywheel, and in other processes, has the important function of making the crankshaft rotate smoothly by causing the energy of the rotational coast to be discharged there. Flywheels are generally made of cast iron and are wheel shaped with a cross section of the peripheral rim.

Figure 14.　Flywheel location

1-3 Valve train

An intake / exhaust valve, a valve bridge (4 valve type) valve arm (rocker arm), a valve push rod A push rod), a tappet, a cam shaft, a cam gear, an intermediate gear, a crank gear, a crankshaft and the like.

Figure 15. Valve train components



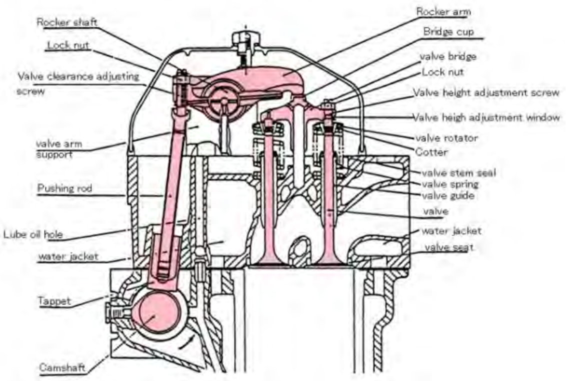


Figure 16. Valve system

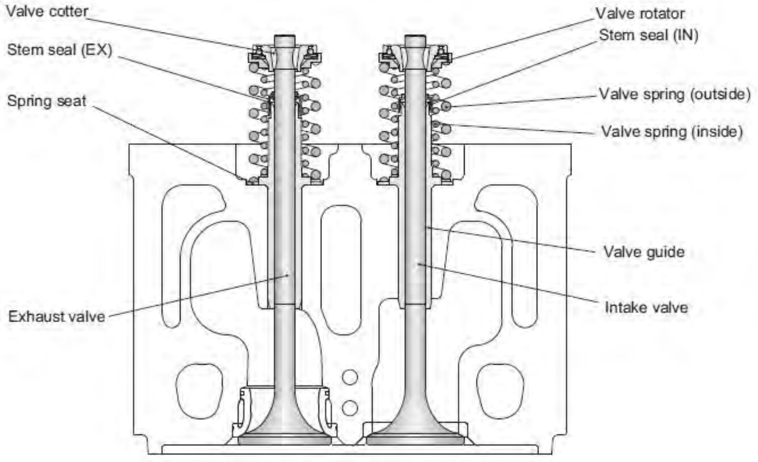
1) Intake / exhaust valve

The valve is opened and closed by a valve mechanism, inhales air and discharges combustion gas. It also has a function to keep airtightness inside the cylinder. The shape of the intake valve used in a general 4-cycle engine is related to the shape of the intake port, and it is desirable that the intake resistance is small. Also, since the valve of the exhaust valve material has a high temperature of about 600 ° C. to 800 ° C., a material having good heat conduction and excellent durability against high temperature is desired. In general, mushroom valves (poppet valves) are widely used, but mushroom valves are given various names depending on the shape of the umbrella section. The mushroom type is a standard type of SAE, considering the strength of the center part, the head part is a spherical surface. Valves of this type are mainly used for low-speed diesel engines, but the disadvantage is that the weight and the heat receiving area are increased. Flat head type valves are also widely used because they are easy to manufacture except for the disadvantages of the mushroom type. Unlike intake valves, exhaust valves are constantly exposed to high temperature exhaust gases, and therefore high temperature strength is particularly required.

In general, the number of valves is two valve type each having one intake valve and one exhaust valve, but especially when high speed performance and high output are desired, three valve type or four valve type is adopted for increasing the filling efficiency. In the case of the four-valve type, the total opening area of the valve increases by 30 to 40% as compared with the two valve type, but the total weight of the valve increases by 10 to 15%, and the valve device becomes complicated.

Since the combustion gas temperature momentarily reaches 2,700 ° C. and this temperature is much higher than the melting temperature of steel (1,500 ° C.), heat-resisting steel such as chromium steel, austenitic steel and the like with less decrease in strength at high temperature used. Heat-resistant steel is difficult to be molded even when heated, so after forming by die stamping forging, extrusion processing, etc., the valve seat surface, valve stem portion, stem end and the like are lapped and the strength decreases for the portion subjected to the impact load It is careful not to do.

In recent years, in order to increase the wear resistance of the valve seat, the valve seat and the stem end, as shown in the figure below, many stents with high hardness welded are also adopted.



Intake Exhaust Valves

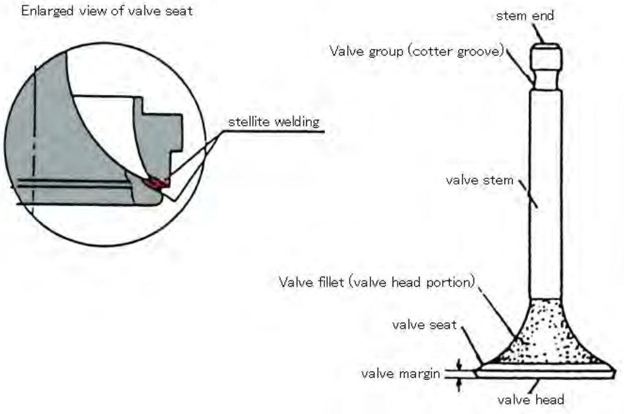


Figure 17. Intake & Exhaust valve components and parts

2) Valve guide

The valve guide serves to position so that the seating position of the intake and exhaust valve seat does not change and also to release heat from the valve.

If the gap between the valve stem and the valve guide is too large, the seating position cannot be fixed, and the valve seat will be incompletely attached. In the case of the exhaust valve, if the gap is too wide, the combustion gas leaks through this gap, heat transfer to the valve guide gets worse, and the valve overheats. In the case of the intake valve, the lubricating oil is sucked into the intake air from the gap, resulting in an obstacle such as an increase in consumption. To prevent this, a valve stem seal as shown in the figure below is attached.

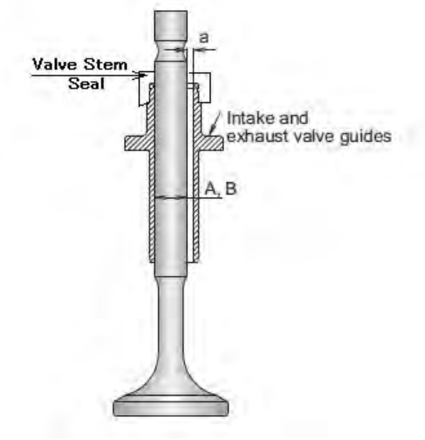


Figure 18. Valve stem

Generally, the amount of leakage through the gap is proportional to the cube of the gap and inversely proportional to the length, so the effect of wear and the like on the increase of the leak amount becomes very large. On the contrary, when the gap is small, although cooling is good, there is a danger of baking due to thermal deformation, and a proper gap must be maintained at all times. Recently, some of the valve guide inner surfaces are threaded to improve wear resistance and valve seizure.

In small, low-speed engines, the valve guide may be made directly as a cylinder head, but in general considering the exchange at the time of wear, a valve guide such as a gray cast iron is pressed into the head.

3) Valve arm (rocker arm)

The figure below shows the structure of the valve arm. Intermittent lubrication from the oil hole drilled on the upper surface of the valve arm of the lubricant on the valve side is transmitted through the arm and reaches the valve stem. On the valve push rod side, lubricating oil is supplied to the hole on the lower side of the valve arm or the center of the valve gap adjusting screw from the valve arm shaft, and lubricates both ends of the valve push rod.

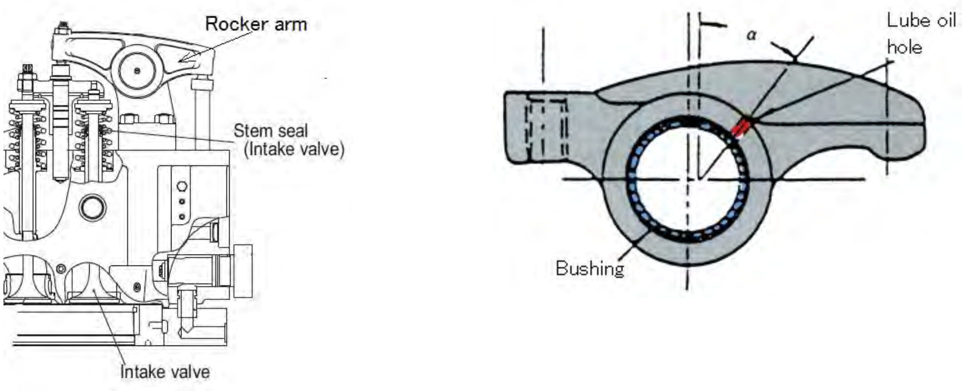


Figure 19. Valve arm

Since the bending moment acts on the valve arm, it is necessary to have sufficient mechanical strength and rigidity and be lightweight. The contact part with the valve stem or the valve stem end (valve stem end) is a point, a line or a face, slip occurs except when both are in contact at a right angle, so the contact part is hardened by hardening or chill hardening, the hardness is enhanced.

4) Valve spring

The valve spring brings the valve and the valve seat into close contact with each other, gives a sealing pressure higher than the pressure inside the cylinder by compression and combustion to the contact surface of the valve seat, and at the same time, Transfer, so that the tappet does not separate from the cam surface via the valve arm and the valve stem.

When the spring force is insufficient, the movement of the valve does not operate according to the lift of the cam, and the opening / closing timing of the valve is deviated, which causes a reduction in engine output. Also, the tappet may collide with the cam surface suddenly to generate striking sound. Conversely, if the valve spring force is too strong, wear and damage of the valve seat and valve seat surfaces will be accelerated so that consideration is given to the design of the valve spring. As the valve spring, a coil spring wound with a steel wire of a circular cross section is used, and one or several valve springs are attached to one valve.

Recent high-speed engines are equipped with multiple springs to prevent abnormal phenomena such as valve drag and surging during high-speed rotation, to improve the durability of the valve system and to reduce noise, and uneven pitch Spring is used.

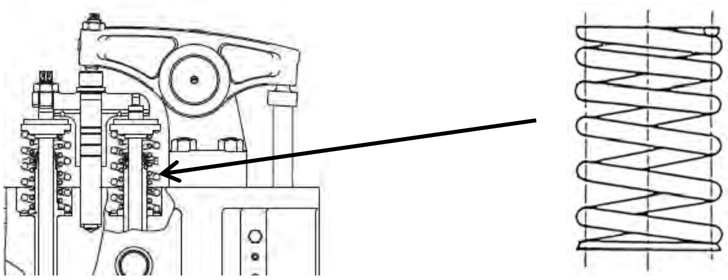


Figure 20. Valve spring

Piano wire oil tempered wire and the like are usually used as the material of the valve spring. Piano wire is made from cold work hardened material, but oil tempered wire is subjected to heat treatment after molding and used.

5) Valve rotator

A valve rotator is used so that the valve can be rotated during operation, in order to evenly hit the contact of the seat surface of the valve and the valve seat over the entire circumference and reduce uneven wear of the seat surface. An example of the structure is shown in the figure below.

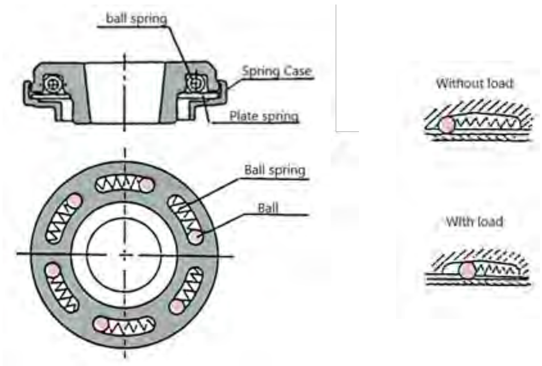


Figure 21. Valve rotator

6) Valve push rod (push rod)

It acts to smoothly transfer the up and down (reciprocating) movement of the tappet to the valve arm. An inertial force and a spring load act on the valve push rod. Since the load increases at the time of high-speed rotation, sufficient strength against compressive load is required, at the same time it is necessary to increase the rigidity and reduce the deformation amount. When the amount of deformation is large, the valve opening / closing timing varies depending on the number of revolutions, the intake / exhaust efficiency at the time of high-speed decreases, the valve dents are generated, the suction efficiency decreases, noise and other troubles occur.

In addition, it is desirable to reduce the weight in order to reduce the inertia force, and to use a material with less thermal expansion against overheating and overcooling of the engine. Therefore, the shape is a hollow structure having a large diameter and a shortened length. Also, in order to reduce the change in the valve gap due to thermal expansion at the time of engine operation, the amount of increase in length due to thermal expansion of the cylinder block, the cylinder head, and the valve arm bearing portion and the length of the valve push rod and the valve due to the thermal expansion of the valve Materials and lengths are taken into account so as not to cause large differences in the amount of increase.

Although the shape is a hollow round bar as described above, spherical surfaces are often used for both end shapes as shown in the figure below. There are two types of spherical form: convex spherical or concave spherical on the valve arm side, the latter being widely used for providing valve clearance adjustment screws on valve arms and lubricating oil supplying.

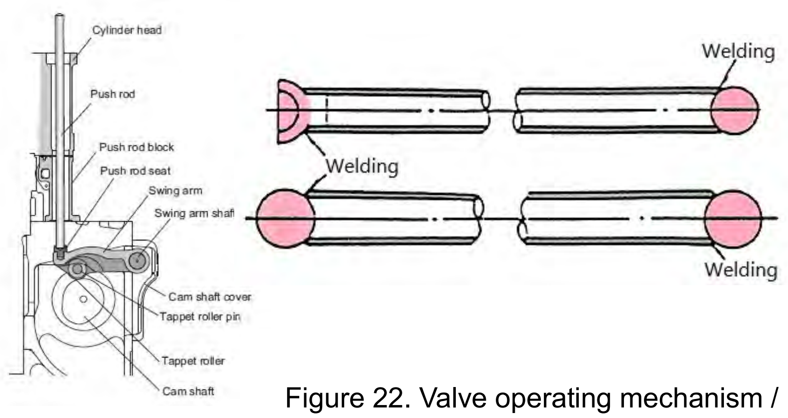
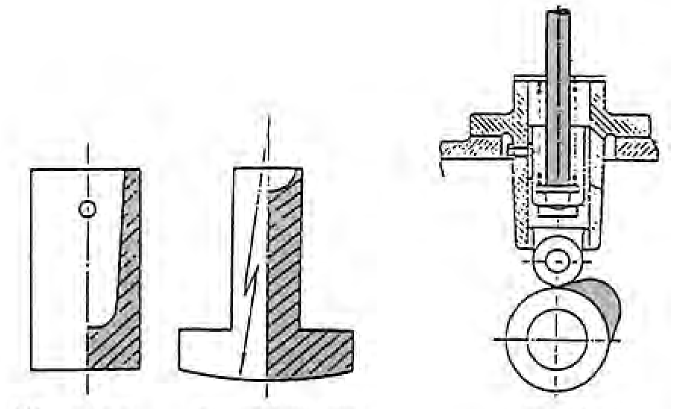


Figure 22. Valve operating mechanism / pushing rod types

7) Tappet

The end face always moves reciprocally up and down while contacting the intake / exhaust cam and moves the valve arm via the valve push rod.

As shown in the figure below, the shape of the tappet is a piston type, a mushroom type, and a roller type. Generally, there are many pistons type, but both mushroom type and roller type are used. The contact surface of the tappet with the cam other than the roller type is machined into a flat surface or a spherical surface.



(a)Piston type (b)Mashroom type (c)Roller type

Figure 23. Types of tappets

8) Camshaft and cam

The motion of the cam is transmitted to the valve in the order of the tappet, the valve push rod, the valve arm, and gives the necessary lift to the valve. During operation of the engine, the cam and cam follower contact surfaces are subject to impact loading due to the valve gap. Generally, the diameter of the tappet in the small engine is made larger than the cam width, and as shown in the figure, the tappet center line is offset from the cam width center, and the mounting tappet is rotated simultaneously with upward and downward motions and even contact with the entire contact surface So that it will occur.

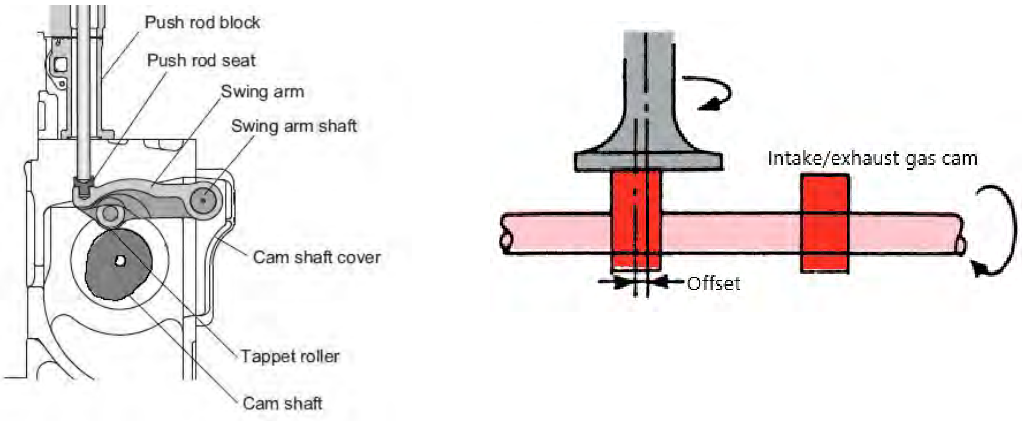
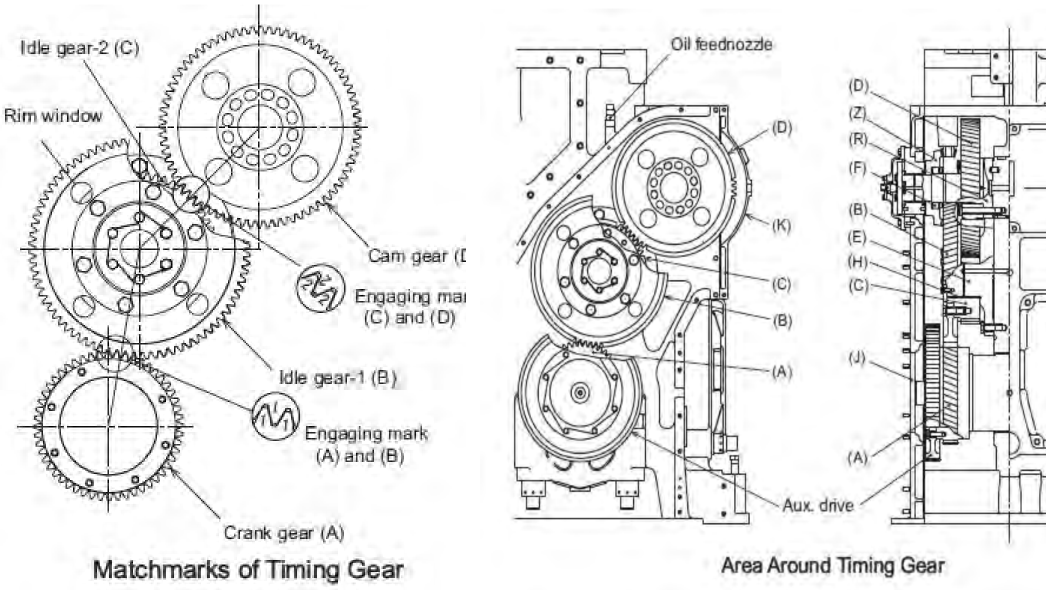


Figure 24. Camshaft and Cam

There is a system in which an intake and exhaust cam and a cam for a fuel injection pump are integrally structured as a camshaft, a suction and exhaust cam and a cam for a fuel injection pump are separately structured and keyed to a cam shaft, but in a small engine, Is commonly used as a method. Since most in-line type fuel injection pumps are used in recent high-speed engines, the intake / exhaust camshaft and the camshaft for fuel injection pump are often separate. The force applied to the camshaft is maximized when the exhaust valve opens. This is because the pressure in the cylinder at the time of exhaust valve opening, the valve spring force and the inertia force of the moving part are added. Therefore, exhaust cams are generally arranged close to the bearings. Generally, the number of cam bearings provided in the cylinder block is equal to the number of main bearings or every other one.

9) Timing gear train (gear train)

In the case of a 4-cycle engine, the camshaft is rotated from the crankshaft by the crank gear at a speed as fast as half the engine rotation, the valve arm is moved via the tappet and the valve push rod, and at the specified time, the intake and exhaust valves And to inject fuel, and the figure below shows an example of transmission by gears. The rotation of the crankshaft is transmitted to the idle gear, the camshaft gear and the fuel injection pump drive gear. The camshaft gear and the injection pump drive gear are twice the number of teeth of the crankshaft gear. The engagement marks are engraved on each gear, and by matching them, the valve opening and closing timing and the injection timing are matched.



Matchmarks of Timing Gear

Area Around Timing Gear

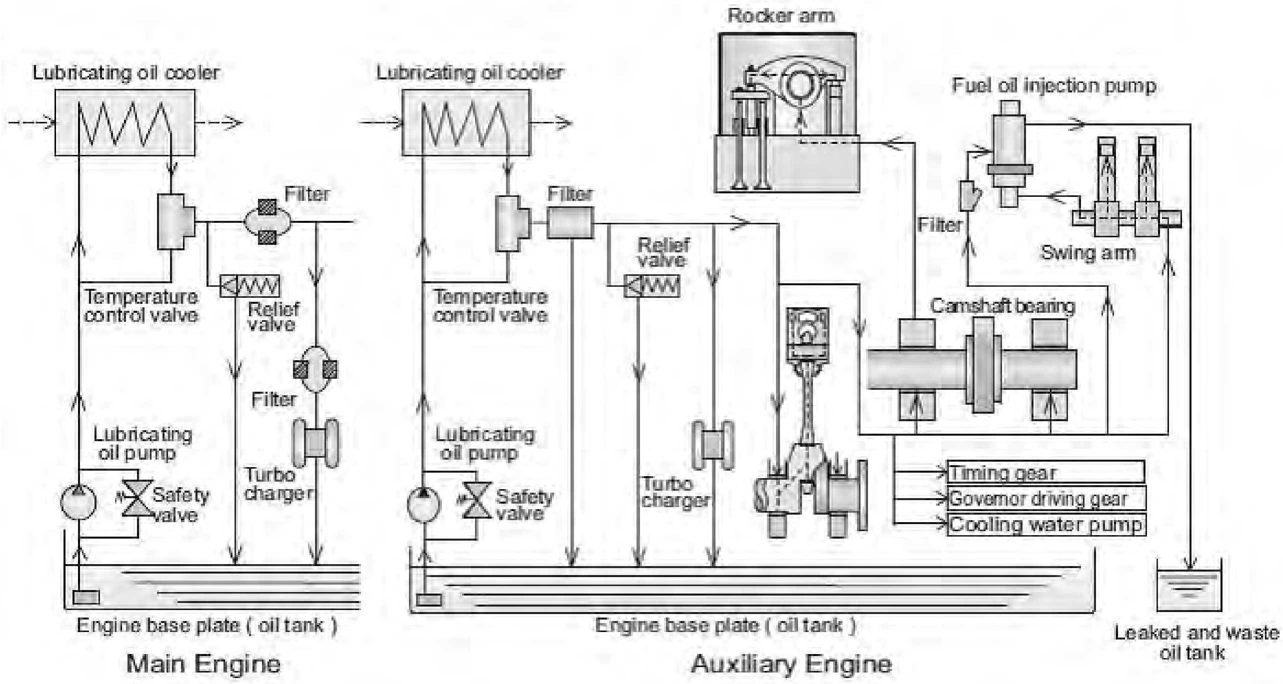
Figure 25. Timing gear train

1-4 Lubrication equipment

A lubricating oil pump is used for supplying lubricating oil to each moving part, and as related equipment, it is composed of a lubricating oil cushioning device, a hydraulic pressure regulating valve, a hydraulic pressure gauge, an oil cooler and the like.

1) Lubricating oil system

The lubricating oil system ranges from extremely simple to lubricating only the main bearing part to those that jet cooling a turbocharger or piston, which varies from manufacturer to model. An example is shown in the figure below.



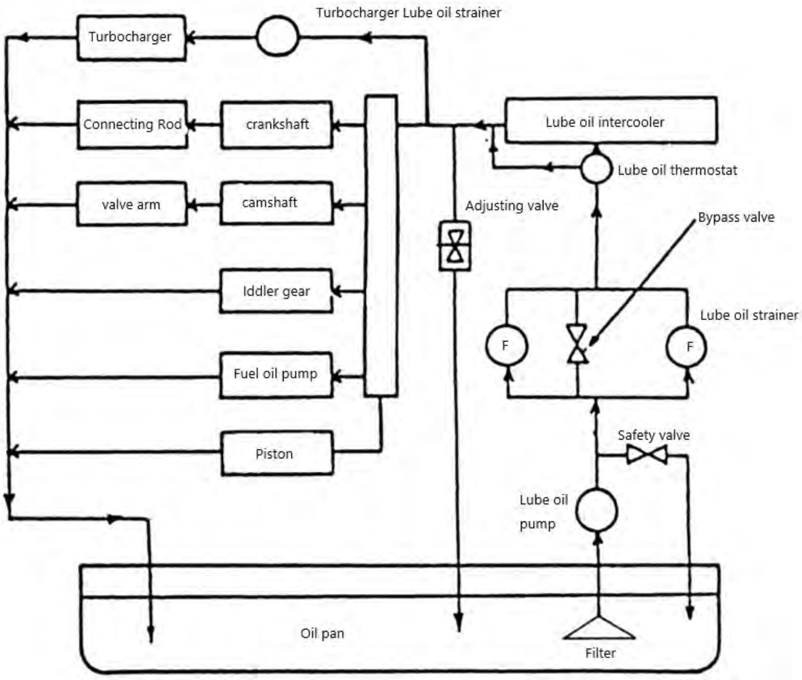


Figure 26. Lubricating oil system

The lubricating oil pump uses a gear type, through the entrance arms through the entrance pole piece, sucks up the engine oil, forcibly lubricates the main metal, valve arms, and other parts. A hydraulic switch is provided in the middle of the route to monitor the lubricating oil.

2) Lubricating oil pump

Generally, a gear pump is used as a lubricating oil pump, but in some small engines, a trochoid pump is used.

(1) Construction and function

(A) Gear pump

As shown in the figure, by rotating the two gears, the lubricating oil is sucked from the part A and the lubricating oil is pressure fed by the rotation of the gear.

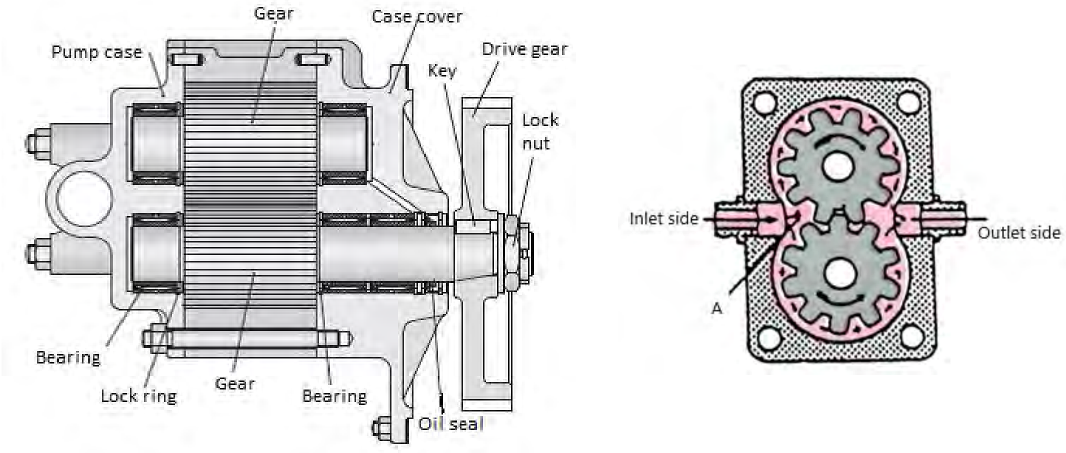


Figure 27. Gear pump

(B) Trochoid pump

As shown in the figure, by rotating the two rotors having different numbers of teeth using the trochoid curve in the same direction, the part A is brought into a vacuum state, the lubricating oil is sucked in, and the lubricating oil is pushed to the discharge side

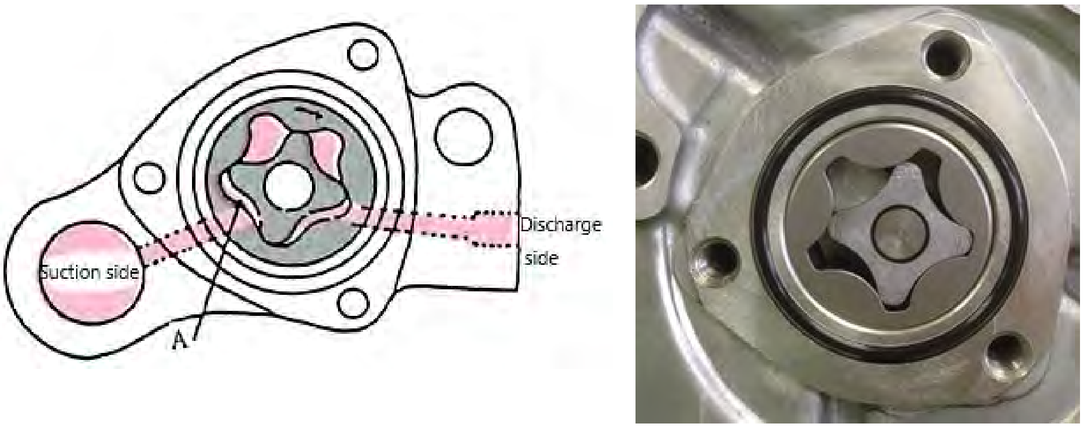


Figure 28. Trochoid pump

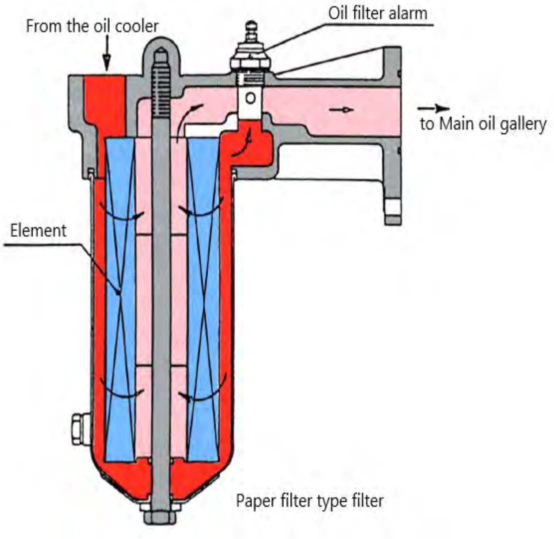
(https://www.hai-sya.com/column/mechanical_univ010.html)

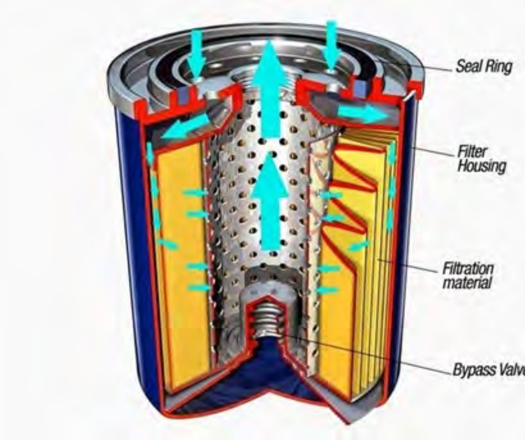
3) Lubricating oil filter

Lubricating oil absorbs dust when lubricating the interior of the engine, and dust enters during storage or lubrication. It is the filter that removes this dust and serves to clean the oil.

In high-speed engines, cartridge type and filter paper type are used. In the medium and low speed engines, the goose wire type and the notch wire type are often used.

The structure of the filter is as shown below and is an important part to remove impurities in the engine oil and to prevent wear of each sliding surface, but if it is also handled wrongly it will not play its role at all





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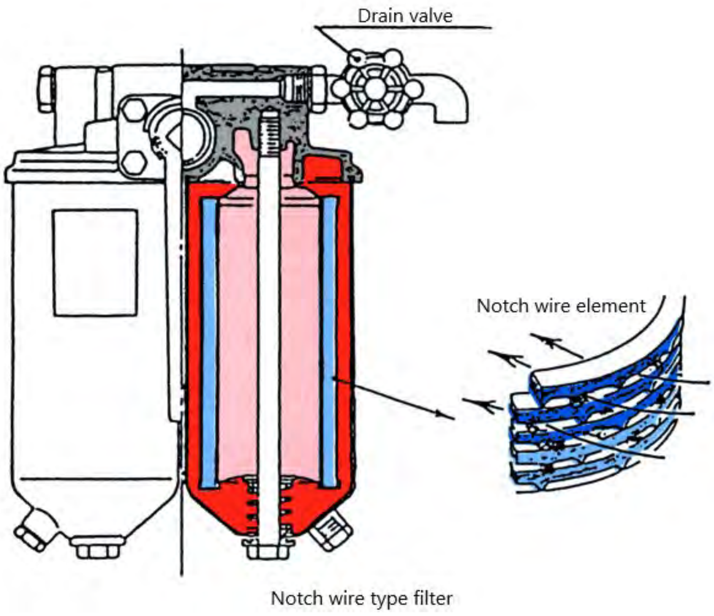
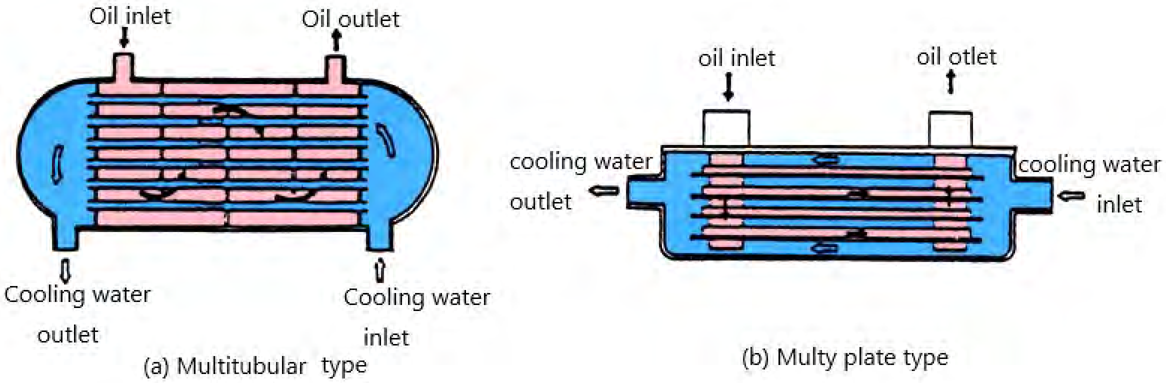


Figure 29. Lubricating oil filter types

4) Lubricating oil cooler (oil cooler)

The lubricating oil is also circulated in the high temperature portion of the engine to lubricate and to take away the heat generated by the combustion of the fuel and to cool the piston liner and the like. Therefore, in a high-speed and high-power engine, in order to prevent the temperature of the oil from rising above a specified level, a lubricating oil cooler is provided except for some engines. This lubricating oil cooler is of water cooling type (multitubular type [tube type], multiple plate type [plate type]) and air cooling type, but mainly for water cooling type is used for land An example is shown in the figure below.



(a) Multitubular type

(b) Multy plate type

Figure 30. Types of Lubricating oil cooler

Picture 1. Tubular type oil cooler

5) Hydraulic pressure control valve

A hydraulic pressure regulating valve has a function of adjusting the pressure to an appropriate pressure so that the oil delivered from the lubricating oil pump sufficiently strikes the parts of the engine. A simple one is an oil signal type, and the precise one is a real adjustment valve with a valve and a spring.

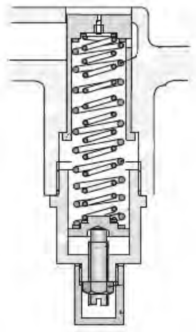


Figure 31. Lubricating oil relief valve

1-5 Cooling system

If the engine is not cooled, the cylinder and the piston etc. will expand due to the high heat generated in the combustion chamber, seizure will occur, and operation become impossible. Alternatively, lubrication to the cylinder will lose effect and it will be impossible to suck air into the cylinder sufficiently, or it will cause premature ignition. Cooling is necessary to prevent these failures and operate the engine smoothly.

As cooling methods, there are air cooling and water cooling, but in general, a water-cooling method is adopted.

The water-cooling device is composed of a cooling water pump, a freshwater cooler, a radiator, etc. Methods include a primary cooling type and a secondary (tertiary) cooling type.

(1) Primary cooling system

The cooling water passes through the lubricating oil cooler through the air oil cooler through the cooling water pump, enters from the lower portion of the cylinder, and cools the engine main body, the cylinder head, etc., and is discharged.

In some circumstances, the engine is overcooled and may cause low temperature corrosion wear, so some automatic temperature control valves are adopted to prevent this.

(2) Secondary cooling system

Primary coolant pump and secondary chilled water pump has been attached by primary water cooling of the engine is each have alternate routes, and secondary water heat exchanger via the cooler (radiator). Also, the lubricating oil performs heat exchange with primary water or secondary water with an oil cooler (lubricating oil cooler).

Adjustment of the primary water temperature is performed by adjusting the amount of fresh water flowing through the freshwater cooler with the automatic temperature control valve.

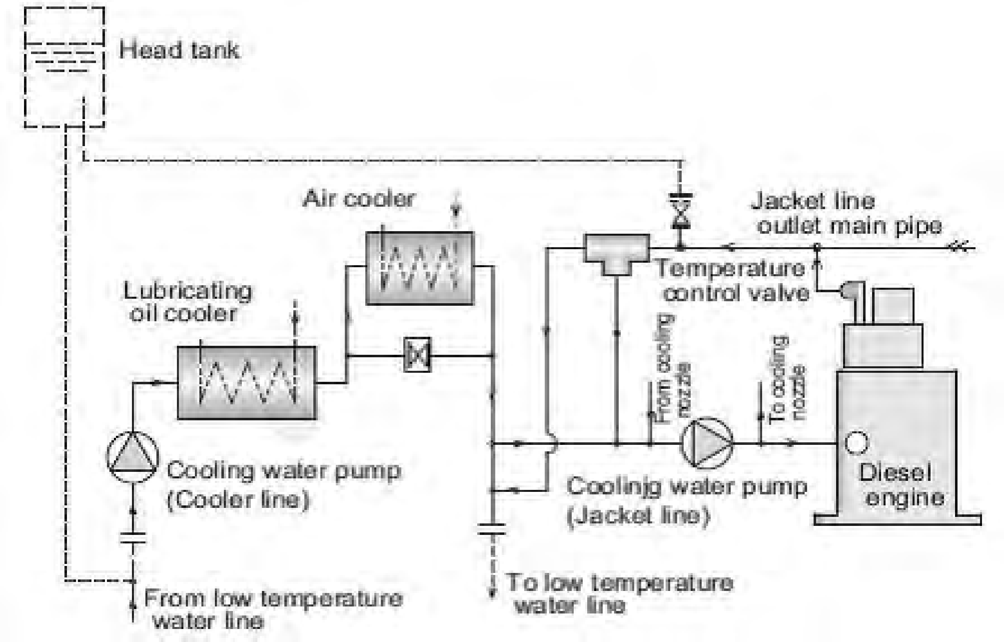


Figure 32. Cooling water system

1) Cooling water pump

As a cooling water pump, a plunger pump, a spiral pump, or a Yabusuko pump is used. The spiral type of pump is mainly used for a constant rotation engine, and the plunger type pump and the Yabusuko type rotary type pump are used for an engine whose rotation speed changes like a main marine vessel. Spiral type pumps include those driven by gears, those driven by belts, and those of self-priming type

Spiral pump

As shown in the figure below, the impeller (impeller) is rotated at high speed inside a metallic swirl chamber and water is discharged using centrifugal force.

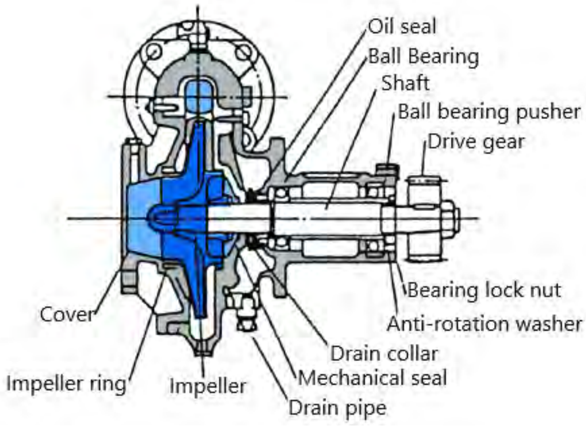
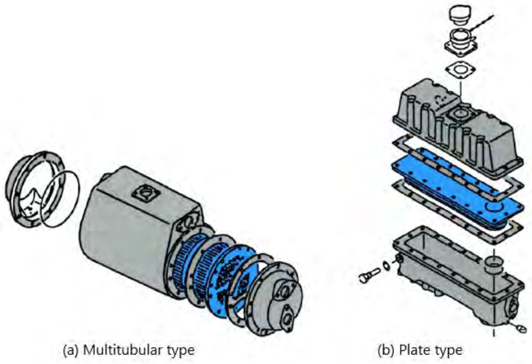


Figure 33. Cooling water pump

2) Clean water cooler

There is a multi-tubular type and plate type fresh water cooler, and in the multi-tubular type, the temperature of the primary water flowing outside the tube is lowered by passing the secondary water through the tube.


(a) Multitubular type

(b) Plate type

Figure 34. Types of freshwater cooler

1-6 Fuel devices

As shown in the figure, a fuel tank, an oil water separator, a fuel supply pump, a fuel squeezer (filter) is used to feed fuel into a combustion chamber having a high temperature and high pressure in the compression stroke of the piston in a fine mist form so as to facilitate burning of the fuel. A fuel injection pump, a fuel high-pressure pipe and a fuel injection valve are included in the fuel system.

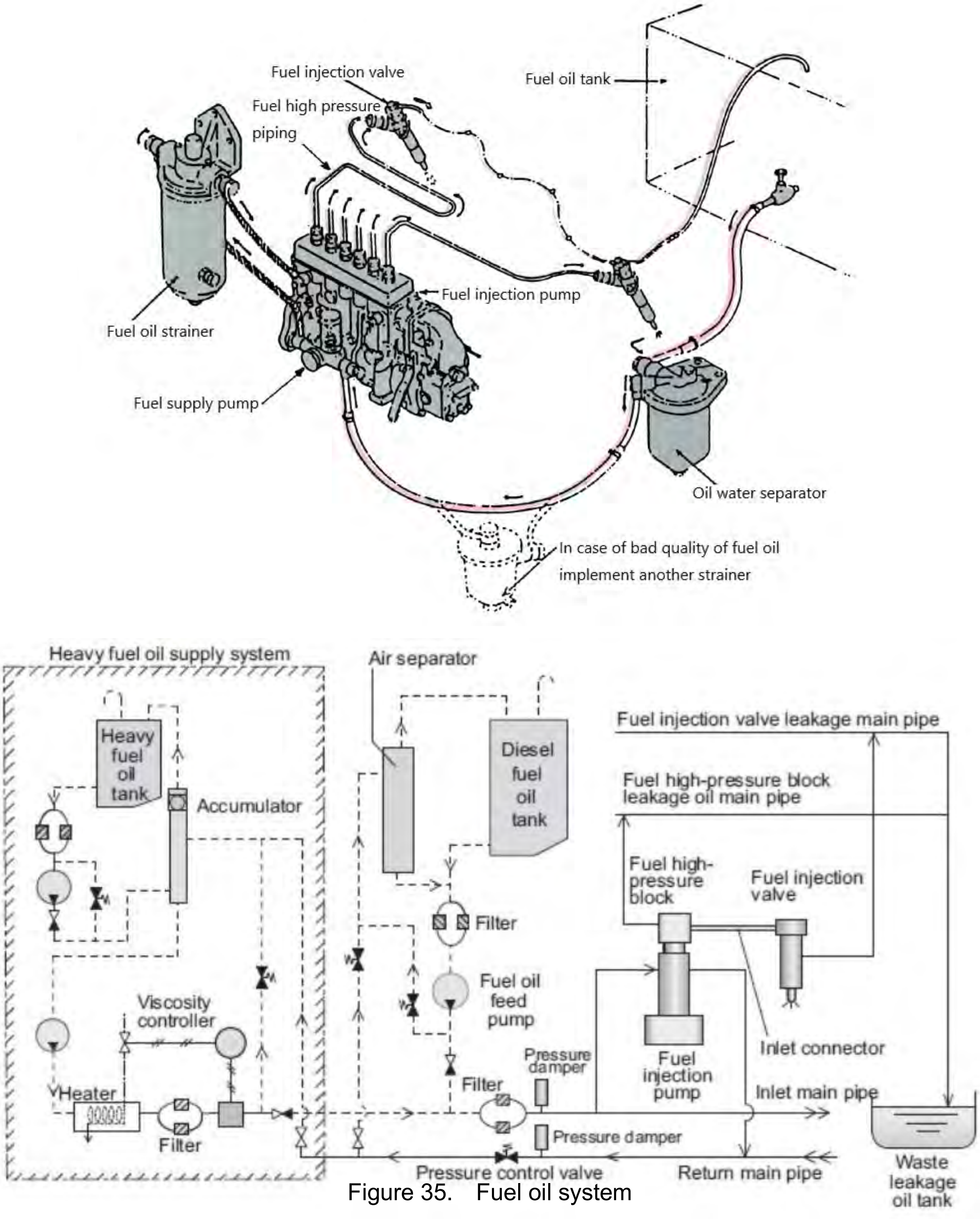
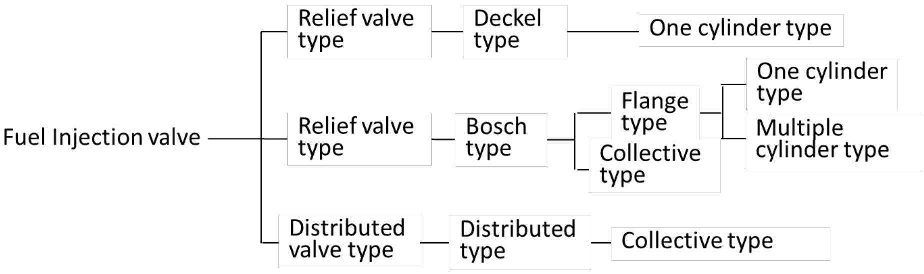


Figure 35. Fuel oil system

1) Fuel Injection pump

The fuel injection pump is sensitive to the rotational speed and load of the engine and has a function of feeding an appropriate amount of fuel into the cylinder at an appropriate time. Therefore, it is necessary to appropriately adjust the amount of fuel, select the injection timing and pressurize.

The types of fuel injection pumps are classified as follows.



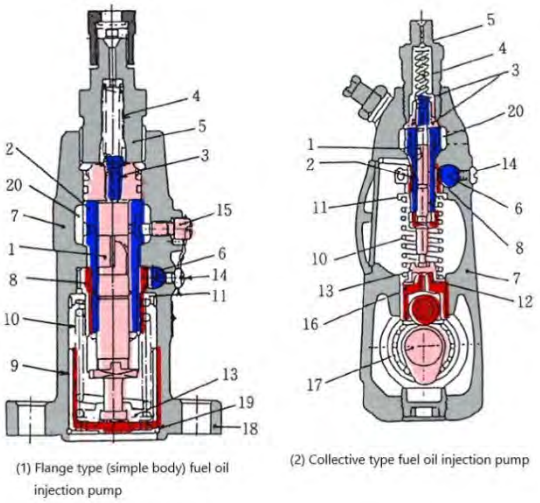
The Bosch type fuel injection pump which is frequently used for the generator engine is a flange type attached by a flange on the cam shaft of the engine main body and an injection pump of all the cylinders are united and assembled together with a dedicated cam and those of aggregate type (inline pump).

(Construction)

The Bosch type pump consists of a pump main body, a plunger, a plunger barrel, a discharge valve, a fuel control ring, and the barrel is provided with suction holes and escape holes.

On the side of the plunger, longitudinal grooves are cut in the axial direction and grooves obliquely cut away in the lower part, so that the lower obliquely cut groove and the cylinder part of the head communicate with each other by the longitudinal grooves.

The lowermost part of the plunger has an inverted T shape and is fitted into the groove of the cylinder of the reduction wheel and the plunger is rotated by the rotation of the reduction wheel. The cross section of the pump and the name of each part are shown in the table below.

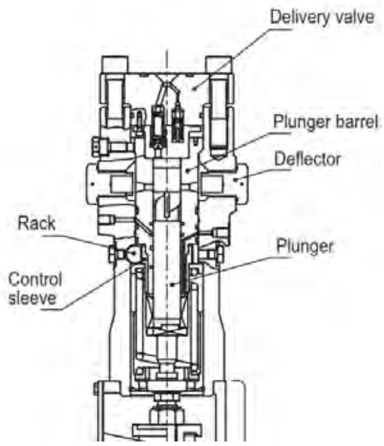


(1) Flange type (simple body) fuel oil injection pump

(2) Collective type fuel oil injection pump

Part Name	№	Part Name
Plunger	11	Spring upper hanger
Plunger barrel	12	Plunger position adjustment shim
Delivery valve	13	Spring bottom hangers
Delivery valve spring	14	Rack guide screw
Delivery holder	15	Deflector
Control rack	16	Tappet
Pump	17	Camshaft
Control sleeve	18	Mounting flange
Plunger guide	19	Snap ring
Plunger spring	20	Oil reservoir

Figure 36. Types of fuel injection valves



The plunger barrel is completely retained by the shoulder of the pump body and cannot move but the plunger moves up and down and the inverted T-shaped collar portion at the lowermost part of the plunger is fitted into the groove of the control sleeve and the control rack, So that the plunger rotates via the control sleeve. On the upper part of the plunger there is a delivery valve, which is held by the delivery valve holder, and the fuel oil pressure-fed by the plunger is conveyed to the fuel valve through the high-pressure pipe.

(Operation)

The bottom figure shows the main operating part of the Bosch type fuel injection pump, the plunger is pushed up by the cam via the tappet and the plunger guide, and constant motion pushed back by the plunger and spring is repeatedly performed.

1) Fuel oil is filled in the oil reservoir chamber formed by the pump body and the outer periphery of the barrel. In the descending stroke of the plunger, it is sucked through the suction and discharge hole of the barrel and fills the plunger chamber.

2) When the upper side of the plunger blocks the suction and discharge hole of the barrel (referred to as static injection start), the oil reservoir chamber and the plunger chamber are shut off, and the pressure of the fuel oil rises as the plunger rises. (A)

3) Furthermore, the plunger rises, and the compressed fuel oil lifts up the delivery valve and is pumped to the fuel injection valve.

4) At the moment when the lower lead of the plunger looks into the intake / discharge oil hole, the high-pressure fuel oil passes through the intake / discharge oil hole from the longitudinal groove of the plunger and is rapidly returned to the oil reservoir chamber and the injection is terminated. (B)

5) From the start of injection to the end of injection, the period during which fuel oil is actually pumped is referred to as effective stroke.

6) By making the longitudinal groove of the plunger and the intake / discharge oil hole coincide, no injection occurs. (C)

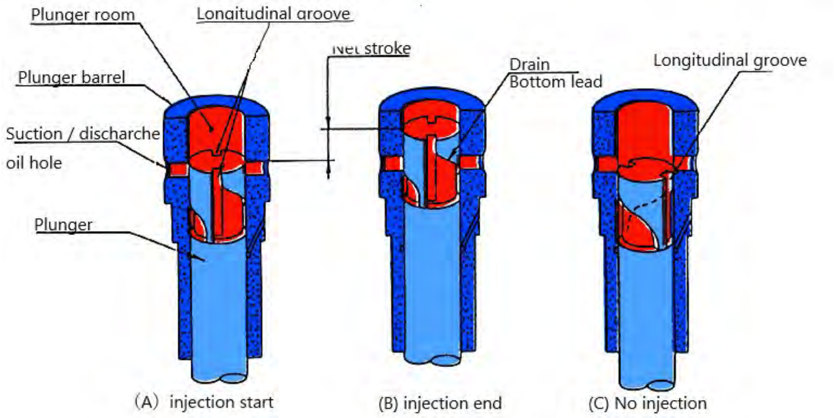


Figure 37. Plunger movement

(Adjustment of injection volume)

The lower figure shows the injection amount increasing / decreasing mechanism, the control sleeve turns according to the movement of the control rack as explained in the structure, and likewise the plunger can be rotated to change the effective stroke and the injection amount can be adjusted, the following can be said.

When the effective stroke is long, the injection volume is large.

When the effective stroke is slightly short, the injection volume is small.

When the effective stroke is at its shortest, the injection volume is at its smallest.

When there is no effective stroke, no injection occurs.

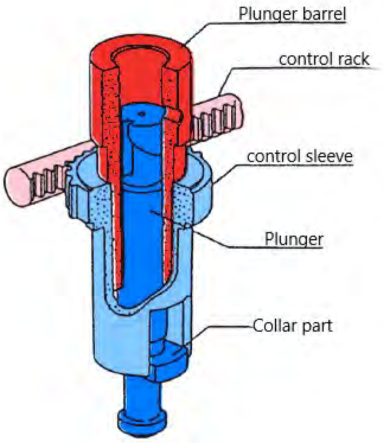


Figure 38. Fuel adjustment components

(Relationship between the injection quantity and injection timing)

The plunger of the fuel injection pump has only the lower lead and the upper lead as shown in the figure below. With the upper lead, the injection timing can be changed according to the injection amount by the upper lead as follows.

When the injection amount is large, injection occurs earlier.

When the injection amount is small, injection occurs later.

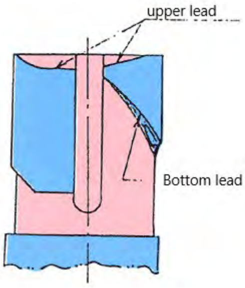


Figure 39. Plunger lead detail

In a large-sized engine, there is a variable timing type fuel pump which is applied for the purpose of controlling the explosion pressure by changing the injection timing, and which can adjust the timing by rotating the barrel from the outside.

(Adjusting mechanism of fuel injection amount)

The amount of fuel injection varies by turning the plunger, but since this operation is directly linked to the engine speed and load, it will eventually be manipulated by governor (governor device).

The figure below shows the state where it is connected with the speed governor (governor).

In the figure, if the governor lever is pulled with the regulator spring,

① when the rotation of the engine becomes faster, the governor weight opens to the outside by centrifugal force and pushes the control rack through the governor lever to the right direction of the arrow to rotate the control sleeve. When the plunger rotates to the right according to the rotation of the control sleeve, the upper and lower lead portions move to the smaller effective stroke, so the fuel injection amount decreases. Therefore, the rotation speed decreases.

② When the rotation of the engine is low, the governor weight is closed inward by the regulator spring and the governor lever moves to the left of the arrow. Since the plunger is rotated to the left, the upper and lower leads move to the larger effective stroke. As a result, the injection amount increases, and the rotation speed also increases. (Depending on the form, plunger cutout direction may be different, so the rack movement and the direction of increase / decrease of the fuel injection amount are reversed).

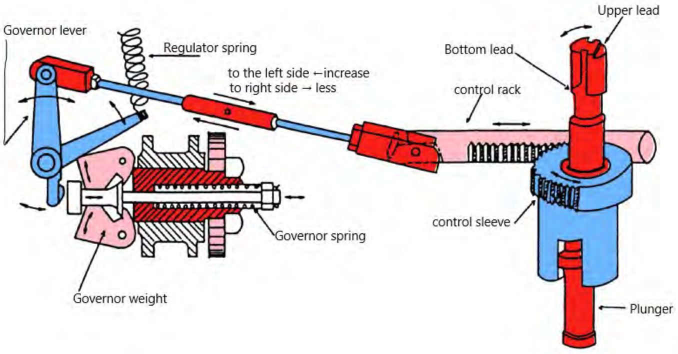


Figure 40. Fuel adjustment mechanism

2) Fuel injection valve

The principle of the diesel engine is to inject the fuel into the compressed hot air in the form of a fine mist and cause the ignition and burned hot gas to act on the piston and take out this power as a power source. There are air injection type and inhalation injection type as a method, and the present engine is almost inexhaustible injection type. Air injection is a method of injecting fuel and compressed air at the same time, and there is a feature that fuel can be miniaturized. The airless injection is a method of injecting only fuel, and its structure is simple as compared with air injection. The structure of the fuel valve is shown in the figure below.

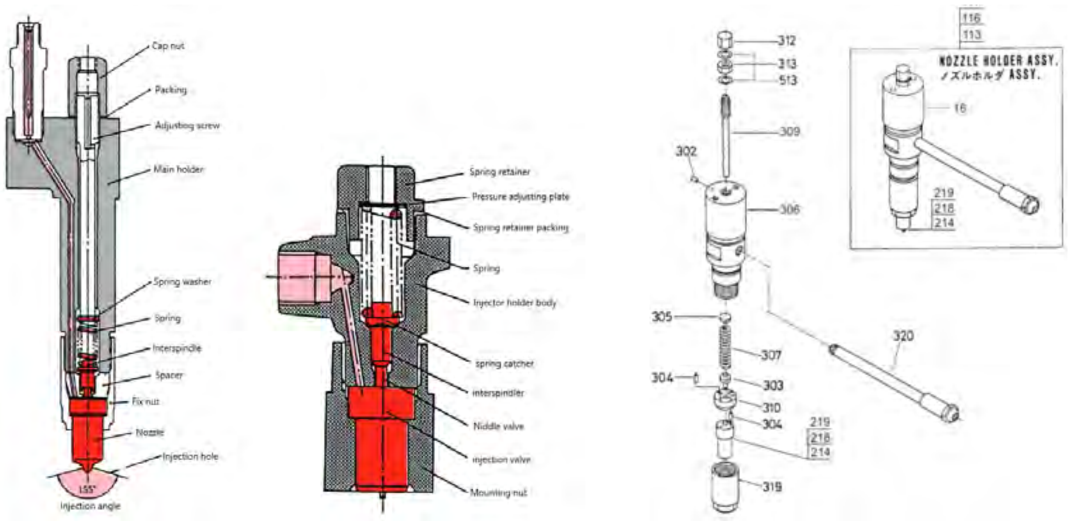


Figure 41. Fuel injection valve

In order to obtain good combustion at restricted places, various conditions are required, and whether the combustion is good or not depends greatly on the state of fuel injection, so the following four conditions are naturally required for fuel injection.

Each one of these is accompanied by various conditions, which is a complicated problem, but now we will briefly explain it.

① Atomization

The atomization is aimed at increasing the total heat receiving area of the fuel by making the fuel into a fine mist to improve ignition and combustion. For that reason, pressure is applied to the fuel, and it is injected from a fine nozzle hole. When the pressure is raised, it becomes a finer mist, and when the pressure is low, the atomization is bad, finally it becomes a rod shape, and it becomes difficult to burn. On the other hand, if the fog is too fine, it gets thinned by friction with dense air in the middle, finally becomes a gas body, all reach the fresh air and cannot come in contact with sufficient air, so burning is rather bad There are times when it can be.

② Penetrating force

The penetrating force aims to increase the rate at which the injected fuel particles penetrate through the dense air and sufficiently reach the fresh air and come into contact with each other, for which purpose fuel particles Size and mass are necessary. If the penetrating force is too strong, the fuel collides with the wall of the cylinder, incompletely burning, rather it generates carbon and has an adverse effect. The conditions of penetrating power and atomization are in an incompatible relationship.

③ Dispersion

Dispersion is aimed at increasing the rate at which the injected fuel is uniformly dispersed in each direction in the combustion chamber and in contact with fresh air. If some injection holes are blocked by the multiple injection hole valve, the dispersion is also bad Become.

④ Distribution

Distribution is aimed at the density of the injected fuel particles being uniform in the distance from the injection hole and various parts in the combustion chamber so that air can be more rationally utilized.

Considering only the injection pressure from the above complicated problem, it is not always possible to obtain good combustion by merely increasing the pressure, and the most appropriate injection pressure is specified from various experiments.

(2) Types of fuel injection valves

The fuel injection valve has a function corresponding to the engine in order to satisfy the injection condition as described above.

There are three kinds of injection valves used for diesel engines: pintle type, throttle type, and hole type.

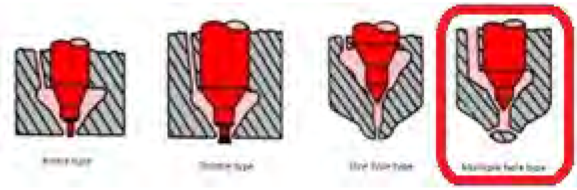


Figure 42.　Type of pintles

Pintle type and throttle type are used for sub-chamber type engines, and hole type porous type is used for direct injection type engines.

(3) Injection pressure

In order to satisfy the injection condition to be given to the injection valve, the injection pressure is determined by the type of the engine, the combustion method and the like, respectively, but the injection pressure of a general diesel engine is used in the range as shown in the following table.

Table 1. Injection pressure according to the nozzle type

Nozzle type	Combustion chamber	Injection pressure kgf/cm^2
Single-hole nozzle	Pre-combustion chamber type	120～160
Multi-hole nozzle	Direct injection type	200～350

3) High pressure fuel pipe

The fuel injection pipe is a fuel pressure oil pipeline leading to the fuel high pressure pumped by the injection pump to the injection valve, usually it is referred to as the injection pipe. In the case of direct injection type, the pressure inside the pipe of the high pressure pipe instantaneously ranges from 78.4 to 98 MPa (800 to 1,000 kgf/㎠), so thick walled high-pressure steel pipe is used and both ends are molded into the shape as shown in the figure below Has been done.

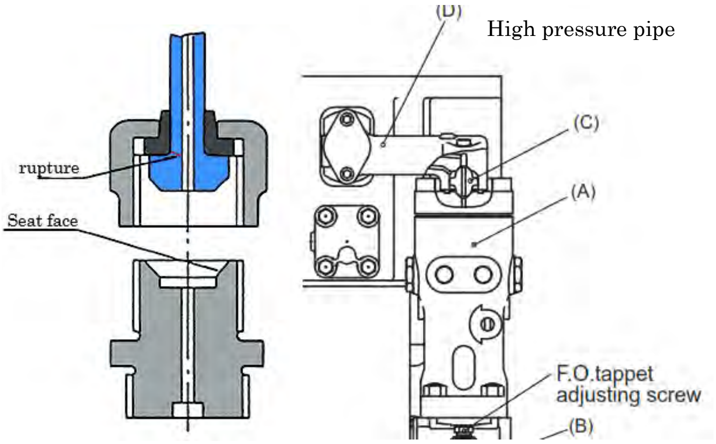


Figure 43. Pressure pipe connector

Since the length of the high-pressure pipe is related to the injection delay and the pressure wave in the pipe, each cylinder has the same length. Also, if the center is not fitted and forcibly inclined, screwing it in will cause a spray leak from the seat surface causing damage to the seat surface and cracks in the stepped portion of the neck so as not to forcefully attach both the cap nuts It is important to loosen the screws so that both ends can be mounted without difficulty and to tighten the screws.

Some high-tension pipes are provided with anti-shake stoppers to prevent vibrations, so do not necessarily install such a vibration prevention, if there is no steady rest, the high-pressure pipe may crack due to vibration.

The interior of the high-pressure pipe may corrode or collapse due to pitching or cavitation, it is not possible to distinguish by appearance, so it is preferable to prepare it as a spare item.

4) Fuel feed pump

Most of the fuel feed pump is provided in the engine except for some small engines, and it is also called a feed pump for reliably supplying fuel. In general, the most widely used feed pump is a Bosch type fuel feed pump, and in addition to it, there are trochoid type and vane type pumps used for medium and large size engines. Diaphragm type etc. are also used in small form.

(1) Bosch type fuel feed pump

Although this pump is singly used, most of it is built in the injection pump and has the structure and operation shown in the figure below.

Failure of the pump of this formula is mainly due to leakage from the sealed part such as the O ring and leakage due to malfunction of suction valve, discharge valve, etc., malfunction of the discharge valve and roughness of the sheet, etc. In addition to fuel leakage If there is a shortage and malfunctioning at overload, danger such as stopping will be accompanied, so periodic checking is necessary.

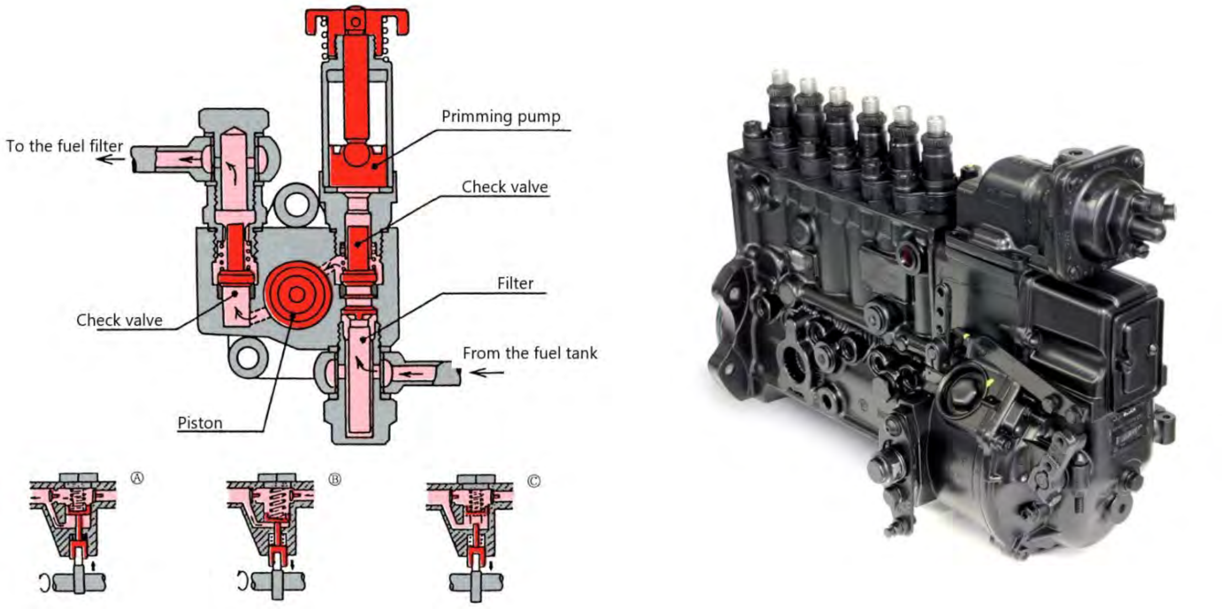


Figure 456. Fuel feed pump

(2) Other fuel feed pumps

In the case of a large engine, the oil delivery amount also increases, so there are cases where a fuel feed pump is separately provided. As a representative example, a trochoid pump shown in the figure below is used. Failure of this type of pump is caused by a decrease in discharge capacity due to wear, a leakage from the relief valve and the seat, a valve spring failure, and the like.

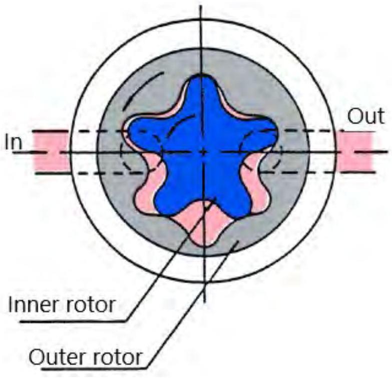


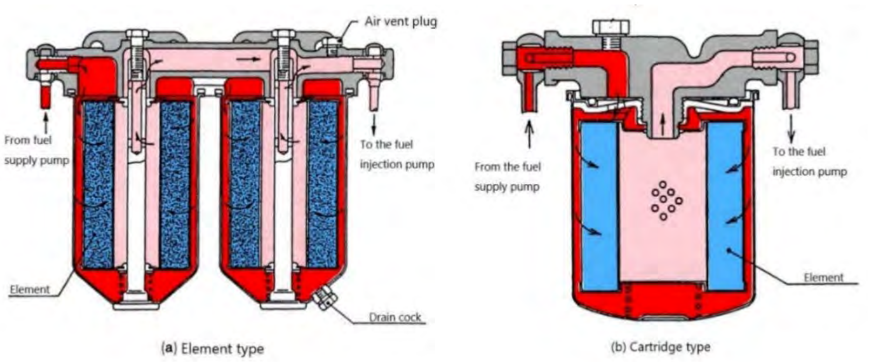
Figure 46. Trochoid fuel pump

5) Fuel filter

As a filter with a machine, it is provided in front of the fuel injection pump, it is an important fuel filter which greatly influences the life of the injection pump plunger, injection valve, etc. Various kinds are used depending on the engine. Particularly in direct injection engines, mesh fine notch wire type (about 40 micron) and paper element type (about 10 micron) are available. In large engines, double engines are adopted that can clean one of the filters even while driving.

(1) Paper filters

By using paper for the element inside the filter, impurities blocked by the element as shown in the figure below (a) are either accumulated in the bottom of the filter or got to the element. Also, the elements of these filters must be replaced at regular intervals. In replacing the elements, it is necessary to clean the interior of the filter and also to replace expendable items such as O rings. Recently used cartridge type has a filter case and an element integrated as shown in (b) in the figure below. Since the mounting surface contains O ring, replace it with a new one and carefully tighten it with a hand so as not to protrude.



(a) Element type

(b) Cartridge type

Figure 47. Type of fuel filters

(2) Auto clean type (CUno type)

This type has the construction shown in the figure below, inside has a spacer plate and a cleaning plate between the thin scraper plate and the scraper plate, and when the fuel passes through the gap (100 microns) between the scraper plate, it becomes like to filter Impurities larger than the clearance are blocked and accumulated in the outer periphery of the plate and in the skimmer.

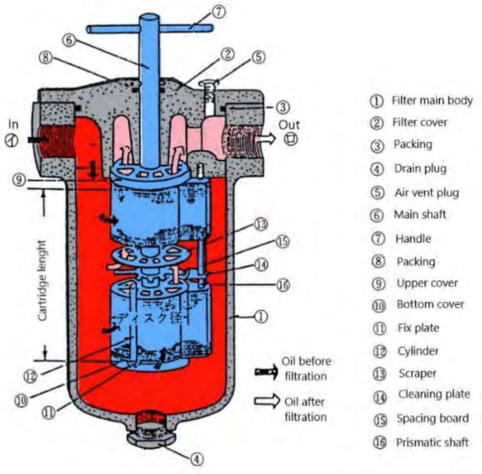


Figure 48. Auto clean filter

(3) Notch wire type and wire mesh type

As shown in the figure below, cleaning is done by removing the internal elements, dipping it in wash oil, and blowing compressed air. At this time, it is also necessary to clean impurities adhering to the bottom of the main body. It is duplex in large-sized agencies, it is also important to perform blow-off, etc., and also to switch and switch after switching for a certain period during operation. Remove the element, replace expendable items such as O rings when assembling after cleaning. If it is used for a long time, the rubber will degenerate and stretch, possibly causing oil leakage.

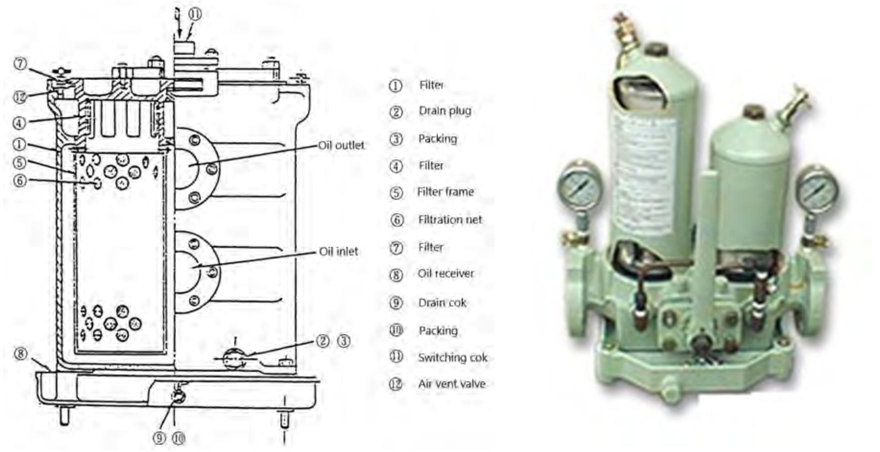


Figure 49. Notch wire fuel filter

6) Oil-water separator

A direct injection type engine using a fuel valve with a small injection hole hates impurities such as dust and moisture contained in the fuel, so when installing the engine installation piping it is necessary to install the oil / water separator after the settling tank desirable. The construction is as shown below and contains special elements inside to block impurities such as moisture and dust when passing through the fuel oil and precipitate to the bottom part, impurities deposited in the lower part sometimes Open the cock and discharge it. The oil-water separator is a type of fuel filter provided with a large exhaust cock, and internal elements need to be exchanged for a fixed period of time as the effect decreases when used for a certain period of time. Also, at least once a day, the drain plug or cock must be opened as well as the sedimentation tank to discharge impurities.

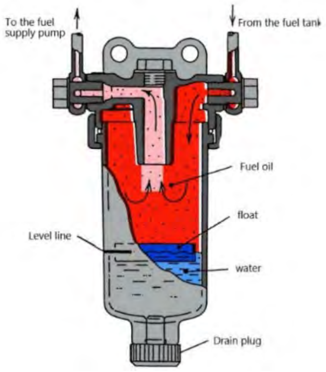


Figure 50. Oil-water separator

In large-scale engines that have been known from the beginning to use bad fuels containing a large amount of water and impurities contained in fuel oils to be used, it is necessary to consider using a centrifugal type oil-water separator or the like as shown in the figure below.

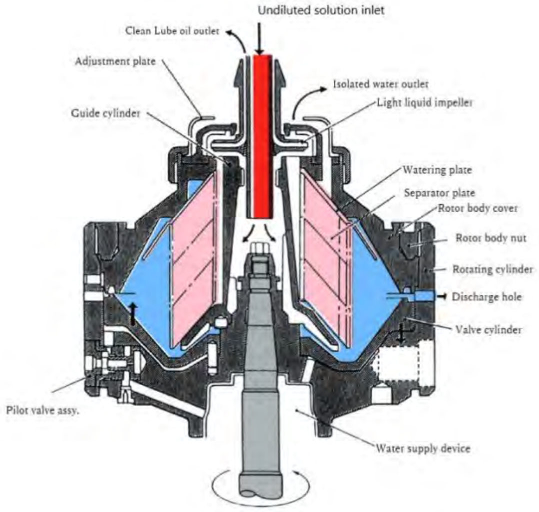


Figure 51.　Centrifugal Oil-water separator

1-7 Governor

The governor is a device that detects the rotational speed of the engine when the load on the engine changes and automatically adjusts the fuel injection amount of the fuel pump so as to achieve the set speed as requested. It is a device having the function of keeping the rotation speed of the engine constant.

1) Types of governors

In general, the following types of governors are often used.

（1） Mechanical governor

（2） Mechanical hydraulic governor

（3） Electronic governor

Most of the small diesel engines are mechanical governors, medium diesel engines employ hydraulic governors, and air controlled hydraulic governors are adopted for large and super large diesel engines, but recently electronic governors are increasingly adopted.

Since (2) and (3) are almost the same as the operation of fuel control, the structure and operation of the mechanical governor and the hydraulic governor will be explained here.

Picture 2.　Daihatsu engine governor

2) Mechanical governor

(1) Construction and function

With the governor of all speed (acting from low speed to high speed) type which adjusts the fuel injection amount by the balance of the centrifugal force and the spring force generated when the weight rotates and keeps the rotation speed constant is there.

(1) Mechanical governor for single cylinder fuel pump

As shown in the figure below, it consists of a speed adjustment handle that determines the rotation speed of the engine, a governor weight portion rotating in conjunction with the rotation of the engine, a connection link with the injection amount adjustment rod of the fuel pump, a spring, etc.

Governor weights are attached to the weight support by pins.

The governor weight supporter, the governor shaft and the governor gear are fixed with a key or a nut, and when the crankshaft rotates, the governor gear is driven via the crank gear and the intermediate gear, the governor support rotates, the centrifugal force is applied to the governor weight.

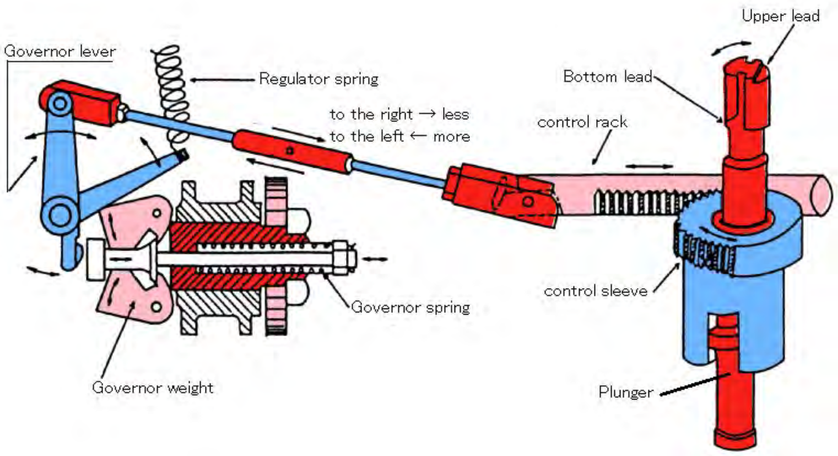


Figure 52. Governor mechanism

As the rotation speed of the engine increases, the centrifugal force acting on the governor weight increases and compresses the governor spring while pulling the regulator spring around the governor weight pin as the governor spring is opened outward.

When the governor weight is opened by centrifugal force, the governor spindle is moved to the left side, and this head moves the lever to operate the adjustment rod (Bosch type pump) of the fuel injection pump or the regulator spindle (deckle type pump) .

On the contrary, when the rotation speed decreases and the centrifugal force applied to the governor weight decreases, the governor weight is closed by the pressure of the governor spring and the tensile force of the regulator spring, and the governor weight of the fuel pump adjustment rod (Bosch type) or the regulator spindle Type) to increase the fuel injection amount. That is, as the opening of the governor weight increases, the fuel injection amount decreases, and as the opening decreases, the injection amount increases. A regulator spring is provided to adjust the opening and closing of the governor weight and to increase or decrease the rotational speed. This spring is strong enough to raise the adjustment handle, the governor weight becomes difficult to open, the fuel increases, and the rotation speed increases. Conversely, lowering the adjustment handle will weaken the spring force, the governor weight will be easier to open, the fuel will be less and the engine speed will be lower. There is a relationship shown in the following figure between the change in the rotation speed due to the change in the load applied to the engine at the constant rotation speed and the operation of the speed governor.

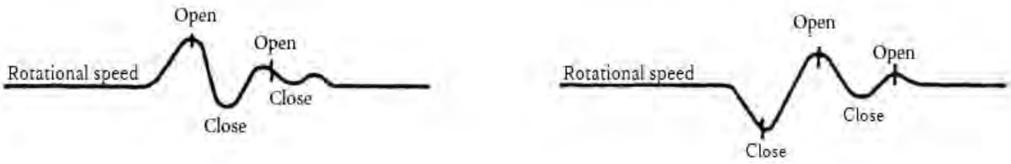


Figure 53. Relationship between rotation and load

→ Governor weight opening → Adjusting injection amount decreasing → Rotating speed decreasing → Governor weight closing → Increasing injection amount → Increasing rotation speed → Governor weight opening → decreasing injection amount → turning speed decreasing With this kind of work, the engine speed is constantly kept constant. However, if the adjustment of each part is bad, the rotation speed may be uneven, the rotation speed may not rise, or the rotation speed may not rise or fall, so if you do not make a thorough adjustment, it cannot operate normally

3) Mechanical hydraulic governor

(1) Construction and function

Woodward governor (SG type, PSG type) produced by Woodward Corporation and Zexel governor (RHD 6 type) produced by Zexel are widely used as a hydraulic governor used for diesel engines.

As an example, a description of a Woodward governor is given. SG type is a simple governor, PSG type can be operated at constant speed by a buffer type correction device, and a droop mechanism is provided. There are two types of hydraulic fluid torque capacity, 12 or 24 pound inches, over the full operating range of 36 degrees, which are exactly the same except for the spring of the built-in safety valve. Both require return springs to pull back in the fuel reduction direction on the output take-off shaft, with the former having 20 lb. of inch and the latter having a torque of about 40 lb. inch on the output shaft. In most cases, hydraulic oil requires system pressure of at least 0.05 MPa at the entrance of the governor with system oil, filter mesh needs 40 microns, capacity needs more than 8 l / min.

As shown in the figure below, these governors are mounted upright or horizontally to the engine, the drive shaft is driven by a camshaft or the like by splines or gears, and the output shaft can be taken out from either side of the governor or from both sides. Also, turning the speed adjustment shaft further than the idle speed position stops the engine.

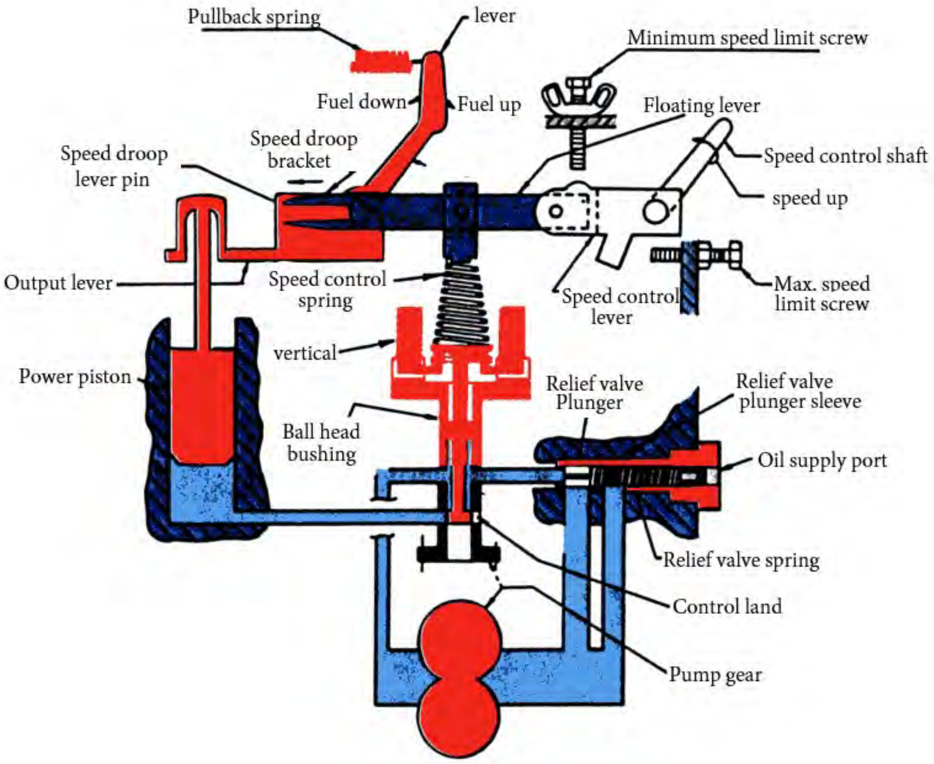


Figure 55. Mechanical-hydraulic governor mechanism

When the system oil enters the governor from the fuel supply port, when the pressure is increased by the gear pump, the relief valve opens, circulating the oil and increasing the relief valve spring force to restrict the inflow from the fuel filler port.

When the working oil pressure decreases, the relief valve restricts returning circulating oil and causes oil to flow from the oil filling port. Excess oil is discharged from the drain hole into the engine interior.

When the engine is operating at a constant rotation speed, the control land closes the hole leading to the power piston of the ball head, and the centrifugal force of the weight and the spring force of the speed adjusting spring (speed spring) are balanced. When the load increases, the rotation speed decreases, the centrifugal force of the weight weakens and the balance collapses, hydraulic oil pushes up the power piston by pushing the control land down by the spring force and hydraulic oil pushes up the power piston, pushing the output lever to push the output shaft in the fuel increasing direction. The injection rate is increased, and the rotation speed is increased. When the output lever is pushed up, the speed droop lever pin is pushed upward, the floating lever is lifted up and the speed adjusting spring is pulled up, the spring force is weakened, the centrifugal force of the weight is strengthened, the control land is pulled up and the hole is closed, the power Stop the movement of the power piston by stopping the inflow of hydraulic fluid to the piston part. The characteristic of returning the pilot plunger to its original position in this way is called speed droop.

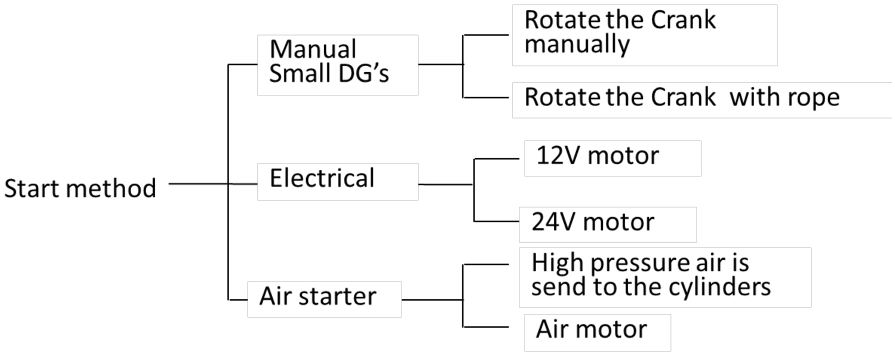
When the load is reduced, the rotational speed of the engine is increased, the centrifugal force of the weight is increased, the control land is pulled up, the oil acting on the lower portion of the output piston escapes, and the pressure decreases. The return spring force rotates the output shaft and the output lever in the fuel decreasing direction, the speed droop pin position also falls, the floating lever moves downward, the speed adjusting spring force increases, balances with the centrifugal force of the weight, pushes the control land down, the ball head Clog the hole.

The amount of change in the speed with respect to the rotation angle of the output shaft is determined by the position of the speed droop pin, decreasing when moving in the weight direction, and changing when moving in the direction of the power piston.

1-8 Starter

Various starting methods are taken depending on the use and size of the engine in a series of devices related to starting of the engine.

There are three ways to start the engine.



1) Electric starter

A ring-shaped gear is mounted on the outer periphery of an engine mousecar, engaged with the pinion of the starting motor, and the engine is turned and started, the power is taken from the battery.

(1) Starting motor

- Construction and function

As shown in the figure below, the main part is roughly divided into an engage magnetic switch and a motor.

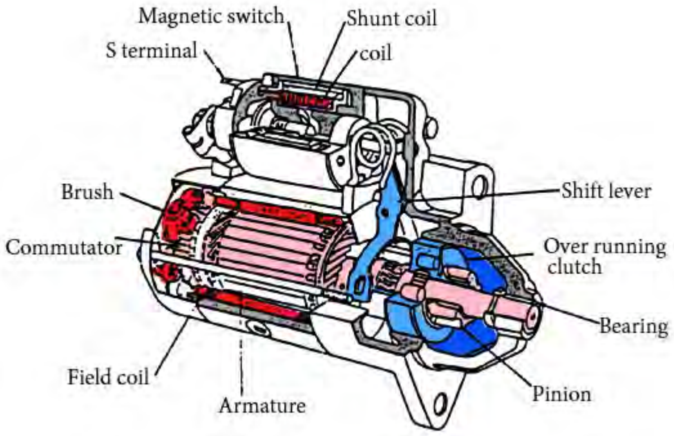


Figure 56.　Electrical starter components

(2) Battery (DC power supply)

- Construction and function

As shown in the figure below, when the lead dioxide (PbO 2) and lead (Pb) are diluted in dilute sulfuric acid, the lead dioxide becomes the anode and the lead becomes the cathode, and the battery is formed. The electromotive force is 2V. This is usually referred to as a storage battery, and a battery in which two or more storage cells are connected in series as shown in the figure below is called a battery.

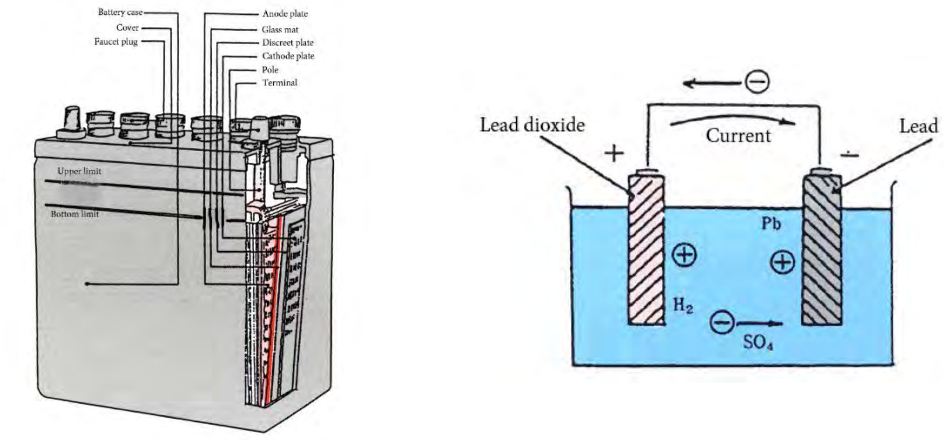


Figure 57.　Lead acid battery parts

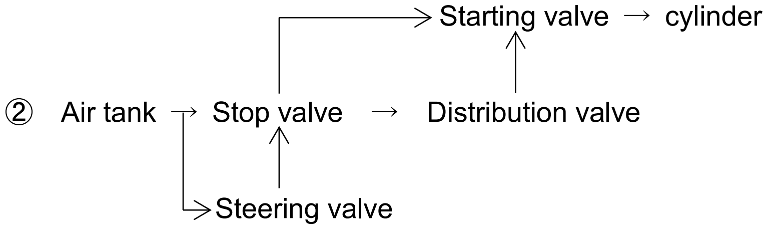
The capacity of the battery is expressed in Ah (ampere-hour), which shows how many current (ampere) can be discharged for hours.

For example, if it can be continuously discharged for 10 hours with a current of 10 A, it can be said that there is a capacity of 10 × 10 = 100 AH.

2) Air starter

The air starting device blows compressed air stored in the air tank into the cylinder to start the engine. As shown in the figure below, there are those which consist of an air tank, a distribution valve, a starting valve and a steering valve and a stop valve separately. Typical types are as follows.

① Air tank → distribution valve → start valve → cylinder



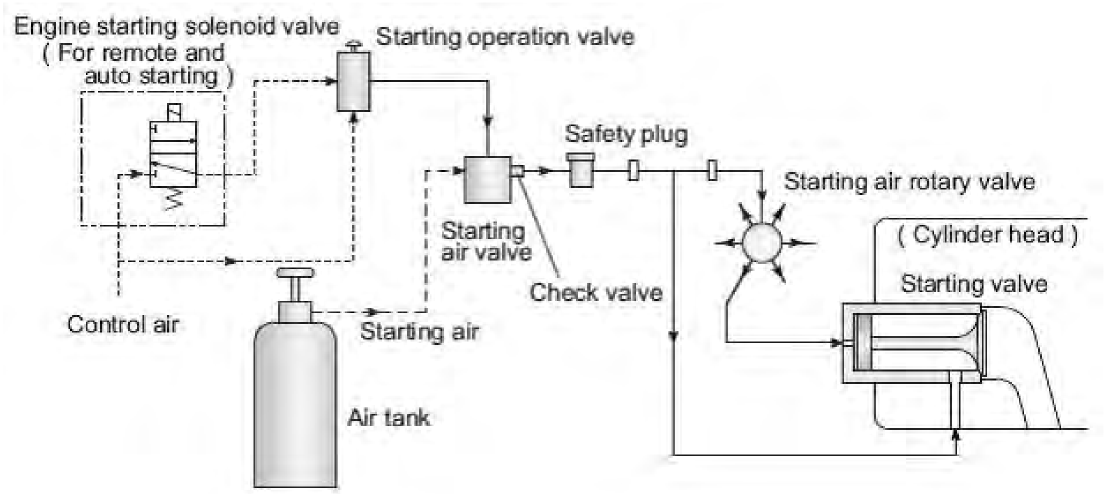


Figure 58. Starting air system (Pilot-starting valve type)

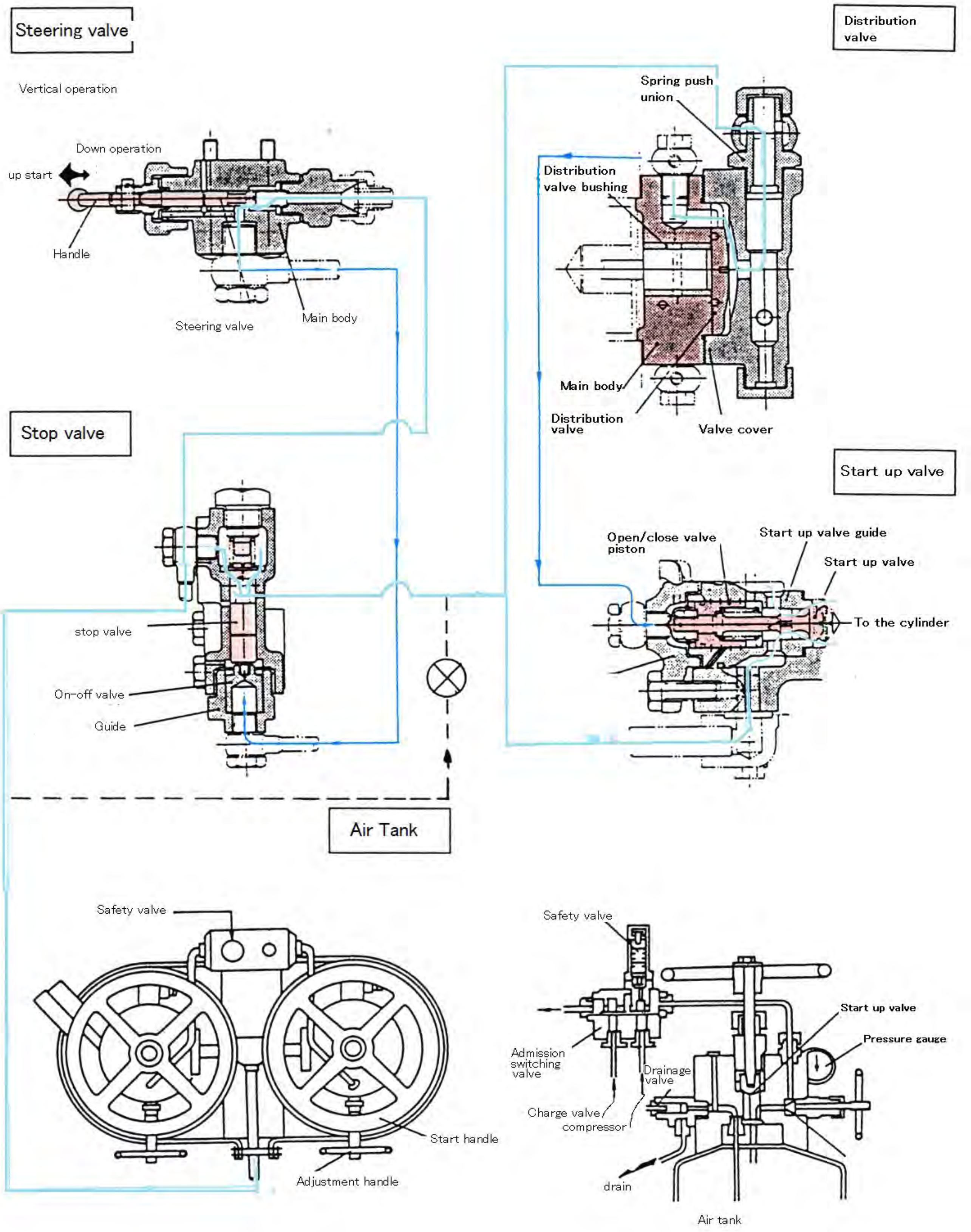


Figure 59. Air starting system components

(1) Air tank

It consists of a valve chest fitted with an accessory device and an air tank main body, and stores the starting air at a pressure of 2.94 MPa maximum. Regarding the capacity, it depends on the size and application of the engine, and an air tank starting valve, an air tank charging valve,

a drain releasing valve, a safety valve, a pressure gauge, a lead stopper, etc. are attached as attachment devices.

Picture 3. Air tank

(2) Air start distribution valve

It operates to blow compressed air in conformity with the piston position for each cylinder. It consists of a valve, a valve body and a valve lid and is driven by a camshaft.

When the notch (or hole) of the valve coincides with the hole of the valve body as shown in the figure below, the valve comes around by the rotation of the camshaft, and the air at the back of the valve passes through the hole of the valve body and the start valve.

The starting position is the position where the valve opens at 1/5 th position and the opening degree is sufficient that air passes sufficiently, generally being at the position of 15 degrees past the compression top dead center.

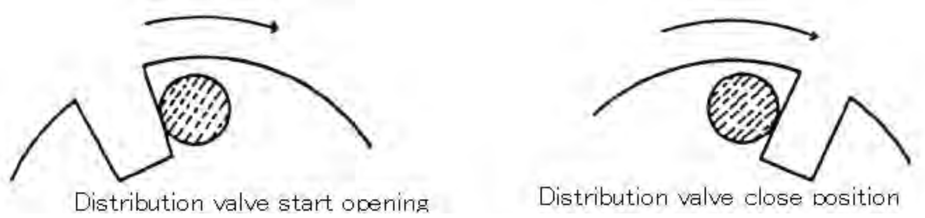


Figure 60. Air valve start-close position

(3) Start valve

It is attached to the cylinder head to prevent the inflow of starting air and backflow of combustion gas. Operation is automatically opened by the start air as shown in the figure below, closed by the valve spring and cylinder pressure. Starting air acts on this piston at the top of the piston to push down on the piston and starts the engine.

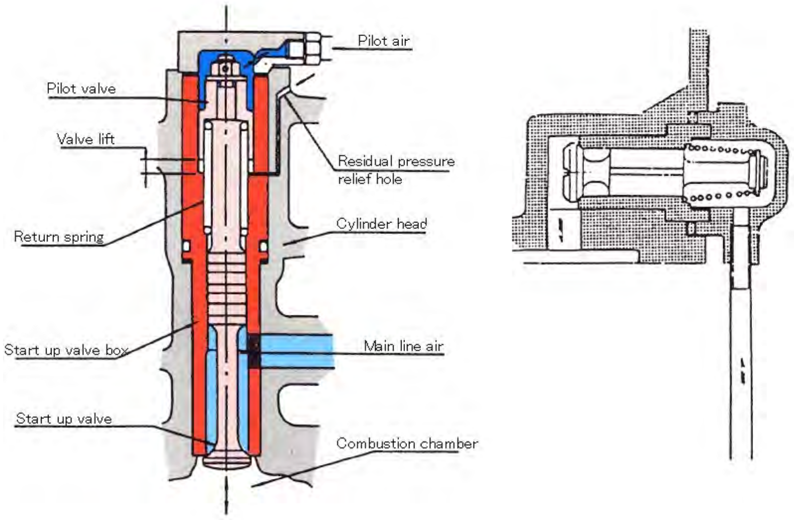
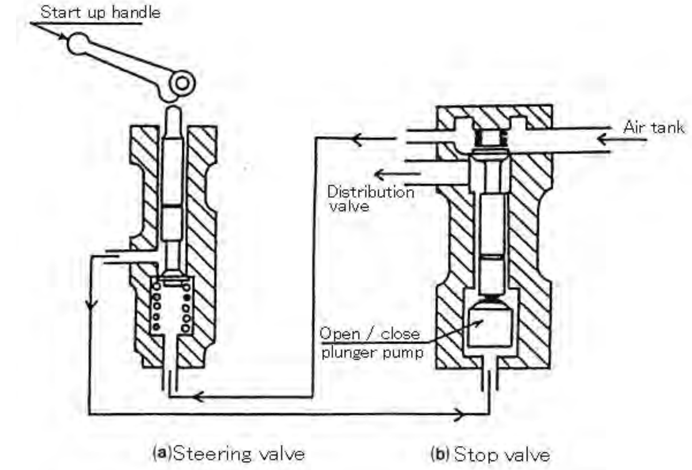


Figure 61. Start valve components

(4) Steering valve

As shown in the figure below, the control valve consists of a main body, a valve, a valve spring and a starting handle, which is for feeding a part of the starting air to the opening and closing plunger portion of the closing valve to open the closing valve. Operate manually. In the engine of the automatic starting device, this is replaced with a solenoid valve.



(a)Steering valve (b) Stop valve

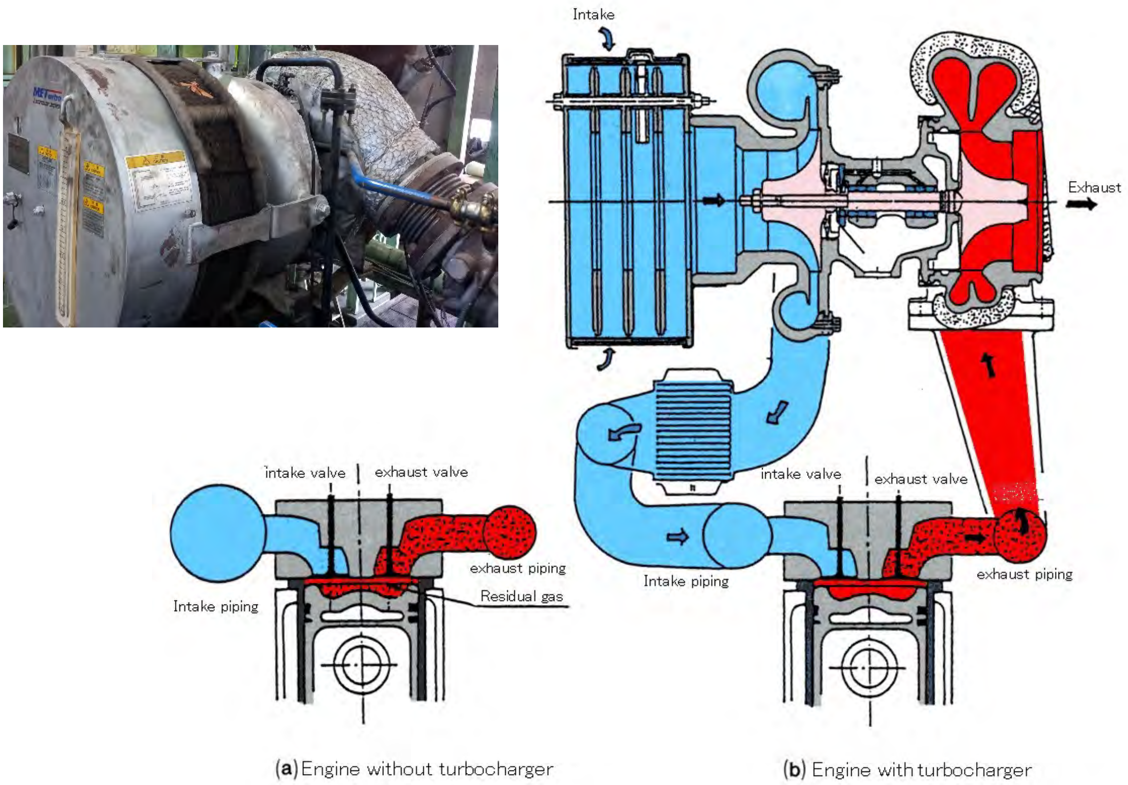
Figure 62. Steering and stop valve

1-9 Turbocharger

1) Purpose of the turbocharger

A certain amount of air is necessary for fuel oil to burn. Therefore, in small cylinders, the amount of air taken in is small, so the amount of fuel oil which can be burned is small and the output is small. If air pressurized above the atmospheric pressure by a compressor (compressor) is sent into the cylinder, even a cylinder of the same volume will push a lot of air, burn more fuel oil than in the case of no supercharging It is possible to increase the output. This is the purpose of supercharging. For this purpose, what is attached to the engine is a turbocharger, superchargers currently in practical use are roughly divided into the following. A conceptual diagram of an exhaust turbine turbocharger that is generally used in general is shown in the figure below.

Turbo charger
- Radial type
- Axial type



(a) Engine without turbocharger (b) Engine with turbocharger

Figure 63. conceptual diagram of turbocharger

2) Exhaust turbine turbocharger

① Recovery of energy in exhaust gas

The exhaust turbo turbocharger has no mechanical connection with the engine and is driven by the exhaust gas of the engine.

The gas pressure in the cylinder when opening the exhaust valve is 0.4 to 0.8 MPa. In order to further lower the pressure in the cylinder, the stroke of the engine has to be made much longer and it is impossible than the restriction on the engine structure. In conventional supercharged engines, exhaust is wasted to the atmosphere from the cylinder, but the exhaust gas contains about 40% of the energy of the total energy of the fuel, of which ¼ Is an energy that can be used mechanically by further effectively expanding the gas to atmospheric pressure. The other 1/4 is energy that can be used as a heat source if a heat exchanger such as an exhaust boiler is used, but the rest are energy which cannot be used anyhow at all. If the exhaust gas is effectively expanded, it is possible that about 10% of the theoretical total energy, that is, about 25 to 30% of the engine output can be recovered in the mechanical work as described above. Generally, the ratio of recoverable energy to engine output generally increases as the engine output increases. The turbocharger increases the supply air pressure by this recovered energy to increase the engine output.

- ➢ Supercharging method

Some supercharging methods of diesel engines utilize the inertia effect of intake and exhaust pipes, most of which are due to exhaust turbine turbochargers.

This is a method in which the exhaust gas turbine is rotated by using the high temperature exhaust gas discharged from the cylinder in the exhaust stroke, pressurized air is produced by the directly connected compressor, and pushed into the cylinder of the intake stroke.

The Static pressure supercharging system is a system in which the exhaust gas of each cylinder is collected in one exhaust manifold having a relatively large volume at which the pulsation energy almost disappears, and the pulsation pressure of the exhaust gas is roughly balanced to make the driving force of the exhaust turbine of the turbocharger. Many have been adopted by large diesel.

② Features of exhaust turbine turbocharger

(A) Features

(1) Can reduce the size and weight of the engine

Compared to a non-supercharged engine with the same output, the supercharging engine is lightweight and compact, and the engine room can be made smaller.

(2) Production cost per horsepower is cheap

Since the engine can be made smaller and lighter, the production cost is also lower.

(3) Mechanical efficiency can be improved

The friction loss horsepower of the engine is strongly influenced by the size and rotation speed of the engine, and when the rotation speed is constant, it does not change at all depending on the magnitude of the average effective pressure. Therefore, when equipped with a turbocharger, the average effective pressure rises and the effective workload also increases, but since the friction loss does not change much, the mechanical efficiency improves.

(4) Low fuel consumption per horsepower

Along with improving the machine efficiency, the fuel consumption rate can be improved by 2 to 10% compared with the no supercharged engine.

(5) There is no mechanical contact with the turbocharger and the engine

Since there is no mechanical contact with the engine, as the required output of the crankshaft increases irrespective of the engine speed, the energy of the exhaust also increases, the rotation of the turbocharger shaft automatically increases, and the intake air pressure also increases It is possible to operate suitable for the state of use of the engine.

(6) There is a sound deadening effect

Since the exhaust gas turbine turbocharger has a strong effect of reducing the explosion sound, a simple exhaust gas silencer is sufficient.

(B) Disadvantages

(1) The temperature around the combustion chamber rises slightly higher than that of a non-supercharged engine

The exhaust temperature varies with the change in the intake air temperature as shown below. As the intake air temperature rises by 10 ° C, the exhaust temperature rises 18 to 23 ° C at the cylinder exit, but this tendency is about 2 to 3 times higher than that of the intake air temperature rise, which is about as high as the high-speed engine.

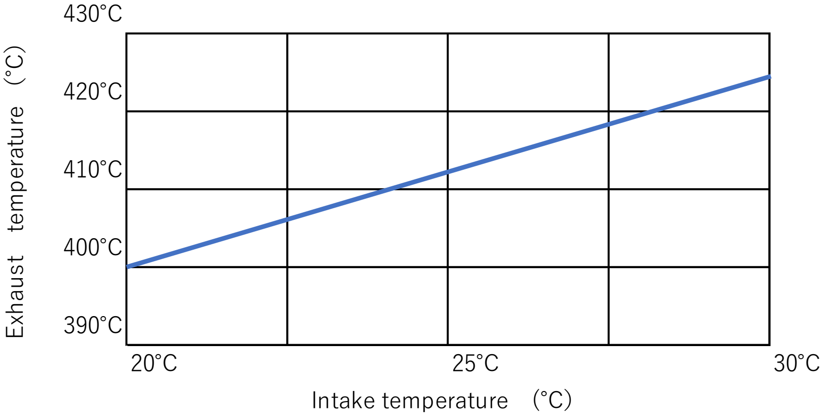


Figure 64. Relation between intake Air and exhaust gas temperature

(2) Since the maximum explosion pressure increases, the vibration of the engine increases. It is also necessary to increase the cylinder head tightening torque.

(3) When the exhaust turbine fails, the engine output decreases

Since the compression ratio is lower than that of a non-supercharged engine and the overlap is large, when the exhaust turbine fails and the supply air pressure does not increase, the exhaust gas flows back into the cylinder at the top dead center, the output is lower than that of the no supercharged engine.

Even when the turbocharger fails, if the turbine shaft is fixed or an emergency short-circuit pipe is used, it can be used at a rotation speed of 50 to 70% of the specified rotation speed.

(4) Burning deteriorates at low load.

(5) Caring for handling and maintenance of the turbocharger shall be taken care.

(A) Axial turbine

Construction and function

In the axial flow turbine, the exhaust gas flow through the turbine blade in the axial direction. Usually are generally employed in a large engine air flow.

A typical sectional view is shown in the figure below.

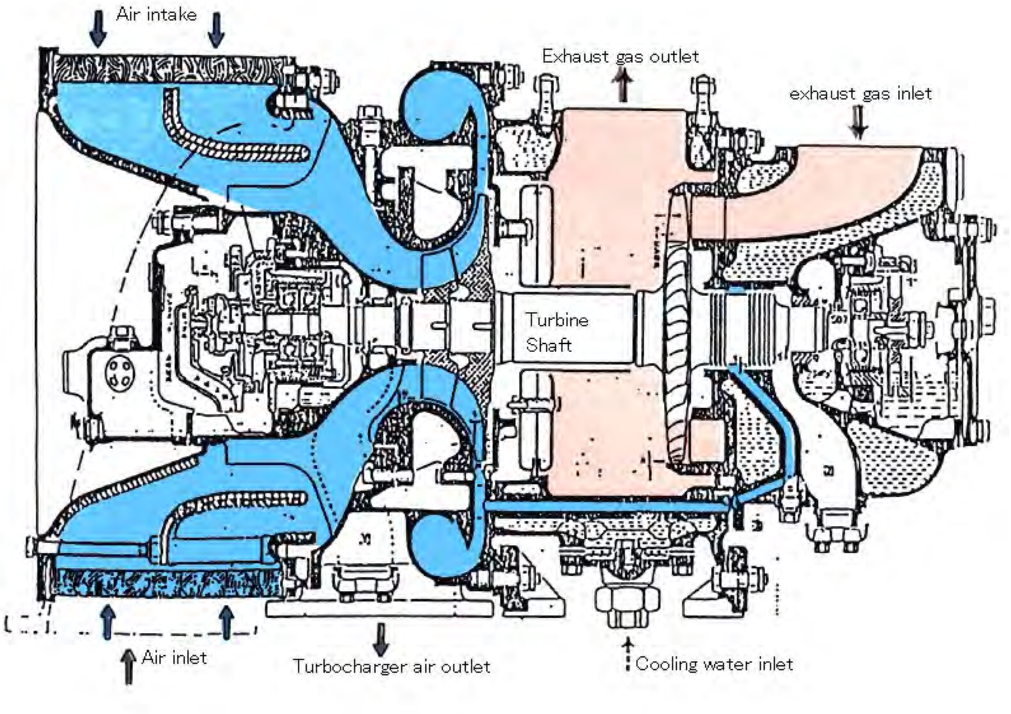


Figure 65. Axial turbocharger

(a) rotary shaft and turbine blade

Turbine blades are fixed to the rotating shaft, and the blades are subjected to centrifugal stress generated by a high gas temperature of 600 ° C. to 700 ° C. and a high rotational speed. Therefore, the rotating part has sufficient dynamic balance.

In order to prevent inflow of gas into the bearing part and suction of lubricating oil, an oil cutting ring and an airtight labyrinth are placed on the shaft to guide the high pressure air from the blower to the central part of the labyrinth.

(b) Air inlet

A felt shape made by overlapping cloth and wire mesh, a wire mesh shape with corrosion resistant metals overlapped and a gold ring filter with many metal or plastic cylinders with diameter and length of about 10 mm packed together.

(c) Blower impeller

Because the blower is centrifugal, it fits into the rotating shaft and torque is transmitted by key or spline. The blade entrance part is curved in the direction of rotation, this part is called the front wing, and the radial part following it is called the impeller or the main wing.

(d) Nozzle and diffuser (guide vane)

In order for the exhaust turbine to operate efficiently at the prescribed rotation, the area and shape of the turbine nozzle and blade (blade) are suitable for exhaust energy and the diffuser of the blower must also be suitable for the required air quantity of the engine. When the amount of air blown is larger than the required air amount of the engine, surging occurs in the blower, the air volume and wind pressure pulsate, and noise and vibration are generated to make operation impossible. When the air volume of the blower becomes extremely larger than the engine required air amount, the pressure on the front face of the blades is high and the pressure on the back face becomes low, so the flow velocity is slow on the front face of the blades and becomes faster at the back face, so that back flow occurs at the front face of the blades, The air flow is unstable and generates noise and vibration. This phenomenon is called surging.

(e) Bearing and lubrication system

The lubrication system currently in use is a ball bearing oil bath lubrication system. The ball bearings fitted in the rotating shaft are supported on the outside by a damper and fitted in the bearing box. Also, the bearing outer ring is fixed. The oil supply disk is fitted and fixed to both ends of the rotation shaft, and the oil supply disk rotates at the same time as the shaft rotates. Since the lubricating oil is retained in the state that the disc is in the range of 2 to 5 mm, the lubricating oil is sucked up to the upper part by rotation of the disc, part of which passes through the lubricating oil passage in the upper part of the bearing housing It drops to the right side of the ball bearing and accumulates and lubricates the bearing.

In recent turbochargers, many auxiliary pumps are installed as bearing lubrication devices. Inside the oil injection cylinder fixed to the turbine shaft, the inserted nipple is fixed to the oil suction enclosure, and the oil suction enclosure is fixed to the bearing box. The oil injection tube and the nipple are kept airtight by the ring. Due to the rotation of the turbine shaft, the oil injection cylinder rotates in the same direction, and the lubricating oil is sucked and discharged by centrifugal force. The lubricating oil discharge port reaches the ball bearing, and a method of supplying the ball bearing is adopted.

Since the shaft rotates at high speed and the temperature rises to 60 ° C to 70 ° C, ball bearings require particularly high-precision bearings, and the use time is limited to 6,000 hours to 8,000 hours to keep safety.

(f) Axial airtight (Labyrinth packing)

Axial air tightness of the turbocharger is made to minimize leakage of air, gas and oil. It has a ring-shaped groove in the shaft. It is fixed to the shaft by caulking by filling the plate-like non-ferrous steel with wire, has excellent airtight performance, and has little damage even when it comes in contact with the shaft. However, careful handling during disassembly / assembly can damage the tip of the strip of plate steel. Also, due to long-term operation, there are many wears due to carbon and the like, and in case of wear, it is structured to be able to replace it.

(B) Radial turbine

In the radial turbine, the gas flows radially through nozzles arranged in the circumferential direction of the turbine impeller and give a large tangential velocity. Then, the gas collides with the turbine blades, flows to the center direction rotating the turbine shaft at 60,000 to 160,000 per minute. Radial turbine has a structure that the gas is discharged axially from the shaft end, and when the air flow rate is small, it is superior to the axial turbine and it is widely adopted for small high-speed engines.

A typical cross section is shown in the figure below.

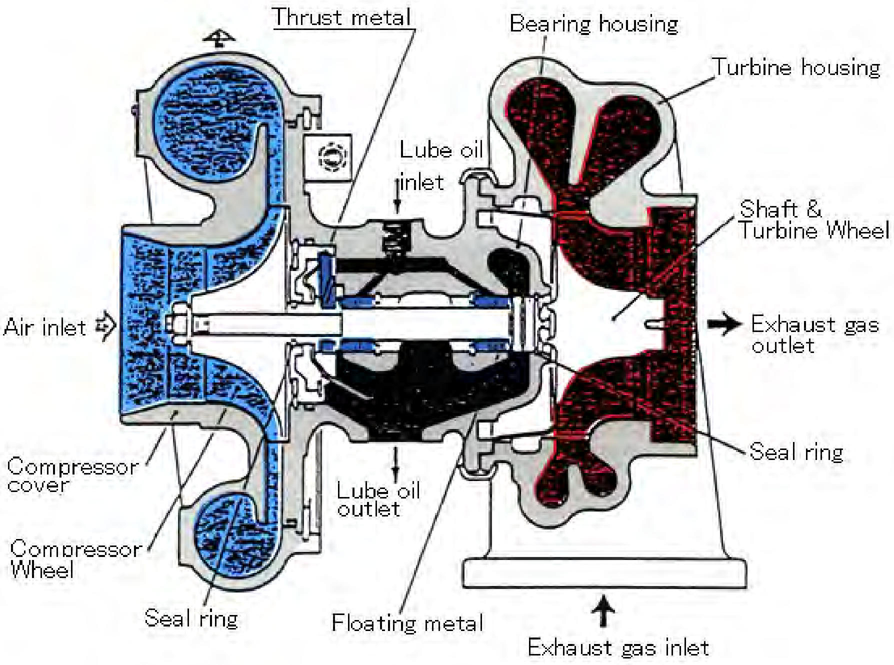


Figure 66. Radial turbocharger

The turbine and the blower are connected by a single shaft, and the blades of the blower are driven at the same rotation speed as the turbine. When the air flowing in the axial direction from the center of the blower passes through the rotating impeller, the pressure is raised and given a large tangential speed, the pressure is increased while being decelerated as it enters the blower case and sent to the intake pipe.

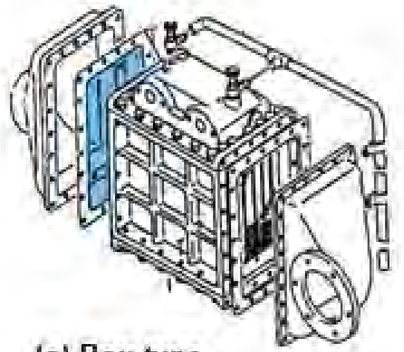
The turbine shaft is supported by a floating metal intermediate the turbine wheel and the blower wheel. The floating metal has a dual oil film on the inner and outer surfaces of the metal, and since the metal turns around, the sliding speed of the bearing surface is lower than the rotation speed of the turbine shaft, and the dynamic stabilizing effect is obtained.

3) Air cooler (intercooler)

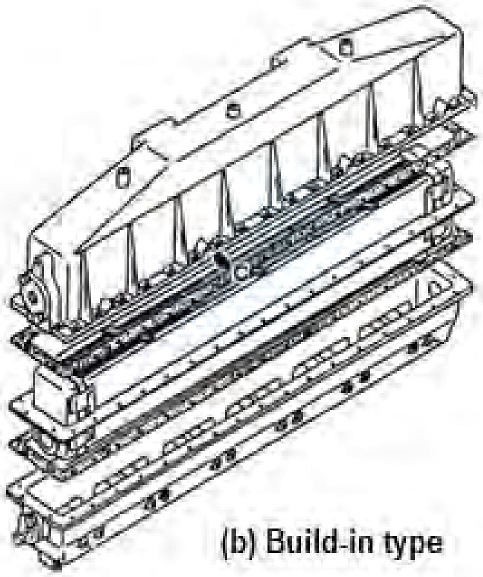
(1) Construction and function

Cooling the hot air exiting the blower of the turbocharger with water to reduce the volume, increase the density of the air to be sent to the cylinder, burn the fuel oil extra, and increase the output of the engine between the blower and the cylinder air cooler is provided.

In the air cooler, as shown in the figure below, a large number of cooling pipes are placed in a rectangular box, and copper or aluminum fin (thin plate) is wound around the outside of the cooling pipe in order to increase the surface area, It is designed to cool by passing air through the outside.



(a) Box type



(b) Build-in type

End

Diesel Generation
Operation and Maintenance Manual

3.2 Main Equipment of Diesel Generation (Electrical Devices)

Kosrae Utilities Authority

INDEX

1. Synchronous Generator

1.1 Role

Diesel power generators are used for a wide range of applications such as commercial power generation; peak cut power supply or emergency power supply in some facilities such as power plants and buildings.

Because actually enhancement of transmission or substation of electricity at power plants, buildings, and other facilities or as the power demand is planned to be concentrated, the tendency of single unit large capacity and multiple unit parallel operation of diesel generators is increasing.

1.2 Principle

As shown in Figure 1-1, the N and S poles of a magnet are rotated, and a conductor is placed around it. The conductor crosses the magnetic flux by the rotation of the magnet, and an electromotive force is generated in the direction of the arrow resulting in the flow of a current with the waveform shown in Figure 1-2. This phenomenon is called electromagnetic induction and is the principle of synchronous generators.

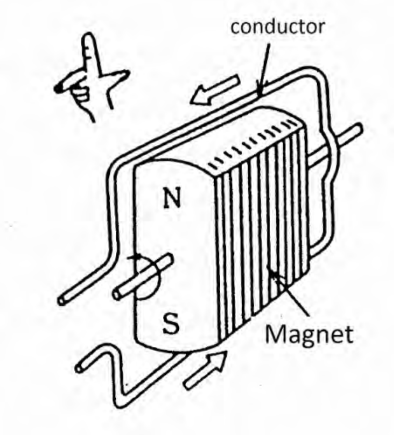


Figure 1-1 Principle of generators

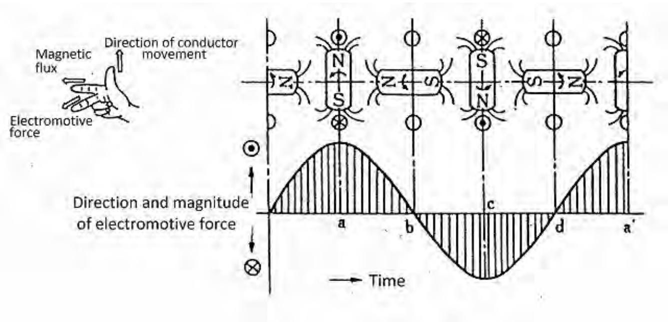
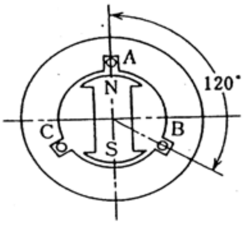


Figure 1-2 Power waveform

Three phase AC generators have three conductors (A, B, C) arranged at intervals of 120° of each other in the stator core, and if the magnet is rotated in this space, an electromotive force with the phase shifted by 1/3 cycle is generated in each conductor. The electromotive forces generated in conductors A, B, and C are collectively called a three-phase electromotive force, and its waveform is shown in Figure 1-4.



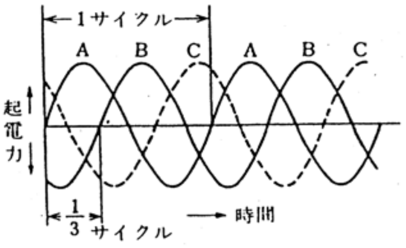


Figure 1-3 Principle of three phase generators

Figure 1-4 Waveform of three-phase electromotive force

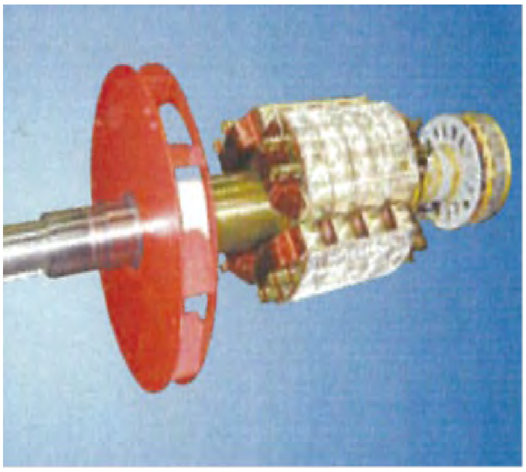
1.3 Construction

- Rotating magnetic field cylinder type

  As shown in Picture 1-1, the rotating magnetic field cylinder type has uniform heat, and even with high centrifugal force, there is no part where stress is concentrated like the salient pole magnetic field type, so it is especially suited for medium and high-speed machines with 10 poles or less. Many generators with a capacity of about 2,000 kVA or less have this construction.

- Rotating magnetic field salient pole type

  With large capacity diesel generators, the rotating magnetic field salient pole type shown in picture 1-2 is generally adopted. These have 12 to 18 more poles, and many generators with a capacity of 2,000 kVA or more have this construction.

	
Picture 1-1	Picture 1-2

Construction of generator parts

①Frame

In general, most have a construction of welded steel plates.

②Stator core

The stator core has a laminated construction of silicon steel plates which aims to reduce iron loss.

③Stator winding

The stator windings are insulated in consideration of heat resistance, moisture resistance, chemical resistance, etc.

④Field core

The field core is formed by laminating high-quality steel plates with good electrical performance and fixing them on the shaft, providing damper windings on the surface of the field core to prevent hunting during parallel operation and to withstand unbalanced load, etc.

⑤Field winding

For field winding, see No. 1

⑥Cooling fan

A fan with a welded steel plate construction is attached to the rotating part, and the cooling air flows as indicated by the arrow in the figure.

⑦Bearing

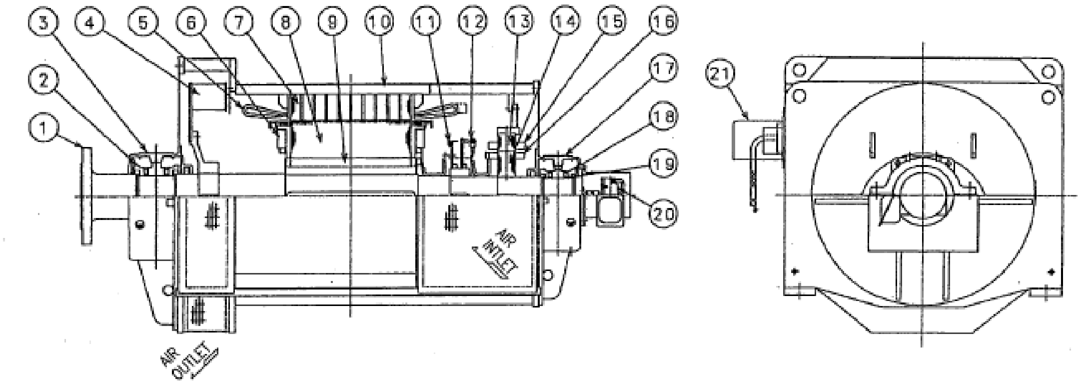
This is to shorten the axial direction by omitting bearings on the side coupled with the diesel engine in consultation with the engine manufacturer. The so-called single bearing type may be used. The bearing lubricating oil system is a highly reliable forced lubrication system, and in many cases, the lubricating oil system of the diesel engine is shared.

⑧AC exciter

For the AC exciter, a rotary armature type AC generator excellent in fast excitation response is adopted. There are built-in types and external types.

⑨Rotating rectifier

A rectifier (composed of a silicon device, discharge resistor, etc.) for converting the output of the AC exciter to direct current and exciting the main generator, and it is attached to the rotating part.



Part No.	Name of part	Part No.	Name of part	Part No.	Name of part	Part No.	Name of part	Part No.	Name of part
1	Shaft	6	Rotor winding	11	Protective resistor	16	Exciter rotor winding	21	Main circuit terminal
2	Bearing	7	Stator core	12	Rectifier	17	Bearing bracket		
3	Bearing bracket	8	Rotor core	13	Exciter stator core	18	Bearing		
4	Fan	9	Rotor frame	14	Exciter rotor core	19	Oil-ring		
5	Stator winding	10	Stator frame	15	Exciter stator winding	20	Tachometer generator		

Fig.5 Type Form NTAKL－SC (protection type)
NTAKL－DC (protected from drip water)
NTAKL－KC (duct ventilating type)
(Double bearing type)

Fig.1-5 Construction example of a rotating magnetic field salient pole alternator

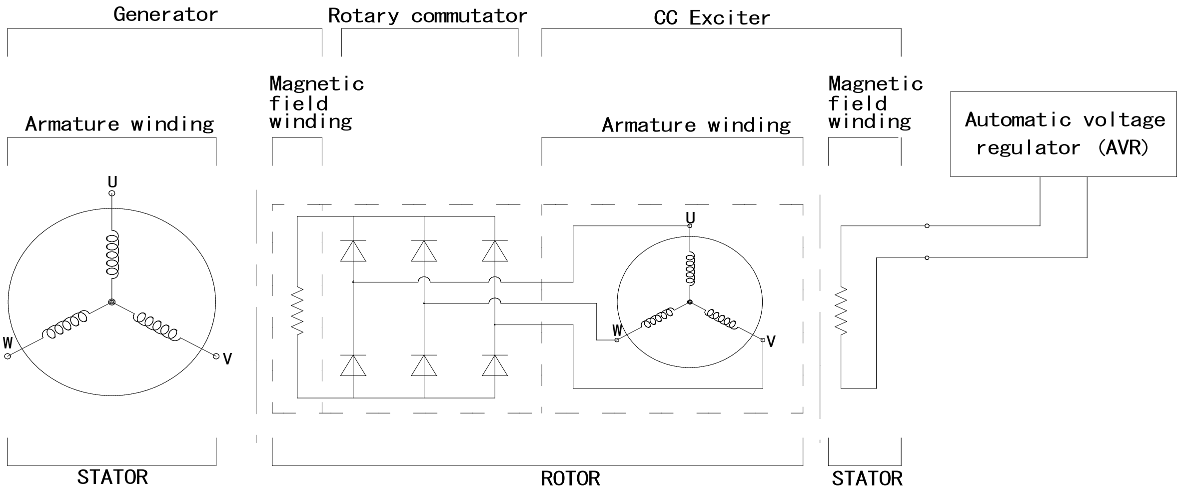


Fig 1-6 Wiring diagram of a brushless generator

1.4 Frequency and speed

The relationship between frequency and rotation speed is expressed by the following equation.

$Ns = 120f/P$

Where Ns = Synchronous speed (rpm)

F = Frequency (Hz)

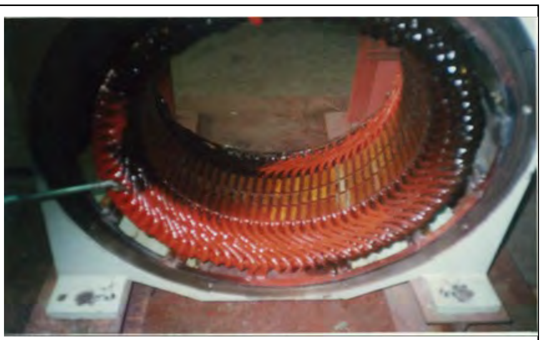
P = Number of poles

Generally, the rotational speed of the AC generator is determined by the economic speed of the diesel engine driving it.

Table 1-1. Relationship between the number of poles, rotation speed, and frequency

Pole	Rotational speed (rpm)	
P	50Hz	60Hz
2	3,000	3,600
4	1,500	1,800
6	1,000	1,200
8	750	900
10	600	720
12	500	600
14	429	514
16	375	450
18	333	400

1.5 Cleaning generator (Factory of generator manufacturer)

	
Pic. 1-3 Stator extraction	Pic.1-4 Varnish application after cleaning
	
Pic.1-5Varnish application to rotor and drying	Pic.1-6 Stator and rotor insertion

2. Exciter

2.1 Role

Since the magnetic field of the generator is an electromagnet, in order to create a magnetic field, electric current must by supplied from an external source. A device that produces a field through this current is called an exciter.

Directly connecting the DC exciter to the shaft end has long been widely used as a method of supplying the excitation current to the magnetic field of the AC generator, but with the advancement of semiconductor rectifiers, the static excitation method has been adopted, and in recent years, it has advanced one step further by equipping the rotating machine with a rectifier. The brushless excitation method, which is made completely contactless by combining with the fixed field AC exciter to reduce maintenance, has become widely used.

2.2 Static excitation method

The generator itself is a brush type generator, and the field coils are directly excited through a brush and a slip ring by a static exciter. Since the field current (large current) of the generator is directly controlled, the voltage response at the time of load fluctuation is extremely fast, but the exciters (storage panel) such as AVRs naturally become large, and currently, they are hardly used due to maintenance of the brush, etc.

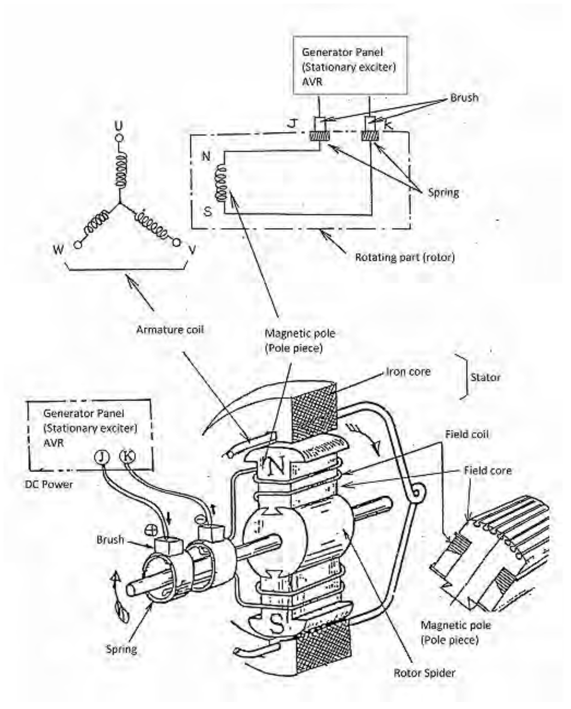


Fig. 2-1 Static excitation method

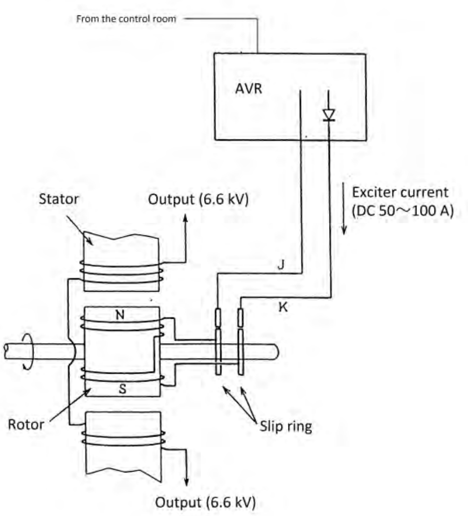


Fig. 2-2 Static excitation method drawing

2.3 Brushless excitation method

This method is the mainstream for current generators. Instead of directly controlling the field current, an AC exciter (synchronous generator) is installed at the end of the generator shaft, and its field current is controlled. The generated current of the AC exciter (synchronous generator) installed at the shaft end is rectified by the rotary rectifier mounted inside the generator to be the field current of the generator. (This is why it is called brushless AC excitation method.)

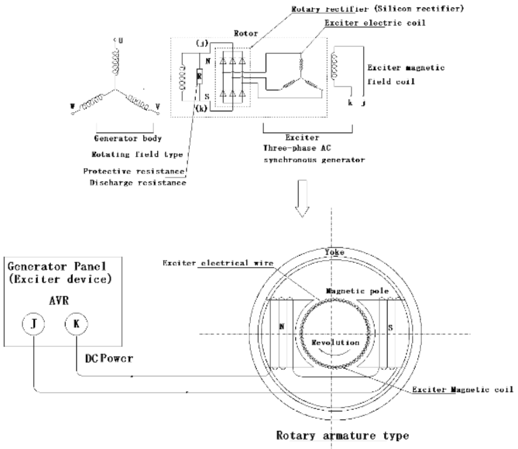


Fig. 2-3　Brushless excitation method

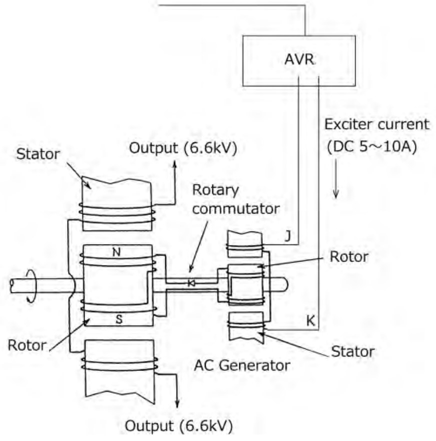
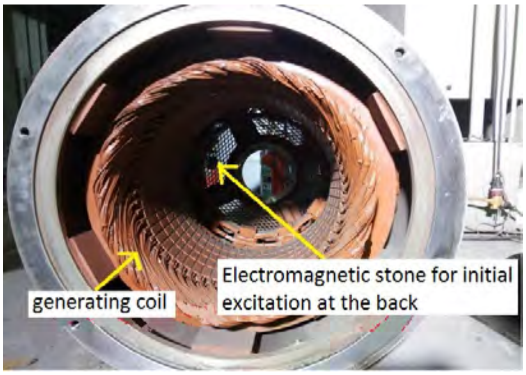
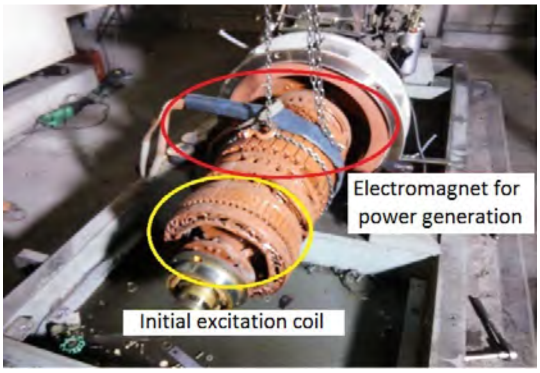
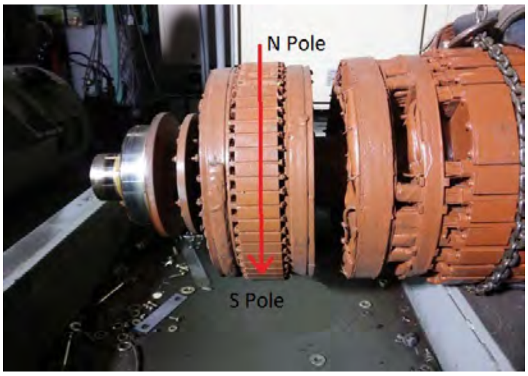
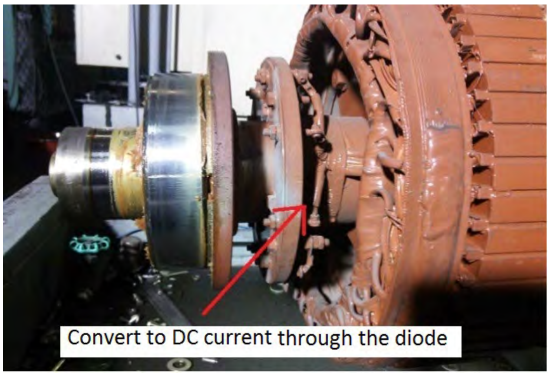
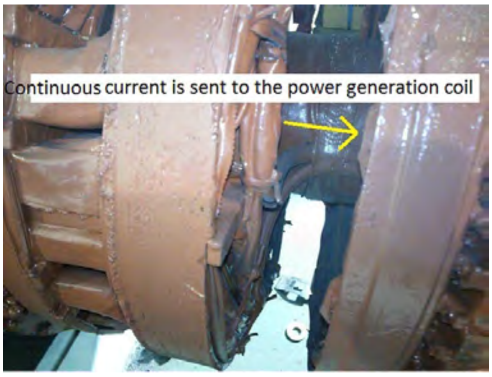
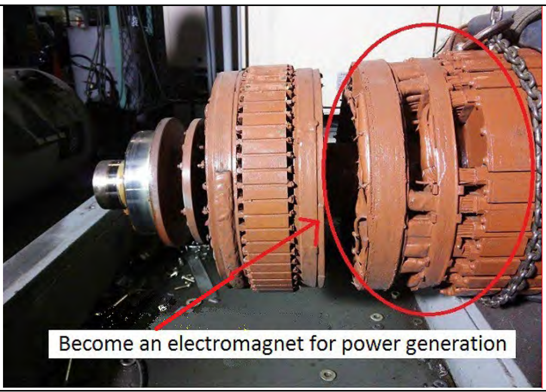
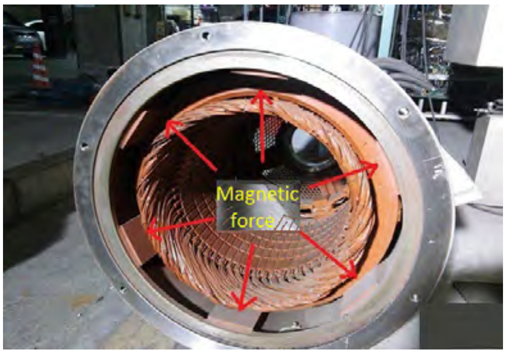
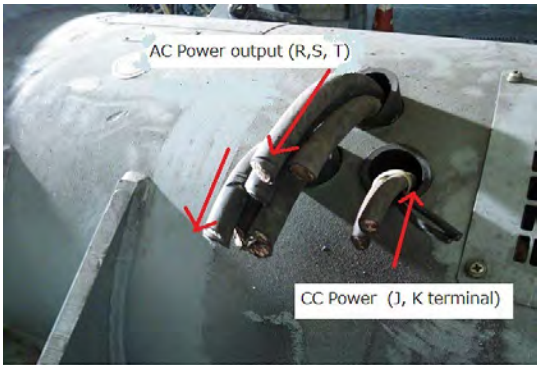


Fig. 2-4　Brushless excitation method

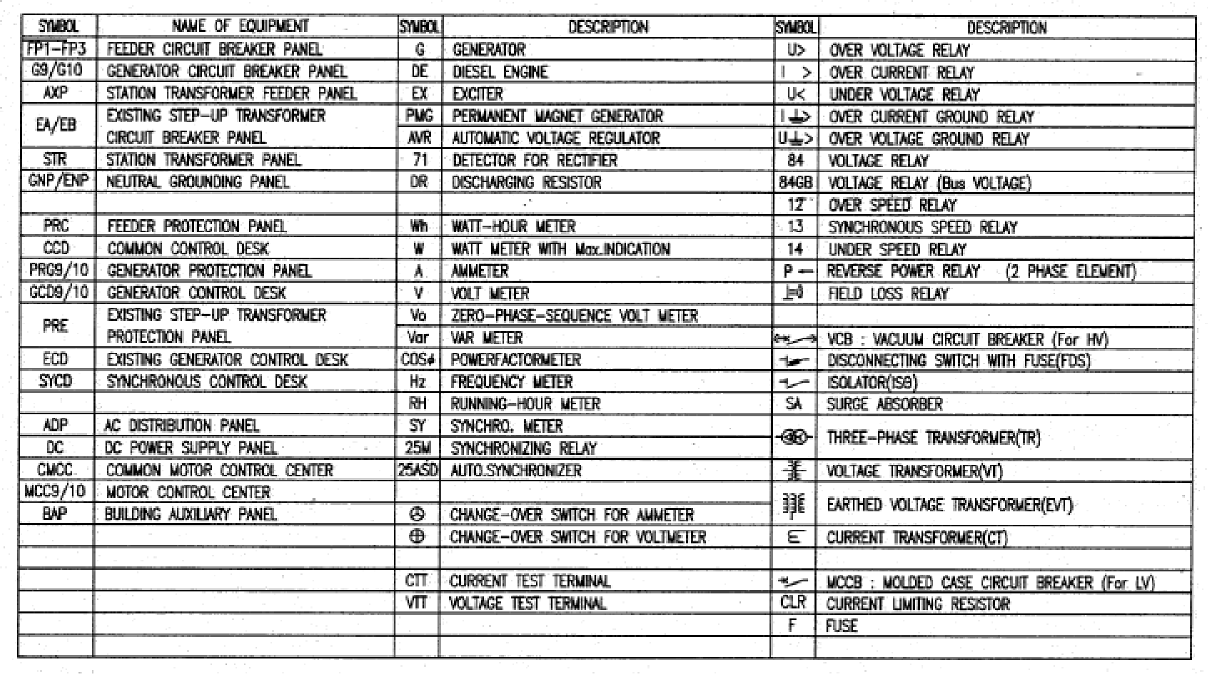
(4) Inside generator

	
Pic.2-1 Stator	Pic.2-2 Rotor
	
Pic.2-3 Exciter	Pic.2-4 Rotary rectifier
	
Pic.2-5 The DC current is passed to the electromagnet for power generation	Pic.2-6 Magnetic force is generated in the electromagnet by the DC current
	
Pic.2-7 A large voltage is generated in the coil in which the coil (copper wire bundle) moves in the magnetic force	Pic.2-8 AC power is generated

3. Protection Relay

3.1 Role

A relay is a device that controls an electric circuit by outputting electric signals according to conditions such as electric quantity and physical quantity. With protective relays aimed at protecting power equipment, upon detecting an abnormal condition such as power generated in the power system of the equipment or a sudden change in power or voltage, its impact is minimized by outputting a control signal to a switch such as a circuit breaker to isolate it.



SYMBOL	NAME OF EQUIPMENT	SYMBOL	DESCRIPTION	SYMBOL	DESCRIPTION
FP1–FP3	FEEDER CIRCUIT BREAKER PANEL	G	GENERATOR	U>	OVER VOLTAGE RELAY
G9/G10	GENERATOR CIRCUIT BREAKER PANEL	DE	DIESEL ENGINE	I >	OVER CURRENT RELAY
AXP	STATION TRANSFORMER FEEDER PANEL	EX	EXCITER	U<	UNDER VOLTAGE RELAY
EA/EB	EXISTING STEP–UP TRANSFORMER CIRCUIT BREAKER PANEL	PMG	PERMANENT MAGNET GENERATOR	I⏚>	OVER CURRENT GROUND RELAY
		AVR	AUTOMATIC VOLTAGE REGULATOR	U⏚>	OVER VOLTAGE GROUND RELAY
STR	STATION TRANSFORMER PANEL	71	DETECTOR FOR RECTIFIER	84	VOLTAGE RELAY
GNP/ENP	NEUTRAL GROUNDING PANEL	DR	DISCHARGING RESISTOR	84GB	VOLTAGE RELAY (Bus VOLTAGE)
				12	OVER SPEED RELAY
PRC	FEEDER PROTECTION PANEL	Wh	WATT–HOUR METER	13	SYNCHRONOUS SPEED RELAY
CCD	COMMON CONTROL DESK	W	WATT METER WITH Max.INDICATION	14	UNDER SPEED RELAY
PRG9/10	GENERATOR PROTECTION PANEL	A	AMMETER	P ←	REVERSE POWER RELAY (2 PHASE ELEMENT)
GCD9/10	GENERATOR CONTROL DESK	V	VOLT METER	⊥=θ	FIELD LOSS RELAY
PRE	EXISTING STEP–UP TRANSFORMER PROTECTION PANEL	Vo	ZERO–PHASE–SEQUENCE VOLT METER		
		Var	VAR METER	↤⁄↦	VCB : VACUUM CIRCUIT BREAKER (For HV)
ECD	EXISTING GENERATOR CONTROL DESK	COSφ	POWERFACTORMETER	—▬—	DISCONNECTING SWITCH WITH FUSE(FDS)
SYCD	SYNCHRONOUS CONTROL DESK	Hz	FREQUENCY METER	—⁄—	ISOLATOR(ISθ)
		RH	RUNNING–HOUR METER	SA	SURGE ABSORBER
ADP	AC DISTRIBUTION PANEL	SY	SYNCHRO. METER	-◎◎-	THREE–PHASE TRANSFORMER(TR)
DC	DC POWER SUPPLY PANEL	25M	SYNCHRONIZING RELAY		
CMCC.	COMMON MOTOR CONTROL CENTER	25ASD	AUTO.SYNCHRONIZER	⫶⫶	VOLTAGE TRANSFORMER(VT)
MCC9/10	MOTOR CONTROL CENTER			⫶⫶⫶	EARTHED VOLTAGE TRANSFORMER(EVT)
BAP	BUILDING AUXILIARY PANEL	⊛	CHANGE–OVER SWITCH FOR AMMETER		
		⊕	CHANGE–OVER SWITCH FOR VOLTMETER	∈	CURRENT TRANSFORMER(CT)
		CTT	CURRENT TEST TERMINAL	—*⁄—	MCCB : MOLDED CASE CIRCUIT BREAKER (For LV)
		VTT	VOLTAGE TEST TERMINAL	CLR	CURRENT LIMITING RESISTOR
				F	FUSE

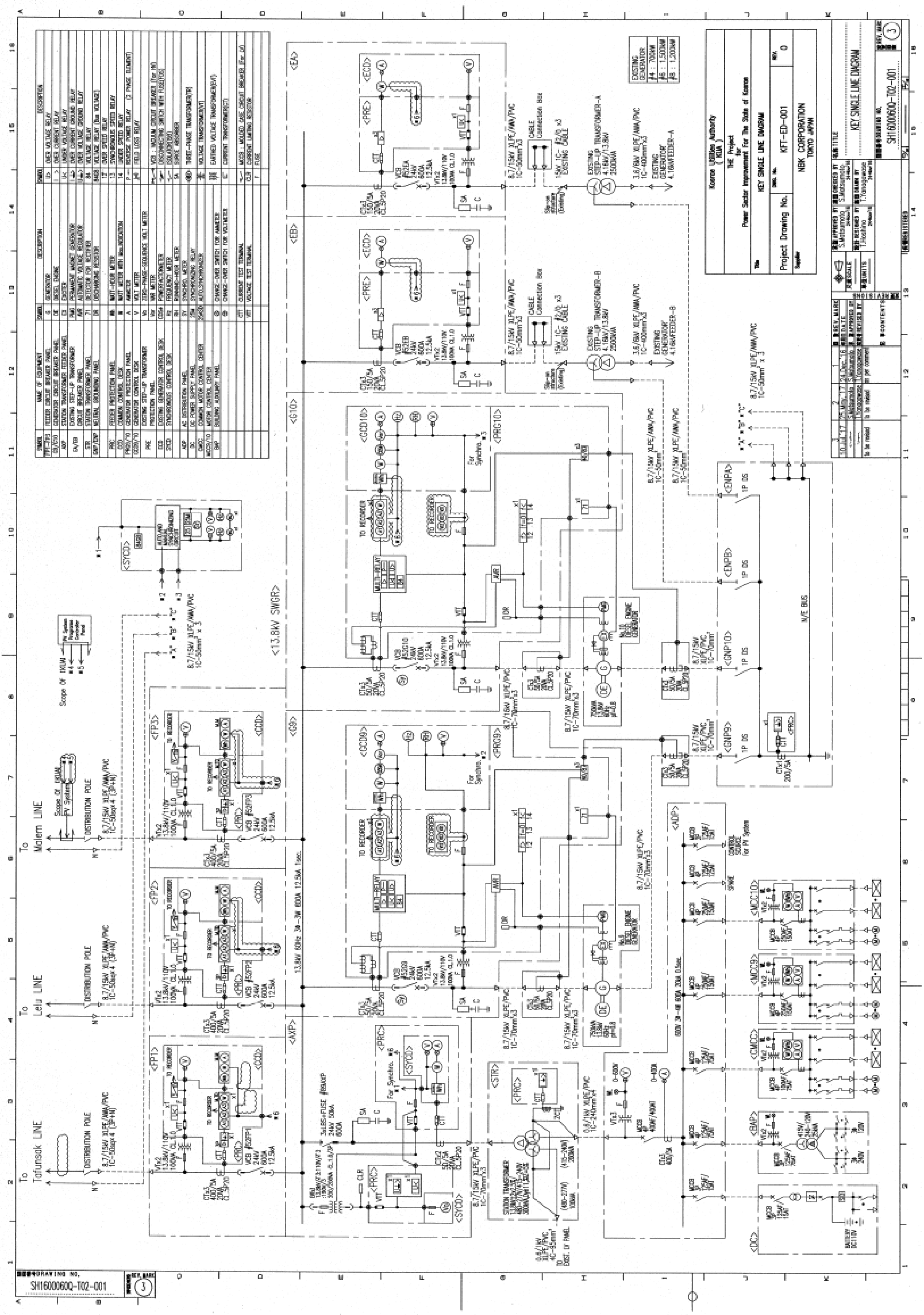


Fig. 3-1 Single-line system diagram

3.2 Protection relay

51G (Overcurrent relay) This relay picks up an overcurrent due to a short circuit or overload of a circuit using a current transformer (CT), detects it according to the magnitude of the current value, and performs operations such as tripping the circuit breaker. ● Fixed-time limit characteristic: If overload detection level is exceeded, it operates after a predetermined time has passed. ● Inverse-time limit characteristic: If overload detection level is exceeded, it operates after a time in inverse proportion to the magnitude of the input current has passed.	 Multifunction protective relay 51G, 59G, 32G, 27G, 84G
59G (Overvoltage relay) This relay detects an increase in the generation voltage due to a failure of a generator or the like and performs an operation such as tripping a circuit breaker.	
67G (Reverse power relay) By detecting the active power of a three-phase circuit, this relay protects against motoring of the generator (state in which electric power flows from the system to the generator which is the reverse of the normal state) and detects the direction of current flow to perform operations such as tripping a circuit breaker. * It may be displayed as 32G (DC reverse current relay).	
27G (AC under-voltage relay) This relay detects a decrease in power generation voltage due to power outage, short circuit, etc., and displays a warning, etc.	
84G (Voltage relay) Detects that the generator voltage has risen to a previously settled value and uses it for warning display and each voltage establishment condition (such as turning on generator circuit breaker).	
87G (Ratio differential relay) This relay detects a short-circuit inside the generator by noticing a change in the balance of each phase and the direction of current flow from when operation is sound and conducts operations such as tripping a circuit breaker.	

40G (Loss of excitation relay) When the excitation of the generator ceases, synchronous operation becomes impossible, and operation is performed at a speed higher than the synchronous speed. As a result, a high voltage is induced in the field windings which is dangerous. This relay detects the load impedance from the terminal voltage and current of the generator and performs operations such as tripping a circuit breaker.	

4. Circuit Breaker

4.1 Role

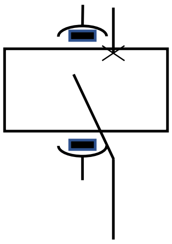
A device that interrupts current flow when a failure or abnormality in the electric circuit occurs. When turning off a circuit in which current is flowing, the current has a property of trying to flow against it. When this occurs, sparks are scattered, so if left as it is, it will cause a fire, etc. The circuit breaker's function is to shut this off. In addition to normal times, the circuit breaker can also interrupt circuits when a ground fault, short circuit, or overcurrent occurs.

- Overcurrent means that the amount current flowing in the circuit significantly increases for some reason.
  * If the current continues to flow, the circuit in which the wire gets hot may ignite.
- A ground fault occurs when a portion of a circuit that normally does not touch the ground or another part touches the ground or the like.
- A short circuit is a state in which a current flows through a part where the current normally does not flow.

4.2 Circuit breaker (VCB) (main high voltage use)

Vacuum circuit breaker (VCB)

A high-voltage circuit breaker with a unit called a "vacuum valve" which opens and closes the electrode in a vacuum. It is a mechanism which diffuses the metal vapor of sparks generated when the current is interrupted by the high vacuum and extinguishes them.Many of these are installed in power plants.

	Graphic symbol 

Pic. 4-2 Vacuum circuit breaker (VCB)

5. Transformer

5.1 Role

A device that decreases the voltage of 6.6 kV or 22 kV supplied by the electric utility to a voltage of 100 V or 200 V so that it is easy to use inside buildings or increases a voltage of 6.6 kV to a high voltage of 22 kV. The conditions of use for the transformer are specified, and its usage limit is called the rated capacity.

5.2 Construction

A transformer consists of a primary winding, a secondary winding, and an iron core.

The voltage applied to the primary winding is transformed and output to the secondary winding.

* This figure outlines a single phase transformer used for ordinary substation facilities.

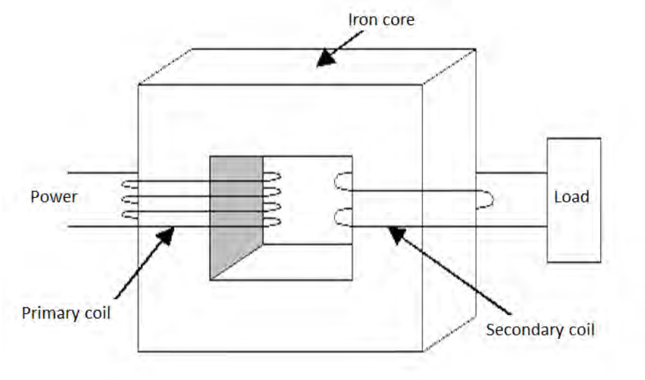


Fig. 5-1 Outline of single-phase transformer

Applying the voltage V1 [V] to the primary winding of the transformer causes current 1 [A] to flow, and a magnetic flux is induced in the iron core according to Ampère's circuital law. The magnetic flux passes through the secondary winding through the iron core.

The passing of magnetic flux through the winding is referred to as coupling.

The coils induce voltage when the coupling magnetic flux changes. This is called Faraday's law (law of electromagnetic induction). This law states that a voltage to apply a current that causes magnetic flux in the secondary winding that interferes with the change of the coupling magnetic flux is generated.

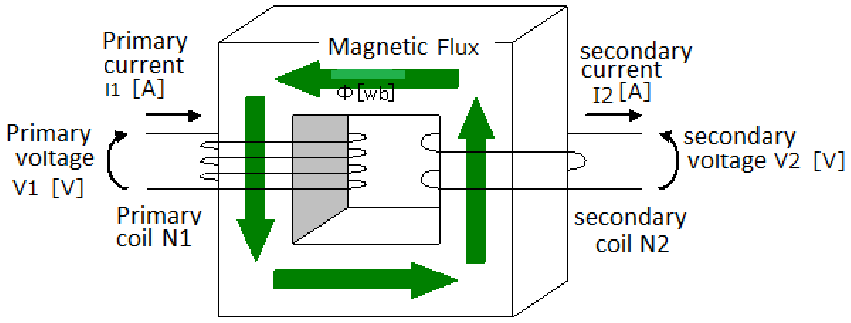
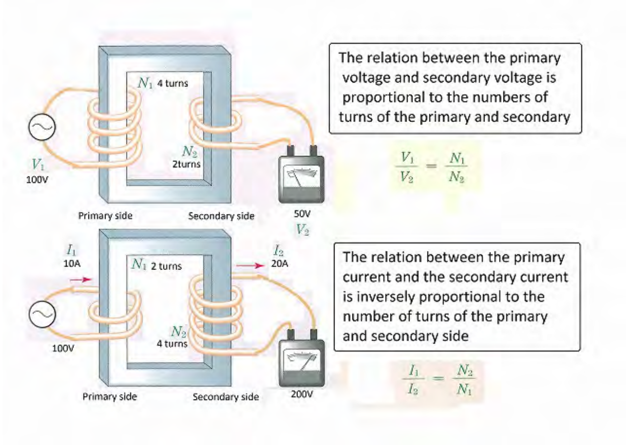


Fig. 5-2 Faraday's law outline

The power on the primary side and the secondary side of the transformer is the same in principle. With the transformer just above, the primary side will be 100 V × 10 A = 1,000 W, and the secondary side will also be 200 V × 5 A = 1,000 W. In other words, there is no change in power between the primary side and the secondary side.



The relation between the primary voltage and secondary voltage is proportional to the numbers of turns of the primary and secondary

$$\frac{V_1}{V_2} = \frac{N_1}{N_2}$$

The relation between the primary current and the secondary current is inversely proportional to the number of turns of the primary and secondary side

$$\frac{I_1}{I_2} = \frac{N_2}{N_1}$$

Fig. 5-3 Relation between primary and secondary current

The conductor is made a coil, and a power supply whose size and direction will change is connected to it. Then, current flows in this coil for a time indicated by → and the magnetic field → is generated by the current.

When this magnetic field is applied (coupled) to another coil placed at a certain distance, current will flow through the coil so as to prevent the magnetic field. This is called electromagnetic induction.

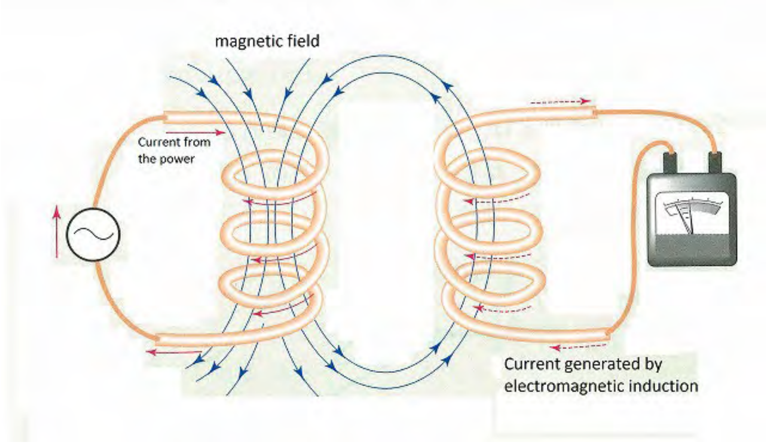
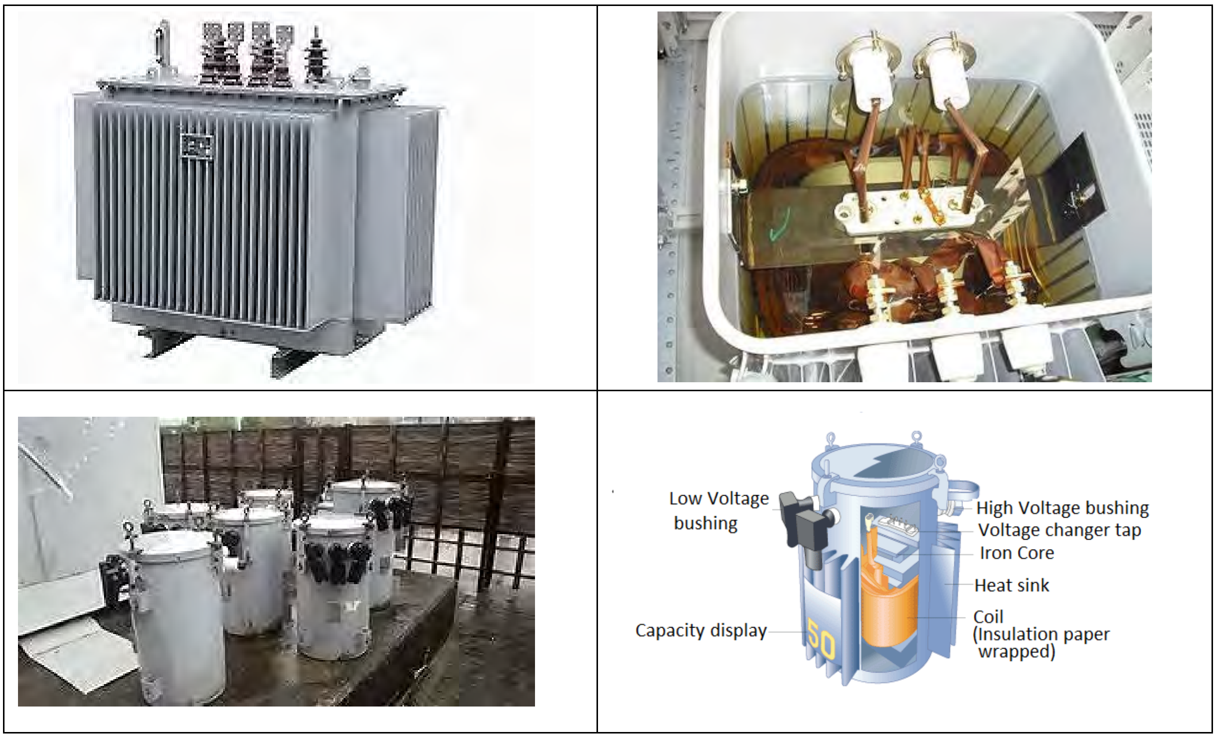


Fig. 5-4 Generation of magnetic field schematic



Pic. 5-1 Types and parts of transformers

6. PT and CT

6.1. Name

PT is the abbreviation for Potential Transformer and is now referred to as Voltage Transformer and abbreviated as VT.

CT is the abbreviation for Current Transformers.

6.2. Construction

VT a small capacity transformer composed of a primary winding, a secondary winding, and an iron core and does not differ much in structure and principle from traditional transformers. Many have fuses on the primary side, and the purpose of these fuses is to prevent the spread of faults on the power supply side due to the breakdown of insulation, etc. of the instrument transformer main body.

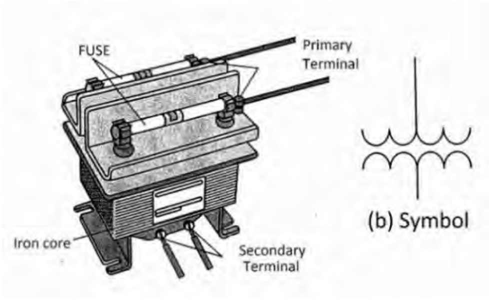


Fig.6-1　Image drwg of VT

There are ring-type and bar-type CTs depending on the structure of the primary winding. With the ring-type, only the secondary conductor is wound around the iron core, and the primary conductor goes through the ring. This type is often used in control panels.

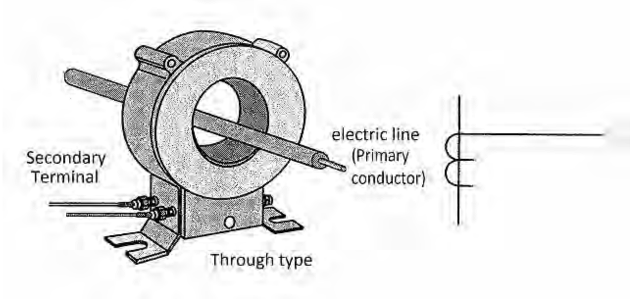


Fig.6-2 Image drwg of CT

6.3. Use

It is dangerous and unsafe to directly connect an instrument to the circuit when measuring the voltage or current of the AC high voltage circuit of the power generation equipment or even when measuring a large current in a low voltage circuit or using a protective relay. The cables for large currents are thick, so it is difficult to connect instruments, which makes construction cost high.

A VT reduces the voltage to be measured at a certain rate and supplies it to a voltmeter, and the secondary side rated voltage is 110 V.

A CT reduces the current to be measured at a certain rate and supplies it to the ammeter, and the rating of the current on the secondary side is specified to be 5 A for any rated CT of the primary current.

VTs and CTs are also designed such that even high voltages and large currents can be directly measured by instruments, so it could say they are accessories of instruments.

F: Fuse
VS: Voltmeter selector switch
AS: Ammeter changeover switch
V: Voltmeter
A: Ammeter

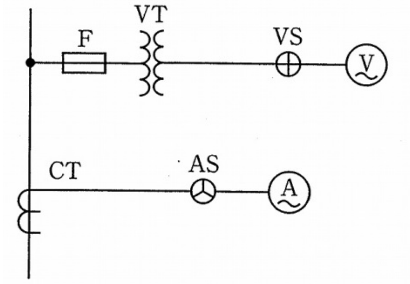


Fig 6-3 Connection of VT, CT

7. Direct Current Power Supply

7.1 Role

A direct current power supply is a power supply that supplies electricity with direct current, and plays an important role in equipment whose electricity should never be interrupted including disaster prevention systems such as communication facilities and wireless-activated disaster warning systems, emergency lighting, and power supply for control of power generation equipment in power plants (start/stop of an engine, warning display).

7.2 Construction

Operation in power plants

・For voltage compensation load, it is used for control power supply (DC 100 V) for engine start/stop, warning display circuit, etc.

・For emergency light load, it is used as a breaker input power supply (DC 110 V)

・If AC input power supply cannot be supplied, DC power is supplied from a storage battery for back up.

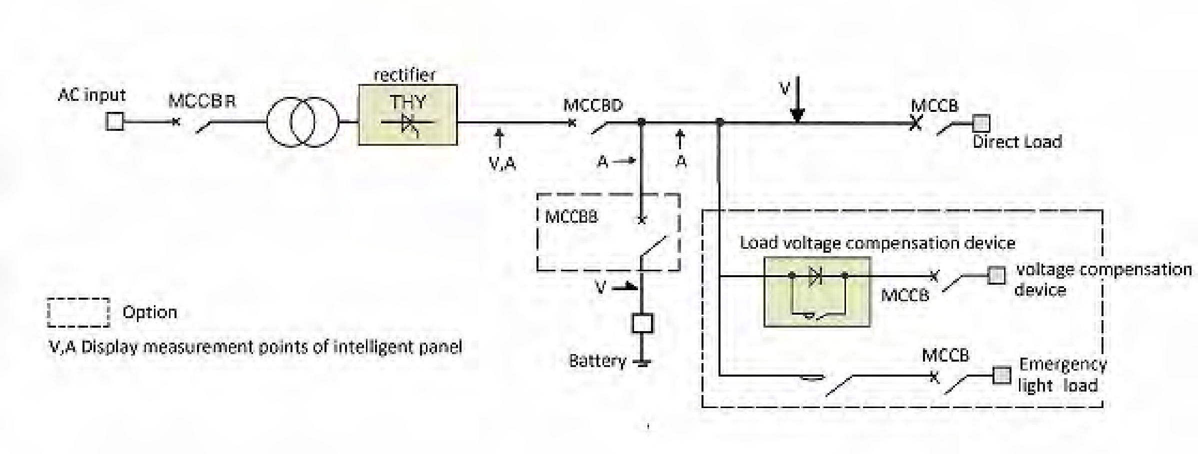


Fig 7-1 DC power supply circuit

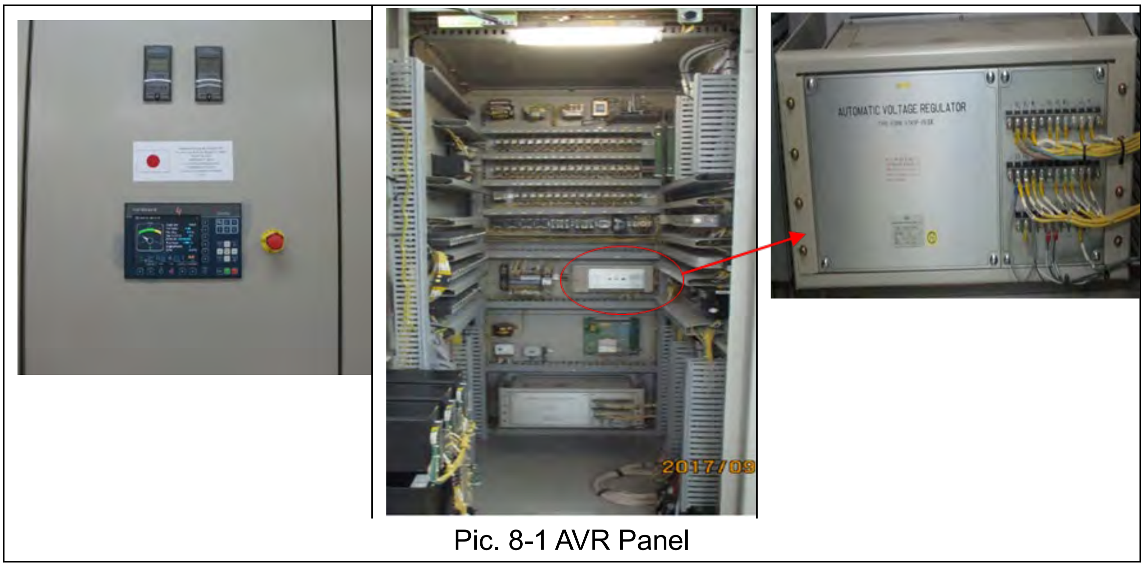
	
Pic 7-1 Conversion from AC to DC power supply	Pic 7-2 Backup storage battery

8. AVR (automatic voltage regulator)

8.1 Role

An AVR, which is the control device for synchronous generators, applies an AC voltage to the armature when a direct current is applied to the field winding. (Current flows when a load such as lighting or motive power is connected to the generator.) The control target of the generator is voltage, and the generator voltage is increased or decreased by increasing or decreasing the field current. It is not realistic for people to manually adjust the field current. Therefore, it is common to automatically control it with an AVR (automatic voltage regulator). The AVR (automatic voltage regulator) has a basic function of detecting the generator voltage and adjusting the field current according to the deviation from the set value.

8.2 AVR (automatic voltage regulator)



Pic. 8-1 AVR Panel

8.3 Circuit diagram

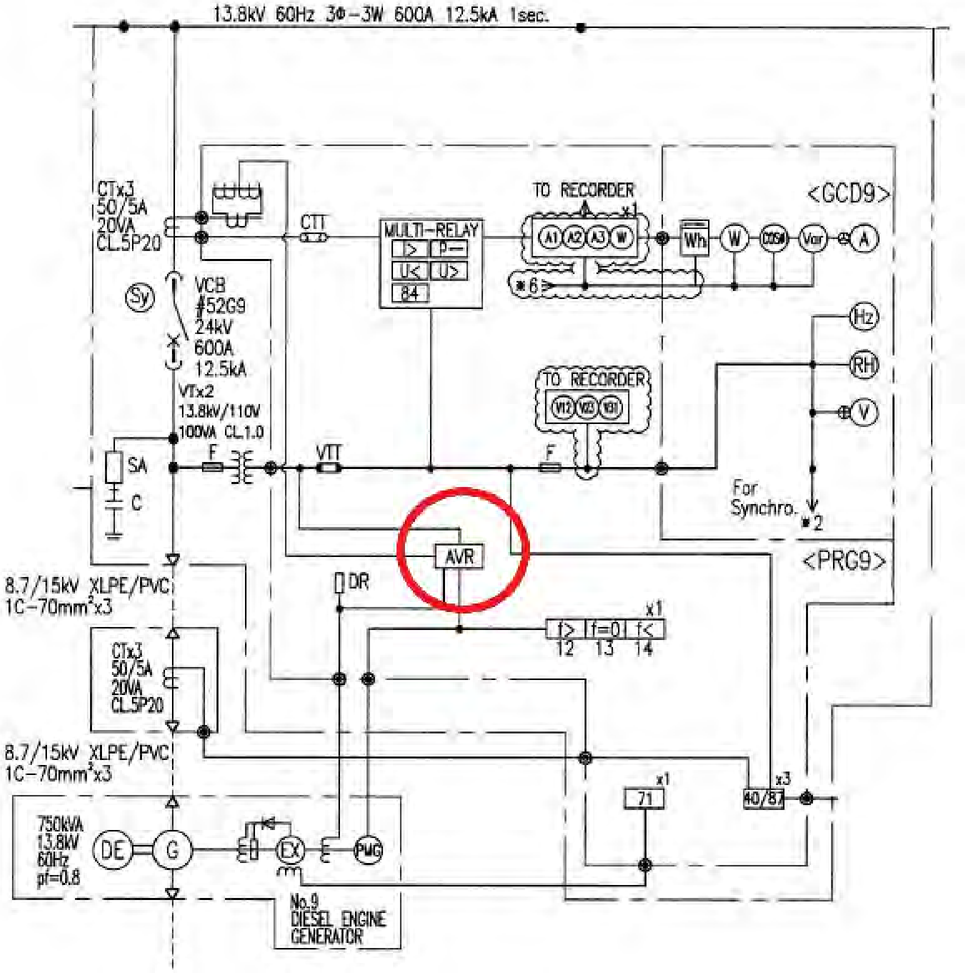


Fig 8-1 AVR circuit

8.4 Operation of AVR (Automatic Voltage Regulator) (Outline)

The generator terminal voltage is detected through the voltage transformer (VT) to determine the deviation from the voltage setter, and the field current is adjusted to regulate the voltage.

1) The generator voltage derived from the voltage transformer (VT) is compared with the reference voltage in the error voltage detection circuit to determine the difference from the set value.
2) This error voltage is amplified by the error signal amplification circuit and applied to the pulse generating circuit.
3) In the pulse generating circuit, a pulse for igniting the SCR (thyristor) is generated.
4) When the generator voltage is higher than the set value, the SCR (thyristor) is ignited with the pulse phase leading, and it shunts most of the excitation current and acts to lower the generator voltage.
5) When the generator voltage is lower than the set value, the SCR (thyristor) is not ignited with the pulse phase lagging, and the combined current of the reactor and the current transformer (CT) is led directly to the field winding and acts to raise the voltage.

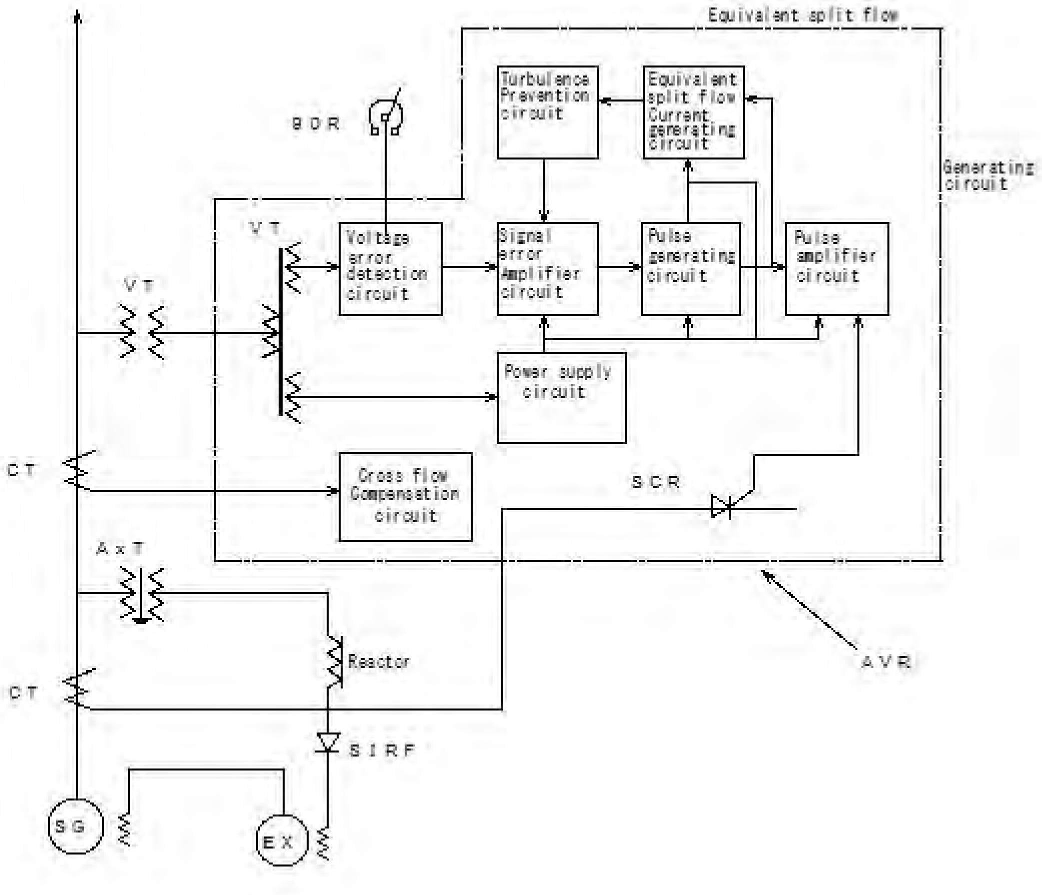


Fig.8-2 AVR (automatic voltage regulator) Configuration Diagram

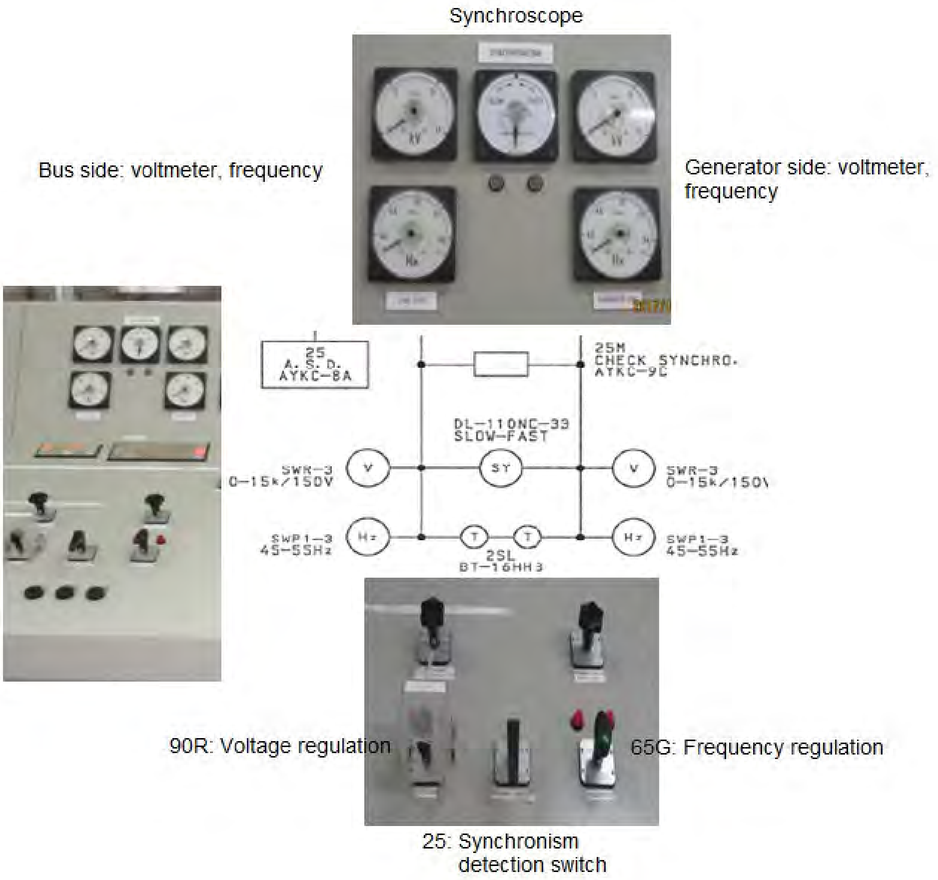
8.5 Daily maintenance and inspection

Since it is composed of all static parts, there is no item in particular which requires daily inspection but rusting of the terminals and wire connections and loosening of screws should be checked for during periodic inspections.

9. Synchronism Detection Panel

9.1 Role

This device is used to detect whether the frequencies and phases of two AC circuits match i.e. are synchronized when connecting two or more generators in parallel to the bus. When two AC circuits are connected in parallel, it is necessary to make the voltages and frequencies of both circuits nearly coincide with a synchroscope and send a command to close the circuit breaker at the point where the voltage phases coincide. When connecting in parallel when synchronized by closing the circuit breaker, there is no problem since no current flows between both circuits, but if the phases do not match, an excessive current will flow, which will adversely affect the equipment, and in some cases, lead to an accident. There is one type of synchroscope which indicates the synchronization state with a pointer by utilizing synchronizing lamps and the force between the fixed coil and the moving coil. Generally, pointer type synchroscopes are installed in power plants and substations.



Pic. 10-1 Synchroscope panel

9.2 Parallel operation of generators

1) Parallel operation conditions

When generators are operated in parallel, each generator must satisfy the following conditions.

- The rated voltages are equal
- The rated frequencies are equal
- The phases of the voltages are equal

* In order to connect the generators in parallel to the bus, adjust the frequency so that the frequencies of both the bus side and the generator side are equal and the magnitudes of the voltages are equal, and if the circuit breaker is closed at the moment the phases of the voltages coincide, the inrush current will be small, and the impact can be reduced.

2) Mechanism of synchroscope

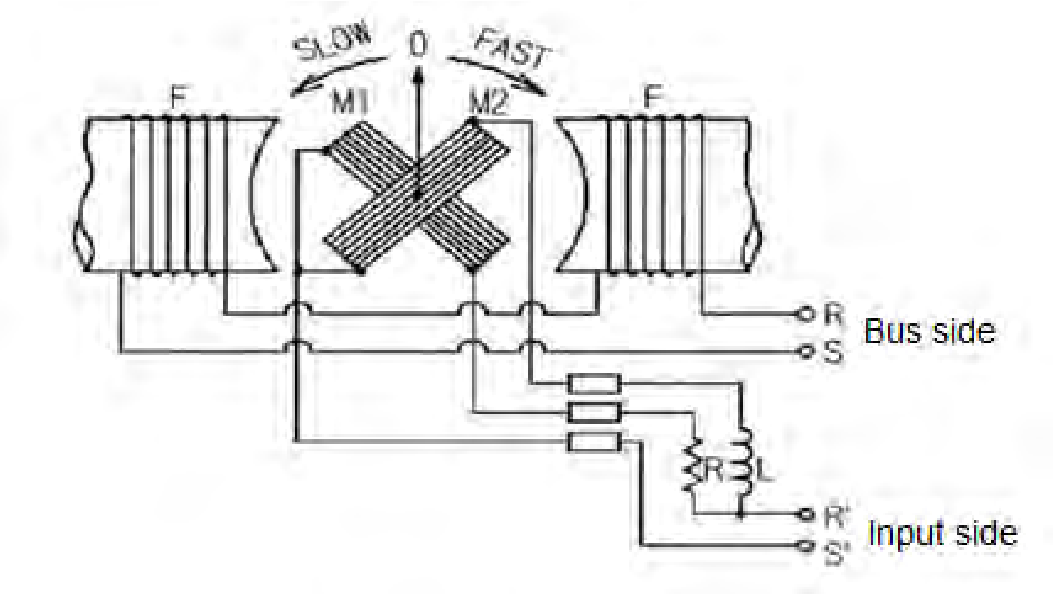


Fig. 9-2 2) Mechanism of synchroscope

F are fixed coils, and M1 and M2 coils are joined at right angles to each other, attached to the shaft, and equipped with a pointer. A resistor R is connected in series to the M1 coil, and an inductance L is connected in series to the M2 coil. The terminals R and S are connected to the input side to be operated in parallel by the terminals R' and S', and the terminals R and S connect the bus side to the fixed coil F wound around the laminated iron core. This basic circuit operates through the interaction between the alternating magnetic field produced by the power supply of the stator F and the magnetic field created by the moving coils M1 (to which the resistor R is connected) and M2 (to which the large inductance is connected).

9.3 Synchroscope pointer position

Shows the pointer state of the synchroscope based on the frequencies and phases of the bus side and the input side. When the pointer is upright and stationary, it indicates a synchronized state.

Table 10-1 List

Frequency	Phase	Pointer position
Frequencies are equal	Phases coincide	SLOW ■ FAST ⇧ Upright and stationary
Frequency	Phase	Pointer position
Frequencies are equal	Input side is leading	SLOW ■ FAST ⇗ FAST side diagonal and stationary
	Input side is lagging	SLOW ■ FAST ⇖ SLOW side diagonal and stationary
Frequencies are unequal	Speed of the input side is fast	SLOW ■ FAST ↷ Rotates to FAST side (clockwise)
	Speed of the input side is slow	SLOW ■ FAST ↶ Rotates to FAST side (counterclockwise)

End

Diesel Generation
Operation and Maintenance Manual

4. Operation of diesel generation
4.1 Operating Procedure of Diesel Power Plant

Kosrae Utilities Authority

INDEX

1. Operation Precautions

1.1. Operator precautions

1.1.1 General precautions

(1) Those who work for power plant must constantly recognize the mission of the electric power business, encourage business with close attention and a strong sense of responsibility, and strive to maintain and improve business performance.

(2) Those who are engaged in power plant operation should pay close attention to his daily health, keep their minds calm and be careful during operation.

(3) When you are sick, inform to the person in charge.

(4) Each worker or operator in the PS should always be familiar with the system, function, characteristics, operation condition etc. of the facility and deal with calm even in case of accident or other urgent need.

(5) For operation purpose, always try self-development such as acquisition of knowledge and improvement of technology, so that if disaster occurs should try to be able to take appropriate measures.

1.1.2 Clothing

(1) Operators must wear appropriate clothing suitable for power plant operation.

(2) Do not wear the following clothes.

① Buttons clothes.

② Wear upper clothes and pants that do not fit your body.

③ Clothing that exposes up to arms and legs.

④ Sandals, slippers, athletic shoes.

(3) Wear safety hats, ear-muffs, in the power station.

(4) Wear safety shoes in the power station.

1.1.3 Operation procedures

(1) Operators should be aware of the following matters according to the instruction of the generation manager.

① Operating procedures should be performed according to each method and operation manual.

② Please report to the generation manager after the operation shift is over.

③ Do not act on your own without instructions.

④ Do not attempt to solve the problem only during self-driving operation, immediately report it to the generation manager and get instructions.

1.2. Safety precautions

1.2.1 General safety precautions

(1) Daily precautions

① Keeping in mind that **"safety is given priority to everything"**, all the coworkers who work on the site should try to achieve the safety policy in accordance with each safety action guideline.

② Always keep safety in mind for those engaged in operation, be familiar with each regulation document and keep in mind the safety.

③ When paying attention to daily health and operation, keep your mind calm and do it carefully.

④ In order to safely carry out the operation and maintenance, we always try to acquire knowledge about the facility. In the event of a disaster, keep in mind that we can make appropriate emergency measures according to the direction of the generation manager or the power plant manager

(2) Compliance with safety signs

Strict observance of items indicated by safety signs and work safety signs.

(3) Compliance with status indicator tags

When using the status indicator tag, you must observe the marked matter and do not change it at all.

(4) Order of safe driving operation

Operators should operate the power plant according to the direction of the generation manager.

(5) Secure safety condition

Do not remove safety equipment.

1.2.2 Safety precautions of the generation manager.

(1) Precautions in the state of equipment, always aware that generation manager is responsible for prevention of disasters, strive to improve knowledge and skills, instruct operators, and make best efforts to prevent disasters.

(2) In the case of a disaster, generation manager shall instruct the operator calmly and promptly take the appropriate measures.

(3) Generation manager must positively discover unsafe conditions of facilities and unsafe acts of operators and take appropriate guidance and measures.

(4) Precautions before the power plant operation

① If the generation manager think that the mind and body health condition of the operator is inappropriate, must give the necessary direction to not operate.

② Check the conditions of tools and protective equipment required for operation and maintenance works.

③ When operating in the vicinity of dangerous places, take protective measures in advance and make thorough attention to operators

④ Generation manager shall take care to ensure communication between related parts when operation is made. When operation is made by 2 or more operators at the same time, operation manager must take care to prevent accident caused by insufficient communication.

(5) Precautions before operation

① When operator is in a dangerous location, attention should be paid in posture, clothes etc. to carried out an appropriate operation.

② In case of operation involving danger, do not perform alone an independent operation. Give appropriate instructions so that disasters do not occur.

③ Always pay attention to whether the use of tools and protective equipment during operation and handling are appropriate, and whether there is no mistake in motion, posture, etc.

(6) Precautions at the end of operation

① At the end of the operation, make sure that there is no abnormality in the relevant equipment, and confirm that the status indicator tag etc. is surely used.

② Confirm that tools, protective equipment and other forgets or overruns used for operation have not left.

(7) Precautions of driving operation accompanying site works

① Operation before starting work

(a) Study the scope of the work and the order of operation in advance. In addition, if you have complicated operations related to contact and make necessary arrangements and meetings beforehand outdoors, please. Also, to prepare operation procedures sheets without exception, thoroughly observe compliance.

(b)To carrying out works, the generation manager can inform to the workers that they can start the work after the operation is completed. Also, he must confirm that there is no abnormality and whether there is no obstacle to starting work

The generation manager charge of the operation will indicate to the workers to start the work. The generation manager shall give and receive the tags of work status indicator to the operators who shall put and removes the tag.

② Operation at the end of work

The work supervisor shall inform to the generation manager (or the operator) that the work is finished after verifying that there is no abnormality or obstacle to start power plant operation.

1.2.3 Staff & Operator's safety understanding

(1) Precaution of maintenance works

① Maintenance staff should understand their purpose, sequence and result sufficiently and repeat them so that they do not perform blind maneuvers, and confirm with the generation manager the work procedure.

② Check the quality of tools and protective equipment necessary for works and keep it in perfect condition.

③ The tools and protective equipment necessary for the plant operation shall be prescribed and not prescribed items shall not be used or substituted.

④ Before the maintenance work confirm the state of the device, instruments, display, protective device and so on.

⑤ When works is made in a dangerous or unsafe place, start the works after confirming that protective measures are being taken.

⑥ Be careful not to inadvertently touch the tool or approach the tool when operating near the rotating equipment or the charging section.

⑦ Before operating the gear switch and circuit breaker, be sure to check instructions, status indicator tags, opening / closing of the breaker, etc. at the work site and operate afterwards, check the breaker signal lamp and display the status indicator tag after the operation

⑧ When operating in the vicinity of high-voltage, high-temperature equipment (exhaust pipe, cylinder), pay attention to leak gas, bare pipes, etc.

(2) Getting to know after driving operation

① After works confirm whether if there is any abnormality in the state of the facility and protection equipment

② Confirm that there are no tools, protective equipment, other forgotten items or oversight at the end of the works.

③ After completing the operation, the operator reports to the generation manager in charge.

④ Be aware that accidents are easy to happen at the end of the operation or during the changeover, so be very careful.

(3) Precautions of operation accompanying work

① Operation before starting work

(a) In the stop operation, confirm the operation procedure and operate accordingly.

(b) Before operation, make sure to check the equipment or transmission or distribution line to be stopped, and check the switch or breakers amount to be operated according to the operation manual to no make mistake.

(c) In case of opening the circuit breaker, disconnecting switch, other switches, locking or securing so that breakers, disconnecting switches and other switches cannot be operated.

(d) When attaching work grounding, below (4) it is based on safety of ground operation.

(e) Report to the generation manager if the operation before the start of work is over.

② Operation at the end of work

After finishing the work, in case of starting operation confirm the following matter before and assure that there is not hindrance to the operation

(a) Confirm that there is no misplacement of tools or materials and not obstacles in the rotating parts

(b) Confirm that there is no difference in the state between before and after the work

(c) Whether the working grounding is completely removed.

(d) Check indication tags (status), and if the locking or securing part is released.

(4) Safety comprehension during earthing operation

① Be especially careful of the following matters when attaching / detaching the earth ground.

(a) Be sure to thoroughly inspect each part of the grounding tool before use.

(b) When attaching / detaching the grounding, use the status indicator tag.

(c) When attaching the ground, check the open circuit of the relevant disconnecting switch and make sure that it is not surely charged by the electricity detector.

(d) To attach a grounding tool, first connect the grounding side metal fitting to the grounding wire and then make sure that the wire side metal fitting is in contact with the equipment or electric wire.

(e) Those who attach or detach the grounding tool should pay attention so that the grounding conductor does not approach other people's equipment, electric wires, etc. as well as the body of others.

(f) Be sure to use words such as "attaching the ground" and "disconnecting the grounding" for the term of grounding attachment and detaching "remove the grounding" and "take the ground".

1.3. General precautions of operation

1.3.1 Start, stop, driving operation etc. are based on each manufacturer procedure manual.

1.3.2 Record Diary

(1) For each type of record, fill in predetermined items and numerical values at the prescribed time.

(2) The operator fills in the necessary items before the shift change.

(3) After confirming the contents, the operator responsible for operation shall confirm the fact that there is no misunderstanding, and then stamp it and keep it under the responsibility of the generation manager.

1.3.3 Receiving Equipment

After completion of the works, the operator in presence of the generation manager, confirms that there is no abnormality by carrying out the necessary site check (operation test, cleanliness), and approve the equipment receiving.

1.3.4 Shift take over

(1) Shift operator must write clearly in the diary contact matter, works and operation situation during the shift, and this information must be taken over on every shift. For items particularly necessary informed by the last shift, must be informed to the next shift. The explanation must be done in

the operation room or in site when it is necessary status confirmation.

In some cases, the generation manager will further explain to the operator about the handover details and give necessary instructions.

2. Efficient operation

2.1. Economic load allocation

Basically, generation manager must operate the power generation facility in line with economic load allocation. However, this is not applicable in case of emergencies or accidents. Also, when the generation manager is absent, the operator must decide by himself and report afterwards.

3. Patrol inspection

3.1. Purpose

The patrol aims to prevent accidents beforehand by discovering each of the equipment in advance in order to maintain safe operation of the power generation facility, and to improve economic efficiency by monitoring economical operation.

3.2. General knowledge of patrol inspection

(1) Operators make efforts to familiarize themselves with the power generation facilities from daily life, and in patrolling, operators should pay attention to slight abnormalities and strive for the early detection of abnormal equipment, appropriate measures must be taken.

(2) It is important for operators to study the characteristics of each equipment's well and to be familiar with their mutual relationships and systems. Also, to understand the state of equipment, temperature, vibration, driving noise, operators must be familiar with normal operation of the degree of openness of the valve's damper, changes indicators of each instruments depending on the load, etc.

(3) Matters specifically directed by the person responsible for power generation, things to be careful about in the takeover matters from prior shift and those who are affected by the operation, etc. are especially noted, and equipment with defects is always inspected as needed to try to avoid grasping the delay in countermeasures.

(4) In patrols, carefully wear protective hats as well as carefully wear clothing so that there is no unsafe act.

(5) When carrying out a patrol, be sure to carry the check sheet which is necessary for operation records, check the condition of the stopped equipment in addition to the operating equipment, if there is any abnormality, describe the condition and outline of the process, submit to the person responsible for power generation. In case of emergency, directly contact the generation manager.

(6) Keep instruments and glass of the oil level gauge cleaned at all times to make it easy to inspect.

(7) If any abnormality is found in equipment or other, immediately report the situation to the generation manager and if you have made an emergency repair at work site, report and receive further instructions. The generation manager shall confirm the site and give appropriate instructions and state it in a prescribed form and submit it to the operation manager. When it

is impossible to process within the shift hours, take over in the form and display the status on the site, and make sure to inform the next shift worker.

(8) Calmly handle matters in case of accident occurring during patrol on a regular basis.

(9) In case of stormy weather (typhoons, storms) or other disasters, follow the instructions of the power generation manager and try not to neglect the warning indications.

3.3. Inspection cycle

Normal checkup and inspection should be done once a shift or more basically but check it whenever necessary.

3.4. Inspection items

Inspection should be specified in the "Daily inspection item list".

3.5. Inspection procedure

3.5.1 Internal combustion engine and auxiliary equipment

(1) Check fuel tank oil level

(2) Check if lubricating oil main pressure and turbocharger lubricating oil pressure show specified pressure and lubricating oil lubricates each part and there is no abnormality in each part temperature. Note normal operating standard.

Standard pressure of lubricating oil (main lubricating oil)

Standard temperature of lubricating oil (engine outlet, oil cooler inlet)

(Note)

(a) Note that hydraulic pressure rises for about 30 minutes at the beginning of operation and then gradually drops with rise in temperature.

(b) Alarm device operation value.

Alarm setting value of lubricating oil pressure / oil temperature (depending on the manufacturer's design value) should be grasped for each unit so that measures can be taken against abnormal values.

(3) Check whether the cooling water pressure gauge shows the correct pressure, the cooling water circulates through the required parts and there is no abnormality in the cooling water outlet temperature.

Cooling water pressure standard (pump outlet) (according to manufacturer's design value)

Coolant temperature standard (cylinder head outlet average) (according to manufacturer's design value)

(Note)

(a) Alarm operation value.

The alarm set value of cooling water pressure / temperature (depending on the manufacturer's design value) is correct for each unit, ensure to correct abnormal values.

(b) Check the operation status (opening degree) of the thermostat valve.

(4) Check the fuel supply pressure; check the fuel injection pump rack scale, and whether each

cylinder is evenly distributed with fuel.

(5) Check if there is no abnormality in each cylinder exhaust temperature or there are differences in the exhaust temperature

(6) Check if there is any abnormality in the air supply, exhaust valve stem, valve arm, other sliding part, movement part

(7) Check if there is a place where sound, noise, and vibration of the turbocharger rotating part are different from normal operation

(8) Check if there is low level of lubricating oil in the manual lubricating point (external lubrication)

(9) Pay attention to the pointer and load change, and check if there is any places where the fuel control system, such as governor, fuel injection pump fuel pressure gauge, etc. is different from normal operation

(10) Check if there is any abnormality in rotation condition, pressure, temperature (rise) of each part, sound, vibration, etc. of cooling water pump, lubricating oil pump, fuel delivery pump etc.

(11) Check if there is any leakage from water, fuel, lubricating oil, exhaust gas, air system flanges, gasket, etc.

(12) Check if the cooling and heating of the lubricating oil cooler, air cooler, heavy oil heater etc. is normal

(13) Check if the exhaust pipe connections are not loose due to vibration by loosen bolts, nut split pins, etc.

(14) Keep the interior clean, especially to avoid dust near the turbocharger air inlet or the air supply valve.

(15) Check the cooling water tank, freshwater tank water volume, temperature and check the standard temperature. Also, check if there are fallen leaves and other stagnant objects in the tank and do not interfere with the function of the supply valves

(16) Check fuel flow meters and fuel consumption during every shift.

(17) Check the amount of lubricating oil. (Sampling regularly, request analysis)

(18) Check indications of each auxiliary machine operation (start, stop) and other status

(19) Check for leaks in the piping pit.

3.5.2 Generator

(1) Generator body

① Check for any abnormality in vibration, sound and temperature.
② Check if the slip ring and brush are in normal condition and no spark.
③ Check if the ambient temperature is not too high.
④ Check for any dust or garbage in the vicinity.

(2) Exciter body

① Check if the commutator brush is clean and no spark.
② Check the color of the commutator.
  1. Normal: chocolate color.

2. When brush pressure is too strong: Copper color.
3. When brush pressure is too weak: Darkened color.

③ Check a specific part of the commutator surface or other part that changed to black at regular intervals.

④ Check for any abnormal vibration or overheating of the brush.

⑤ Whether the brush length is extremely exhausted, the replacement criteria (when the brush rivet appears in the cage opening) (1/2 of the total length is a guide).

(3) Bearing

① Check the state of oil quantity, vibration, temperature of the bearing.

(4) Static excitation device (including automatic voltage regulator)

① Check for any abnormality such as overheating, abnormal noise, odor, etc.

(5) Ground wire

① Check for any abnormality in grounding wire connection and the cable protection.

3.5.3 Switchboard switchgear

(1) Generator panel, high-voltage switchboard

① Check indicated value of the voltmeter, ammeter, wattmeter, frequency meter, power factor meter, integrated wattmeter etc.

② Check equilibrium of each phase by operating voltage and current switching (VS, AS)

③ Check for loose fuse or overheating of the fuse, or if there is looseness in the test terminal.

④ Check the normal operation of each relays. (Check the contacts condition and check for abnormal noise.)

⑤ Check carefully the changing condition of the load and normal values of voltage and frequency.

⑥ Check alarms or other signal indication indicating the normal current condition. Also check any bulb burnout, or malfunction of indicator lit.

⑦ Check the condition of circuit breaker.

⑧ Check dirt and dust on the instrument board and other equipment.

(2) Operation monitoring board, power board

① Check if the display of each pressure gauge, thermometer, power meter, voltmeter is normal

② Check if the current status indication during operation or stop being normal or is there no burnt bulb

③ Check all relays are in normal working condition

④ Check if the opening and closing status of accessories and other valves is normal

(3) Oil Circuit breaker

① Check for temperature rise, oil leakage, bolts of mechanical parts, nut, split pins, etc.
② Check for any abnormality in the crack, breaker, protective cover etc. of the pipe.
③ Check for any abnormality in the opening / closing display.

(4) Power station transformer

① Check for any oil leakage, slackening of clamping portion, temperature rise.
② Check for any accumulation of dust.

(5) Isolator switch

① Check for any abnormality such as crack, breakage in the pipe.
② Check for dirt condition due to dust adhesion.
③ Check for contact conditions and overheating at the contact part.
④ Check the pin of the moving part of the complete arm and if there is slackness in the terminal part.
⑤ Check if the earth is grounded completely.

(6) Lightning arrestor

① Check for any abnormality such as cracking or breakage in the terminal, and there is no dirt.
② Check the terminal part for looseness.
③ Check for any abnormality in earth ground.
④

(7) Conductors and supportive insulation

① Check for any abnormalities such as cracks and breakage of supporting insulation.
② Check if the conductor is discolored.
③ Check for looseness at the contact part, and if there is no overheating.

(8) Cable

① Check for any abnormality such as crack, breakage, etc. at the bushing part and the terminal.
② Check for looseness or overheated terminals.
③ Check for crack/break in the cable of lead-processed part.
④ Check the grounding.
⑤ Check inside the cable pit.

3.5.4 Others

(1) Internal pumps

① Check if rotation condition and pressure is normal.
② Check for any leakage in valves, fittings, etc.

③ Check for any rarely corroded places, opening and closing of valves and cocks.
④ Conduct switching regularly with the standby pump and confirm that the spare machine can start normally.
⑤ Check if the bearing oils level and any discoloration in the oil.
⑥ Check for any presence of vibration, abnormal noise, odor, etc.
⑦ Check if the bearing temperature is normal.
⑧ Check for any abnormality in the ground wire connection condition.

(2) Storage battery and charger

① Check for any abnormal noise, odor, overheating in the charger
② Check if the voltage and current during floating operation is appropriate.
③ Check if the load current is normal.
④ Check if the earth fault display is normal and the indicator light is not faulty
⑤ Check for any abnormal switching of the Non fuse beaker (NFB). And check the state of the under-voltage relay.
⑥ Check for any looseness in each terminal
⑦ Check the color of the electrode plate of the storage battery.
⑧ Check for any curvature, short circuit, or crack dropout of the electrode plate.
⑨ Check the electrolyte level.
⑩ Check for cracks in the electrode and its support.
⑪ Check condition in contacts with the electrode plate.
⑫ Check the voltage and liquid temperature.
⑬ Check the battery compartment floor and ventilation.

(3) Fuel storage tank

① Check for any leaks in valve gland or attachment part
② Check for any rusting or corrosion.
③ Check if the level meter indication is normal.
④ Check for any abnormality in the inspection ladder, etc.
⑤ Check for any abnormality in drain valves, expansion joints, etc. (Tank drain valve and oil fence drain valve shall be always closed and make sure to open and close only when necessary)
⑥ Confirm that there is no stagnant drop of oil in the oil bunk at the time of patrol inspection and perform discharging operation appropriately.
⑦ Check the inclination of the tank.
⑧ Check for any leaked in the drum storage for waste oil.

(4) Buildings & Other

① Check for any damage in the buildings, gate fences, storage area etc.
② Check the drainage ditch for rubbish and others.

Daily inspection item list

Appendix 1-1

Eq	Items		Inspection	Remarks
Internal Combustion Engine and Auxiliary Equipment	Internal Combustion Engine	Intake / exhaust valves, valve arms, lubrication	Presence of gas leak, abnormal pressure, oil quantity	
		Governor link mechanism	Presence of looseness of pin bolt	
		Exhaust pipe	Presence of gas leak	
		Exhaust gas temperature	Presence of abnormal	
		Cylinder cover	Presence of gas leak	
		Startup main pipe	Presence of heating	
		Intake	Presence of heating	
		Chamber Door	Presence of heating	
		Mist pipe	Presence of mist abnormality	
		Chimney	Exhaust color situation	
		Acoustic and vibration	Presence of abnormality	
		Odor	Presence of abnormality	
		Fuel rack	Presence of abnormality	
		Fuel handle	Presence of abnormality	
		Commissioning of long-term stop unit		Perform trial operation at least once a month for the institution under suspension

Daily inspection item list

Appendix1-2

Eq	Items			Inspection	Remarks
internal Combustion Engine and Auxiliary Equipment	Fuel	Filtration	Hydraulic/ Strainers	Presence of abnormal differential pressure	
		Service tank		Quantity of oil, presence of leakage oil	
		Fuel meter		Status	
		Piping		Abnormal vibration, presence of leakage oil	
	Turbo charger	Status		Presence of abnormal sound and abnormal vibration	Be aware of abnormalities in bearings and rotating parts
		Casing and coolant outlet temperature		Presence of abnormality	Be careful of cooling water shortage or water cutoff
		Lubricant			
		Blower water wash		By machine side cleaning device	
	Lubricant oil	Property analysis of lubricating oil		Depending on the analysis results, some oil change or total oil change	Follow lubrication oil collection method
		Main bearing metal inlet pressure		Presence of abnormal	
		Cam chamber and inlet pressure		Presence of abnormal	
		Valve operating lubrication pressure		Presence of abnormal	

Daily inspection item list

Appendix 1-3

Eq	Items			Inspection	Remarks
Internal Combustion Engine and Ancillary Equipment	Lubricant	Filtering	Hydraulic/ Strainers	Presence of differential pressure abnormality	
		Piping		Abnormal vibration / presence of leakage oil	
		Lubricating oil pump		Presence of abnormal sound or overheating	
	Primary cooling water system	Pump		Appearance inspection	
		Bearing		Presence of overheating	
		Sound / vibration		Presence of abnormality	
		Motor		Presence of overheating	
		Piping		Appearance inspection and presence of water leakage	
		Expansion tank		Presence of abnormal water level	
	Secondary cooling water system	Pump		Appearance inspection	
		Bearing		Presence of overheating	
		Sound / vibration		Presence of abnormality	
		Motor		Presence of overheating	
		Piping		Appearance inspection and presence of water leakage	
	Cooling	Radiator		Fin condition	
		Fan motor		Presence of abnormal sound or overheating	

Daily inspection item list

Appendix1-4

Eqp	Items		Inspection	Remarks
Internal Combustion Engine and Ancillary Equipment	Air compressor	Air tank	Confirmation of pressure	
		Oil amount	Good or bad	
		Cooling water	Water flow situation	
		Sound / vibration	Presence of abnormality	
		Bearing	Presence of overheating	
		Motor	Presence of overheating	
		Drive belt	Presence of looseness	
		Piping	Presence of vibration or leakage	
		Automatic starting and stopping device	Confirmation of normal operation	
		Unloader valve	Confirmation of normal operation	
Generator	Vibration		Presence of abnormality	
	Sound		Presence of abnormality	
	Bearing	Temperature	Presence of abnormal temperature rise	
		Oil level	Difference from reference oil level	
		Oil leakage	Presence of leakage oil	

Daily inspection item list

Appendix1-5

Eqp	**Items**		**Inspection**	**Remarks**
Generator	Air cooler	Cooling water	Water situation, temperature of inlet and outlet	
		Water leak	Presence of leakage	
		Other	Presence of water, contamination of dust etc.	
Switching board	Generator panel / High voltage switchboard	Meter	Indicated value	
		Failure indicator	Confirm by test lighting	
	Circuit breaker / transformer	Oil level	Indicated value / degree of contamination	
		Oil leakage	Presence of leakage	
		Temperature	Presence of overheating	
		Lamp	Presence of blinking or disconnection	
		Other	In-board mounted equipment inspection	
Other	In-house pumps	Pump	Appearance inspection	
		Bearing	Presence of overheating	
		Sound / vibration	Presence of abnormality	
		Motor	Presence of overheating	
		Piping	Appearance inspection and presence of water leakage	
	Battery and charger	Abnormal sound	Presence	
		Strange smell	Presence	
		Overheating	Presence	
		Voltage/current	Presence of abnormal value	
	Heavy oil storage tank	Oil leakage	Presence of leakage	
		Oil level	Indicated value	
		Drain of oil fence	Presence of drain	Drain appropriately
	On the premises	Drain	Presence of sediment	
		Other	Presence of abnormal	

4. Periodical inspection (Mechanical)

This manual specifies implementation standards for periodic inspection of the diesel engine. Here, the diesel engine means an engine body and attached equipment.

4.1. Types of Inspection

The contents of the periodical inspection of the diesel engine are classified and implemented as follows.

4.1.1 Partial Inspection（Inspection C）

Implemented by adding disassembly, inspection and visual inspection of fuel valve, exhaust valve, intake valve, starting valve, supercharger, intercooler, and accessories.

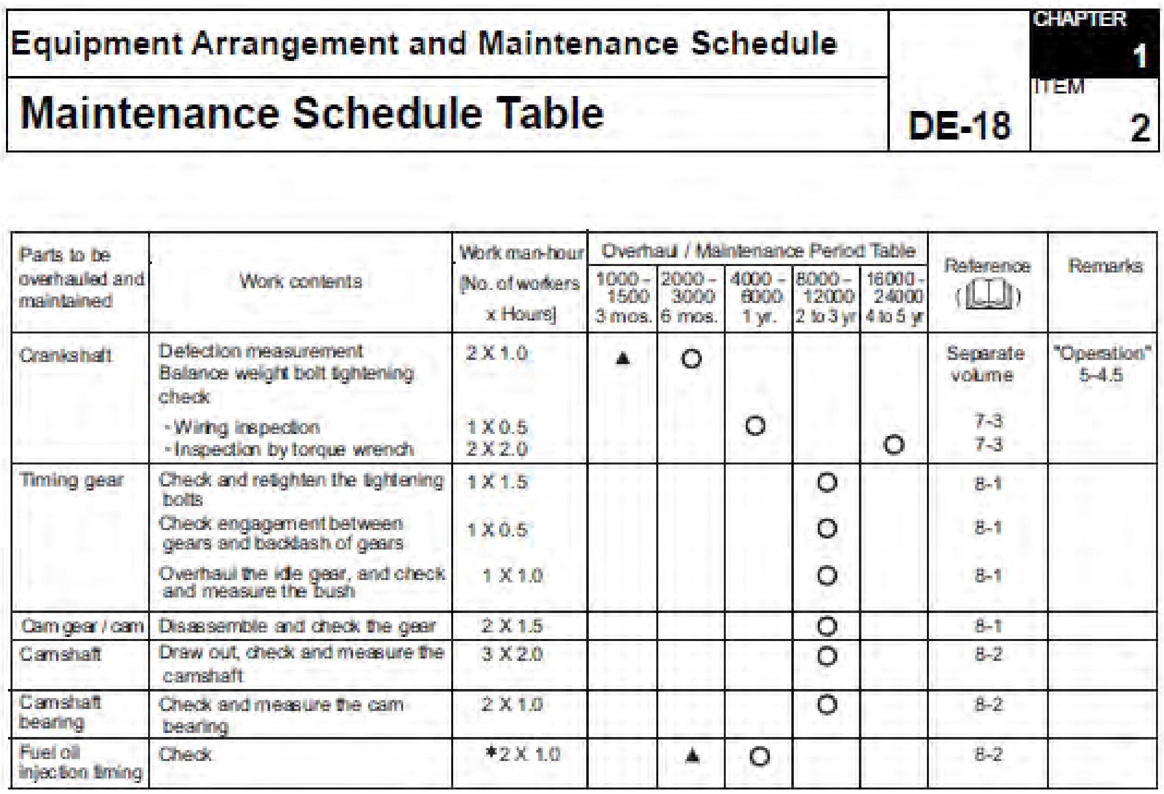
4.1.2 Middle term Inspection（Inspection D）

Implemented by adding piston release check and disassembling of other accessories to the partial inspection.

4.1.3 Total overhaul（Inspection E）

Implemented by adding total disassembly inspection of main bearings, cams, metals, gears and other accessories to the middle (intermediate) inspection.

4.2. Periodical Inspection Cycle



Equipment Arrangement and Maintenance Schedule		CHAPTER 1
Maintenance Schedule Table	**DE-18**	ITEM 2

Parts to be overhauled and maintained	Work contents	Work man-hour [No. of workers x Hours]	Overhaul / Maintenance Period Table					Reference (📖)	Remarks
			1000 - 1500 3 mos.	2000 - 3000 6 mos.	4000 - 6000 1 yr.	8000 - 12000 2 to 3 yr	16000 - 24000 4 to 5 yr		
Crankshaft	Defection measurement Balance weight bolt tightening check	2 X 1.0	▲	○				Separate volume	"Operation" 5-4.5
	･Wiring inspection	1 X 0.5			○			7-3	
	･Inspection by torque wrench	2 X 2.0					○	7-3	
Timing gear	Check and retighten the tightening bolts	1 X 1.5				○		8-1	
	Check engagement between gears and backlash of gears	1 X 0.5				○		8-1	
	Overhaul the idle gear, and check and measure the bush	1 X 1.0				○		8-1	
Cam gear / cam	Disassemble and check the gear	2 X 1.5				○		8-1	
Camshaft	Draw out, check and measure the camshaft	3 X 2.0				○		8-2	
Camshaft bearing	Check and measure the cam bearing	2 X 1.0				○		8-2	
Fuel oil injection timing	Check	*2 X 1.0		▲	○			8-2	

Fuel oil injection pump	Disassemble, and check	∗1 X 2.0			○/◎			9-4	
	- Deflector replacement		▲		◎			9-4	
	- Plunger assembly and delivery valve assembly replacement	Replace					◎	9-4	
	- Spring, spring seat and tappet replacement						◎	9-4	
Fuel oil injection valve	Check and clean and adjust the injection pressure	∗1 X 1.0	○						"Operation" 5-4
Fuel oil block	Replace O-ring (fuel high pressure block)					◎			
Fuel oil piping system	- Replacement of O-rings	2 X 2.0			○	◎			
Valve operating device	Disassemble the swing arm and check the tappet roller and bush	∗1 X 1.0			○			10	
☆ Governor	Disassemble, and check							Separate volume	Instruction manual
Governor driving device	Disassemble, check and clean - Replace the bearing and O-ring	1 X 2.0				○ ◎		11	
☆ Turbocharger	Disassemble, check and clean							Separate volume	Instruction manual
Air cooler	Disassemble, check and clean Perform hydraulic test	2 X 3.0			○			12-3	
Starting valve	Disassemble, check and replace O-ring					○/◎		13-2	
Starting air rotary valve	Disassemble, and check					○		13-2	
Fuel oil relief valve	Disassemble and check	1 X 0.5				○		14-2	
Fuel oil feed pump	Disassemble, check and replace the bearing	1 X 2.0				○/◎		14-3	Option
Pulse absorber	Replacement	1 X 0.5				◎		14-1	
Lubricating oil pump	Disassemble, check and clean - Check and replace the bearing and oil seal	2 X 1.5				○ ○/◎		15-2 15-2	

Parts to be overhauled and maintained	Work contents	Work man-hour [No. of workers x Hours]	Overhaul / maintenance Period Table					Referance (📖)	Remarks
			1000 - 1500 3 mos.	2000 - 3000 6 mos.	4000 - 6000 1yr.	8000 - 12000 2to3 yrs.	16000 - 24000 4to5 yrs.		
Cylinder head	Checking that the cylinder head bolts are tightened, and re-tightening	∗2 X 0.2		▲		○		3-1	
	Overhauling the cylinder head (top hole)	∗2 X 1.0				○		3-1	
	· Cylinder head inspection and cleaning	∗1 X 1.5				○		3-1	
	· Replacement of O-ring nozzle holder guide	∗1 X 0.5					◎	3-1	
	· Replacement of exhaust valve seat and O-ring	∗1 X 2.0					◎	3-1	
	· Jacket inspection	∗1 X 0.25				○		3-1	
	· Disassembly and inspection of indicator and safety valve	∗1 X 1.5				○		3-4	
	· Disassembly, inspection and running-in of intake and exhaust valves	∗1 X 2.0				○		3-2	
	· Disassembly and inspection of valve rotator	∗1 X 0.5		▲		○		3-2	
	· Inspection of valve spring and cotter	∗1 X 0.25		▲		○		3-2	
	· Disassembly and inspection of rocker arm	∗1 X 1.0				○		3-3	
	· Disassembly and inspection of starting valve	∗1 X 1.0				○		3-3	
Piston	Piston extraction (including connecting rod small end part)	∗2 X 1.0				○		4-3	
	· Piston inspection, cleaning and measurement	∗1 X 0.5				○		4-4	
	· Piston ring replacement	∗1 X 0.25				◎		4-4	
	· Piston pin inspection and measurement	∗1 X 0.25				○		4-4	
	· Piston pin bush inspection	∗1 X 0.25				○		4-4	

Connecting rod	Connecting rod bolt inspection and retightening	★2 X 1.0		▲	○			4-5	
	Crankpin bearing overhaul inspection, and metal replacement	★2 X 1.5				○	◎	4-4	
	· Crankpin inspection and measurement	★1 X 0.5				○		4-4 / 7-3	
	· Connecting rod bolt replacement	★2 X 1.0				○	◎	4-4	
Protection ring	Extraction, inspection, cleaning and measurement	★1 X 0.25				○		4-3 / 5-3	
Cylinder liner	Cylinder liner inner surface inspection and measurement	★1 X 1.0				○		5-3	
	Cylinder liner extraction	★2 X 2.0					○	5-4	
	· Inspection on jacket side and replacement of O-ring	★1 X 1.0					○/◎	5-5	
Main bearing	Checking that the main bearing cap bolt is tightened	★2 X 0.5				○		6-3	
	Checking main bearing disassembly and inspection, replacement of metal	★2 X 2.0				○	◎	6-3	

Parts to be overhauled and maintained	Work contents	Work man-hour [No. of workers x Hours]	Overhaul / Maintenance Period Table					Reference (📖)	Remarks
			1000 - 1500 3 mos.	2000 - 3000 6 mos.	4000 - 6000 1 yr.	8000 - 12000 2 to 3 yr	16000 - 24000 4 to 5 yr		
Lubricating oil cooler	Disassemble and clean	2X 4.0			○			15-3	Instruction manual
Lubricating oil relief valve	Disassemble and check	1 X 0.5				○		15-4	
Lubricating oil thermostat valve	Disassemble, check, clean and replace the tappet	1 X 1.0				○	◉	15-5	
Lubricating oil filter	Disassemble, check and clean							15-6	Instruction manual
Cooling water pump	Disassemble, check and clean ◦Replace the oil seal and mechanical seal ◦Replace the bearing	★ 2 X 2.0				○ ◉ ◉		16-2 16-2 16-2	
Cooling water bypass valve	Disassemble, check and clean and replace the O-ring	1 X 1.0				○/◉		16-3	
Cooling water thermostat valve	Disassemble, check and clean or replace	1 X 0.25			○	◉			
Fuel oil control cylinder (fuel oil shutoff/ control device)	Disassemble, check and clean and replace the O-ring and seal	1 X 1.0				○/◉		17	
Instruments	Replace the pressure gauge hose	1 X 1.0					◉	18	
	Check the pressure gauge and tachometer	(adjustment)	○				(○)	18	
	Seal pot (heavy fuel oil type) Change ethylen glycol	1 X 0.5			◉			18	

Notes:

1. The above table shows the standard values of the man-hour as well as the overhaul and maintenance period under the conditions of general use of the heavy fuel oil.

   In servicing an actual engine, initially set the work man-hour more, and set the overhaul and maintenance interval shorter than those shown in the table.

   Later reset the work man-hour as well as the overhaul and maintenance interval to the most appropriate values, according to the operating conditions, work environment, and the results of the overhaul.
2. The work man-hour is based on the standard values for the experienced workers who are also skilled in restoration. Therefore, please plan to have extra times for beginner.
3. The mark "★" given in the work-hour column indicates the man-hour per unit (one cylinder or one bearing). When the number of the objects is "n" pieces, multiply the value by "n".
4. Have the work marked with "☆" executed by a professional technician of the manufacturer or maintenance company, of conduct the work under his guidance.

Table-1 Standard Periodical Inspection Cycle

4.3. Periodical Inspection Manual

The table 2 shows the inspection items of the diesel engine main body and attached equipment. In principle, parts are exchanged in accordance with the replacement criteria set for each model according to the regular inspection type. In this case, when a defective part (crack, scratch and misconnection) is found even for a part other than replacement standard, repairment or replacement is performed.

4.4. Result of Inspection

The person responsible for the work (or the operator) shall confirm whether the regular inspection work was carried out by the contractor based on this procedure. In addition, the construction supervisory section shall submit a report from the regular inspection work contractor and keep it during the life of the unit.

4.5. Others

For fuel filters of high-speed unit, replacement should be carried out every 1,000-hour operation.

Table-2-①　　Inspection Items（Diesel Engine）

Name / Inspection Items	All Repair	Inspection, State of Repairment, Treatment, Findings
1. Meetings		
(1) Meeting about construction overview and safety work	○	
2.Check before disassembly		
(1) State of starting	○	
(2) Inspection of vibration, noise, existence of leakage oil and water	○	
(3) Intake and exhaust valves Rotating of Roto-Cap	○	
3.Check before disassembly		
(1) Inspection of coupling and bolts	○	

5. Periodical inspection (Electrical and Instrumentation Equipment)

5.1. Objective

This manual shall specify the implementation standards for periodic inspections of electrical and instrumentation equipment out of the periodic inspections specified in the "Internal Combustion Power Plant Maintenance and Inspection Manual".

5.2. Types of Periodical Inspection

The inspections of electrical and instrumentation equipment shall be classified and implemented as follows. (See Table 3)

5.2.1 Regular inspection

Conduct general items considered to be necessary from the viewpoint of securing the safety of power generation facilities and maintaining functions.

5.2.2 Detailed inspection

In addition to ordinary inspection items, conduct inspections on equipment requiring internal checks such as generators, exciters, circuit breakers, tramsformers, AVR, AFC, data loggers, and instruments (instrument collecting panel and accessories).

5.3. Periodical Inspection Cycle

5.3.1 Regular inspection

The 1st capacity unit at each power plant is once a year, the other units and the common facilities are once every 2 years.

5.3.2 Detailed inspection

Appropriate implementation is made according to judgment of the power generation manager.

5.4. Periodical Inspection Manual

The procedures for implementing regular inspection and detailed inspection are shown in Table-3 for the types of inspections (electrical and instrumentation equipment) and regular inspection method (electrical equipment) (Table-4), (instrumentation equipment) (Table-5).

Repair or replace the defective part found as a result of regular inspection.

5.5. Result of Inspection

The responsible person for the work (or the power plant person) should confirm whether the inspection was carried out by the contractor based on this manual.

5.6. Insulation Measurement

For long-term stop units, insulation measurement shall be carried out at a time not exceeding one month and test operation shall be confirmed.

Table－3 Types of Periodical Inspection (Electrical Equipment)

Part	Equipment Name	Regular inspection	Detailed inspection
Unit	1. Generator	○	
	2. Exciter	○	
	3. Generator Control Panel	○	
	4. Generator Circuit Breaker Panel	○	
	5. Auxiliary Relay Panel	○	
	6. Power plant Transformer Panel		○
	7. Power plant Transformer Circuit Breaker Panel		○
	8. Low Voltage Power Panel	○	
	9. Electromagnetic Switch Panel	○	
	10. Auxiliary Machine Operation Panel（On-site）	○	
	11. Auxiliary Machine Operation Panel（Remote）	○	
	12. Connecting Terminal Panel	○	
Common	14. Busbar Panel		○
	15. Distribution Control Panel		○
	16. Distribution Circuit Breaker Panel		○
	17. Main Transformer Circuit Breaker, Common Auxiliary Machine Circuit Breakers	○	
	18. DC Power Supply	○	
	19. DC Panel board	○	
	20. Data Logger	○	
	21. Auto Frequency Control	○	
	22. Transducer / Converter	○	
	23. Watt-Hour Meter	○	
	24. Recorder	○	
	25. Syncroscope Panel	○	
	26. Remote Control Panel	○	
	27. Main Transformer	○	
	28. Auxiliary devices Motor	○	

Table－4 Periodical Inspection Manual（Electrical Equipment）

Inspection Items	**Regular inspection**	**Detailed inspection**
1. Alternator		
1. Visual inspection, cleaning	○	
2. Rotor, Stator, clearance measurement	○	
3. Rotor, Stator, internal inspection, cleaning	○	
4. Slip ring inspection, cleaning	○	
5. Washing and drying generator（cover disassemble）	○	
6. Brush and brush holder inspection	○	
7. Axial current prevention insulating plate check	○	
8. Space heating inspection（Operation Check）	○	
9. Tacho-generator inspection（Voltage Measurement）	○	
10. Coil Insulation inspection	○	
11. Winding wire holding wedge	○	
12. Connecting and Leading Wire inspection	○	
13. End of Coil inspection	○	
14. Iron core support, fastening metal inspection	○	
15. Air duct, Filter inspection, cleaning	○	
16. Lead terminal inspection	○	
17. Grounding inspection	○	
18. Insulation Resistance Measurement（Rotor, Stator）	○	
2. Exciter		
1．Visual inspection, cleaning	○	
2．Internal inspection, cleaning	○	
3．Armature, Field Winding clearance measurement	○	
4．Washing and Drying Exciter	○	
5．Commutator inspection	○	
6．Brush and Brush Holder inspection	○	
7．Coil Insulation inspection	○	
8．Winding wire holding wedge inspection	○	
9．Connecting and Leading Wire inspection	○	
10. Iron core support, fastening metal inspection	○	
11. Air Duct, Filter inspection, cleaning	○	
12. Lead terminal inspection	○	
13. Insulation Resistance Measurement（Armature, Field Winding）	○	
3. Generator Control Panel		
1. Visual inspection	○	
2. Check dust or rust of inside panels	○	
3. Check damaged mechanical equipment	○	

Inspection Items	Regular inspection	Detailed inspection
4. Light wiring of inside panel inspection	○	
5. Grounding wire inspection	○○	
6. Damaged wiring, discoloration, dust, terminal, connection point and damage of tightening inspection	○	
7. CT, PT inspection, error inspection	○	
8. Meter inspection, Care, Error inspection Ammeter, Voltmeter, Tachometer, Watt meter, power factor meter	○	
9. Protection Relay inspection adjustment Structural inspection, Characteristic test Over current relay, Over voltage relay, Reverse Power Relay, Ratio differential relay, Voltage relay, Undervoltage relay	○	
10. Auxiliary relay inspection adjustment Sequence configuration relay, Power relay, Timers 86-1, 86-2	○	
11. Damaged operating switch contacts, Contact status inspection	○	
12. Indicator inspection		
13. Converter inspection adjustment, Error inspection Voltage converter, Current converter, Power converter, Power factor converter	○	
14. Watt meter inspection adjustment, Error, inspection	○	
15. Distribution circuit breaker (MCB) inspection	○	
16. Magnet switch (MS) inspection	○	
17. Cables inspection	○	
18. Fuses inspection	○	
19. Connection terminals inspection adjustment	○	
20. Sequence test	○	
4. Generator Circuit Breaker Panel		
1. Visual inspection	○	
2. Check dust or rust of inside panels	○	
3. Check damaged mechanical equipment	○	
4. Light wiring of inside panel inspection	○	
5. Grounding wire inspection	○	
6. Damaged wiring, discoloration, dust, terminal, connection point and damage of tightening inspection	○	
7. Busbar inspection High, Low voltage	○	
8. Disconnect Switch inspection, Operating Mechanism, Contact point inspection	○	
9. Voltage Transformer, Current Transformer inspection	○	

Inspection Items	Regular inspection	Detailed inspection
10. Circuit Breakers ①inspection ②Open/Close test	○	
● Vacuum Circuit Breaker		
①Vacuum interrupter inspection	○	
a . Measurement of contact consumption		
b . Three phases complete or not		
②Disassembly inspection	○	
③Operation mechanism inspection	○	
④Interruption time measurement	○	
⑤Degree of vacuum measurement	○	
11. Meter inspection	○	
Ammeter, Voltmeter, Watt meter, Power factor meter		
12. Protection Relay inspection adjustment	○	
Over current relay, Over voltage relay, Reverse Power Relay,		
Ratio differential relay, Voltage relay, Under voltage relay		
13. Auxiliary Relay inspection adjustment Timer	○	
14. Operating device inspection	○	
15. Indicator inspection	○	
16. Distribution Circuit Breaker(MCB) inspection	○	
17. Magnet switch(MS)inspection	○	
18. Cables inspection	○	
19. Fuses inspection	○	
20. Connection terminals inspection	○	
21. Sequence test implement with control panel	○	
22. Insulation Resistance Measurement	○	
5. Exciter Panel		
1. Visual inspection	○	
2. Check dust or rust of inside panels	○	
3. Check damaged mechanical equipment	○	
4. Light wiring of inside panel inspection	○	
5. Grounding wire inspection	○	
6. Damaged wiring, discoloration, dust, terminal, connection point	○	
and damage of tightening inspection	○	
7. CT, PT inspection, error inspection	○	
8. Exciter inspection	○	
9. Meter inspection, Error inspection, Ammeter, Voltmeter	○	
10. Protection relay inspection, adjustment, Structural inspection,	○	
Characteristic test, Ratio differential relay, Winding temperature		
relay		

Inspection Items	Regular inspection	Detailed inspection
11. Auxiliary Relay inspection adjustment Sequence configuration relay, Power relay, Timers	○	
12. Operating device inspection adjustment Push-button switch	○	
13. Indicator inspection	○	
14. Distribution Circuit Breaker(MCB) inspection	○	
15. Magnet switch(MS)inspection	○	
16. Cables inspection	○	
17. Fuses inspection	○	
18. Connection terminals inspection adjustment	○	
19. Sequence test, Imprement with starting panel and control panel	○	
20. Insulation Resistance Measurement	○	
6. Auxiliary Control Relay Panel		
1. Visual inspection	○	
2. Check dust or rust of inside panels	○	
3. Check damaged mechanical equipment	○	
4. Main and other grounding wire inspection	○	
5. Damaged wiring, discoloration, dust, terminal, connection point and damage of tightening inspection on the back of panel	○	
6. Speed relay inspection adjustment, error inspection （Electronic）	○	
7. Auxiliary control relay inspection, Sequence configuration relay, Power relay, Timer	○	
8. Distribution circuit breaker(MCB) inspection	○	
9. Magnet switch(MS)inspection	○	
10. Cables inspection	○	
11. Fuses inspection	○	
12. Connection terminals inspection	○	
13. Sequence test	○	
7. Power plant Transformers Panel		
1. Visual inspection		○
2. Check dust or rust of inside panels		○
3. Check damaged mechanical equipment		○
4. Light wiring of inside panel inspection		○
5. Grounding wire inspection		○
6. Damaged wiring, discoloration, dust, terminal, connection point and damage of tightening inspection		○

Inspection Items	Regular inspection	Detailed inspection
7. Disconnect switch inspection, Contact point inspection		○
8. CT, PT inspection, error inspection		○
9. In-house transformer inspection, Insulating oil inspection Insulating oil resistance voltage test		○
10. Meter inspection adjustment, error inspection Ammeter, Voltmeter, Watt meter, Power factor meter		○
11. Protection Relay inspection adjustment, Structural inspection, Characteristic test, Over current relay, Under voltage relay		○
12. Auxiliary Relay inspection Sequence configuration relay, Power relay, Timer		○
13. Operating device inspection		○
14. Indicator inspection		○
15. Converter inspection adjustment, error inspection Voltage converter, Power converter, Current converter		○
16. Watt-hour meter inspection adjustment, error test		○
17. Load Breaker Switch (LBS) inspection Operation mechanism inspection, Contact point inspection		○
18. Distribution Circuit Breaker(MCB) inspection		○
19. Magnet switch(MS) inspection		○
20. Cables inspection		○
21. Fuses inspection		○
22. Connection terminals inspection		○
23. Sequence test		○
24. Insulation resistance measurement		○
8. Power station transformer, circuit breaker		
1. Visual inspection		○
2. Check dust or rust of inside panels		○
3. Check damaged mechanical equipment		○
4. Light wiring of inside panel inspection		○
5. Grounding wire inspection		○
6. Damaged wiring, discoloration, dust, terminal, connection point and damage of tightening inspection		○
7. Disconnect switch Operation mechanism , Contact point inspection		○
8. PT, CT inspection		○

Inspection Items	Regular inspection	Detailed inspection
9. Circuit Breakers ①inspection ②Open Close test		
● Vacuum circuit breakers		○
①inspection		
②Vacuum interrupter inspection		
ａ. Measurement of contact consumption		
ｂ. Three phases complete or not		
③Disassembly inspection		
④Operation mechanism inspection		
⑤Interruption time measurement		
⑥Degree of vacuum measurement		
･Visual structural inspection		
･Measurement		
･Disassembly inspection		
10. Protection relay inspection adjustment, structural inspection, Characteristic test		○
11. Converter inspection adjustment, error inspection Voltage converter, Current converter, Power converter, Power factor converter		○
12. Meter inspection adjustment Ammeter, Voltmeter, Watt meter, Power factor meter		○
13. Auxiliary relay inspection adjustment Sequence configuration relay, Power relay, Timer		○
14. Distribution circuit breaker(MCB) inspection		○
15. Magnet switch(MS) inspection		○
16. Operating device inspection		○
17. Push-button switch inspection		○
18. Indicator inspection		○
19. Status indicator inspection		○
20. Watt-hour meter inspection, error inspection		○
21. Cables inspection		○
22. Fuses（Low, High Voltage）inspection		○
23. Connection terminals inspection		○
24. Sequence test		○
25. Insulation resistance measurement		○

Inspection Items	Regular inspection	Detailed inspection
9. Low Voltage Panel		
1. Visual inspection	○	
2. Check dust or rust of inside panels	○	
3. Check damaged mechanical equipment	○	
4. Light wiring of inside panel inspection	○	
5. Grounding wire inspection	○	
6. Damaged wiring, discoloration, dust, terminal, connection point and damage of tightening inspection	○	
7. Busbar（Low voltage）inspection	○	
8. Instrument converter, CT inspection	○	
9. Protection relay inspection adjustment, Structural inspection, Characteristic test, over current relay	○	
10. Meter inspection, error inspection Ammeter, Voltmeter Watt meter Power factor meter	○	
11. Auxiliary Relay inspection adjustment Sequence configuration relay, Power relay, Timer inspection	○	
12. Distribution Circuit Breaker (MCB) inspection	○	
13. Magnet switch (MS) inspection	○	
14. Operating device inspection	○	
15. Indicator inspection	○	
16. Watt-hour meter inspection adjustment, error inspection	○	
17. Cables inspection	○	
18. Fuses inspection	○	
19. Connection terminals inspection	○	
20. Insulation resistance measurement	○	
10. MCCB Panel		
1. Cables inspection	○	
2. Fuses inspection	○	
3. Connection terminals inspection	○	
4. Sequence test	○	
5. Insulation resistance measurement	○	

Inspection Items	Regular inspection	Detailed inspection
11. Auxiliary Machine Operation Panel（On-site）		
1. Visual inspection	○	
2. Check dust or rust of inside panels	○	
3. Check damaged mechanical equipment	○	
4. Grounding wire inspection	○	
5. Damaged wiring, discoloration, dust, terminal, connection point and damage of tightening inspection	○	
6. Meter inspection adjustment error inspection Ammeter, Voltmeter, Watt meter	○	
7. Distribution circuit breaker(MCB) inspection	○	
8. Operating device inspection	○	
9. Indicator inspection	○	
10. Cables inspection	○	
11. Fuses inspection	○	
12. Connection terminals inspection	○	
13. Sequence test. Implement with magnet switch	○	
12. Auxiliary Machine Operation Panel（Remote）		
1. Visual inspection	○	
2. Check dust or rust of inside panels	○	
3. Check damaged mechanical equipment	○	
4. Grounding wire inspection	○	
5. Damaged wiring, discoloration, dust, terminal, connection point and damage of tightening inspection	○	
6. Meter inspection adjustment error inspection Ammeter, Voltmeter, Watt meter	○	
7. Distribution circuit breaker(MCB) inspection	○	
8. Operating device inspection	○	
9. Indicator inspection	○	
10. Cables inspection	○	
11. Fuses inspection	○	
12. Connection terminals inspection	○	
13. Sequence test. Implement with magnet switch	○	

Inspection Items	**Regular inspection**	**Detailed inspection**
13. Connecting Terminal Panel / junction box		
1. Visual inspection	○	
2. Check dust or rust of inside panels	○	
3. Grounding wire inspection	○	
4. Connection point, damage of tightening inspection	○	
5. Connector inspection	○	
6. Cables inspection	○	
14. Busbar Panel		
1. Visual inspection	○	
2. Check dust or rust of inside panels	○	
3. Check damaged mechanical equipment	○	
4. Light wiring of inside panel inspection	○	
5. Status of grounding	○	
6. Damaged wiring, discoloration, dust, terminal, connection point and damage of tightening inspection	○	
7. Busbar inspection	○	
8. Disconnect switch inspection	○	
Main body and Operation mechanism inspection		
Contact point inspection		
9. PT, CT inspection	○	
10. Circuit Breakers ①inspection ②Open close test	○	
● Vacuum Circuit Breakers	○	
①inspection	○	
②Vacuum interrupter inspection	○	
a . Measurement of contact consumption		
b . Three phase complete or not		
③Disassembly inspection	○	
④Operation mechanism inspection	○	
⑤Interruption time measurement	○	
⑥Degree of vacuum measurement	○	
11. Protection relay inspection adjustment Structural inspection, Characteristic test, over current relay	○	
12. Converter inspection adjustment error inspection	○	
Current converter , Power converter,		
13. Meter inspection adjustment error inspection	○	
Ammeter, Watt meter		

Inspection Items	Regular inspection	Detailed inspection
14. Auxiliary relay inspection Sequence configuration relay	○	
15. Distribution Circuit Breaker(MCB) inspection	○	
16. Magnet switch(MS)inspection	○	
17. Operating device inspection	○	
18. Indicator inspection	○	
19. Watt-hour meter inspection adjustment error inspection	○	
20. Cables inspection	○	
21. Fuses（Low, High voltage）inspection	○	
22. Connection terminals inspection	○	
23. Insulation resistance measurement	○	
15. Distribution Control Panel		
1. Visual inspection		○
2. Check dust or rust of inside panels		○
3. Check damaged mechanical equipment		○
4. Grounding wire inspection		○
5. Damaged wiring, discoloration, dust, terminal, connection point		○
and damage of tightening inspection		○
6. Protection Relay, inspection adjustment, Structural inspection, Characteristic test, Over current relay, Ground fault direction relay, Ground overvoltage relay, Frequency relay, Reclosing relay		○
7. Converter, inspection adjustment, error inspection Current converter, Power converter,		○
8. Meter, inspection adjustment, error inspection, Ammeter, Voltmeter, Watt meter, Power factor meter		○
9. Auxiliary Relay, inspection, Sequence configuration relay, Power relay, Timer		○
10. Distribution Circuit Breaker(MCB) inspection		○
11. Magnet switch(MS)inspection		○
12. Operating device , inspection		○
13. Indicator, inspection		○
14. Watt-hour meter, inspection adjustment, error inspection		○
15. Cables, inspection		○
16. Fuses（Low, High voltage）inspection		○
17. Connection terminals inspection		○
18. Sequence test		○
19. Insulation resistance measurement		○

Inspection Items	Regular inspection	Detailed inspection
16. Distribution Circuit Breaker Panel		
1. Visual inspection		○
2. Check dust or rust of inside panels		○
3. Check damaged mechanical equipment		○
4. Light wiring of inside panel inspection		○
5. Grounding wire inspection		○
6. Damaged wiring, discoloration, dust, terminal, connection point and damage of tightening inspection		○
7. Busbar（High voltage）inspection		○
8. Disconnect switch Main body and Operation mechanism inspection, Contact point inspection		○
9. PT, CT, inspection		○
10. Circuit Breakers		○
① Inspection		
② Open close test		
・Vacuum Circuit Breakers		
①Inspection		
②Vacuum interrupter inspection		
a . Measurement of contact consumption		
b . Three phase complete or not		
③Disassembly inspection		
① Operation mechanism inspection		
② Interruption time measurement		
③ Degree of vacuum measurement		
11. Protection Relay, inspection adjustment, Structural inspection, Characteristic test Over current relay, Ground fault direction relay, Ground overvoltage relay, Frequency relay		○
12. Converter inspection adjustment error inspection Current converter Voltage converter, Power converter		○
13. Meter inspection adjustment error inspection, Ammeter, Watt meter		○
14. Auxiliary Relay, inspection, Sequence configuration relay, Power relay, Timer		○
15. Distribution Circuit Breaker(MCB) inspection		○
16. Magnet switch(MS) inspection		○
17. Operating device inspection		○
18. Indicator inspection		○

Inspection Items	Regular inspection	Detailed inspection
19. Watt-hour meter inspection adjustment error inspection		○
20. Grounding potential transformer(GPT）inspection		○
21. Zero phase current transformer (ZCT) inspection, Characteristic test, Implement with ground fault direction relay		○
22. Lightning arrester inspection		○
23. Cables inspection		○
24. Fuses（Low, High voltage）inspection		○
25. Connection terminals inspection		○
26. Sequence test		○
27. Artificial ground fault test		○

17. Main Transformer Circuit Breaker, Common Auxiliary Machine Circuit Breakers		
1. Visual inspection	○	
2. Check dust or rust of inside panels	○	
3. Check damaged mechanical equipment	○	
4. Light wiring of inside panel inspection	○	
5. Grounding wire inspection	○	
6. Damaged wiring, discoloration, dust, terminal, connection point and damage of tightening inspection	○	
7. Grounding wire（High voltage）inspection	○	
8. Disconnect switch main body and operation mechanism inspection, contact point inspection	○	
9. PT, CT inspection	○	
10. Circuit Breakers ① inspection ② Open close test	○	
● Oil Circuit Breaker ① Insulating oil resistance test ② Operation mechanism inspection ③ Disassembly inspection ④ Contact resistance measurement ⑤ Open time measurement	○	
● Vacuum Circuit Breakers ① Inspection ② Vacuum interrupter inspection a . Measurement of contact consumption b . Three phase complete or not ③ Disassembly inspection ④ Operation mechanism inspection ⑤ Interruption time measurement ⑥ Degree of vacuum measurement	○	
11. Protection Relay, inspection adjustment, Structural inspection, Characteristic test Over current relay, Ground fault direction relay, Ground overvoltage relay, Frequency relay	○	
12. Converter inspection adjustment error inspection Current converter, Voltage converter, Power converter	○	
13. Meter inspection adjustment error inspection Ammeter, Watt meter	○	
Inspection Items	**Regular inspection**	**Detailed inspection**

14. Auxiliary Relay, inspection	○	
Sequence configuration relay, Power relay, Timer		
15. Distribution circuit breaker(MCB) inspection	○	
16. Magnet switch(MS) inspection	○	
17. Operating device inspection	○	
18. Indicator inspection	○	
19. Watt-hour meter inspection adjustment error inspection	○	
20. Grounding potential transformer(GPT） inspection	○	
21. Zero phase current transformer (ZCT) inspection,	○	
Characteristic test		
Implement with ground fault direction relay		
22. Lightning arrester inspection	○	
23. Cables inspection	○	
24. Fuses（Low, High voltage） inspection	○	
25. Connection terminal inspection	○	
26. Sequence test	○	
18. DC Power Supply Panel		
1. Visual inspection	○	
2. Check dust or rust of inside panels	○	
3. Check damaged mechanical equipment	○	
4. Light wiring of inside panel inspection	○	
5. Grounding wire inspection	○	
6. Damaged wiring, discoloration, dust, terminal, connection point and damage of tightening inspection	○	
（Battery）		
7. Status inspection	○	
a. Total voltage measurement of storage battery during floating charging		
b. Voltage measurement of single cell during floating charging		
c. Specific gravity measurement		
d. Temperature measurement		
e. Liquid level inspection		
8. Visual inspection	○	
a. Element and electrolyte level inspection		
b. Loose connection inspection		
c. Check Steel rack fouling, damage		
d. Leakage, rust inspection		

Inspection Items	Regular inspection	Detailed inspection
9. Equalizing charge	○	
10. Replenishment of purified water	○	
11. Retightening connection	○	
12. Capacity test	○	
13. Specific gravity adjustment	○	
（Charger）		
14. Status inspection	○	
ａ. AC input voltage measurement		
ｂ. Floating charge voltage measurement		
ｃ. Equal charge voltage measurement		
ｄ. Output current measurement		
ｅ. Load current measurement		
ｆ. Load voltage measurement		
15. Visual inspection	○	
ａ. Dirty and damaged parts inspection		
ｂ. Check discoloration, noise or smell of parts		
ｃ. Check temperature, overheating of parts		
ｄ. Check loosening of each tightening parts		
16. Retightening connection	○	
17. Sequence test	○	
18. Check setting values	○	
19. DC Distribution Panel		
1. Visual inspection	○	
2. Check dust or rust of inside panels	○	
3. Check damaged mechanical equipment	○	
4. Grounding wire inspection	○	
5. Damaged wiring, discoloration, dust, terminal, connection point and damage of tightening inspection	○	
6. Distribution circuit breaker (MCB) inspection	○	
7. Magnet switch (MS) inspection	○	

Inspection Items	Regular inspection	Detailed inspection
20. Data Logger		
1. Visual inspection	○	
2. Check dust or rust of inside panels	○	
3. Damaged wiring, discoloration, dust, terminal, connection point and damage of tightening inspection	○	
4. Operating device inspection	○	
5. Indicator inspection	○	
21. Auto Frequency Control Panel		
1. Visual inspection	○	
2. Check dust or rust of inside panels	○	
3. Damaged wiring, discoloration, dust, terminal, connection point and damage of tightening inspection	○	
4. Indicator inspection	○	
5. Cables and connectors inspection	○	
6. Fuses inspection	○	
7. Connection terminals inspection	○	
22. Transducer Panel		
1. Visual inspection	○	
2. Check dust or rust of inside panels	○	
3. Cables inspection	○	
4. Fuses（Low, High voltage）inspection	○	
5. Connection terminals inspection	○	
23. Watt-hour meter Panel		
1. Visual inspection	○	
2. Check dust or rust of inside panels	○	
3. Check damaged mechanical equipment	○	
4. Light wiring of inside panel inspection	○	
5. Grounding wire inspection	○	
6. Damaged wiring, discoloration, dust, terminal, connection point and damage of tightening inspection	○	
7. PT, CT inspection Watt-hour meter inspection adjustment error inspection	○	
9. Cables inspection	○	
10. Fuses inspection	○	
11. Connection terminals inspection	○	

Inspection Items	Regular inspection	Detailed inspection
24. Recorder Panel		
1. Visual inspection	○	
2. Check dust or rust of inside panels	○	
3. Light wiring of inside panel inspection.	○	
4. Damaged wiring, discoloration, dust, terminal, connection point and damage of tightening inspection		
5. Connection terminals inspection	○	
25. Syncroscope Panel		
1. Visual inspection	○	
2. Check dust or rust of inside panels	○	
3. Damaged wiring, discoloration, dust, terminal, connection point	○	
and damage of tightening inspection	○	
4. Cables inspection	○	
5. Connection terminals inspection	○	
26. Main Transformer		
1. Windings, Iron core	○	
vibration, noise check		
Oil leakage check		
Oil level check		
Check at oil gauge		
Oil dirtiness check		
Extract oil from drain cock and check		
Silica gel discoloration check		
Pink : Not good		
Purple : Good		
White : Bad		
2. Lead wires	○	
Rust check		
Insulator dirtiness check		
Crack check		
3. Winding supporting structure	○	
Temperature recording		
4. Dial thermometer Check a gap of the vibration-proof and crack	○	
Window surface cleaning, Alarm contact continuity check		
5. Insulation resistance measurement	○	
6. Insulating oil resistance test	○	

Inspection Items	Regular inspection	Detailed inspection
28. Auxiliary Motor		
1. Visual inspection	○	
2. Insulation Resistance Measurement	○	
3. Auxiliary cable connection/ disconnection	○	

Table-5 Types of Periodical Inspection (Measurement Equipment)

Inspection Items	Regular inspection	Detailed inspection
1. Instrument Panel		
1. Pressure gauge inspection, adjustment	○	
2. Pressure switch inspection, adjustment	○	
3. Temperature indicating switch inspection, adjustment TIS	○	
4. Temperature switch inspection, adjustment TS	○	
5. Transmitter inspection, adjustment	○	
6. Alarm setter inspection, adjustment	○	
7. Transducer inspection, adjustment	○	
8. Indicator inspection, adjustment	○	
9. Indicator alarm inspection, adjustment	○	
2. Control room		
1. Indicator inspection, adjustment	○	
2. Recorder inspection, adjustment	○	
3. Transducer inspection, adjustment	○	

End

Diesel Generation
Operation and Maintenance Manual

4.2 Trouble Shooting
(Automatic Control Device Number)

Kosrae Utilities Authority

INDEX

1. Operation during accident

1.1 General information

(1) In case of the operator cannot operate the plant properly; the operator shall report immediately to the operation manager and shall perform the operation specified in each manual.

(2) To proceed calmly and quickly when events occur, usually operators shall pay attention in operation status of each unit, relays, alarms, and also operators need to master operation procedures.

(3) Even if the accident does not occur, the operator should report to the operation manager immediately if there is an abnormality such as voltage, current, or continuous voltage drop.

(4) In case of accident, the operation manager shall give the appropriate instruction to the operators and report to the CEO. Depending of the circumstances shall also perform the recovery operation on its own.

(5) Operators should grasp the status of the load and the condition of the facility beforehand and keep in mind the supply method at the time of trouble and ensure to take immediate measures when troubles occur.

(6) When an accident occurs and emergency is required, the operator should conduct an inspection in site and take the appropriate measures to minimize the spread of damage.

(7) Operators must constantly grasp the operation status of the power plant and the current condition of the equipment, and when a trouble occurs, operators must take contact closely to the power generation manager to ensure supply capability measures, guidance for early restoration work for power transmission, supervision and self-recovery.

(8) Operation manager should recognize the shutdown sequence of trunk lines that limit the emergency load at the time of an accident beforehand and confirm the disconnection at emergency times. Also, operation manager should inform to the operator the same shutdown sequence and ensure thorough communication with major customers.

(9) Operation manager will contact the necessary related persons as the accident occurs and guide the staff, plan and implement the necessary personnel mobilization depending on the situation.

(10) Operation manager shall immediately prepare a prescribed report in a prescribed format and report it to the power plant manager.

1.2 Procedures when protective relays are activated

1.2.1 In case of generator CB trips.

(1) In case of overvoltage in the generator

(2) In case of overcurrent in the generator

(3) In case of overspeed in the diesel engine (Stop automatically when the revolution goes over 110% of the rated revolutions)

(4) Diesel engine / In case of dropping of oil pressure.

(5) Others. In case of serious failure in the diesel engine and auxiliary devices.

Operation manager	Operator
1. Check the operating point and immediately considering the load situation instruct startup operation of the backup engine so that other generators in operation do not become overloaded. (However, in case of absence of the operation manager, it shall be carried out by the operator.)	1. (1) Confirm alarm device operation status (relay alarm), stop the alarm bell. (Only signal lamp indication is performed.) Also, in case of other engines are running, stop operation of the engine is performed according to instructions from the operation manager. (2) Return to the right side the blocked relay. However, in the case of overcurrent and overvoltage return the indicator of each relay, but in case of oil pressure drop and overspeed return to the right position the switch in the engine side.
2. After the trunk line restoration, report to the opreration manager as soon as possible the cause of the failure. (Example. #5 generator by (time) operation · laura trunk line trip · troubled electric power 800 KW)	2. Fast start up of backup generator.
3. Report to the power station manager the power transmission start time, blackout time, cause, situation, etc. (note) Confirmation check should be carried out to prevent misjudge in restart-up after overspeed occurs.	3. Parallel standby of backup generator (running without load) 4. Restore trunk lines tripped by priority shutdown. (For above 3.4, make changes if it necessary according to the system load and units status after tripping) 5. Investigate the cause of failure and report it to the operation manager. 6. Restore the point of failure. (note) In the case of overspeed, restart according to the instruction of the operation manager as long as restart is possible. (Check if it is due to malfunction.)

1.2.2 Case of tripping of distribution CB board

Case of automatic tripping of distribution CB board

(1) In case of over current

(2) In case of grounding

Operation Manager	Operator
1. Report to the general manager as soon as possible the cause of the trip, time, trunk number or name, actuator relay name and disruptive power. (Example XXXX hour, in XXX line, XXX actuator, troubled electric power XXX KW) 2. When retransmission succeeds, report to the operation manager XXX Line Retransmission Success"	1. Check the relays, alarms, signals, etc. of the operated trunk lines, report them to the operation manager, return the motion indicator piece of the relay, and stop the alarm bell. 2. According to the operation manager tripped trunk line CB is ON and start transmission. (Only monitoring in case of automatic reclosing circuit type)

1.2.3 When the alarm device operates

Alarm place	**Alarm indication method**	**Operation manager**	**Operator**
1.Low or high air pressure	In case of alarm in the startup air tank, the alarm lamp in the generator ※ control board will lights up and alarm sounds.		(1) When pressure drop, Air compressor is activated and after the drain is eliminated, the air valve in the tank opens and it’s charged. (2) When the air pressure raised, immediately stop the air compressor and close the charge valve. (3) The air pressure of the start air tank should always be within the set pressure range.
2.Coolant water cutoff (pressure drop)	(1) When the amount of cooling water amount is not enough than the required, the alarm lamp in the generator ※ control board will lights up and alarm sounds.	(1) Instruct confirmation of on-site engine cooling water system. In case of alarm malfunction ・Under the responsibility of the operation manager after suppressing load Judge the system operation In case of actual operation ・Instruct switching operation of the cooling , etc. and try to recover water pressure	(1) According to the instruction of the operation manager, check the cooling water system of the engine and verify the presence or absence of alarm malfunction.

Alarm place	Alarm indication method	Operation manager	Operator
2.Coolant water cutoff (pressure drop)	(2)In case of shortage of cooling water, the alarm lamp in the generator※ control board will lights up and alarm sounds.	(2) Instruct confirmation of on-site engine cooling water system	2) According to the instruction of the operation manager, check the cooling water system of the engine and verify the presence or absence of alarm malfunction. (Note)After water cut do not quench when the engine is in high temperature because there is the possibility of cracking in the engine body
3.Rise of Lubricating oil temperature	If in the engine outlet lubricant oil temperature rise, the alarm lamp in the generator ※ control board will lights up and alarm sounds.	(1) In case of each bearing temperature increase over the limit, reduce the output and procedure to stop the engine	(1) Check the condition of high or normal temperature of each bearing. In case of Discover fault, reduce the output of the generator or disconnect from the grid and stop the engine (2) Check the LO cooler inlet and outlet temperature (water and oil) .In the case of high temperature of inlet cooling water reduce the output of the generator.
4.Generator bearing temperature rise	In case of the bearing temperature increase over the setting limit, Alarm lamp light up and alarm sounds in the control board.	(1) According to the situation of the bearing temperature over the limit, reduce the output and procedure to stop the engine	(1) Check oil level and temperature condition of bearing lubricant oil, and stop or reduce output of the generator according to situation.
6. Cooling water temperature rise	In case of engine outlet cooling water rise over the setting limit, alarm sounds or alarm lamp lighs up in the operation room.		

2. Engine emergency stop

2.1 In the following cases, immediately stop the engine and carefully inspect the involved parts.

(1) When confirmed obvious abnormal sound, vibration in movement parts.
(2) When confirming smoke on bearing and other friction part.
(3) When the lubricating oil pressure suddenly decreases. (Protection device inoperative)
(4) Supply of cooling water ceases and it is impossible to replenish immediately. (Protection device inoperative)
(5) When confirming that the number of engine revolutions rises sharply. (Protection device inoperative)
(6) When checking the slack or loosening of the setscrew or bolt of the main part.
(7) When there is damage in the fuel oil, lubricating oil or cooling water pipe .
(8) When leaked water is confirmed in lubricating oil.
(9) When overvoltage or overcurrent has occurred in the generator. (Protection device inoperative)
(10) When the generator voltage and current change abruptly, regardless of the load.
(11) When checking the abnormality in the indications of the meters in the control panel of the switchboard etc.

3. Failure of diesel engine and workaround

3.1 In case of the engine does cannot start up

Failure situation	Failure Cause	workaround
1.Crankshaft cannot rotate with starting air	1) Frictional resistance of the moving part is large. 2) Starting device defective (1) Startup air tank 3)Check if the starting position matching method is correct (In the case of 5 cylinders or less, it may not be in the starting position.) 4) Burden on the engine	1) After lubricating using oil priming pump (manually), rotate the flywheel and compare with the normal movement. 2) Open the cock (valve) and check the main start valve slightly open. (1) Check air pressure in the startup air tank. 3）Adjust the engine manually to start position. 4) Remove the load.

Failure situation	Failure Cause	workaround
2.Although it rotates well with starting air, it does not ignite.	1) Check if the fuel tank has fuel or If the fuel is flowing to fuel supply pump.	1) Check and replenish fuel tank oil.
	2) Check the function of the fuel pump. (1) When fuel is not pumping Check for any damage or loosening of the link (ring) leading to the injection pump around the speed governor.	2) Check fuel injection condition. (1) check
	3)Is there loose or broken attachment of the fuel injection pipe or no air mixed in the fuel oil	3) Tightening check or air cleaning.
	4) Confirm if the maneuver handle lever is in the starting position	4) Adjust the engine to start position.
	5) Is there slackness or breakage of the link from the governor to the fuel injection pump	5) Check
	6）Confirm if the fuel pump is sufficiently filled with fuel (1) Confirm if the cock or oil pipe of the fuel tank is not blocked or damaged (2) Whether fuel filter blockage or fuel pump malfunction	(1) check (2) check and cleaning

3.2 In case of the exhaust gas color is defective

Failure situation	Failure Cause	workaround
1. When exhaust gas from the chimney is black or dark gray	1) Check if the engine is not overloaded	1) Reduction of the load
	2) Confirm if the amount of fuel injected by each pump is the same. (1) Confirm if the rack set screw is not loosened. (2) Fuel pump rack scales are not uniform.	(1) Adjustment, tightening (2) Adjustment
	3) Confirm if there is not leakage of air or gas inside of the cylinder (1) Confirm if there is not leak of gas through the packing between the cylinder and cilynder head	(1) Check

Failure situation	Failure Cause	workaround
1. When exhaust gas from the chimney is black or dark gray	4) Others (1) Confirm if there is not air or water mixed with the fuel (2) Confirm if there is not clogs in the air supply pipe. (3) Confirm if there is not clogs in the gas exhaust pipe.	(1) Removal of water or air (2) Check (3) Check
	※(5)Confirm if there is not reduction in the rpm of the turbocharger due mechanical malfunction ※In the case of diesel with turbocharger.	(5) Check
2. When exhaust gas from the chimney is white or blue	1) Confirm if there is not leackage of lubricating oil into the combustion chamber thorough piston clearance. (1) Confirm if the viscosity of the lubricating oil is not too low (2) Confirm if amount of lubricating oil is not too much.	(1) Take a sampling of oil and check the analysis result. (2) Check the amount of oil.
	2) Confirm if there is not oil accumulated in the exhaust duct due to long-term no-load operation	2) Check inside of the exhaust gas ducts.
	3) Confirm if the engine is not over cooled	3) Check the temperature of the cylinder cooling water outlet
	4) Confirm if in the engine have not oil leakage or breakage in the fuel injection pipe	4) Tightening or replacement
3. When the number of rpm exceeds the set rotation regardless of the load	1) Confirm if the fuel handle is located at the specified position	1) Check regulated position
	2) Confirm if the rack of the fuel injection pump does not remain stuck (1) Confirm if the injection pump plunger is not caught or damaged (2) Confirm if the fuel injection pump installation without distortion	(1) Check (2) Check
4. When the supercharger surges	1) Confirm if there is not excessive overload applied.	1) Reduction of the load
	2) Confirm if the combustion of the cylinders is unbalanced and only specific cylinder is overloaded.	2) Check exhaust gas temperature of each cylinder

3.3 When the output of the Genset is not enough.

Failure situation	**Failure Cause**	**workaround**
1. When the RPM drops	1) Confirm if there is not shortage in fuel supply amount. (1) Confirm if the fuel system and strainer are not blocked. (2) Confirm if the fuel high pressure piping fittings are not loosened (3) Confirm if the amount sent by the fuel pump is not enough. (イ) Confirm if there is incomplete connection of the governor and rack of fuel injection pump or Incomplete connection link of the governor or there is something wrong with the position of the fuel adjustment rod claw. (ロ)Confirm if the operation of the governor is not correct.(Due to incomplete lubricating oil filling) (ハ) Confirm if there is not slack of the pinion rack setting screw.	(1) Check and cleaning (2) Tightening check (イ) Check (ロ)Check (ハ) Adjustment inspection
2. In case of failure of the turbocharger	Refer to the section on exhaust gas color failure.	Note: In the case of diesel with turbocharger.
3. Others	Refer to the section on exhaust gas color failure.	

3.4 When the engine stops

(Sudden dropping of the output of the genset, sudden stop of the engine or engine stop after exhaust gas color failure

Failure situation	**Failure Cause**	**workaround**
1. When fuel does not flow to the fuel valve	1) Confirm if there is fuel inside the tank.	1) Fuel check
	2) When there is fuel inside the tank (1) Confirm if the fuel cock seems to be closed naturally (2) Confirm if water mixed in the fuel. (3) Confirm if there is not a blockage in the fuel system or mixing of air (failure in the pipe from strainer or fitting slack, or introduction of air from the upper plug in the pump)	(1) Check (2) Check (3) Remove the air from the fuel filter, strainer and inspect the existence of air mixed in the fuel

Failure situation	Failure Cause	workaround
2.When fuel flows to the fuel valve	1) Confirm if it is possible engine turning	1) After lubricating using the priming lubricant oil pump, try to rotate the flywheel manually and compare with the normal state.
	2) When it is possible engine turning (1) Confirm if there is not air pocket in the fuel system. (2) Confirm if there is not a dropout or breakage of the governor link mechanism	(1) Air bleed check (2) Check

3.5 When the amount of lubricant oil consumption is abnormal and when the supply of cooling water is not available

Failure situation	Failure Cause	workaround
1. When the consume of lubricant oil is high	1) Lubricating oil viscosity is too low (lubricant oil)	1) Check lube oil analysis results and replace if necessary.
	2)Confirm if the lubricating oil pressure is too high	2) Check
	3) Confirm if there is not fuel mixed in the lubricant oil.	3)Replace lubricant with new one
	(1) Leak of oil from the plunger of the fuel pump (failure of the fuel injector device)	(1) Check
	(2) Confirm if there is not fuel oil accumulation on the top of the piston(Due to failure of the fuel injection valve or other reasons)	(2) Check
	(3) Confirm if there is not fuel leakage from pipe located in the upper side of the cylinder cover.	(3) Check
2.The amount of lubricant consumption is too small, or the oil amount increases.	1) Confirm if there is not water mixed in the lubricant oil.	1) Replace lubricant with new one
	(1) Confirm if there is not slack in the expanding pipe of the lubricant oil cooler.	(1) Check
	(2) Confirm if there is not leakage from the packing of the lubricant oil cooler.	(2) Check
	(3) Confirm if there is not leakage of water into the lubricant oil from pump packing, oil seal, etc.	(3) Check

Failure situation	Failure Cause	workaround
3. Cooling water is not pumped.	1) When cooling water amount is not enough (1) Confirm if the cooling water pump works. (1) Confirm if there no dust in the suction (2) Confirm if there is not leak of cooling water in the line. (3) Confirm if there is not too much leak from the gland packing of the pump or there is not sucking air 2) When cooling water does not flow out (1) Confirm if air is sucking from the suction line	(1)Check (2) Check (3) Check ,(1) Check

3.6 Breakdown of AC generator and its countermeasure

Failure situation	Failure Cause	workaround
1.The generator vibrate.	(1) Confirm if there is an extreme imbalance in generator three-phase current (2) Confirm condition of the anti-vibration bed rubber or spring.	(1) Each phase load check (2) Check
2. When the generator voltage no reach the settled value	(1) Confirm if there is any abrasion part in the brush that make bad contact.	(1) Check
3.When the exciter voltage is not induced.	(1) Confirm if the position of the brush is appropriate	(1) Check
4.Generator voltage is unbalanced	(1) Confirm if there is any load current imbalance	(1) Check
5. When a spark occurs in the commutator slip ring.	(1) Vibration is high (2) Is there dust and oil attached (3) Whether the brush retainer is holding the brush, the spring is cut, or the elasticity is insufficient.	(1) Check (2) Check (3) Check

Failure situation	Failure Cause	workaround
6. When the generator voltage drops.	(1) Confirm if the rectifier is not deteriorated. (2) Confirm if the Rectification of the exciter is good (3) Confirm if the three-phase reactor has vibration or beat	(1) Change the selenium（life10 year） (2) Check the brush and Cleaning of the exciter and around parts. (3) Tightening of tightening bolt
7. When the generator voltage drops.	(1) Confirm if the Rectification of the exciter is good (2) Confirm if the three-phase reactor has vibration or beat	(1) Check the brush and Cleaning of the exciter and around parts. (2) Tightening of tightening bolt

3.7 Problems in the distribution board

	Failure situation	Failure Cause	workaround
Votimeter	1.When there is no voltage	(1) Confirm if there is any dropout of the wiring to the voltmeter terminal	(1) Check internal wiring
	2. When the voltmeter pulsates.	(1) Confirm if there is any poor contact between the generator slip ring and the brush	(1) Check
	3. When there is voltage imbalance between the three phases	(1) Confirm if there is failure of the voltmeter selector switch (VS)	(1) Check
Ammeter	1. When there is current imbalance between the three phases	(1) Confirm if there is poor contact of the ammeter changeover switch (AS) (2) Confirm if there is poor contact at the test terminal.	(1) Internal check of AS (2) Check
	2. When there is no current	(1) Confirm if there is not dropout of the wiring to the ammeter terminal. (2) Among the wiring to the ammeter switch (AS), Check wiring of the ammeter.	(1) Check (2) Check

	Failure situation	Failure Cause	workaround
Relays	1.When not operate in case of failure	(1) Confirm if there is not damage in the internal coil of the relay or dropping of the external wiring (2) Confirm if there is not a bad contact caused by roughness mainly due to the arc on the contact surface or adhesion of dust (3) In the case of induction type, confirm if there is a breakdown of the pivot part with respect to the rotating plate (mainly caused by the entry of dust).	(1) Check (2) Check and fixing (3) Check
Governor motor switch	1.When even we control the frequency does not change	(1) Confirm if there is not contact failure at the contacts of the switch or dropout of the external wiring (2) Confirm if there is not disconnection on the power supply of the governor motor or there is fuse blow up. ※(During parallel operation, not response of load changing in GS operation)	(1) Check (2) Check
Stationary exciter device	1.When the voltage no reach the settled value	(1) Confirm if there is not poor contact between the slip ring and the brush of the generator	(1) Slip ring fixing and pressure adjustment of the brushing
	2.When the voltage pulsates.	(1) Confirm if there is not poor contact between the slip ring and the brush of the generator	(1) slip ring fixing and pressure adjustment of the brushing
Automatic voltage reg	1. When the voltage no reach the settled value	(1) Confirm if there is not poor contact between the slip ring and the brush of the generator	(1) Care of slip ring and adjustment of brush pressure
	2. When the voltage pulsates	(1) Confirm if there is a poor contact of the brush with the slip ring of the generator	(1) Slip ring care and brush pressure adjustment

The criteria for failure factors and countermeasures for anticipated faults but during operation is showed, but it is necessary to carefully check and analyze the cause until the failure (normal part situation different from normal situation) during operation to be able to process promptly for recovery.

4. Basic number and name of the automatic control device

4.1 Basic number and name of the automatic control device table

Basic device number	Device number	Device name
1	1	Master controller or switch
2	2	Start or close time limit relay or close delay relay
3	—	Operation switch
	3-28B	Operation switch (For restoring Bell relay)
	3-28Z	Operation switch (For restoring buzzer relay)
	3-30	Operation switch (For restoring display)
	3-30L	Operation switch (For restoring lamp display)
	3-41	Operation switch (For field breaker)
	3-41M	Operation switch ((For main field breaker)
	3-41S	Operation switch (For spare field breaker)
	3-52	Operation switch (For AC field breaker)
	3-66F	Operation switch (For restoring flicker relay)
	3-86	Operation switch (For restoring lockout relay)
	3-86B	Operation switch (For restoring lockout relay of boiler)
	3-86G	Operation switch (For restoring lockout relay of generator)
	3-86T	Operation switch (For restoring lockout relay of turbine)
	3-88	Operation switch (For auxiliary contactor)
	3-89	Operation switch (For disconnect switch)
	3R	Operation switch (For general restoration)
4	4	Controller for main control circuit or relay
5	5	Stop switch or relay
	5B	Stop switch or relay (boiler)
	5E	Emergency stop switch
	5P	Panic switch
	5T	Stop switch or relay (turbine)
6	6	Start breaker, switch, contactor, or relay
7	-	Regulation switch
	7-55	Regulation switch (for automatic power factor regulator)
	7-65	Regulation switch (for speed governor)

Basic device number	Device number	Device name
7	7-70	Regulation switch (field excitation regulator of generator)
	7-70E	Regulation switch (field excitation regulator of exciter)
	7-70M	Regulation switch (for field excitation regulator of main exciter)
	7-70S	Regulation switch (for field excitation regulator of spare exciter)
	7-70SS	Regulation switch (for subexciter excitation regulator of spare exciter)
	7-77	Regulation switch (Load regulator)
	7-90R	Regulation switch (for voltage settings of automatic voltage regulator)
	7-IR	Regulation switch (for induction voltage)
8	8	Control power switch
9	9	Field rotation switch, contactor, or relay
10	10	Sequential switch or program controller
	10P	Program controller
11	11	The test switch is a relay
	11-41	Test switch (for field breaker)
	11-52	Test switch (for breaker)
	11J	Jogging switch
	11L	Test switch (for lamp inspection)
12	12	Overspeed switch or relay
13	13	Synchronous speed switch or relay
14	14	Low speed switch or relay
15	-	Speed adjusting device
	15	Automatic speed control device
	15L	Operating relays for automatic speed control device (decrease)
	15R	Operating relays for automatic speed control device (increase)
16	16	Display line monitoring relay
17	17	Wire-pilot relay
18	18	Acceleration or deceleration contactor or acceleration or deceleration relay
19	19	Start-up/operation switching contactor or relay

Basic device number	Device number	Device name
20	20	Auxiliary valve
	20A	Air valve
	20B	Bypass valve
	20C	Solenoid valve for control
	20F	Fuel valve
	20G	Gas valve
	20Q	Oil valve
	20S	Steam valve
	20SS	Steam safety valve
	20V	Vacuum valve
	20W	Water valve
21	-	Main engine valve
	21B	Boiler main steam valve
	21F	Fuel shutoff valve
	21T	Turbine main steam valve
	21TR	Turbine reheat steam stop valve
	21W	Boiler main water supply valve
22	22	Earth leakage circuit breaker, contactor, or relay
23	23	Temperature regulator or relay
24	24	Tap changer
24	24LR	Tap changer (for load voltage regulator)
25	-	Synchronization detection device
	25	Synchronization detection device or automatic synchronous closing device
	25A	Automatic synchronous closing device
	25B	Automatic synchronous closing (for backup)
26	26	Stator temperature switch or relay
	26LR	Temperature switch or relay (for load voltage regulator)
	26RG	Temperature switch or relay (for recirculating gas)
	26SSH	Temperature switch or relay (for overheated steam)

Basic device number	Device number	Device name
26	26T	Temperature switch or relay (for transformer)
27	27	AC undervoltage relay
	27C	AC undervoltage relay (for control power supply)
28	28	Alarm device
	28B	Bell relay
	28F	Fire detector
	28LA	Lightning arrester motion detector
	28Z	Buzzer relay
29	29	Fire extinguishing equipment
30	30	Device status or fault indication device
	30F	Fault indicator
	30S	State indicator
31	31	Field breaker, switch, contactor, or relay
32	32	DC reverse current relay
33	33	Position detection switch or device
	33C	Level switch (for coal)
	33NL	Position detection switch (for no load)
	33Q	Oil level detection switch or device
	33T	Torque switch
	33W	Water level detection switch or device
34	34	Electric sequence controller
	34B	Boiler start sequence controller
35	35	Brush operating device or slip ring short circuit device
36	36	Polarity relay
37	37	Undercurrent relay
	37B	Automatic break detector for distribution breaker
	37F	Fuse break detector
38	38	Bearing temperature switch or relay
39	39	Mechanical anomaly monitoring device or detection switch

Basic device number	Device number	Device name
40	40	Field current relay or field loss relay
41	41	Field breaker, switch, or contactor
	41A	Field switch or contactor (for inserting the field amplifier)
	41C	Closing coil for 41
	41D	Differential field breaker, switch, or contactor
	41I	Initiating excitation breaker, switch, or contactor
	41M	Field breaker (for main exciter)
	41MP	Field breaker (for primary generator main exciter)
	41MP	Field breaker (for secondary generator main exciter)
	41R	Adjustment field breaker or switch
	41S	Field breaker (for preliminary excitation)
	41SP	Field breaker (for primary generator preliminary exciter)
	41SS	Field breaker (for secondary generator preliminary exciter)
	41T	Tripping coil for 41
42	42	Operating breaker, switch, or contactor
43	43	Control circuit changeover switch, contactor, or relay
	43-25	Changeover switch (for synchronization detection circuit)
	43-55	Changeover switch (for automatic power factor regulator)
	43-64E	Changeover switch (field grounded trip relay)
	43-65	Changeover switch (for speed governor)
	43-77	Changeover switch (for load adjustment device)
	43-87B	Changeover switch (for bus bar protection)
	43-90	Changeover switch (for automatic voltage regulator)
	43-95	Changeover switch (for frequency relay)
	43AM	Changeover switch (manual - automatic)
	43L	Changeover switch (for lock)
	43R	Changeover switch (direct - remote)
44	44	Distance relay
	44G	Distance relay (for generator backup protection)

Basic device number	Device number	Device name
45	45	DC overvoltage relay
46	46	Reverse phase or phase unbalanced current relay
47	47	Open phase or reverse phase voltage relay
48	48	Congestion detection relay
	48-24	Congestion detection relay (for tap changeover device)
	48-25	Congestion detection relay (for synchronous parallel)
49	49	Rotating machine temperature switch or relay or overload relay
	49R	Temperature relay (for rotor)
	49S	Temperature relay (for stator)
	49T	Temperature relay (for low-pressure exhaust chamber)
50	50	Short circuit selection relay or ground fault selection relay
	50G	Ground fault selection relay
	50S	Short circuit fault selection relay
51	51	AC overcurrent relay or ground fault overcurrent relay
	51B	AC overcurrent relay (for busbar)
	51G	AC overcurrent relay (for generator) or ground fault overcurrent relay
	51H	AC overcurrent relay (for in-house transformer)
	51N	AC overcurrent relay (for neutral point)
	51S	AC overcurrent relay (for starting transformer)
	51V	AC overcurrent relay with voltage suppression
52	52	AC breaker or contactor
	52C	Closing coil for 52
	52G	AC breaker (for generator)
	52H	AC breaker (for in-house transformer)
	52N	AC breaker (for neutral point)
	52NR	AC interrupter (for neutral point resistor)
	52PC	AC breaker (for arc suppression coil)

Basic device number	Device number	Device name
52	52S	AC breaker (for starting transformer)
	52T	Tripping coil for 52
53	53	Excitation relay
54	54	High speed breaker
55	55	Automatic power factor regulator or power factor relay
	55L	Operating relay (lowering) for 55
	55R	Operating relay (raising) for 55
56	56	Slip detector or out-of-step relay
57	57	Automatic current regulator or current relay
58	58	Reserve number
59	59	AC overvoltage relay
	59F	Voltage/frequency limiter or relay
	59G	AC overvoltage relay (for generator)
60	60	Automatic voltage balancing regulator or voltage balance relay
	60L	Operating relay (reduction) for 60
	60R	Operating relay (increase) for 60
	60PT	Voltage balance relay (for voltage transformer fault detection)
61	61	Automatic current balancing regulator or current balance relay
62	62	Stop or open time limit relay
63	63	Pressure switch or relay
	63A	Pneumatic switch or relay
	63D	Differential pressure switch or relay
	63F	Fuel hydraulic switch or relay
	63G	Gas pressure switch or relay
	63Q	Hydraulic switch or relay
	63V	Vacuum switch or relay
	63W	Water pressure switch or relay
64	64	Ground overvoltage relay
	64B	Ground overvoltage relay (for busbar)

Basic device number	Device number	Device name
64	64D	Direct current control circuit ground fault relay
	64E	Excitation circuit ground fault relay
	64F	Excitation circuit ground fault relay
	64G	Ground overvoltage relay (for generator)
	64H	Ground overvoltage relay (for in-house transformer)
	64N	Ground overvoltage relay (for neutral point)
	64S	Ground overvoltage relay (for starting transformer)
65	65	Governor
	65L	Operating relay (reduction) for 65
	65R	Operating relay (increase) for 65
	65M	Motor for governor speed adjustment
66	66	Intermittent relay
	66F	Flicker relay
67	67	AC power directional relay or ground fault directional relay
	67G	AC power directional relay (for generator) or ground fault directional relay
68	68	Contamination detector
	68A-H	Hydrogen purity detector
68	68W-Q	Water detector (in oil)
69	69	Flow switch or relay
	69A	Airflow switch or relay
	69F	Fuel flow switch or relay
	69G	Gas flow switch or relay
	69Q	Oil flow switch or relay
	69W	Water flow switch or relay
70	-	Rheostat
	70	Field regulator
	70E	Field regulator (for exciter)
71	71	Rectifier element failure detector
72	72	DC breaker or contactor

Basic device number	Device number	Device name
73	73	Short circuit breaker or contactor
74	-	Regulating valve
	74	Regulating valve or vane
	74A	Air regulating valve
	74G	Gas regulating valve
	74Q	Oil regulating valve
	74W	Water regulating valve
75	75	Braking device
76	76	DC overcurrent relay
77	77	Load regulator
	77L	Operating relay (reduction) for 77
	77R	Operating relay (increase) for 77
	77M	Motor for 77
78	78	Transport protection phase comparison relay
79	79	AC reclosing relay
80	80	DC undervoltage relay
	80C	DC undervoltage relay (for control power supply)
81	81	Governor drive unit
82	82	DC reclosing relay
83	-	Selection switch, contactor, or relay
	83	Power supply transfer switch or contactor
84	84	Voltage relay
85	85	Signal relay
	85F	Flame detector
86	86	Lockout relay
	86B	Lockout relay (for boiler fuel cutoff)
	86G	Lockout relay (for generator)
	86T	Lockout relay (for turbine)

Basic device number	Device number	Device name
87	87	Differential relay
	87B	Differential relay (for busbar)
	87G	Differential relay (for generator)
	87H	Differential relay (for in-house transformer)
	87M	Differential relay (for main transformer)
	87S	Differential relay (for starting transformer)
88	88	Auxiliary breaker, switch, contactor, or relay
	88C	Auxiliary breaker, switch, contactor, or relay (for closing direction)
	88F	Auxiliary breaker, switch, contactor, or relay (normal rotation, forward, rise, increase, or to the right)
	88O	Auxiliary breaker, switch, contactor, or relay (for opening direction)
	88R	Auxiliary breaker, switch, contactor, or relay (reverse rotation, backward, decline, decrease, or to the left)
89	89	Disconnector
	89C	Closing coil for 89
	89-IL	Interlock magnetic switch
	89T	Tripping coil for 89
90	90	Automatic voltage regulator or automatic voltage regulator relay
	90R	Voltage setting device for 90
	90RM	Motor for operating voltage setting device for 90
91	91	Automatic power conditioner or power relay
	91P	Automatic power conditioner or power relay
	91Q	Automatic reactive power conditioner or reactive power relay
92	92	Door or damper
92	92A	Air damper
	92C	Coal dust damper
	92G	Gas damper
93	93	Preparation
94	94	Tripping automatic contactor or relay
95	95	Automatic frequency regulator or frequency relay

Basic device number	Device number	Device name
96	-	Stator internal fault detector
	96	Buchholz relay
	96-1	Buchholz relay (for alarm)
	96-2	Buchholz relay (for removing)
	96P	Sudden pressure relay
	96V	Pressure release valve
97	97	Runner
98	98	Coupler
99	99	Automatic recording device
	99F	Automatic fault recorder
	99S	Automatic motion recorder

4.2 Supplementary code and main content of automatic control device (Table 2)

Code	Content
A	AC, automatic, analog, air, wind, air compressor, amplification, current
B	Breaking of wire, bypass, break, bell, belt, battery, busbar, bearing
C	Common, cooling, closing, open clutch operation, control, condenser, compensation
D	DC, release, differential, deterioration, dial, droop, digital
E	Emergency, excitation
F	Float, fire, failure, fuse, fan, frequency, positive, flicker
G	Grease, gravity, ground fault, guide vanes, gas, generator
H	High, in-house, hold, electric heat, harmonic
I	Internal, initial
J	Joint, jet
K	Cathode, tertiary side, casing
L	Lamp, leak, lower, low, line, load, lockout, left
M	Meter, microwave, main, motor, moment, motor, manual
N	Nozzle, nitrogen, neutral, negative electrode
O	Ohmic element, outer, open

P	Program, voltage transformer, pump, primary, positive electrode, power, pressure, position
Q	Reactive power, oil, hydraulic equipment, hydraulic pump
R	Restoration, raise, regulation, remote, receiving, reverse, resistance, reactor, reception, room interior, rotor
S	Solenoid, action, synchronization, short circuit, secondary, synchronous machine, speed, secondary, remote
T	Transformer, tailrace, temperature, time limit, tripping, turbine, rotation, torque
U	Use
V	Vacuum tube, voltage, vacuum, valve
W	Water, wastewater, water level, water current, water supply
X	Auxiliary
Y	Support
Z	Buzzer, auxiliary

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4.3 Supply and Demand Management

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1. Purpose

The content of this guideline is to improve fuel economy reducing fuel cost and aimimg smooth operation by highly efficient operation of DG's unit taking in consideration economical reserve operation and reducing operation time of each generator to reduce maintenance cost.

2. Demand-supply management

2.1 Efficient operation

Power plant operators should predict the peak of the day and the load after several tens of minutes while considering the weather of the day with reference to the supply-demand curve of the previous day. (See below graph 1)

During the operation, operators should try to allocate the load according to the Economic load allocation table (A table showing the relationship between total demand and generator) and EDC support system (A system that calculates and displays only the economic load distribution based on the current parallel DG's) and if it is necessary to control and stop the generator each set several minutes to operate according to the economic load allocation table.

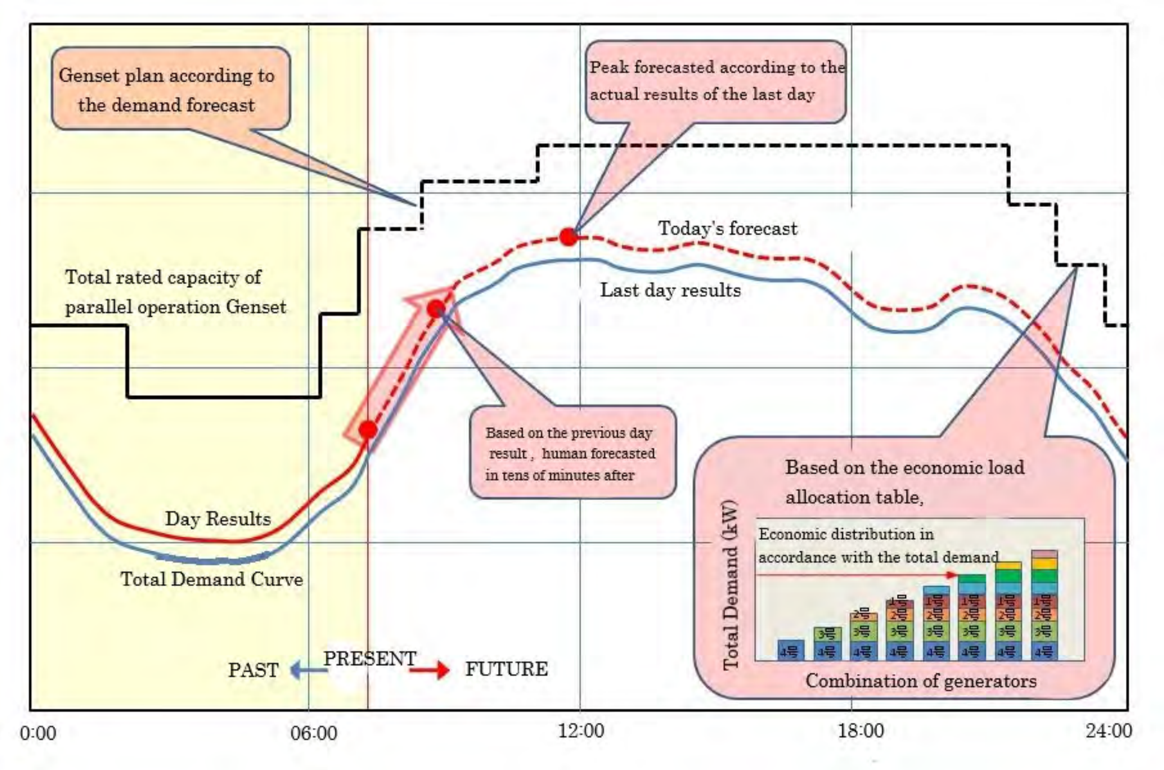

Figure-1 Supply-demand curve

2.2 System frequency adjustment

Frequency is determined by the balance between electric power demand and power supply that changes from moment to moment.

As demand fluctuates with the time, in order to maintain the frequency constant, it is necessary to adjust the amount of power generation to match the demand amount.

There are various components in the time domain of load fluctuation ranging from a long cycle of about a several minutes to a short one of a few seconds or less. Each one is adjusted by sharing control of the frequency (1).

Furthermore, operators should be try to keep the frequency adjustment range within the adjustment range defined in (2). In addition, operators will strive to maintain sufficient frequency adjustment ability so that frequency fluctuation falls within the setting range even when the demand suddenly changes, such as rising in the morning.

Table 1. (1) Frequency control sharing

Load fluctuation component (Time domain)	Adjustment method	Contents (adjustment amount, Method of securing, coordinator etc.
Few minutes～about several minutes	EDC	For the long-term load fluctuation, the generator output is adjusted by the control device based on the EDC output command value considering the economic load distribution.
Few minutes～about several minutes	EDC Economical load control	For long cycle load fluctuation, adjust the generator output manually based on the EDC output target value that takes economical load distribution
Few seconds～about several minutes	AFC Automatic frequency control	For relatively short cycle load fluctuation, it is detected as frequency deviation, and the generator output is automatically controlled with the AFC output command value calculated so as to return to the set system frequency.
Few seconds～about several seconds	DG's Governor	The short cycle load fluctuation is adjusted by the generator governor
Few seconds or less	System inertia	The load fluctuation in a very short cycle time is absorbed by the inertia of the system.

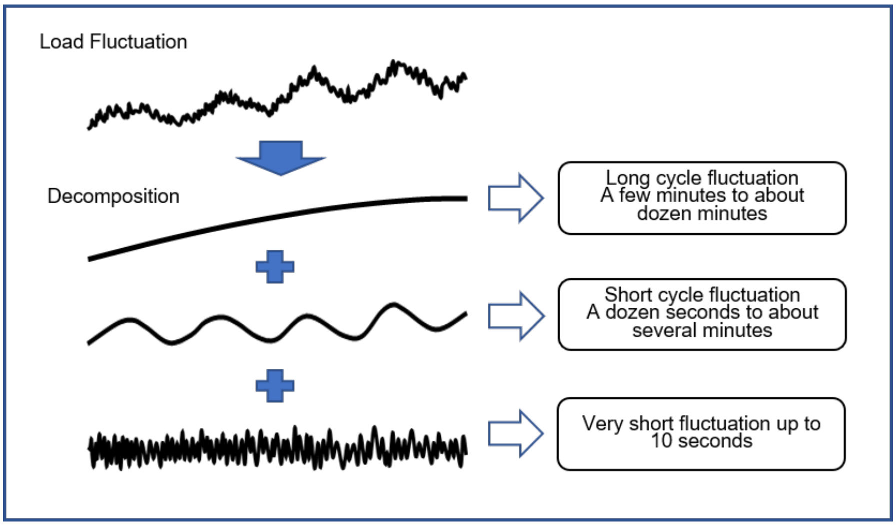

Figure 2. Image of load fluctuation component

(1) Flow of control for each component at the occurrence of frequency fluctuation

①Unbalance between demand and supply (occurrence of frequency fluctuation)
②Frequency fluctuation control due to generator governor-free function (small variation)
③Recovery to the setting frequency by AFC control
④Secure AFC control amount by EDC control

(2) Target value of frequency adjustment

Within 60.0±0.3Hz

(3) Frequency controller

Control the output of the DG's to maintain the frequency value inside the standard value when choose a frequency controller and perform AFC operation. Increase output when de frequency is below and reduce output when frequency is higher than the setting value.

2.3 Voltage management

In order to ensure the stability of the voltage of the power system, strive to maintain proper system voltage establishing operational target of the system voltage

(1) Adjustment of voltage & reactive power flow

Operators should monitor the voltage and reactive power flow of the system and constantly strive for leading control by predicting the change of demand and try to maintain the system voltage. The adjustment way is as follows.

①Adjustment by excitation of generator
②Adjustment by transformer tap change
③Adjustment of reactive power by the phase-matching facility (power capacitor (SC), shunt reactor (ShR))
④Changing system structure

(2) Voltage operational value and target value

Table 2. operational value and target value

Nominal voltage (kV)	Setting range of target value (kV)
6.6	6.6±0.2
22	22±1.1

3. DG's operation

3.1 Types of power generation units

(1) Diesel Generators

Diesel power generation has advantages such as small size, light weight, high reliability, good starting performance, and high thermal efficiency. However, it has disadvantages such as difficulty in increasing the power generation capacity in big engines, and because is a reciprocating engine, parts consumption is big and repair costs are expensive as disadvantage.

(2) Gas turbine generation

Since the structure of the gas turbine power generation is simple, construction cost is low, startability is good, load followability is good. However, it has the disadvantages of high fuel cost and low thermal efficiency. Therefore, it is used for mainly for peak load and for emergency times as a backup.

(3) Mobile generator

Mobile generator is used mainly as a backup for emergency backup and emergency power supply. Mobile generator is usually diesel or gas turbine generator mounted on a vehicle.

In the case of small-scale remote islands, it will be transported by ferry, so it takes about several days to start generating electricity.

(4) RE power generation

RE is the source to be permanently available as an energy source like "solar, wind power, hydropower, geothermal, solar heat, atmospheric heat and others naturally existing heat, and biomass "

Renewable energy is an excellent energy that can be used repeatedly without being exhausted and resources that emit little carbon dioxide during power generation, but due to weather and other factors the power output may fluctuate greatly, which may hinder the stable supply, so storage batteries, etc. Measures such as stabilizing devices are required.

3.2 Power reserve

3.2.1 Classification of Power reserve

Table 3. Classification of Power reserve

Classification	Facility		Definition
Operation reserve	Operation margin	Spinning reserve	Governor-free part of the operated generator in governor free mode. Responsive to instantaneous response to the frequency drop at the time of power failure, rapidly raise of the output (within about 10 seconds) at least is continued until activation of others power reserve supply. Power capable of automatic generation
		Reserve capacity of the generator during operation	Output adjustment of generators in parallel
	Standby capacity: stop standby gas turbine		Power supply that can starting up in a short period of time, taking load and continuously generate while standby reserve power to start loading.
Standby reserve	Diesel with stop standby DG's capable of generating power continuosly for a long time		Sufficient power supply required for several minutes from the start up to taking full load
Mobile power reserve	Generator that can be moved as needed		Supply capacity (gas turbine, diesel) that requires time to supply. It needs about several days from delivery to completion of placement in site

3.2.2 Reserve response status

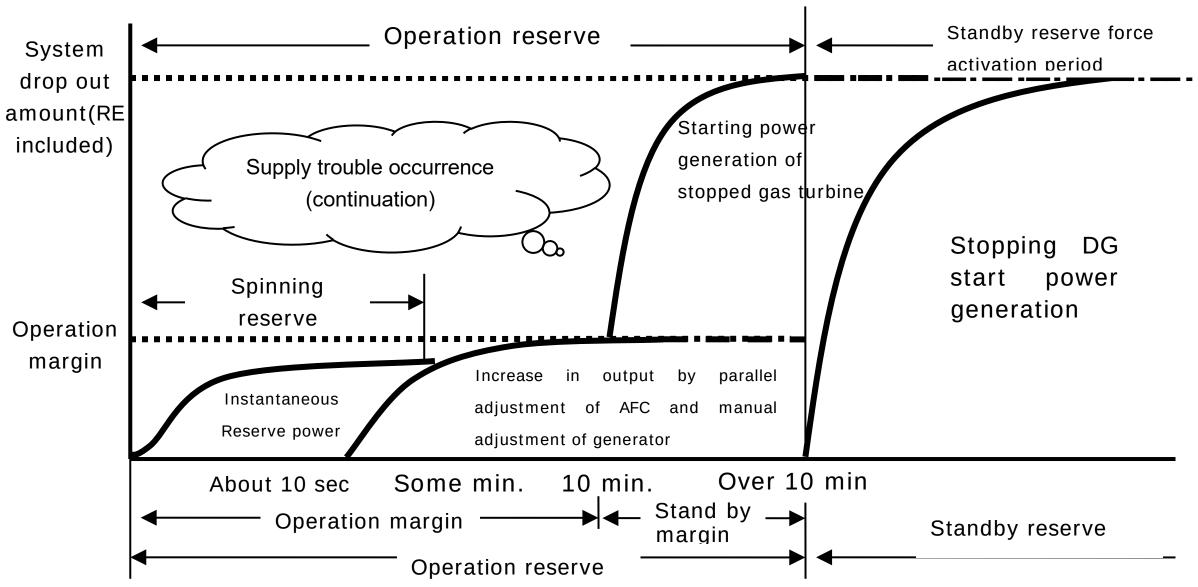

Figure 3. Reserve response status

3.3 Securing reserve power

3.3.1 Securing operation reserve

(1) Basic idea of operation reserve

①Considering supply-demand balance, operation reserve strives for economical efficiency by combination of number of parallel generators that will improve fuel economy. However, in case of accidents in the power system as output fluctuation caused in natural energy (RE: wind power, solar power etc.) facilities by sudden change of the weather, demand fluctuation, storm, thunderstorms, it is necessary increase operation reserve.

②If the supply capacity is less than 105% of the annual maximum load (annual maximum 3 days average electricity) in the demand assumption, it is necessary coordinate with the related department about the increase of generation equipments.

③In the winter, the demand decreases and at the same time the ratio of RE output (wind power, solar power, etc.) come large and the number of diesel generators in parallel tends to decrease. Taking in consideration the weather at least tries to mainten highly efficient operation (low fuel consumption, high RE utilization rate)

Securing operation reserve.

④During peak off hours with low demand load and when supply can be handled by one generator, taking in consideration economics try to operate one unit.

However, one unit operation is excluded when there is concern about accidents in the power system due to rapid weather changes like storms, thunderstorms, etc. or fluctuations in the demand.

(2) Reserve securing method

①Operation in normal condition

Considering the characteristics of equipment such as output change speed, adjustment capacity, type of fuel, economic efficiency in the supply/demand operation, specifically the operation reserve holding is as follow

(a) Output adjustment of power generators in parallel (reserve capacity)

(b) Stop standby gas turbine or diesel generator.

②Operation in case of abnormality

When countermeasures to increase operation reserve are necessary, the following countermeasures must be implemented.

(a)Addition of standby reserve (Stop standby Diesel generators are applicable)

(b)Canceling output curtailment (including transmission and substation equipment)

(c)Deployment of mobile generators etc.

3.3.2 Operation margin

（1） Regarding the determination of the parallel DG’s, in accordance with the total demand, determine the generators to be used based on the economic load distribution table to minimize the total fuel cost.

（2）Regarding the allocation table of economic loads, create group for each system in the administrative group, promptly review the configuration change of the generator due to the increase in the number of units, etc., or when there is a large fluctuation in each unit fuel consumption rate.

（3）The fuel consumption rate setting of each unit of the EDC support system will also be reviewed appropriately according to the actual state of fuel consumption rate.

3.3.3 Securing instant reserve

(1) Basic thinking of instant reserve

①To respond to the supply and demand imbalance occurring within an extremely short time, the instantaneous reserve power is in principle based on all-DG's governor-free operation.

(2) How to maintain spinning reserve

①In governor free operation against frequency fluctuation, DG's outputs changes according to the characteristics of the governor (adjustment rate), considering the economics of the operation, keep it distributed to as many generators as possible.

3.3.4 Securing black start generator

(1) Operation at Blackout times

①Blackout means that all units are stopped, and the internal power supply is lost.

②If the in house power supply is lost due to unforeseen circumstances, promptly start up the black start DG and secure the power supply.

③The black start DG is a unit that can be activated without the in-house power supply and shall be more than two in each island. (Because some generators can not be started due to regular inspection etc.)

3.4 Measures to be taken in tight supply and demand times

3.4.1 Measures to increase supply capacity

(1) In the case that supply reserves are insufficient and supply and demand are tight, or tightness operation is expected, in order to ensure balance of supply and demand, while monitoring the demand trend (the degree of increase in demand) and changes in weather conditions, supply power is increased taking the following measures.

①Secure supply capacity by generator of the utility.

(a)Stop output curtailment of the generators (substation facilities included)

(b)Gas turbine operation

(c) Deployment of mobile generators, etc.

②Margin of power received from persons who operate specific scale of electricity business etc.

3.4.2 Demand curtailment and dump load test

(1) If the supply capacity is insufficient despite the above-mentioned measures, request to the customers to stop demand and shut down the load.

(2) In the case where there is no time margin, demand restraint and load interruption may be carried out before all measures to increase supply capacity are completed.

3.4.3 Output curtailment to RE power producer

（1）Depending on the demand forecast of today or the next day, when it is expected that the supply of electricity for RE generation will exceed the demand amount, the utility can make curtailment without compensation measures after taking the following procedure (priority feed rule).

- Old rule
  Solar and wind power generation equipment of 500 kW or more up to 30 days / year
- New rule
  50kW over solar power generation facilities 360 hours/year, Wind power generation equipment 720 hours / year
- Designation rule
  Unlimited, uncompensated (In principle, solar power facilities of more than 10 kW, wind power is not covered)

① Power generation curtailment (excluding solar power, wind power, small hydraulic power) owned by the utility (up to 50% output which is the minimum load of diesel)

② Stop of utility owned RE facilities (sunlight, wind power, small hydropower)

(2) If it is necessary curtailmenmt beyond 30 days and 360 hours (720 hours), the output can be curtailed under condition of compensating measures equivalent to the purchase of electricity are carried out to the RE power producer.

3.5 Time required to start up the power generation unit

Table 4. Start-up of diesel engine

Diesel Engine	10～15 minutes
Fixed type gas turbine	8～10 minutes
Mobile generator	5～10 minutes

4. System operation

4.1 Method of line switching

(1) In case of line switching of the electric power system, as a rule make parallel switching or loop switching. If it is inevitable, switch by blackout switching.

4.2 Stopping of electric facility

(1) Make the necessary adjustment to stopping collectively the power plant, electric lines, etc.as possible. Also, as much as possible on low loaded days such as holidays, or low loads at midnight.

4.3 Emergency time alert action

(1) Be aware of weather conditions such as storms, thunderstorms, etc. and take the following measures, as necessary.

① Secure communication
② Power system switching
③ Increase generator reserve capacity

5. Comunication equipments

Communication facilities must be fully equipped so as not to interfere with the demand and supply operation.

6. Related documents

Manual of drawing up economical load dispatch sheet.

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4.4 Economical Load Dispatch System (EDC)

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1. Diesel Power Generation Operation Efficiency

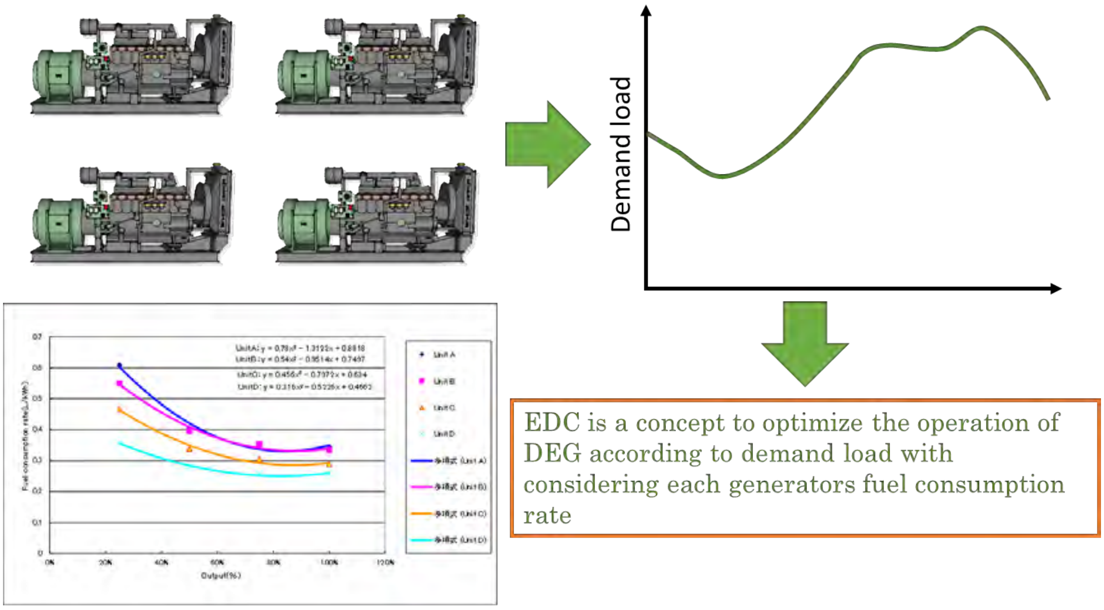
There are many methods for efficient diesel power generation operation, but the one regarded as the best is Economic load Dispatching Control (EDC) of multiple generators.

2. EDC (Economic load Dispatching Control) Operation

Power demand is mainly affected by consumer lifestyle, and it changes from one minute to the next. Looking changes on a daily basis, when dividing weekdays and weekends, each have similar trends in terms of time, but these trends are also affected by changes in weather.

With EDC, aimed these changes in demand, which generators should be operated and at what output for the output band of each power plant will lead to the most efficient operation is considered in advance, and the efficient operation of the generators is carried out based on the results.

With EDC, normally, forecasts for demand and supply are made and plans for everything from the start/stop of the generators to output values must be planned in advance, but unlike thermal and nuclear power generators, which use steam for power generation, since diesel generators can be started and stopped easily and in a short amount of time and can quickly perform load tracking for load fluctuations, EDC operation is possible without forecasting as optimal output is calculated as needed instantly.



EDC is a concept to optimize the operation of DEG according to demand load with considering each generators fuel consumption rate

Figure 1. Concept of EDC

3. Fuel consumption characteristics of each generator

In performing EDC operation, the most important factor is the fuel consumption characteristics of each power generation unit. Fuel consumption characteristic indicates the amount of fuel consumed for power generation, and is expressed as ℓ/kWh, Gal/kWh, g/kWh, etc.

Figure 3-1 shows the fuel consumption characteristics curve (example) for each generator.

Fuel consumption characteristics curve differ depending on the generator, in most cases, they are expressed as a quadratic curve as shown in the graph. As can be seen from the graph, normally, each generation unit will operate at the best fuel efficiency when operating at the rated output. In addition, fuel efficiency tends to become worse as output drops. Therefore, operating each unit as close to the rated output as possible leads to reduced fuel consumption.

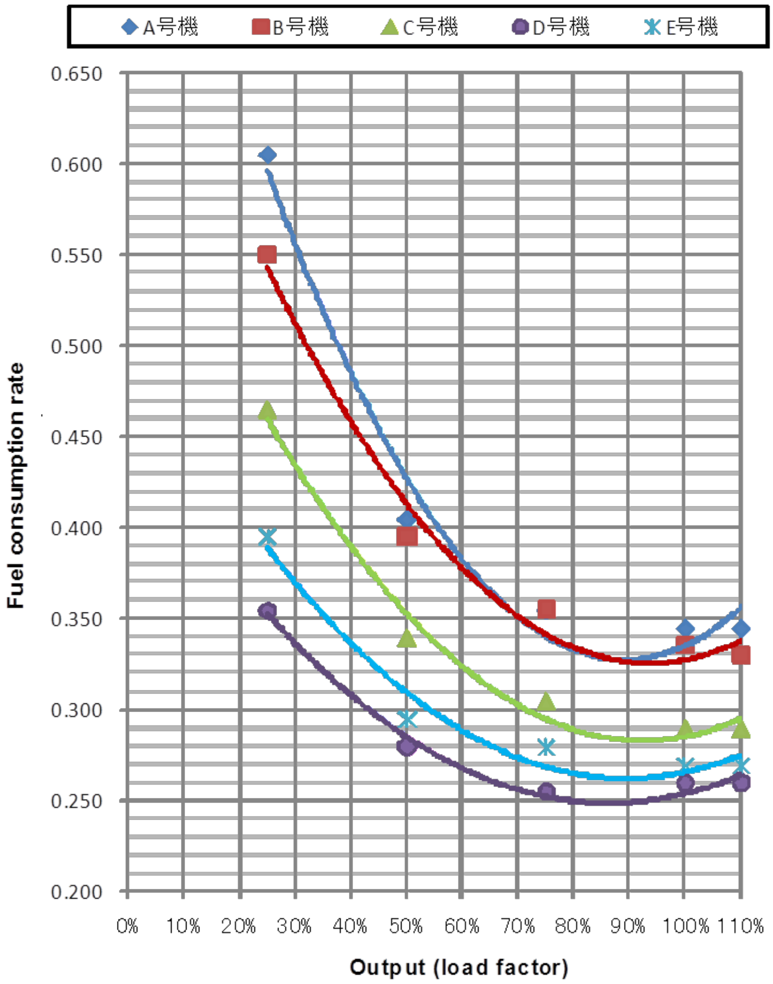


Figure 2. Fuel consumption characteristics curve (example) for each generator

4. Diesel engine performance (performance curve)

Scale of output and torque of diesel engines vary with their purpose of use, so the fuel consumption rates and other performance factors are different with each engine. The performance is not identical even between the engines of same manufacture and model with same manufactured date, since it depends on the frequency of use and method of maintenance. Figure 4-1 and figure4-2 show performance curves of diesel engines with about 18kW of rated output scale.

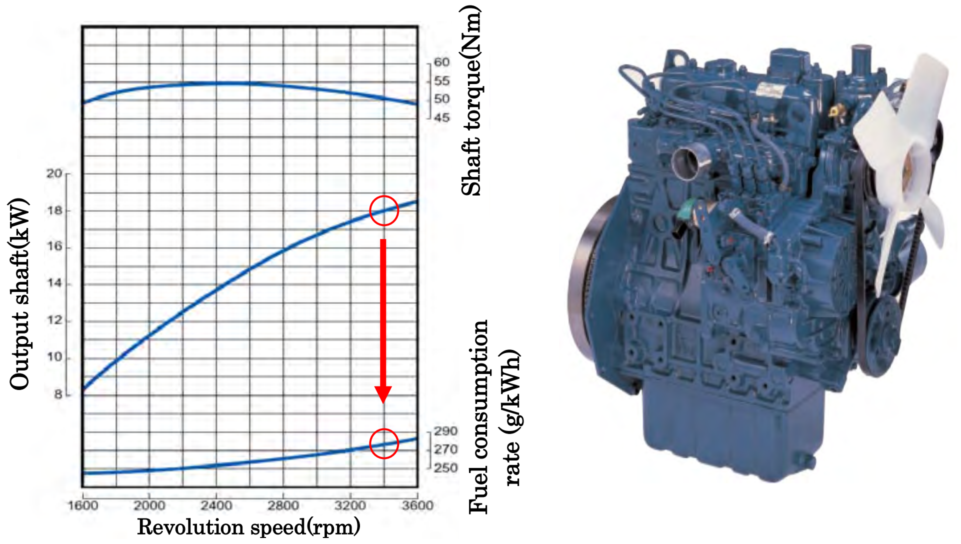


Figure 3. performance curve and appearance of a diesel engine #1
Source: Kubota Corporation. Catalog

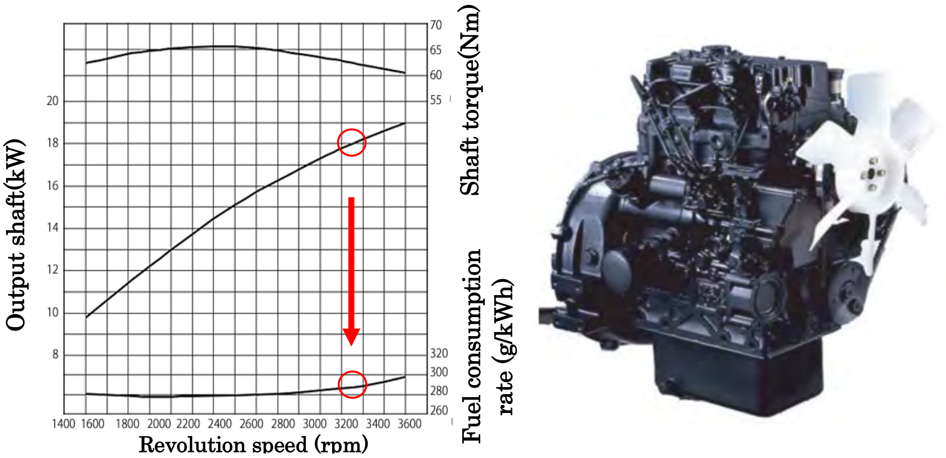


Figure 4 performance curve and appearance of a diesel engine #2
Source: Shibaura IHI Co. catalog

Above graph indicates shaft torque (Nm), shaft output (kW) and fuel consumption ratio from the top. In comparing the fuel efficiency of those two graphs, the engine #1 records about

280g/kWh and engine #2 shows about 290 g/kWh at the same output scale of 18kW. This implies although receiving the same level of output with similar generators, their use of fuel is different.

Since the performance of diesel engines are different with each unit, It is important for the power plants with multiple units to employ the "economic load dispatching," which minimize the fuel cost based on the principle of equal incremental fuel cost.

5. Mechanism of lower performance in low load operation

Generally, diesel engines perform the best around rated output level and the worst around the low load range. Figure 5-1shows comparison of fuel consumption rate in two generators (unit A: rate output 100kW, unit B: rated output 350kW) used in Japan's remote islands. This indicates that both of diesel generators function most efficiently around the rated output range and worsen as the load factor decreases.

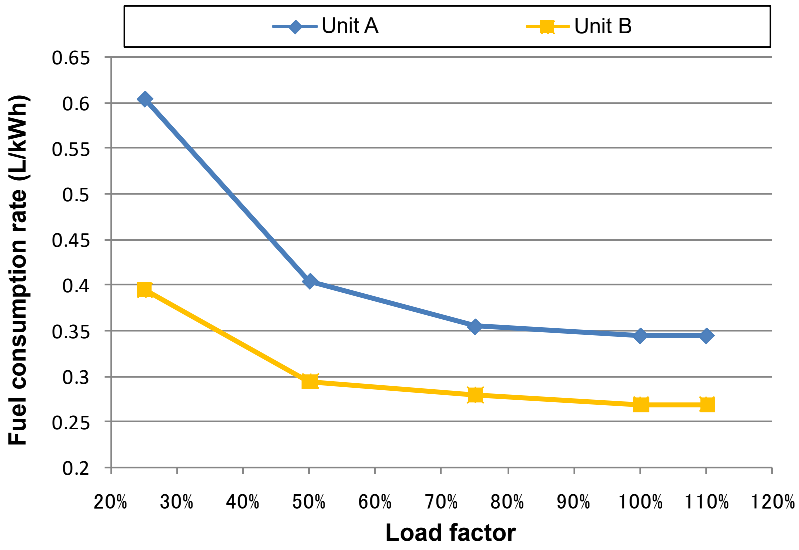


Figure 5. Fuel efficiency and load factor in diesel engines

When operating with low load factor, a primary phenomenon can be seen in diesel engine is the incomplete combustion, a poor burning of fuel-air mixture in the cylinder. A portion of fuel oil turning into soot is released as black smoke or white fume (liquid smoke), the fuel itself is discharged by the imperfect combustion. If the injected fuel doesn't converts fully into heat energy, necessary output can't be attained, thus more fuel needs to be supplied. This is the cause of increase in fuel consumption ratio.

One of the reason of incomplete combustion is that decreased amount of air charge in cylinders associated with low pressure during the air intake. This leads to the decline of compression pressure as well as compression temperature, thus it becomes difficult for fuel to ignite and combust.

Another reason is that injection pressure delivered through fuel pump to the nozzle decreases during low load operation as shown in figure 3-5. Therefore, the diameter of fuel particle sprayed from the valve becomes large and unevenly distributed fuel cannot combust in time (image of incomplete combustion in figure3-6 The effort to maintain the appropriate spraying process in low load operation can lead to later increase of fuel pressure during high load factor range and cause excessive burden on the injection pump and valves by contrast.

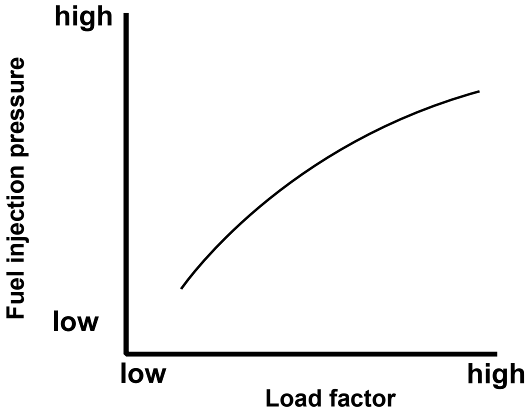


Figure 6. Load factor and fuel injection pressure

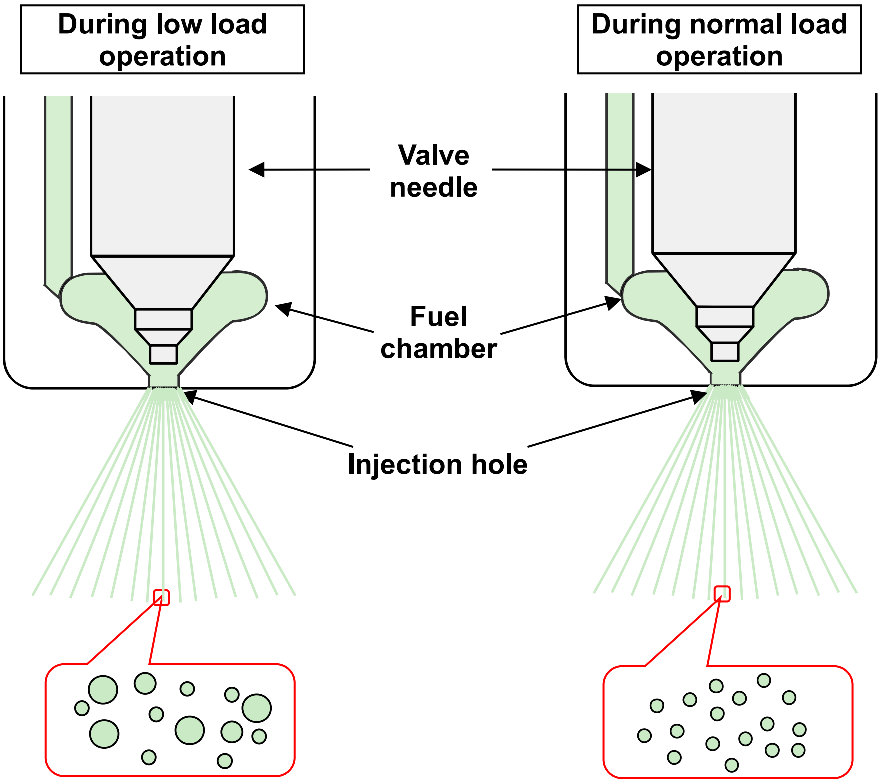


Figure 7. Image of fuel distribution in different injection pressure

Key points:

- **Diesel power generator's energy efficiency is as high as above 40%**
- **Performance (fuel consumption, etc) varies with each generators**
- **Performance (fuel consumption, etc) can be different with the operation**

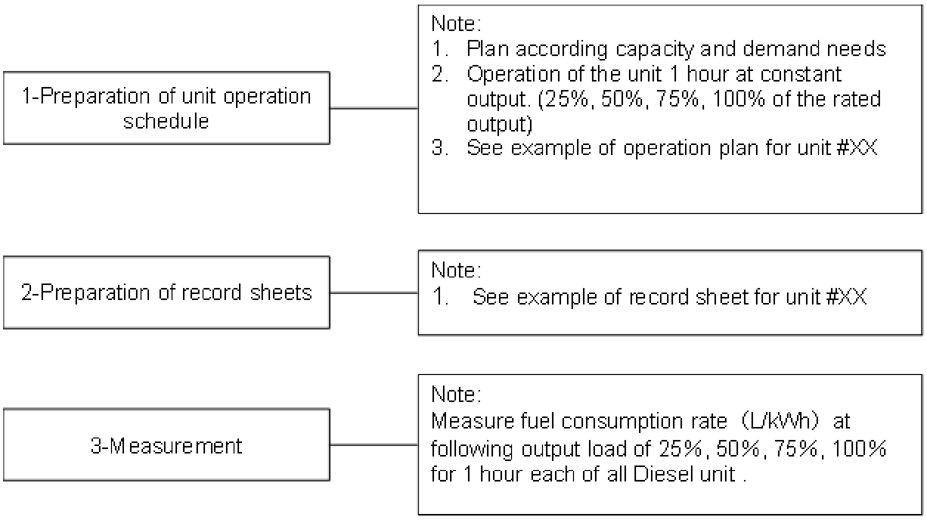
6. Measuring Fuel Consumption Rate

As can be seen from the unit of measure, fuel consumption rate is the amount of fuel consumed (ℓ or gal) per kWh in a given output range. Therefore, when measuring, the amount of fuel consumed and amount of power per unit of time must be measured while maintaining a constant output in a given output range.

As evident in the example data measurements shown below, 3 items [amount of power, fuel flow (intake), and fuel flow (return)] must be measured, the start and end times for each measurement must be the same to the second. If there is a gap in measuring time, the accuracy of the data is reduced, and thereby reduces the accuracy of the fuel consumption characteristics curve and moreover the reduction in fuel consumption during EDC operation.

Therefore, personnel in charge of taking measurements must be chosen according to each measurement item where possible to ensure that times and values are measured accurately.

- Fuel consumption measurement flow diagram



1-Preparation of unit operation schedule

Note:
1. Plan according capacity and demand needs
2. Operation of the unit 1 hour at constant output. (25%, 50%, 75%, 100% of the rated output)
3. See example of operation plan for unit #XX

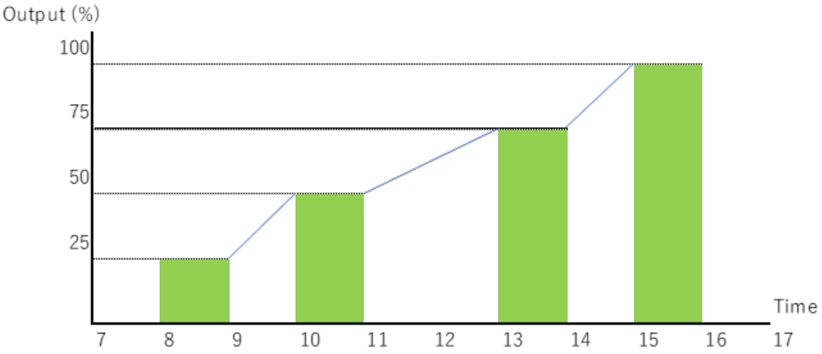
2-Preparation of record sheets

Note:
1. See example of record sheet for unit #XX

3-Measurement

Note:
Measure fuel consumption rate （L/kWh） at following output load of 25%, 50%, 75%, 100% for 1 hour each of all Diesel unit .

- Operation plan



・Data measurement (example)

Shown below are example data for Unit 2 (Majuro Power Plant No.1) when measured at a constant output (1.5 MW).

Time	Measurement start 9:00		Measurement end 10:00	XXｋW
Power meter value	a 40,769.55 【MWh】	→	b 40,771.09【MWh】	Amount of power: a－b 1.54【MWh】
Fuel flow meter value (Intake: tank→engine)	c 1,916,717 [Gal]	→	d 1,917,113 [Gal]	d－c ① _ 396 [Gal]
Fuel flow meter value* (Return: engine→tank)	e 1,498,428 [Gal]	→	f 1,498,706 [Gal]	f－e ② _ 278 [Gal]
Fuel consumed				①－② 118 [Gal]

Fuel consumption rate = fuel consumed / amount of power

= 118 [Gal] / 1,540 [kWh]

＝ **0.0766【Gal/kWh】＝ 13.054kWh/Gal**

＜for ℓ/kWh＞

Since 1 [gal] = 3.7856 [ℓ]

＝ 0.0766 × 3.7856

＝ **0.2899【ℓ/kWh】**

*There is an "inlet" line and a "return" line for sending fuel between the fuel tank and the engine for each unit. The intake pipe sends fuel from the tank to the engine, and the return line sends fuel not burned in the engine back to the tank.

The fuel flow meters attached to each pipe are referred to here as "intake fuel flow meter" and "return fuel flow meter" respectively.

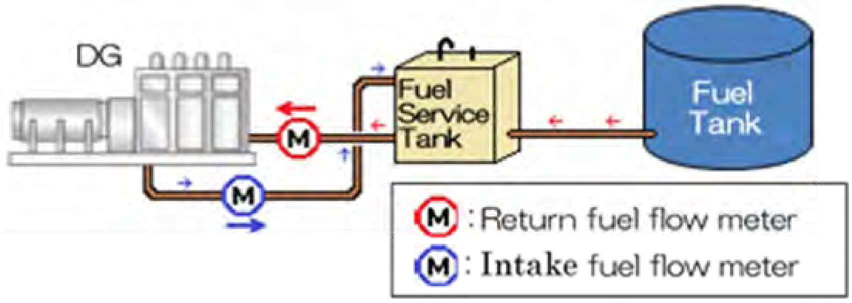


Figure 8 Schematic diagram of fuel piping for diesel power unit

7. Preparing an economical load dispatching table with Microsoft Excel

Create fuel consumption characteristics curves by using the measured fuel consumption rate values as shown in Figure 3-1

.Below is the designing flow.

Table 1. Designing flow

	Flow	Description
1	■Measurement of fuel consumption rate	■Measure fuel consumption rate（L/kWh）at following output load of 25％, 50％, 75％, 100％ for each Diesel unit.
2	■Designing a fuel consumption curve	■Develop a curve (scatter diagram) of fuel consumption rate based on measured values.
3	■Obtaining an approximation curve	■Obtain a formula with a polynomial square approximation curve.
4	■Calculation of fuel consumption rate for each unit output	■Calculate fuel consumption rate (L/kWh) from obtained approximation curve for each unit output (ex: per 10kW)
5	■Calculation of fuel consumption rate for each unit output	■Calculate fuel consumption amount (L/h) from obtained fuel consumption rate (L/kWh) for each unit output (ex: per 10kW
6	■ Develop an Economical load dispatching table by combined unit operation	■Determine minimum output of each unit and calculate fuel consumption at each output level and create a load allocation table with minimum fuel consumption.

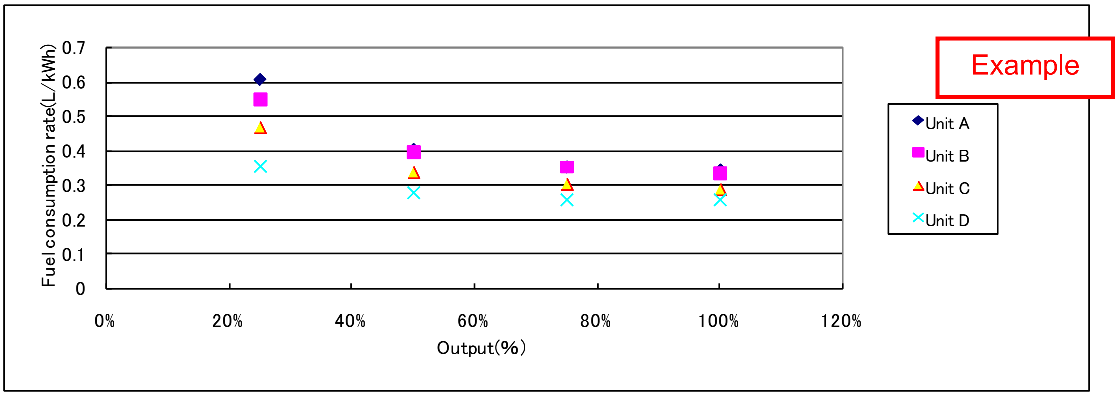
(1) Fuel consumption rate（re-described）

Fill in the specification of diesel units in your country in below.

Units	**Rated output**	**Max. output**	**Min. output**	**Fuel consumption rate(L/kWh)**			
	(kW)	**(kW)**	**(kW)**	**25%**	**50%**	**75%**	**100%**
Unit A	**100**	**100**	**50**	**0.608**	**0.404**	**0.353**	**0.344**
Unit B	**100**	**100**	**50**	**0.550**	**0.396**	**0.353**	**0.334**
Unit C	**200**	**200**	**100**	**0.467**	**0.338**	**0.304**	**0.289**
Unit D	**300**	**300**	**150**	**0.357**	**0.279**	**0.257**	**0.258**

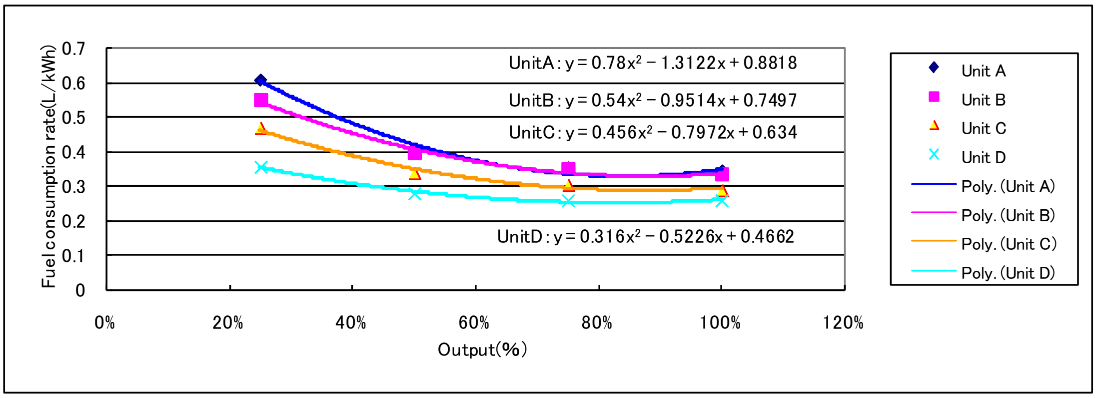
(2) Develop a curve of fuel consumption rate

Design a curve (scatter chart) of fuel consumption rate.



(3) Draw an approximation curve

Obtain a formula with polynomial approximation curve (square).

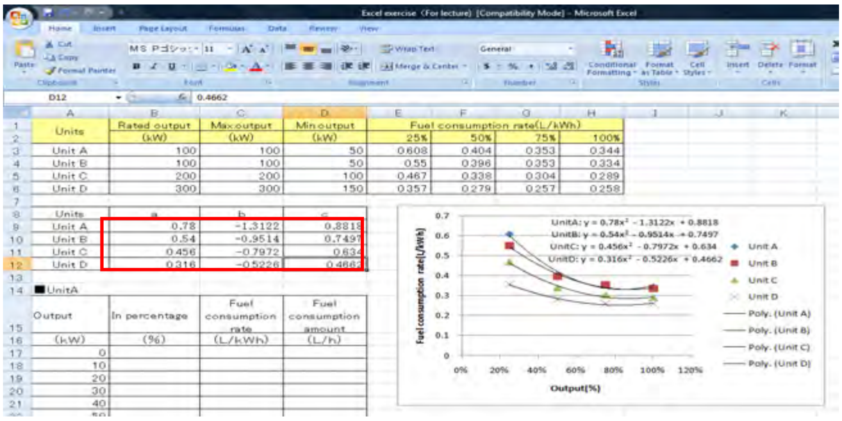


＜Formula＞

Units	Formula
Unit A	**y = 0.780x2 - 1.3122x + 0.8818**
Unit B	**y = 0.540x2 - 0.9514x + 0.7497**
Unit C	**y = 0.456x2 - 0.7972x + 0.6340**
Unit D	**y = 0.316x2 - 0.5226x + 0.4662**

(4) Calculation of fuel consumption

① Input coefficient of each approximation



Units	Rated output (kW)	Max output (kW)	Min output (kW)	Fuel consumption rate(L/kWh) 25%	50%	75%	100%
Unit A	100	100	50	0.608	0.404	0.353	0.344
Unit B	100	100	50	0.55	0.396	0.353	0.334
Unit C	200	200	100	0.467	0.338	0.304	0.289
Unit D	300	300	150	0.357	0.279	0.257	0.258

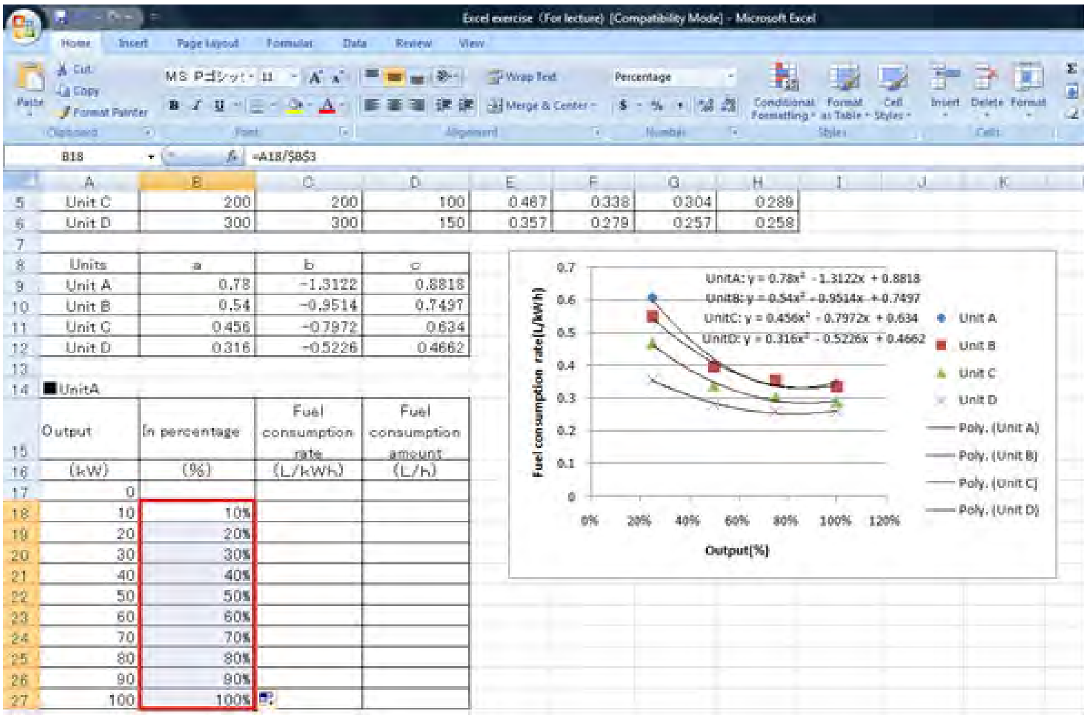
Units	a	b	c
Unit A	0.78	-1.3122	0.8818
Unit B	0.54	-0.9514	0.7497
Unit C	0.456	-0.7972	0.634
Unit D	0.316	-0.5226	0.4662

■UnitA

Output (kW)	In percentage (%)	Fuel consumption rate (L/kWh)	Fuel consumption amount (L/h)
0			
10			
20			
30			
40			

② Calculate output percentage against its rated output

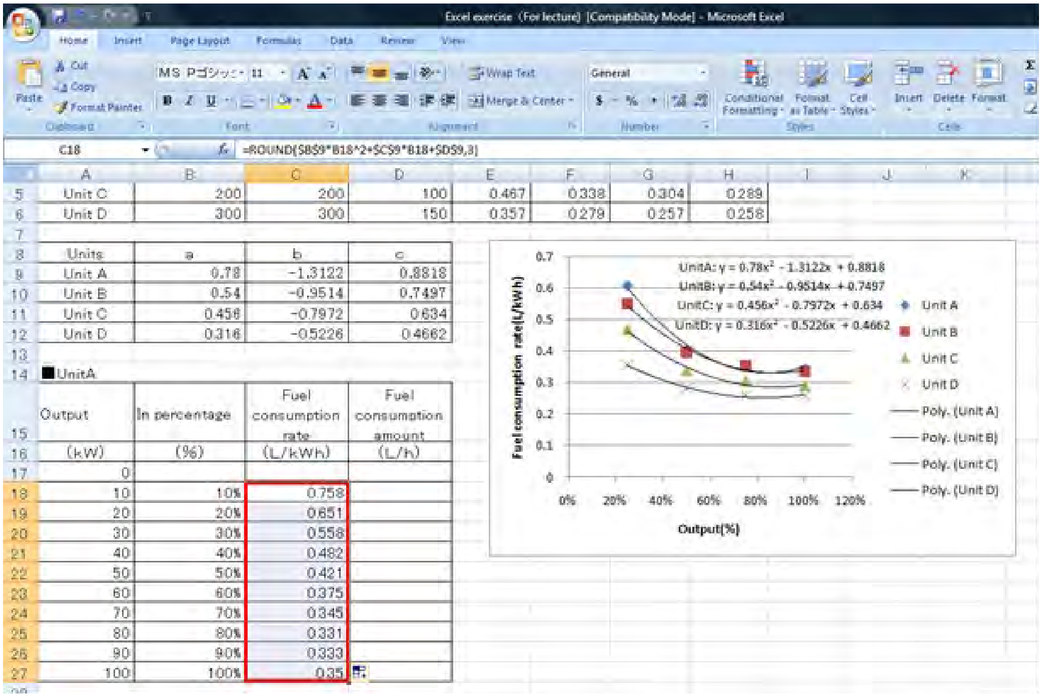
Calculation formula ——→ Output percentage＝output / rated output



B18 =A18/$B$3

	A	B	C	D	E	F	G	H
5	Unit C	200	200	100	0.467	0.338	0.304	0.289
6	Unit D	300	300	150	0.357	0.279	0.257	0.258
7								
8	Units	a	b	c				
9	Unit A	0.78	-1.3122	0.8818				
10	Unit B	0.54	-0.9514	0.7497				
11	Unit C	0.456	-0.7972	0.634				
12	Unit D	0.316	-0.5226	0.4662				
13								
14	■UnitA							
15	Output	In percentage	Fuel consumption rate	Fuel consumption amount				
16	(kW)	(%)	(L/kWh)	(L/h)				
17	0							
18	10	10%						
19	20	20%						
20	30	30%						
21	40	40%						
22	50	50%						
23	60	60%						
24	70	70%						
25	80	80%						
26	90	90%						
27	100	100%						

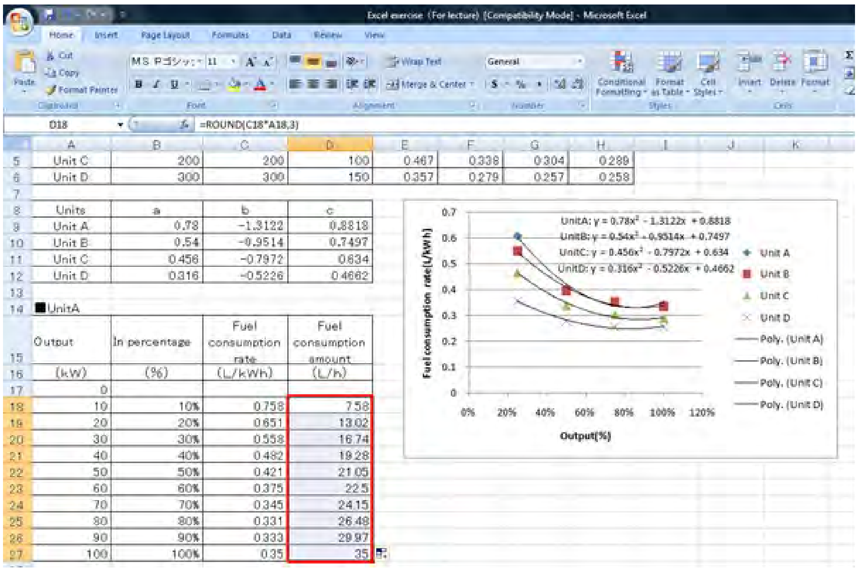
③ Calculate fuel consumption rate for all of the output percentage



C18 =ROUND($B$9*B18^2+$C$9*B18+$D$9,3)

	A	B	C	D	E	F	G	H
5	Unit C	200	200	100	0.467	0.338	0.304	0.289
6	Unit D	300	300	150	0.357	0.279	0.257	0.258
7								
8	Units	a	b	c				
9	Unit A	0.78	-1.3122	0.8818				
10	Unit B	0.54	-0.9514	0.7497				
11	Unit C	0.456	-0.7972	0.634				
12	Unit D	0.316	-0.5226	0.4662				
13								
14	■UnitA							
15	Output	In percentage	Fuel consumption rate	Fuel consumption amount				
16	(kW)	(%)	(L/kWh)	(L/h)				
17	0							
18	10	10%	0.758					
19	20	20%	0.651					
20	30	30%	0.558					
21	40	40%	0.482					
22	50	50%	0.421					
23	60	60%	0.375					
24	70	70%	0.345					
25	80	80%	0.331					
26	90	90%	0.333					
27	100	100%	0.35					

④ Calculate fuel consumption rate for all of output range



D18 =ROUND(C18*A18,3)

	A	B	C	D	E	F	G	H
5	Unit C	200	200	100	0.467	0.338	0.304	0.289
6	Unit D	300	300	150	0.357	0.279	0.257	0.258
7								
8	Units	a	b	c				
9	Unit A	0.78	−1.3122	0.8818				
10	Unit B	0.54	−0.9514	0.7497				
11	Unit C	0.456	−0.7972	0.634				
12	Unit D	0.316	−0.5226	0.4662				
13								
14	■UnitA							
15	Output	In percentage	Fuel consumption rate	Fuel consumption amount				
16	(kW)	(%)	(L/kWh)	(L/h)				
17	0							
18	10	10%	0.758	7.58				
19	20	20%	0.651	13.02				
20	30	30%	0.558	16.74				
21	40	40%	0.482	19.28				
22	50	50%	0.421	21.05				
23	60	60%	0.375	22.5				
24	70	70%	0.345	24.15				
25	80	80%	0.331	26.48				
26	90	90%	0.333	29.97				
27	100	100%	0.35	35				

⑤ Calculation of fuel consumption rate and fuel consumption for each unit output

Unit A			
Output (kW)	In percentage (%)	Fuel consumption rate（L/kWh）	Fuel consumption amount（L/h）
10	10%	0.75838	7.58
20	20%	0.65056	13.01
30	30%	0.55834	16.75
40	40%	0.48172	19.27
50	50%	0.42070	21.04
60	60%	0.37528	22.52
70	70%	0.34546	24.18
80	80%	0.33124	26.50
90	90%	0.33262	29.94
100	100%	0.34960	34.96

Unit B			
Output (kW)	In percentage (%)	Fuel consumption rate（L/kWh）	Fuel consumption amount（L/h）
10	10%		
20	20%		
30	30%		
40	40%		
50	50%		
60	60%		

70	70%		
80	80%		
90	90%		
100	100%		

■Unit A and B

Below table shows an optimum load allocation with minimum fuel consumption for each load level.

■Operation of unit A and unit B

Selection machine	Unit A 100(kW)	Unit B 100(kW)	Fuel consumption amount (L/h)		Total	Min. value
Max.	100(kW)	100(kW)	Unit A	Unit B		
Min.	50(kW)	50(kW)			L/h	L/h
100	50	50	21.04	20.45	41.49	41.49
110	50	60	21.04	22.4	43.44	42.97
	60	50	22.52	20.45	42.97	
120	50	70	21.04	24.38	45.42	44.63
	60	60	22.52	22.4	44.92	
	70	50	24.18	20.45	44.63	
130	50	80	21.04	26.73	47.77	46.58
	60	70	22.52	24.38	46.9	
	70	60	24.18	22.4	46.58	
	80	50	26.5	20.45	46.95	
140	50	90	21.04	29.78	50.82	48.56
	60	80	22.52	26.73	49.25	
	70	70	24.18	24.38	48.56	
	80	60	26.5	22.4	48.9	
	90	50	29.94	20.45	50.39	
150	50	100	21.04	33.83	54.87	50.88
	60	90	22.52	29.78	52.3	
	70	80	24.18	26.73	50.91	
	80	70	26.5	24.38	50.88	
	90	60	29.94	22.4	52.34	
	100	50	34.96	20.45	55.41	
160	60	100	22.52	33.83	56.35	53.23
	70	90	24.18	29.78	53.96	
	80	80	26.5	26.73	53.23	
	90	70	29.94	24.38	54.32	
	100	60	34.96	22.4	57.36	
170	70	100	24.18	33.83	58.01	56.28
	80	90	26.5	29.78	56.28	
	90	80	29.94	26.73	56.67	
	100	70	34.96	24.38	59.34	
180	80	100	26.5	33.83	60.33	59.72
	90	90	29.94	29.78	59.72	
	100	80	34.96	26.73	61.69	
190	90	100	29.94	33.83	63.77	63.77
	100	90	34.96	29.78	64.74	
200	100	100	34.96	33.83	68.79	68.79

V 8. Economic load dispatching software

(1) About economic load dispatching software

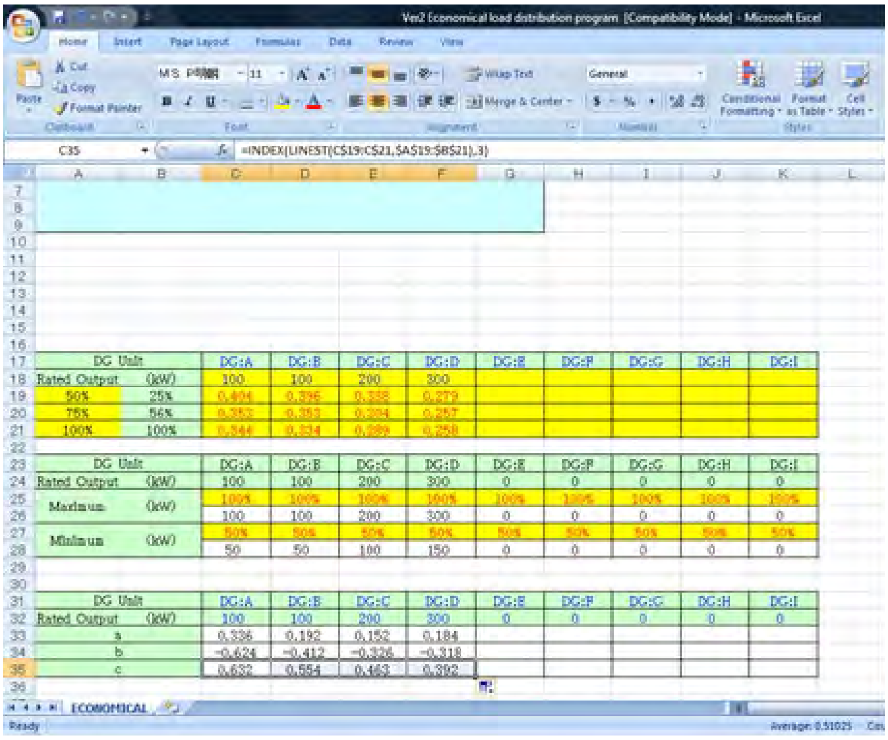
When supplying electric power, generally multiple generation units are installed in case of the failures and accidents.

In operation with economic load dispatching, the outputs of multiple diesel units are controlled to operate the most effectively. This helps reduce the consumption of fossil fuel in remote islands and achieve lower emission of the greenhouse gas such as carbon dioxide.

The economic load dispatching software calculates the best distribution pattern with the least fuel consumption in operation of multiple diesel generators. (Hereafter referred as DG) This software is programmed with the VBA (Visual Basic for Applications) of Microsoft office Excel and mainly used to develop a load distribution table.

(2) Economic load dispatching software

First, input data of DGs into a table and execute the calculation program.



Ver2 Economical load distribution program [Compatibility Mode] - Microsoft Excel

C35 =INDEX(LINEST(C$19:C$21,$A$19:$B$21),3)

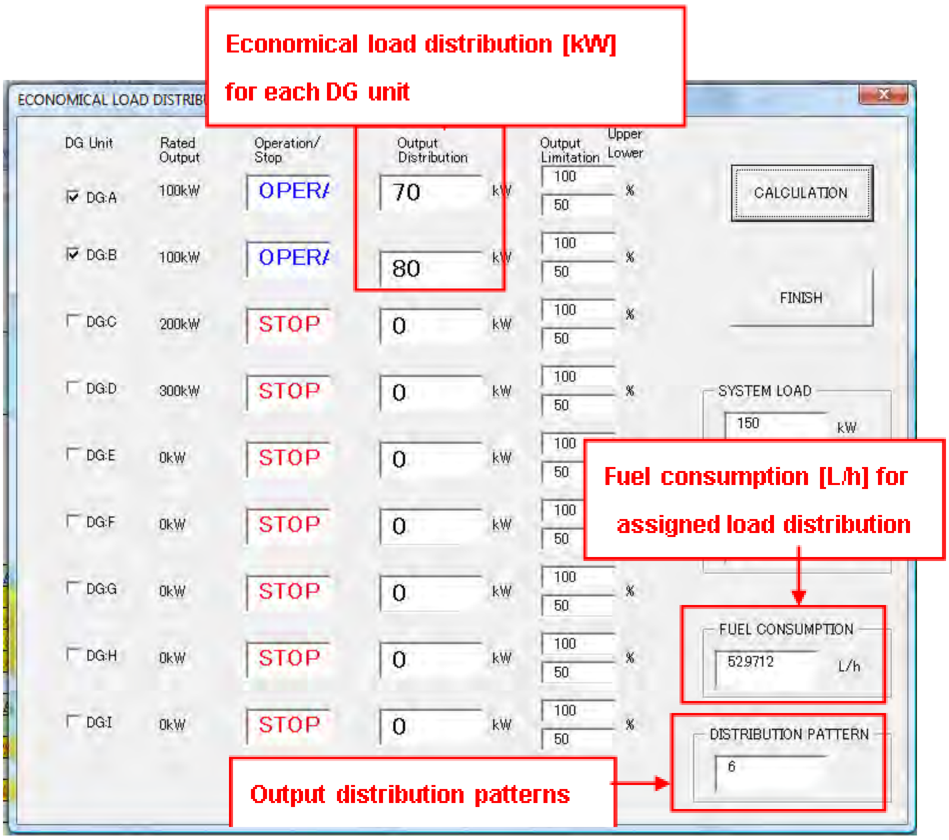
DG Unit		DG:A	DG:B	DG:C	DG:D	DG:E	DG:F	DG:G	DG:H	DG:I
Rated Output	(kW)	100	100	200	300					
50%	25%	0.404	0.396	0.338	0.279					
75%	56%	0.352	0.353	0.304	0.257					
100%	100%	0.344	0.334	0.289	0.258					

DG Unit		DG:A	DG:B	DG:C	DG:D	DG:E	DG:F	DG:G	DG:H	DG:I
Rated Output	(kW)	100	100	200	300	0	0	0	0	0
Maximum	(kW)	100%	100%	100%	100%	100%	100%	100%	100%	100%
		100	100	200	300	0	0	0	0	0
Minimum	(kW)	50%	50%	50%	50%	50%	50%	50%	50%	50%
		50	50	100	150	0	0	0	0	0

DG Unit		DG:A	DG:B	DG:C	DG:D	DG:E	DG:F	DG:G	DG:H	DG:I
Rated Output	(kW)	100	100	200	300	0	0	0	0	0
a		0.336	0.192	0.152	0.184					
b		-0.624	-0.412	-0.326	-0.318					
c		0.632	0.554	0.463	0.392					

Calculation result appears.

The results will be displayed for; economical load distribution [kW] for each DG unit, fuel consumption for assigned condition and output distribution patterns.



Economical load distribution [kW] for each DG unit

DG Unit	Rated Output	Operation/ Stop	Output Distribution		Output Limitation Upper	Output Limitation Lower	
☑ DG:A	100kW	OPERA	70	kW	100	50	%
☑ DG:B	100kW	OPERA	80	kW	100	50	%
☐ DG:C	200kW	STOP	0	kW	100	50	%
☐ DG:D	300kW	STOP	0	kW	100	50	%
☐ DG:E	0kW	STOP	0	kW	100	50	
☐ DG:F	0kW	STOP	0	kW	100	50	
☐ DG:G	0kW	STOP	0	kW	100	50	%
☐ DG:H	0kW	STOP	0	kW	100	50	%
☐ DG:I	0kW	STOP	0	kW	100	50	%

SYSTEM LOAD: 150 kW

Fuel consumption [L/h] for assigned load distribution

FUEL CONSUMPTION: 52.9712 L/h

Output distribution patterns

DISTRIBUTION PATTERN: 6

End

5. Maintenance of Diesel Generators

5.1 Overhaul of Diesel Generator
and
Auxiliary Equipment

Kosrae Utilities Authority

INDEX

1. Overhaul

1.1 Purpose of overhaul

1) Types of Overhaul

There are two types of overhaul, one for repair and second for periodic inspections carried out based on the instruction manual.

2) Precautions for overhaul

Overhaul includes the process including from inspection to assembly, if the way disassembly is performed poor, parts will be damaged or lost making it impossible to assemble, so it is necessary to disassemble using the proper tools and correct procedure. Therefore, it is important to carefully read the engine's instruction manual, maintenance manual, etc. before disassembly. It is also important to neatly arrange the disassembled parts so that they will not get lost at the time of assembly.

In addition, if a damaged part is found during disassembly, it will be necessary to arrange for additional parts, so report it to the person in charge.

① Disassemble using the proper tools

To loosen bolts, use a spanner that matches the dimensions of the bolts and nuts, and use a box wrench or ring spanner where possible to loosen screws. (Do not use a monkey wrench or pipe wrench.) Also, since there are places that cannot be disassembled unless special tools for engines are used so prepare them in advance.

② Consider assembly when disassembling

Parts causing problems with fitting parts are numbered with a marker, etc. so that the combination does not change. It is also important to mark parts whose orientation becomes difficult to track so that you will not get lost during assembly.

③ Organization of parts

Each of the disassembled parts is sorted by type (by cylinder) and organized such that it will not become unrecognizable at the time of assembly. Divide small parts into boxes, etc. so as not to lose them. It is also important to cure with a curing sheet, etc. so that dirt does not enter.

1.2 Washing parts

Disassembled parts must be washed for easy inspection.

1) Carbon removal

Since a lot of carbon accumulates and fixes on parts exposed to combustion gas such as cylinder heads, pistons, intake and exhaust valves, and superchargers, the carbon must be removed. Since this carbon is fixed firmly and cannot be removed easily, it must be forcibly scraped off with a chisel, etc., and care must be taken not to scratch the part.

It is also effective to soak the carbon by immersing it in chemicals and removing the carbon with a high-pressure washer.

2) Washing of coolers, etc.

Shell & tube type coolers such as a lubricating oil cooler, an air cooler, a fresh water cooler, etc. have a complicated construction, and their method of circulating chemicals to remove scale is effective. If water quality is poor, clogging may occur in the tube, and special jigs must be made to clean the inside of the tube. Recently, plate-type coolers which are easy to maintain are becoming mainstream.

3) Washing with washing oil

For ordinary dirt, a container filled with wash oil and parts are washed in it.

1.3 Inspection of parts

The judgment on whether to repair or replace the parts is made based on the manufacturer's maintenance standard (repair limit and usage limit), but care shall be taken such that there is no error in inspection or judgment. Rather than making a decision independently when it’s unclear what should be done, it is important to resolve the issue in consultation with the manufacturer.

1) Appearance inspection

Visually inspect external defects. Pay particular attention to the following points.

① Surface condition

Abnormal wear of sliding part of pistons, cracks on piston top surface and ring grooves, scratches on the inner surface of the cylinder liner, galling of the bearing, peeling damage on the bearing metal or plating, etc.

② Presence of damage

Damage of shaft, gears, piston rings, springs, etc.

③ Presence of corrosion

Corrosion state of parts exposed to water such as liner collar part and outer circumference, water jacket part of cylinder head, pump parts, etc.

2) Dimensional inspection

For important parts, measure the main dimensions of each part and correct or replace those exceeding the limit according to maintenance standards. Abnormal wear can be determined by keeping a record of dimensions for each servicing.

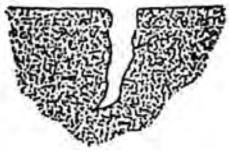
3) Inspection for cracks

Scratches and cracks that cannot be found visually are investigated by non-destructive inspection such as penetrant testing (PT) and magnetic particle testing (MT), etc., and if there is an abnormality, it shall be taken care of by parts replacement or consultation with manufacturer.

① Penetrant dye testing (color check)

This is a method of finding cracks where a red penetrant penetrates into cracks such that they are easy to see. This method is a very easy method, and a 3-in-one set which includes an aerosol type of cleaning solution, a penetrant liquid, and developing solution should be purchased. Magnetic particle testing is better at detecting scratches, but without such equipment or with parts that cannot be magnetized (heat resistant steel, stainless steel, nonferrous metal parts), this method is used.

1. Pretreatment



Adhering substances such as fats and oils, paints, rusts, scales, dirt, etc. which prevent penetration liquid from penetrating into the defects shall be removed.
The washing method is performed with a solvent or the like, and after the treatment, the solvent, the washing solution, and the moisture are sufficiently dried.

2. Penetration treatment

As a general rule, penetrant liquid is applied by spraying, and depending on the conditions, dipping, applied with a brush, etc. The standard penetration time is 5 to 20 minutes, and in particular, very narrow cracks such as a hair cracks should be given at least twice the time. When the penetrant liquid dries, the penetration effect becomes weak, so it is desirable to apply it again.

3. Washing

Remove excessive penetrant adhering to the surface and do not perform excessive washing such that the liquid penetrating into the defect leaks out.

4. Development

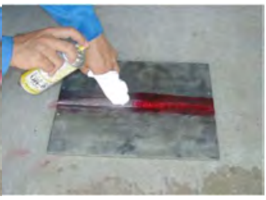
Thoroughly stir the developing solution and spray it while shaking the container up, down, left, and right 30 ㎝ from the test surface, and apply it evenly so that the color of the skin of the test surface appears slightly permeated. As the developing solution dries for a while, if there is a scratch, the red penetrant liquid will ooze out in the book part which makes scratches easy to find.

When the color check is carried out, not only are the fats and oils on the surface of the specimen removed, but since a developing solution with a strong hygroscopic property is adhered, the developing solution adhered to the surface must be completely removed when necessary and rustproofed after testing.

Pretreatment

Penetration

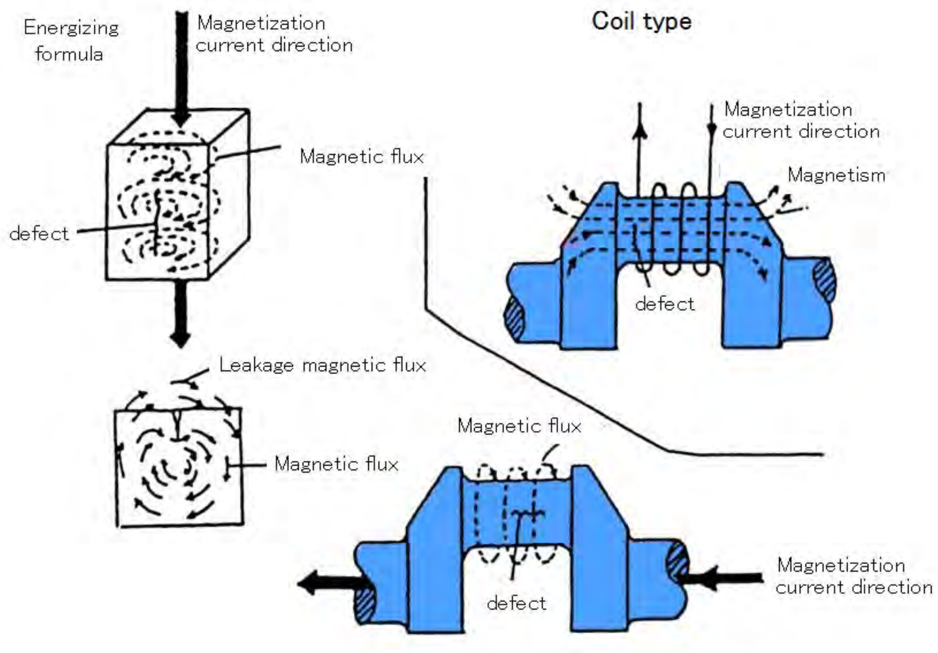
Washing



Development

② Magnetic particle testing

This is currently a widely used method of finding scratches and even small scratches where a part is magnetized by applying magnetizing current to it and applying magnetic powder. As shown in the figure below, when a current is applied, a magnetic flux line is generated in a direction perpendicular to the magnetizing current, and if there is a scratch near the surface, the magnetic flux line cannot easily pass through the area of the scratch, so it leaks out near the scratch. At this time, if fine iron powder (magnetic powder) with high magnetic permeability dissolved in diesel oil is sprinkled on this surface, the magnetic powder is attracted by the leaked magnetic flux. That is, it appears as a scratch on the surface.



Using special magnetic powder (fluorescent flaw detection), which emits light when fluorescent light is applied to the magnetic powder, makes it even easier to detect scratches. However, as mentioned in the previous section, it cannot be applied to inspection of non-magnetic parts. This inspection is carried out in the following procedure. After completion of the test, demagnetization must always be performed to completely eliminate magnetism.

Preparation → magnetization → magnetic powder application → inspection → demagnetization → washing

Pretreatment (preparation) Magnetization Magnetic powder application Inspection

The check points of these nondestructive inspections are shown in the table below.
As described above, if the magnetic particle testing cannot be performed, penetrant inspection is performed instead. When inspecting for scratches, be careful not to mistake the remains of mark-off lines, clasp fitted snugly, or the boundary between the metal part and the base material as they may look like scratches.

Checkpoints for crack inspection of major parts

Part Name	PT	MT	Checkpoints
Crankshaft		○	Scratches on the surface of the shaft, especially scratches near the arm and Radius part
Journal and crankpin metal	○		Cracking of bearing surface, peeling of bearing layer (check at end surface)
Crankpin bolt		○	Scratches on the surface, especially scratches of R and screws of the top and base
Piston	○		Cracking of the combustion surface, ring groove base, sliding surface, rim of the piston pin boss
Cylinder head	○		Cracking of the combustion surface
Intake/exhaust valve	○		Scratches on cotter
Cam and shaft		○	Scratches on each surface
Gear		○	Scratches on the tooth surface and base
Coupling		○	Scratches on the key groove base
Others	○	○	Scratches on the surface

1.4 Engine maintenance standards

In accordance with maintenance standards specified for each model, it must be decided whether to replace parts with a new one. Depending on the degree of damage and wear, it must be decided whether or not to replace it considering the conditions of use and the time of use up to the next inspection, etc. If too much care is taken, repair costs will increase, and if not enough care is given, there is a risk of major faults, so difficult judgment is required. For those involved in the maintenance of diesel engines, long experience, intuition, and know-how is essential. In addition, maintenance will be carried out according to the maintenance standard table for each model.

1.5 Regarding assembly

Like disassembly, in assembly, proper tools and special tools according to the procedure of the engine instruction manual or maintenance manual are used to confirm that no assembly of parts, tightening, etc. is forgotten, and it is important to reliably assemble sliding parts one by one while applying lubricating oil, etc. It is also important to check the checkpoints during assembly without fail and confirm that there is no mistake before moving on to the next point.

1) General precautions

① In order to prevent dust from entering during assembly, bearings and other sliding surfaces are washed again with wash oil before assembling the parts, dried by spraying with compressed air, sufficient lubricating oil is applied, and then the parts are assembled.

② Checkpoints (assembly standard dimensions, clearance, backlash, timing, etc.) shall be measured and recorded during assembly.

③ Appropriate packing (genuine parts) shall be used. Use of rubber packing, etc. without oil resistance and heat resistance will result in unexpected accidents.

④ When assembling the oil seal, careful attention such as applying grease to the shaft and lip so as not to scratch the lip and assembling it using a guide is required.

⑤ Always replace bent metal washers, split pins, etc. with new ones and install them correctly. In particular, it shall be confirmed that the split pin of the moving part does not move after bending.

⑥ Oil or lubricant specified by the manufacturer shall be applied to the threaded portion and washer of the bolt/nut and tightened.

⑦ Replace stiff screws, screws with stripped threads, nuts or washers that have curls on the skin side.

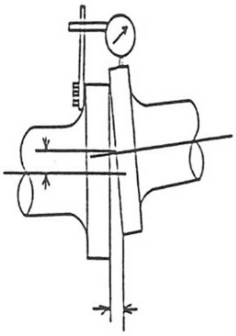
⑧ Main bolts such as those of the cylinder head shall be gradually tightened in two or three steps in accordance with the tightening order specified by the manufacturer to avoid uneven tightening, and finally, tightened with the specified torque using a torque wrench. Instructions provided by manufacturers such as tightening angle or elongation measurement and tightening shall be followed.

⑨ For bolts/nuts exposed to high heat, anti-seizing agent such as Moricoat shall be lightly applied to the threaded part.

⑩ Bolts with different lengths of the threaded part or different materials shall not be used.

1.6 Centering adjustment

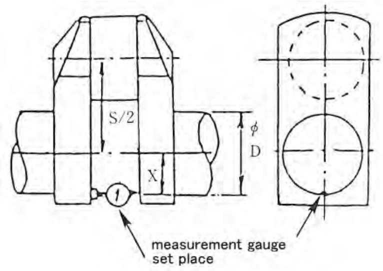
In the case of connecting the two rotating shafts, the adjustment of the core is always performed. Adjusting the amount of change in both shafts to a predetermined value is called centering adjustment.



When using a dial gauge

A method in which the dial gauge is fixed to one side of the shaft and the shaft is rotated to numerically know the position of the other shaft.

Tolerance is different for each manufacturer.

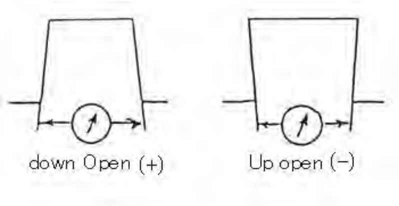


Deflection measurement

The allowable deflection shall be judged based on the numerical value stated in the instruction manual of each engine manufacturer.

Measurement is usually carried out during cold conditions to check in which direction the crankshaft is deforming.

Please be aware that + and - may be reversed if the gauge is read directly during measurement.



The measurement position of the crankshaft deflection is as shown in the left figure.

1-7 Start-up and commissioning

Since it is the first time operating after assembly, you must do it after thoroughly inspecting each part. The following points shall be checked carefully.

1) Checks before measuring

① Be sure to tighten each part.

② Check each part to see if you have left the spanner, tools, etc. on moving parts such as rotating parts, valve arm, etc.

③ If necessary, the lubricating oil system may be cleaned using flushing oil with a separate pump. Also, you can use the lubricating oil being used as it is without using flushing oil, but in either case, putting a strainer in front of the main bearing metal and directing oil directly into the oil pan without allowing it to flow oil to the metal shall be considered.

④ After injecting water or oil, pressure shall be applied with a separate pump to check for water and oil leaks, and the lubricating oil shall be primed to confirm that oil is being supplied to the inside of the engine.

⑤ With the fuel handle in the stop position, it shall be confirmed that the rack of the fuel pump is in the cut position (whether the fuel can be cut off) for each cylinder. For column type pumps, it shall be checked whether fuel can be cut off with the stop lever.

⑥ It shall be checked whether the connection link of the governor and fuel pump works smoothly and whether the ring pin is securely retained.

⑦ The crankshaft shall be turned to make sure that there is no abnormality in the rotating part and that the combustion chamber is not contaminated.

2) Caution after start-up

① Each part shall be thoroughly checked for water leaks and oil leaks and abnormalities, if any, shall be repaired.

② Oil pressure, water pressure, and the output condition of cooling water shall be checked and a check shall be performed for abnormal noise, odor, etc.

③ Check for abnormality by taking note of the engine sound, exhaust color, and the amount of mist gas.

④ The engine shall be stopped a few minutes after starting and each bearing checked for abnormal heat.

3) Precautions for commissioning

① Increase the load gradually, inspect and repair any abnormalities, adjust the discharge amount and injection timing of the fuel pump, and align the maximum pressure in the cylinder (Pmax) with the exhaust temperature.

② When replacing sliding parts such as piston rings, cylinder liners, main bearing metals, etc., break-in operation (gradual increase in rotational speed and load in stages) must be performed. For step-up of this load, the manufacturer's instructions shall be followed. In particular, when using a chrome plated liner or chrome plated piston ring, sufficient break-in operation is necessary.

③ Special attention to each bearing temperature during operation shall be paid to check whether centering is normal or not.

End

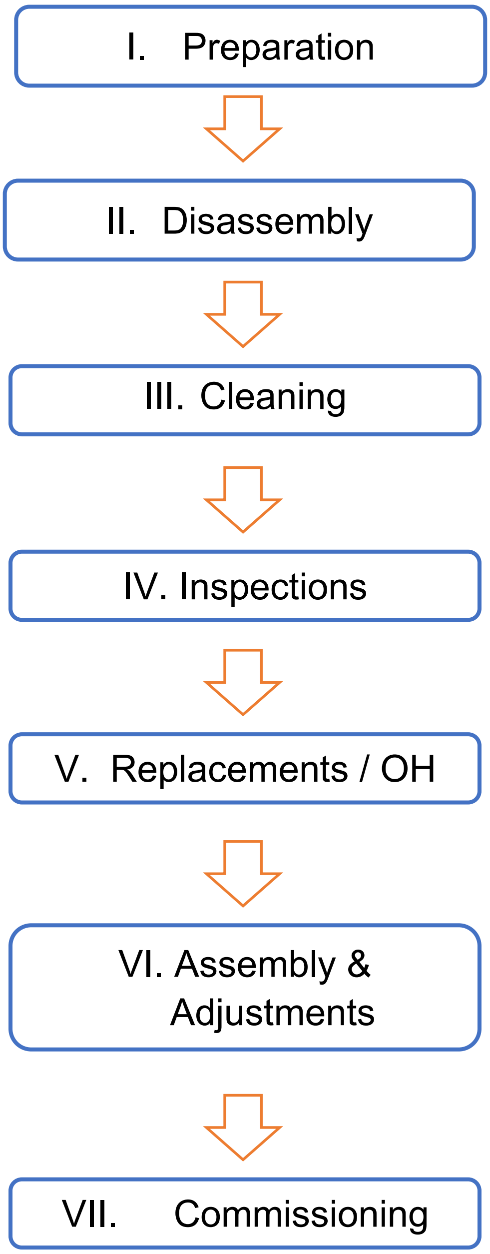
Diesel Generation
Operation and Maintenance Manual

5. Maintenance of Diesel Generators
5.2 Maintenance of diesel generators (Mechanical)

Kosrae Utilities Authority

Overhaul Process Flow Chart

To carry-out overhaul follow below process.



Engine OH Process flow

1. Preparation before Periodic inspection
2. Pre-periodic inspection meeting
3. Pre-disassembly test run
4. Red tag attachment
5. Periodic inspection parts check
6. Cover
7. Deflection measurement
8. Removal of piping around the cylinder head
9. Cylinder head removal
10. Cylinder head disassembly, explosion surface washing, color check
11. Piston extraction, disassembly
12. Cylinder liner extraction
13. Cylinder jacket interior cleaning
14. Main metal overhaul
15. Cylinder liner cleaning, color check
16. Intake valve polishing & lapping
17. Piston disassembly, cleaning, color check
18. Connecting rod Big end removal, cleaning & color check
19. Cylinder liner inner diameter measurement
20. Measurement of piston parts
21. Starting valve polishing & lapping
22. Exhaust valve polishing & lapping
23. Cylinder head washing
24. Intake valve assembly
25. Fuel injection pump removal
26. Exhaust valve box cleaning, assembly, water pressure test
27. Cylinder liner embedding
28. Piston assembly
29. Con-rod big end Assembly and insertion
30. Piston insertion
31. Engine lubricating oil pump overhaul
32. Cylinder head installation
33. Cylinder head tightening
34. Installation of various piping around cylinder head
35. Rocker arm installation
36. Valve end clearance adjustment
37. Fuel injection valve overhaul, injection pressure adjustment
38. Fuel injection pump disassembly, maintenance, installation
39. Lubricating oil removal, sump tank cleaning
40. Replenish lubricating oil
41. Governor replacement
42. Deflection measurement (after assembly)
43. Main bearing pipe restoration, lubrication check
44. Gear backlash measurement
45. Crankshaft thrust measurement
46. Tappet related inspection
47. Oil/water flow test
48. Fuel pump air removal
49. Pre-trial run meeting
50. No-load operation
51. Internal inspection
52. No-load operation
53. Internal inspection
54. Start-up rotational speed test, protective device operation
55. Load step-up adjustment operation
56. Internal inspection
57. Performance test
58. Vibration measurement
59. Internal inspection, bearing temperature measurement
60. Load rejection test

Auxiliary Devices OH Process flow

1 Primary cooling water pump and motor overhaul

2 Secondary cooling water pump, motor overhaul

3 Pressurized water pump, motor overhaul

4 Fuel oil filter disassembly and cleaning

5 Lubricating oil filter disassembly cleaning

6 Supercharger overhaul

7 Each cooler inspection and cleaning (primary water, lubricating oil, air)

8 Temperature control valve operation test (primary water, lubricating oil)

9 Generator bearing overhaul

10 Secondary cooling water flow test

11 Primary water flow test

12 Radiator inspection

13 CJC filter unit inspection

14 Air system related maintenance

15 Expansion water tank inspection

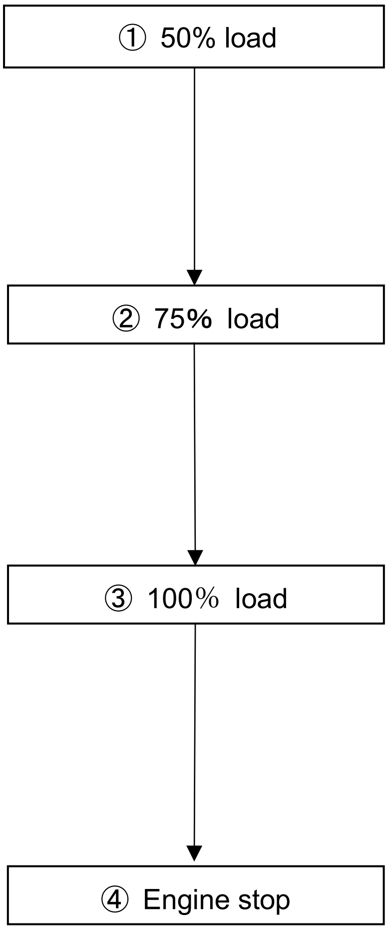
1. Preparation before Periodic inspection

Order of parts to be used	･Periodic inspection parts List Replacement standard parts vary depending on the periodic inspection type (C, D, E) Check the parts that were recommended to be replaced at the last periodic inspection, etc.
↓	
Prepare work execution plan	･Organization chart (construction management, safety management, emergency contacts) ･Worker roster, Work schedule, Stop request, Safety work directions, Procedure (test run), Other. ※Consider process including operation time, possibility of stopping unit
↓	
Materials and equipment preparation	・Disassembly tools, general tools、Measuring instruments ※Tools and measuring instruments vary depending on the target unit.

2. pre-periodic inspection meeting

① Meeting with customer	① Meeting with customer ・Construction execution plan (organization, schedule, roster) ・Work request table ・Listening to operating condition ・Confirm existence of a separate work ・Confirm whether lubricating oil has been changed
↓	
② Workers meeting	② Workers meeting ・Construction execution plan Notify all workers of work content ・Education of new entrants to plant Power plant rules, etc. / Record Minutes of the meeting

3. Pre-disassembly test run



① 50% load

Measurement of each temperature, pressure

Measured fuel consumption rate

Check around the engine

(oil/water leaks, abnormal sounds, odor)

② 75% load

Measurement of each temperature, pressure

Measured fuel consumption rate

Check around the engine

(oil/water leaks, abnormal sounds, odor)

③ 100% load

Measurement of each temperature, pressure

Measured fuel consumption rate

Check around the engine

(oil/water leaks, abnormal sounds, odor)

④ Engine stop

As soon as the trial run is completed, request engine stop

* To cool down engine

※ Periodic inspection report (load test records)

- Wear gloves during explosion pressure measurement (high temperature)
- Pay attention to rotating parts around the engine (entanglement)

Comments

4. Red tag attachment

① Witness attaching of red tags

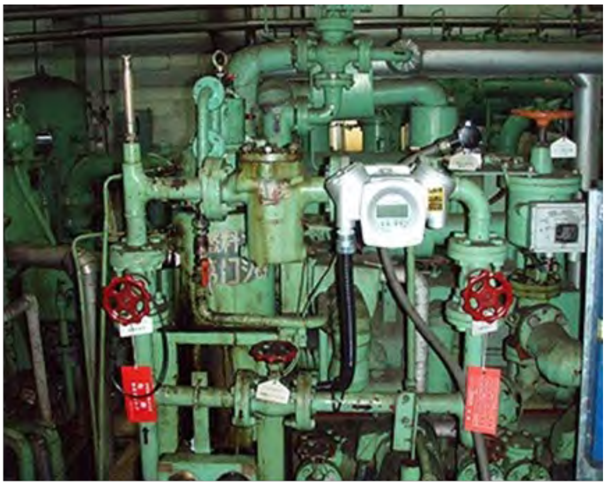
- Red tags shall be handled by the customer in witness of the person responsible for the work. Workers shall not operate the valve breaker.
- Always check for energization when disconnecting switch is operated.

① Isolation from existing facilities, safety measures

- Site requested to be red tagged

1.	Main CB	「Open」
2.	Breaker operation switch	「Off」
3.	Disconnector (in generator breaker panel)	「Open」
4.	Fuel oil flow meter inlet valve	「Close」
5.	Primary cooling water pump (No. 1) inlet valve	「Close」
6.	Primary cooling water pump (No. 2) inlet valve	「Close」
7.	Primary cooling water expansion tank outlet valve	「Close」
8.	Primary cooling water pressure pump inlet valve	「Close」
9.	Starting air engine inlet main valve	「Close」
10.	Fuel oil engine inlet valve	「Close」
11.	Lubricant priming pump breaker	「Off」
12.	Primary cooling water pump (No. 1.2) breaker	「Off」
13.	Primary cooling water pressurized pump breaker	「Off」
14.	Control power supply breaker	「Off」

- Operation manual



Comments

At PUB, we use radiator for cooling both cooler line and jacket therefore we have One pump for jacket and one for coolers.

5. Periodic inspection parts check

① Check of parts to be used

② Classify by use

① Confirmation of parts delivered to the site

- Periodic inspection parts list ※
- Check the order list, part number, quantity.

② Parts classification

- Organize parts for each process and cylinder for easy understanding.

- If the part number is different, immediately check with the manufacturer.
- If there is a shortage or additional parts are needed, promptly ordered after coordinating with customer. (Deliver within the periodic inspection period.)
- Review the periodic inspection work according to the delivery date of additional parts.

6. Cover

① Cover around engine

② Covering maintenance room (washing area)

① Place plywood, etc around the engine

- Cover the parts as they may be
- Cover the parts as they may be placed directly on the floor.
- Preventing falls from spilled oil, etc.

② Cover the maintenance space with plywood

- Cover the parts as they may be placed directly on the floor.
- Preventing falls from spilled oil, etc.
- Prevent scattering of cleaning liquid (water)

- Apply duct tape to the plywood joints. (Stumbling prevention)
- Cover existing equipment with plastic sheets, etc. as necessary.

Comments

7. Deflection measurement

① Deflection measurement

① Measure according to the manufacturer's manual.

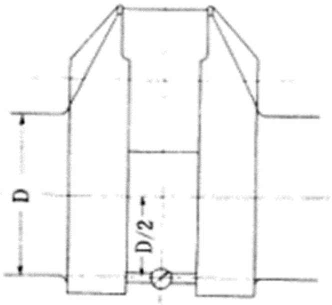
Place the crankshaft at 30°past top dead center (TDC).

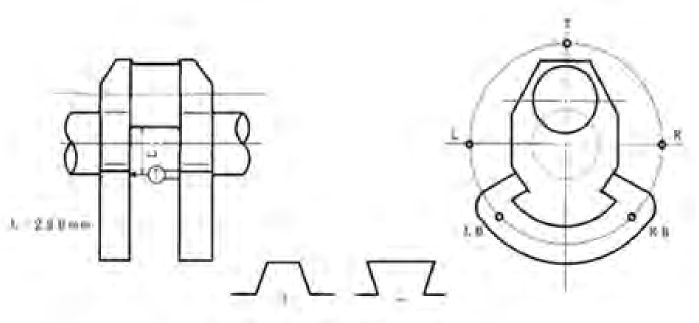
- Set the deflection gauge to the manufacturer specified location and measure.

  Rotate the crankshaft in the direction of rotation and record the scale at 30°, 90°, 180°,270°, and 330°.
- Since there are + - values, be sure not to mistake them.
- Measure in cold state.
- Depending on the engine (manufacturer), measurements may be taken in hot state.

- Turning is done during measurement, so ensure thorough communication. (Beware of entanglement)

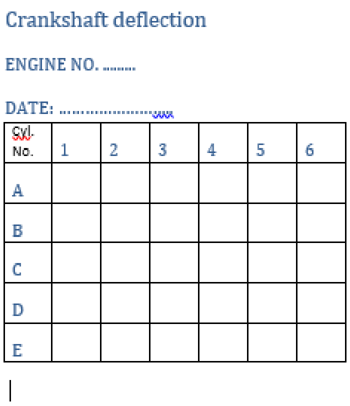
※Periodic inspection report (Form 4)





Comments

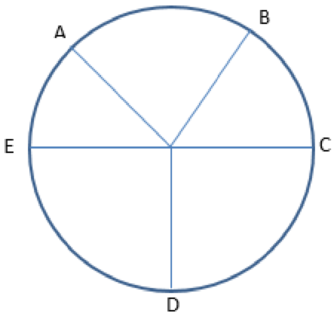
This is PUBs simplified table and diagram of deflection measurement


Crankshaft deflection

ENGINE NO. ………

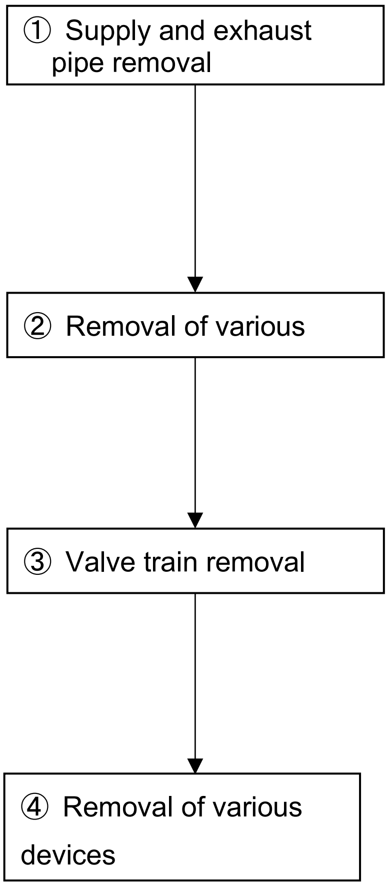
DATE: ……………………

Cyl. No.	1	2	3	4	5	6
A						
B						
C						
D						
E						



VIEW FROM FLYWHEEL

8. Removal of piping around the cylinder head



① Supply and exhaust pipe removal

- Loosen the bolt on the cylinder head side and detach it
- Beware of packing, bolts, washers, etc. falling
- Depending on the model, it may be necessary to lift the supply/exhaust pipe with a crane.

② Removal of various piping

- Fuel, air, cooling water, lubricating oil piping removal
- Beware as liquid in piping may leak
- For familiarity, mark each cylinder.

③ Valvetrain removal

- Depending on the position of the cam, the valve spring may be held down, so remove it while turning.
- Push rod removal

④ Removal of various devices

- Pressure indicator valve removal
- Remove thermometer, sensor etc (if necessary)

- Communication/signaling during turning (beware of entanglement)
- Sort parts (by cylinder) so that small parts will not be scattered.
- Caution when lifting of heavy objects

Comments

9. Cylinder head removal

① Hydraulic jack installation

② Head clamping nut loosening

③ Cylinder head lifting

① Hydraulic jack preparation

- Preparation of hydraulic jack, high pressure hose, hydraulic pump
- Installation of jacks in 4 places on a diagonal line

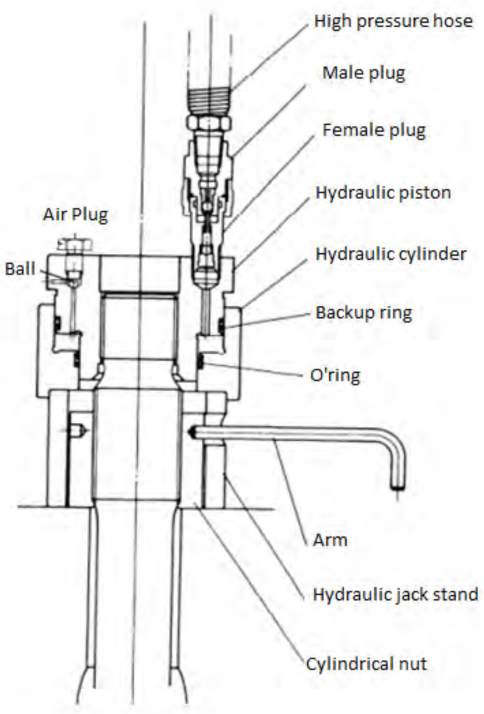
② Head clamping nut loosening

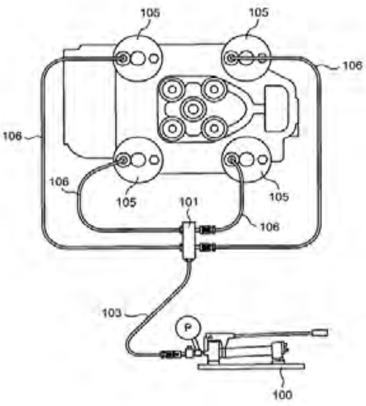
- Raise the oil pressure to 800 kgf/cm2 and loosen nut There only 4 bolts so the loosening was done in one step

③ Cylinder head lifting

- Mount lifting jig to the head
- Slowly lift with the crane (chain block) while confirming that all piping has been separated.
- Lift keeping it level so that the cooling water in the jacket does not enter the cylinder

- Refer to the manufacturer's manual when performing work.
- Be very careful when lifting heavy objects
- Do not scratch the head packing surface.





Comments

10. Cylinder head disassembly, explosion surface washing, color check

① Exhaust valve box extraction, disassembly

↓

②Intake valve disassembly

↓

③ Remove high pressure fuel pipe and drain pipe

↓

④Starting valve extraction

↓

⑤ Head explosion surface cleaning

↓

⑥ Head explosion surface color check

① Exhaust valve box extraction

・Remove valve box mounting nut, valve box extraction

・ Mount opening tool to the valve box, disassemble

② Intake valve disassembly

・Mount intake valve disengagement tool on top of head

・Turn the jack bolt to hold down the spring and remove the cotter

③ Fuel injection valve extraction

・Remove the high-pressure fuel pipe and drain pipe

・Extract from the head using a nozzle holder disassembling tool

④ Starting valve extraction

・Remove starting valve piston case

・Remove startup valve spring holder clamping nut split pin, nut, spring bearing, and spring

・Extract starting valve rod to combustion chamber side

⑤ Head explosion surface cleaning

・Check for carbon deposit on the combustion chamber surface and wash it

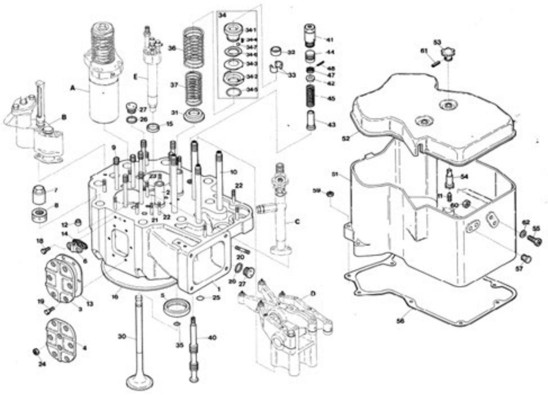
⑥ Head explosion surface color check

・Color check the explosion surface (PT inspection) and check for cracks

・Refer to the manufacturer's manual when performing work.

・Handle cotters in pairs since they combine two.

・Also check the rotation status of the valve rotator.



11. Piston extraction, disassembly

①Preparation

②Removing of the protection ring

③Removing of connecting rod bolts

④Piston extraction

⑤Removal of rings & cleaning

⑥ Disassembly of piston (connecting rod)

① Remove crankcase doors on both side and place the piston at about 50 degrees before TDC.

② Remove carbon deposits on and around the protection ring and remove the protection ring using a special tool

③ Set the piston to be released at the position of BDC and remove locking wires of Con-rod Bolts-2 and then remove all 4 bolts

④ Attach M12 eye bolt to the top of the piston and slowly lift the piston with con-rod small end using a chain block. Cover the top of the liner with a board to avoid foreign debris.

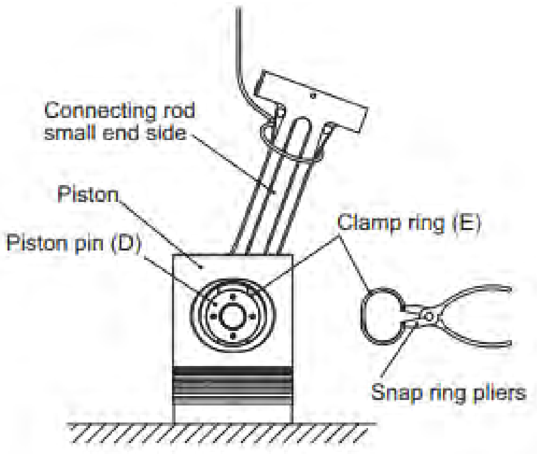
⑤ Put the piston and conrod small end on a piston stand tool and remove piston rings. Clean the carbon around the piston

⑥ Disassembly of piston (connecting rod)

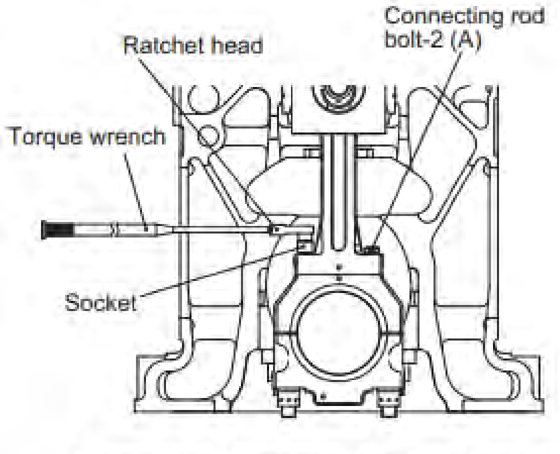
・Turn the piston upside down, and while lifting the connecting rod with the crane, pull out piston pin to disconnect the piston.

・Refer to the manufacturer's manual when performing work.
・Use a wrench to loosen the connecting rod bolt. (Do not use torque wrench)
・Be careful not to scratch the crankpin, metal, and serration when pulling out.

Comments：



Extraction of Piston



Removal of Connecting Rod Bolt-2

12. Cylinder liner extraction

① Preparation

② Removal Jigs mounting

③ Liner extraction

① Before removing the liner from the engine block, make sure the jacket water is drained out completely. Collect dirt and foreign matter so they don't fall into the sump

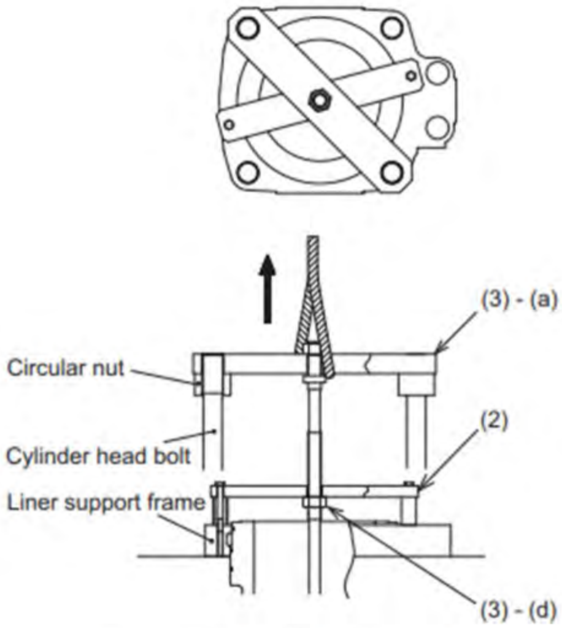
② Remove cylinder support frame by loosening the mounting hexagonal bolts and then use support frame removal tool attached to the liner removal tool.

③ Liner extraction. Remove the liner using the liner removal tool. Lift the liner and the tool using the crane slowly and carefully

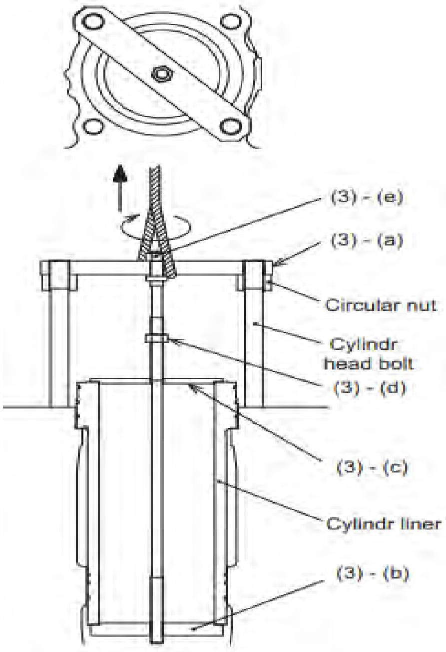
・Cover the crankcase so that dirt does not fall into it.

> ・Refer to the manufacturer's manual when performing work.
> ・Be careful when lifting and moving heavy objects

Comments



Removal of Liner Support Frame



Extraction of Cylinder Liner

13. Cylinder jacket interior cleaning

① Jacket interior cleaning

↓

② Anti-rust coating

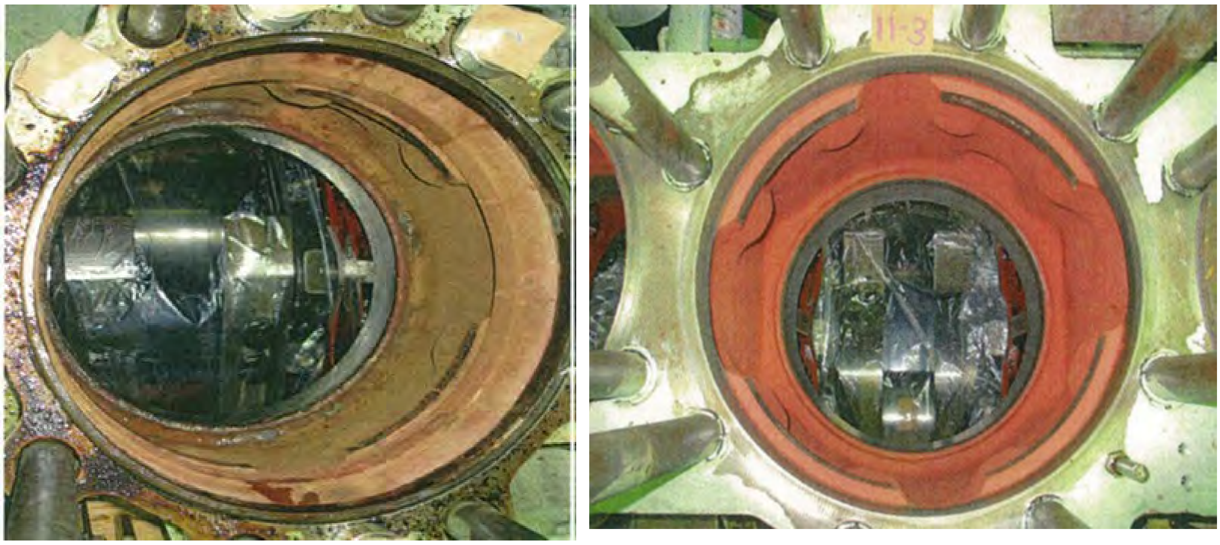
① Jacket interior cleaning

- Remove scale from jacket interior
- Clean the liner fitting (part making contact with O-ring)
- Check for cavitation

② Anti-rust coating

- Apply anti-rust coating

- Cover so that dirt will not fall into the crankcase.
- After cleaning, cover the opening. (Fall prevention)



14. Main metal overhaul

① Removal of main metal cap

②Extraction of main metal

③ Metal inspection (replacement)

④ Clearance measurement

⑤ Embedding, restoration

① Removal of main metal cap

- Remove the nut of the metal cap clamping bolt and pull out the cap.

② Extraction of main metal

- Mount special tool (pin) to oil hole in crank journal. Push out the metal while turning

③ Metal inspection

- Appearance inspection, wall thickness measurement, color check

④ Clearance measurement (Lead wire)

- Install a soft lead wire on the journal and tighten the metal cap and measure how much the lead wire has collapsed

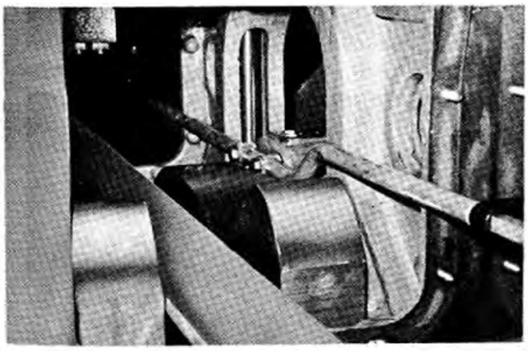
(Bridge gauge)

- Install a bridge gauge on the journal and measure the clearance between the journal and gauge

⑤ Embedding, restoration

- Insert the metal as far as you can by hand and use special tools to insert the rest of the way.
- Tighten the cap mounting bolt with the specified torque

- If the gaps between the metal become too large, cracking, burning, etc. occurs or the lubricating oil pressure decreases
- Turning gently when extracting/inserting metal. (Do not force)
- If you pull out the metal at once, the crankshaft will fall, work one half at a time.



15. Cylinder liner cleaning, color check

① Inner surface inspection & cleaning

↓

② Inspection of outer circumference (water container)

↓

③ Color check

① Inner surface inspection & cleaning

- Check inner surface for scuffing or seizing
- Deglaze any mirror-finished inner surface (Also consider replacement if the service life has been reached)

② Inspection of outer circumference (water container)

- Check for cavitation on the outer peripheral surface
- Check for corrosion of O-ring
- Check for gas leakage (blow-through) on the liner upper surface

③ Color check

- Perform a color check for cracks near the base under the collar

- If there is severe scuffing or seizure on the inner circumferential surface, replace it, but for minor issues, use it after finishing it smooth with an oil grindstone.
- If there is cavitation, check with the manufacturer

Comments

16. Intake valve polishing & lapping

① Intake valve cleaning

② Measurement

③ Polishing & lapping

① Intake valve cleaning

- Clean carefully when reusing intake valves
- Check the condition of the sheet contact surface

② Measurement

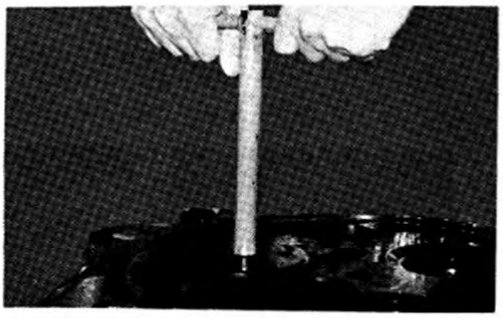
- Measure areas specified by manufacturer
- Replace items exceeding the reference value

③ Polishing & lapping

- Polish and lap while observing the contact between the valve and the valve seat
- Lap carefully by applying an appropriate amount of compound and using lapping tools.
  Use medium and fine grain compound, and last, wash thoroughly and rub oil on it.
- In the case of Stellite heaping, since the material is hard, to correct the contact surface gliding is desirable

- When replacing valve seat and valve guide, refer to the manufacturer's manual
- Be sure to emboss on the valve so as not to mistake the installation location

/ Periodic inspection report (Form 2)



Comments

17. Piston disassembly, cleaning, color check

① Cleaning

② Disassembly (crown, skirt)

③ Color check

① Cleaning

- Remove carbon from piston explosion surface
- Clean piston ring groove

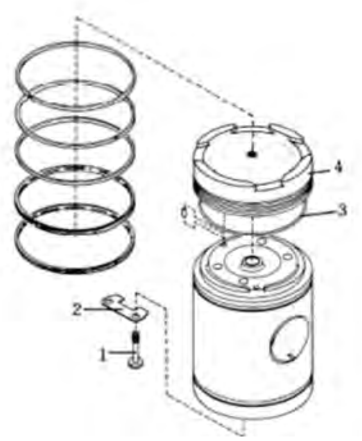
② Disassembly

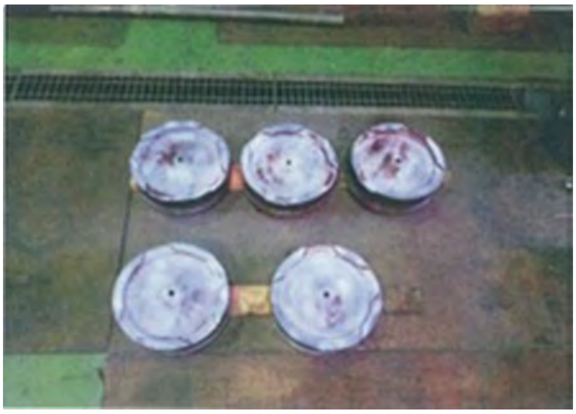
- Open as needed (adherence of sludge, etc.)
- Replace items exceeding the reference value

③ Color check

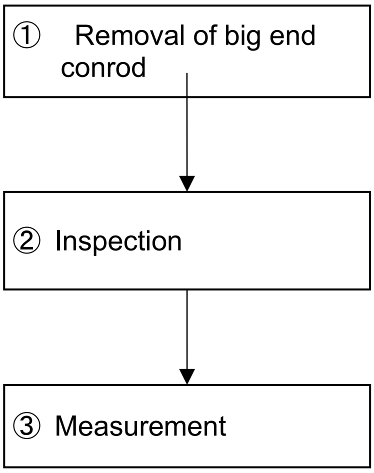
- Check piston crown explosion surface, color check top of piston skirt

- Measure the clearance between the crown and skirt





18. Connecting rod Big end removal, cleaning & color check



- When performing maintenance, refer to the manufacturer's manual
- When replacing the crankpin metal, be sure to replace in upper and lower pairs

① Removal of big end conrod

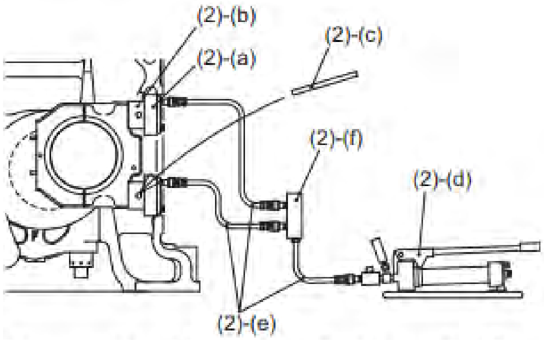
- Rotate the crankshaft so that the big end is closer to one door (Remember to hold the big end during rotation so that it doesn't hit the block)
- Place a timber support underneath the big end while placing the big end sideways so that the nuts are accessible from outside
- Install the hydraulic jacks on the bolts and loosen the nuts
- Slide out the two pieces of big end gap to both sides of the engine

② Remove the big end bearings

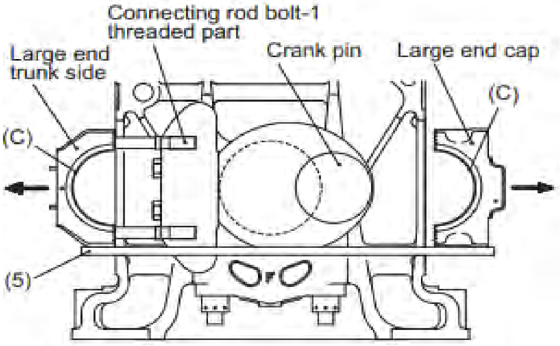
- Inspect the bearings, cap and crankshaft journal
- Conduct a color check on metal and cap

③ Conduct the measurement with bore gauge

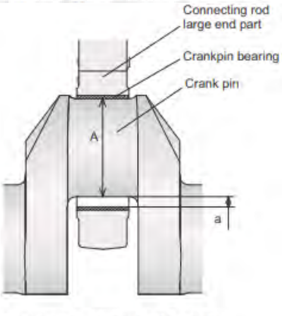
- tightened crankpin bolts and conrod bolts-2 to specified torque (1st with bearings and 2nd without bearings) to inspect if any distortion of shape. (Mark the bolts so you won't interchange their positions)
- record the measurement and calculate the clearance between the crankshaft and crankpin cap with metal



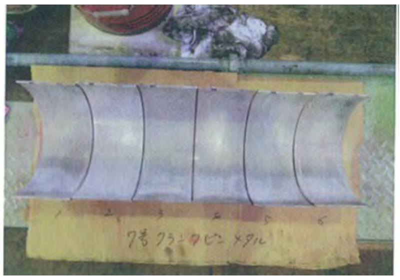
Disassembly of Connecting Rod Large End Part (Connecting of Hydrauric Jack and Hydrauric Pump)



Removal of Connecting Rod Large End Part (Top and Bottom)



Clearance of Crank Pin Shell



19. Cylinder liner inner diameter measurement

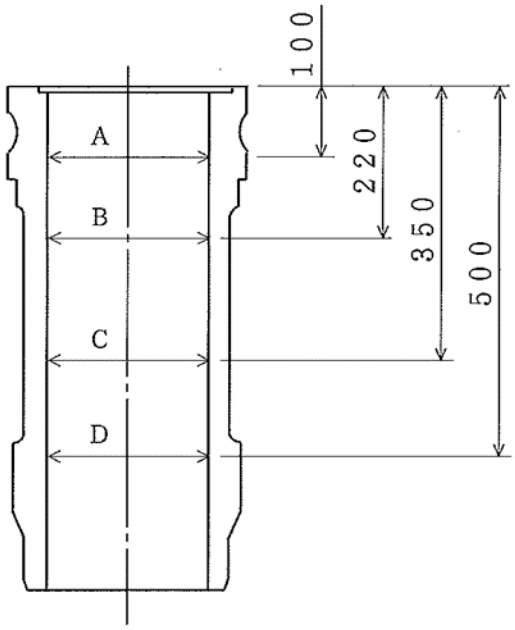
① Measurement

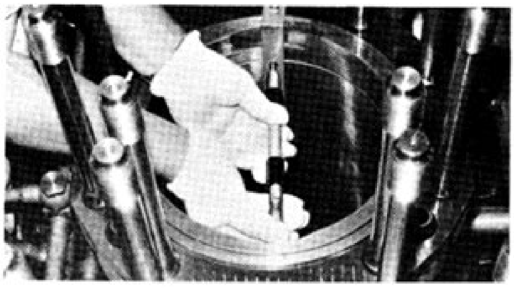
① Inner diameter measurement

- Measure 100, 220, 350, and 500 mm from the top of the liner
- Use a cylinder gauge for measurement
- Measure in the axial and rotational direction
- Check the amount of wear and deformation

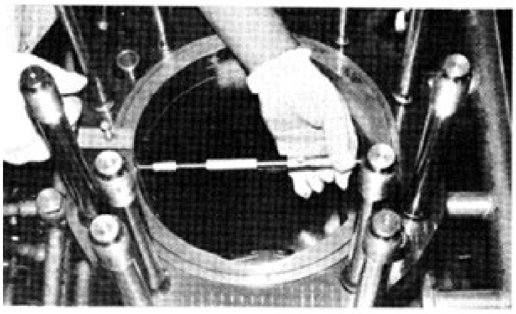
※ Periodic inspection report (Form 8)

- When performing maintenance, refer to the manufacturer's manual.
- Compare with the data from the previous measurement.
- Use calibrated equipment for the measurement.





シリンダーライナー計測要領 (1)



20. Measurement of piston parts

① Cleaning

② Color check

① Measurement

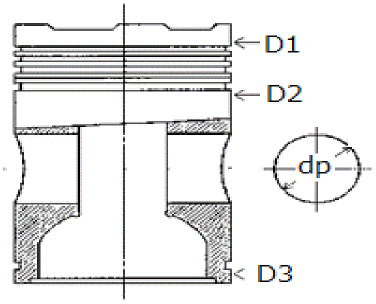
- Piston outer diameter measurement
- Piston pin outer diameter measurement
- Piston boss inner diameter measurement
- Piston pin metal inner diameter measurement
- Piston pin metal inner diameter measurement
- Piston ring butting gap measurement

* Check the amount of wear and deformation

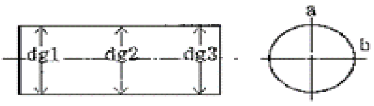
② Color check

- Piston pin color check

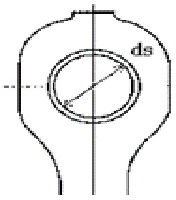
- When performing maintenance, refer to the manufacturer's manual.
- Compare with the data from the previous measurement.
- Use calibrated equipment for the measurement.



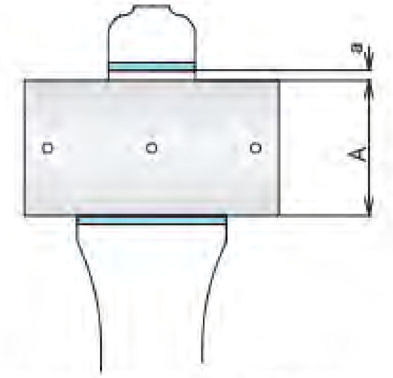
dp : Basic dimension
Wear limit:



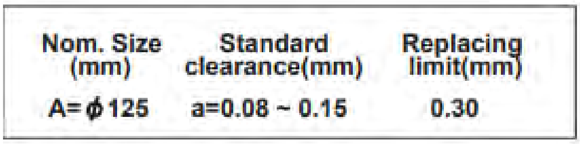
dg: Basic dimension
Wear limit:



ds: Basic dimension
Wear limit:



Clearance of Piston Pin Bush Inner Diameter



Nom. Size (mm)	Standard clearance(mm)	Replacing limit(mm)
A=ϕ125	a=0.08 ~ 0.15	0.30

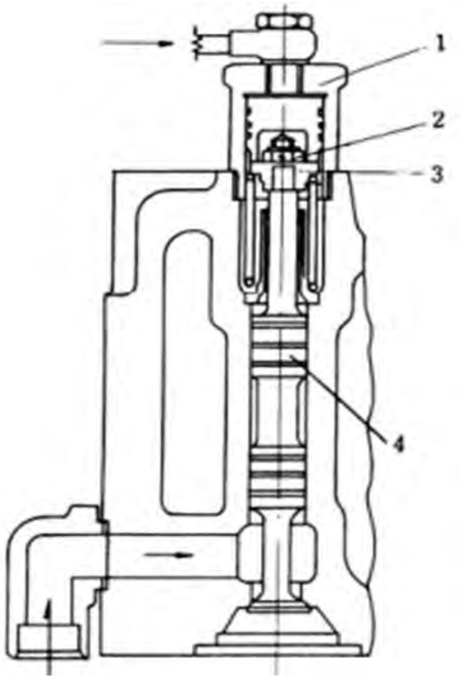
21. Starting valve polishing & lapping

① Polishing & lapping

① Polishing & lapping

・If lapping is poor or the valve rod or the starting valve piston sticks, the combustion gas backflows to the starting air main pipe and causes the start rotating valve, the starting valve, etc. to stick and become damaged, so inspect thoroughly before lapping.

・When performing maintenance, refer to the manufacturer's manual.



22. Exhaust valve polishing & lapping

① Exhaust valve Cleaning

② Measurement

③ Polishing & lapping

① Exhaust valve cleaning

- When reusing the exhaust valve clean carefully
- Check the condition of the sheet contact surface (blow-through)

② Measurement

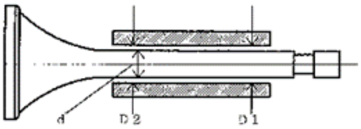
- Measure areas specified by manufacturer
- Replace items exceeding the reference value

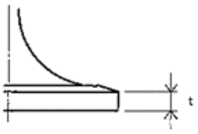
③ Polishing & lapping

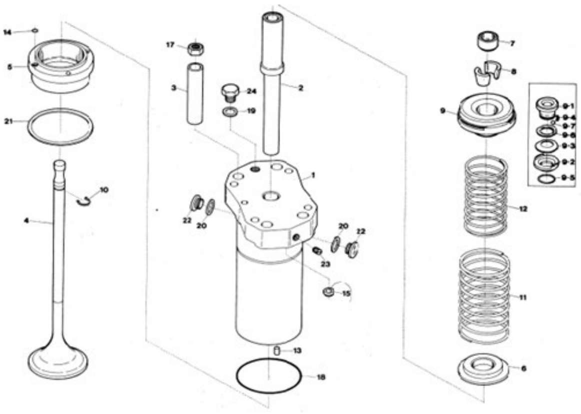
- Polish and lap while observing the contact between the valve and the valve seat
- Lap carefully by applying an appropriate amount of compound and using lapping tools. Use medium and fine grain compound, and last, wash thoroughly and rub oil on it.
- In the case of Stellite heaping, since the material is hard, to correct the contact surface, gliding is desirable

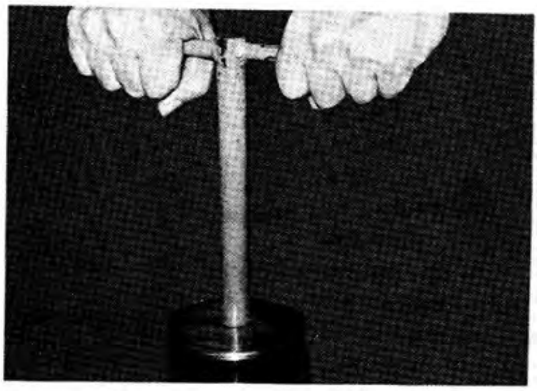
※ Periodic inspection report (Form 1)

- When replacing valve seat and valve guide, refer to the manufacturer's manual
- Be sure to emboss on the valve so as not to mistake the installation location









23. Cylinder head washing

① Washing

① Washing

- Wash before assembling

- Be careful not to scratch the head packing contact surface

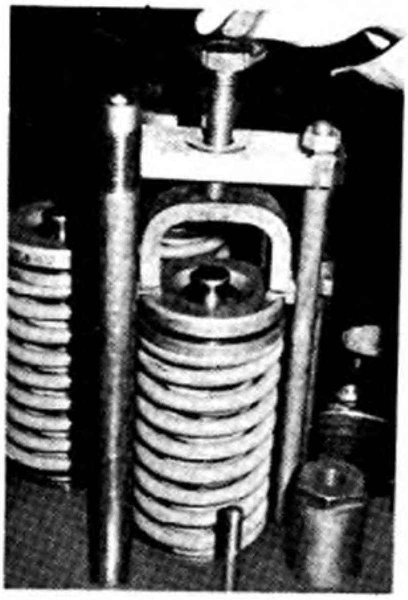
24. Intake valve assembly

① Assembly

① Assembly

- Insert intake valve from cylinder head combustion side
- Valve spring, cotter, valve rotator assembly
- Assemble by holding the spring using the intake valve disengaging tool

- Correctly mount intake valve disengaging tool
- Correctly mount on the embossed cylinder



25. Fuel injection pump removal

① Pump removal

・Fuel may leak, so handle with care

① Removal

- Be sure the fuel link (rack) surrounding is separated
- Remove fuel injection pump (for 6 cylinders)
- Temporarily place it in a place not dusty until maintenance is performed.

26. Exhaust valve box cleaning, assembly, water pressure test

① Exhaust valve Cleaning → ② Measurement → ③ Polishing & lapping

① Washing

- Wash the exhaust valve, valve seat, valve box, and valve spring

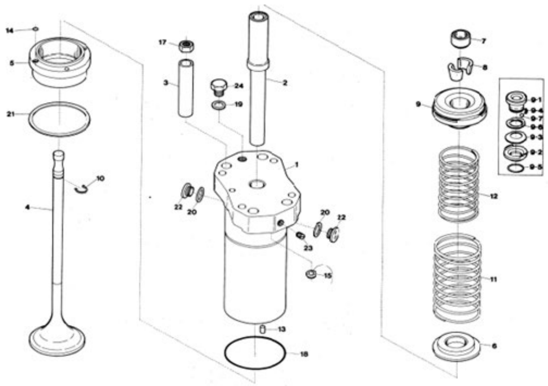
② Assembly

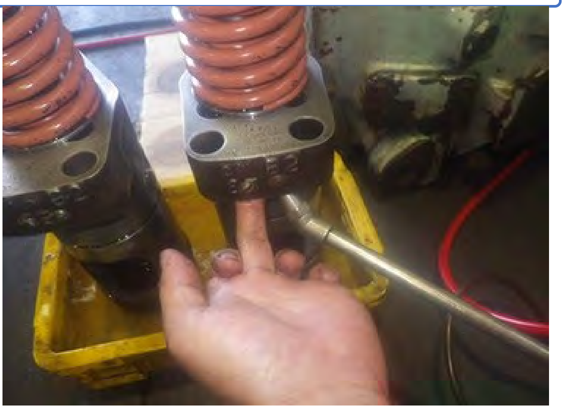
- Assemble the exhaust valve, valve seat, and valve box
- Replace the O-ring (valve box, valve seat)

③ Water pressure test

- Since it's a valve seat cooling type, perform water pressure test
- About 1.5 times the normal operating pressure

・Be sure to replace expendable items (O-ring, etc.).
・Do not tighten valve box clamping nut with more than the specified torque





27. Cylinder liner embedding

① Lifting

② O-ring replacement

③ Insertion

① Lifting

・Lift the liner using special tools

② O-ring replacement

・Replace O-ring

③ Insertion

・Confirm cylinder block side

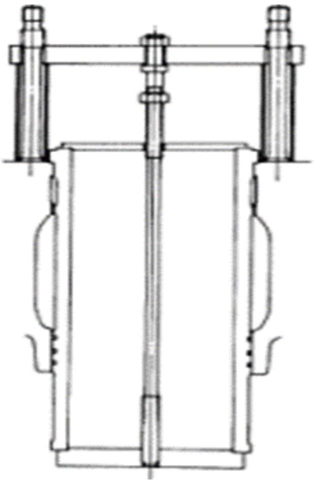
・Replace liner packing

・Insert liner

・Be careful not to cut the O-ring when inserting it.

・When inserting, carefully insert paying attention to cylinder number and orientation.

Comments



28. Piston assembly

① Washing

② Assembly of crown and skirt.

③ Assembly of piston and small end connecting rod

① Washing

- Clean individual parts before assembling.
- Make sure to use antifreeze/molycote paste to threaded bolts

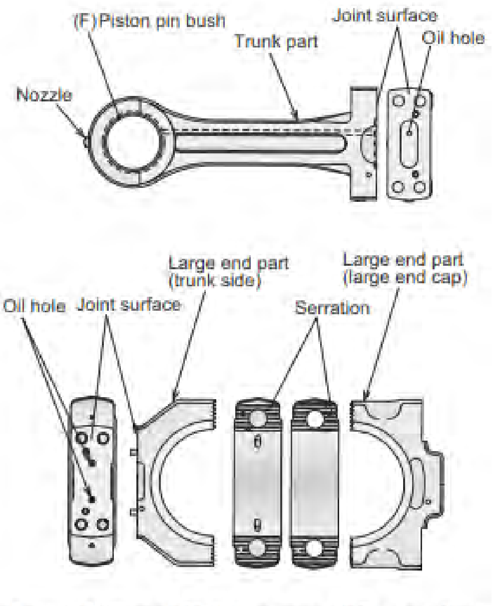
② Assembly of crown and skirt.

- Tighten bolts diagonally with specified torque; 103Nm and then 147Nm

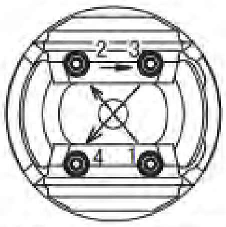
③ Assembly of piston and small end connecting rod

- Use the crane to lift small end con-rod and insert it carefully in the piston (note the emboss mark on both the piston and conrod to be on the same side)
- Insert the piston pin and the retaining ring

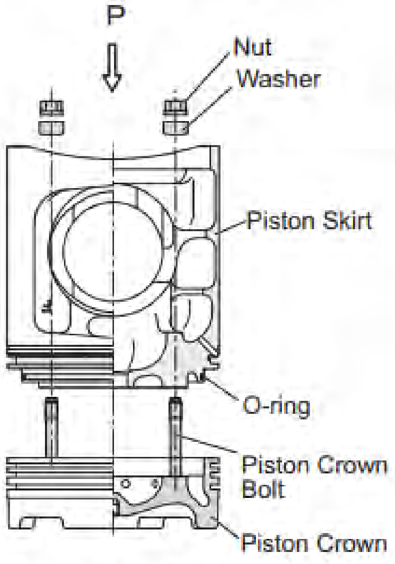
・Assemble in reverse order of disassembly



Inspection and Maintenance of Connecting Rod Parts



Sequence to Loose the Fastening Nuts (View "P")



Separation of the Piston Crown

29. Con-rod big end Assembly and insertion

① Assemble

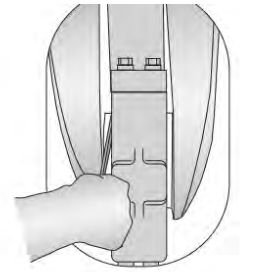
② Check Free Play

① Assemble the Big end cap with bearings on the crankshaft

- Reverse the disassembling procedure
- Tighten the conrod bolts-1 using the hydraulic jacks to 83.4MPa

② Check the free play

Comments:



Confirmation of Connecting Rod Side Motion

30. Piston insertion

① Lifting

② Insertion

③ Conrod Bolts-2 Tightening

① Lifting

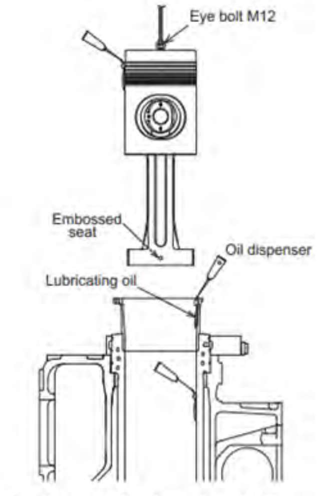
- Use a crane to lift the piston and conrod small end assembly.
- Arrange piston rings and put the piston insert tool onto the engine block.
- Put the crankshaft at BDC.
- Spray or paste Molycote to the contact surfaces

② Insertion

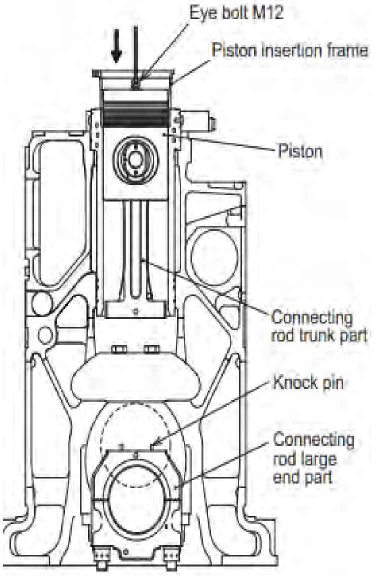
- Spray lube oil around the piston, rings and liner
- Have two staff at the two crankcase doors to observe
- Slowly insert the piston and conrod downwards until it touches surfaces with the big end assembly

③ Conrod Bolt-2 tightening

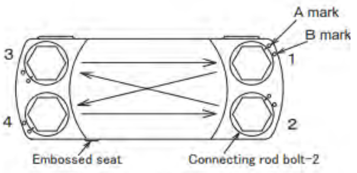
- Spray molycote onto the conrod bolts thread and Insert all 4 bolts on the conrod and mark them according to their position
- Tighten the bolts diagonally (1-4-2-3-1) to 100Nm and then to 196Nm (A torque) and mark the position of A on the bolt.
- Angularly tighten the bolts further from A-B (25°) diagonally and then install the locking wires



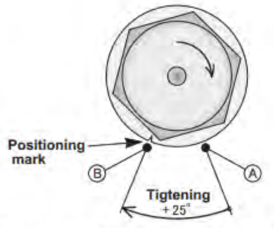
Application of Lubricating Oil When Assembling Piston



Insertion of Piston



Bolt Tightening Order



Connecting Rod Bolt Angular Tightening

31. Engine lubricating oil pump overhaul

① Disassembly

② Disassembly, cleaning

③ Parts replacement

④ Assembly

① Disassembly

- Remove lid mounting nut
- Remove lid
- Remove pump gear
- Remove drive gear mounting nut
- Remove drive gear
- Remove pump gear shaft

② Disassembly, cleaning

- Check gear teeth surface (color check)
- Open and clean safety valve and check for sticking

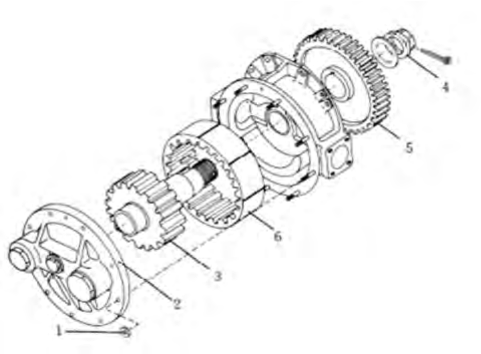
③ Parts replacement

- Replace bearing (needle bearing)
- Replace oil seal

④ Assembly

- Assemble in reverse order of disassembly

- Do not use packing on the lapping surface of the pump lid and pump body.
- When installing the drive gear, make sure to tighten the tapered part.



32. Cylinder head installation

① Removal

② Element cleaning

① Lifting

- Mount lifting jig to the head
- Perform final check of each part

② Installation

- Final check of piston top (liner inside)
- Head packing installation
- Head mounting

- Check the surroundings when lifting heavy objects
- Replace head packing with new one (thickness check)

33. Cylinder head tightening

① Clamping nut cleaning

② Hydraulic jack installation

③ Tighten head bolt

① Clamping nut cleaning

- Clean the clamping nut and apply lubricant

② Hydraulic jack installation

- Install hydraulic jack, high pressure hose, hydraulic pump
- Install jacks in-four spots on the diagonal

③ Tighten head bolt

- Pull the head bolt with the specified pressure using a hydraulic jack and tighten the nut
- Refer to the manufacturer's manual

when handling the hydraulic jack

- Hydraulic pressure shall be lowered slowly.
- Be careful as gas leakage occurs with uneven clamping

34. Installation of various piping around cylinder head

① Piping installation

② Installation of various devices

③ Intake/exhaust pipe installation

① Piping installation

- Fuel, air, cooling water, lubricating oil piping installation
- Replace consumables such as packing

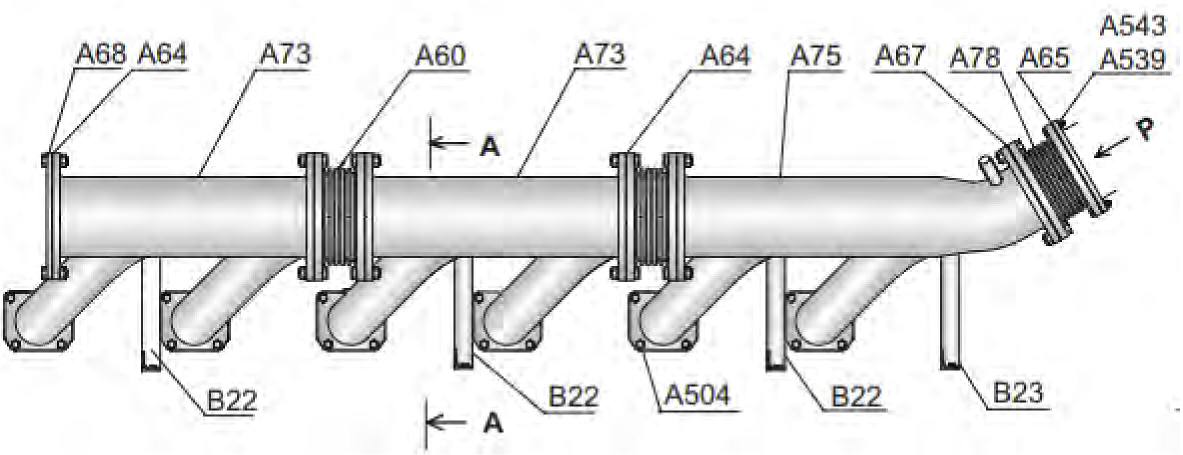
② Installation of various devices

- Install pressure indicator valve
- Installation of thermometer, sensor, etc.

③ Intake/exhaust pipe installation

- Replace packing and install intake/exhaust pipe

- Be sure to replace with new packing
- Do not forcefully tighten to prevent leaking from pipe connection points



Comments

35. Rocker arm installation

① Push rod installation

② Rocker arm installation

- Be sure to wash and check the lubricating port
- Loosen the valve arm screw (adjusting screw)

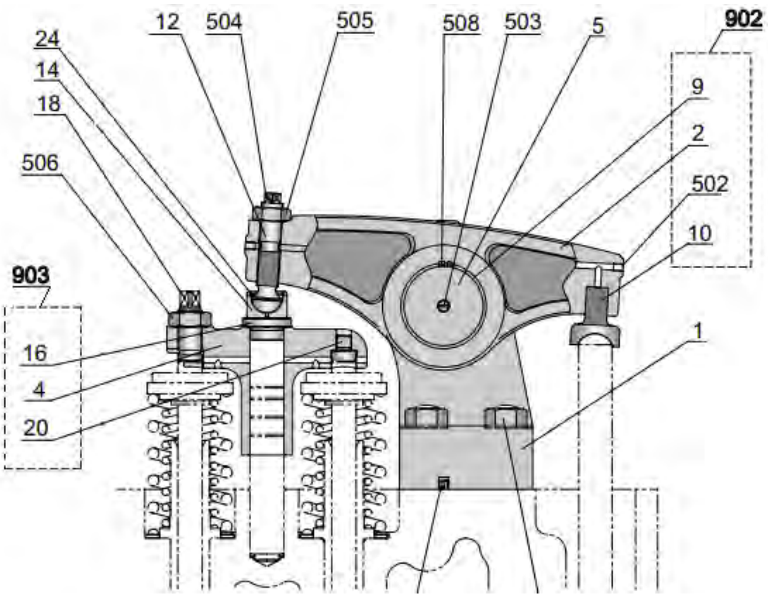
Comments:

① Push rod installation

- Wash before installation
- Check the condition of both ends of the push rod

② Rocker arm installation

- Wash before installation (check lubricating port)
- Install the rocker arm while turning
- Tighten the valve arm shaft holder mounting nut with the specified torque



36. Valve end clearance adjustment

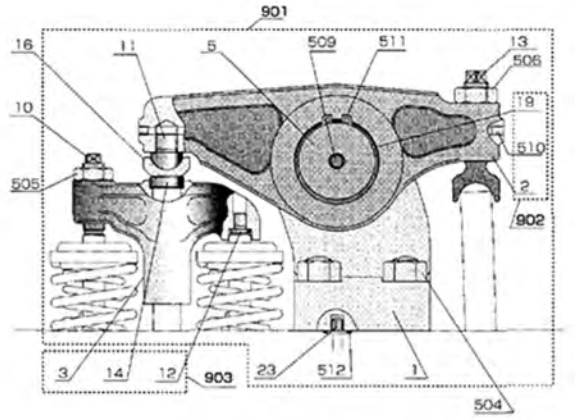
① Valve setting

① Valve setting

・With the valve not pushed by the cam, insert the specified clearance gauge into the gap between the valve and the rocker arm and adjust.

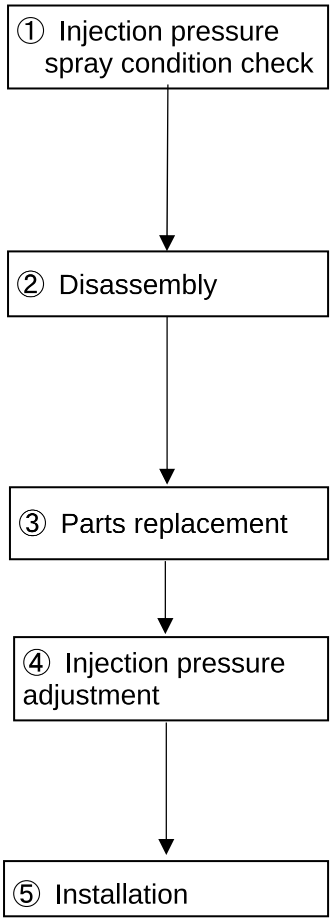
Intake 0.5 mm ・ Exhaust 0.5 mm (Changed from 0.6mm to 0.5mm)

・Adjust in cold state



Comments

37. Fuel injection valve overhaul, injection pressure adjustment



① Injection pressure spray condition check

・Check and record injection pressure and spray condition before maintenance

• Set the fuel injection valve to the nozzle tester and check it

② Disassembly

· Fix the nozzle holder on the vise base and disassemble it

・Wash the nozzle holder body, cap, spring, etc. and check for wear.

③ Parts replacement

・Nozzle, knock pin, spacer, packing, O-ring

④ Injection pressure adjustment

・Set to the manufacturer specified pressure

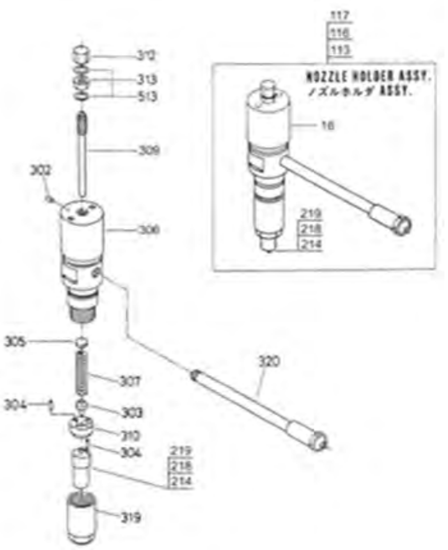
・Apply the specified pressure to check the state of fuel spray and whether there is any dripping from the nozzle.

⑤ Installation

・Attach the fuel injection valve to the cylinder head

・Press the nozzle tester lever vigorously

・When mounting the nozzle holder to the cylinder head, if you tighten it above the specified torque, the holder may become distorted causing the nozzle to stick.



38. Fuel injection pump disassembly, maintenance, installation

① Disassembly → ② Washing → ③ Parts replacement → ④ Assembly → ⑤ Installation

① Disassembly

- Mount pump to vise base and remove valve seat holder
- Remove delivery spring and delivery valve
- Remove plunger guide, spring, and plunger
- Remove adjusting gear and plunger barrel

② Washing

- Check each part for abnormalities such as wear when washing

③ Parts replacement

- Replace the plunger and plunger barrel in pairs.
- Replace deflector, delivery valve, O-ring, and packing

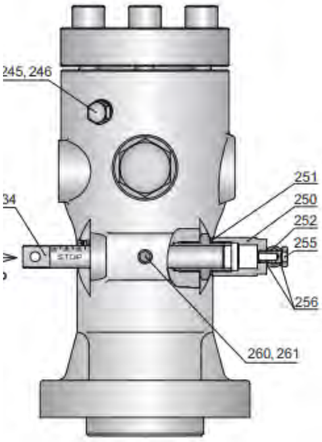
④ Assembly

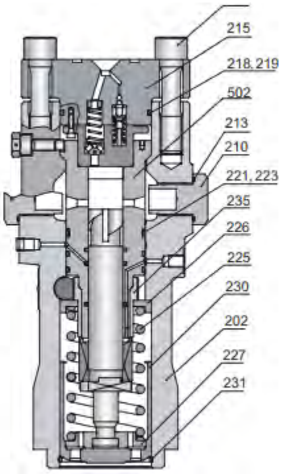
- Assemble in reverse order of disassembly

⑤ Installation

- Install fuel injection pump

- When inserting plunger barrel, check the suction/discharge direction and set the set screw
- Tighten the delivery valve seat firmly, but be careful as the rack will become stiffer when too much torque is applied.
- The rack, the pinion gear, and the plunger each have matching marks so that they are reliably matched.





39. Lubricating oil removal, sump tank cleaning

① LO removal

↓

② Cleaning

① LO removal

- Pump out lubricating oil into a drum
- Check whether the oil should be reused or changed

② Cleaning

- Open sump tank side lid and clean the interior

- Coordinate whether to reuse the lubricating oil based on the analysis result.
- Be careful not to forget rags, etc. in the tank

Comments

40. Replenish lubricating oil

①Refill lubricating oil

②Leak check

① Refill lubricating oil

- Refill the specified amount of lubricating oil

② Leak check

- Check various spots to ensure that there are not leaks
- Tighten if there are any leaks

- Report the amount of refill to customer

Comments

41. Governor replacement

① Governor removal

②Governor installation

③ Refill lubricating oil

① Governor removal

・Confirm the current installation condition before removing

Each setting value (droop, load limit, etc.)

Lever angle

② Governor installation

・Replace with a serviced governor

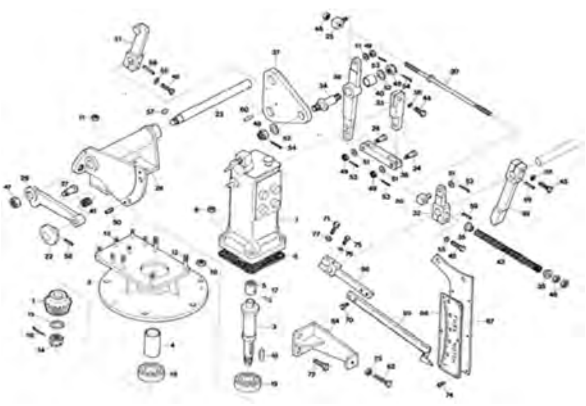
· Set to the state before replacement

③ Refill lubricating oil

・Refill lubricating oil up to the specified amount

* Bleed air when starting engine

- At the time of governor replacement, perform a load interruption test to check the fluctuation rate and settling time
- Store the removed governor until the test run is completed, and ensure that there is no abnormality in the replaced governor before sending it to the manufacturer for maintenance.



42. Deflection measurement (after assembly)

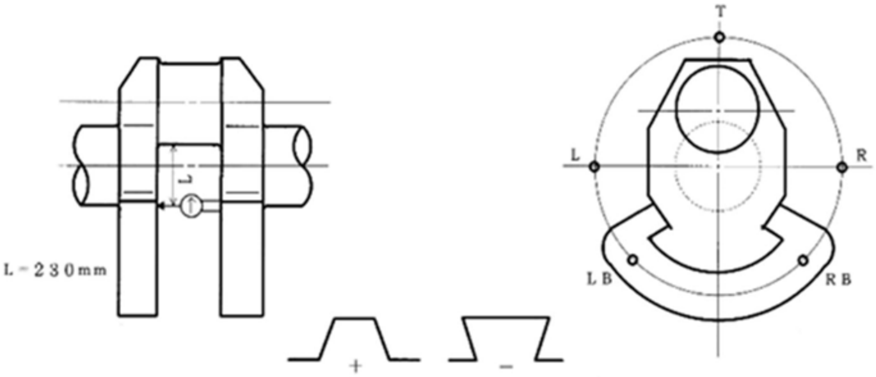
① Deflection measurement

① Measure according to the manufacturer's manual.

- Place the crankshaft at 30°past top dead center (TDC).
- Set the deflection gauge to the manufacturer specified location and measure.
- Rotate the crankshaft in the direction of rotation and record the scale at 30°, 90°, 180°,270°, and 330°.
- Since there are + - values, be sure not to mistake them.
- Measure in cold state.
- Depending on the engine (manufacturer), measurements may be taken in hot state.

※Periodic inspection report (Form 4)

- Turning is done during measurement, so ensure thorough communication. (Beware of entanglement)



43. Main bearing pipe restoration, lubrication check

① Restoration of piping around main bearing

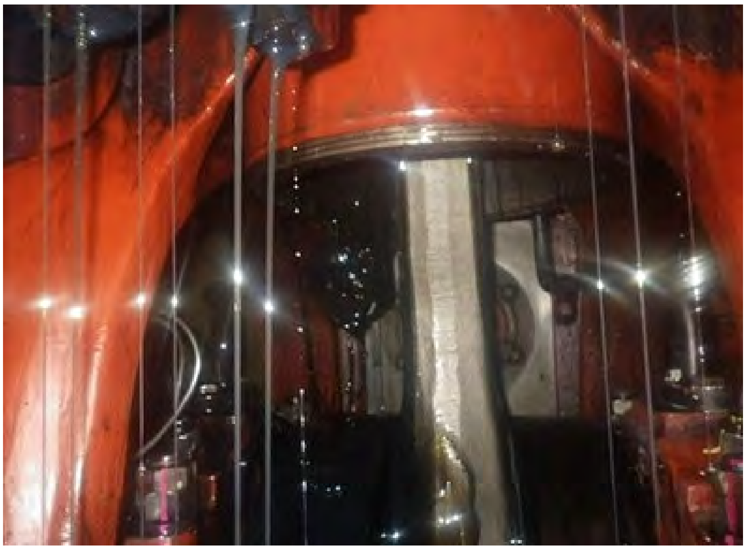
② Lubrication check, Restoration of piping

① Restoration of piping around main bearing

② Lubrication check, Restoration of piping around main bearing

- Start lubricating oil priming pump
  Confirm that the oil has reached each spot

- Beware of entanglement when turning
- Final crankcase internal check



44. Gear backlash measurement

① Each gear backlash (Measure the gear gap and thrust with a dial gauge)

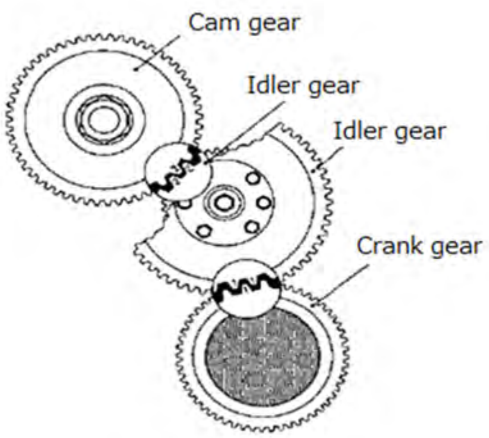
② Set the dial gauge on the magnet stand and measure the cam idle and accessory gear.

① Measure each gear when removing pump on engine.

Make sure that it is within the manufacturer standard value

* Refer to manufacturer standard table

- When measuring, use it to inspect the tooth surface as well.
- If the measured value exceeds the limit, replace the gear with a new one.
- Thoroughly confirm signals to avoid getting entangled in the rotating body.



タイミングギヤ噛合せ

45. Crankshaft thrust measurement

① Setting the dial gauge on the crankshaft

② Place personnel on the intake/exhaust side and slide it to the fuel handle

③ Set the dial gauge scale to zero

④ Slide again to the generator side to read the value of the dial.

⑤ After measurement is completed, slide the crankshaft to the center.

① Set the dial gauge on the crankshaft, and 2 people shall separate from the crankcase lid of the intake and exhaust, and slide it to the side of the fuel handle at the same time with a bar.

② Set the dial gauge scale to zero, then slide the crankshaft to the opposite side of the generator to read the dial gauge number.

③ Confirm that the thrust value is within the manufacturer's standard value.
* Refer to manufacturer standard values table

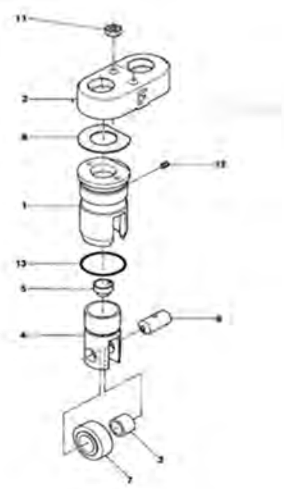
④ Slide the crankshaft to the median gap value after measurement.

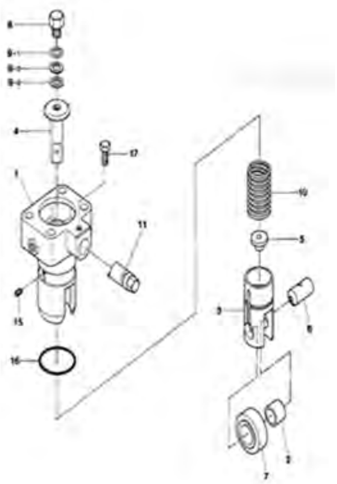
・When sliding with bars, be careful where you place the bars.
・If you do not slide at the same time, the shaft will not move, so thoroughly confirm the signal.

46. Tappet related inspection

① Remove tappet	① Inspect fuel and intake/exhaust tappet rollers
② Inspect and wash	② Check for abnormal wear, etc.
③ Color check the roller	③ Perform a color check on the rollers for inspection
④ Install tappet	

- Parts should be inspected in the same way so that they are not scattered.
- Air blow the lubrication port to check the flow.





47. Oil/water flow test

① Oil flow test

② Water flow test

① Oil flow test

・Start turning while starting the lubricating oil priming pump and check for lubrication status, leaks, and pressure hunting

② Water flow test

・Start secondary water pump and primary cooling water pump, check for leaks and pressure hunting

・Check thoroughly as it is the final check before operating

48. Fuel pump air removal

① Fuel inlet/outlet valve "open" check

② Air bleeding from the fuel injection pump

① Fuel inlet/outlet valve "open" check

② Air bleeding from the fuel injection pump

・Loosen fuel injection pump air bleeding bolt

・Inject fuel while pumping (or turning)
Bleed air vent from the pump

・Tighten air bleeding bolt

・Check thoroughly as it is the final check before operating

49. Pre-trial run meeting

① Meeting

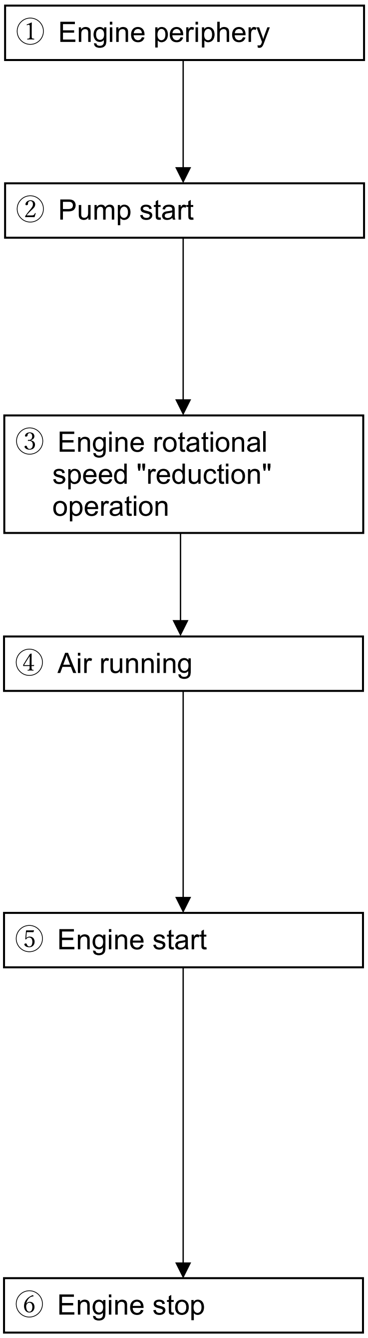
① Meeting

・Tentative report of inspection result
Submit inspection results (record) and report that there is no abnormality

・Test run schedule
Coordinate each schedule
Coordinate protective device test (actual operation items)

・Since there were no issues in the inspection results, confirm with everyone to start test run.

50. No-load operation



① Engine periphery check
- Perform final check of engine periphery
- Red tag removal

② Pump start
- Start primary water, secondary water, and lubricating oil pumps　Check pressure, leakage, and lubrication status
- Open indicator cock and turn

③ Engine rotational speed "reduction" operation
- Turn the speed setting knob (upper right) of the governor Counterclockwise to the lowest speed position.
- Confirm the generator lines J and K are disconnected

④ Air running
- Confirm fuel handle "stop position"
- Check air tank pressure (Refill if low)
- Open the start valve and perform air run
- Check for leaks in the cylinder

⑤ Engine start
- Check air tank pressure (Refill if low)
- Fuel handle "operation" position
- Open the start valve and start the engine (on-site start)
- Operate for 5 minutes at the rotational speed (400 min-1)
- Check each temperature and pressure and for abnormal noise, odor, vibration, etc.

⑥ Engine stop
- Position the fuel handle to the "stop" position and stop the engine

- All personnel shall communicate/signal thoroughly.

51. Internal inspection

* Fuel handle "stop position," air inlet valve "closed"

① Crankcase side cover opening

② Internal inspection

③ Crankcase side cover restoration

① Open the crankcase side cover.

・Open after confirming lubricating oil pump is stopped

② Internal inspection

・Measure each temperature

Main metal, clamp pin metal, piston pin metal temperature

・Check the inner surface of the liner

Check for vertical scratches on the inner surface of the liner using a mirror· Check for connecting rod side motion

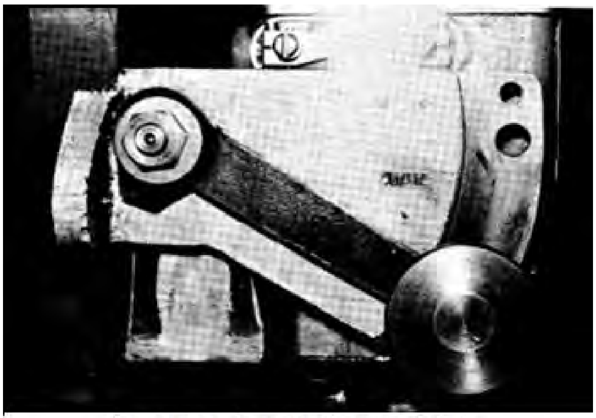
Push the connecting rod in direction of the shaft with a bar, etc. and confirm that it moves lightly

・Turn and confirm that there is no abnormality in rotation

③ Crankcase side cover restoration

・The inside of the engine is hot, so be cautious of burn injuries

・Be careful not to drop things inside the crankcase



Governor / operation position

52. No-load operation

① JK restoration
② Pump start
③ Air running
④ Engine start
⑤ Engine stop

① JK restoration

② Pump start
- Start primary water, secondary water, and lubricating oil pumps Check pressure, leakage, and lubrication status
- Open indicator cock and turn

③ Air running
- Confirm fuel handle "stop position"
- Check air tank pressure (Refill if low)
- Open the start valve and perform air run
- Check for leaks in the cylinder

④ Engine start
- Check air tank pressure (Refill if low)
- Fuel handle "operation" position
- Open the start valve and start the engine (on-site start)
- Gradually increase rotational speed to rated speed
- Check each temperature and pressure and for abnormal noise, odor, vibration, etc.

⑤ Engine stop
- Position the fuel handle to the "stop" position and stop the engine

- Pass engines with a critical speed through the critical speed as quickly as possible
- Since the engine pump starts to work as the rotational speed increases, stop the priming pump (about 80% speed), and when it is stopped, start the priming pump

53. Internal inspection

* Fuel handle "stop position," air inlet valve "closed"

① Crankcase side cover opening

② Internal inspection

③ Crankcase side cover restoration

① Open the crankcase side cover.

- Open after confirming lubricating oil pump is stopped

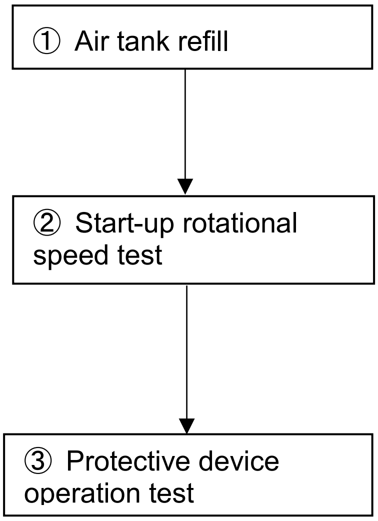
② Internal inspection

- Measure each temperature
  Main metal, clamp pin metal, piston pin metal temperature
- Check the inner surface of the liner
  Check for vertical scratches on the inner surface of the liner using a mirror
- Check for connecting rod side motion
  Push the connecting rod in direction of the shaft with a bar, etc. and confirm that it moves lightly
- Turn and confirm that there is no abnormality in rotation

③ Crankcase side cover restoration

- The inside of the engine is hot, so be cautious of burn injuries
- Be careful not to drop things inside the crankcase

54. Start-up rotational speed test, protective device operation



① Air tank refill

- Start air compressor and fill up to 3 MPa
  Stop air compressor after filling and close bypass valve

② Start-up rotational speed test

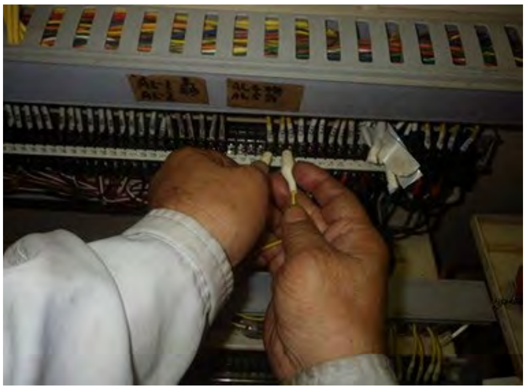
- Start the engine from the central control room
- Start 5 times and record the degree of reduction in the air tank

③ Protective device operation test

- Conduct protective device operation test in parallel with the start-up test
- Confirm engine stop by causing major failure

※Periodic inspection report (Form 19)

- Communicate/signal thoroughly
- The protective device operation test should be carried out in conditions as close to the actual operation as possible.



55. Load step-up adjustment operation

① Disconnector "Open" → "Close"

② Engine start-up

③ Circuit breaker "On"

④ Load step-up operation

⑤ Circuit breaker "Off"

⑥ Engine stop

① Disconnector "closed" check

- After checking the circuit breaker is off, close disconnect switch

② Engine start-up

- Start engine from the central control room
- Check engine periphery and communicate it's OK to connect load

③ Circuit breaker "On"

- Perform connect operation in the central control room (synchroscope panel) Check for rotational speed hunting when loading

④ Load step-up operation

- Gradually raise the load according to the test run schedule submitted separately
- Check engine periphery
- Check each temperature and pressure and for abnormal noise, odor, vibration, etc.
- Check the exhaust color

⑤ Circuit breaker "Off"

- Lower the load to near 0 kW and disconnect

⑥ Engine stop

- After-cooling after stopping engine (automatic)

- Communicate/signal thoroughly
- When extracting piston or replacing metal, sufficiently perform step-up operation.

56. Internal inspection

* Fuel handle "stop position," air inlet valve "closed"

② Crankcase side cover opening

② Internal inspection

③ Crankcase side cover restoration

① Open the crankcase side cover.

- Open after confirming lubricating oil pump is stopped

② Internal inspection

- Measure each temperature
  Main metal, clamp pin metal, piston pin metal temperature
- Check the inner surface of the liner
  Check for vertical scratches on the inner surface of the liner using a mirror
- Check for connecting rod side motion
  Push the connecting rod in direction of the shaft with a bar, etc. and confirm that it moves lightly
- Turn and confirm that there is no abnormality in rotation

③ Crankcase side cover restoration

- The inside of the engine is hot, so be cautious of burn injuries
- Be careful not to drop things inside the crankcase

57. Performance test

① Engine start-up
② Circuit breaker "On"
③ Performance test
④ Circuit breaker "Off"
⑤ Engine stop

① Engine start-up

- Start engine from the central control room
- Check engine periphery and communicate it’s OK to connect load

② Circuit breaker "On"

- Perform connect operation in the central control room (synchroscope panel)

③ Performance test (50%, 75%, 100% load)

- Gradually raise the load according to the test run schedule submitted separately
- Record at each load range
  Measurement of each temperature, pressure
  Measured fuel consumption rate
  Check around the engine
  (oil/water leaks, abnormal sounds, odor)

④ Circuit breaker "Off"

- Lower the load to near 0 kW and disconnect

⑤ Engine stop

- After-cooling after stopping engine (automatic)

- Operate at 100% load for 2 hours or more (until saturation)
- Limit load and adjust rack stopper after measuring fuel consumption at 100% load (can also be done during step-up adjustment operation)

58. Vibration measurement

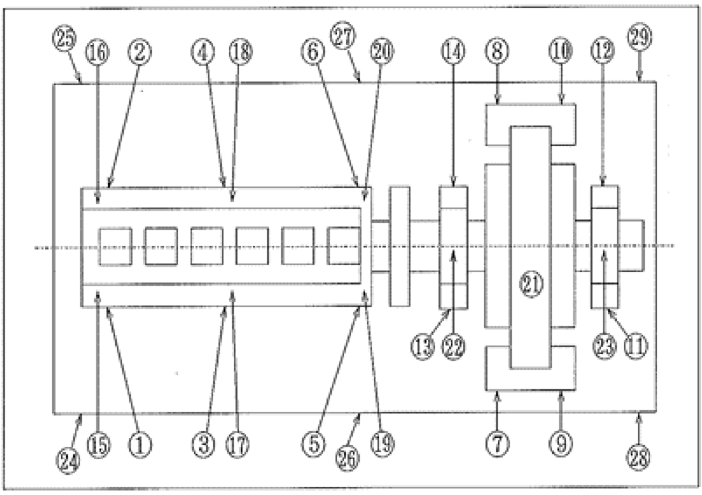
① Vibration measurement

① Vibration measurement

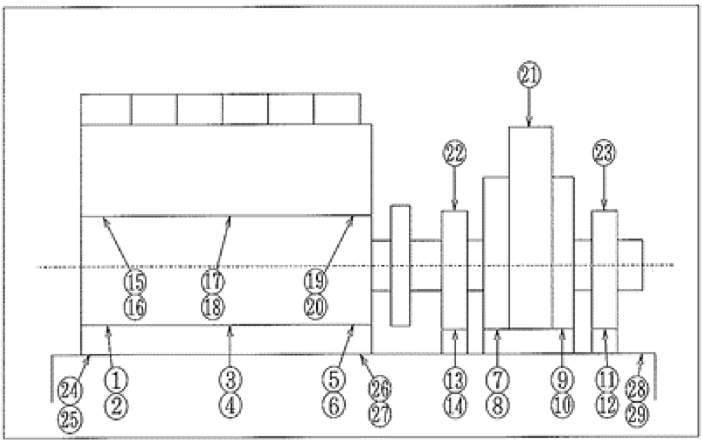
- Measure during 100% load operation of performance test.
- Measure the same place as the last measured location
- Measure in the vertical and horizontal direction for each point

- Since vibration is affected by the surrounding environment, so also check the operating conditions of other units for reference.

Plan view



Side view



59. Internal inspection, bearing temperature measurement

* Fuel handle "stop position," air inlet valve "closed"

① Crankcase side cover

② Internal inspection
Bearing temperature measurement

③ Crankcase side cover

① Open the crankcase side cover.

・Open after confirming lubricating oil pump is stopped

② Internal inspection

・Measure each temperature

Main metal, clamp pin metal, piston pin metal temperature

・Check the inner surface of the liner

Check for vertical scratches on the inner surface of the liner using a mirror

・Check for connecting rod side motion

Push the connecting rod in direction of the shaft with a bar, etc. and confirm that it moves lightly

・Turn and confirm that there is no abnormality in rotation

② Crankcase side cover restoration

* Also clean each filter depending on the condition

※ Periodic inspection report (Form 19)

・The inside of the engine is hot, so be cautious of burn injuries

・Be careful not to drop things inside the crankcase

60. Load rejection test

① Engine start-up,

② 95 Trip lock

③ Load rejection (25%, 50% 75%, 100%)

① Engine start-up, connection

- Start up the engine and connect to grid (25% load)
- Adjust the output of other engine in preparation for load rejection

② 95 Trip lock

- To prevent the underfrequency relay from operating, remove the lock pin

③ Load rejection test

- 25%, 50%, 75%, 100% load rejection
  (Decide on when to conduct after coordinating with customer)
- Record maximum (minimum) settling value before load rejection
  (Generator voltage, frequency, excitation current, rotational speed, governor indicator, settling time)

- For the load rejection test, place personnel in various places and have them count down and records simultaneously
- Be careful not to forget to return the trip lock after completing the test

60. Tidying up

① Tidying up, cleaning

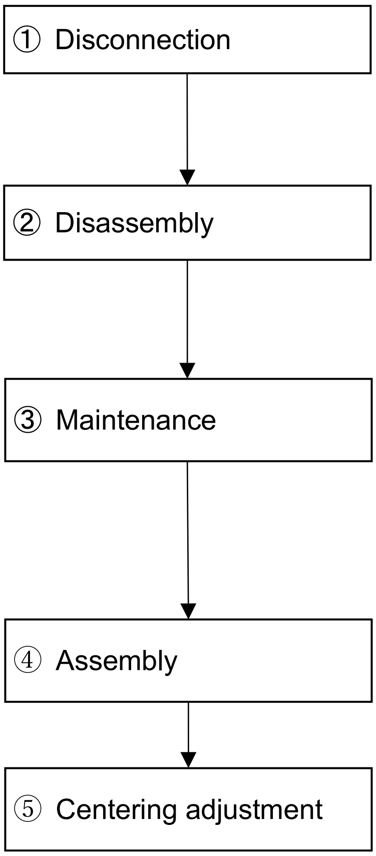
① Tidying up, cleaning

- Remove the covering around the engine
- Check that special tools, etc. used have been removed
- Put away tools
- Disposal of replaced parts (transfer to specified location)
- Cleaning of engine area and wash area

- Put things in order

Auxiliary Devices inspections

1. Primary cooling water pump and motor overhaul



① Disconnection

- Disconnect the motor's cable.
- Cover the cable

② Disassembly

- Open the casing and extract the impeller and shaft
- Extract the bearing from the shaft

③ Maintenance

- Clean the disassembled parts
- Check the wear status of each part
- Apply anti-rust coating where necessary

④ Assembly

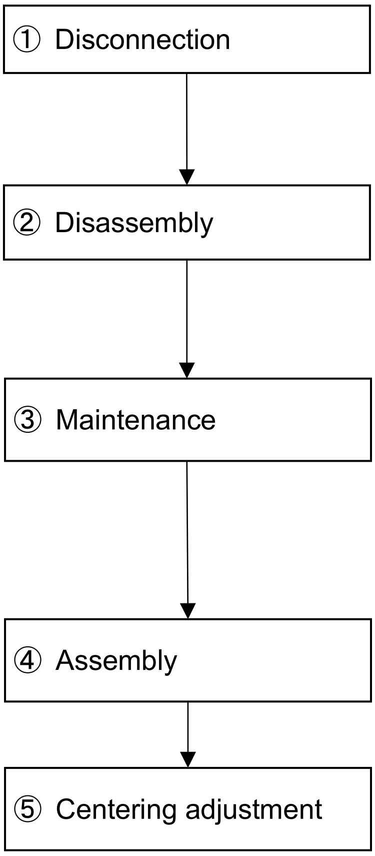
- Replace and assemble bearings and consumables

⑤ Centering adjustment

- Set and adjust the dial gauge to the coupling
- Adjust core runout and face deflection to within the reference value
- Connect the cable after adjustment

- Confirm rotational direction and measure operation current and insulation resistance before test run

2. Secondary cooling water pump, motor overhaul



① Disconnection

- Disconnect the motor's cable.
- Cover the cable

② Disassembly

- Open the casing and extract the impeller and shaft
- Extract the bearing from the shaft

③ Maintenance

- Clean the disassembled parts
- Check the wear status of each part
- Apply anti-rust coating where necessary

④ Assembly

- Replace and assemble bearings and consumables

⑤ Centering adjustment

- Set and adjust the dial gauge to the coupling
- Adjust core runout and face deflection to within the reference value
- Connect the cable after adjustment

- Confirm rotational direction and measure operation current and insulation resistance before test run

Comments

3. Pressurized water pump, motor overhaul

① Disconnection

② Disassembly

③ Maintenance

④ Assembly

① Disconnection

- Disconnect the motor's cable.
- Cover the cable

② Disassembly

- Open the casing and extract the impeller and shaft
- Extract the bearing from the shaft

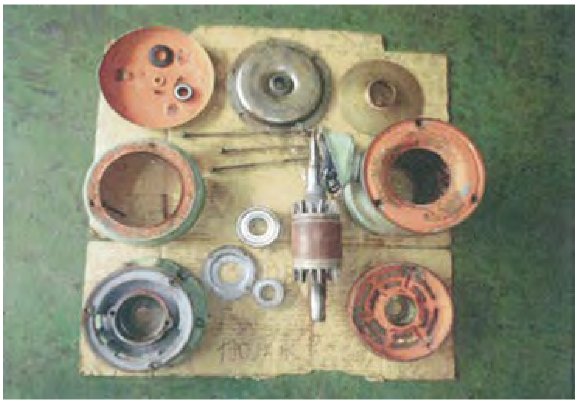
③ Maintenance

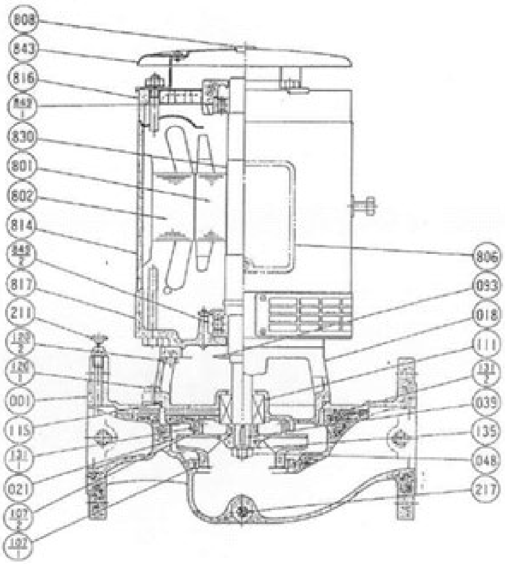
- Clean the disassembled parts
- Check the wear status of each part
- Apply anti-rust coating where necessary

④ Assembly

- Replace and assemble bearings and consumables

- Confirm rotational direction and measure operation current and insulation resistance before test run





4. Fuel oil filter disassembly and cleaning

① Removal

↓

② Element cleaning

↓

③ Parts replacement

↓

④ Installation

① Removal

・Remove fuel oil filter and filter in front of flow meter

② Element cleaning

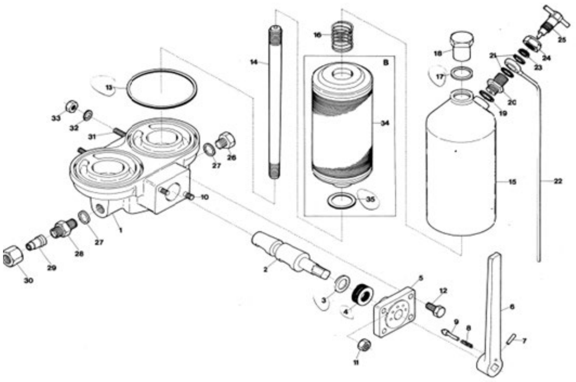
• Check dirtiness before cleaning

③ Parts replacement

・Replace packing, etc.

④ Installation

・Be sure to air bleed before operation



Comments

5. Lubricating oil filter disassembly cleaning

① Removal

↓

② Element cleaning

↓

③ Parts replacement

↓

④ Installation

① Removal

- Remove lubricating oil filter, bearing lubricating filter, valvetrain lubricating filter

② Element cleaning

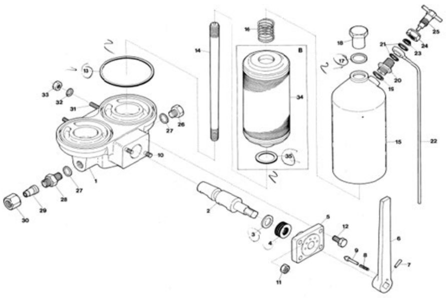
- Check dirtiness before cleaning

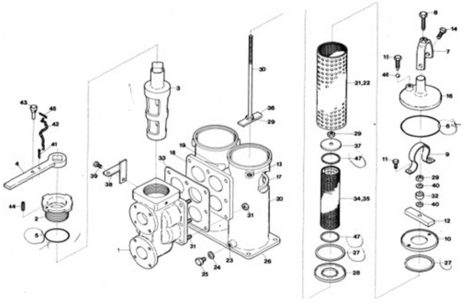
③ Parts replacement

- Replace packing, etc.

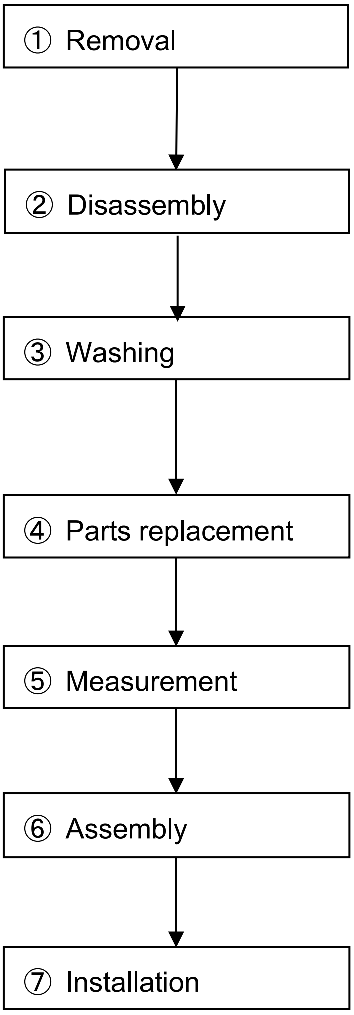
① Installation

- Be sure to air bleed before operation





6. Supercharger overhaul



① Removal

- Remove each pipe and lift them with a removal crane.

② Disassembly

- Remove the casing carefully so that it does not to touch the blade.

③ Washing

- Wash the nozzle, impeller, diffuser, etc.
- Color check the impeller and diffuser to check for cracks

④ Parts replacement

- Replace bearings, labyrinth bush, etc.

⑤ Measurement

- Perform measurements at points specified by the manufacturer (clearance and core deflection)

⑥ Assembly

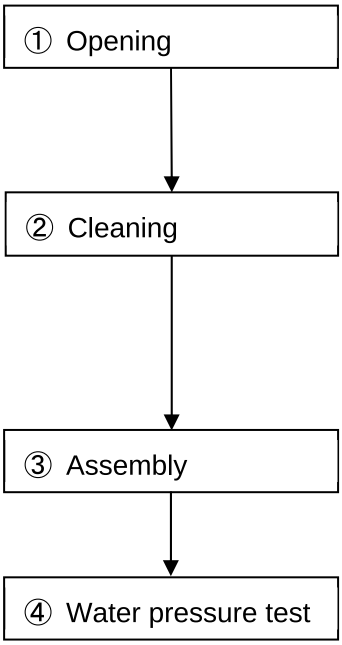
- Assemble each part and refill turbine oil

⑦ Installation

- Lift the supercharger with a crane and install
- Also Install each pipe

- Carefully perform maintenance as the supercharger is a high-speed rotating part
- Replace the bearings before they reach their service life
- Refill turbine oil with oil specified by the manufacturer

7. Each cooler inspection and cleaning (primary water, lubricating oil, air)



① Opening

· Discharge the medium in the cooler

・Remove the lid

② Cleaning

・Secondary water channel cleaning

・Clean the scale inside the tube with a drill, etc.

* Sometimes cleaned by circulating chemical

③ Assembly

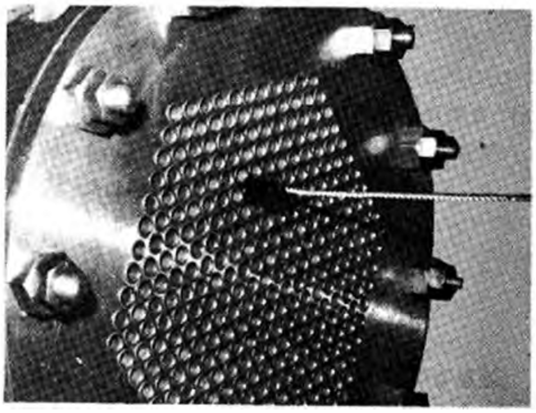
・Apply anti-rust coating to the lid and assemble it

④ Water pressure test

· Perform water pressure test as necessary

・If the tube is clogged, the cooling efficiency drops, so clean it thoroughly

・Be careful not to damage the air side fin portion of the air cooler



8. Temperature control valve operation test (primary water, lubricating oil)

① Disassembly

② Parts replacement

③ Operation test

④ Installation

① Disassembly

- Disassemble the temperature control valve and check the internal condition

② Parts replacement

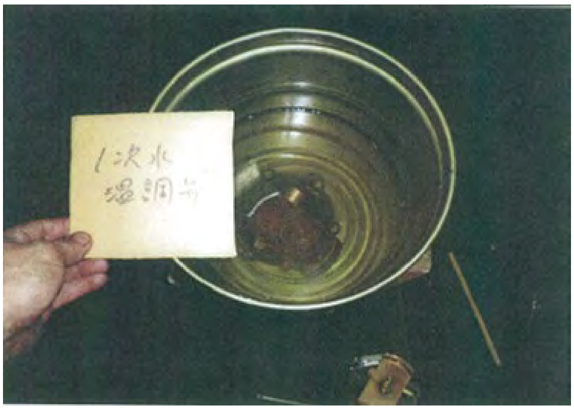
- Replace consumables (packing, O-ring)
- Replace element (in case of malfunction)

③ Operation check

- Actually immerse in hot water and check the operating range Opening start XX ℃ Fully open XX ℃ (nameplate check)

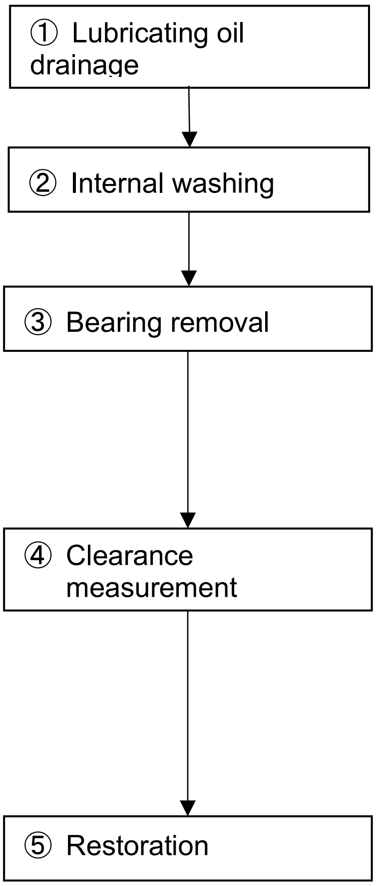
④ Installation

- Confirm actual operation during test run



Comments

10. Generator bearing overhaul



① Lubricating oil drainage

- Drain the lubricating oil from the drain valve

② Internal washing

- Check for pieces of metal (metal scrap) inside

③ Bearing removal

- Remove bearings and check the condition of the contact surface
- Also check the condition of the shaft

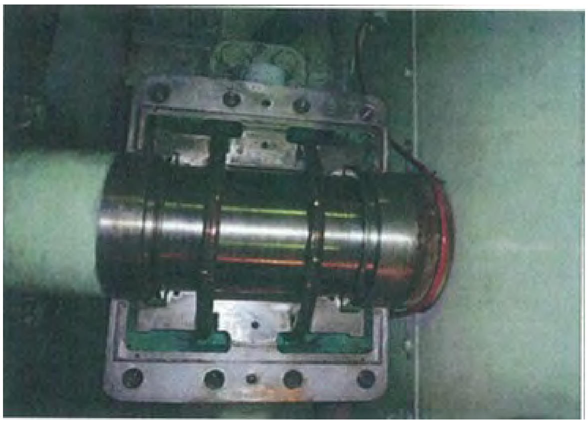
④ Clearance measurement

- Temporarily restore by installing a soft lead wire between the bearing and the shaft
- Open again and measure the crimp of the lead wire with a micrometer and measure the gap

⑤ Restoration

- Confirm that there are no foreign matter inside and restore it
- Always refill the specified amount of lubricating oil (manufacturer specified)

- When the bearing temperature sensor is installed, also put lubricating oil into the sensor insertion hole during restoration



11. Secondary cooling water flow test

① Restoration check

② Secondary water flow

③ Leak check

④ Secondary water pump start

⑤ Leak check

① Restoration check

- Make absolutely sure that each pipe is restored

② Secondary water flow

- Open the secondary water inlet/outlet valve

③ Leak check

- Check for leaks with the pipes filled with secondary water
- Tighten if there are any leaks

④ Secondary water pump start

- Start pump
- Also check pump if pump has undergone maintenance
  Rotational direction, operating current, pressure, etc.

⑤ Leak check

- Start pump and check pressure
- Tighten if there are any leaks

- Check for hunting of pressure by performing air bleeding at various places
- Be sure to stop any leaks

12. Primary water flow test

① Restoration check

② Primary water flow

③ Leak check

④ Primary water pump start

⑤ Leak check

① Restoration check

・Make absolutely sure that each pipe is restored

② Primary water flow

・Open the secondary water inlet/outlet valve

③ Leak check

・Check for leaks with the pipes filled with primary water

• Tighten if there are any leaks

④ Primary water pump start

・ Start pump

・Also check pump if pump has undergone maintenance
Rotational direction, operating current, pressure, etc.

⑤ Leak check

・Start pump and check pressure

• Tighten if there are any leaks

・Check for hunting of pressure by performing air bleeding at various places

・Be sure to stop any leaks (if there is a leak, it will contaminate the lubricating oil, and the oil will have to be replaced)

13. Radiator inspection

① Fan motor removal

② Fan motor maintenance
Bearing replacement

③ Fin washing
* With high-pressure washer

④ Fan motor installation

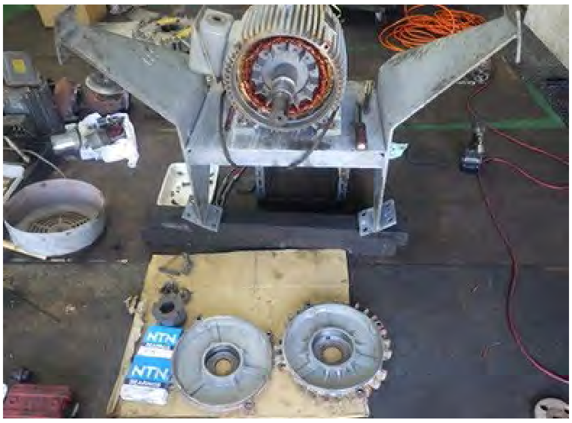
① Using a crane, carefully lift the fan so that it does not touch the case.

② Check for corrosion/abrasion, etc., and replace parts such as bearings.

③ When using the high-pressure washer, wash vertically so that the fins do not bend.

④ Same as when lifting

- Be careful of the sling when lifting fan motor.
- Since it is a heavy item, thoroughly confirm the signal when working



14. CJC filter unit inspection

① Element case disassembly

① Use a chain block as necessary to disassemble the case. When disassembling, measure the length, etc. of the spring.

② Inspecting and washing inside case

② Wash inside the case using a sponge, etc.

③ Element replacement

③ Replace the element with a new one and assemble it with the same spring tension as when disassembled.

④ Pump maintenance*
Replace bearings, etc.

④ If equipped with a pump, replace the pump seal, bearing, etc. with new ones.

⑤ Assembly, trial run

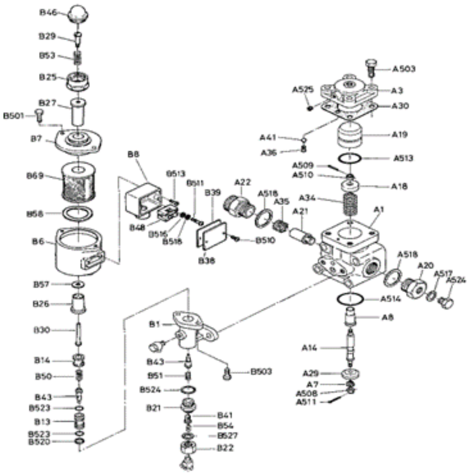
⑤ Confirm that there is no leak, etc. at the time of lubrication after assembly.

・When disassembling the case, use a hoist, etc. as it is a heavy item.
・Ensure that no foreign materials enter when washing the inside.

15. Air system related maintenance

① Stop valve, controlling valve, and distributing valve disassembly	① Check for corrosion, abrasion, etc. when disassembling
② Inspection, cleaning, and replacement of stop valves, controlling valves, and distributing valves	② When replacing required parts, apply grease, etc. as necessary.
③ Stop valve, controlling valve, and distributing valve assembly	③ When assembling, check if the operation of the valve is smooth.
④ Check stop valve, controlling valve, and	④ After assembling, check for air leaks with detergent, etc. * A failure to start up may occur if there is a leak.

- Check for corrosion, etc. when disassembling stop valves, controlling valves, and distributing valves
- Be sure to check for air leaks after assembly (risk of start failure)



16. Expansion water tank inspection

① Drain water from the expansion water tank

① Because it is high temperature water, take time to drain it.

② Clean the interior of the tank

② Since there is a risk of oxygen deficiency when washing the inside, wash with sufficient ventilation.

③ Inspect the ball tap

③ Confirm whether water supply/water stop has been secured by checking operation of the ball tap.

④ Check water supply and ball tap operation inside tank

・Be careful to prevent oxygen deficiency when washing inside the tank.
・Use a level meter also when washing.
・Since it is installed at a high place, wear protective equipment when inspecting.

END

Diesel Generation
Operation and Maintenance Manual

5. Maintenance of Diesel Generators
5.3 Maintenance of diesel generators (Electrical)

Kosrae Utilities Authority

INDEX

1. Purpose

This manual establishes implementation standards for periodic inspection of electrical and instrumentation equipment.

2. Periodic inspection type

Regular inspection of electrical and instrumentation equipment shall be carried out as follows. (See Table 1)

2-1 Normal inspection

Conducted on general items considered to be necessary from the viewpoint of securing the safety of power generation facilities and maintaining functions.

2-2 Detailed inspection

Inspection conducted on in-house transformer boards, in-house transformer breaker board, bus bar connecting boards, distribution line control boards, distribution line breaker boards, etc.

3. Periodic inspection cycle

3-1 Normal inspection

The first capacity unit at each power station is once a year, and the other units and the common facilities are once every two years.

3-2 detailed inspection

Conducted at the discretion of the power generation manager.

4. Periodic inspection guidelines

The procedure for conducting normal inspections shall be as shown in the inspection content (Table 1) and the periodic inspection procedure (Table 2).

5. Inspection results

The person responsible for the work (or power plant personnel) should confirm whether the periodic inspection was carried out by the contractor according to this procedure.

6. Insulation measurement

For units that are shut down for a long term, insulation measurement shall be conducted at a time not exceeding one month, and a test operation shall be conducted.

Table 1　Normal inspection content

Class	Device Name	Normal inspection	Detailed inspection	Pg.
Unit	1. Generator	○	-	3
	2. Exciter	○	-	4
	3. Generator control panel	○	-	5
	4. Generator breaker panel	○	-	6
	5. Exciter panel	○	-	7
	6. Auxiliary relay panel	○	-	8
	7. For in-house transformer panel	-	○	9
	8. For in-house circuit breaker panel	-	○	10
	9. Low voltage incoming panel	○	-	12
	10.Electromagnetic switch board	○	-	13
	11.Auxiliary equipment operation panel (on-site)	○	-	14
	12. Auxiliary equipment operation panel (remote)	○	-	15
	13. Junction terminal panel	○	-	16
Shared	14. Bus tie panel	-	○	17
	15. Distribution line control panel	-	○	19
	16. Distribution line circuit breaker panel	-	○	20
	17. Main circuit breaker, common auxiliary equipment circuit breaker	○	-	22
	18. DC power supply	○	-	24
	19. DC distribution panel	○	-	25
	20. Data logger	○	-	26
	21. Automatic frequency controller	○	-	26
	22. Converter panel	○	-	27
	23. Energy meter panel	○	-	28
	24. Recorder panel	○	-	28
	25. Synchronism detection panel	○	-	29
	26. Control panel	○	-	29
	27. Main transformer	○	-	30
	28. Auxiliary motor	○	-	31

Table 2 Normal periodic inspection procedures

1.Generator

1. Appearance inspection, cleaning
2. Rotor & stator gap measurement
3. Rotor & stator internal inspection/cleaning
4. Slip ring inspection/cleaning
5. Generator cleaning & drying (generator cover disassembly)
6. Brush & brush holder inspection
7. Axial current prevention piece (insulating plate) inspection
8. Space heater inspection (Operation check)
9. Inspection of tacho-generator (voltage measurement)
10. Coil insulation inspection
11. Inspection of winding securing wedge
12. Inspection of jump wires & lead wires
13. Coil end inspection
14. Inspection of iron core support & fasteners
15. Air duct/filter inspection & cleaning
16. Lead out terminal inspection
17. Ground wire inspection
18. Insulation resistance measurement (Rotor & stator)

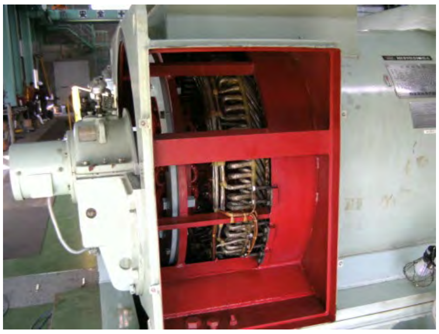
Precautions

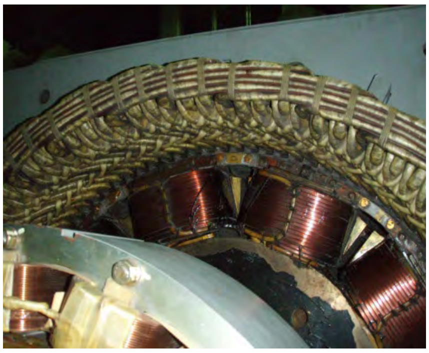
Turning during generator maintenance and inspection is dangerous, so it shall be performed in close communication with the maintenance and inspection personnel.

Since the generator is a rotating body, checks for foreign matter contamination shall always be performed before breaks, before finishing work every day, and before closing the cover at the end of maintenance and inspection.

The pressure when washing the generator with an electric cleaning agent is adjusted to the pressure suitable for the place. Usually 0.3-0.5 MPa.

For burnout due to poor insulation of the generator, since there are many coil ends and lead terminals of the stator, peeling, cracks, etc. are always repaired with varnish.





2. Exciter

1. Appearance inspection, cleaning
2. Internal inspection, cleaning
3. Armature & field winding gap measurement
4. Exciter washing & drying
5. Commutator inspection
6. Brush & brush holder inspection
7. Coil insulator inspection
8. Inspection of winding securing wedge
9. Inspection of jump wires & lead wires
10. Inspection of iron core support & fasteners
11. Air duct/filter inspection & cleaning
12. Lead out terminal inspection
13. Insulation resistance measurement (Armature, field winding)

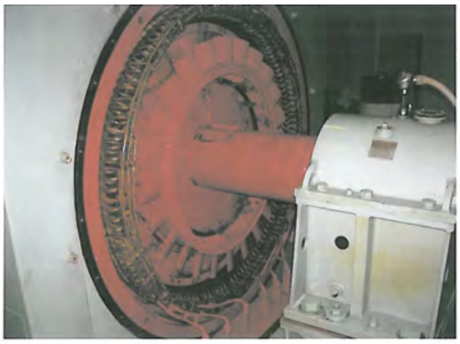
Precautions

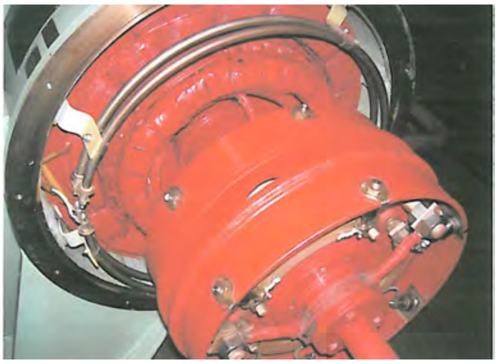
Turning during exciter maintenance and inspection is dangerous, so it shall be performed in close communication with the engine maintenance and inspection personnel.

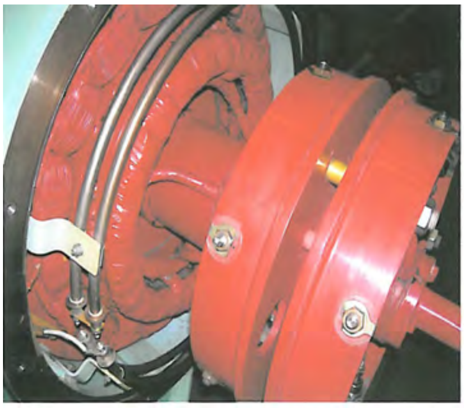
Since the exciter is a rotating body, checks for foreign matter contamination shall always be performed before breaks, before finishing work everyday, and before closing the cover at the end of maintenance and inspection.

Check the fixing and disconnection of the exciter diode directly by hand.

It is recommended to short-circuit the primary and secondary of the diode so that there is no voltage difference when taking measurements of the exciter with a megger.







3. Generator control panel

1. Appearance inspection
2. Check for dust, rust, etc. inside panel
3. Check for damage, breakage, etc. of machinery and equipment
4. Inspection of wire disconnection, etc.
5. Inspection of ground wire condition
6. Inspection for damage, discoloration, dust, terminals, connection points and other fastening parts for panel wiring.
7. Instrument current transformer, instrument transformer inspection/cleaning & error check
8. Instrument inspection, cleaning, error check
   Ammeter, Voltmeter, Tachometer, Wattmeter, Power factor meter
9. Protective relay- Inspection & adjustment,structure inspection, characteristics test, Overcurrent relay, Overvoltage relay, Reverse power relay, Votage relay, Ratio differential relay, Undervoltage relay
10. Auxiliary relay- Inspection & adjustment,
    Sequence configuration relay, Power relay, timer 1,86-1,86-2
11. Operation switch
    Damage to switching contacts, contact status inspection & cleaning
12. Display inspection & cleaning
13. Converter inspection & adjustment, error check
    voltage converter, current converter, power converter, power factor converter
14. Distribution circuit breaker (MCB) inspection
15. Electromagnetic switch (MS) inspection
16. Cable inspection
17. Fuse inspection
18. Terminal inspection & adjustment
19. Sequence test

Precautions

During the VT, CT input test, make sure that there is no wrap around, voltage boost, etc. in the circuit diagram and input so that there is no short circuit, ground fault, disconnection, and no contact with other power supplies.

Clean and tighten the panel so as not to cause CT circuit disconnection, VT circuit short circuit, DC/AC circuit ground fault. short circuit, etc.

Sequence tests are performed after closing valves for fuel, lubricating oil, cooling water, air, steam, etc., and confirming the manual operating position of the switch, and making sure there are no malfunctions in the common circuits.

4. Generator breaker panel

1. Appearance inspection
2. Check for dust, rust, etc. inside panel
3. Check for damage, breakage, etc. of machinery and equipment
4. Inspection of wire disconnection, etc.
5. Inspection of ground wire condition
6. Inspection for damage, discoloration, dust, terminals, connection points and other fastening parts for panel wiring.
7. Bus bar inspection & cleaning, low & high voltage
8. Disconnector- Inspection & cleaning, operation mechanism & contact inspection
9. Instrument current transformer, instrument transformer inspection & cleaning
10. Vacuum circuit breaker
    ① Inspection & cleaning
    ② Switching operation test
    ③ Vacuum valve inspection
        a. Contact wear measurement
        b. Presence of three phase unevenness
    ④ Internal disassembly inspection
    ⑤ Operation mechanism inspection
    ⑥ Measurement of interruption time
    ⑦ Vacuum pressure check
11. Actuator inspection & cleaning
12. Display inspection & cleaning
13. Distribution circuit breaker (MCB) inspection
14. Electromagnetic switch (MS) inspection
15. Cable inspection
16. Fuse inspection
17. Fuse inspection
18. Sequence test- Combine with control panel
19. Insulation resistance measurement

Precautions

When inspecting the generator breaker, make sure it is in the "OFF "position before performing withdrawal. * Electrical inspection may be required depending on the panel structure.

Before inspecting the circuit breaker, make sure that the spring can not be turned ON/OFF by that there is no spring release, tripping condenser stored energy, and control and operation power supply.

Since the VCB vacuum pressure test and OCB oil pressure test use high-voltage power supply, confirm separation, demarcation, and work method.

When cleaning and tightening the panel, inspect to ensure that there is no primary and secondary voltage and discharge before installing the ground wire.

5.Exciter panel

1. Appearance inspection
2. Check for dust inside panel, rust, etc.
3. Check for damage, breakage, etc. of machinery and equipment
4. Inspection of wire disconnection, etc.
5. Inspection of ground wire condition
6. Inspection for damage to wiring, discoloration, dust, terminals, connection points and other fastening parts.
7. Instrument current transformer, instrument transformer inspection & cleaning, Error check
8. Exciter inspection & cleaning
9. Instrument inspection, cleaning, error check
   Ammeter, voltmeter
10. Protective relay- Inspection & adjustment, structure inspection, characteristics test
    Ratio differential relay, winding temperature relay
11. Auxiliary relay- Inspection & adjustment
    Sequence configuration relay, power relay
    Timer
12. Actuator- inspection & adjustment, push-button switch
13. Display inspection & cleaning
14. Distribution circuit breaker (MCB) inspection
15. Electromagnetic switch (MS) inspection
16. Cable inspection
17. Fuse inspection
18. Terminal inspection & adjustment
19. Sequence test. Combine with start-up panel and control panel
20. Insulation resistance measurement

Precautions

When measuring insulation resistance, confirm it with a drawing, etc. so as not to apply it to the circuit board inside the panel.

When the generator is stopped, it is demagnetized, so the main circuit has no voltage, but since the control power supply is in the ON state, clean and tighten the board so as not to cause a short circuit or ground fault.

6. Auxiliary relay panel

1. Appearance inspection
2. Check for dust, rust, etc. inside panel.
3. Check for damage, breakage, etc. of machinery and equipment
4. Check the condition of the equipment and the main grounding wire
5. Check a damage on rear side wiring, discoloration, dust and terminals
   Inspection for damage to connection points and other fastening parts.
6. Meter Inspection
   Ammeter, Voltmeter, Wattmeter、Power factor meter
7. Protection Relay inspection adjustment
   Structural inspection, Characteristic test
   Over current relay, Over voltage relay,
   Reverse Power Relay, Ratio differential relay,
   Voltage relay, Under voltage relay
8. Speed relay inspection adjustment、Check error （Electronic type）
9. Auxiliary relay inspection adjustment Sequence configuration relay, Power relay, Timers
10. Distribution circuit breaker (MCB) Inspection
11. Electromagnetic switch (MS) inspection & cleaning
12. Cable inspection & cleaning
13. Fuse inspection & cleaning
14. Terminal inspection & cleaning
15. Sequence test

Precautions

Since there is a sequencer, etc., and the control power supply is in the ON state, inspect it so as not to cause a short circuit or a ground fault.

Since the number of auxiliary relays and terminal blocks is large, pay particular attention to the mounting condition of the relay mounting bracket and the tightening of the external terminal block.

7. In-house transformer panel

1. Appearance inspection
2. Check for dust inside panel, rust, etc.
3. Check for damage, breakage, etc. of machinery and equipment
4. Inspection of wire disconnection, etc.
5. Inspection of ground wire condition
6. Inspection for damage to wiring, discoloration, dust, terminals, connection points and other fastening parts.
7. Disconnector- Inspection & cleaning, contact inspection
8. Instrument current transformer, instrument transformer inspection & cleaning, error check
9. Transformer (substation transformer) inspection & cleaning, Insulating oil inspection & insulation resistance test (oil)
10. Instrument inspection & adjustment, error check
    Ammeter, Voltmeter, Wattmeter, Power factor meter
11. Protective relay- Inspection & adjustment, structure inspection, characteristics test
    Overcurrent relay, undervoltage relay
12. Auxiliary relay- Inspection & cleaning
    Sequence configuration relay, power relay Timer
13. Actuator inspection & cleaning
14. Display inspection & cleaning
15. Converter inspection & adjustment, error check
    Voltage converter, power converter, current converter
16. Energy meter inspection & adjustment, error test
17. Load disconnector LBS inspection & cleaning
    Operation mechanism inspection, contact inspection
18. Distribution circuit breaker (MCB) inspection
19. Electromagnetic switch (MS) inspection
20. Cable inspection
21. Fuse inspection
22. Terminal inspection & cleaning
23. Sequence test
24. Insulation resistance measurement

Precautions

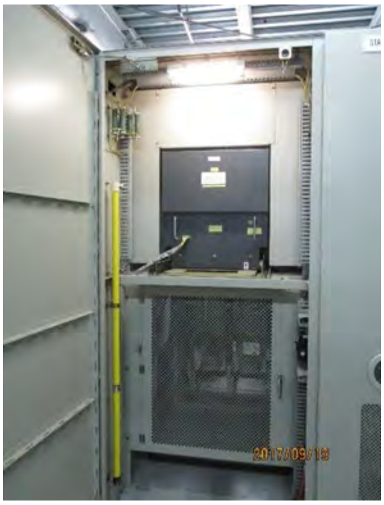
Since there are both high-voltage circuits and low-voltage circuits, check with the in-house system diagram, etc. to get an understanding before performing inspection.
Before inspecting and cleaning the in-house transformer, ensue that there is no primary and secondary voltage and install the ground wire after discharging

8. In-house transformer breaker panel

1. Appearance inspection
2. Check for dust inside panel, rust, etc.
3. Check for damage, breakage, etc. of machinery and equipment
4. Inspection of wire disconnection, etc.
5. Inspection of ground wire condition
6. Inspection for damage to wiring, discoloration, dust, terminals, connection points and other fastening parts.
7. Disconnector- Inspection & cleaning of operation mechanism and contacts
8. Instrument current transformer, instrument transformer inspection & cleaning
9. Circuit breaker
   - ① Inspection & cleaning
   - ② Switching operation test
   - Oil circuit breaker
     - ① Insulating oil voltage tolerance test
     - ② Operation mechanism inspection
     - ③ Internal disassembly inspection
     - ④ Contact resistance measurement
     - ⑤ Measurement of interruption time
   - Vacuum circuit breaker
     - ① Inspection & cleaning
     - ② Vacuum valve inspection
       - a. Contact wear measurement
       - b. Presence or absence of three phase unevenness
     - ③ Internal disassembly inspection
     - ④ Operation mechanism inspection
     - ⑤ Measurement of interruption time
     - ⑥ Vacuum pressure check
       - Structural appearance inspection
       - Various measurements
       - Disassembly inspection
10. Protective relay- Inspection & adjustment, structure inspection, characteristics test
11. Converter inspection & adjustment, error check
    Voltage converter, current converter, power converter, power factor converter
12. Instrument inspection & adjustment
    Ammeter, Voltmeter, Wattmeter, Power factor meter
13. Auxiliary relay- Inspection & adjustment

Sequence configuration relay, power relay, timer

14. Distribution circuit breaker (MCB) inspection
15. Electromagnetic switch (MS) inspection
16. Actuator inspection & cleaning
17. Push-button switch inspection
18. Display inspection & cleaning
19. Status display inspection & cleaning
20. Power meter inspection & cleaning, error check
21. Cable inspection
22. Fuse inspection (high/low voltage)
23. Terminal inspection
24. Sequence test
25. Insulation resistance measurement



Precautions

When inspecting the in-house circuit breaker, make sure it is in the "OFF "position before performing withdrawal. * Electrical inspection may be required depending on the panel structure.

Before inspecting the circuit breaker, make sure that the spring can not be turned ON/OFF by that there is no spring release, tripping condenser stored energy, and control and operation power supply.

Since the VCB vacuum pressure test and OCB oil pressure test use high-voltage power supply, confirm separation, demarcation, and work method.

Before cleaning and tightening the panel, inspect to ensure that there is no primary and secondary voltage and install the ground wire after discharging.

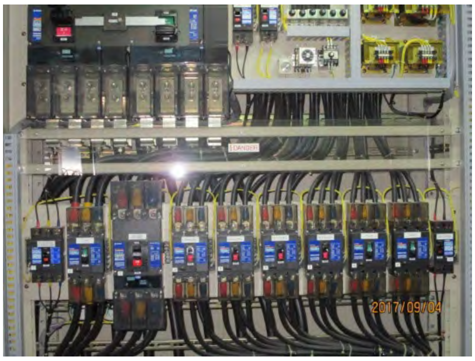
9. Low Voltage Power Incoming Panel

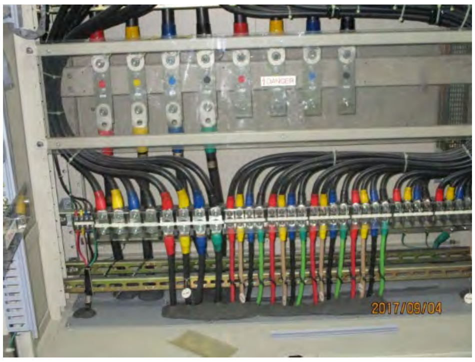
1. Appearance inspection
2. Check for dust, rust, etc. inside panel.
3. Check for damage, breakage, etc. of machinery and equipment
4. Inspection of wire disconnection, etc.
5. Inspection of ground wire condition
6. Inspection for damage, discoloration, dust, terminals, connection points and other fastening parts for panel wiring.
7. Bus bar (low voltage) inspection & cleaning
8. Instrument converter, instrument transformer inspection & cleaning
9. Protective relay- Inspection & adjustment, structure inspection, characteristics test
   Overcurrent relay
10. Instrument inspection, cleaning, error check
    Ammeter, Voltmeter, Wattmeter, Power factor meter
11. Auxiliary relay- Inspection & adjustment,
    Sequence configuration relay
    Power relay, timer operation time inspection
12. Distribution circuit breaker (MCB) inspection & cleaning
13. Electromagnetic switch (MS) inspection & cleaning
14. Actuator inspection & cleaning
15. Display inspection & cleaning
16. Energy meter inspection & adjustment, error check
17. Cable inspection & cleaning
18. Fuse inspection & cleaning
19. Terminal inspection & cleaning
20. Insulation resistance measurement

Precautions

During the VT, CT input test, make sure that there is no wrap around, voltage boost, etc. in the circuit diagram and input so that there is no contact with other power supplies.

Since the low-voltage receiving panel hardly stops, clean the and tighten the panel so as not to turn the breaker off, cause ground fault short circuit, etc.



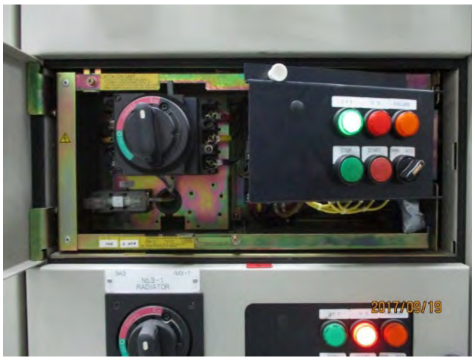


10. Electromagnetic switch board

1. Cable inspection & cleaning
2. Fuse inspection & cleaning
3. Terminal inspection & cleaning
4. Sequence test
5. Insulation resistance measurement

Precautions

Make sure the breaker of the unit is in the off position and inspect it after pulling it out, and cover the lid so that a hand cannot be put in.



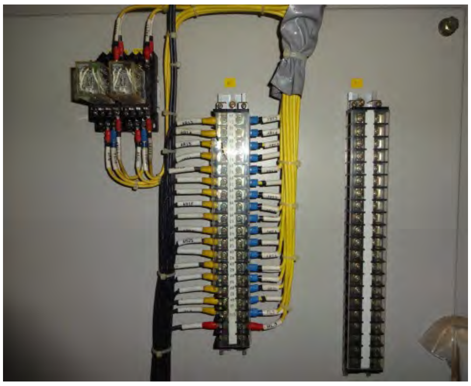
11. Auxiliary equipment operation panel (On-site)

1. Appearance inspection
2. Check for dust, rust, etc. inside panel.
3. Check for damage, breakage, etc. of machinery and equipment
4. Inspection of ground wire condition
5. Inspection for damage, discoloration, dust, terminals, connection points and other fastening parts for panel wiring.
6. Instrument inspection & adjustment, error check Ammeter, Voltmeter, Wattmeter
7. Distribution circuit breaker (MCB) Inspection & cleaning
8. Actuator inspection & cleaning
9. Display inspection & cleaning
10. Cable inspection & cleaning
11. Fuse inspection & cleaning
12. Terminal inspection & cleaning
13. Sequence test combine with electromagnetic switch

Precautions

When inspecting and cleaning, be sure not to press the push-button, etc. and return it to its original position when operating the selector switch, etc.

Since it is dangerous when working on the auxiliary equipment side, have the breaker turned off and switched from automatic to manual.



12. Auxiliary equipment operation panel (Remote)

1. Appearance inspection
2. Check for dust, rust, etc. inside panel.
3. Check for damage, breakage, etc. of machinery and equipment
4. Inspection of ground wire condition
5. Inspection for damage to internal wiring, discoloration, dust, terminals, connection points and other fastening parts.
6. Instrument inspection & adjustment, error check Ammeter, Voltmeter, Wattmeter, Distribution circuit breaker (MCB) inspection & cleaning
7. Distribution circuit breaker (MCB) inspection & cleaning
8. Actuator inspection & cleaning
9. Display inspection & cleaning
10. Cable inspection & cleaning
11. Fuse inspection & cleaning
12. Terminal inspection & cleaning
13. Sequence test combine with electromagnetic switch

Precautions

When inspecting and cleaning, be sure not to press the push-button, etc. and return it to its original position when operating the selector switch, etc.

Since it is dangerous when working on the auxiliary equipment side, have the breaker turned off and switched from automatic to manual.

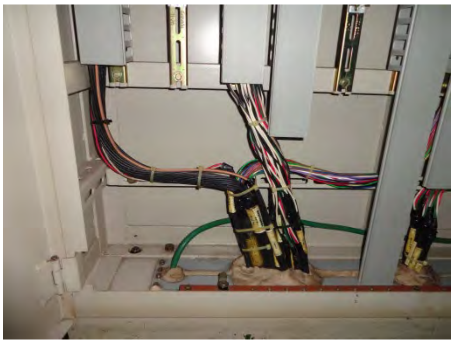
13. Junction terminal panel

1. Appearance inspection
2. Check for dust, rust, etc. inside panel.
3. Inspection of ground wire condition
4. Inspection for damage to connection points and other fastening parts.
5. Terminal inspection & cleaning
6. Cable inspection & cleaning

Precautions

Since the number of terminal blocks is large, pay particular attention to the tightening of the external terminal blocks.

For cleaning and tightening of the panel, take precautions against short-circuits and ground faults by taping screwdrivers, brushes, etc.



14. Bus tie panel

1. Appearance inspection
2. Check for dust inside panel, rust, etc.
3. Check for damage, breakage, etc. of machinery and equipment
4. Inspection of wire disconnection, etc.
5. Ground wire condition
6. Inspection for damage to panel wiring, discoloration, dust, terminals, connection points and other fastening parts.
7. Bus bar inspection & cleaning
8. Disconnector- Inspection & cleaning, Main body and operation mechanism inspection, Contact inspection
9. Instrument current transformer, instrument transformer inspection & cleaning
10. Circuit breaker
    ① Inspection & cleaning
    ② Switching operation test
    - Oil circuit breaker
      ① Insulating oil voltage tolerance test
      ② Operation mechanism inspection
      ③ Internal disassembly inspection
      ④ Contact resistance measurement
      ⑤ Measurement of interruption time
    - Vacuum circuit breaker
      ① Inspection & cleaning
      ② Vacuum valve inspection
        a. Contact wear measurement
        b. Presence or absence of three phase unevenness
      ③ Internal disassembly inspection
      ④ Operation mechanism inspection
      ⑤ Measurement of interruption time
      ⑥ Vacuum pressure check
11. Protective relay- Inspection & adjustment, structure inspection, characteristics test, Overcurrent relay
12. Converter inspection & adjustment, error check Current converter, power converter
13. Instrument inspection & adjustment, error check Ammeter, wattmeter
14. Auxiliary relay- Inspection & cleaning, Sequence configuration relay
15. Distribution circuit breaker (MCB) inspection & cleaning
16. Electromagnetic switch (MS) inspection & cleaning
17. Actuator inspection & cleaning

18. Display inspection & cleaning
19. Energy meter inspection & adjustment, error check
20. Cable inspection & cleaning
21. Fuse (high/low voltage) inspection & cleaning
22. Terminal inspection & cleaning
23. Insulation resistance measurement

Precautions

When inspecting the busbar insulation, make sure it is in the "OFF "position before performing withdrawal. * Electrical inspection may be required depending on the panel structure.

Before inspecting the circuit breaker, make sure that the spring cannot be turned ON/OFF by that there is no spring release, tripping condenser stored energy, and control and operation power supply.

Since the VCB vacuum pressure test and OCB oil pressure test use high-voltage power supply, confirm separation, demarcation, and work method.

When cleaning and tightening the panel, since the bus cannot be stopped due to the panel structure and operation, perform only where possible by consulting with the customer.

15. Distribution line control panel

1. Appearance inspection
2. Check for dust, rust, etc. inside the panel.
3. Check for damage, breakage, etc. of machinery and equipment
4. Inspection of ground wire condition
5. Inspection for damage to panel wiring, discoloration, dust, terminals, connection points and other fastening parts.
6. Protective relay- Inspection & adjustment, structure inspection, characteristics test, Overcurrent relay, ground fault directional relay, Ground fault overvoltage relay, frequency relay, Reclosing relay
7. Converter inspection & adjustment, error check Current converter, power converter
8. Instrument inspection & adjustment, error check Ammeter, voltmeter, wattmeter, power factor meter
9. Auxiliary relay inspection & cleaning, Sequence configuration relay, Power relay, Timer
10. Distribution circuit breaker (MCB) inspection & cleaning
11. Electromagnetic switch (MS) inspection & cleaning
12. Actuator inspection & cleaning
13. Display inspection & cleaning
14. Energy meter inspection & adjustment, error check
15. Cable inspection & cleaning
16. Fuse (high/low voltage) inspection & cleaning
17. Terminal inspection & cleaning
18. Sequence test
19. Insulation resistance measurement

Precautions

When cleaning and tightening the panel, be sure not to make mistakes on the distribution line side during operation because it is impossible to stop all distribution lines at the same time due to the panel structure and operation.
During operation, cover the distribution line side with red tape and vinyl to demarcate.

16. Distribution line circuit breaker panel

1. Appearance inspection
2. Check for dust inside panel, rust, etc.
3.Check for damage, breakage, etc. of machinery and equipment
4. Inspection of wire disconnection, etc.
5. Inspection of ground wire condition
6. Inspection for damage to panel wiring, discoloration, dust, terminals, connection points and other fastening parts.
7. Bus bar (high voltage) inspection & cleaning
8. Disconnector- Main body and operation mechanism inspection, Contact inspection
9. Instrument transformer, instrument current transformer inspection & cleaning
10. Circuit breaker
   ① Inspection & cleaning
   ② Switching operation test
- Oil circuit breaker
   ① Insulating oil voltage tolerance test
   ② Operation mechanism inspection
   ③ Internal disassembly inspection
   ④ Contact resistance measurement
   ⑤ Measurement of interruption time
- Vacuum circuit breaker
   ① Inspection & cleaning
   ② Vacuum valve inspection
      ａ. Contact wear measurement
      ｂ. Presence or absence of three phase unevenness
   ③ Internal disassembly inspection
   ④ Operation mechanism inspection
   ⑤ Measurement of interruption time
   ⑥ Vacuum pressure check
11. Protective relay- Inspection & adjustment, structure inspection, characteristics test, Overcurrent relay, ground fault directional relay, Ground fault overvoltage relay, Frequency relay
12. Converter inspection & adjustment, error check
    Current converter, voltage converter, power converter
13. Instrument inspection & adjustment, error check
    Ammeter, wattmeter
14. Auxiliary relay inspection & cleaning
    Sequence configuration relay, Power relay, Timer

15. Distribution circuit breaker (MCB) inspection & cleaning
16. Electromagnetic switch (MS) inspection & cleaning
17. Actuator inspection & cleaning
18. Display inspection & cleaning
19. Energy meter inspection & adjustment, error check
20. Grounding transformer (GPT) inspection & cleaning
21. Zero-phase current transformer (ZCT) inspection & cleaning, characteristics test- combine with ground fault directional relay.
22. Arrester inspection & cleaning
23. Cable inspection & cleaning
24. Fuse (high/low voltage) inspection & cleaning
25. Terminal inspection & cleaning
26. Sequence test
27. Artificial ground fault test

Precautions

When inspecting the distribution line breaker, make sure it is in the "OFF "position before performing withdrawal. * Electrical inspection may be required depending on the panel structure.

Before inspecting the circuit breaker, make sure that the spring cannot be turned ON/OFF by that there is no spring release, tripping condenser stored energy, and control and operation power supply.

Since the VCB vacuum pressure test and OCB oil pressure test use high-voltage power supply, confirm separation, demarcation, and work method.

When cleaning and tightening the panel, since the bus cannot be stopped due to the panel structure and operation, perform only where possible by consulting with the customer.

17. Main transformer circuit breaker, auxiliary equipment circuit breaker

1. Appearance inspection
2. Check for dust inside panel, rust, etc.
3. Check for damage, breakage, etc. of machinery and equipment
4. Inspection of wire disconnection, etc.
5. Inspection of ground wire condition
6. Inspection for damage to wiring, discoloration, dust, terminals, connection points and other fastening parts.
7.Ground wire (high voltage) inspection & cleaning
8. Disconnector- Main body and operation mechanism inspection, Contact inspection
9. Instrument transformer, instrument current transformer inspection & cleaning
10. Circuit breaker
   ① Inspection & cleaning
   ② Switching operation test
- Oil circuit breaker
   ① Insulating oil voltage tolerance test
   ② Operation mechanism inspection
   ③ Internal disassembly inspection
   ④ Contact resistance measurement
   ⑤ Measurement of interruption time
- Vacuum circuit breaker
   ① Inspection & cleaning
   ② Vacuum valve inspection
      ａ. Contact wear measurement
      ｂ. Presence or absence of three phase unevenness
   ③ Internal disassembly inspection
   ③ Operation mechanism inspection
   ⑤ Measurement of interruption time
   ⑥ Vacuum pressure check
11. Protective relay- Inspection & adjustment, structure inspection, characteristics test, Overcurrent relay, ground fault directional relay, Ground fault overvoltage relay, Frequency relay
12. Converter inspection & adjustment, error check
    Current converter, voltage converter, power converter
13. Instrument inspection & adjustment, error check
    Ammeter, wattmeter
14. Auxiliary relay inspection & cleaning
    Sequence configuration relay, Power relay, Timer
15. Distribution circuit breaker (MCB) inspection & cleaning

16. Electromagnetic switch (MS) inspection & cleaning
17. Actuator inspection & cleaning
18. Display inspection & cleaning
19. Energy meter inspection & adjustment, error check
20. Grounding transformer (GPT) inspection & cleaning
21. Zero-phase current transformer (ZCT) inspection & cleaning, Characteristics test- combine with ground fault directional relay.
22. Arrester inspection & cleaning
23. Cable inspection & cleaning
24. Fuse (high/low voltage) inspection & cleaning
25. Terminal inspection & cleaning
26. Sequence test

Precautions

When inspecting the main transformer circuit breaker, make sure it is in the "OFF "position before performing withdrawal. * Electrical inspection may be required depending on the panel structure.
Before inspecting the circuit breaker, make sure that the spring cannot be turned ON/OFF by that there is no spring release, tripping condenser stored energy, and control and operation power supply.
Since the VCB vacuum pressure test and OCB oil pressure test use high-voltage power supply, confirm separation, demarcation, and work method.
Since the disconnector panel has a charged part due to its structure, only the circuit breaker panel is cleaned and tightened, but not above the head because there is an extra high-voltage line.

18. DC power supply panel

1. Appearance inspection
2. Check for dust, rust, etc. inside panel.
3. Check for damage, breakage, etc. of machinery and equipment
4. Inspection of wire disconnection, etc.
5. Inspection of ground wire condition
6. Inspection for damage, discoloration, dust, terminals, connection points and other fastening parts for panel wiring.

(Battery)

7. Inspection of current state
    - a. Total voltage measurement of storage battery during float charging
    - b. Total voltage measurement of a single battery during float charging
    - c. Specific gravity measurement
    - d. Temperature measurement
    - e. Liquid level inspection
8. Visual appearance inspection
    - a. Element, electrolyte level inspection
    - b. Check for loose connection
    - c. Presence of contamination or damage to metal box & steel rack
    - d. Inspection for leakage and rust
9. Equalizing charge
10. Tightening connections

(Charger)

11. Inspection of current state
    - a. Measurement of the AC input voltage
    - b. Measurement of float charging voltage
    - c. Measurement of equalizing charge voltage
    - d. Measurement of the output current
    - e. Measurement of the load current
    - f. Measurement of equalizing load voltage
12. Visual appearance inspection

    Inspection of each part for contamination & damage
13. Tightening of each fastening part

Precautions

Since it is used as an uninterruptible power supply at the power plant and it is constantly being charged, it is not operated at one’s discretion without permission.

To clean and tighten the panel, tools such as a spanner are taped when used so as not to cause a short-circuit fault.

Be sure that your clothing and skin does not make contact with the battery solution as it contains dilute sulfuric acid.

Since lead-acid batteries generates combustible gas, rooms shall be ventilated.

Tools, etc. which have come in contact with dilute sulfuric acid will deteriorate, so shall be washed with water, dried, and stored.

19. DC distribution panel

1. Appearance inspection
2. Check for dust, rust, etc. inside panel.
3. Check for damage, breakage, etc. of machinery and equipment
4. Inspection of ground wire condition
5. Inspection for damage to panel wiring, discoloration, dust, terminals, connection points and other fastening parts.
6. Distribution circuit breaker (MCB) inspection & cleaning
7. Electromagnetic switch (MS) inspection & cleaning
8. Operation sound inspection & cleaning

Precautions

Since it is used as an uninterruptible power supply at the power plant and it is constantly being charged, it is not operated at one’s discretion without permission.

For cleaning and tightening of the panel, take precautions against short-circuits and ground faults by taping screwdrivers, brushes, etc.

20. Data Logger device

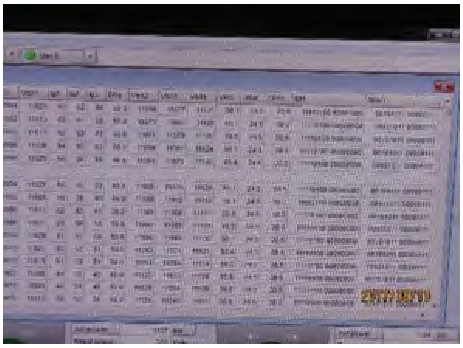
1. Appearance inspection
2. Check for dust inside panel, rust, etc.
3. Inspection for damage to panel wiring, discoloration, dust, terminals, connection points, and other fastening parts.
4. Actuator inspection & cleaning
5. Display inspection & cleaning

Precautions

For cleaning and tightening of the panel, take precautions against short-circuits and ground faults by taping screwdrivers, brushes, etc.

Be careful not to turn off breakers, etc. as it is a PC.

That does not cause a tool of static electricity or the like, so PC, to use the material.



21. Converter panel

1. Appearance inspection
2. Check for dust inside panel, rust, etc.
3. Inspection for damage to panel wiring, discoloration, dust, terminals, connection points, and other fastening parts.
4. Display inspection & cleaning
5. Cable connector inspection & cleaning
6. Fuse inspection & cleaning
7. Terminal inspection & cleaning

Precautions

For cleaning and tightening of the panel, take precautions against short-circuits and ground faults by taping screwdrivers, brushes, etc.

Be careful not to turn off breakers, etc. as it is common equipment.

22. Energy meter panel

1. Appearance inspection
2. Check for dust, rust, etc. inside panel.
3. Check for damage, breakage, etc. of machinery and equipment
4. Inspection of wire disconnection, etc.
5. Inspection of ground wire condition
   Inspection for damage, discoloration, dust, terminals, connection points and other fastening parts for panel wiring.
6. Instrument current transformer, instrument transformer inspection & cleaning
7. Energy meter inspection & adjustment, error check
8. Cable inspection & cleaning
9. Fuse inspection & cleaning
10. Terminal inspection & cleaning

Precautions

During the VT, CT input test, make sure that there is no wrap around, voltage boost, etc. in the circuit diagram and input so that there is no short circuit, ground fault, disconnection, and no contact with other power supplies. Clean and tighten the panel so as not to cause CT circuit disconnection, VT circuit short circuit, DC/AC circuit ground fault. short circuit, etc.

23. Recorder panel

1. Appearance inspection
2. Check for dust, rust, etc. inside panel
3. Inspection of wire disconnection, etc.
4. Inspection for damage, discoloration, dust, terminals, connection points and other fastening parts for panel wiring.

Precautions

When cleaning or tightening the panel, pay attention to cutting the wires and connectors coming off as the wires used are thin signal wires.
Be careful not to turn off breakers, etc.

24.Synchronism detection panel

1. Appearance inspection
2. Check for dust, rust, etc. inside panel
3. Inspection for damage to wiring, discoloration, dust, terminals, connection points and other fastening parts.
4. Cable inspection & cleaning
5. Terminal inspection & cleaning

Precautions

Since it is a panel shared with other devices, be careful as there is VT voltage of other circuits.
For cleaning and tightening of the panel, take precautions against short-circuits and ground faults by taping screwdrivers, brushes, etc.

25. Control panel

1. Appearance inspection
2. Check for dust, rust, etc. inside panel
3. Inspection for damage to wiring, discoloration, dust, terminals, connection points and other fastening parts.
4. Cable inspection & cleaning
5. Terminal inspection & cleaning

Precautions

When cleaning or tightening the panel, pay attention to cutting the wires and connectors coming off as the wires used are thin signal wires.
Be careful not to turn off breakers, etc. as it is common equipment.

26. Main transformer

1. Winding, iron core
   - Check for vibration and abnormal sound
   - Oil leak check
   - Check with oil gauge
   - Check dirtiness of oil
   - Extract sample from the drain cock and check
   - Check for discoloration of silica gel, etc.
     - Pink: Slightly poor
     - Purple: Good
     - White: Poor
2. Lead wires
   - Check for rusting
   - Check for fouling of glass, etc.
   - Check for cracking, etc.
3. Winding support
   - Temperature reading records
4. Dial thermometer
   - Check for misalignment of anti-vibration rubber, cracking, Clouded glass surface cleaning
   - Alarm contact continuity check
5. Insulation resistance measurement
6. Oil insulation voltage resistance measurement

Precautions

Insulation bushing is made of porcelain, so be careful not to break it.

The upper part of the transformer has thin piping, etc., and it is filled with oil, so do not put weight on it.

The top of the radiator has poor footing, so watch your step.

27. Auxiliary equipment motor

1. Appearance inspection & cleaning
2. Insulation resistance measurement
3. Auxiliary equipment cable disconnection/connection
4. Operation current measurement

Precautions

When measuring the auxiliary equipment motor with a megger, conduct the test only after confirming that the breaker is off and there is no voltage.

During operation, measurements shall be taken so as nothing gets entangled with the rotating body and a short-circuit or ground fault does not occur.

28. Instrument set panel

1. Pressure gauge inspection & adjustment
2. Pressure switch inspection & adjustment
3. Temperature indication switch inspection & adjustment
4. Temperature switch inspection & adjustment
5. Transmitter inspection & adjustment
6. Alarm setting device inspection & adjustment
7. Converter inspection & adjustment
8. Indicator inspection & adjustment
9. Indicator w/alarm inspection & adjustment

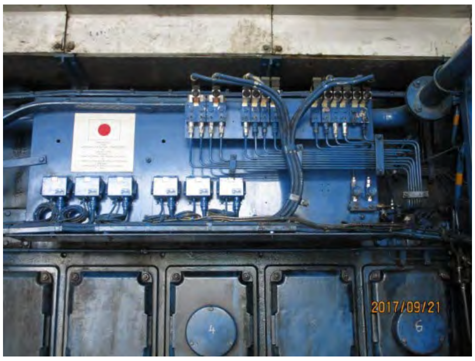
Precautions

Make sure each instrumentation equipment is stopped, there is no pressure, and high temperature, etc. before performing.

Each instrumentation device shall be inspected individually.

Prepared so as to prevent scattering and fouling because residue remains in each pipe.

After checking each instrumentation device, check for tightening and leaks during operation.



29. Central control room

1. Indicator inspection & adjustment
2. Recorder inspection & adjustment
3. Converter inspection & adjustment

Precautions

When performing inspection and adjustment of the central control room panel, since there are the same type of equipment, confirm with drawings and name plates.

Demarcate the unit being inspected so that it is easily recognizable.

Reference (test related)

No	Name	Inspection items	Photo
1	Protective relay	Relay operation test	
2	Integrating wattmeter	Integrating wattmeter test	

Reference (test related)

No	Name	Inspection items	Photo
3	Circuit breaker	Vacuum pressure test	
4	Circuit breaker	Switching test	

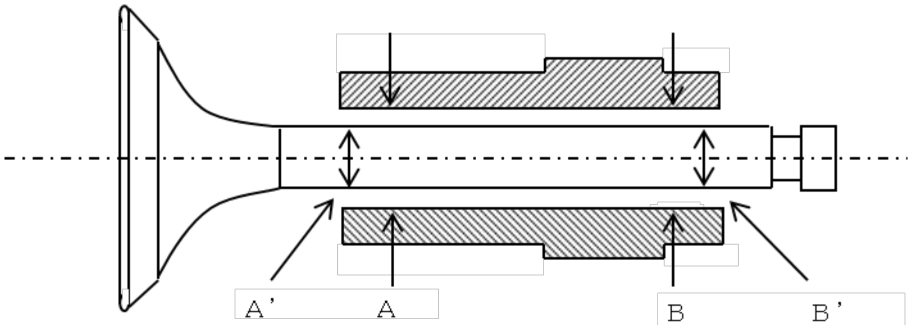
Diesel Generation
Operation and Maintenance Manual

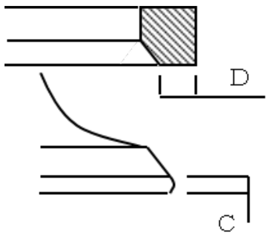
5. Maintenance of Diesel Generators
Attachments

Kosrae Utilities Authority

Maintenance of diesel generators (Mechanical)
ATTACHMENT INDEX

Form-1：Exhaust Valve measurement record





Measurer：________________

Measurement Date：

Valve replacement time：　　(　　　)hr

Valve operating time：　　(　　　)hr

Bush inner diameter standard dimension

Valve rod outer diameter standard dimension

Bush inner diameter limit

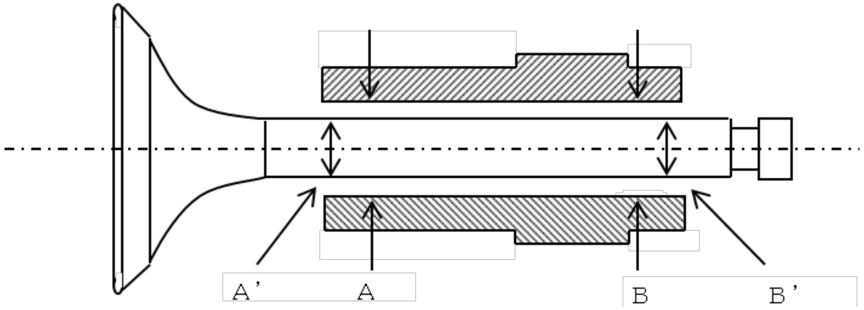
Valve rod outer diameter limit

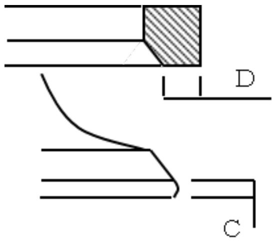
C :　Valve face Usage limit

Unit 1/100 ㎜

Cylinder No.		1		2		3		4		5		6		7		8	
H:Eng Side　G:Gen Side		H	G	H	G	H	G	H	G	H	G	H	G	H	G	H	G
Body Stamping No.																	
Bush Inner diameter dimension	A																
	B																
Valve rod outer diameter dimension	A’																
	B’																
Valve rod bush clearance	A-A’																
	B-B’																
Valve face dimensions	C																
Valve seat dimension	D																
Summary																	

Form-2：Intake valve measurement record





Measurer：

Measurement Date：

Valve replacement time： ( )hr

Valve operating time： ( )hr

Bush inner diameter standard dimension

Valve rod outer diameter standard dimension

Bush inner diameter limit

Valve rod outer diameter limit

C： Valve face Usage limit

Unit 1/100 ㎜

Cylinder No.		1		2		3		4		5		6		7		8	
H:Eng Side G:Gen Side		H	G	H	G	H	G	H	G	H	G	H	G	H	G	H	G
Body Stamping No.																8-1	8-2
Bush Inner diameter dimension	A																
	B																
Valve rod outer diameter dimension	A’																
	B’																
Valve rod bush clearance	A-A’																
	B-B’																
Valve face dimensions	C																
Valve seat dimension	D																
Summary																	

Form-5-1：Crank pin metal (crank metal)　measurement record

Measurer:_______________________

Measurement Date：

Crank pin volt replacement criteria hour

Crank pin Punch mark ( ) Usage time ( ) hour

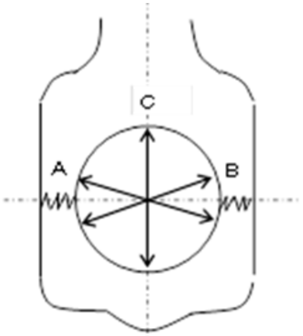
Crank pin metal replacement time ( ) hour

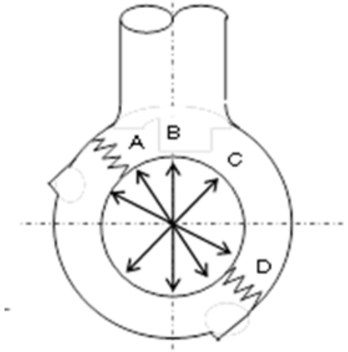
Crank pin metal usage time ( ) hour

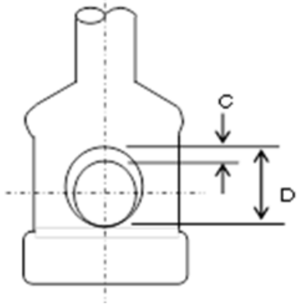
Main metal replacement time ( ) hour

Main metal usage time ( ) hour

H:Eng Side　G:Gen Side		Standard	Limit	R1	R2	R3	R4	R5	R6	L1	L2	L3	L4	L5	L6
Crank pin metal Clearance （C）	Before disassembly			—	—	—	—	—	—	—	—	—	—	—	—
	After assembly														
Crank pin metal Inner diameter measurement （D） (No metal state)	D－A H/G														
	D－B H/G														
	D－C H/G														
	D－D H/G	—	—												
Crank pin metal Thickness （D） （Upper metal only）	H side														
	G side														







Form-5-2：Crank pin metal (crank metal)　measurement record

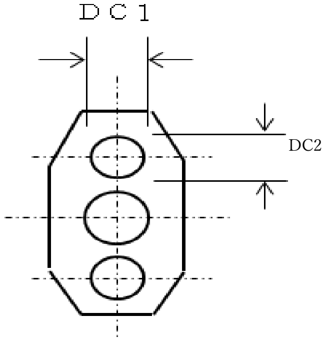
Measurer：

Crank pin outer diameter measurement

Standard dimensions　　Uneven wear limit　　Unit 1/100 ㎜

Cylinder No. / Measurement point		R1	R2	R3	R4	R5	R6	L1	L2	L3	L4	L5	L6
DC1	H side												
	G side												
DC2	H side												
	G side												
Uneven wear	H side												
	G side												

Measurement Date：

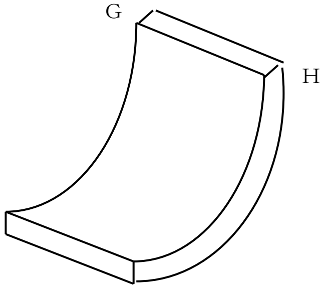


Main metal measurement

Unit ㎜

		Standard	1	2	3	4	5	6	7
Main metal Clearance	Before disassembly H/G								
	After assembly H/G								
Main metal Thickness (t)	H/G								

Measurement Date：



Form-6-1：Main bolt tightening record

Tightener：

Cylinder head tightening nut

Tightening reference torque　　　　Unit　N･m

Cylinder No.	R1	R2	R3	R4	R5	R6	L1	L2	L3	L4	L5	L6
Tightening torque												

Tightening Date：

Spindle pressure clamp nut

Tightening reference torque　　580N･m + 90°　　Unit　N･m

Spindle tightening torque	R－1	R－2	R－3	R－4	R－5	R－6	R－7
Spindle tightening torque	L－1	L－2	L－3	L－4	L－5	L－6	L－7

Tightening Date：

※Look from the engine gear side L,R

Form-6-2：Main bolt tightening record

Tightener：________________________

Tightening Date：

Connecting rod volt

Tightening reference torque 196N・m + 90°

Cylinder No.	R						L					
	1－1	2－1	3－1	4－1	5－1	6－1	1－1	2－1	3－1	4－1	5－1	6－1
Crank pin bolt tightening torque												
Cylinder No.	1－1	2－1	3－1	4－1	5－1	6－1	1－1	2－1	3－1	4－1	5－1	6－1
Crank pin bolt tightening torque												
Cylinder No.	1－1	2－1	3－1	4－1	5－1	6－1	1－1	2－1	3－1	4－1	5－1	6－1
Crank pin bolt tightening torque												
Cylinder No.	1－1	2－1	3－1	4－1	5－1	6－1	1－1	2－1	3－1	4－1	5－1	6－1
Crank pin bolt tightening torque												

Form-7-1：Piston measurement record

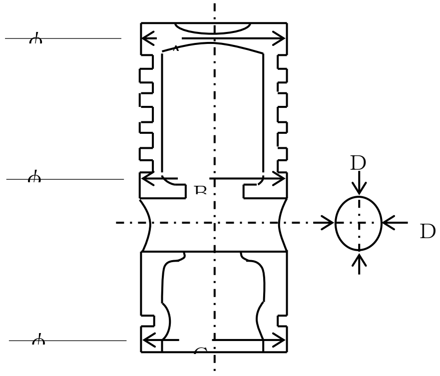
Measurer：

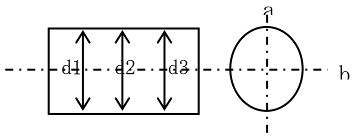
Measurement Date：

C　　：Standard dimensions

D1,D2：Standard dimensions　　Usage limitt　　Unit 1/100 ㎜

Measurement point			No.	R						L					
				1	2	3	4	5	6	1	2	3	4	5	6
Piston outer shape	A	Direction of rotation													
		Axial rotation													
	B	Direction of rotation													
		Axial rotation													
	C	Direction of rotation													
		Axial rotation													
Piston pin Outer shape	d1	a/b													
	d2	a/b													
	d3	a/b													
Piston boss Inner diameter	D1	F(H)Side													
		F(H)Side													
	D2	F(H)Side													
		F(H)Side													
Piston pin metal inner diameter	d	H	UP to Down												
			rotation												
		G	UP to Down												
			rotation												





d1,d2,d3：Standard dimensions	68.000
d1,d2,d3：Gap limit	67.944

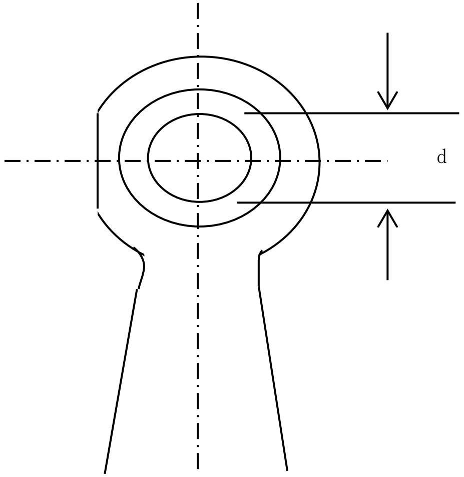
Form-7-2：Piston measurement record

Measurer：

Measurement Date：

Unit 1/100 ㎜

Measurement point	Ring No.	Reference value	Repair limit	R1	R2	R3	R4	R5	R6	L1	L2	L3	L4	L5	L6
Piston ring abutment section gap	1														
	2														
	3														
	Oil														
Piston ring groove gap	1														
	2														
	3														
	Oil														



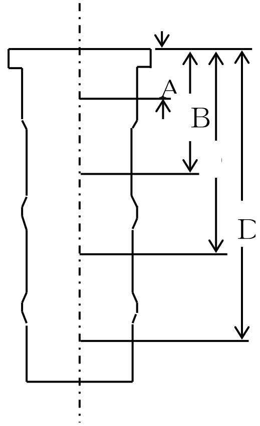
d…Standard dimensions	68.030
d…Usage	68.049

Form-8 ：Cylinder liner measurement record [6DK-26]

Measurer :

Measurement Date：

Cylinder No. Measurement point		1	2	3	4	5	6	7	8
A (60)	Axial rotation								
	Direction of rotation								
	Uneven wear								
B (9500)	Axial rotation								
	Direction of rotation								
	Uneven wear								
C (24500)	Axial rotation								
	Direction of rotation								
	Uneven wear								
D (39000)	Axial rotation								
	Direction of rotation								
	Uneven wear								



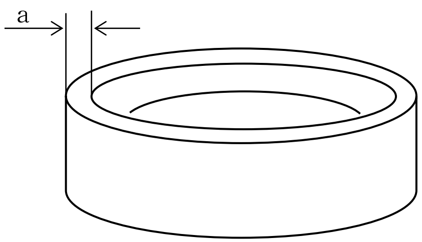
A.B.C.D. Dimensions use the equipment attached to the engine

Standard dimensions	2000
Wear limit	30
Uneven Wear limit	100

Protecting ring thickness measurement

Unit 1/100 ㎜

Nominal dimensions	a	870
Exchange limit	-	25 (845)



1	2	3	4	5	6	7	8
+	+	+	+	+	+	+	+

Form-9：Cam metal and Gear measurement record

Measurer：

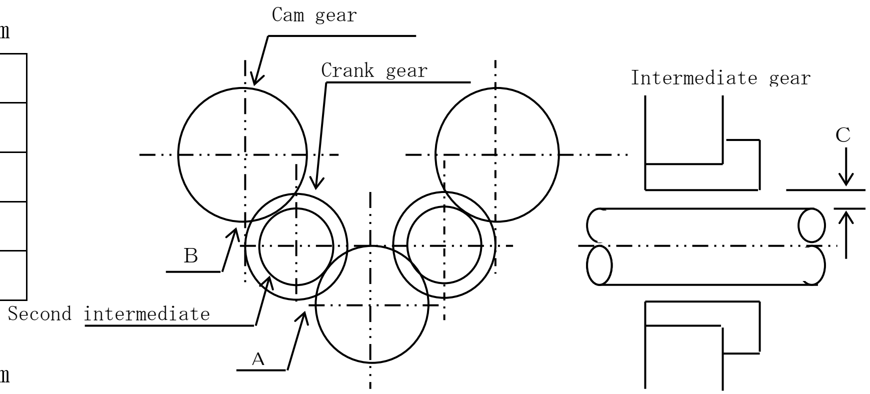
Measurement Date：

Cam metal gap Standard 4～12 Repair limit 20 Unit 1/100 ㎜

		1	2	3	4	5	6	7	8	9	10
Cam metal gap	Before Dismantling H/G										
	After Dismantling H/G										

Bush gap Unit 1/100 ㎜

Measured value Gear name	Symbol	Reference value	Repair limit	Measurement	
				L	R
(1)Middle gear	C	3～15	25		
(2)					
(3)					



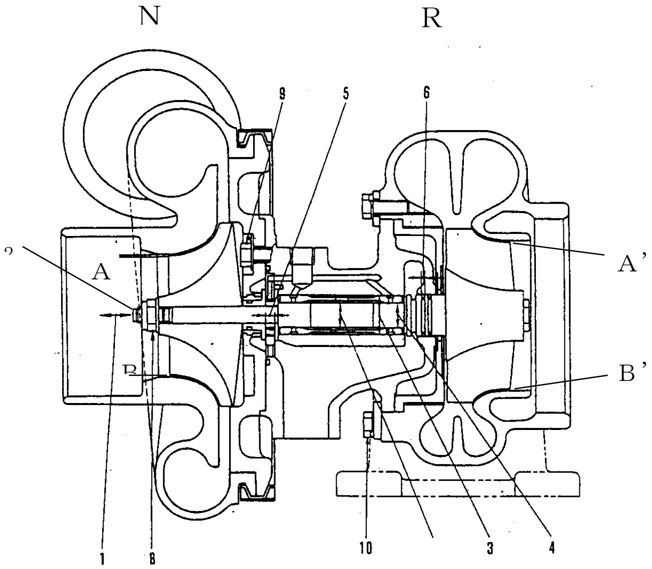
Back space measurement table Unit 1/100 ㎜

Measured value Gear name	Symbol	Reference value	Repair limit	Measurement	
				L	R
(1)Crank gear and first intermediate gear	A	20～30	50		
(2) Second intermediate gear and cam gear	B	20～30	50		
(3) LO pump drive gear and LO pump gear	—	20～30	50		
(4) Governor drive gear and governor gear	—	20～30	50		
(5) Fuel valve cooling drive gear and governor gear	—	20～30	50		
(6) Valve lubricating oil pump drive gear and pump gear	—				
(7)Cooling water pump gear	—	20～30	50		

Form-10：Turbocharger measurement record

Measurer：

Measurement Date：



Bearing, thrust bearing replacement time 20000～30000 hour

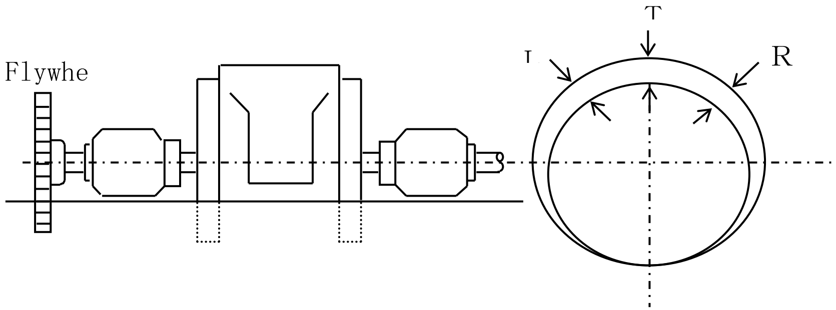
Bearing, thrust bearing usage time ( ) hour

Unit ㎜

Symbol	Measured value Measurement point	Reference value	Measured value	
			Before Dismantling	After Dismantling
1	Axial clearance measurement (axial direction)	0.1～0.18		
2	Radial clearance measurement	0.62～1.35		
A,B	Measurement of clearance between casing and wing (N side) (A + B ÷ 2)	0.28～0.68		
	Measurement of clearance between casing and wing (R side) (A '+ B' ÷ 2)	0.58～0.91		

Form-11 ：Generator measurement record

Measurer：____________________



		Flywheel side		Exciter side	
Standard gap	$D=\frac{1\sim1.5}{1000}$	(20	～ 30)	(16	～ 24)
Gap limit	$D=\frac{1.5}{1000}+10$	(40)		(34)	

Bearing metal gap

Unit 1/100 ㎜

		Flywheel side		Exciter side	
		H	G	H	G
Bearing metal gap	L				
	T				
	R				

Measurement Date：

Measurement Date：

※Shaft diameter	Flywheel side Shaft diameter	20000
	Exciter side Shaft diameter	16000

Form-15-1：Generator load test record Part 1 (Before inspection)

Measurer：

Measurement Date： Weather：

	Load (kW)	Voltage (V)	Current(A)			Frequency (Hz)	Power factor (%)	Electricity Meter Reading	Electric Energy (kWh)	Temperature (℃)								
										Stator winding			Duct		Bearing		Indoor Temp.	Outdoor Temp.
			R	S	T					R(U)	S(V)	T(W)	Suction	Discharging	No.1	No.2		
Management value Check	600	11000 ±5%	109	109	109	50 ±0.3%	100～80	—	—	120	120	120	—	—	85	85	—	—

Remark	

Form-15-2：Generator load test record Part 1 (After inspection)

Measurer：

Measurement Date：

Weather：

	Load (kW)	Voltage (V)	Current(A)			Frequency (Hz)	Power factor (%)	Electricity Meter Reading	Electric Energy (kWh)	Temperature (℃)								
			R	S	T					Stator winding			Duct		Bearing		Indoor Temp.	Outdoor Temp.
										R(U)	S(V)	T(W)	Suction	Discharging	No.1	No.2		
Management value Check	600	11000 ±5%	109	109	109	50 ±0.3%	100～80	—	—	120	120	120	—	—	85	85	—	—
Remarks																		

Form-16-1：Engine load test record Part 2 (Before inspection)

Measurer：________________

Measurement Date： Weather：

	Load (kW)	Rotational Speed (min^{-1})	Governor Pointer Handle/ GL	Fuel Consumption			Pressure (MPa)							Cylinder maximum explosion pressure (MPa) / Fuel pump rack scale								
				Flowmeter		Consumption rate (L/kWh)	Fuel	Lubricant			Primary water	Secondary water	Fuel valve cooling oil	1	2	3	4	5	6	7	8	Average
				reading	Consumption (L)			Turbocharger inlet	Engine inlet	Valve oiling												
Management value Check	600	750	— / 7.4	—	—	—	0.216	0.378	0.35	—	0.15	0.1	—	15.7 / —	15.7 / —	15.7 / —	15.7 / —	15.7 / —	15.7 / —	15.7 / —	15.7 / —	—
Time																						
Remark																						

Form-16-2　: Engine load test record Part 2 (After inspection)

Measurer :

Measurement Date :　　Weather :

	Load (kW)	Rotational Speed (min^{-1})	Governor Pointer Handle/ GL	Fuel Consumption			Pressure (MPa)							Cylinder maximum explosion pressure (MPa) / Fuel pump rack scale								
				Flowmeter		Consumption rate (L/kWh)	Fuel	Lubricant			Primary water	Secondary water	Fuel valve cooling oil	1	2	3	4	5	6	7	8	Average
				reading	Consumption (L)			Turbocharger inlet	Engine inret	Valve oiling												
Management value Check	600	750	— 7.4	—	—	—	0.216	0.378	0.35	—	0.15	0.1	—	15.7 / —	15.7 / —	15.7 / —	15.7 / —	15.7 / —	15.7 / —	15.7 / —	15.7 / —	—
Time																						
Remarks																						

Form-17-1 ：Engine load test record Part 3 (Before inspection)

Measurer：

Measurement Date： Weather：

	Load (kW)	Fuel oil (℃) FQ / Eng	Primary water (℃)		Secondary water (℃)			Lubricant (℃)		Intake air (℃)			Valve cooling oil (℃) In / Out	Engine coolant outlet (℃)								
			Engine In / Out	Water cooler In / Out	Air Cooler In / Out	Lubricant Cooler In / Out	Water cooler In / Out	Engine In / Out	Cooler In / Out	Turbocharger inlet	Engine inret	Valve oiling		1	2	3	4	5	6	7	8	Average
Management value Check	600	— / —	85 / 85	85 / 85	55 / 55	55 / 55	55 / 55	— / —	— / 65	—	—	—		85	85	85	85	85	85	85	85	85
Time																						
Remarks																						

Form-17-2 ：Engine load test record Part 3 (After inspection)

Measurer :

Measurement Date :　　　Weather :

	Load (kW)	Fuel oil (℃) FQ / Eng	Primary water (℃)		Secondary water (℃)			Lubricant (℃)		Intake air (℃)			Valve cooling oil (℃) In / Out	Engine coolant outlet (℃)								
			Engine In / Out	Water cooler In / Out	Air Cooler In / Out	Lubricant Cooler In / Out	Water cooler In / Out	Engine In / Out	Cooler In / Out	Turbocharger inlet	Engine inret	Valve oiling		1	2	3	4	5	6	7	8	Average
Management value Check	600	— / —	85 / 85	85 / 85	55 / 55	55 / 55	55 / 55	— / —	— / 65	—	—	—		85	85	85	85	85	85	85	85	85
Time																						
Remarks																						

Form-18-1：Engine load test record Part 4 (Before inspection)

Measurer：

Measurement Date： Weather：

Time	Load (kW)	Cylinder outlet exhaust temperature (℃)									Turbocharger							
											Number of rotations (min^{-1})	Air pressure		Exhaust pressure		Exhaust pressure temperature (℃)		
		1	2	3	4	5	6	7	8	Average		Gage (MPa)	Mercury column (hPa)	In (hPa)	Out (kPa)	In		Out
																(Upper)	(Under)	
Management value Check	600	500	500	500	500	500	500	500	500	—	48850	—	—	—	—	500		500
Time																		
Remarks																		

Form-18-2：Engine load test record Part 4 (After inspection)

Measurer：

Measurement Date：　　Weather：

Time	Load (kW)	Cylinder outlet exhaust temperature (℃)									Turbocharger							
											Number of rotations (min^{-1})	Air pressure		Exhaust pressure		Exhaust pressure temperature (℃)		
		1	2	3	4	5	6	7	8	Average		Gage (MPa)	Mercury column (hPa)	In (hPa)	Out (kPa)	In		Out
																(Upper)	(Under)	
Management value Check	600	500	500	500	500	500	500	500	500	—	48850	—	—	—	—	500		500
Time																		
Remarks																		

Form-20 : Load rejection test record (After inspection)

Measurer : ______________________

Date :　　　　　　　　　Weather :　　　　Temp　　　Outside　℃　Inside　℃

Test number				Management value	1	2	3	4	Remarks
Shutoff time				—					
Generater	Shut off time		(kW)	—					
	Voltage	Before shutting off	(V)	6600±5%					
		Max	(V)	—					
		After stabilization	(V)	25%or less					
	Frequency	Before shutting off	(Hz)	60±0.3Hz					
		Max	(Hz)	—					
		After stabilization	(Hz)	—					
Engine	**Rotational speed**	Before shut off	(min^{-1})	900					
		Max	(min^{-1})	—					
		Before shutting off	(min^{-1})	—					
		Rate of change (%)	Gauge	10%or less					
			Oscilloscope	—					
		Settling rate (%)	Gauge	3%or less					
			Oscilloscope	—					
	Governor Pointer	Before shut off		—					
		Minimum(Max)		—					
		After stabilization		—					
		Closing time(sec)		—					
		Recovery time(sec)		—					

In the case of hydraulic governor
- ■Droop
- ■Compensation adjustment pointer
- ■Needle valve opening
- ■Load limit

Startup test

Date :

Unit : MPa

Inside Temp.		℃	Start count	Before Start up Air tank press.	After Start up Air tank press.	Start up OK or NG	Remarks
Outside Temp.		℃	1				
Primary cooling water Temp.		℃	2				
Secondary cooling water Temp.		℃	3				
Lubricant oil Temp.		℃	4				
Starting air tank capacity	600	L	5				

※5 times confirmed by automatic start

Bearing temperature

Date	
Continuous	750kW Running
Measuring instrument	Non-contact type thermometer (Type PI-3LF)
Lubricant Temp.	L.O.cooler outlet temperature before engine stop :　℃

Management value :　85　℃

Item \ Cylinder		1	2	3	4	5	6	7	8	9
Main Bearing										
Crank pin metal	L									
	R								—	—
Piston pin metal	L									
	R							—	—	—

Form-21 : Protective device operation test record(After inspection)

Measurer : ____________________

Name		Reference value	Adjusted value		Result	
			Operating value	Adjusted value	Operating conditions	Remarks
Lubricant pressure drop	63Q2	0.3MPa less than				
Over speed	12	1035min^{-1}				
Emergency stop 2	5E2	Push Button				
Emergency stop 1	5E1	Push Button				
Low speed	14	855min^{-1}				
Startup failure	48	10sec				
Turbocharger lubricating oil pressure drop	63QT	0.15MPa or less				
Primary cooling water outlet temperature rise	26WJ2	90℃ or more				
Secondly cooling water outlet temperature rise	26WC2	60℃ or more				
Primary cooling water disconnection	69WJL	23.5 m^3/h or less				
Secondary cooling water disconnection	69WCL	23.5 m^3/h or less				
Generator stator winding temperature rise	26S2	130℃ or More				
Over voltage		130Ｖ				
Generator bearing overheating	38G2	95℃ or more				
Turbocharger lubricating oil pressure drop	63QT	0.15MPa or less				
Over current	51	5Ａ				
Reverse power	67	40Ｗ				
Turbocharger lubricating oil temperature drop	26G2	550℃ or more				
Primary cooling water outlet temperature rise	26WJ1	85℃ or more				
Secondly cooling water outlet temperature rise	26WC1	55℃ or more				
Generator bearing temperature rise	38G2	95℃ or more				

Name		Reference value	Adjusted value		Result	
			Operating value	Adjusted value	Operating conditions	Remarks
Primary cooling water pressure drop	63WJL	0.15MPa or less				
Secondly cooling water pressure drop	63WCL	0.1MPa or less				
Lubricant temperature rise	26Q	65℃ or more				
Bearing lubricant pressure drop	63Q1	0.35MPa or less				
CTC filter error	63QF	0.2MPa or more				
Turbocharger outlet exhaust gas temperature rise	26G1	500℃ or more				
Lubricant filter differential pressure rise	63QD	0.09MPa or more				
Turbocharger Lubricating oil filter differential pressure rise	63QTD	0.06MPa or more				
Control air pressure drop	63C	0.65MPa or less				
Generator stator winding temperature rise	26S1	120℃ or more				
Generator bearing temperature rise	38G1	85℃ or more				
Load limit	77	110％ or more				
Lubricant oil sump tank oil level abnormal	33Q	Operate at upper limit and lower limit				
Engine vibration abnormal	V S	Operates with Abnormal vibration				
Engine main bearing temperature rise	38E	85℃ or more				
Fuel oil leak	33HF	Operate with rising value				
Pure water expansion tank water level abnormal	33W1	Operate at upper limit and lower limit				
Diesel fuel oil service tank oil level	33F1	Operate at More upper limit and lower limit				
Air tank pressure drop	63AL	1.77MPa or less				

Form-22 : Vibration measurement record(After inspection)

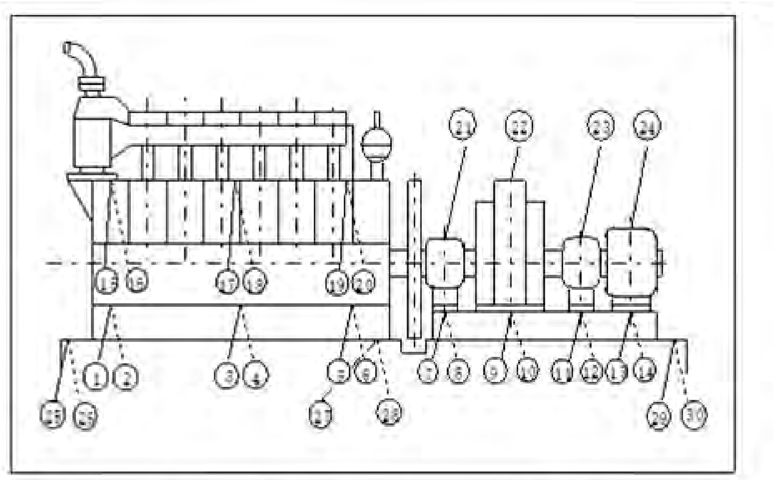
Measurer :

Measurement Date :

Measuring instrument :

No.	Measuring points	Measured value		No.	Measuring points	Measured value		Remarks
		Vertical	Horizontally			Vertical	Horizontally	
1	Engine base plate			16	Upper part of frame			
2	Engine base plate			17	Upper part of frame			
3	Engine base plate			18	Upper part of frame			
4	Engine base plate			19	Upper part of frame			
5	Engine base plate			20	Upper part of frame			
6	Engine base plate			21	Generator bearing upper E side			
7	Generator base plate			22	Generator top			
8	Generator base plate			23	Generator bearing upper part			
9	Generator base plate			24	Exciter top			
10	Generator base plate			25	Power plant basics			
11	Generator base plate			26	Power plant basics			
12	Generator base plate			27	Power plant basics			
13	Generator base plate			28	Power plant basics			
14	Generator base plate			29	Power plant basics			
15	Upper part of frame			30	Power plant basics			

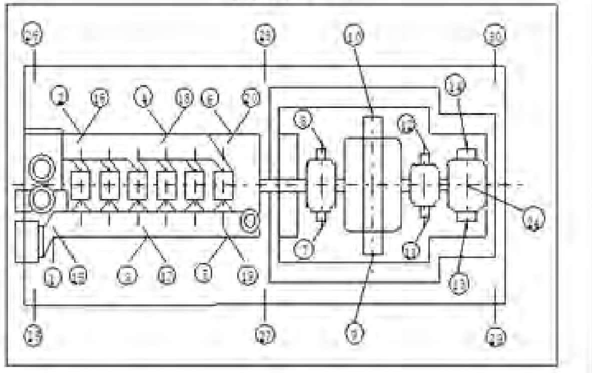
Side view



※ Reference value : Upper of frame 150/1000 ㎜

Base foundation bolt 30/1000 ㎜

Plan view



※ Fill in the plan and side view after the test

Maintenance of diesel generators (Electrical)
ATTACHMENT INDEX

1. Generator & Exciter Inspection

2. Confirmation of switchboard interior/exterior condition

3. Protective device operation test

4. Circuit Breaker Inspection

5. Meter calibration test
   - 5.1 Wattmeter
   - 5.2 Power factor meter
   - 5.3 Ammeter
   - 5.4 Voltmeter
   - 5.5 Tachometer
   - 5.6 Integrating wattmeter
   - 5.7 Timer test

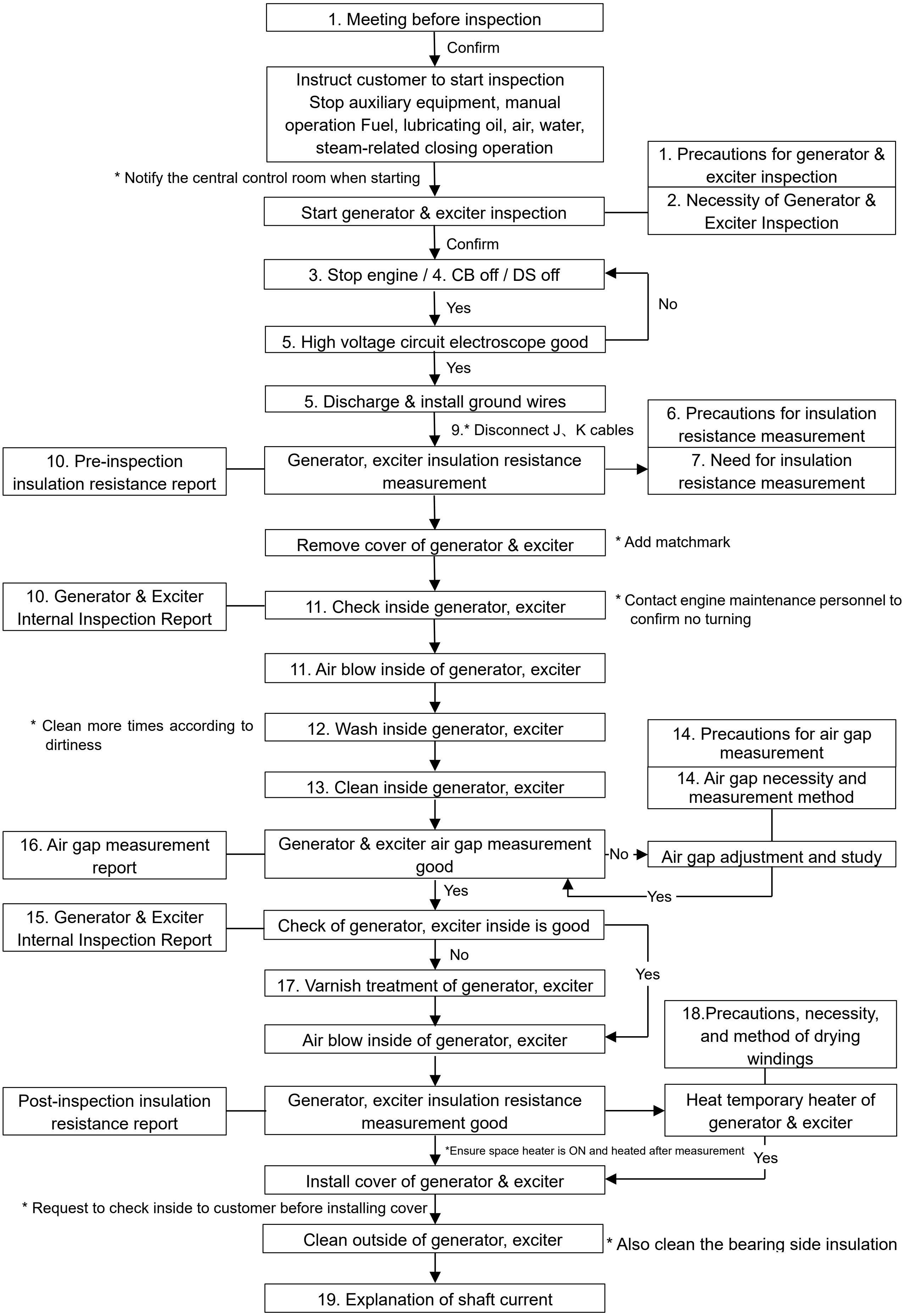
6. Battery storage system

7. Switchboard and auxiliary equipment inspection

8. Instrumentation
   - 8.1 Test report
   - 8.2 Measurement device list
   - 8.3 Road tool list
   - 8.4 Pressure gauge inspection
   - 8.5 Pressure switch inspection
   - 8.6 Pressure transmitter inspection
   - 8.7 Flow switch inspection
   - 8.8 Temperature switch inspection
   - 8.9 Digital panel meters inspection
   - 8.10 Resistance temperature detector (RTD) inspection
   - 8.11 Thermocouple inspection
   - 8.12 Oil mist concentration meter disassembly inspection
   - 8.13 Loop test

9. Test run

1. Generator & Exciter Inspection

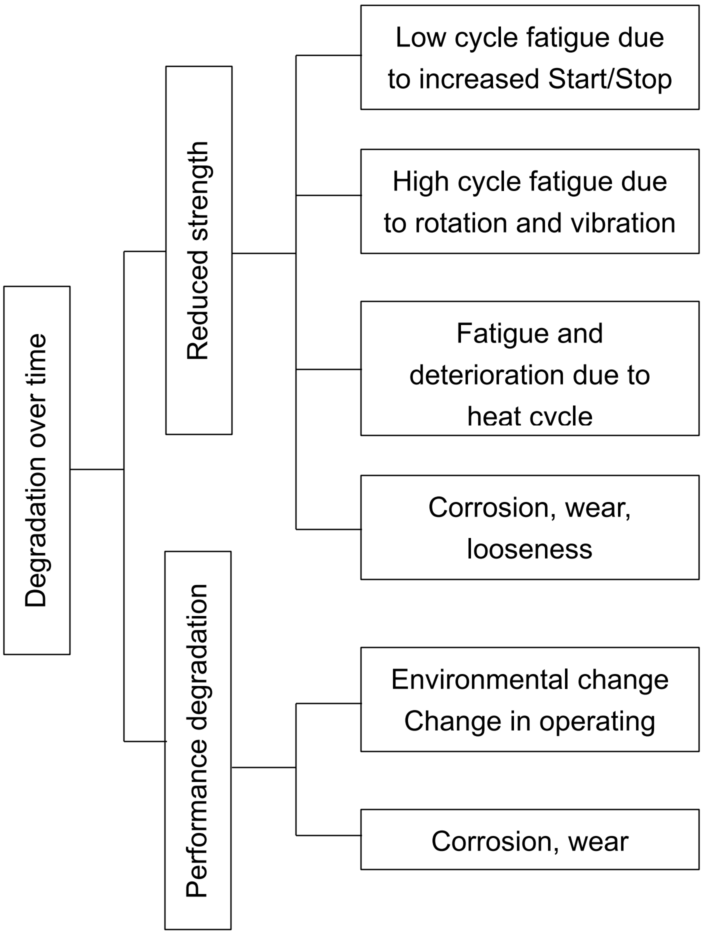


1. Precautions for Generator & Exciter Inspection

1. Sufficiently alert people in the area so as not to turn, etc.
2. Attach operation prohibited tags, etc. to the turning device.
3. Bear in mind to work so that people, tools, and materials can be pulled out even if turning is performed incorrectly.
4. Take extreme care so as not to scratch the insulation with tools or materials.
5. When checking the inside of the generator and exciter, use proper lighting etc. so as not to miss small internal trouble, etc.
6. When resting and completing the work, check the number of tools, materials, and workers so that they are not left as foreign objects.
7. When work ends each day, cover with sheets, etc. so that foreign matter and moisture do not enter.

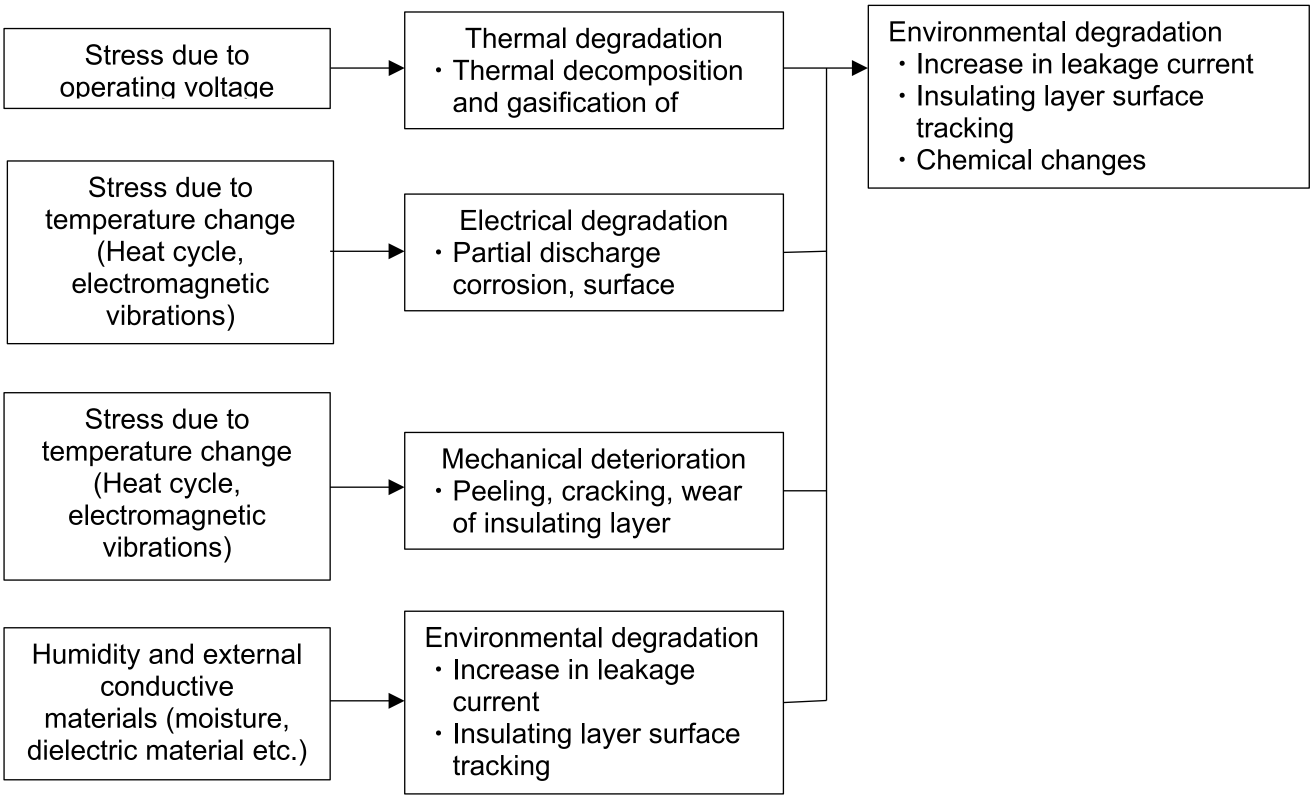
2. Necessity of Generator & Exciter Inspection

If the generator and exciter are used for a long time, the possibility that the following trouble w will increase, and responding to trouble will be costly in terms of both money and time. In order to prevent such trouble from occurring, it is also necessary to carry out periodic inspect by collecting data at the time of inspection and comparing the transitions, predicting trouble, an preventive measures, the life of the generator and exciter can be extended.



- Breaking of shaft material
- Breaking of retaining ring for rotor coil end Rotor
- Breaking and deformation of rotor coil
- Terminal stud damage
- Rotor coil interphase short circuit, ground fault
- Excessive shaft vibration
- Collector ring damage
- Rotor surface damage
- Burnout and damage of the stator core end
- Stator coil insulation damage
- Stator coil end insulation damage
- Stator coil interphase cross-over copper band damage
- Damaged stator coil water cooled parts
- Bearing burnout
- Degradation of cooler performance

Factors of insulation deterioration



Stress due to operating voltage

Stress due to temperature change (Heat cycle, electromagnetic vibrations)

Stress due to temperature change (Heat cycle, electromagnetic vibrations)

Humidity and external conductive materials (moisture, dielectric material etc.)

Thermal degradation
- Thermal decomposition and gasification of

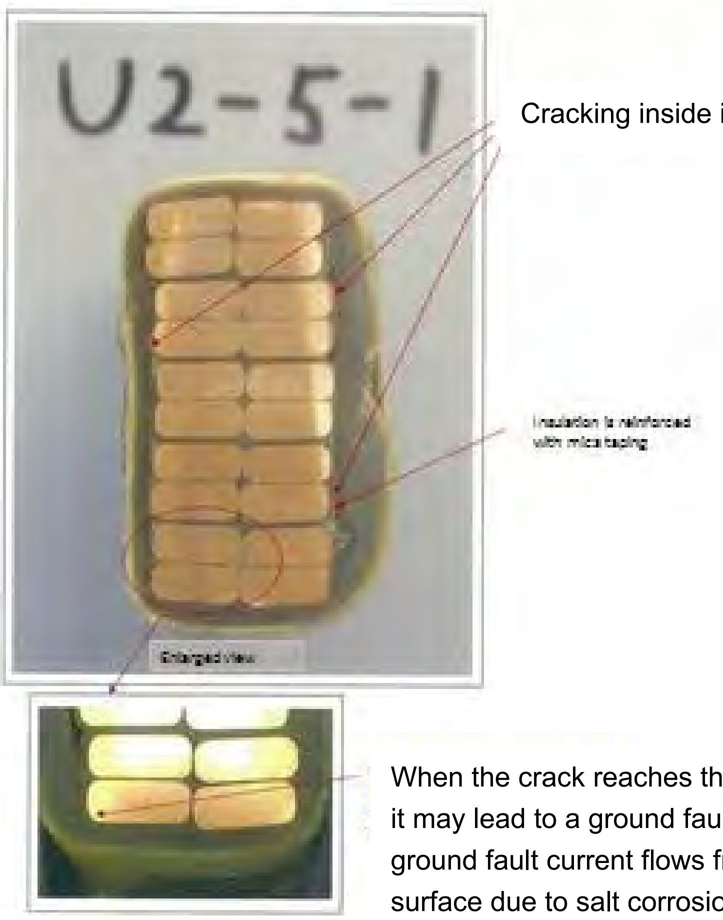
Electrical degradation
- Partial discharge corrosion, surface

Mechanical deterioration
- Peeling, cracking, wear of insulating layer

Environmental degradation
- Increase in leakage current
- Insulating layer surface tracking

Environmental degradation
- Increase in leakage current
- Insulating layer surface tracking
- Chemical changes

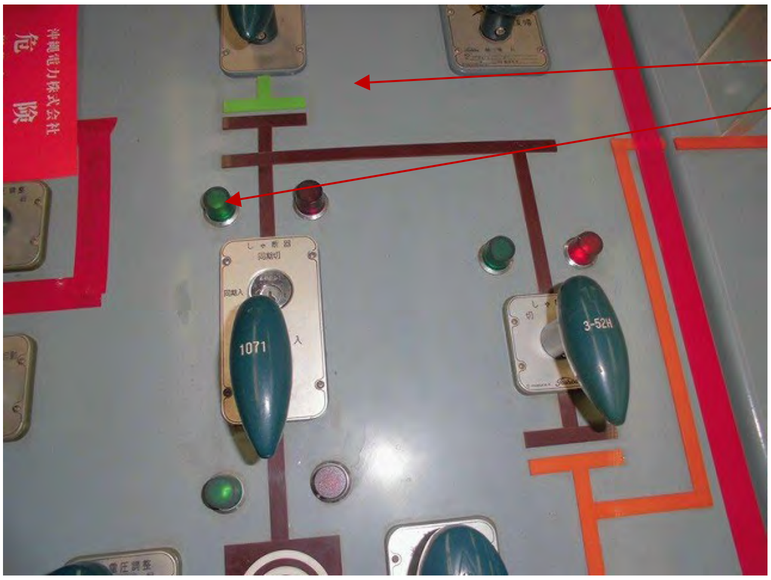
Stator winding cross section (crack)

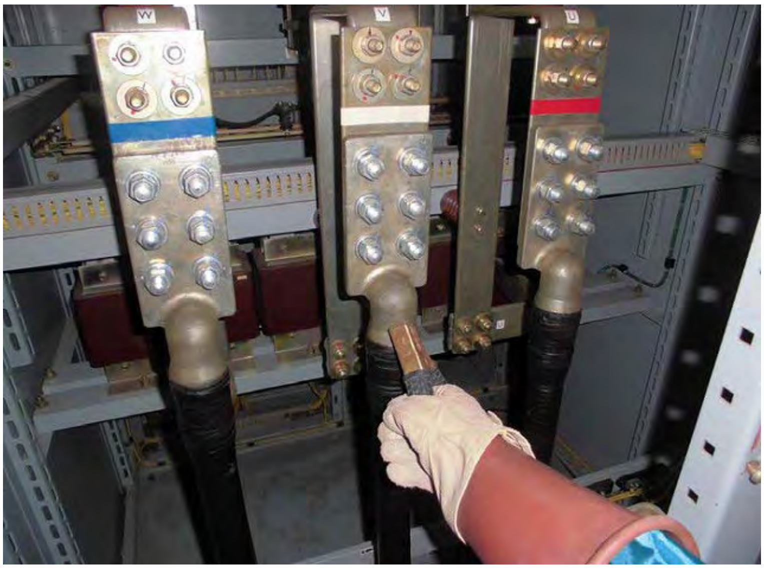


Cracking inside insulation

When the crack reaches the surface, it may lead to a ground fault where ground fault current flows from the surface due to salt corrosion, mist,

	3. Engine STOP Picture ● Generator control panel ● Start lock indication ● Start switch Red tagged ● Generator circuit breaker OFF indication
	● Start lock indication
	● Start switch Red tagged

	4. CB OFF Picture ● Generator control panel ● Generator circuit breaker OFF indication
	● Generator circuit breaker DISCONNECT position
	● Generator circuit breaker OFF

	5. Generator electroscope grounding picture Electroscoping
	▪ Discharging after inspection
	▪ Ground wire installation after discharge

6. Precautions for insulation resistance measurement

1. Confirm the circuit of the measurement point on drawings,etc.
2. Before measuring, electroscope the circuit and make sure thatit is not energized.
3. Use measuring instruments suitable for the circuit.
4. Check whether you will touch the circuit when measuring.
5. Confirm that weak electric circuits are disconnected from the circuit to be measured.
6. Due to the possibility of the exciter diode breaking, bypass the primary and secondary to avoid voltage difference to measure.
7. After measurement, connect to ground and discharge.

7. Need for insulation resistance measurement

Measure the insulation resistance of the stator and field winding periodically. The temperature of the winding shall be recorded along with the resistance reading. Since the decline of the insulation resistance meter is a danger signal for insulation, compare it with the previous measurement result when insulation resistance is measured. For comparison, it is more convenient to measure when the applied voltage and temperature and the application time are the same. It is recommended that insulation resistance be measured in a state where the winding is still warm immediately after the engine has been stopped and relatively not absorbing heat.

Winding resistance measurements are resistance to leakage currents flowing through and across the winding insulation when a certain amount of DC voltage is applied.

Although this value depends on the moisture content of the winding, dustiness, and the condition of the insulating material and is not a measure of the insulation strength, it indicates whether the machine is in good condition to operate or if a voltage test can be performed on it. By measuring the insulation resistance periodically, it is possible to detect insulation abnormalities and prevent failures beforehand.

Insulation resistance changes drastically if the temperature, humidity, presence of dust, the applied voltage and the time it is applied, etc. change.

Measurements that seem contradicting can also be explained well in light of these factors.

Therefore, when insulation resistance is measured, it is desirable to keep the temperature, voltage applied, and application time constant at all times, and if this is impossible, these values shall be recorded along with the resistance measurement values.

8. Insulation resistance report

Insulation measurement report (DEG #   )

	Inspection date	Weather	Temp.	Humidity	Measurer
Inspection					

Instrument specification	Model	Rating	Serial No.	Year built	Manufacturer
Insulation tester					

a. High-voltage circuit **(Unit: MΩ)**

Generator circuit breaker panel (A)			Generator board + cable (B)		
Before Inspection	U		Before Inspection	U	
	V			V	
	W			W	
After Inspection	U		After Inspection	U	
	V			V	
	W			W	

b. Low voltage circuit **(Unit: MΩ)**

	Generator rotor
Before Inspection	
After Inspection	

c. Low voltage circuit (J, K) (Unit: MΩ)

	Exciter stator
Before Inspection	
After Inspection	

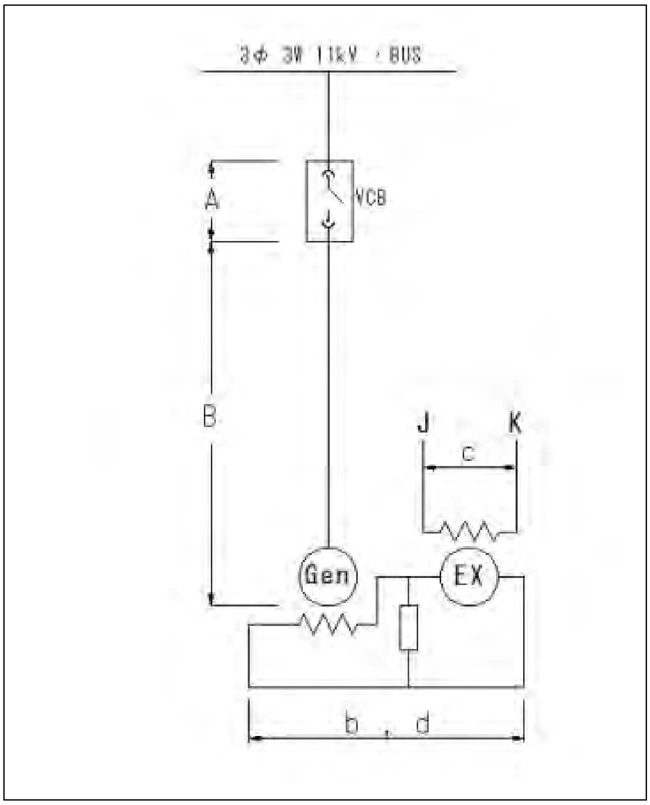
d. Low voltage circuit **(Unit: MΩ)**

	Exciter rotor
Before Inspection	
After Inspection	

e. Result

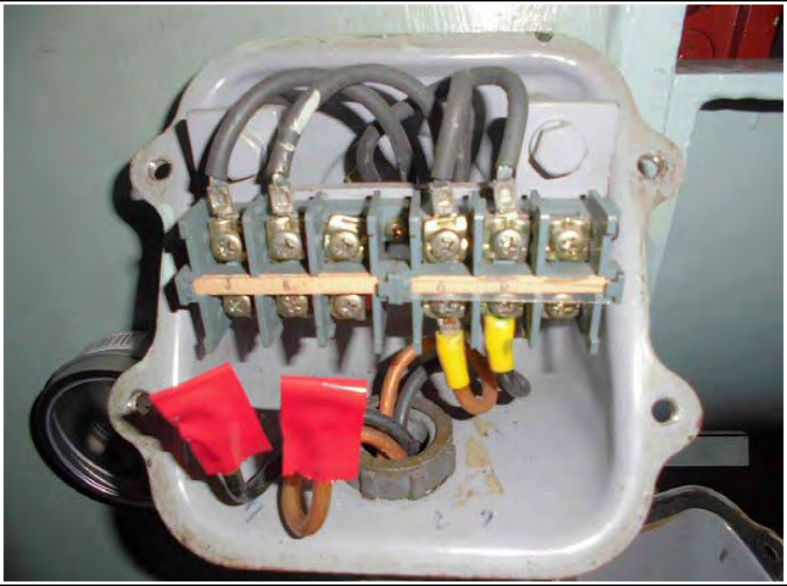
General evaluation	**Good**

Circuit Diagram



Notes : ……………………………………………………………………………………………………

………

	9. Insulation resistance J, K picture · Exciter panel side · High voltage circuit insulation resistance measurement
	Exciter side · J, K removal
	Exciter side · Low voltage circuit insulation resistance measurement

10. Generator & Exciter Internal Inspection Report

（１） Main specifications of diesel generator

Name :			
Model :			
Current :	A	Voltage :	V
Frequency :	HZ	No. of poles :	P
Output :	kVA	Power factor :	%
Field current :	A	Excitation voltage :	V
Manufacturer :			
Production date :			
Serial No. :			

Exciter

Name :	Brushless exciter		
Model :			
Current :	A	Voltage :	V
Output :	kW	No. of poles :	P
Field current :	A	Excitation voltage :	V
Serial No. :			
Manufacturer :			
Production date :			

Engine model :

Inspection date	Weather	Temperature	Humidity	Inspector
Date: Y/ M/ D		℃	%	

(2) Stator & rotor

a. Degradation/withering of insulation · · · · · · · · · · · · · · · · · · · Good : Bad

ｂ． Presence of cracks · Good : Bad

c. Winding retainer fitting · Good : Bad

d. Check for clogging between lines due to foreign matter · · · · · · · · · · Good : Bad

e. Inspection of jump wires & lead wires · · · · · · · · · · · · · · · · · · Good : Bad

f. Coil end deformation · Good : Bad

g. Condition of iron core support & fasteners · · · · · · · · · · · · · · Good : Bad

h. Clogging of air duct · Good : Bad

Special Notes: 1) Wash with an electrical cleaning agent.

2) Air blow after wiping with rag.

3) Apply touch-up varnish coating.

(3) Lead terminal

a. Terminal tightness · Good : Bad

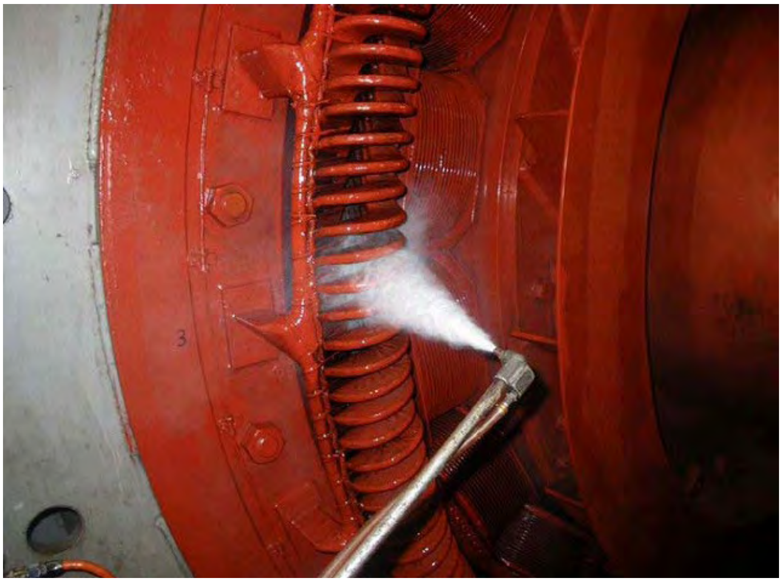
ｂ． Degradation/filthiness of insulator · · · · · · · · · · · · · · · · · · Good : Bad

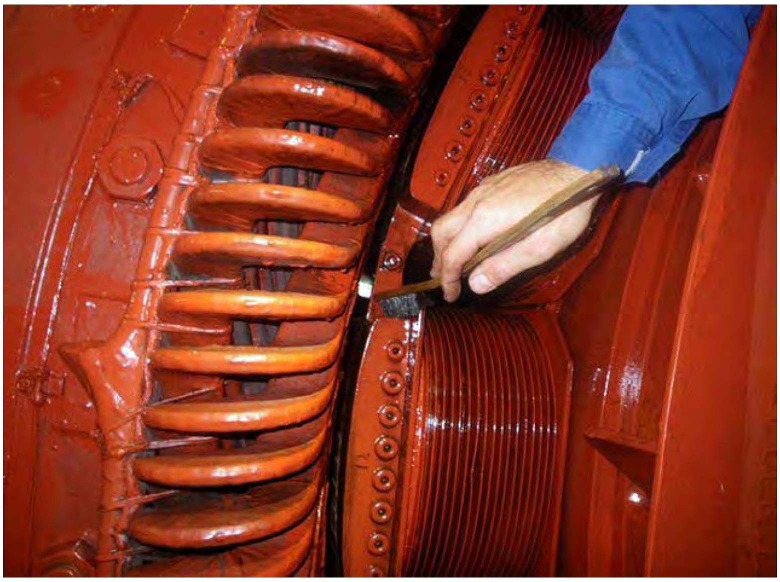
c. Crimp terminal, solder state · Good : Bad

ｄ． Taping status · Good : Bad

Special Notes: 1) Wipe clean with a rag using an electrical cleaning agent.

	11. Internal inspection Air blow picture ・Generator Checking inside 1
	・Generator Checking inside 2
	・Generator Air blow

	12. Generator Washing photo ▪ Washing with an electrical cleaning agent
	▪ Washing with an electrical cleaning agent
	▪ Washing with an electrical cleaning agent

	13. Generator Cleaning picture ▪ Cleaning inside 1
	▪ Cleaning inside 2
	▪ Cleaning inside 3

14. Precautions for air gap measurement

1. Sufficiently alert people in the area so as not to turn, etc.
2. Attach operation prohibited tags, etc. to the turning device.
3. Bear in mind to work so that even if turning is performed incorrectly, people and measuring instruments can be pulled out.
4. Since the measuring instrument is made of metal, etc., be careful not to scratch the insulator.
5. Confirm the number of workers, measuring instruments, etc. before and after so as not to leave as foreign matter.
6. If the air gap exceeds the standard value, inquire the manufacturer, etc. to correct it, and decide whether to continue use it and continue to monitor the bearing temperature, vibration, etc. during operation if use is continued.

15. Generator & Exciter Internal Inspection Report

（4） Exciter

a. Degradation, withering, cracking o· · · · · · · · · · · · · · · · · · Goo : Bad
b. State of winding · Goo : Bad
c. Inspection of jump wires & · Goo : Bad
d. Check for loose· Goo : Bad
e. Presence of shaking· Goo : Bad

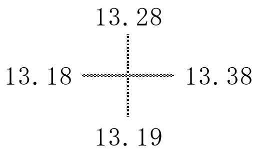
Special Notes: 1) Wash with an electrical cleaning agent.
2) Air blow after wiping with rag.
3) Apply touch-up varnish coating.

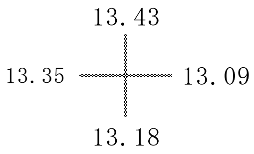
（5） Air gap measurement (Unit: mm)

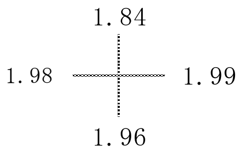
Inspection date	Weather	Temperat	Humidity	Inspector
Date: Y/ M/ D		℃	%	

Tolerance range = Difference between max value and min value is within ± 15% of the average value.

a. Direct connection side b. Opposite direct connection side c. Exciter side





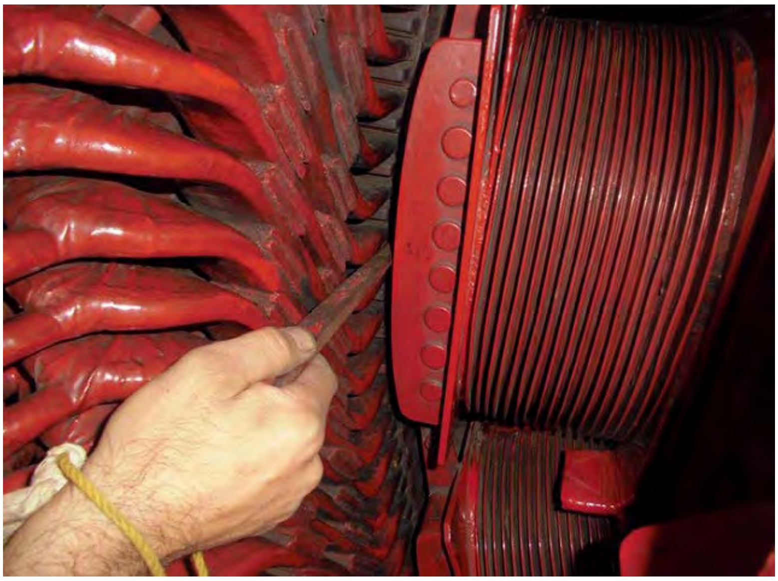
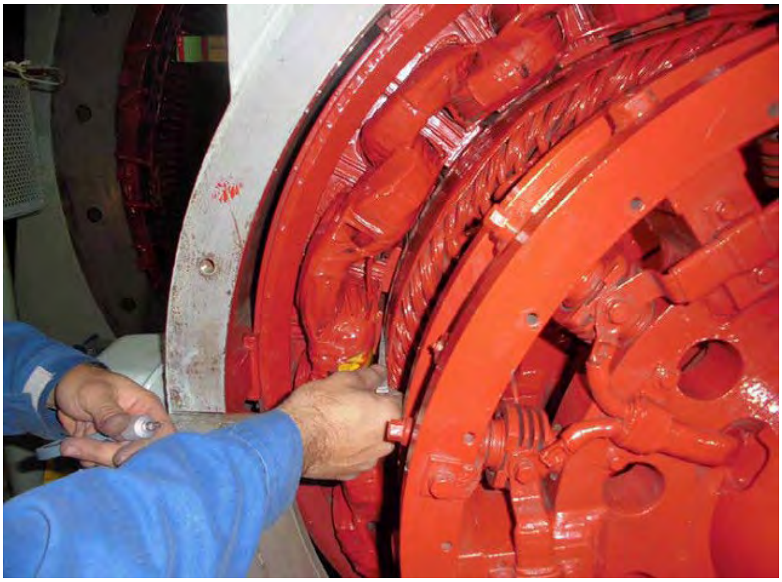


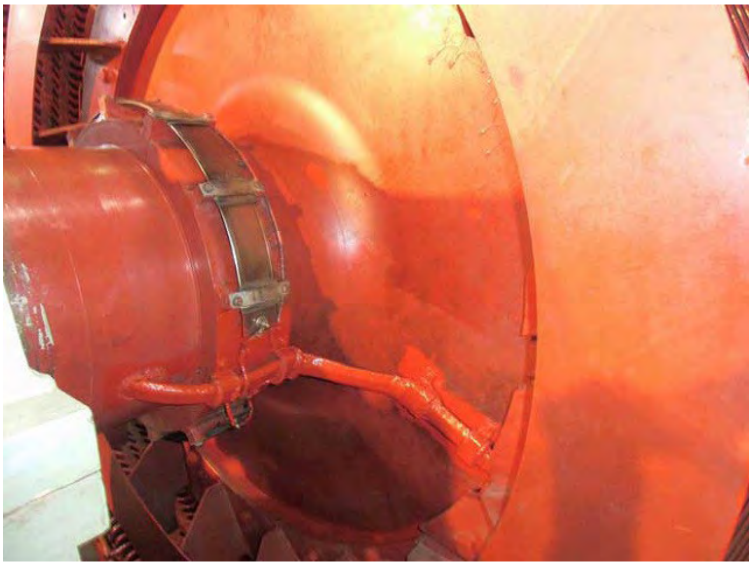
$$a = \frac{\text{x value - min val}}{\text{Avg value}} \times 100(\%) = \frac{13.38 - 13.18}{13.258} \times 100 = 1.51\ \%$$

$$b = \frac{13.43 - 13.09}{13.263} \times 100 = 2.56\ \% \qquad c = \frac{1.99 - 1.84}{1.943} \times 100 = 7.72\ \%$$

a. 1.51 %	b. 2.56 %	c. 7.72 %	Comprehensive judgment: Goo

SPECIAL INSTRUCTIONS:

	16. Air Gap picture ▪ Generator air gap Measurement
	▪ Generator air gap Measurement
	▪ Generator air gap Measurement

	17. Generator Varnish repair ・Exciter side varnish repair
	・Generator rotor varnish repair
	Generator stator lead terminal varnish repair. A spray type transparent varnish is used for parts not accessible by Bakelite board and brushes.

18. Precautions, necessity, and method of drying windings

1. Precautions for drying windings

① When drying windings, the temperature and current values are periodically checked depending on the drying method.

② Partially applying a temporary heater, etc. too much may lead to burnout, so be careful.

③ It is better to completely seal when heating, but you can open the moisture release port.

2. Necessity of drying windings

Normally it is dried by heat during operation, but during inspection, it is washed and cleaned with the space heater turned off, so moisture may be absorbed and the insulation may decrease. Therefore, the windings must be dried for test runs and normal operation.

Even during normal stop, it is necessary to always keep the windings dry with a space heater to prevent accidents.

3. Method of drying windings

If the insulation resistance of each phase shows a satisfactory value, and there is no evidence that the winding has absorbed moisture, drying is not necessary. However, if the armature and the field winding have absorbed moisture, and the insulation resistance is low, they must be dried.

There are several drying methods. Which method is used depends on the equipment that can be used.

(1) Using a space heater

This is the easiest method. This is the easiest way, if the space heater is equipped on the inner surface of both sides of the outer frame of the synchronous machine. When drying manually, adjust the space heater circuit so that the inside temperature is constantly kept a few degrees higher than room temperature.

(2) Method of passing electric current through windings

There is also a method of passing an appropriate amount of short-circuit current through the armature winding by short-circuiting the armature winding and rotating the synchronous machine to increase or decrease the field current.

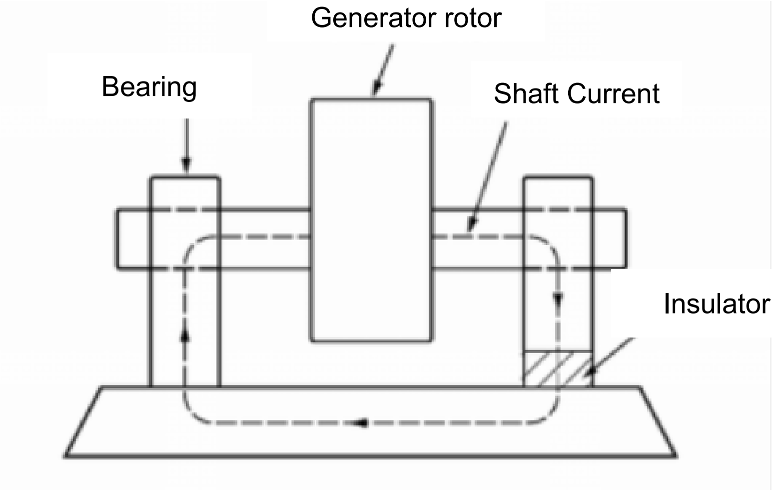
Regarding drying, start with low current and gradually increase the temperature of the stator and rotor windings to about 50℃. To measure the winding temperature, you can use an embedded thermometer or alcohol thermometer, and in some cases, the temperature can be determined from the change in resistance of the winding. Beware that the field current value does not exceed 1/3 of the field current value at full load near the sixth hour to prevent reaching the maximum temperature within 6 hours.

Insulation resistance initially declines rapidly as the winding is heated and begins to rise gradually as moisture is expelled, and in the end, it settles at a constant value.

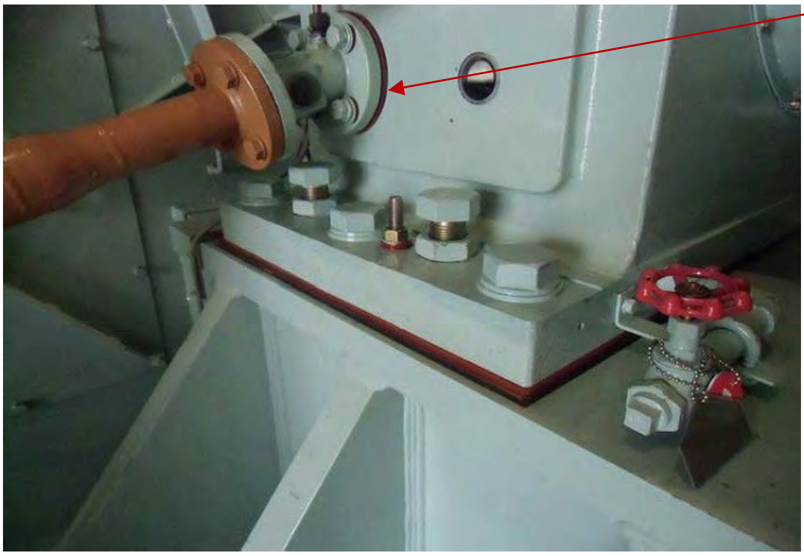
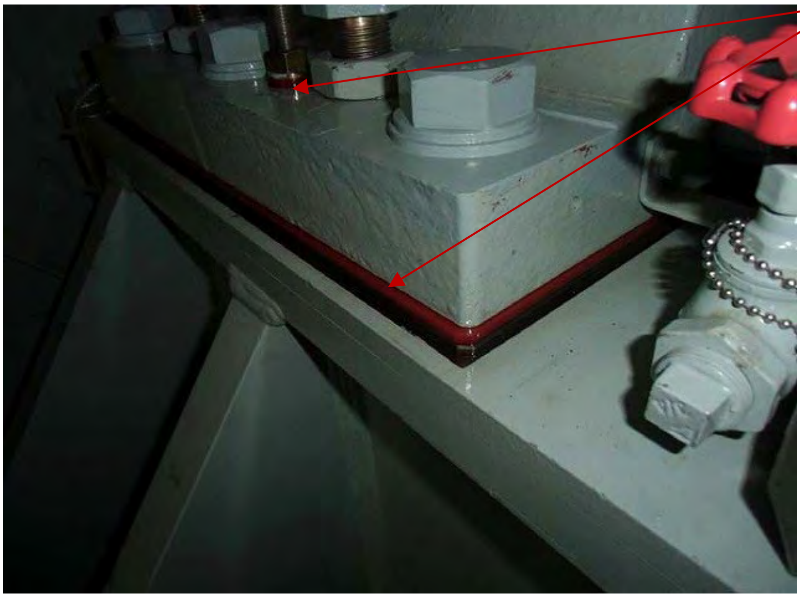
(3) Prepare a temporary heater (a warm air heater in particular is good) according to the size of the generator to heat the generator forcibly.

19. Explanation of shaft current

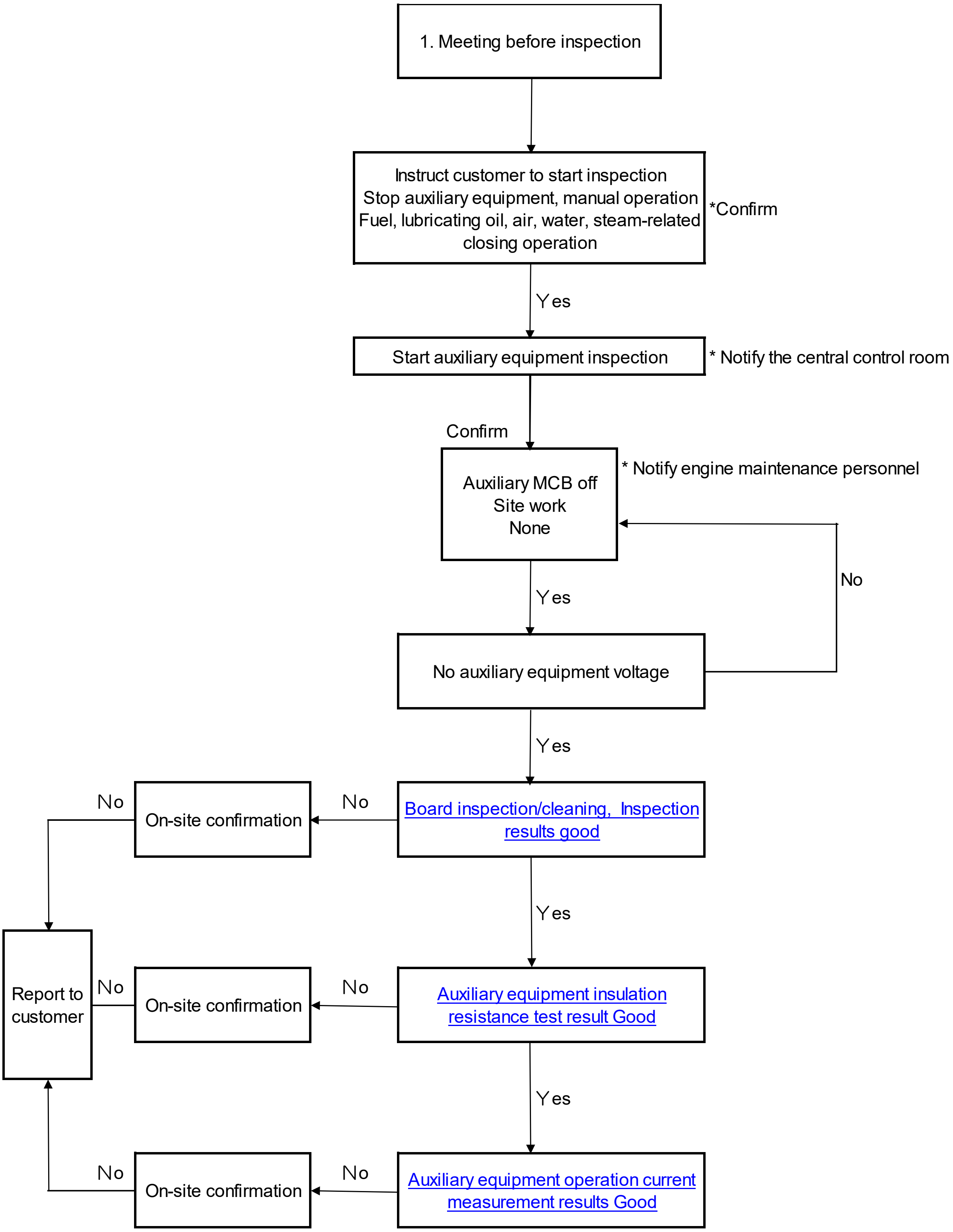
As shown in the figure, shaft current, the current flowing through the shaft of the generator rotor is several tens to several hundred amperes and may break the oil film on the bearing surface and damage the bearing surface and thus overheat and damage the bearings. In order to prevent this, an insulator is inserted so as to cut off the shaft current. Shaft current occurs when a magnetic flux, which interlinks with the shaft, is generated due to uneven magnetic resistance of the rotor, and a voltage in the direction of the shaft is generated on the shaft due to fluctuation of the magnetic flux.



Voltage is generated across the shaft of the rotor during rotation of the synchronous generator. The mechanism of this occurrence can be roughly divided into the following two categories.
As one mechanism, due to structural reasons, if the magnetoresistance of the rotor core is not in the same circumferential direction, an alternating magnetic field which interlinks with the shaft of the rotor is generated, and induces electromotive force on the shaft. This electromotive force is usually a few volts. During rotation of the synchronous generator, the shaft of the rotor rests on the oil film of the bearing, so the insulation of the oil film will not be broken at this voltage. However, if the oil film breaks down due to lack of lubrication, etc., and the shaft and bearing surface make metal contact, a closed circuit similar to a short circuit state consisting of the shaft, bearing, stator or the base is formed causing a considerably large current to flow. This current is called shaft current. As this current becomes large, it damages the bearing surface, which in extreme cases leads to damage of the bearing from overheating and causes excessive vibration on the shaft leading to an accident. In order to prevent this, it is only necessary to design so that the number of divisions of the iron core with respect to the number of magnetic poles is optimized, but since variations in the work are inevitable, measures such as inserting insulators between the bearing metal support and the stator frame of the bearing bracket, or between the bearing base and the base have been adopted.

	18. Bearing side insulation Partial cleaning photos ● Generator bearing side Cleaning insulation part 1
	● Cleaning insulation part 2
	● Cleaning insulation part 3

2. Confirmation of switchboard interior/exterior condition and Auxiliary equipment insulation resistance and operation current measurement

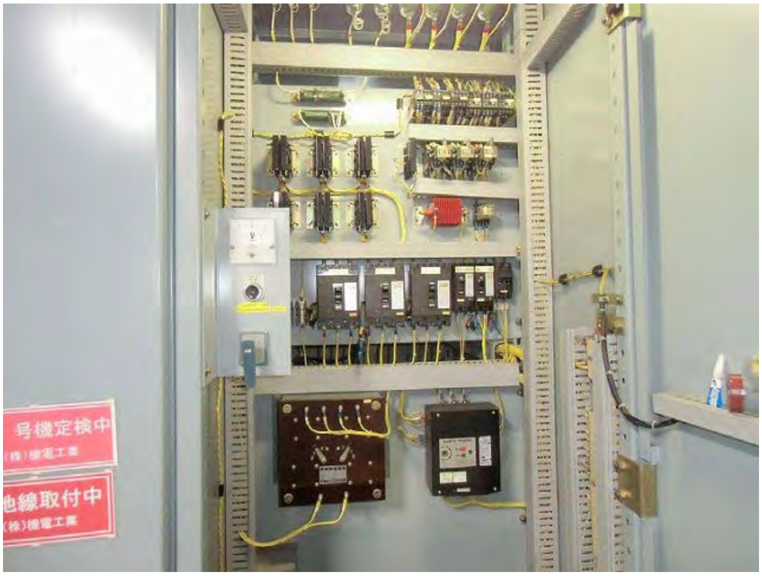


Switchboard board									Power plant	Unit

Inspection start date	Date:	Y/	M/	D	Weather:	Temp: ℃	Humidity: %
Inspection end date	Date:	Y/	M/	D	Weather:	Temp: ℃	Humidity: %

№	Name of board	Appearance inspection	Internal inspection	Inspector
1	Generator circuit breaker panel	Good/Bad	Good/Bad	
2	Generator control panel	Good/Bad	Good/Bad	
3	Electromagnetic switch board	Good/Bad	Good/Bad	
4	Auxiliary relay panel	Good/Bad	Good/Bad	
5	Automatic load balancing device	Good/Bad	Good/Bad	
6	Field meter collection display panel	Good/Bad	Good/Bad	
7	Auxiliary panel	Good/Bad	Good/Bad	
8	Energy meter panel	Good/Bad	Good/Bad	
9	DC power supply	Good/Bad	Good/Bad	
10	DC power supply (additional rectifier)	Good/Bad	Good/Bad	
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
25				
26				
27				
28				
29				
30				
31				
32				

Remarks :

	Panel inspection & cleaning Appearance inspection Burnout, damage, discoloration, odor check
	
	

	Panel inspection & cleaning Internal inspection Installation, wiring fastening check Clean equipment with brush, etc.
	Installation, wiring fastening check Wipe insulator with rag
	Wipe insulator with rag Copper bar bolt fastening check

Auxiliary equipment operation current / insulation resistance measurement

Power plant unit ....

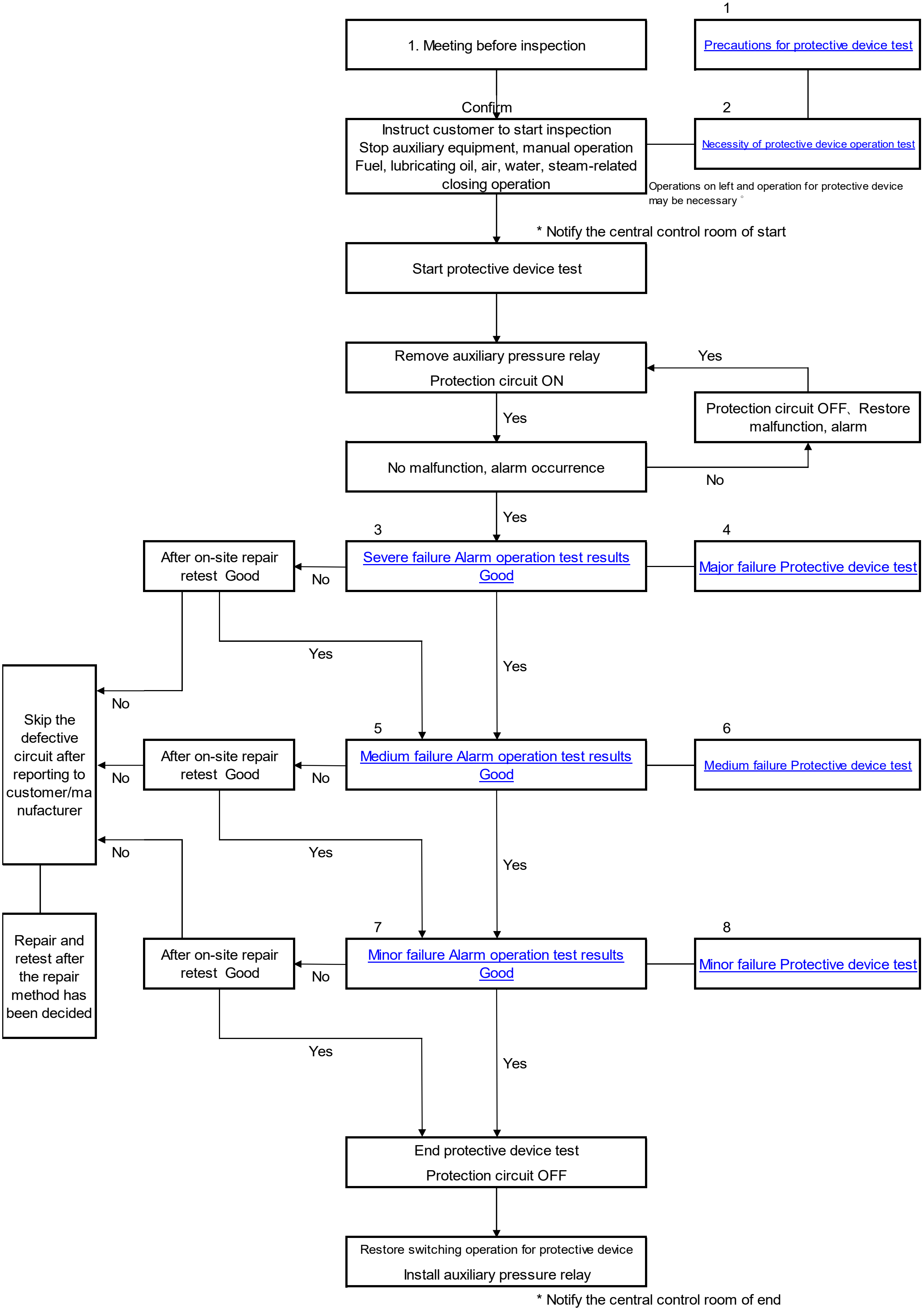
Measurement start date	Date: Y/ M/ D	Weather:	Temp: ℃	Humidity: %
Measurement end date	Date: Y/ M/ D	Weather:	Temp: ℃	Humidity: %
Measurer				

Instrument name	Manufacturer	Model	Serial No.	Year built	Rating

№	Device name	Rating (kV－V)	Rated current (A)	Thermal Setting value (A)	Operating current (A)			Insulation resistance (MΩ)	Judgement
					R phase	S phase	T phase		
1	Lubricating oil priming pump	—							
2	Secondary cooling water pump (A)	—							
3	Secondary cooling water pump (B)	—							
4	Primary cooling water supply pump	—							
5	Cooling tower fan	-							
6	Primary cooling water priming pump	-							
7	Starting air compressor	-							
8	* Generator space heater	—							
9									
10									
11									
12									
13									
14									
15									
16									

Remarks :

3. Protection device operation test



1. Precautions for protective device test

1. Before conducting the test, get an understanding of the operation of the entire facility through drawings, etc.
2. Be sure to check valves, etc. are closed before conducting the test to prevent fuel, lubricating oil, water, air, and steam from leaking.
3. Since the test involves the operation of the entire facility, notify the mechanical, electrical, and instrumentation maintenance personnel and inspectors of the test.
4. During the test, reconfirm the test site in drawings so that there is no mistake in where contact is made, voltage, etc.
5. When testing, test one circuit at a time where possible to avoid forgetting to restore, and restore immediately after the test.
6. At the end of the test, do not forget to restore where operations, etc. were performed before the test.

2. Necessity of protective device operation test

Protective device testing is performed to check the operation of the circuit breaker related to the sequence and whether failure indication and warning are performed correctly in response to the operation of the relays when they detect abnormalities in the equipment or facility. The testing method shall be a single-unit characteristics test of a relay, and manual or actual operation (including by simulation signal) of the relay and interlock testing of the relevant protective devices is conducted.
The judgment criteria are that the operating characteristics of the relay are within the reference values of JIS, JEC, etc. and are within the control value specified by the manufacturer in the protective relay single-unit characteristics test, and in the protective interlock test, that the relevant circuit breaker operates reliably and failure indication and warning are performed correctly.

3. Major failure protective device report

: Date: Y/ M/ D	Weather :	Temperature : ℃	Humidity : %
: Date: Y/ M/ D	Weather :	Temperature : ℃	Humidity : %
:		Powwer Plant Unit	

	No.	Item	Alarm display window	GOT	PC-1 PC-2	CB 1072	Operation 86-1	Buzzer	Logger	Actual operation test	Remarks
				Alarm display	Alarm display						
Major failure	1	Lubricating oil pressure low									
	2	Supercharger lubricating oil pressure low									
	3	Primary cooling water pressure low									
	4	Primary cooling water temperature high									
	5	Engine main bearing temperature high									
	6	Engine crankpin temperature high									
	7	Mist concentration in crankcase high									
	8	Oil mist pressure in crankcase abnormal									
	9	Emergency stop (Meter collection display panel)									
	10	Emergency stop (PC) (Unit 2 General Control Board)									
	11	Starting congestion									
	12	Overspeed 1-stage (12-1)									
	13	Overspeed 2-stage (12-2)									
	14	Generator bearing temperature high									
	15	Generator stator winding temperature high									
	16	Exciter failure (71)									
	17	Generator internal failure (87 - 3 phase bulk)									
	18	Generator ground fault (64GN)									
	19	Generator overvoltage (59)									
	20										
	21										
	22	* CB shall break by 86-1 operation.									
	23										
	24										
	25										

4. Major failure protective device operation test

（1）Purpose

Operate engine with no load, set the generator breaker to the "ON" state, induce major and medium failures, and confirm that the engine stopped and generator circuit breaker tripped.

(2) Inspection due date

(a) Date/Time Date: / / Start :
End :

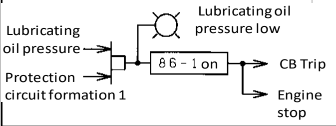
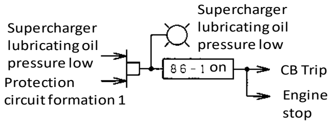
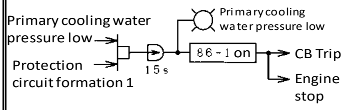
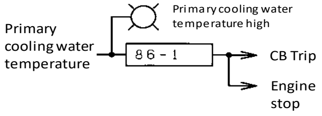
(b) Weather

(c) Indoor Temperature ℃ Humidity %

(3) Testing procedure and results

(a) Operate the engine with no load on a simulated circuit.
(b) Set the generator circuit breaker to the "ON" state on the simulated circuit.
(c) Make sure that no heavy or medium failure has occurred.
(d) Set protection circuit to "TEST"
(e) Perform the test at the same time as "Alarm Indication Test" in Section 5.

IRY 1: Unit 2 General Control Panel panel surface
GOT: Unit 2 General Control Panel Touch Panel
PC−1: Monitor and control system（A）

No.	Test name	Block diagram	Testing method	Setting value	Operating value	Alarm indication				Buzzer	Circuit breaker trip indication				Stop engine （86-1 operation）	Result	Remarks
						IRY1	GOT	PC-1 Alarm list	PC-2 Alarm list		IRY1	GOT	PC-1	PC-2			
1	Lubricating oil pressure low Dev.No 263Q-3 Tag.No 2L113 (SH.NoAD02)		External terminal block of meter collection display panel Make contact between 2P2C and PS3A with a fuse. 5. Also check No. 1 of the alarm indication test. Engine stop	0.539 + 0.029MPa − 0.000MPa	Make	○	○	○	○	○	○	○	○	○	○		
2	Supercharger lubricating oil pressure low Dev.No 263QT-3 Tag.No 2L307 (SH.NoAD02)		External terminal block of meter collection display panel Make contact between 2P2C and PS3A with a fuse. 5. Also check No. 2 of the alarm indication test.	0.078 + 0.010MPa − 0.000MPa	Make	○	○	○	○	○	○	○	○	○	○		
3	Primary cooling water pressure low Dev.No 263W1-3 Tag.No 2W110 (SH.NoAD02)		External terminal block of meter collection display panel Make contact between 2P2C and PS3A with a fuse. 5. Also check No. 3 of the alarm indication test.	0.117 + 0.020MPa − 0.000MPa	Make	○	○	○	○	○	○	○	○	○	○		15 s timer
4	Seawater pressure low Dev.No 263SW-3 Tag.No 2W306 (SH.NoAD02)		Simulate external terminal blocks X3-1 and X3-5 of Unit 2 on-site auxiliary relay panel Make contact with a switch		Make	○	○	○	○	○	○	○	○	○	○		30 s timer
5	Primary cooling water temperature high Dev.No 226W1-3 Tag.No 2W115 (SH.NoAD02)		External terminal block of meter collection display panel Make contact between 2P2C and PS3A with a fuse. 5. Also check No. 5 of the alarm indication test.	96 ± 1℃	Make	○	○	○	○	○	○	○	○	○	○		

5. Medium Failure Protective Device Report

Test start date :	Date: Y/ M/ D	Weather :	Temperature : ℃	Humidity : %
Test end date :	Date: Y/ M/ D	Weather :	Temperature : ℃	Humidity : %
Conducted by :			Powwer Plant Unit	

	No.	Item	Alarm display window	GOT	PC-1 PC-2	CB break 1072	86-1	Buzzer	Logger	Actual operation test	Remarks
				Alarm display	Alarm display						
	No.						86 -2				
Medium failure	1	Generator overcurrent (51)									
	2	Generator reverse power (67)									
	3										
	4										
	5										

6. Medium Failure Protective Device Operation Test

（1）Purpose

Operate engine with no load, set the generator breaker to the "ON" state, induce major and medium failures, and confirm that the engine stopped and generator circuit breaker tripped.

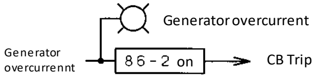
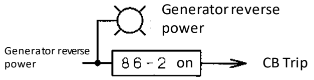
(2) Inspection due date

(a) Date/Time Date: / / Start :
End :
(b) Weather
(c) Indoor Temperature ℃ Humidity %

(3) Testing procedure and results

(a) Operate the engine with no load on a simulated circuit.
(b) Set the generator circuit breaker to the "ON" state on the simulated circuit.
(c) Make sure that no heavy or medium failure has occurred.
(d) Set protection circuit to "TEST"
(e) Perform the test at the same time as "Alarm Indication Test" in Section 5.

IRY 1: Unit 2 General Control Panel panel surface
GOT: Unit 2 General Control Panel Touch Panel
PC−1: Monitor and control system（A）

No.	Test name	Block diagram	Testing method	Setting value	Operating value	Alarm indication				Buzzer	Circuit breaker trip indication				CB trip （86-2 Operation）	Result	Remarks
						IRY1	GOT	PC-1	PC-2		IRY1	GOT	PC-1	PC-2			
								Alarm list	Alarm list								
23	Generator overcurrent Dev.No 251 Tag.No 51		Forcefully operate relay 251 of Unit 2 general control panel	4.6 ± 2.3A	Make	○	○	○	○	○	○	○	○	○	○		
24	Generator reverse power Dev.No 267P Tag.No 67P		Forcefully operate relay 267 of Unit 2 general control panel	0.28 ± 0.024A	Make	○	○	○	○	○	○	○	○	○	○		

7. Minor Failure Protective Device Report

	No.	Item	Alarm display window	Alarm display		CB break 1072	Operation 86-1	Buzzer	Logger	Actual operation test	Remarks
				GOT	PC-1 PC-2						
Minor failure	1	Speed decrease									
	2	Fuel injection pipe abnormality									
	3	Lubricating oil pressure low									
	4	Supercharger lubricating oil pressure low									
	5	Fuel valve cooling oil pressure low									
	6	Valve train lubricating oil pressure low									
	7	Fuel oil pressure low									
	8	Primary cooling water pressure low									
	9	Secondary cooling water pressure low									
	10	Seawater pressure low									
	11	Lubricating oil strainer abnormality									
	12	Supercharger lubricating oil strainer differential pressure large									
	13	Fuel oil secondary strainer differential pressure large									
	14	Fuel oil primary strainer differential pressure large									
	15	Supercharger intake air filter differential pressure large									
	16	Air tank pressure low									
	17	Lubricating oil inlet temperature high									
	18	Lubricating oil outlet temperature high									
	19	Supercharger lubricating oil outlet temperature high									
	20	Fuel valve cooling oil inlet temperature high									
	#	Primary cooling water outlet temperature high									
	22	Secondary cooling water outlet temperature high									
	23	Seawater outlet temperature high									
	24	Engine main bearing temperature high									
	25	Control air pressure low									
	26	Engine crankpin temperature high									
	27	Abnormal engine vibration									
	28	Abnormal supercharger vibration									
	29	Oil mist concentration in crankcase high									
	30	Cylinder leakage									
	31	Load limit									
	32	Turning device failure									
	33	Lubricating oil sump tank level abnormality (High/Low)									
	34	Supercharger lubricating oil sump tank level a (High/Low)									
	35	Fuel valve cooling oil tank level abnormality (High/Low)									
	36	Valve train lubricating oil tank level abnormali (High/Low)									
	37	Marine Diesel Fuel sump tank level abnormal (High/Low)									
	38	Primary cooling water expansion tank level a (High/Low)									
	39	Secondary cooling water expansion tank leve (High/Low)									

8. Minor Failure Alarm Indication Test

（1）Purpose

Confirm whether an alarm is indicated normally on the alarm display window, touch panel (GOT), and monitoring and control systems (A) and (B) of the general control panel.

(2) Inspection due date

(a) Date/Time Date: / / Start :

Date: / / End :

(b) Weather

(c) Indoor ℃ Humidity: %

IRY 1: Unit ○ General Control Panel Alarm Indication Window

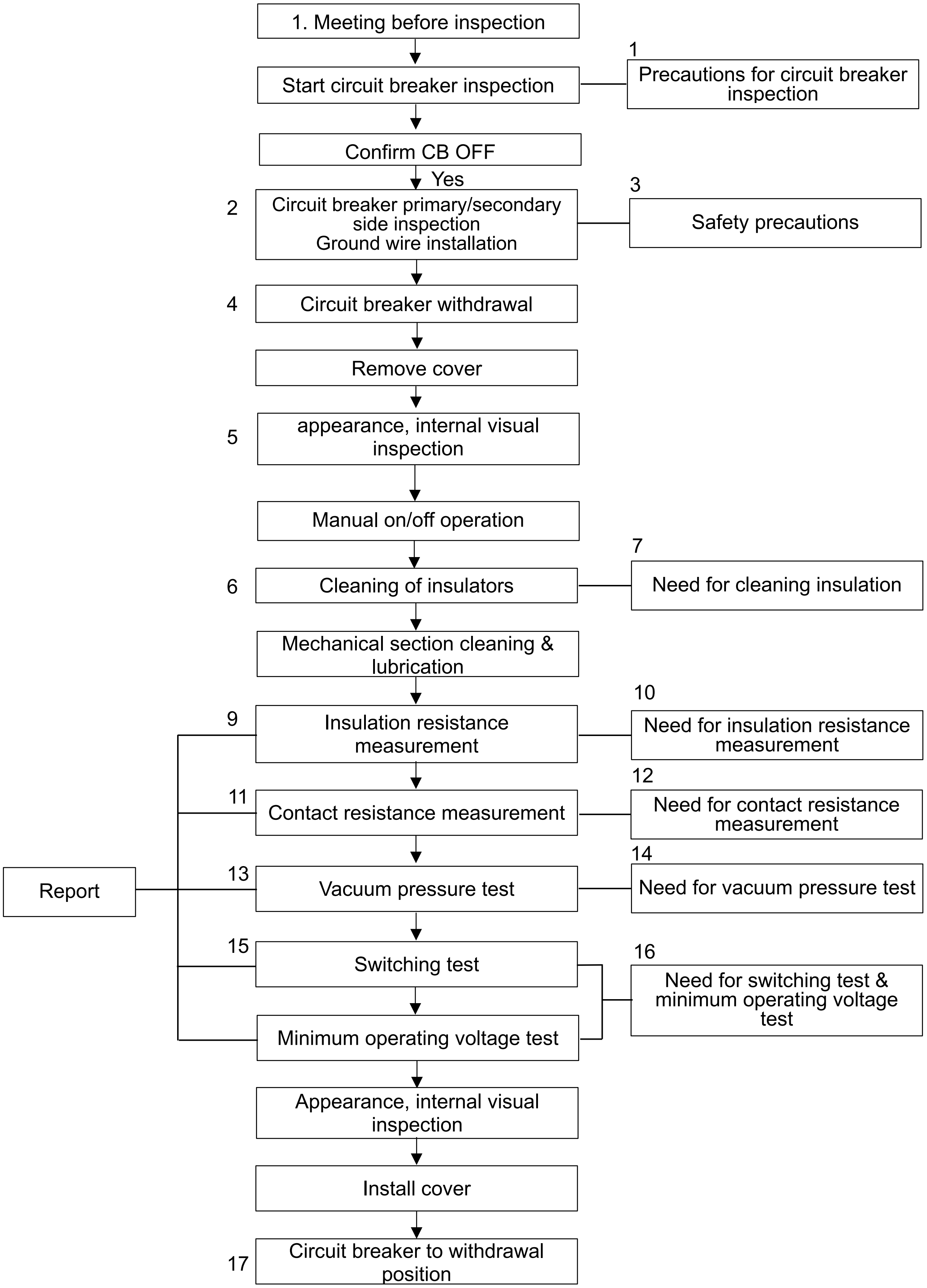
GOT: Unit ○ General Control Panel Touch Panel

(3) Inspection procedure and results (The setting values and operating values are the same as the on-site instruments)

* M → engine room E → electric room C → central control room S → Other

No.	Item			Inspection procedure		Setting value	Operating value	Alarm indication										Result	Remarks
	Indication Name	Tag.No	Dev.No	Operation position	Inspection method			IRY1	G O T		PC-1			PC-2			Buzzer		
									Alarm list	Alarm indication	Alarm list	Status history	Alarm indication	Alarm list	Status history	Alarm indication			
1	Lubricating oil pressure low (SH.NoAD02)	2L113	263Q-3	Meter collection display panel	External terminal block of meter collection display panel Make contact between 2P2C and PS3A with a fuse. 8, Check when conducting No1 of the protection operation test.	0.539 + 0.029MPa − 0.000MPa	Make	○	○	○	○	○	○	○	○	○	○		Protection circuit formation 1
2	Supercharger lubricating oil pressure low (SH.NoAD02)	2L307	263QT-3	Meter collection display panel	External terminal block of meter collection display panel. Make contact between 2P2C and PS4A with a fuse. 8, Check when conducting No2 of the protection operation test.	0.078 + 0.010MPa − 0.000MPa	Make	○	○	○	○	○	○	○	○	○	○		Protection circuit formation 1
3	Primary cooling water pressure low (SH.NoAD02)	2W110	263W1-3	Meter collection display panel	External terminal block of meter collection display panel Make contact between 2P2C and PS1A with a fuse. 8, Check when conducting No3 of the protection operation test.	0.117 + 0.020MPa − 0.000MPa	Make	○	○	○	○	○	○	○	○	○	○		Protection circuit formation 1 Timer 15 s
4	Seawater pressure low (SH.NoAD02)	2W306	263SW-3	Meter collection display panel	External terminal block of meter collection display panel Make contact between 2P2C and PS2A with a fuse. 8, Check when conducting No3 of the protection operation test.	——	Make	○	○	—	○	—	—	○	—	—	○		Protection circuit formation 1 Timer 30 s
5	Primary cooling water temperature high (SH.NoAD02)	2W115	226W1-3	Meter collection display panel	External terminal block of meter collection display panel Make contact between 2P2C and TS1B with a fuse. 8, Check when conducting No5 of the protection operation test.	96 ± 1℃	Make	○	○	○	○	○	○	○	○	○	○		
6	Engine main bearing (SH.NoAD02)	2A140	238E-3	Meter collection display panel	External terminal block of meter collection display panel Make contact between 2P2C and MT2 with a fuse. 8, Check when conducting No6 of the protection operation test.	95 ± 1℃	Make	○	○	○	○	○	○	○	○	○	○		
7	Engine crankpin temperature high (SH.NoAD02)	——	226A-3	Meter collection display panel	External terminal block of meter collection display panel Make contact between 2P2C and CT2 with a fuse. 8, Check when conducting No7 of the protection operation test.	95 ± 1℃	Make	○	○	○	○	○	○	○	○	○	○		
8	Crankcase internal oil mist concentration high (SH.NoAD02)	2L126	263CM-3	Oil mist detector	External terminal block of oil mist detector Make contact between 2P2C and No. 5 with a fuse. 8, Check when conducting No8 of the protection operation test.	15 graduations or more	Make	○	○	○	○	○	○	○	○	○	○		
9	Crankcase internal oil mist pressure abnormal (SH.NoAD03)	——	263CG-3	Meter collection display panel	External terminal block of meter collection display panel Make contact between 2P2C and P1T2 with a fuse. 8, Check when conducting No9 of the protection operation test.	1.47Mpa	Make	○	○	○	○	○	○	○	○	○	○		Timer 60 s
10	Emergency stop (Meter collection display panel)	5E	3-64E	Meter collection display panel	Press the EMERGENCY STOP PB of the meter collection display panel to operate	——	Make	○	○	○	○	○	○	○	○	○	○		
	Emergency stop (Unit 2 General control panel)	5E	3-205E	Unit 2 General control panel	Press the EMERGENCY STOP PB of the Unit 2 General control panel to operate	——	PB	○	○	○	○	○	○	○	○	○	○		
	Emergency stop [Monitoring and control system(A)]	5E	3-205E	Monitoring and control system (A)	Press the monitoring and control system (A) operation screen EMERGENCY STOP PB to operate	——	PB	○	○	○	○	○	○	○	○	○	○		
	Emergency stop [Monitoring and control system(B)] (SH.NoAD03)	5E	3-205E	Monitoring and control system (A)	Press the monitoring and control system (A) operation screen EMERGENCY STOP PB to operate 8, Check when conducting No10 of the protection operation test.	——	PB	○	○	○	○	○	○	○	○	○	○		
11	Starting congestion (SH.NoAC32)	48T	248T	Unit 2 General control panel	Start-up with the Unit 2 general control panel and continue for 60 seconds at 400 rpm or less 8, Check when conducting No11 of the protection operation test.	60 ± 0.3s	Make	○	○	○	○	○	○	○	○	○	○		
12	Overspeed 1-stage (SH.NoAA01, AC32)	12-1	212-1	Unit 2 General control panel	Apply voltage from the test device to external terminal blocks X6-31 and X6-32 of Unit 2 general control panel and confirm the operating value 8, Check when conducting No12 of the protection operation test.	(110%) 440 ± 22rpm	(V) rpm	○	○	○	○	○	○	○	○	○	○		

4. Circuit Breaker Inspection



1. Precautions for circuit breaker inspection

1. Confirm test position of the circuit breaker.
2. Confirm that there is no voltage around the equipment with an electroscope.
3. Record the state before removing the connector.
4. Insulate the removed connectors and wires.
5. For the circuit breaker withdrawal, use a special tool and mount.
6. Demarcate the area so that other parties do not enter during the inspection.
7. Confirm the order of opening the cover.
8. Do not touch the internal mechanism with the spring loaded.
9. Confirm OFF state during vacuum pressure test.
10. During the vacuum pressure test, wear protective equipment and check for the presence of voltage with a high voltage electroscope.
11. After the vacuum pressure test, be sure to perform ground discharge.
12. During limited time test, cure the terminals not being used.
13. Use clips with a fuse to make contact.
14. After the inspection, confirm the circuit breaker is OFF.
15. To return the circuit breaker, use a special tool and mount.
16. Return the removed connectors and wires to their original state.

2. Protective equipment, electroscope, ground wires

 Whole body Front	 Whole body Back
 Insulated jacket	 Insulated protective gloves

 Insulated protective boots	 Helmet
 Electroscope	 Electroscope (pencil type)
 Electroscope work	 Electroscope work
 Short-circuit ground wire set	 Short-circuit ground wire

3. Precautions for safety measures

   1. Clearly indicate "Under Inspection," "Operation Prohibited," etc. on the panel of the units to be inspected.
   2. Operation of the equipment shall be confirmed mutually by the person performing the work and the power plant personnel and carried out by pointing and calling out the state, operation, etc.
   3. When installing the short-circuit ground wire, install after confirming there is no voltage by wearing safety protection equipment and using an electroscope. In addition, also inspect the electroscope before using it.
   4. Only personnel wearing protective equipment shall perform inspection and installation of ground wire.
   5. Demarcate adjacent panels, equipment, etc. with tape etc. so as not to miss-operate.

4. 17. Circuit breaker withdrawal

Circuit breaker lift

Circuit breaker rack

Circuit breaker handle

5. Appearance, internal visual inspection

6. Cleaning of insulators

	1.Ensure circuit breaker is OFF. Spring release confirmation with a clean cloth soaked with an alcohol solution (if there is no alcohol, clean dry cloth), clean the entire insulator and wipe off any dust.
	2. Carefully clean fine parts by wrapping a cloth around the tip of a thin rod.
	3. Likewise, carefully wipe dust off the vacuum valve.
	4. Likewise, carefully wipe dust off the vacuum valve.
	5. While and after cleaning, visually inspect the entire VCB insulator and check for carbonized conducting paths (tracking marks) etc. →Tracking marks

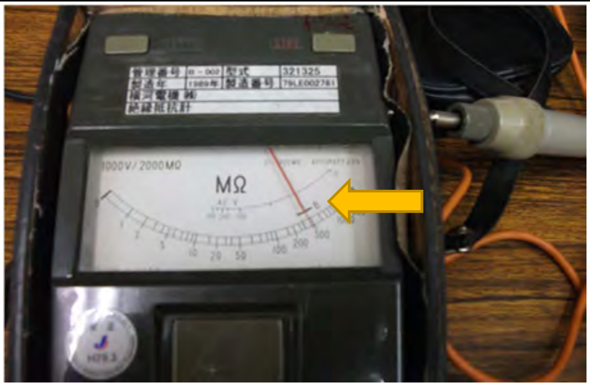
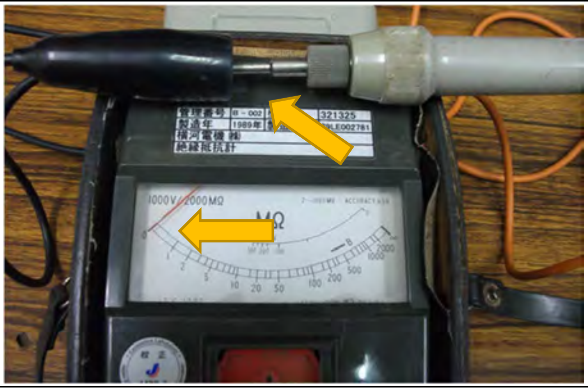
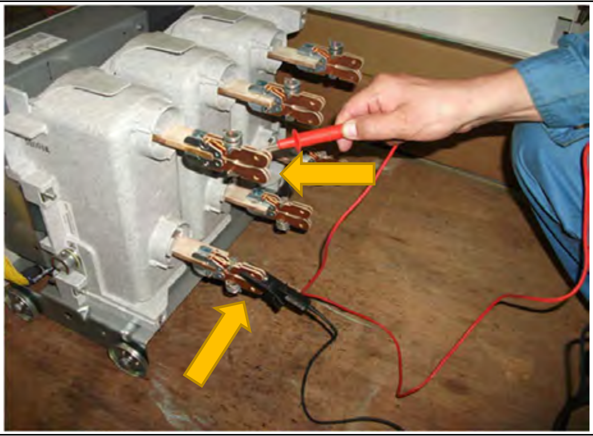
7. Need for cleaning insulation

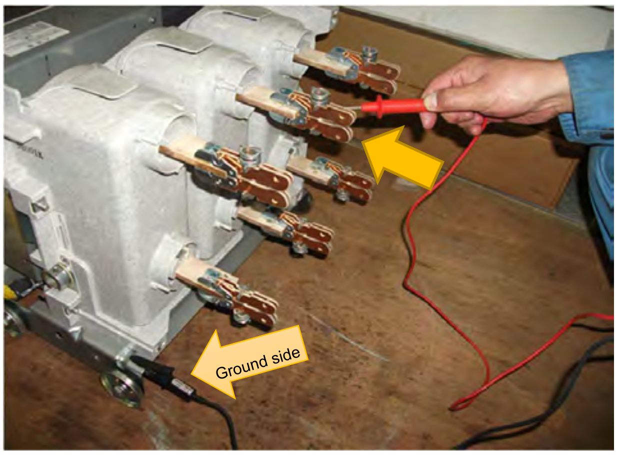
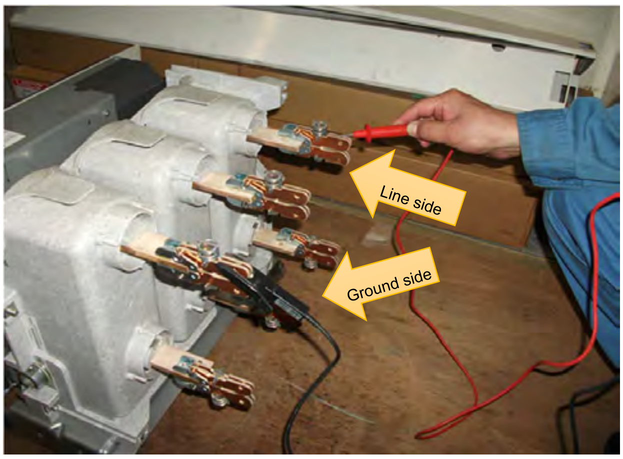
Tracking phenomenon

If dust is left for a long time, it attracts moisture leading to repeated spark discharge. This causes the insulation state deteriorate which leads to electricity flowing on the surface of the insulator. This generates heat which eventually causes it to ignite.

Regular cleaning maintains the insulation state and can prevent faults caused by the accumulation of dust.

9. Insulation resistance measurement

	1. Advance preparation Place circuit breaker in a spacious area, Ensure circuit breaker is OFF. ON. Check megger battery.
	2. Advance preparation Check for disconnections by checking continuity
	3. Measurement of main circuit In-phase measurement of circuit breaker Turn circuit breaker OFF. A-A phase B-B phase C-C phase Measurement of primary and secondary side The measurement is in the 1,000 V range.

	4. Measurement of main circuit Measurement of resistance-to-ground Turn circuit breaker ON. Connect the ground side of the megger to the frame of the circuit breaker. Measure by touching the LINE side of the megger against phase A, phase B, and phase C. The measurement is in the 1,000 V range.
	5. Measurement of main circuit Measurement between phases Turn circuit breaker ON. Connect the ground side of the megger to phase A of the circuit breaker. Measure by touching the LINE side of the megger against phase B. (Photo: Between phases A and C) The measurement is in the 1,000 V range. Do the same between other phases. Between phases b and c and phases a and c
	6. Measurement of low voltage circuit Prepare the low-pressure megger in advance and turn the circuit breaker ON. Connect the ground side of the megger to the frame of the circuit breaker. Measure by touching the LINE side of the megger against the pin of the control connector. Measure all pins. Measurement range is 500 V.

10. Need for insulation resistance measurement

1.Can grasp the insulation state of the equipment.

2.Can detect signs of ground faults and short circuit of equipment due to dust, etc. at an early stage.

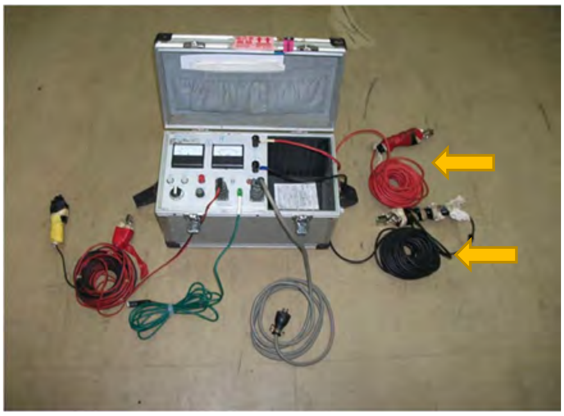
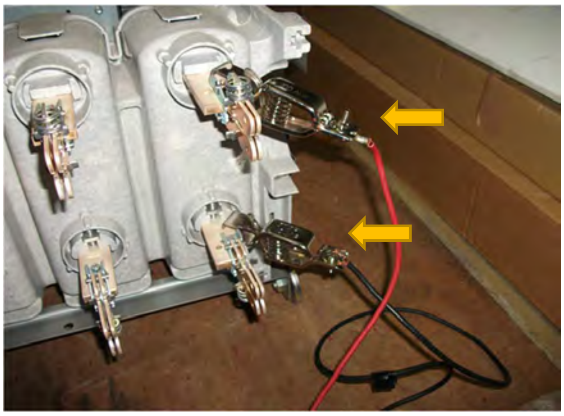
Insulation resistance criteria

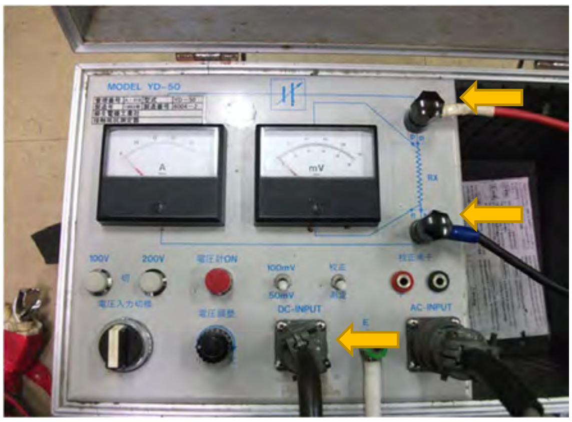
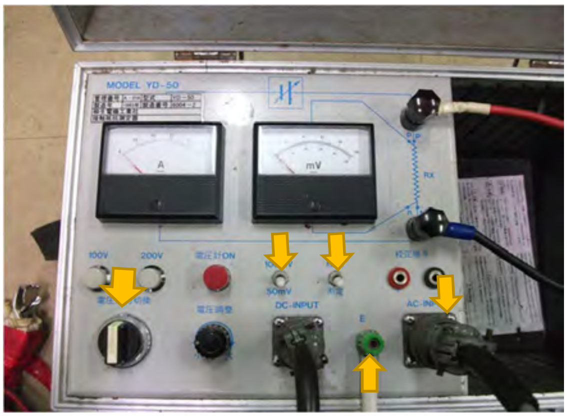
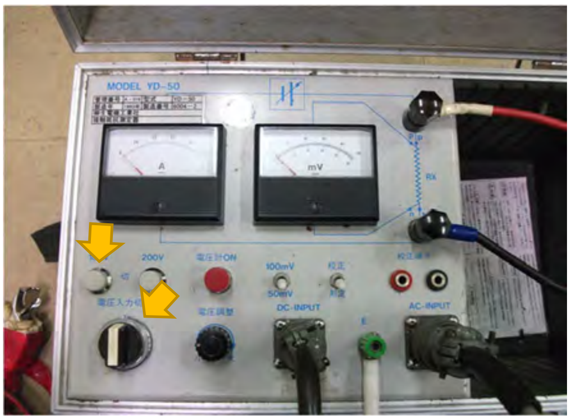
Insulation resistance value of main circuit	Procedure
500 MΩ or above	Can continue to use
30 MΩ or more Under 500 MΩ	After cleaning, remeasure, and if 500 MΩ or more, you can continue to use it. However, if it is remeasured after cleaning, and it does not reach 500 MΩ, check for signs of tracking, arc marks, etc. If there are none, continue using it and reconfirm the insulation state within one year.
Under 30 MΩ	Overhaul inspection of the VCB by the manufacturer. Or make plans to replace it with a new one as soon as possible and replace it accordingly.
	(Fuji Electric) Insulation resistance meter

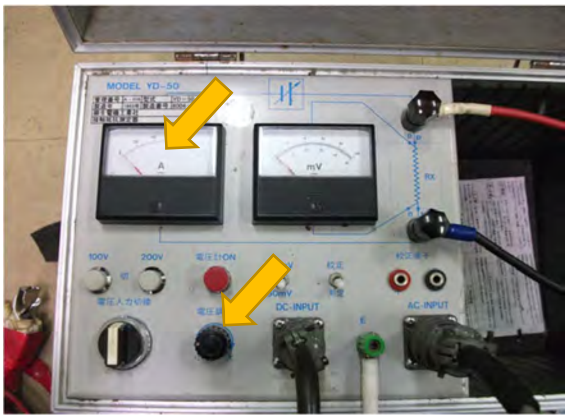
(In case of Mitsubishi)

11. Contact resistance measurement

	1. Place circuit breaker in a spacious area, and verify that the circuit breaker is off

	2–1 Set the main circuit to ON. Connect the current wire (DC + side) to the primary side of phase A of the main circuit (red wire). Connect the current wire (DC primary side) to the secondary side of phase A of of the main circuit. (black wire) Tester side
	2-2 Set the main circuit to ON. Connect the current wire (DC + side) to the primary side of phase A of the main circuit. (red wire). Connect the current wire (DC primary side) to the secondary side of phase A of of the main circuit. (black wire) Circuit breaker side
	3-1 Connect the voltage measurement wire (DC + side) to the primary side of phase A of the main circuit (red wire). Connect the voltage measurement wire (DC - side) to the secondary side of phase A of the main circuit (black wire). Tester side
	3-2 Connect the voltage measurement wire DC + side) to the primary side of phase A of the main circuit (red wire). Connect the voltage measurement wire (DC - side) to the secondary side of phase A of the main circuit (black wire).

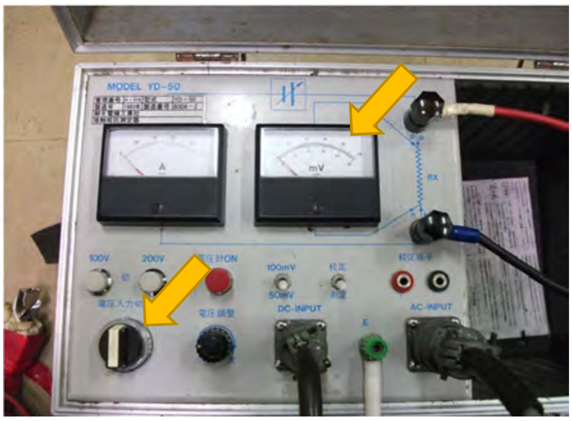
	4. Current wire (DC + side) Current wire (DC + side) Voltage test cable connector Ensure the tester side
	5. voltage input selector switch is OFF. Connect the power cable. Connect the ground wire to the tester. Plug the power cable into the outlet.
	5-2 Ensure the voltage input selector switch is OFF. Voltmeter range 50 mV Selector switch measurement side. Connect the power cable. Connect the ground wire to the tester
	6. Set the voltage input changeover switch to 100 V side. 100 V lamp on Depending on the power supply voltage, it may be 200 V. Center position is OFF. When the switch is turned ON, current flows.



7. Set the current value with the voltage adjustment dial.

Turn right to increase and left to decrease.

Example: 50 A

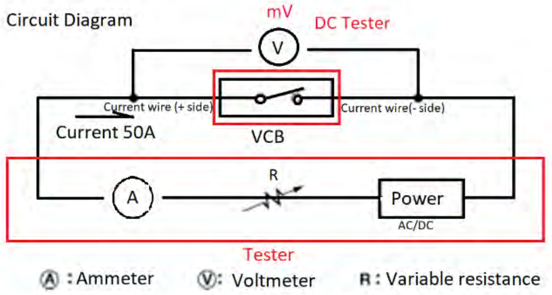


10. Record the voltmeter reading.

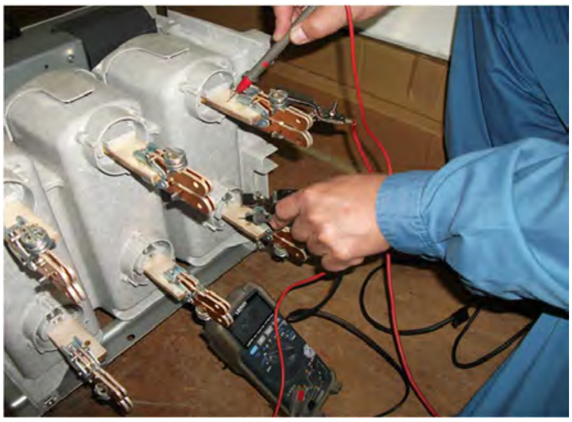
Example: 2 mV

* After recording the voltmeter reading, promptly turn the voltage input selector switch to OFF.

Measure in a short time because it is energized at 50 A.



Use the measured voltage and Ohm's law to determine the resistance Formula R = V/I
Example: current 50 A, measured voltage 2 mV Formula 0.002÷50＝0.00004
Therefore, contact resistance is 40 μΩ.
Perform on the other phases in the same manner, and test one phase at a time.
After measuring all phases turn the circuit breaker OFF.



11. If there is no wire for voltage measurement, it may be measured with a DC tester capable of measuring mV.

・Need for contact resistance measurement

The circuit breaker contacts are worn out by interrupting the current.

When a large current is interrupted, the surface of the contact is worn out by arc heat.

In such case, the contact area decreases, and the contact resistance increases.

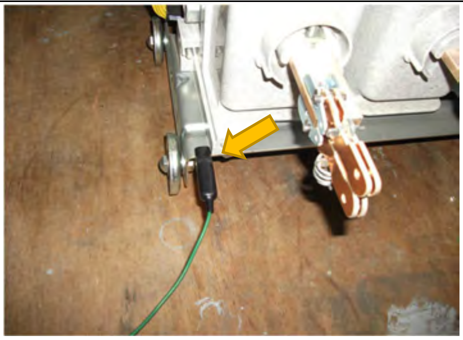
Continued use with increased contact resistance increases the heat generated between the contacts, and if the heat generated exceeds the allowable value, the contacts may be welded. In the worst case, the contacts weld and become unable to interrupt.

Circuit breakers that constantly interrupt the load current can quickly notice abnormalities by periodically measuring the contact resistance and recording the state of the contacts.

In addition, if a fault current is interrupted, the condition of the measured contacts should be confirmed promptly

13. Vacuum pressure test

	1. Place circuit breaker in a spacious area, and verify that the circuit breaker is off. Notify people in the vicinity that high voltage will be generated an clear the area of people to make sure no one enters it
	2. Connect cable "U" of the tester to the A phase primary side of the circuit breaker. Connect cable "V" of the tester to the A phase secondary side of the circuit breaker. Tester side
	2–1 Connect cable "U" of the tester to the A phase primary side of the circuit breaker. Connect cable "V" of the tester to the A phase secondary side of the circuit breaker. Circuit breaker side

	3. Connect the ground to the body of the circuit breaker.
	4. Connect the tester operating section and the output section with a dedicated cable. Connect the ground wire to the tester operating section Connect the tester power supply plug cable.
	5. Verify that the power switch of the tester operation section is off. Verify that the voltage adjustment dial is on 0. After verifying, plug the power plug into the outlet.
	6. Renotify people in the vicinity of the start of the test aloud. Set timer to 60 seconds. Turn the power switch ON Turn the test switch ON.
	7. Turn the voltage adjustment dial to the right and increase voltage until the voltmeter reads 3 kV. Pay attention to the range of the meter

<table>
<tr>
<td>
</td>
<td>8. When voltage has reached 3 kV, verify the occurrence of voltage with an electroscope.
Wear protective gear when performing.</td>
</tr>
<tr>
<td>
</td>
<td>9. After confirming the occurrence of the high voltage, turn the voltage adjustment dial to the right and increase voltage until the voltmeter reads 28 kV.
Pay attention to the range of the meter</td>
</tr>
<tr>
<td>
</td>
<td>10. After setting to 28 kV, set the timer ON, start the test, and
record the mA during the test.</td>
</tr>
<tr>
<td>
</td>
<td>11. After the timer counts ends, judgement is made (automatically).
Good: green lamp on
Bad: yellow lamp on</td>
</tr>
<tr>
<td>
</td>
<td>12. After judgment, promptly turn the voltage adjustment
dial to the left (toward 0) and
step down voltage to 0 kV.</td>
</tr>
</table>

	13. Turn the test switch OFF. Turn the power switch OFF
	14.Connect cable "U"side and "V" side of the tester and verify that voltage is not present. A phase primary side, secondary side wear protective gear when performing
	15. After confirming voltage is not present, ground discharge. A phase primary side, secondary side Wear protective gear when performing.

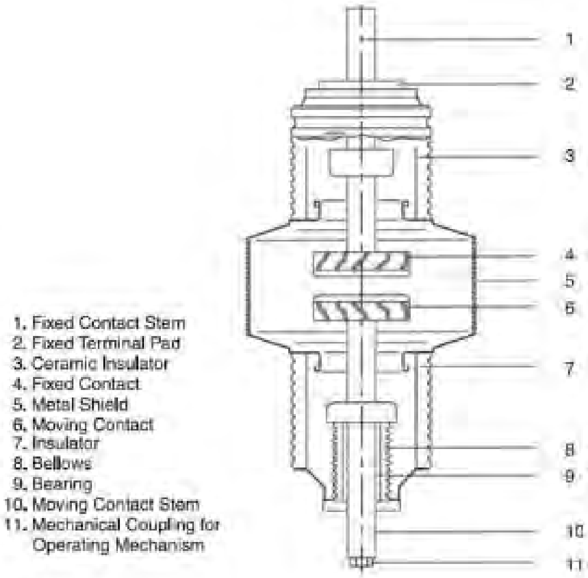
Perform on B phase and C phase in the same manner.　Test one phase at a time

14. Need for vacuum pressure test

If the degree of vacuum is low, glow discharge or spark discharge will occur internally which will make it impossible to raise the voltage. Moreover, there is a possibility that the arc can not be extinguished at the time of interruption causing the contacts to weld and become unable to interrupt.

Circuit breakers that constantly interrupt the load current can quickly notice abnormalities by periodically measuring the degree of vacuum and recording the state of the valves.

In addition, if a fault current is interrupted, the degree of vacuum should be confirmed by promptly taking measurements.

	
https://www.elprocus.com/types-of-circuit-breakers-and-its-application/	https://www.indiamart.com/proddetail/vacuum-circuit-breaker-9159210348.html

15. Switching test

16. Need for switching test & minimum operation test

1. Measuring the opening time, closing time, three phase unevenness time, and the minimum operating voltage will improve the reliability of the equipment.
2. If left uninspected for a long time, malfunction will occur due to stagnation, galling, abrasion, deformation, and corrosion of the mechanism, shortage of grease, poor lubrication, rusting of mechanical parts, and other factors such as springiness, deformation, and damage of the springs.
3. By measuring the minimum operating voltage, the quality of the input coil and tripping coil can be determined.

18.Circuit Breaker Report

Power Plant Unit

Test Date	Y/ M/ D	Weather:	Temp: ℃	Humidity: %
Conducted by				

Instrument name	Manufacturer	Model	Serial No.	Year built	Rating

(1) Specifications Work classification: Detailed/Simplified Last inspection date: Date: Y/ M/ D

Manufacturer		Model	
Year built		Serial No.	
Rated current		Closing operation voltage	
Rated voltage		Control voltage	
Rated interrupting current		Closing method	
Rated interrupting capacity		Gross weight	

（2） Register reading

Before inspection		After inspection		After last inspection:	

Number of operations ( )

（3） Vacuum pressure Judgment:

Remarks: Check vacuum pressure with VCB tester

Judgment criteria: In the open circuit state, apply 28 kV for 1 minute with the vacuum checker to make sure there is no flashover or discharge.

（4）Insulation resistance measurement Unit：MΩ

	High voltage circuit									Low voltage circuit
	Line to ground			Line to line			In-phase (when disconnected)			Bulk line to ground
	R	S－E	T－E	R－S	S－T	T－R	R－R	S－S	T－T	
Insulation resistance value										

（5） Contact resistance measurement (voltage/current measurement method)

Unit: μΩ

A phase	B phase	C phase

Generator capacity (kw)	Contact resistance (μΩ)
～ 500	2000 or less
750～2500	1000 or less
4000～10000	100 or less

（6） Switching test Unit：msec

	R phase	S phase	T phase	Unevenness
On				
Off				

* Operation time table

Circuit Breaker Type	Closing time （msec）	Opening time （msec）
VCB	30ms～60ms	10ms～30ms

（7） Minimum operating voltage test

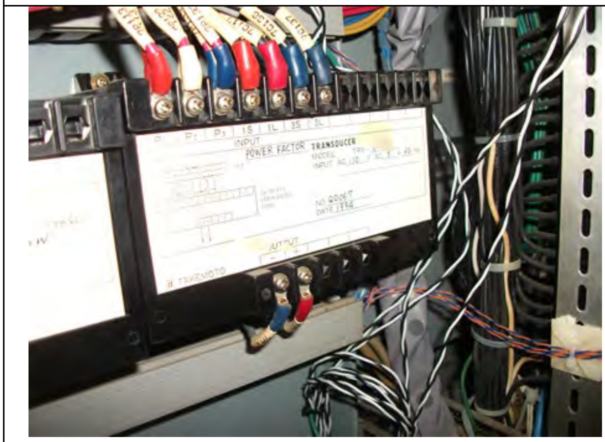
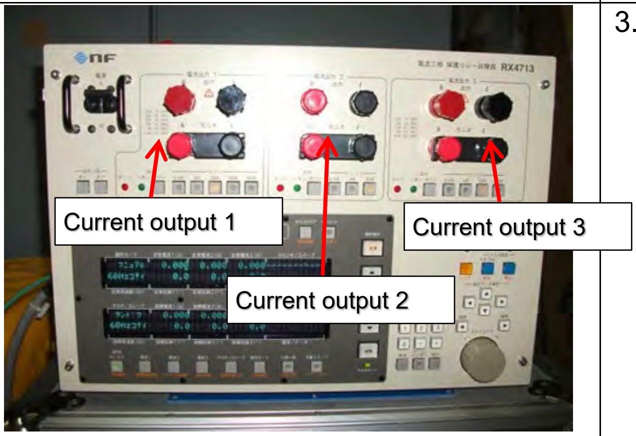
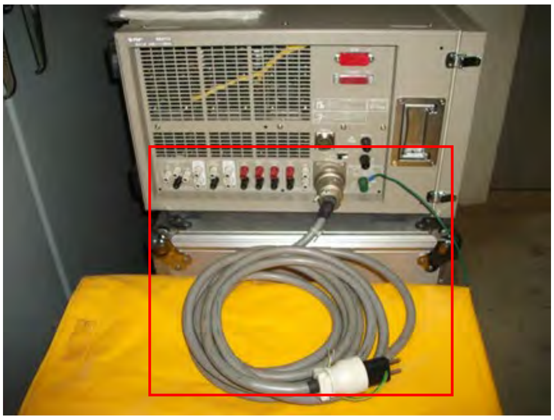
Closing	Tripping
V	V

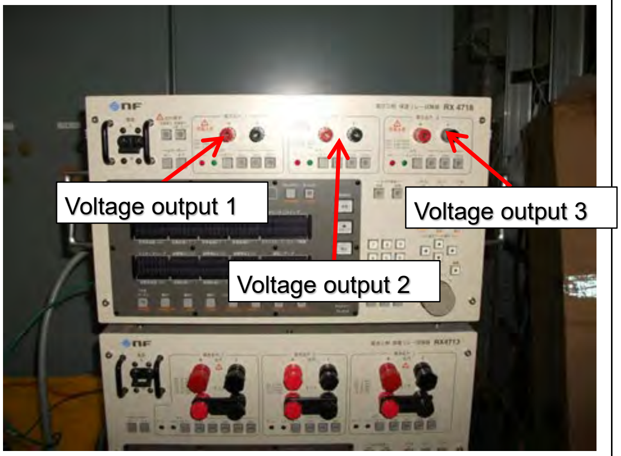
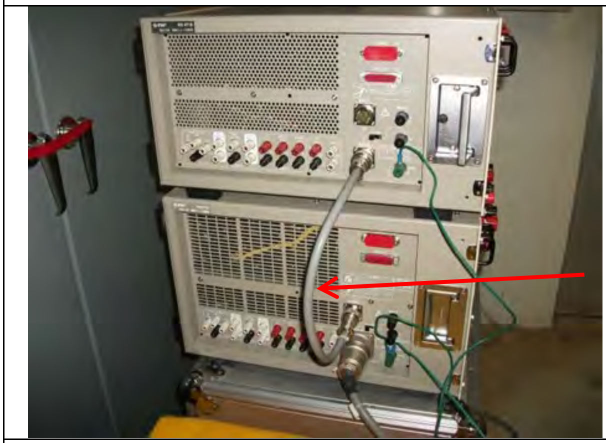
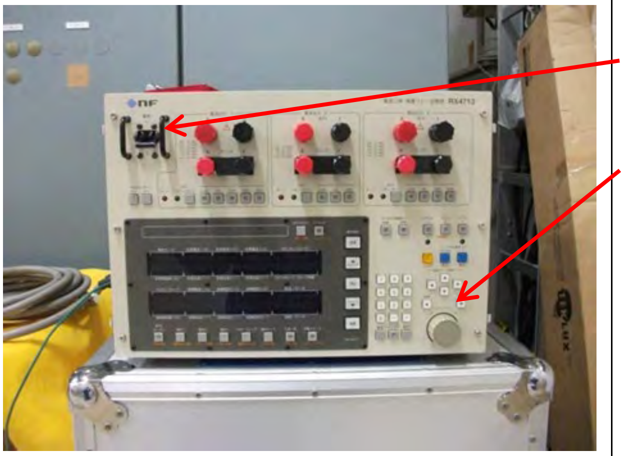
Closing 75% or less of rated operation/control voltage.

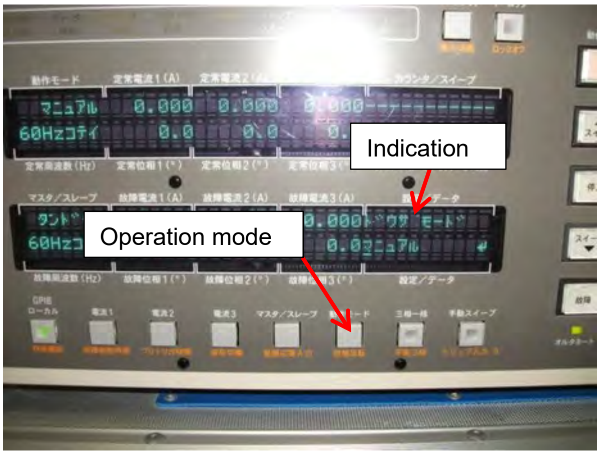
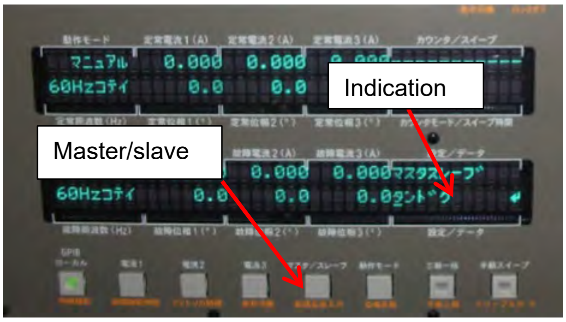
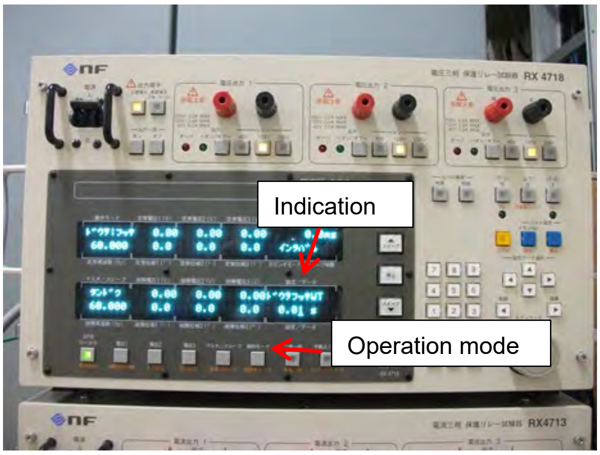
Tripping 60% or less of rated operation/control voltage.

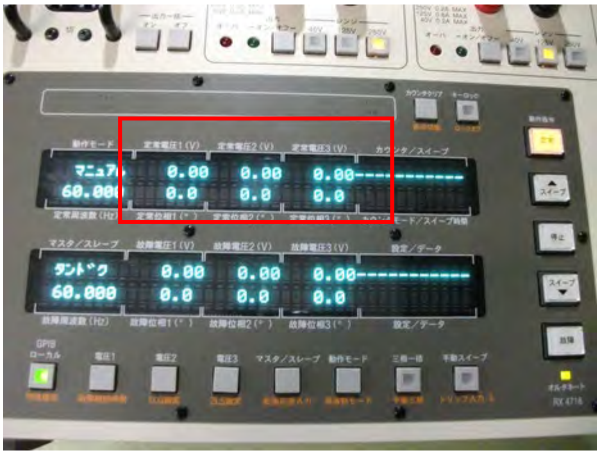
Comprehensive judgment: Good

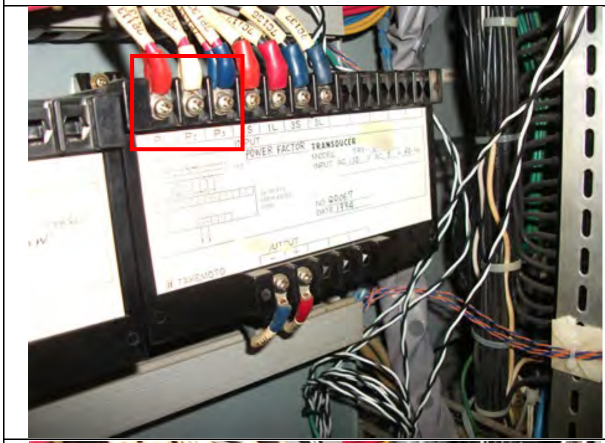
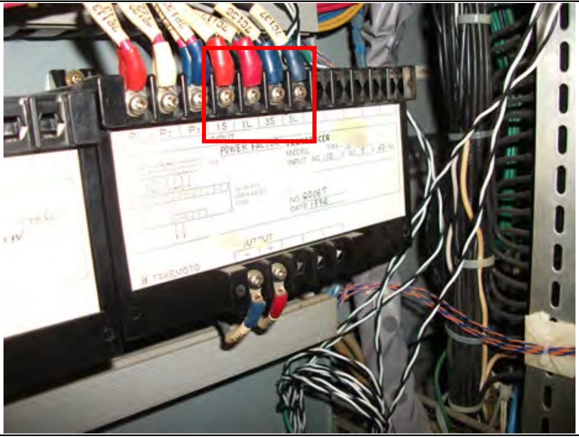
5.1 Wattmeter

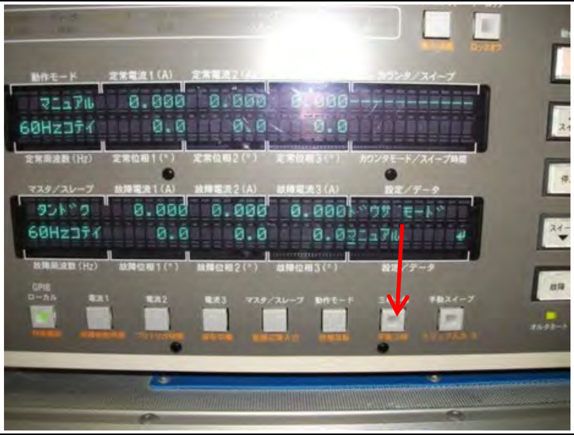
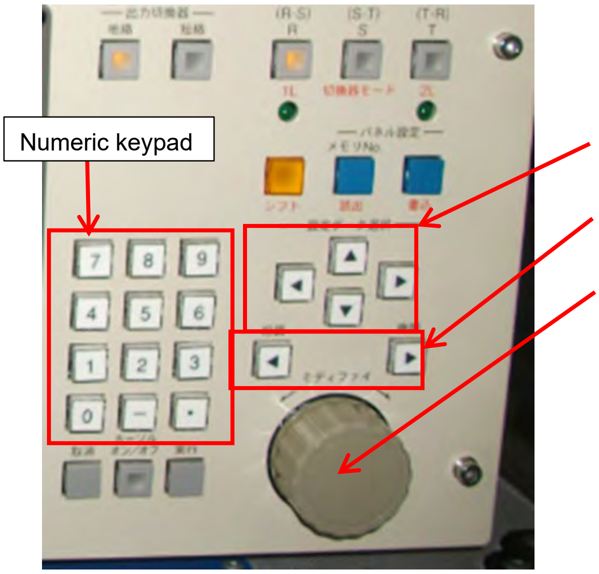
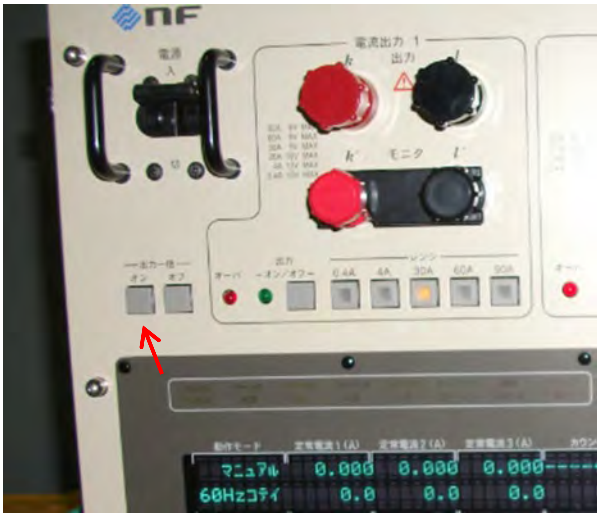
	1. Confirm meter range. Photo shows 0-240 kW Check the CT ratio and VT ratio in the drawing and check for the presence of auxiliary equipment. Photo shows CT ratio 50/5 A VT ratio 6,600/110 V
	2. Disconnect the wire connected to the accessory of the meter on the back or bottom of the panel. Record wire code before disconnecting. Note Check for existence of voltage with a tester beforehand. Beware of electric shock.
	3. Prepare tester. Photo of Current Protective Relay Tester RX4713
	4. Connect the power cable and ground to the tester. Left side of tester

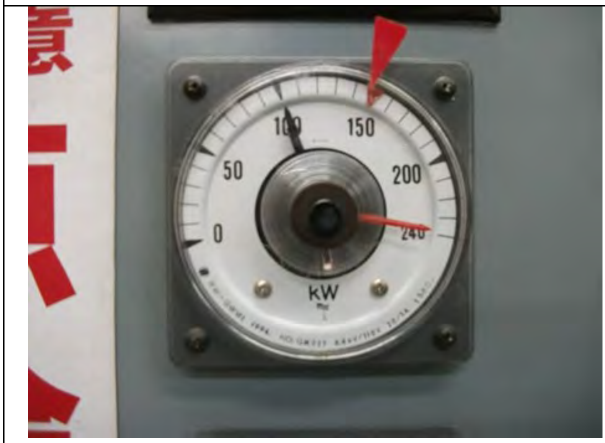
	5. Prepare tester. Photo of voltage protective relay tester RX4718
	6. Connect the power cable and ground to the tester. Left side of tester Connect the power supply input to the power supply output of the Current Protective Relay Tester RX 4713.
	7. The Voltage Protective Relay Tester RX 4718 and the Current Protective Relay Tester RX 4713 are connected by a parallel control cable. Right side of tester
	8 Turn on the tester (Current Protective Relay Tester 4713). Selection dial

	9. Turn on the tester (Voltage Protective Relay Tester RX 4718). Selection dial
	10. Set operation mode of Current Protective Relay Tester 4713 to "manual." Switch with dial 8.
	11. Set the master/slave of Current Protective Relay Tester 4713 to "master." Switch with dial 8.
	12. Set operation mode of Voltage Protective Relay Tester RX 4718 to "manual." Switch with dial 8.

	13. Set the master/slave of Voltage Protective Relay Tester RX 4718 to "slave." Switch with dial 8. Photo of Current Protective Relay Tester RX4713
	14. Check the output range of Voltage Protective Relay Tester RX 4718, and select the 125 V range.
	15. Check the output range of Current Protective Relay Tester RX4713, and select the 30 A range.
	16. Enter voltage and phase in Voltage Protective Relay Tester RX 4718 with numeric keypad. "working voltage 1" 63.5 V "working voltage 2" 63.5 V "working voltage 3" 63.5 V "working phase 1" 0° "working phase 2" 120° "working phase 3" 240°

	17. Lock by pressing "key lock" after entering voltage and phase in Voltage Protective Relay Tester RX 4718 with numeric keypad.
	18. Enter phase in Current Protective Relay Tester RX4713 with numeric keypad. "working phase 1" 0° "working phase 2" 0° "working phase 3" 240°
	19. Connect the electric wire from Voltage Protective Relay Tester RX 4718 to the auxiliary equipment. Auxiliary equipment side, Tester side P1 — U of "Voltage output 1" P2 — U of "Voltage output 2" P3 — U of "Voltage output 3"
	20. Connect the electric wire from Current Protective Relay Tester RX4713 to the auxiliary equipment. Auxiliary equipment side, Tester side 1S — K of "Current output 1" 1L — L of "Current output 1" 3S — K of "Current output 3" 3L — L of "Current output 3"

	21. Press the "three phase simultaneous" switch on the "Current Protective Relay Tester RX4713."
	22-1 Move the screen cursor to "working current 1." Move the cursor Rough and fine range adjustment Selection dial
	22-2 "working current 1" Cursor
	23. Press the "Batch Output ON" button on the "Current Protective Relay Tester RX4713." Note The output of "Voltage Protective Relay Tester RX 4718" also turns on at the same time.

	24. Since "current output 2" will not be used, output is stopped with the "ON/OFF" switch.
	25. Gradually increase "working current 1" and "working current 3." Turn the selection dial to the right to increase current. Turn the selection dial to the left to decrease current. Since the "three phase batch" switch is pressed, "working current 1" and "working current 3" will simultaneously change when turning the dial.
	26. Check (any) 3 to 5 instructions. Voltage is fixed at 63.5V × √3 Photo shows 100 kW instruction, 2.18 A energization CT ratio 50/5 A VT ratio 6,600/110 V Example: 0 A energization, indication 0 kW 1.09 A energization, indication 50 KW 2.18 A energization, indication 100 KW 3.28 A energization, indication 150 KW 4.37 A energization, indication 200 KW 5.24 A energization, indication 240 KW
	27. After confirming instruction, press the "Batch Output OFF" button on the "Current Protective Relay Tester RX4713." Note The output of "Current Protective Relay Tester RX 4713" also turns off at the same time.

19. Meter calibration report

8. Meter calibration test

Power plant Unit

(1) Test Date Weather: Temp: ℃ Humidity: %

Name : Wattmeter	Model :	
Serial No. :	Auxiliary equipment :	
Measurement range : 0 ~ kW	Class :	Year built :

Instrument name	:
Manufacturer	:
Model	:
Serial No.	:
Year built	:
Rating	:

Scale	(kW)					
Input value	(A)					
Measured value	(kW)					
Error	(%)					
Measured value	( )					
Error	(%)					

SPECIAL INSTRUCTIONS:

Tester		Judgement	Good

(2) Test Date Weather: Temp: ℃ Humidity: %

Name :	Model :	
Serial No. :	Auxiliary equipment :	
Measurement range : LEAD 0.5 ～ 1 ～ LAG 0.5	Class :	Year built :

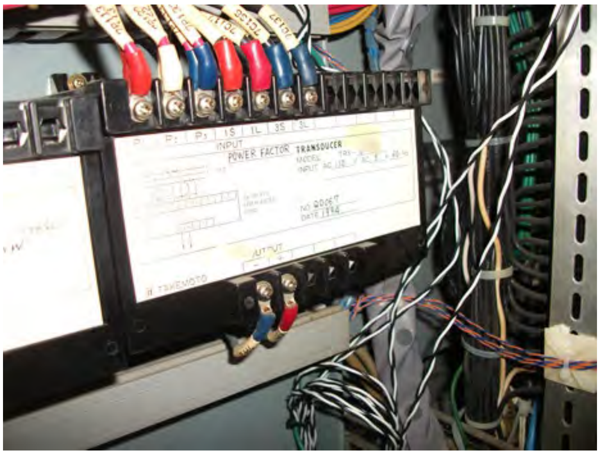
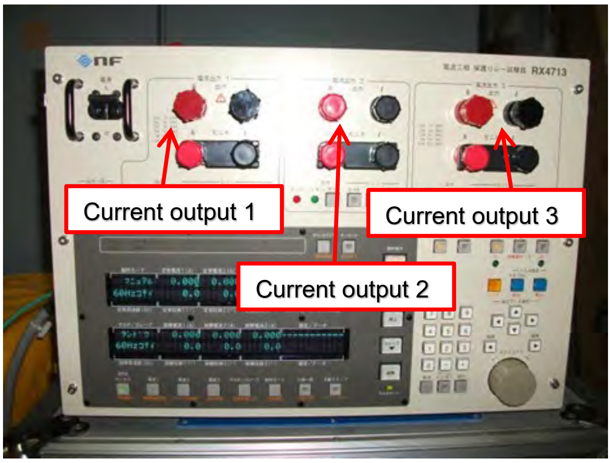
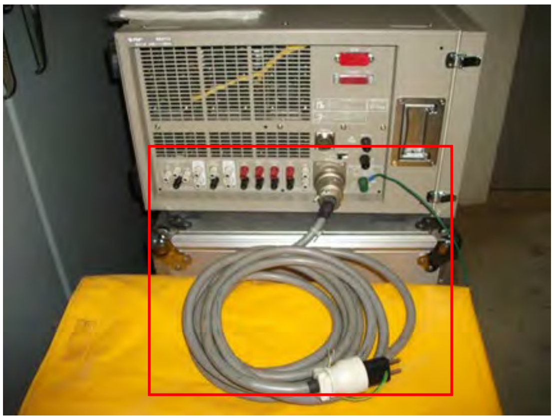
Instrument name	:
Manufacturer	:
Model	:
Serial No.	:
Year built	:
Rating	:

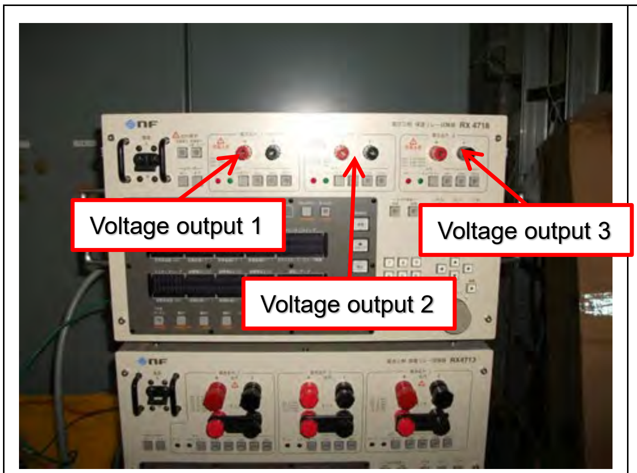
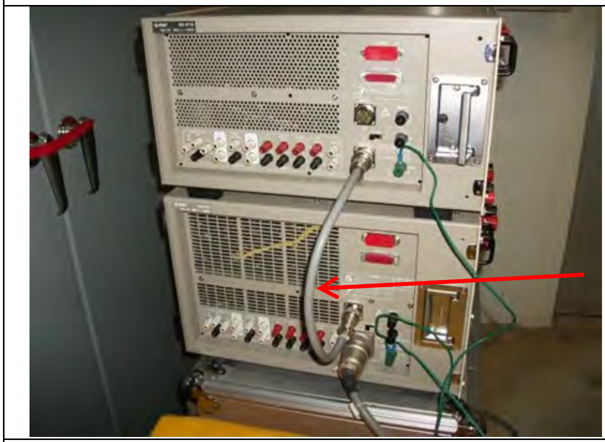
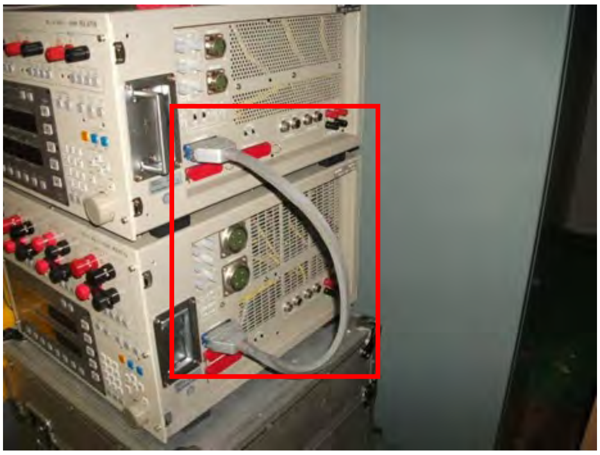
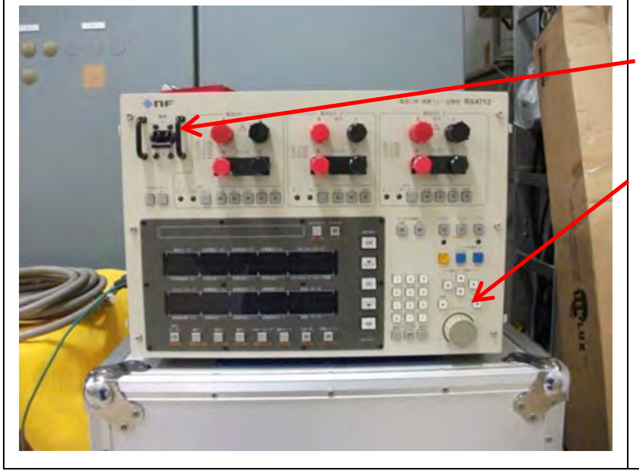
Scale (COSφ)	LEAD 0.50	LEAD 0.866	1	LAG 0.866	LAG 0.50
Input value (COSφ)	-60°	-30°	0	30°	60°
Measured value (COSφ)	LEAD	LEAD		LAG	LAG
Allowable range	LEAD 0.422 ~ LEAD 0.573	LEAD 0.819 ~ LEAD 0.906	LEAD 0.996 ~ LAG 0.996	LAG 0.819 ~ LAG 0.906	LAG 0.422 ~ LAG 0.573
Judgement	Good	Good	Good	Good	Good

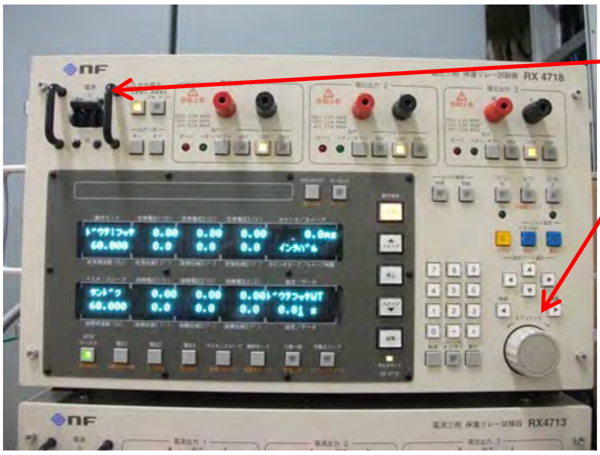
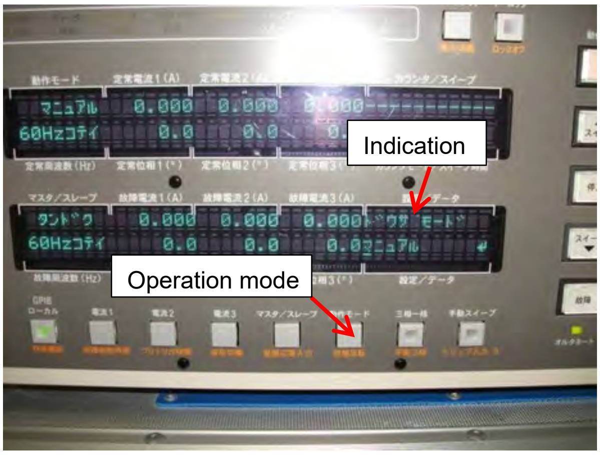
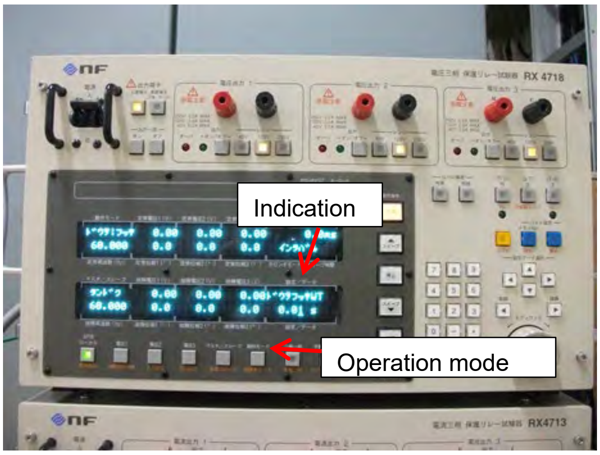
SPECIAL INSTRUCTIONS:

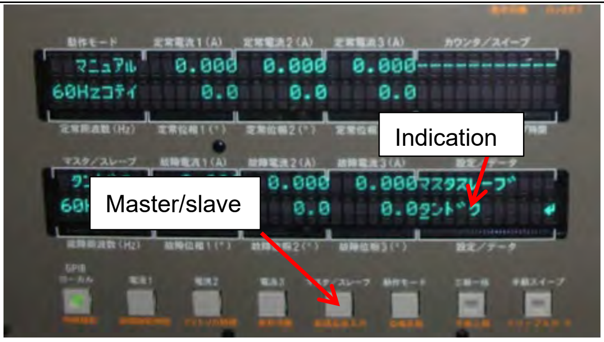
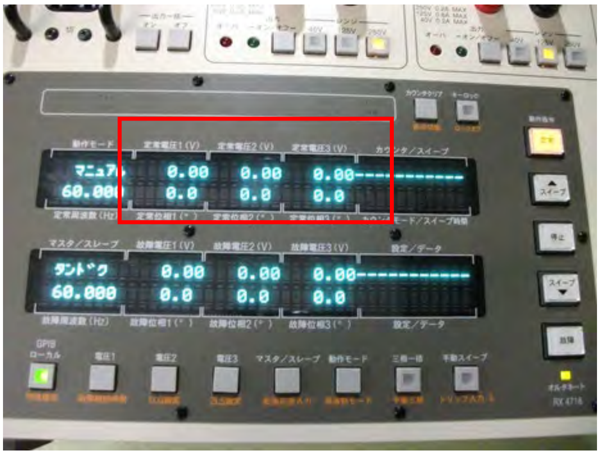
Tester		Comprehensive judgment:	Good

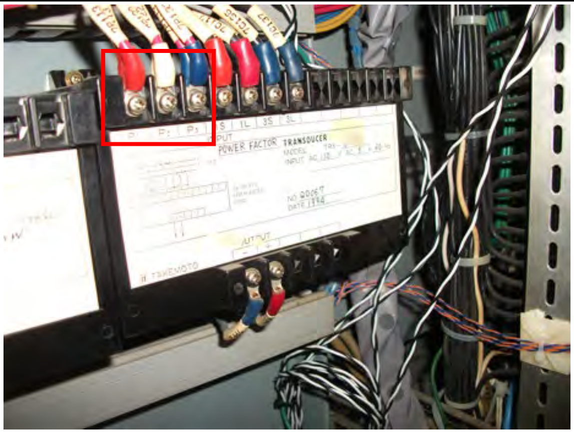
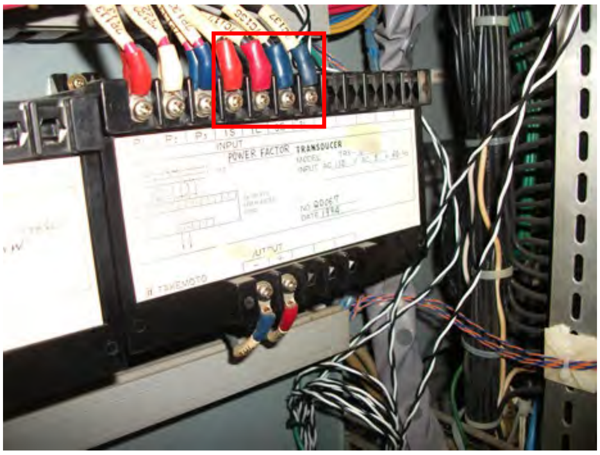
5.2 Power factor meter

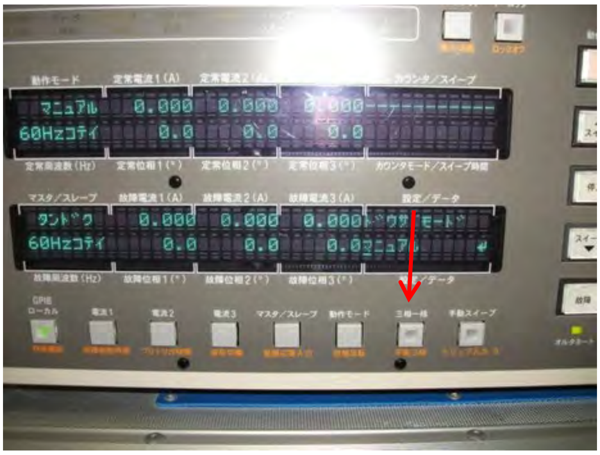
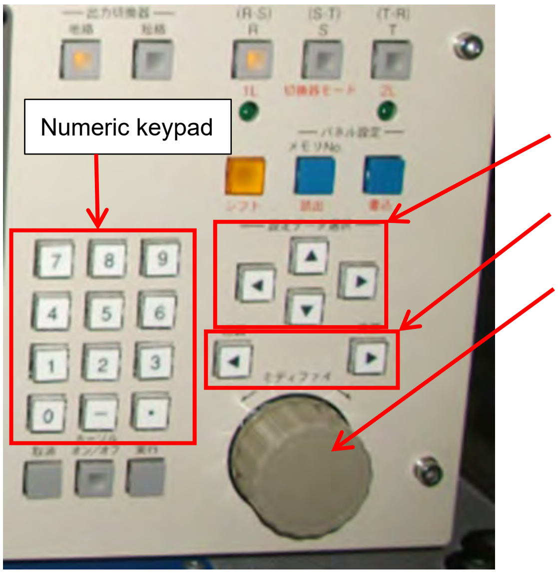
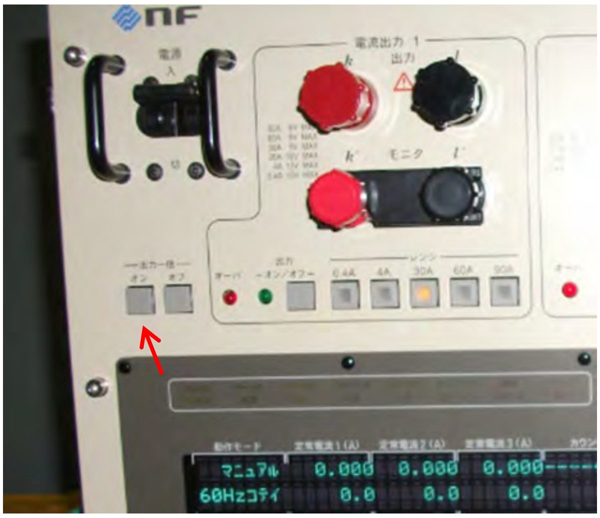
	1. Confirm meter range. Photo shows LEAD0.5~1~LAG0.5 Check the CT ratio and VT ratio in the drawing and check for the presence of auxiliary equipment. Photo shows CT ratio 50/5 A VT ratio 6,600/110 V
	2. Disconnect the wire connected to the accessory of the meter on the back or bottom of the panel. Record wire code before disconnecting. Note Check for existence of voltage with a tester beforehand. Beware of electric shock.
	3. Prepare tester. Photo of Current Protective Relay Tester RX4713
	4. Connect the power cable and ground to the tester. Left side of tester

	5. Prepare tester. Photo of voltage protective relay tester RX4718
	6 Connect the power cable and ground to the tester. Left side of tester Connect the power supply input to the power supply output of the Current Protective Relay Tester RX 4713.
	7. The Voltage Protective Relay Tester RX 4718 and the Current Protective Relay Tester RX 4713 are connected by a parallel control cable. Right side of tester
	8. Turn on the tester (Current Protective Relay Tester 4713). Selection dial

	9. Turn on the tester (Voltage Protective Relay Tester RX 4718). Selection dial
	10. Set operation mode of Current Protective Relay Tester 4713 to "manual." Switch with dial 8.
	11. Set the master/slave of Current Protective Relay Tester 4713 to "master." Switch with dial 8.
	12. Set operation mode of Voltage Protective Relay Tester RX 4718 to "manual." Switch with dial 8.

	13. Set the master/slave of Voltage Protective Relay Tester RX 4718 to "slave." Switch with dial 8. Photo of Current Protective Relay Tester RX4713
	14. Check the output range of Voltage Protective Relay Tester RX 4718, and select the 125 V range.
	15. Check the output range of Current Protective Relay Tester RX4713, and select the 4A range.
	16. Enter voltage and phase in Voltage Protective Relay Tester RX 4718 with numeric keypad. "working voltage 1" 63.5 V "working voltage 2" 63.5 V "working voltage 3" 63.5 V "working phase 1" 0° "working phase 2" 120° "working phase 3" 240°

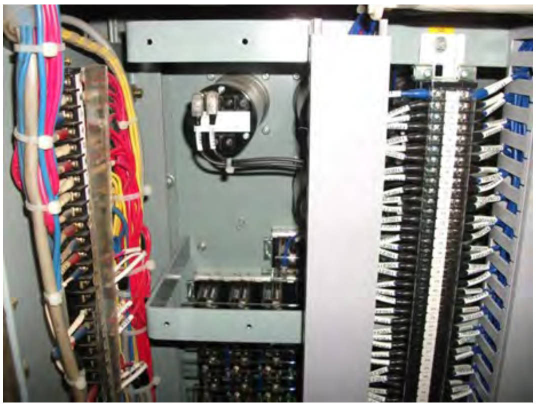
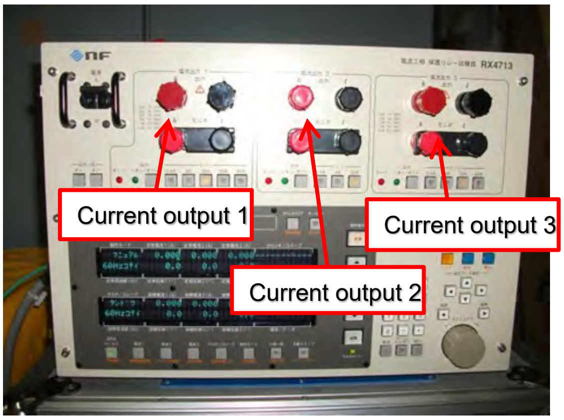
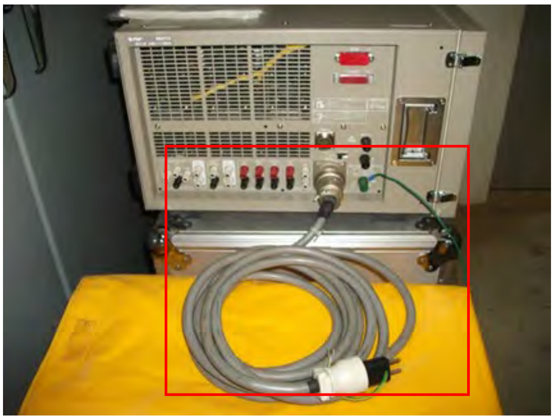
	17. Lock by pressing "key lock" after entering voltage and phase in Voltage Protective Relay Tester RX 4718 with numeric keypad.
	18. Enter phase in Current Protective Relay Tester RX4713 with numeric keypad. "working phase 1" 0° "working phase 2" 0° "working phase 3" 240°
	19. Connect the electric wire from Voltage Protective Relay Tester RX 4718 to the auxiliary equipment. Auxiliary equipment side, Tester side P1 — U of "Voltage output 1" P2 — U of "Voltage output 2" P3 — U of "Voltage output 3"
	20. Connect the electric wire from Current Protective Relay Tester RX4713 to the auxiliary equipment. Auxiliary equipment side, Tester side 1S — K of "Current output 1" 1L — L of "Current output 1" 3S — K of "Current output 3" 3L — L of "Current output 3"

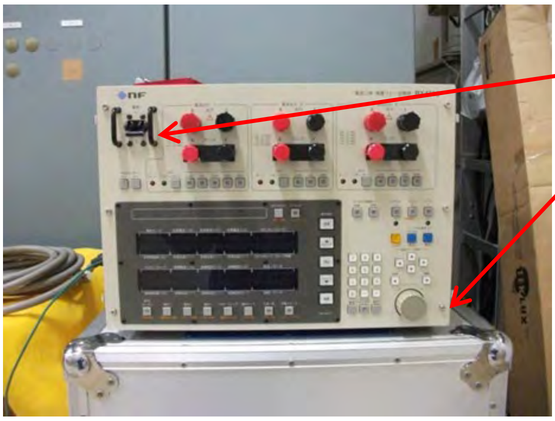
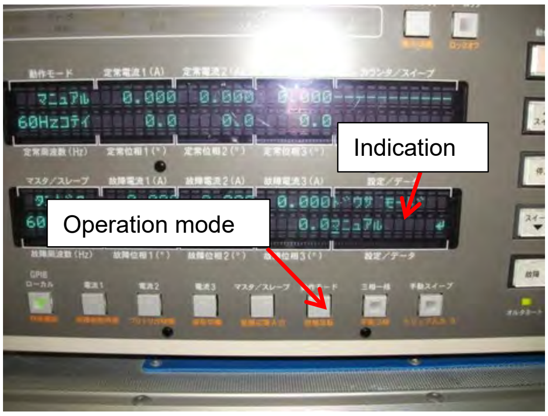
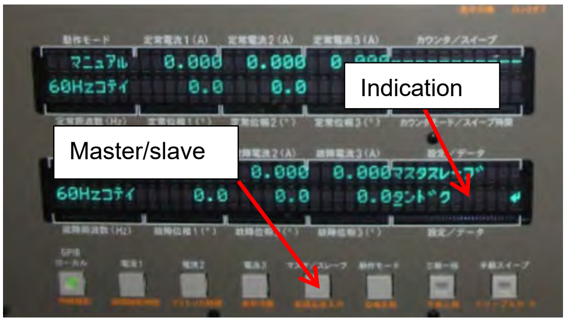
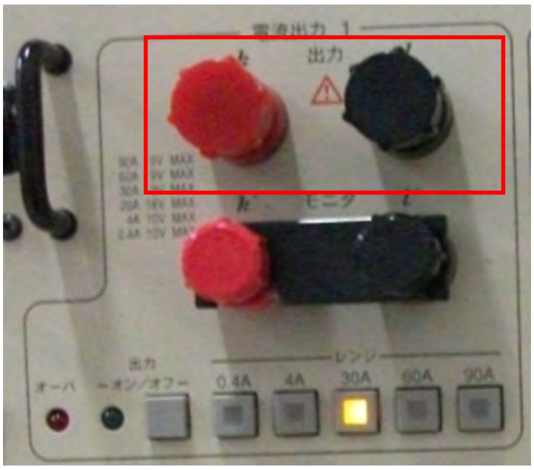
	21. Press the "three phase simultaneous" switch on the "Current Protective Relay Tester RX4713."
	22. Move the screen cursor to "working current 1." Move the cursor Rough and fine range adjustment Selection dial
	22-2 "working current 1" Cursor
	23. Press the "Batch Output ON" button on the "Current Protective Relay Tester RX4713." Note The output of "Voltage Protective Relay Tester RX 4718" also turns on at the same time.

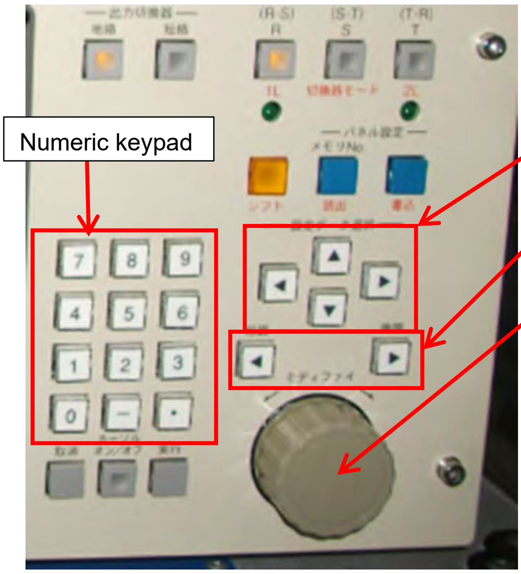
	24. Since "current output 2" will not be used, output is stopped with the "ON/OFF" switch.
	25. Gradually increase "working current 1" and "working current 3" to 3 A. Turn the selection dial to the right to increase current. Turn the selection dial to the left to decrease current. Since the "three phase batch" switch is pressed, "working current 1" and "working current 3" will simultaneously change when turning the dial.
	26. Increase and decrease the phases of "working phase 1" and "working phase 3" and measure. Turn the selection dial to the right to increase current. Turn the selection dial to the left to decrease current. Since the "three phase batch" switch is pressed, "working phase 1" and "working phase 3" will simultaneously change when turning the dial.
	27. Check (any) 3 to 5 instructions. Voltage is fixed at 63.5V × √3 Current is fixed at 3 A Photo shows 1.0 instruction, phase 0° CT ratio 50/5 A VT ratio 6,600/110 V Example: phase 30°, instruction LAG 0.866 phase 60°, instruction LAG 0.5 phase 0°, instruction 1.0 phase -30°, instruction LEAD 0.866 phase -60°, instruction LEAD 0.5

	28. After confirming instruction, press the "Batch Output OFF" button on the "Current Protective Relay Tester RX4713." Note The output of "Current Protective Relay Tester RX 4713" also turns off at the same time.

5.3 Ammeter

	1. Confirm meter range. Photo shows 0-50 A Check the CT ratio in the drawing and check for the presence of auxiliary equipment. Photo shows 50/5A
	2. Disconnect the wire connected to the meter from the back of the panel. Record wire code before disconnecting. Beware of electric shock.
	3. Prepare tester. Photo of Current Protective Relay Tester RX4713
	4. Connect the power cable and ground to the tester. Left side of tester

	5. Turn on the tester. Selection dial
	6 Set operation mode to "manual." Switch with dial 8.
	7 Set master/slave to "stand-alone." Switch with dial 8.
	8 Connect K and L of "Current output 1" to the meter. Note If there are auxiliary equipment, connect them as well.

	9 Check the output range, and select the proper range. Photo shows a range of 30 A
	10-1 Move the screen cursor to "working current 1." Move the cursor Rough and fine range adjustment Selection dial
	10-2 "working current 1" Cursor
	11 Press the output "ON/OFF" switch of "Current Output 1" to output the current.

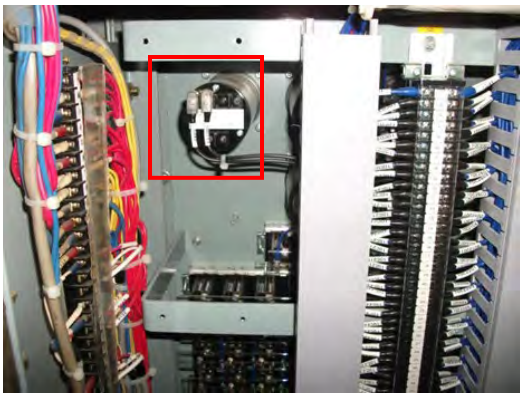
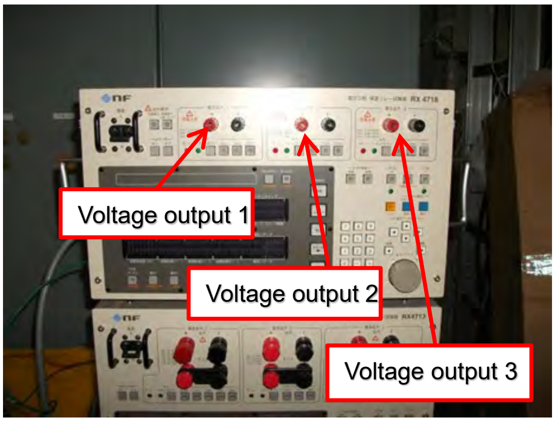
	12 Gradually increase "working current 1." Turn the selection dial to the right to increase current. Turn the selection dial to the left to decrease current.
	13 Check (any) 3 to 5 instructions per 1 A from 0 A to 5 A. Photo shows 40 A during 4 A energization Example: CT ratio 50/5 A 0 A energization, instruction 0 A 1 A energization, instruction 10 A 2A energization, instruction 20A 3A energization, instruction 30A 4A energization, instruction 40A 5A energization, instruction 50A
	14 After measuring up to 5 A, set the current of "working current 1" to 0 A and press the "ON/OFF" switch of "current output 1" to stop current output.

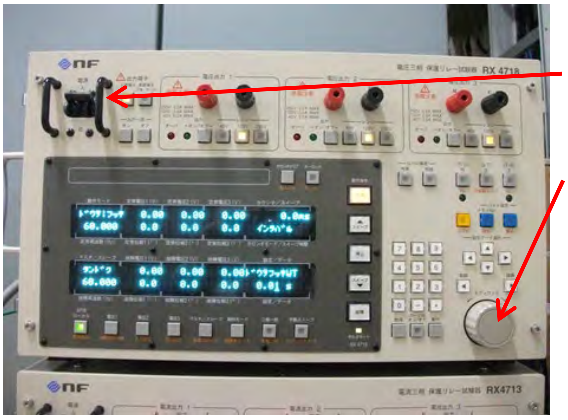
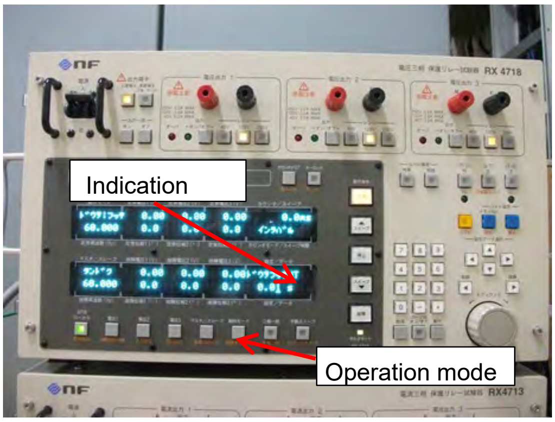
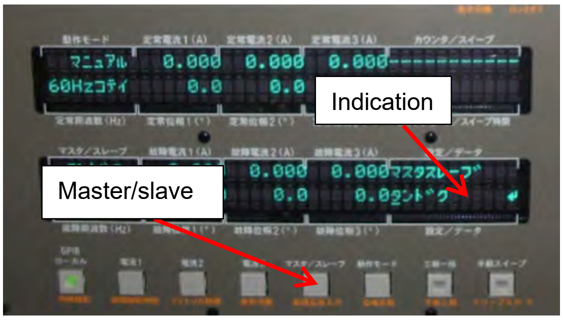
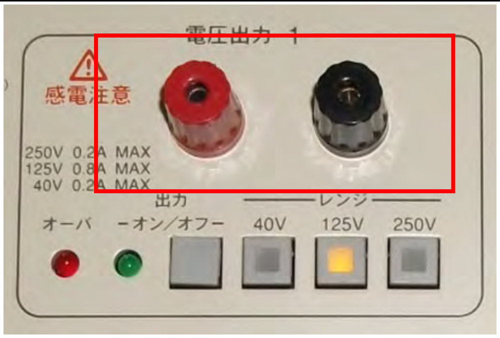
Power plant Unit

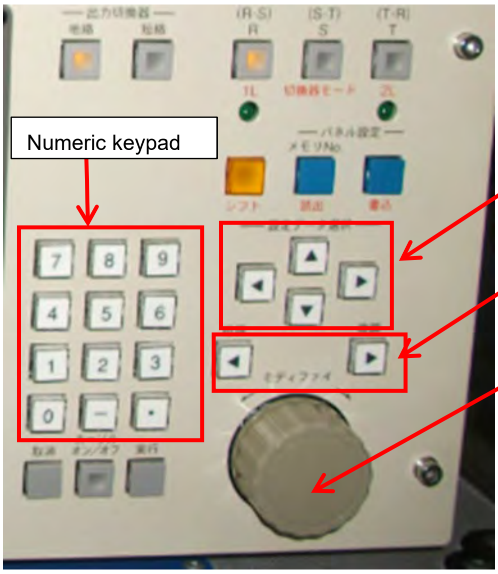
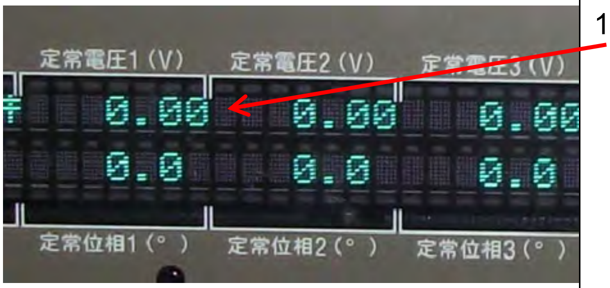
(3) Test Date Weather: Temp: ℃ Humidity: %

Name : Ammeter			Model :		
Serial No. :			Auxiliary equipment :		
Measurement range : 0 ~ A			Class :		Year built :
Instrument name :					
Manufacturer :					
Model :					
Serial No. :					
Year built :					
Rating :					
Scale (A)					
Input value (A)	1	2	3	4	5
Measured value (A)					
Error (%)					
Measured value (A)					
Error (%)					
SPECIAL INSTRUCTIONS:					
Tester				Judgement	Good

5.4 Voltmeter

	1. Confirm meter range. Photo shows 0-9 kV Check the VT ratio in the drawing and check for the presence of auxiliary equipment. Photo shows 6,600/110 V
	2. Disconnect the wire connected to the meter from the back of the panel. Record wire code before disconnecting. Beware of electric shock.
	3. Prepare tester. Photo of voltage protective relay tester RX4718
	4. Connect the power cable and ground to the tester. Left side of tester

	5. Turn on the tester. Selection dial
	6. Set operation mode to "manual." Switch with dial 8.
	7 Set master/slave to "stand-alone." Switch with dial 8. Photo of Current Protective Relay Tester RX4713
	8 Connect U and V of "Voltage output 1" to the meter. Note If there are auxiliary equipment, connect them as well.
	9 Check the output range, and select the proper range. Photo shows a range of 125 V

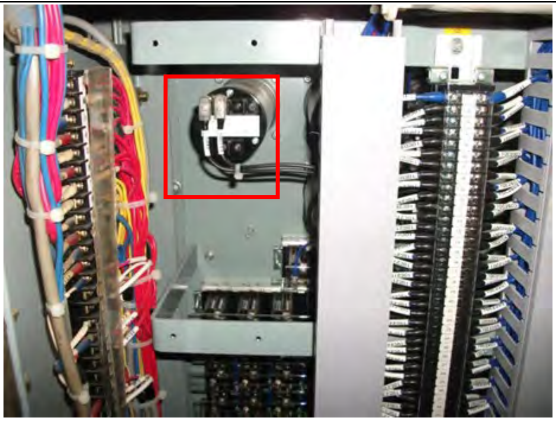
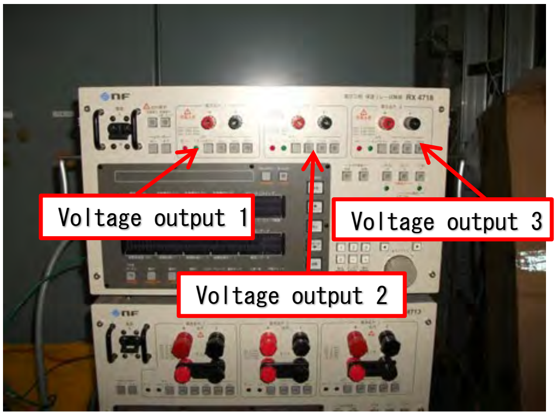
	10-1 Move the screen cursor to "working voltage 1." Move the cursor Rough and fine range adjustment Selection dial
	10-2 "working voltage 1"
	11 Press the output "ON/OFF" switch of "Voltage Output 1" to output the voltage.
	12. Gradually increase "working voltage 1." Turn the selection dial to the right to increase voltage. Turn the selection dial to the left to decrease voltage.

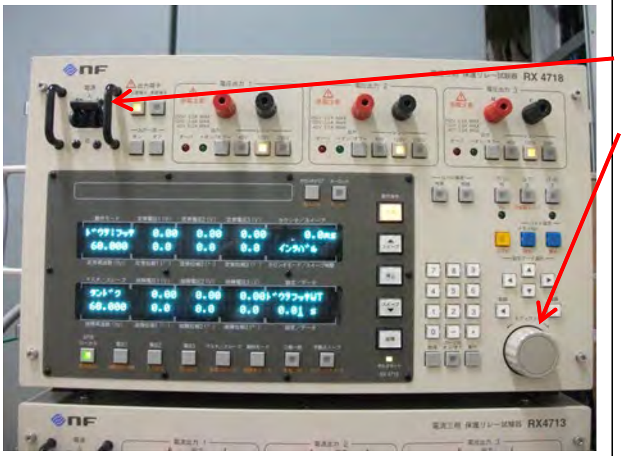
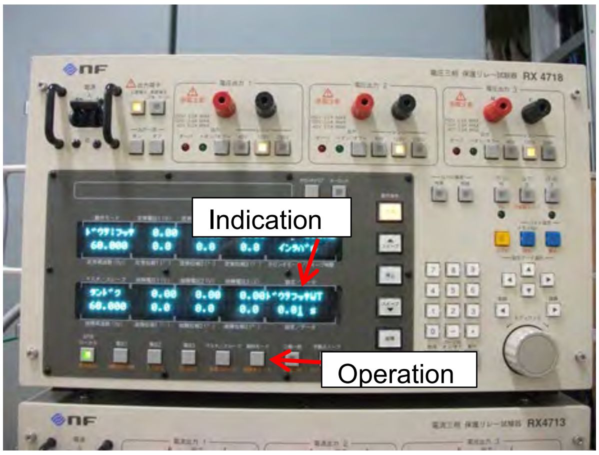
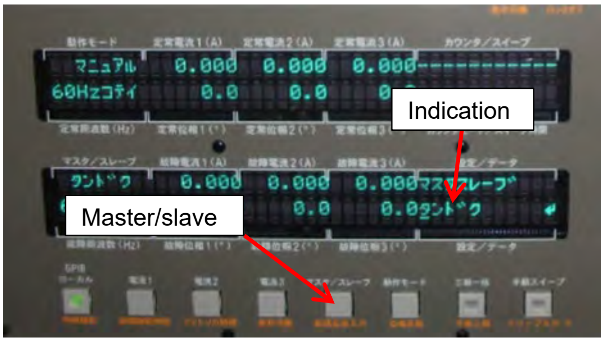
	13 Check 3 to 5 instructions (optional) from 0 V to 100 V. Confirm instructions. Photo shows 6.6 kV during application of 110 V Example: VT ratio 6,600/110 V 0 V application, instruction 0 V 33.3 V application, instruction 2 kV 66.6V application, instruction 4KV Rated 110 V application, instruction 6.6 kV 150 V application, instruction 9 kV
	14 After measuring, set the voltage of "working voltage 1" to 0 V and output "voltage output 1," and press the "ON/OFF" switch to stop voltage output.

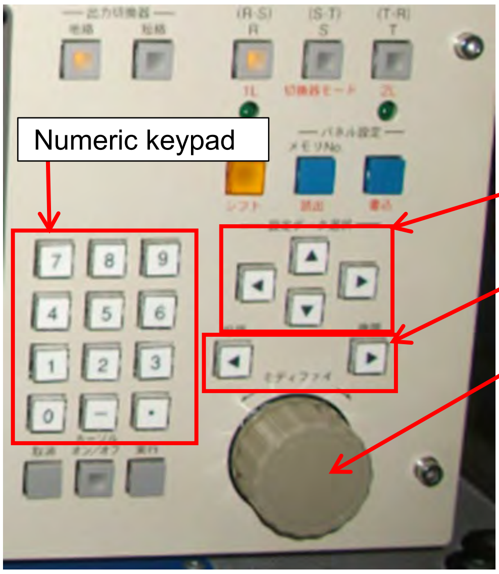
(4) Test Date Weather: Temp: ℃ Humidity: %

Name : Voltmeter			Model :		
Serial No. :			Auxiliary equipment :		
Measurement range : 0 ~ 9 kV			Class :	Year built :	
Instrument name :					
Manufacturer :					
Model :					
Serial No. :					
Year built :					
Rating :					
Scale (kV)					
Input value (V)					
Measured value (kV)					
Error (%)	0.00	0.00	0.00	0.00	0.00
Measured value (kV)					
Error (%)					
SPECIAL INSTRUCTIONS:					
Tester			Judgement	Good	

5.5 Tachometer

	1. Confirm meter range. Photo shows rating of 720 rpm Check the input voltage and frequency in the drawing and check for the presence of auxiliary equipment. Photo shows 720rpm/58.5V
	2. Disconnect the wire connected to the meter from the back of the panel. Record wire code before disconnecting. Beware of electric shock.
	3. Prepare tester. Photo of voltage protective relay tester RX4718
	4. Connect the power cable and ground to the tester. Left side of tester

	5 Turn on the tester. Selection dial
	6 Set operation mode to "manual." Switch with dial 8.
	7 Set master/slave to "stand-alone." Switch with dial 8. Photo of Current Protective Relay Tester RX4713
	8 Connect U and V of "Voltage output 1" to the meter. Note If there are auxiliary equipment, connect them as well.

	9 Check the output range, and select the proper range. Photo shows a range of 125 V
 Numeric keypad	10-1 Move the screen cursor to "working voltage 1." Move the cursor Rough and fine range adjustment Selection dial
	10-2 "working voltage 1"
	11. Press the output "ON/OFF" switch of "Voltage Output 1" to output the voltage.
	12. Gradually increase "working voltage 1." Turn the selection dial to the right to increase voltage. Turn the selection dial to the left to decrease voltage.

	13 Check (any) 3 to 5 indications from 0 rpm to 900 rpm. The instrument in the photo is rated at：720rpm/58.5V Example 0 rpm 0 V application indication 200 rpm 16.25 V application indication 400 rpm 32.50 V application indication 600 rpm 48.75 V application indication 900 rpm 73.13 V application indication
	14 After measuring, set the voltage of "working voltage 1" to 0 V and press the "ON/OFF" switch of "voltage output 1" to stop voltage output.

Power plant Unit

(5) Test Date Weather: Temp: ℃ Humidity: %

Name : Tachometer (in operation)	Model :	
Serial No. :	Auxiliary equipment :	
Measurement range : 0 ~ min^{-1}	Class :	Year built :

Instrument name :

Manufacturer :

Model :

Serial No. :

Year built :

Rating :

Scale (min^{-1})					
Input value (V)					
Measured value (min^{-1})					
Error (%)					
Measured value ( )					
Error (%)					

SPECIAL INSTRUCTIONS:

Tester		Judgement	Good

(6) Test Date Weather: Temp: ℃ Humidity: %

Name : Tachometer (on-site)	Model :	
Serial No. :	Auxiliary equipment :	
Measurement range : 0 ~ min^{-1}	Class :	Year built :

Instrument name :

Manufacturer :

Model :

Serial No. :

Year built :

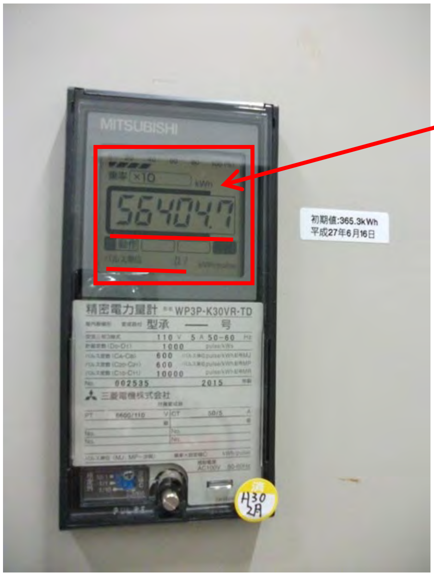
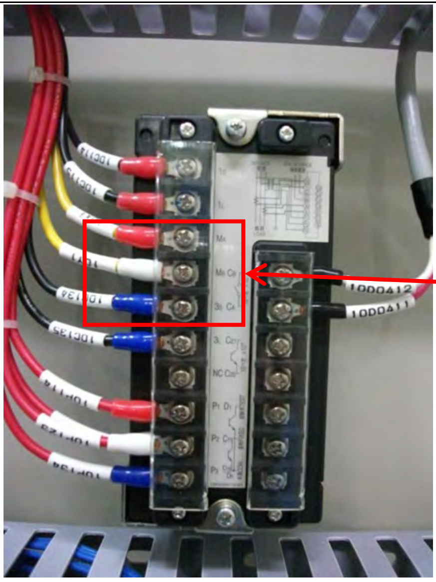
Rating :

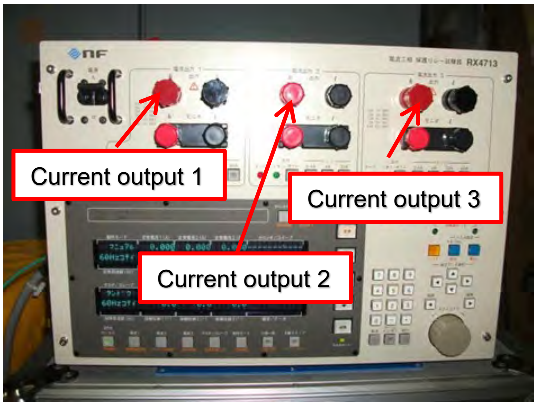
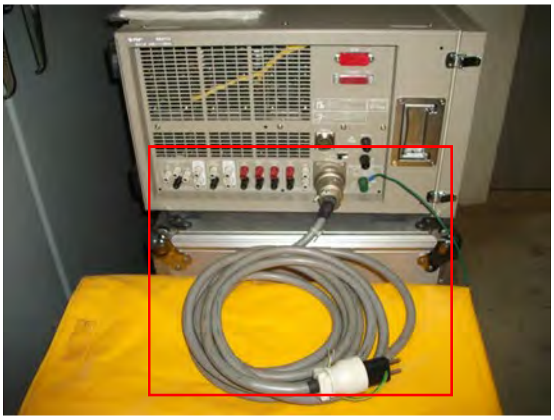
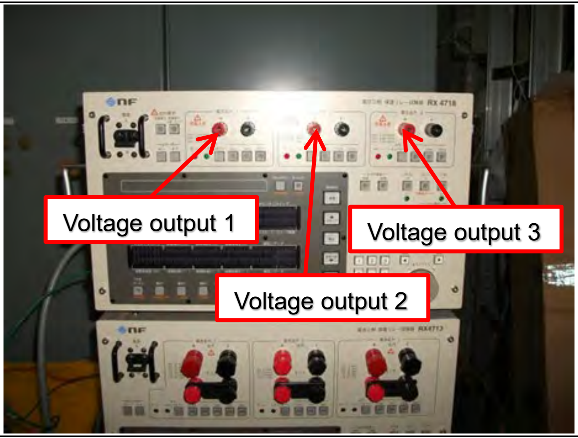
Scale (min^{-1})					
Input value (V)					
Measured value (min^{-1})					
Error (%)					
Measured value ( )					
Error (%)					

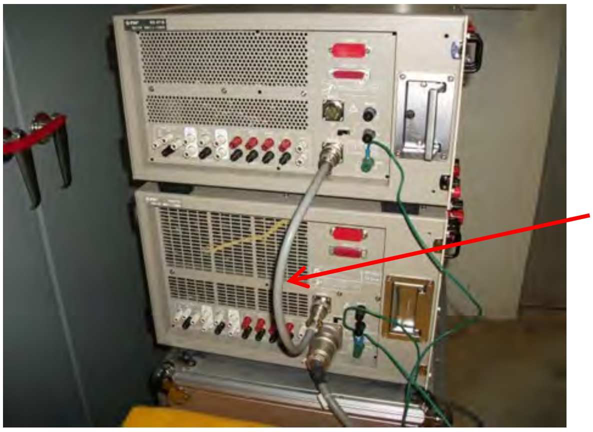
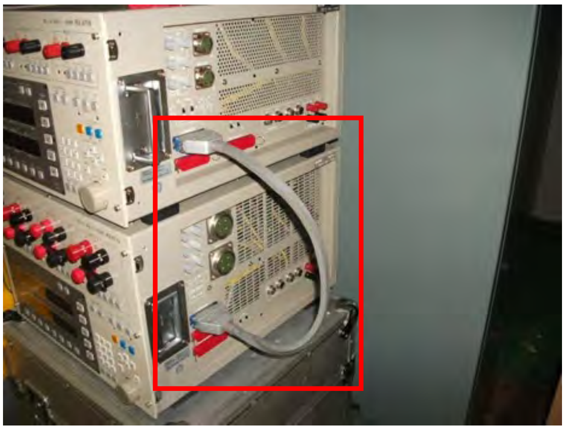
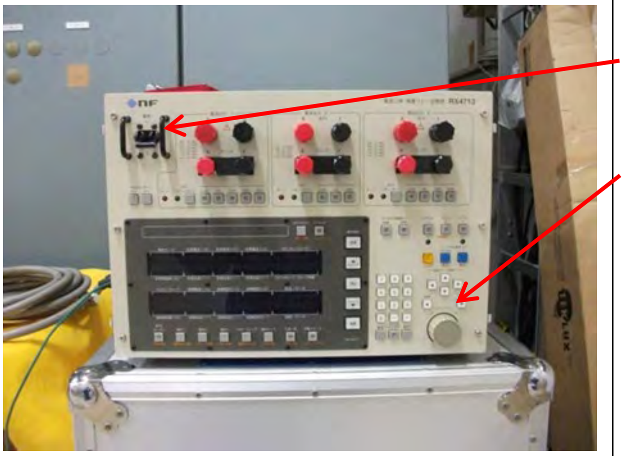
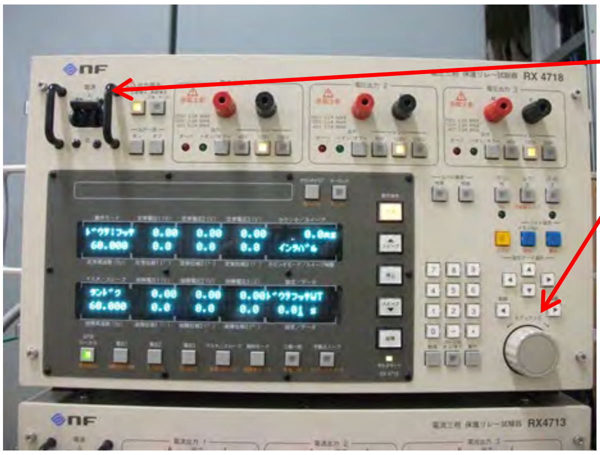
SPECIAL INSTRUCTIONS:

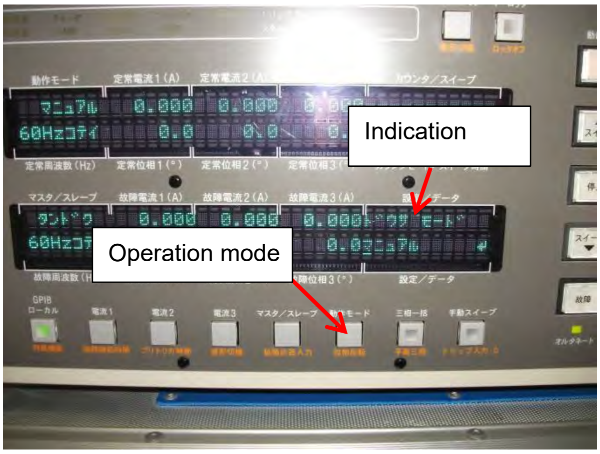
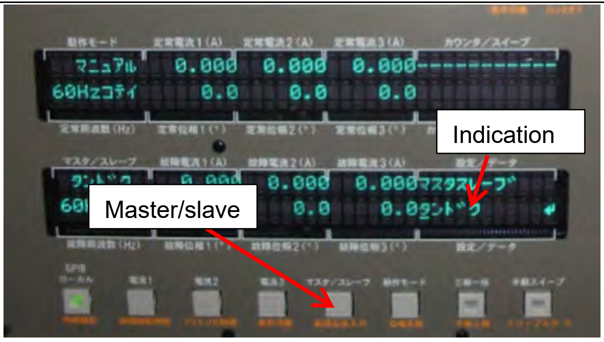
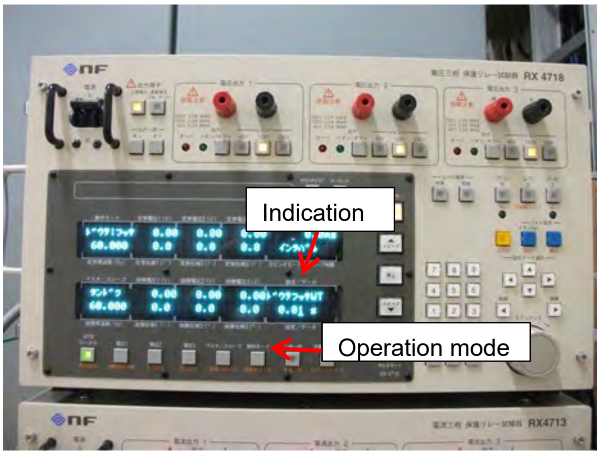
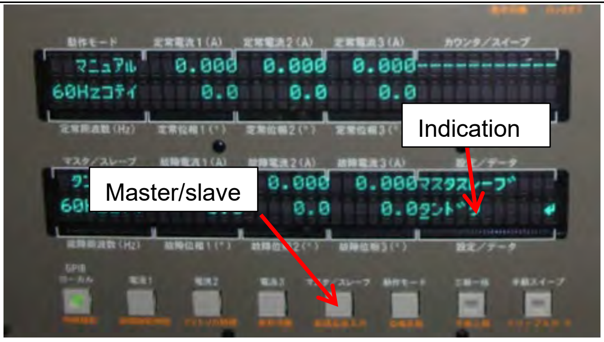
Tester		Judgement	Good

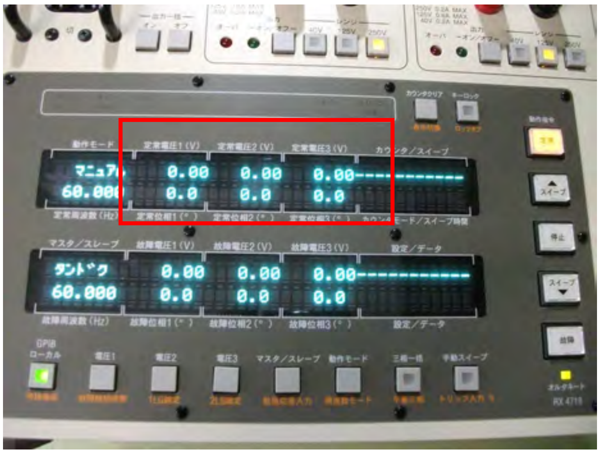
5.6 Integrating wattmeter

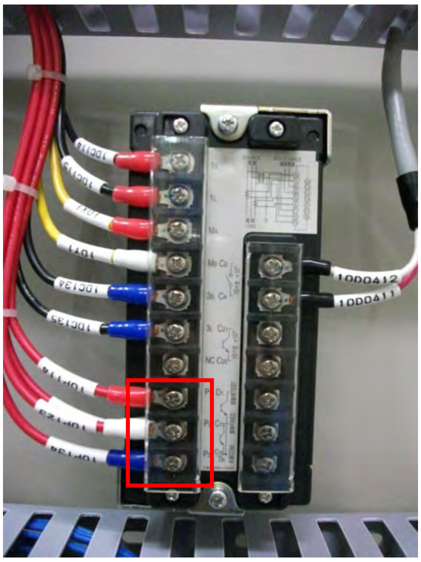
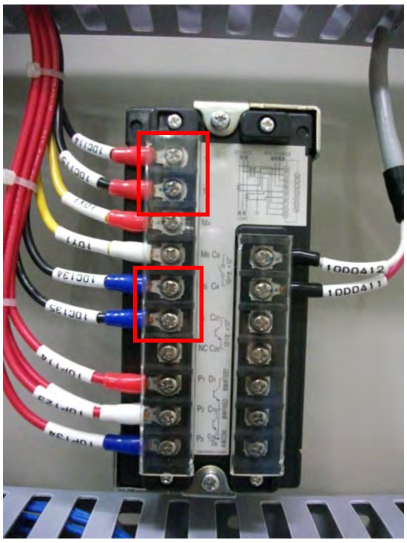
	1. Check the meter's CT ratio, VT ratio, and rating. Check the CT ratio and VT ratio in the drawing and check for the presence of auxiliary equipment. Photo shows 3-phase 3-wire 110 V, 5 A, 50-60 Hz CT ratio 50/5 A VT ratio 6,600/110 V No auxiliary equipment
	2. Record the values before the test. Example Multiplying factor 10 kWh 56404.7 Pulse unit 0.1
	3-1 Disconnect the wire connected to the back of the meter. Record wire code before disconnecting. Note Check for existence of voltage with a tester beforehand. Do not disconnect the MA and MB terminals because they are auxiliary power supplies. Beware of electric shock.

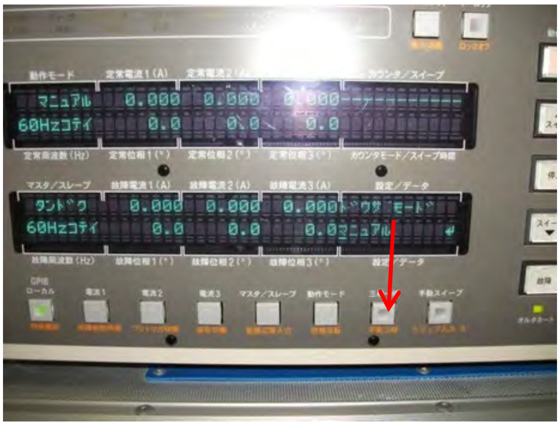
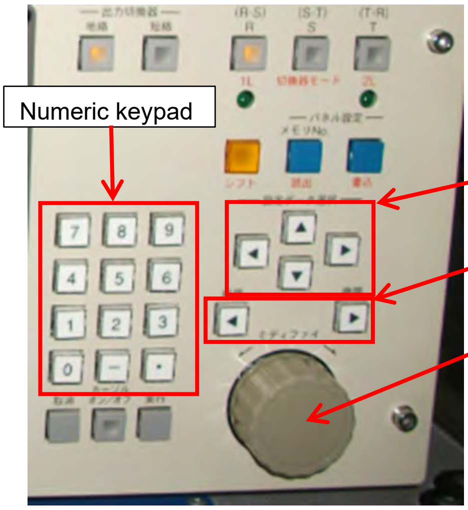
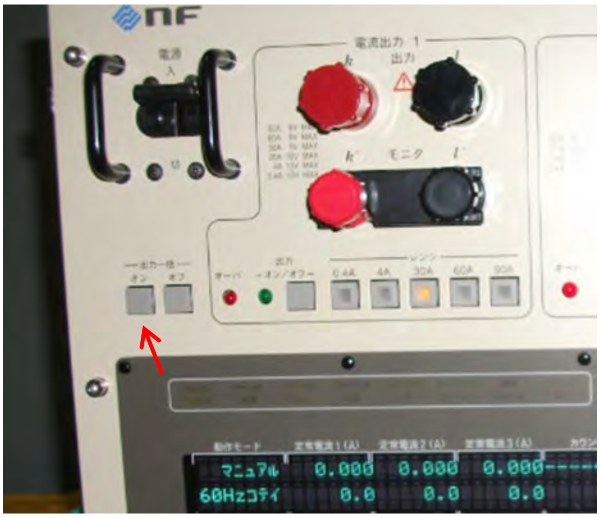
	3-2 Carefully conduct while curing the surrounding with vinyl tape so as not to cause a short circuit or ground fault.
	4. Prepare tester. Photo of Current Protective Relay Tester RX4713
	5. Connect the power cable and ground to the tester. Left side of tester
	6. Prepare tester. Photo of voltage protective relay tester RX4718

	7. Connect the power cable and ground to the tester. Left side of tester Connect the power supply input to the power supply output of the Current Protective Relay Tester RX 4713.
	8. The Voltage Protective Relay Tester RX 4718 and the Current Protective Relay Tester RX 4713 are connected by a parallel control cable. Right side of tester
	9 Turn on the tester (Current Protective Relay Tester 4713). Selection dial
	10 Turn on the tester (Voltage Protective Relay Tester RX 4718). Selection dial

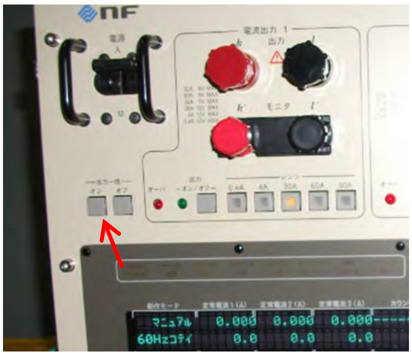
	11. Set operation mode of Current Protective Relay Tester 4713 to "manual." Switch with dial 8.
	12. Set the master/slave of Current Protective Relay Tester 4713 to "master." Switch with dial 8.
	13. Set operation mode of Voltage Protective Relay Tester RX 4718 to "manual." Switch with dial 8.
	14. Set the master/slave of Voltage Protective Relay Tester RX 4718 to "slave." Switch with dial 8. Photo of Current Protective Relay Tester RX4713

	15. Check the output range of Voltage Protective Relay Tester RX 4718, and select the 125 V range.
	16. Check the output range of Current Protective Relay Tester RX4713, and select the 30 A range.
	17. Enter voltage and phase in Voltage Protective Relay Tester RX 4718 with numeric keypad. "working voltage 1" 63.5 V "working voltage 2" 63.5 V "working voltage 3" 63.5 V "working phase 1" 0° "working phase 2" 120° "working phase 3" 240°
	18. Lock by pressing "key lock" after entering voltage and phase in Voltage Protective Relay Tester RX 4718 with numeric keypad.

	19. Enter phase in Current Protective Relay Tester RX4713 with numeric keypad. "working phase 1" 0° "working phase 2" 0° "working phase 3" 240°
	20. Connect the electric wire from Voltage Protective Relay Tester RX 4718. Instrument side, Tester side P1 — U of "Voltage output 1" P2 — U of "Voltage output 2" P3 — U of "Voltage output 3"
	21. Connect the electric wire from Current Protective Relay Tester RX 4713. Instrument side, Tester side 1S — K of "Current output 1" 1L — L of "Current output 1" 3S — K of "Current output 3" 3L — L of "Current output 3"

	22. Press the "three phase simultaneous" switch on the "Current Protective Relay Tester RX4713."
	23-1 Move the screen cursor to "working current 1." Move the cursor Rough and fine range adjustment Selection dial
	23-2 "working current 1" Cursor
	24. Press the "Batch Output ON" button on the "Current Protective Relay Tester RX4713." Note The output of "Voltage Protective Relay Tester RX 4718" also turns on at the same time.

	25. Since "current output 2" will not be used, output is stopped with the "ON/OFF" switch.
	26. Gradually increase "working current 1" and "working current 3" to 3 A. Turn the selection dial to the right to increase current. Turn the selection dial to the left to decrease current. Since the "three phase batch" switch is pressed, "working current 1" and "working current 3" will simultaneously change when turning the dial.
	27. Verify the operation of the instrument. Voltage is fixed at 63.5V × √3 Current is fixed at 3 A Current phase is fixed at 0°, 240°

	28-1. When the numerical value of the instrument changes, press the "Batch Output OFF" button on the "Current Protective Relay Tester RX4713." Note The output of "Current Protective Relay Tester RX 4713" also turns off at the same time. To make it easy to calculate, set the value of the minority first place to 0. 56,404.7→56,405.0 Before test: 56,405.0 (assumed)
	28-2. Press the "Batch Output OFF" button on the "Current Protective Relay Tester RX4713." Note The output of "Current Protective Relay Tester RX 4713" also turns off at the same time.
	29. Press the "Batch Output ON" button on the "Current Protective Relay Tester RX4713." Measure the time with a stopwatch for 30 minutes. Note The output of "Voltage Protective Relay Tester RX 4718" also turns on at the same time.
	30. Since "current output 2" will not be used, output is stopped with the "ON/OFF" switch.

31. After 30 minutes, press the "Batch Output OFF" button on the "Current Protective Relay Tester RX4713."

Note
The output of "Current Protective Relay Tester RX 4713" also turns off at the same time.

32. Record the values after the test.

Note: The values in the photo have not changed, but it is assumed they are changing.
Example
Before test: 56,405.0
After test: 56,411.9 (assumed)
Change 6.9 × (multiplying factor 10) = 69 kWh
Instrument energy reading (1,069 kWh)
Primary side conversion
$\sqrt{3} \times 6{,}600 \times 12 = 137.17$ kWh
30-min. value (standard value)
$137.17 \times (1{,}800 \div 3{,}600) = 68.59$ kWh
Error %
[(Instrument energy reading - standard value) ÷ standard value] × 100
$[(69 - 68.59) \div 68.59] \times 100$
$= 0.598\%$
Instrument error 0.598%

21. Energy meter report

9. Integrating wattmeter test

Power plant　　　　Unit

Test Date	Y/　M/　D	Weather:　Temp:　℃　Humidity:　%
Last test date	Y/　M/　D	Measurer :

(1) Tester specifications

Instrument name	Rating	Year built	Model	Serial No.	Manufacturer

(2) Specifications of device under test

(Control No.: 0908-08014)

Model		Manufacturer	
Serial No.		Year built	
CT ratio	150 / 5 A	Rating	
PT ratio	6600 / 110 V	Accuracy	1.0 Grade

· Rotational speed of device under test (P0) : 500.0

· Rotational speed of standard meter (R) : 497.015

$$\text{Error } \varepsilon = \frac{P0 - R}{R} \times 100 = \frac{500.0 - 497.015}{497.015} \times 100 = 0.6007 \ \%$$

Special Notes: Test power = $\sqrt{3}$ × 110 V × 3 A = 571.577 W was applied and the time to output

50 pulse signals was measured.

Since 1 pulse is 10 kWh, the power of the DUT is 50 x 10 = 500 kWh

Time required for outputting pulse signal 50 times = 28 min 59.1 s (1739.1 s)

Primary side conversion value = $\sqrt{3}$ × 6600 V × 90 A = 1028.8382 kW

$$\text{Standard energy} = 1028.8 \times \frac{1739.1}{3600} = 497.015 \text{ kWh}$$

· Pre-test wattmeter reading = 30770.6 × 100kWh

· After test wattmeter reading = 30775.6 × 100kWh

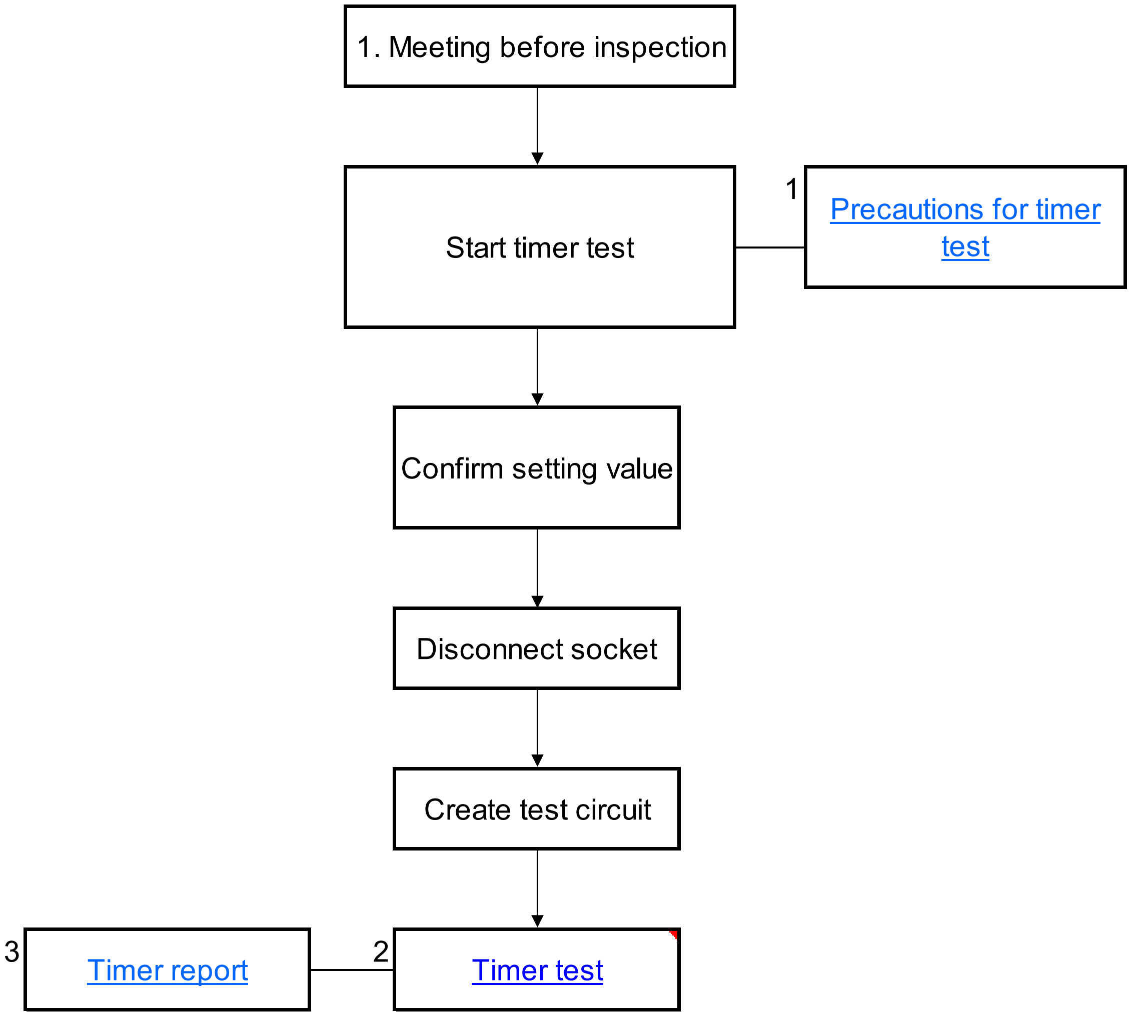
· Change = 5.0 × 100Wh

· Watthour meter reading before regular inspection = × 100kWh

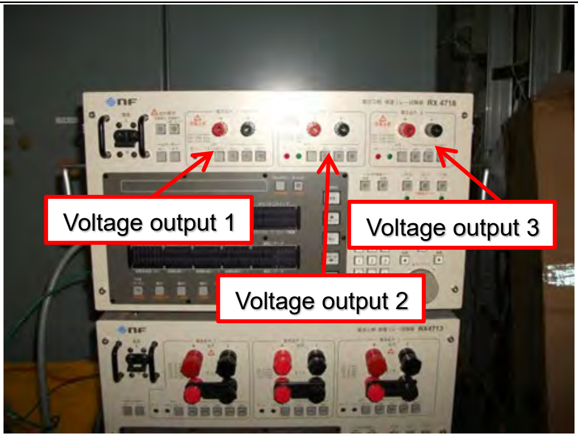
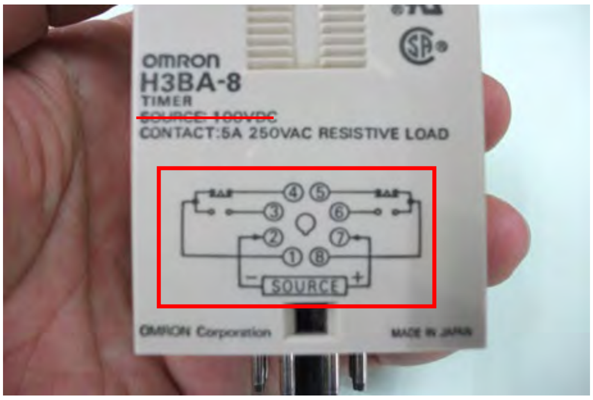
· Watthour meter reading after regular inspection = × 100kWh

Results: Good

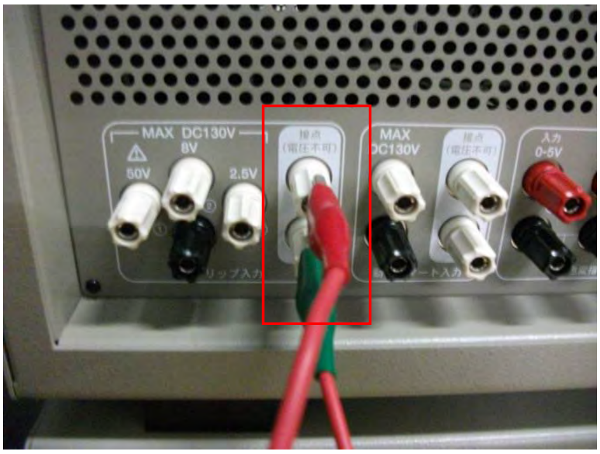
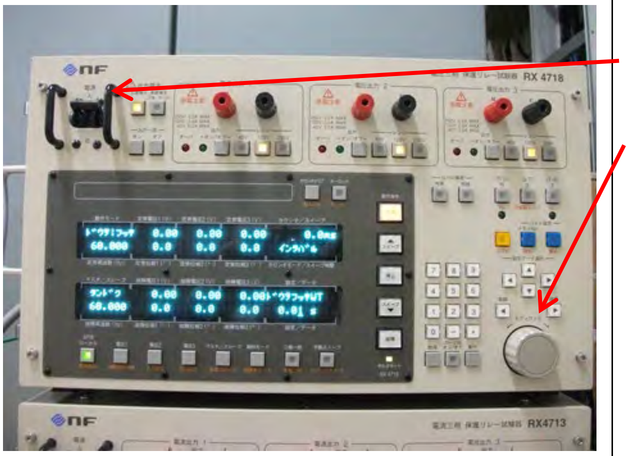
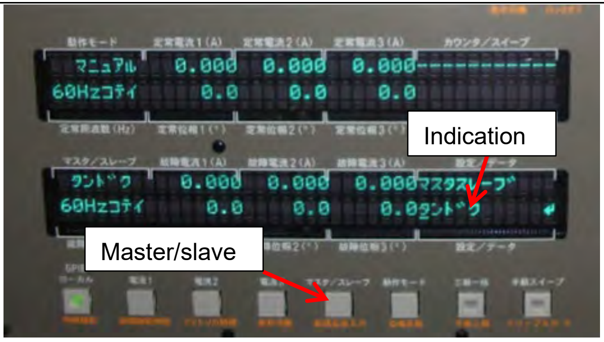
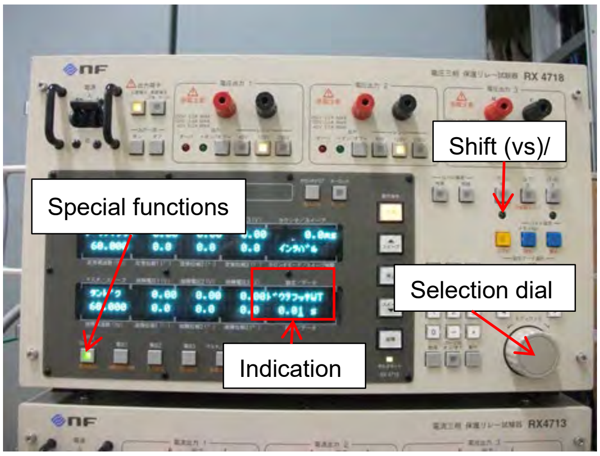
5.7 Timer Test

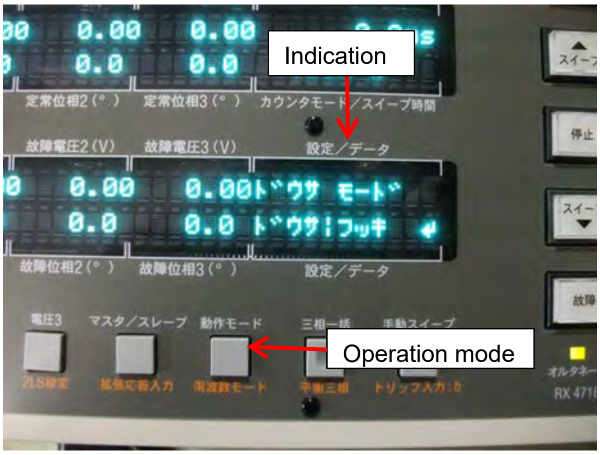
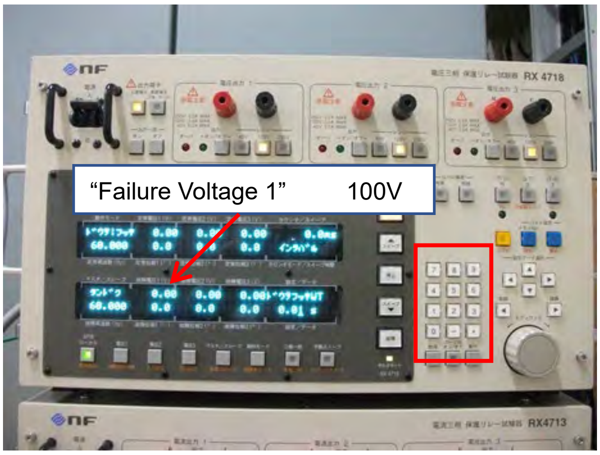


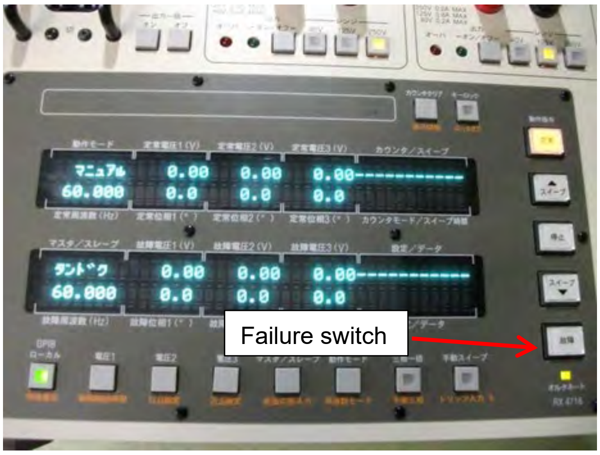
1. Precautions for timer test
    1. Confirm wiring with the sequence diagram.
    2. Record all the codes and numbers of the wires connected to the terminal block of the socket before disconnection. Also, check for any auxiliary equipment.
    3. Confirm and record the settling of the timer.
    4. Cure terminals that are not disconnected, such as control power supplies, with red tape, etc.
    5. Insulate the disconnected terminals.
    6. Put the cover and other items removed in a safe place.
    7. Ensure the output of the power supply, voltage, etc. of the tester is OFF every time.
    8. Confirm the connection of the wire between the tester and timer.
    9. After the test, restore according to the records in 2 at the time of electric wire restoration, and do a final confirmation with drawings, etc.
    10. Beware of short circuit and ground fault.

	1. Prepare tester. Photo of voltage protective relay tester RX4718
	2. Connect the power cable and ground to the tester. Left side of tester
	3. Confirm the settings of the timer. Photo shows 0.5 Unit: min Set to 30 sec due to the above.
	4. Check the timer rating and connection diagram. Control power 100 VDC

	5. Disconnect the timer's socket connection. Note: Record the wire code before disconnecting. Check for existence of voltage beforehand.
	6 Check the socket number.
	7. Connect U and V of "Voltage output 1" on the front of the tester to terminals 7 and 2 of the timer socket. Tester Timer socket U No. 7 （+） V No. 2 （−）
	8. Connect to the contacts on the left side of the tester (no voltage) to terminals 1 and 3 of the timer socket. Once connected, plug the timer into the socket.

	
	9 Turn on the tester. Selection dial
	10 Set master/slave to "stand-alone." Switch with dial 8. Photo of Current Protective Relay Tester RX4713
	11. Set the output waveform of the tester to "+ DC." ① Press shift. ② Press special function. ③ Select waveform switching with the selection dial. ④ Switch waveform to "+ DC."

	12 Set operation mode to "operation restoration." Switch with dial 8.
	13. Check the output range, and select the proper range. Photo shows a range of 125 V
	14-1 Set "working voltage 1” to 0. Enter 100 V for "fault voltage 1" with the numeric keypad. Because the timer rating is 100 VDC.
	14-2 Set to 100V with the numeric keypad.

	15. Press the output "ON/OFF" switch of "Voltage Output 1" to output the voltage.
	16 Press the "failure" switch and measure the operation time and restoration time.
	17 The operation time is displayed in the upper row, and the restoration time is displayed in the lower row. Record the values.
	18 Press the output "ON/OFF" switch of "Voltage Output 1" to stop voltage output. Plug in other timers and test them.

3. Timer report

Power plant Unit

Test Date	Y/ M/ D	Weather:	Temp: ℃	Humidity: %
Tester :				

Instrument name	Manufacturer	Model	Serial No.	Year built	Rating

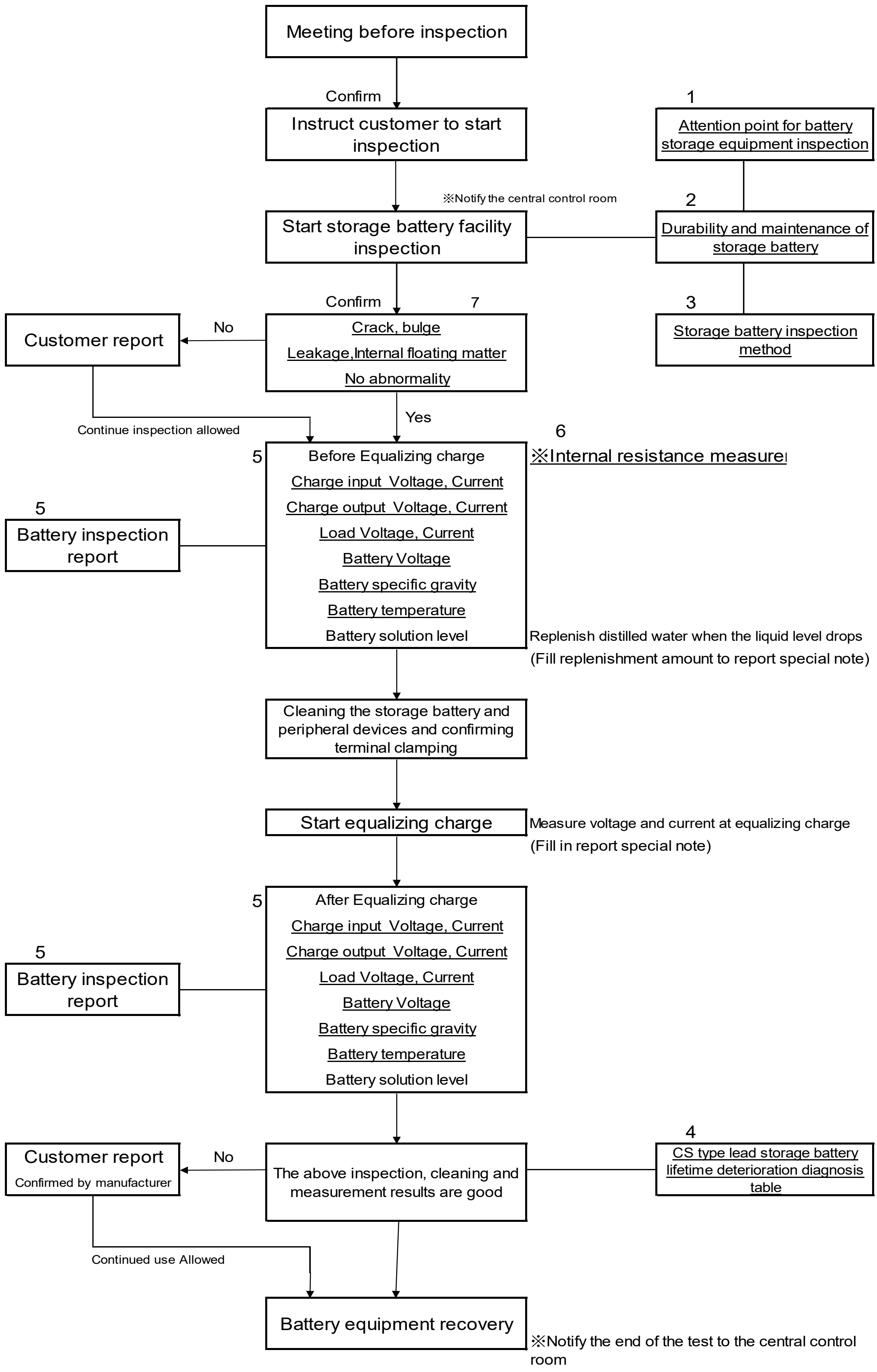
a. Set error → ± 5.0% (ratio of the maximum scale) ± 50 ms or less

Device Name : Solid state timer	Model : H3CR－A8
Manufacturer : OMRON Corporation	Serial No. : —
Year built : —	Rating : 100－240VAC 100-125VDC

Sequence №.	Setting value		Operating value	Error %	Judgment	Max scale		Scale reading	Remarks
63P Q 3X T	1.3 min	78 s	80.36 s	1.31	Good		180 s	1.25 min	
2T		10 s	10.02 s	0.17	Good		12 s	10 s	
14-2X T		9 s	9.21 s	1.75	Good		12 s	9 s	
14-2X T 1		30 s	30.15 s	0.50	Good		30 s	30 s	
48T		20 s	20.17 s	0.57	Good		30 s	20 s	
13T 1		2 s	2.02 s	0.17	Good		12 s	2 s	
41T 1		2 s	2.06 s	0.50	Good		12 s	2 s	
41T 2		10 s	10.21 s	1.75	Good		12 s	9.8 s	
VSRT		2 s	2.07 s	0.58	Good		12 s	1.9 s	
5T		120 s	119.60 s	-0.22	Good	3 min	180 s	2 min	
5T1	10 min	600 s	601.55 s	0.22	Good	12 min	720 s	9.9 min	
5ZT	1.5 min	90 s	88.83 s	-0.65	Good	3 min	180 s	1.5 min	
69WJL3T		10 s	10.16 s	1.33	Good		12 s	10 s	
69WCHLT		10 s	10.07 s	0.58	Good		12 s	10 s	
71T		1 s	— s	—	Good		12 s	1 s	Out of error range (Removed because not in use)
63WJL2T		10 s	9.96 s	-0.32	Good		12 s	10 s	
63WCL2T		10 s	10.07 s	0.58	Good		12 s	10 s	
63QFT		1 s	1.03 s	2.17	Good		1.2 s	1 s	
77T		10 s	10.14 s	1.14	Good		12 s	10 s	
14-1T		1 s	1.04 s	3.08	Good		1.2 s	1 s	
63CT		10 s	10.12 s	1.00	Good		12 s	10 s	
33F1T		5 s	4.98 s	-0.13	Good		12 s	5 s	
33QXT		6 s	5.98 s	-0.17	Good		12 s	5.8 s	
331T		5 s	5.14 s	1.17	Good		12 s	5 s	
33HFT		5 s	5.03 s	0.23	Good		12 s	4.8 s	
33F1HT		5 s	5.01 s	0.12	Good		12 s	4.8 s	

Special Notes:

6. Charger & Battery Test



1. Precautions for Storage Battery Facility Inspection

1. Since storage batteries are low voltage, it is often thought that there is no hazard, but they are dangerous when discharging, so be absolutely sure not to let ground faults and short circuits to occur.
2. Dilute sulfuric acid is used, so take care not to let it come into contact with your clothes and skin, etc. If contact is made, rinse with plenty of water.
3. Since storage battery facilities are used as uninterruptible power supplies, it is necessary to thoroughly understand the drawings and instruction manual to prevent power outage and failures.
4. Cover the tools and materials to be used with insulation tape, etc. when using them.
5. Check the internal condition of the storage battery also by using appropriate lighting, etc.
6. Do not leave tools and materials on the storage battery during breaks and after work is completed.

2. Durability and Maintenance of Storage Batteries

Battery equipment is used for network systems, power sources for operating electrical equipment, emergency power sources for disaster prevention equipment, standby power supplies for communications, etc., so it is important that their functions work properly during power outages of regular power supplies or in the event of an emergency, and high reliability is required.

In addition, for storage batteries to which use chemical reactions, the quality of their maintenance greatly affects performance and life. Here, as a representative model of industrial stationary storage batteries that are mainly used as backup power supply, we describe methods on the market used for the maintenance, inspection, deterioration diagnosis, etc. of lead-acid batteries and nickel-cadmium alkaline batteries (hereinafter referred to simply as alkaline batteries), as well as the durability of the storage batteries.

2.1 Uses of storage Battery

Storage batteries used for emergency power supply and backup power supply mainly use a float charging method or a trickle charging method and are used over a long period of time.

With the float charging method, the storage battery and the load are connected in parallel, and the load power is always supplied while maintaining the storage battery in the fully charged state from the power supply device. The load power is supplied from the storage battery when the regular power supply is lost due to power failure, etc. With the trickle charging method, the power supply circuit to the load and the charging circuit to the storage battery are separated, and the storage battery is maintained in the fully charged state at all times, and power is supplied to the load from the storage battery in an emergency.

The voltage of the cells of a storage battery are low at 2 V for lead-acid batteries and 1.2 V for alkaline storage batteries, so a large number of storage batteries are connected in series to make the voltage suitable for load voltage.

2.2 The role of storage batteries

Storage batteries for emergency power supply and backup power supply always store electrical energy as chemical energy (referred to as charging), and when the regular power source is lost or when an emergency occurs, chemical energy stored in the storage battery is supplied as electrical energy (discharged) to the load.

The role of the storage battery is to supply electric power for a predetermined time to the load (referred to as discharging capacity) when necessary. To fulfill this role, the battery must always be kept fully charged and prepared for the required discharge.

2.3 Maintenance and inspection

A storage battery requiring a predetermined discharge capacity when necessary must be maintained in a sound state of charge, so early detection of abnormalities is important. However, abnormalities of the storage battery during float charging are often not obvious, so they are difficult to detect at an early stage unless maintenance and inspection are performed. Furthermore, by grasping signs of deterioration over time, it is possible to estimate the life span to some extent, and the reliability of the storage battery can be kept extremely high.

In the market, the maintenance and inspection and diagnosis of storage battery facilities comprised of a power supply unit and a storage battery are often performed at the same time.

- Comparison of main items by model

Table 1 shows a comparison of the main items concerning maintenance and inspection for representative models of stationary storage batteries.

Maintenance and inspection items and their reference values

Table 1 Comparison of maintenance and inspection items for stationary storage batteries

		Lead-acid battery			Alkaline batteries *①			
		Vented		*③Control valve method	Pocket type		Sintered	
		CS type	HS type	MSE type	AM type	AMH type	AH type	AHH type
Nominal voltage (V/cell)		2			I. 2			
Capacity indication		10-hour rate			5-hour rate			1-hour rate
Specific gravity of electrolyte (20℃.)		1.215	1.240	Not required	1. 200I I			
Float voltage (V/cell)		2.15	2.18	2.23	1.44	1.42	1.35	
Equalizing charge voltage (V/cell)		2 .3		—	1.63		1.47	
Maintenance	Water refill *②	Once/3-6 months		Not required	Once/6-12 months			
	Frequency of equalizing charge	Once/3-6 months		Not required	Once/6 months			
Expected service life (25℃)		10-14 years	5-7 years	7-9 years	12-15 years			

*①: Float voltage and equaling charge voltage of alkaline storage batteries differ depending on manufacturer.

*②: For catalyst plug type vented storage batteries, water should be replenished once/ 2-3 years. The expected service life of the catalyst plug is 3-5 years.

*③: The expected service life long life valve regulated batteries is 13-15 years, and there are different models depending on manufacturer.

There are differences in alkaline storage batteries, etc. depending on the manufacturer, so please refer to the instruction manual of the corresponding product.

Controlled valve type stationary storage batteries, which have become widely used in the market, require no water replenishment or equalizing charge, and requires much less maintenance as compared with conventional vented stationary batteries, Meanwhile, inspection items such as the inspection of internal parts and solution levels and measurement of the specific gravity of the storage battery have been eliminated, so the number of items used as judgment factors of abnormality and deterioration have been reduced.

2.3.1 Maintenance

Maintenance of stationary storage batteries includes equalizing charge, water replenishment, terminal retightening, and cleaning, and the items specific to storage batteries are explained below.

(1) Equalizing charge

When a large number of storage batteries are connected in series and are used in a charged state over a long period of time, variations occur in the state of charge due to self-discharge of individual storage batteries, etc. In order to eliminate this variation and equalize the state of charge, it is preferable to perform equalizing charge periodically.

(2) Water replenishment

During float charging, water in the electrolytic solution is electrolyzed, and hydrogen gas and oxygen gas are generated as a result. Since this gas is released outside of the cell, the surface of the electrolytic solution is depleted by an amount proportionate to these gases. Water is replenished to make up for this water depletion.

(3) Terminal retightening

The terminals of the storage battery are made of a lead alloy, etc. and are softer than the general steel material, and the tightening torque value is set low. Retightening once a year is advised to prevent loosening of tightening force over time.

2.3.2 Inspection

For the inspection of stationary storage batteries, there is a monthly inspection mainly on panel surface meters and visual inspection, and 6-month and annual inspections where prescribed measurement instruments are used to inspect the condition of each individual battery.

The main inspection items of the 6-month inspection are explained below.

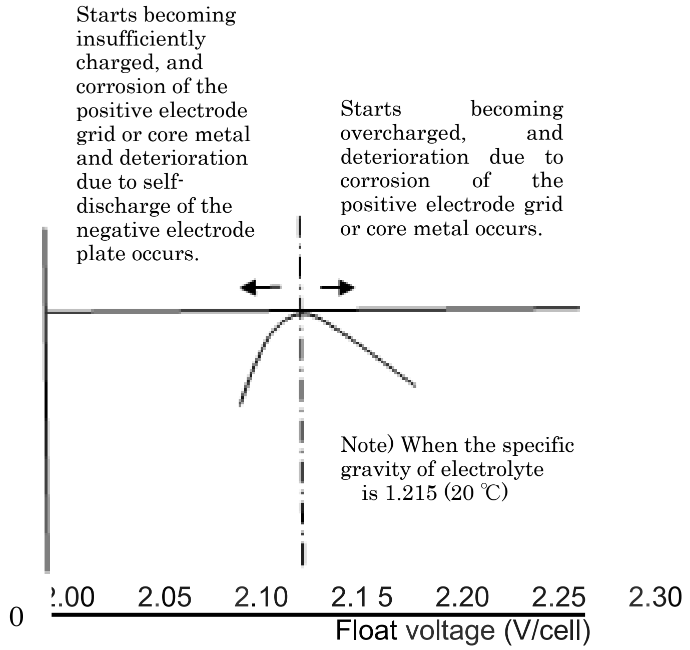


Figure 1 Relationship between float charging voltage and service life

(1) Total voltage during float charging

The total voltage of the battery packs connected in series is measured and checked to determine if it is the specified voltage value. When the total voltage is lower than the specified value, the storage battery becomes insufficiently charged, and sufficient capacity cannot be maintained, so the load cannot be backed up for the predetermined time in some cases.

Conversely, if it is higher than the specified value, the storage battery will be overcharged. When the total voltage is low or when the total voltage is high, if it continues for a long period of time, it leads to deterioration of the storage battery and its life is shortened. Figure 1 shows the relationship between the float charging voltage and the service life of a vented stationary lead-acid battery as an example.

(2) Voltage of all cells during float charging

Measure the voltage of each battery unit during floating charge, and check whether it is within the prescribed range of maintenance. The internal voltage varies from battery to battery due to internal micro short circuits, an increase in self-discharge, an increase in internal resistance, etc.

A single battery that deviates from the prescribed range of maintenance determines that there is an abnormality. If the cause of the abnormality has been found and it was determined that there is no problem in its subsequent use, it may be used as it is. As an example, when one cell in a storage battery comprised of multiple units connected serially is replaced after several years of use, just one new cell may be integrated with the old storage battery group.

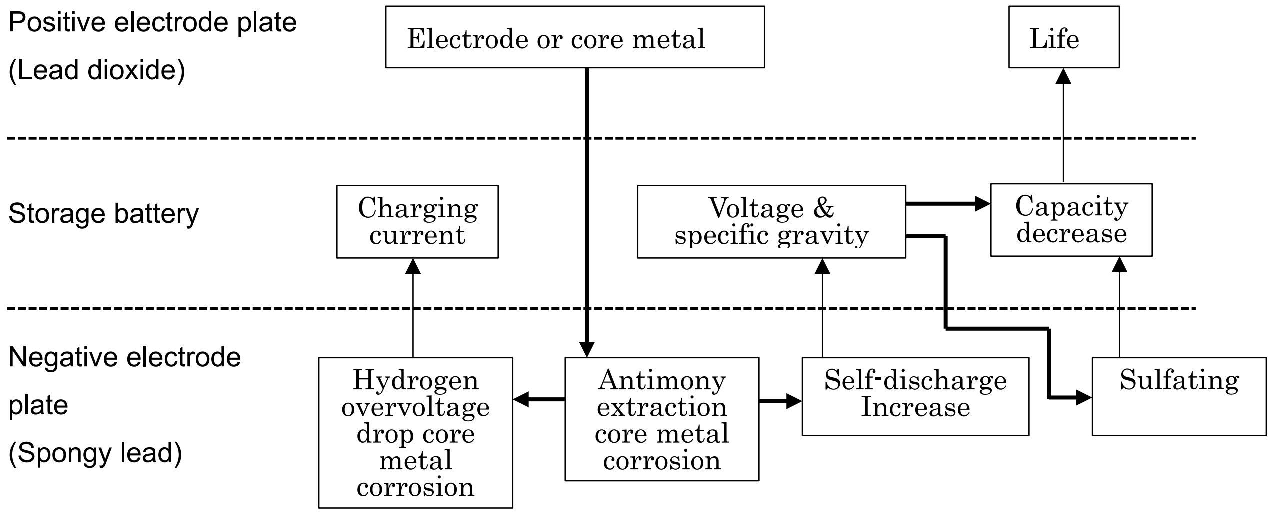


Figure 2 Basic degradation pattern of vented stationary lead storage batteries

In this case, the float charging voltage value may deviate from the prescribed range of maintenance, but there is no problem even if it continues to be used thereafter, and the cause is also clear. If the cause of the abnormality is unknown, or if it is judged that it cannot withstand use, appropriate measures are taken. The storage battery voltage decreases with the progress of degradation. The total voltage during float charging is constant, and the voltage variations from battery to battery become large. As an example, Figure 2 shows the basic degradation pattern of a vented stationary lead-acid battery.

(3) Specific gravity of electrolyte during float charging

For vented stationary lead-acid storage batteries, the electrolyte specific gravity of all cells is measured and checked to determine if is within the prescribed range of maintenance. A single battery that deviates from this range is judged to be abnormal, and it must be investigated in detail. Since the electrolytic solution of the alkaline storage battery is not directly involved in the charge-discharge reaction, it is okay to use only the pilot cell for measuring the specific gravity. In addition, the valve regulated storage battery does not require the item of specific gravity measurement.

(4) Electrolyte temperature, storage battery surface temperature

The electrolyte temperature of vented storage batteries is measured for all cells, and checked to determine whether all the cells are within ±3 ℃ of the average value and not significantly higher than the ambient temperature. In many cases, the workability is good when the measurement of the electrolytic solution temperature is carried out together with the measurement of the specific gravity. For valve regulated lead-acid storage batteries, the surface temperature of the storage battery is measured. When the temperature of all the cells is high, it is conceivable that the charging current is excessive, the charging voltage is excessive, the environmental temperature is excessive, etc. As an example of excessive charging current, it may be caused by the ripple current of the inverter connected in parallel with the storage battery. When the upper side of a specific cell is high, it is determined that the cell is abnormal. If the temperature of a group of cells is high, the ventilation conditions and nearby heat sources are investigated. Temperature is one of the important factors that greatly influences the life of a storage battery, and the service life of a stationary lead-acid storage battery is halved when the average temperature is increased by 10 °C.

(5) Electrolyte level

The liquid level of all cells of the vented storage battery is checked to determine if it is within the standard. In the case where the liquid level of a specific cell is abnormally low, the cell is checked for leaks, etc.

It is predicted that the cause of the slow liquid depletion for all cells include excessive charging current, high setting value for float charging voltage, high environmental temperature, and the presence of defective cells.

For vented lead-acid batteries, as deterioration over time progresses, the rate of liquid depletion decreases, which makes it useful as a diagnosis of deterioration.

(6) Appearance

The electrolytic cells, lids, etc. of the storage battery are check for cracks, deformations, damage, and leaks. For vented storage batteries, further checks for damage of various plugs, packing, and internal parts is performed.

In particular, there has been a case where the electrolytic cells are weak against organic solvents, and vapor of organic solvent from paint on the inside of the battery housing caused the electrolytic cells to crack.

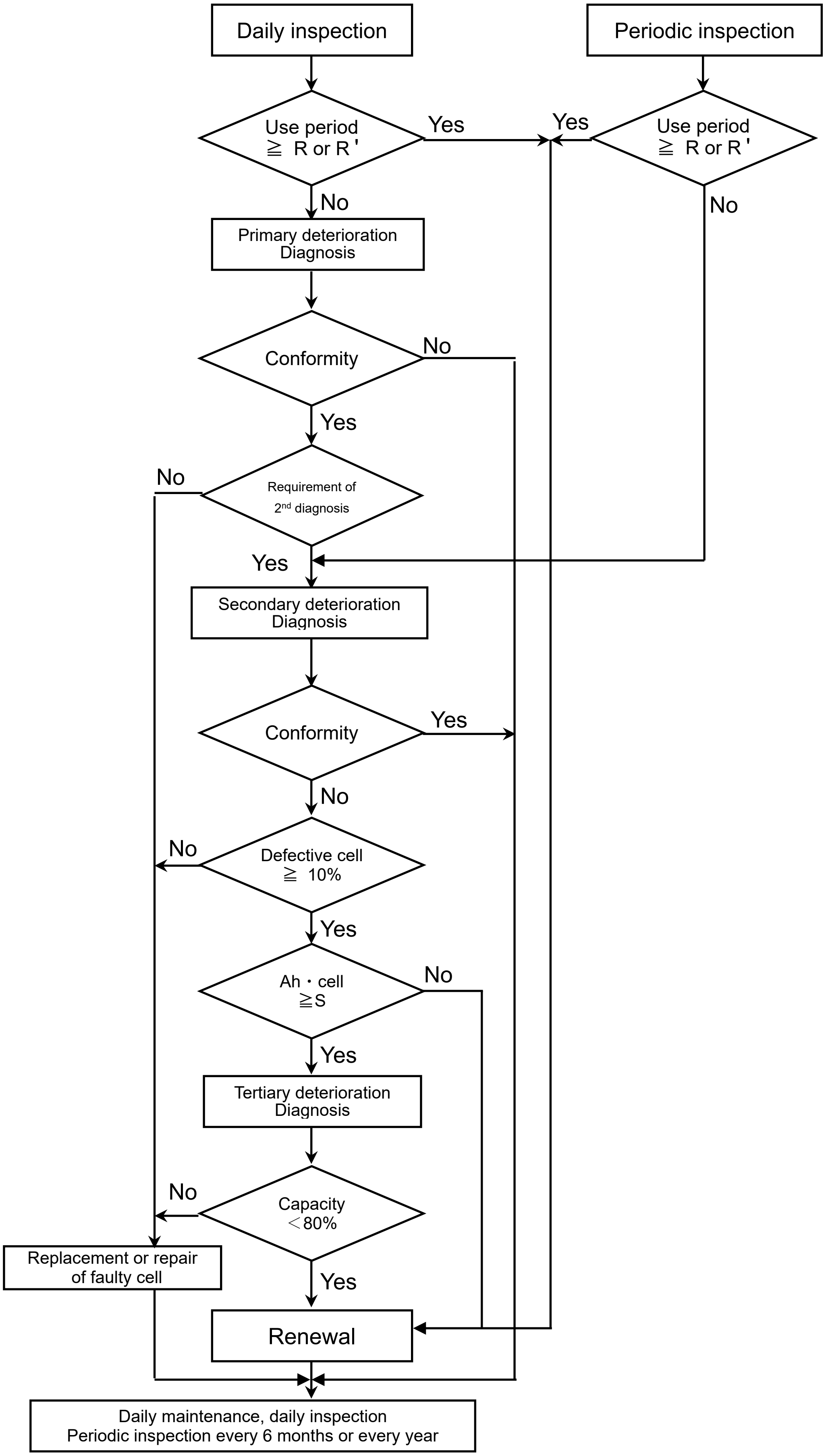
If a solution leak occurs due to a crack in the battery housing, it may cause electric shock and burning of the electrolytic cells due to leakage current, and consequently lead to smoke emission and fire. In addition, the electrolytic solution. could corrode the peripheral equipment.

2.4 Maintenance of storage battery

Preventive maintenance is important for maintaining storage batteries. For preventive maintenance, abnormalities of the storage battery and abnormal state of charge are detected at an early stage through daily maintenance/inspection and corrective measures are taken. In addition, the storage battery components are replaced before they deteriorate.

Figure 3 shows the degradation diagnosis flow as an example of a method for maintenance and degradation diagnosis.

Bad Cell	Those that fall below the allowable lower limit value due to the voltage or specific gravity during defective charging	
Ah/cell	Product of rated capacity and number of cells	
S	Battery size constant	
	Stationary lead-acid battery	15000
	Stationary alkaline storage battery	8000
R	Estimated replacement period	
	HS, HSE type	5 years
	CS type	10 years
	MSE type	7 years
	Stationary alkaline storage battery	12 years
R’	Temperature service life years	
	In particular, it is applied to a valve regulated stationary lead-acid storage batteries which are remarkably affected by temperature. See Figure 4	


Daily inspection
Periodic inspection
Use period
≧ R or R'
Yes
Yes
Use period
≧ R or R'
No
No
Primary deterioration
Diagnosis
Conformity
No
Yes
No
Requirement of
2nd diagnosis
Yes
Secondary deterioration
Diagnosis
Conformity
Yes
No
No
Defective cell
≧ 10%
Yes
Ah・cell
≧S
No
Yes
Tertiary deterioration
Diagnosis
No
Capacity
＜80%
Replacement or repair
of faulty cell
Yes
Renewal
Daily maintenance, daily inspection
Periodic inspection every 6 months or every year

As a result of maintenance, inspection, and deterioration diagnosis, if judged as abnormal, appropriate measures will be taken, but if it cannot be corrected it will be judged as defective.

When the cumulative number of defective cells under the expected service life (battery replacement period) is less than 10% of the total, the defective cells are replaced or small-scale repairs are performed. After the repair, continue performing daily maintenance.

As a result of inspection/diagnosis, if the cumulative ratio of defective cells is 10% or more and less than the constant AH/cell (product of rated capacity and cell number) or less than 80% in the capacity test, a large-scale repair where the storage battery as a whole is replaced is performed.

2.5 Durability of storage batteries

- Battery service life

The service life of stationary storage batteries cannot be decided uniformly because it largely depends on external factors such as manufacturing conditions, usage conditions, maintenance conditions, and so on. When stationary storage batteries are used over a long period of time, in the float charging state or the trickle charging state, the deterioration of the storage battery components progresses, and their capacity decreases. When the capacity of the storage battery decreases and falls to 80% or less of the rated capacity, the capacity decreases at an accelerated rate thereafter, so the service life of stationary storage batteries is generally estimated to be 80% of the rated capacity.

The expected service life of a stationary storage battery refers to the life span as a result of wear and failure on the premise of certain usage conditions and appropriate maintenance conditions.

Figure 4 shows an example of the transition of the number of years in use and capacity.

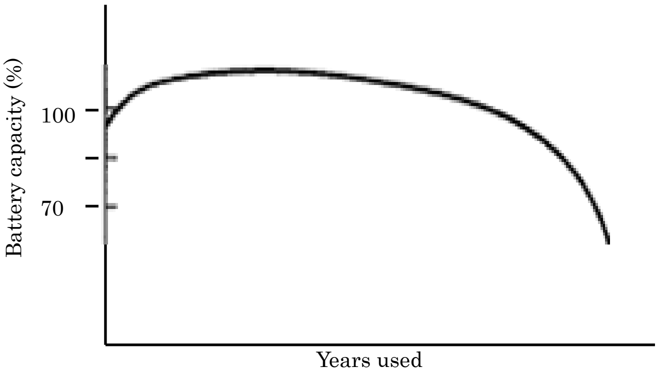


Figure 4 Transition in years of use and capacity

2.6 Deterioration diagnosis of storage batteries

The method of determining the service life of a stationary storage battery can be divided into the following three methods based on judgment accuracy, cost, load usage conditions, etc.

(1) Capacity test method

The deterioration state of the storage battery can be determined by numerical values. In addition, by periodically performing capacity tests, the service life can be estimated. This is the most accurate method for determining service life.

Performing a capacity test is very costly, and depending on the load, the storage battery may not be able to be disconnected. In many cases, several cells are selected from the group of storage batteries to perform a capacity test.

An example of the interior of a storage battery with advanced deterioration is shown in Photo 1.

(2) Daily maintenance/inspection data method

Although less accurate than the capacity test, it can be said that it is sufficient to estimate the service life. This method is widely used for lead-acid storage batteries because it does not require disconnecting the load and costs very little. With valve regulated stationary lead-acid storage batteries, the internal resistance gradually increases with the progress of deterioration. The internal impedance of the storage battery is measured, and the incremental increase ratio of the initial value is taken as one of the criteria for deterioration diagnosis.

The positive electrode plate has no grid strength at all, and if it is touched by hand, it will become deformed.

The negative electrode plate is discolored white due to internal short circuit.

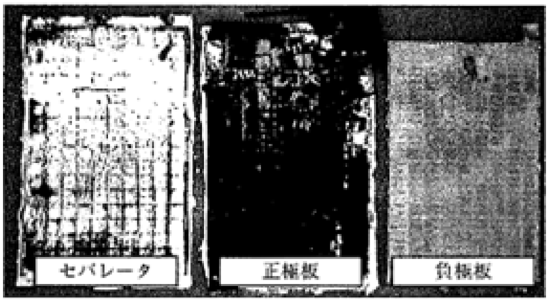


Photo 1 Deterioration inside the battery

(3) Years of use method

Since it does not require much money to determine service life, it is easy to budget replacement. The life of the storage battery differs depending on usage conditions, but in order to ensure reliability, it requires replacement sooner than the average service life. If the replacement timing is delayed, there are cases when the load cannot be backed up when the storage battery has already reached the end of its life.

2.7 Service life and replacement

The capacity of stationary storage batteries decreases with the progress of deterioration. In general, they should be replaced when the prescribed discharge time (backup time) cannot be met by the next inspection.

Generally, it is necessary to determine if replacement of the storage battery is required one to two years before it reaches the end of its lifetime due to factors such as service life determination errors, budgeting, and the delivery date of the replacement battery.

Determination of the life of the storage battery is difficult because it requires deciding on the timing of replacement by predicting the service life.

3. Battery inspection method

<table>
<tr><th>Work Content</th><th>Precautions</th></tr>
<tr><td>Separation
(1) Maintenance (Note 5)
(a) Make sure that surfaces with a door have a space of 0.05 m or more from the other panels, walls, etc. with the door open at 90°.
(b) Open the door within the required range and check whether the door and mounting fixtures make contact with another panel, wall, etc.
(c) Ensure there is enough margins to perform maintenance and inspections by entering the space between the target device and other panels and walls with parts that require withdrawing for maintenance and inspection withdrawn.

(2) Ensure that equipment to which the Fire Services Act and Fire Prevention Ordinance (Fire Ordinance) apply have the following separation.
<table>
<tr><th colspan="2">Parts that must have separation</th><th>Separation</th></tr>
<tr><td rowspan="3">Storage battery (mounted)</td><td>Between columns</td><td>0.6 m or more However, if the height exceeds 1.6 m due to the use of mounting, etc., 1.0 m or more.</td></tr>
<tr><td>Inspection surface</td><td>0.6 m or more</td></tr>
<tr><td>Others surfaces</td><td>0.1 m or more However, excluding between batteries.</td></tr>
<tr><td rowspan="2">Charger</td><td>Operating surface</td><td>1.0 m or more</td></tr>
<tr><td>Inspection surface</td><td>0.1 m or more However, excluding between batteries.</td></tr>
</table>
</td><td>(Note 6)
Excludes self-contained type (package type)</td></tr>
</table>

Parts that must have separation		Separation
Other than cubicle type	Operating surface	1.0m or more
	Inspection surface	0.6 m or more. However, when facing transforming equipment, power generation equipment, power storage equipment, or buildings other than the cubicle type, 1.0 m or more.
	Surface with a ventilation opening	0.2 m or more from the wall *

Storage battery appearance check

Storage battery appearance

(1) Items

(ａ)Electrolytic cell, (ｂ)Lid, (ｃ)Catalyst plug, (ｄ)Each packing (ｅ)Electrode pole, (ｆ)Connection ring (bar), (ｇ)Exhaust vent (corundum), (ｈ)Vent plug, (ｉ)Bolts, nuts, washers, (ｊ)Electrodes in which solution depletion is detected, (ｋ)Temperature sensor, (ｌ)Electrolytic cell and lid sealing part, (ｍ)Exhaust vent (corundum), (ｎ)Terminal/connection ring cover, (ｏ)Number tag

(ｐ)Fire ordinance label

(2) Method

Check by sight, smell, and touch.

(3) Judgement criteria

(a) Check electrolytic cells, lids, catalyst plugs, vent plugs, and electrodes in which solution depletion has been detected for cracks, deformation, fouling, breakage, and leaks or signs of leaks.

(b) Check each packing for cracks, deformations, alterations, leaks or any signs of leaks.

(c) Check connection rings, bolts, nuts, and washers for looseness, corrosion, rusting, discoloration, and heat generation.

(d) Check for looseness in the electrode pole nuts of the alkaline battery.

(e) Check for corrosion, rust and discoloration of the electrode pole.

(f) Check the temperature sensor for cracks, deformation, and breakage

Work Content	Precautions
(g) Check the sealed parts of the electrolytic cells and lids of lead-acid batteries for cracks, bulging, sagging, air bubbles and leaks, and those of alkaline batteries for cracks and leaks. (h) Check the connection wires, electrodes in which solution depletion is detected, and the lead wire of the temperature sensor for cracks, alteration, discoloration, breakage, heat generation, adhesion of electrolytic solution or any such signs. (i) Check terminal covers, number tags, and fire ordinance labels for personnel shortage, cracks, deformation, breakage, and fouling. Inside the storage battery (1) Items (a) Electrode group, (b) Electrolytic solution, (c) Solution level, (d) Strap (power collecting part), (e) Separator (Note 6) (g) Spacer (stiffening plate), (h) Hydrometer and thermometer, (i) Active material drop off the amount (2) Method Check it visually. (3) Judgement criteria (a)Check the straps and electrode poles for corrosion. (b) Check the mounting nuts and bolts of electrode pole/electrode group of alkaline storage batteries for loosening and corrosion. (c)Check spacers for deformation and lifting. (d)Check for deterioration, discoloration, and breakage of the separator. (e)Check the electrode plate for deformation, breakage, and cracks. (Note 7) (f)Check the active material dropout amount indicating large, medium, or small assuming a height of 6 mm or more is large. (g)Check for discoloration, turbidity, and abnormal foaming of the electrolytic solution.	(Note 6) Excludes self-contained type (package type) (Note 7) Exclude deformation for alkaline batteries

Work Content	Precautions
(h)Confirm that the electrolytic solution level is between the highest liquid level and the lowest liquid level. (i)Check for deformation, breakage, and fouling of the hydrometer and thermometer. (j)Check whether the tip of the electrode rod of the electrodes in which solution depletion is detected is near the lowest solution level. Check the cubicle, dolly, and mounting by sight, touch and smell. **Cubicle** (1) Cubicle outer surface (a)Check for deformation and inclination of the box. (b)Check for paint discoloration and peeling, rusting, conspicuous scratches, fouling, and breakage. (c)Check the door, the side plate, the ceiling board, the saddle board, etc. for distortion and depression. (d)Check for squeaking when opening and closing of the door. (e)Check the fixing of the door hinges and check pins to make sure they are not coming out. (2) Inside the cubicle (a) Check for corrosion due to electrolyte leakage, paint discoloration and peeling, rusting, and breakage. (b)Check for missing and loose bolts, nuts, and screws. **Dolly, rail** (a) Check for deformation, inclination, breakage, damage, corrosion due to electrolytic solution leakage, paint discoloration, and peeling, rusting, and fouling. (b) Make sure that the dolly can be drawn out in a level manner and that there is no rattle when drawn out. (c) Check whether the dolly can be withdrawn or inserted smoothly, and whether the ⊕ - lead wire, the lead wire of the electrodes in which solution depletion is detected and the temperature sensor get caught on the dolly or the cubicle, or remain on the storage battery.	

Work Content	Precautions
Frame (a) Check for deformation, inclination, breakage, damage, corrosion due to electrolytic solution leakage, paint discoloration and peeling, rusting, and fouling. (b) Check for loosening of mounting bolts and nuts of columns, beams, upper frame, and upper lateral frame. **Terminal block and relay connector** (a) Check for looseness, corrosion, rusting, discoloration, heat generation, fouling, and breakage. (b) Check whether electrolytic solution is on it or any such signs or possibility. ⊕⊖ Lead wires (c) Check for cracks, deterioration, discoloration, breakage, and heat generation. (d) Check whether stress has been added to the connected terminal. **Anchor bolt** Make sure the anchor bolts are installed, not loose, deformed, or damaged. **Transport and fall prevention frame** (a) Check whether the fall prevention frame is fixed at a height of 1/3 or more from the bottom of the battery and checks whether or not the electrolytic solution level, hydrometer, and thermometer can be seen. (b) Check for deformation, breakage, paint discoloration and peeling, corrosion due to electrolyte leakage or any such signs. **Label, nameplate** Confirm that the fire ordinance label, plant nameplate, rating nameplate, notation nameplate, and other nameplates are installed and not peeled off. **Cushion rubber** Check for misalignment in the installation position, deterioration, discoloration, cracks, breakage, and personnel shortage.	

Work Content

Float charging characteristics

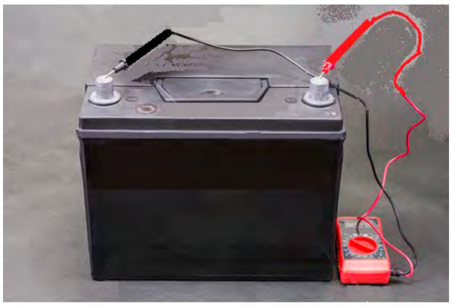
Measurement of float charging voltage of storage battery (Note 8)

(1) Method (Note 9)

(a) Measure the total voltage between the cell No. 1 ⊕ terminal and cell No. 1 ⊖ terminal.

(b) If it is not possible to measure in item (a), measure between the PB and NB terminals of the rectifier.

(c) Measure the voltage of all cells in a single battery.



Judgement criteria

(a) If the total voltage is within 1% of the reference voltage x number of single batteries, the judgment is made using item (b). (Note 10)

(b) The unit cell voltage shall be within the values in the table below. (Note 11)

Type Voltage			Reference value
Lead-Acid	HS , P S (small capacity) PS (190.340)		2.18 V±0.05V (2.13~2.23 V)
	CS P S (excluding 1 9 0. 34 0)		21.5 V±0.05V (21.0~22.0 V)
Alkaline	Pocket	QKC(AM} QSC(AMH) QHC (AH -P)	1.42V±5% (1.35~1.49 V)
	Sintered	QFD(AH-S) Q F W (AHH) QFG (AHH)	1.35V±士 5% (1.28~1.42 V) 1.36 V ±5% (1.29~1.43V)

Measurement of electrolytic solution temperature

(1) Method

Open the vent plug or the catalyst plug, insert the rod-shaped alcohol thermometer or digital thermostat probe into the storage battery solution, and after about 1 minute or more, read the scale of the thermometer. However, for alkaline storage batteries, measure 1 cell for every 10 cells, and measure the temperature of the cell for which specific gravity is measured. (Note 12)

Precautions

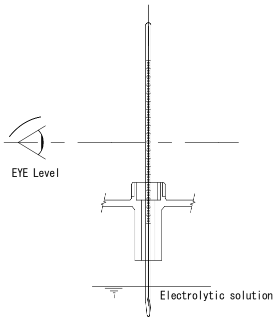
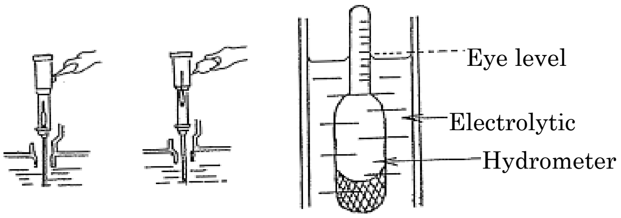
(Note 8) Measure with the voltage stabilized by observing the rectifier output voltmeter.

(Note 9) Beware of poor contact between the measuring rod and the terminal.

(Note 10) Correct when the total voltage deviates from the reference voltage.

(Note 11) Because there are 2.15 V PS (small capacity), it is based on the rating plate of the rectifier.

(Note 12) Do not forget to record the ambient temperature.

Work Content	Precautions
 (2) Judgement criteria (Note 13) (a) 15-35 ° C is preferable, but 45 ° C. or less will suffice. (b) Good if the temperature difference of each cell is within 5 ° C. (c) Good if it is 5 ° C or less from the ambient temperature. Measurement of the specific gravity of the electrolytic solution (1) Method (a) Measure as shown in the figure. However, for alkaline storage batteries, measure one cell for every 100 cells.  (b) Conversion to 20 ℃ specific gravity (Formula) Lead-acid battery S20 = St + 0.0007 (t - 20) Alkaline lead-acid battery S20 = St 0.0007 (t-20) S20: Specific gravity converted to 20 ℃ St: measured specific gravity at t ℃ t: electrolytic solution temperature at the time of measurement (2) Criteria (Note 14, 15, 16) (a) When the electrolytic solution level is between the maximum level and the intermediate level, the judgment is made using item (c).	(Note 13) When 45 °C or higher and when the storage battery electrolytic solution temperature exceeds the ambient temperature by 5 ° C or more, check for charging/discharging, float/equalizing charging voltage and current, etc. (Note 14) It is acceptable if within the range of the maximum value ± 0.015 in the case of a lead-acid storage battery with an equalizing charge voltage of 2.3 V/cell.

Work Content

(b) Measured values at the electrolytic solution levels other than item (a) are reference values.

(c) Specific gravity of the electrolytic solution shall be within the value in the table below.

Type Voltage		Reference value 20 ℃ converted specific gravity
Lead-Acid	HS , P S (small capacity） PS (190.340)	1.240 ±0.010 (1.230 ~ 1.250)
	CS P S (excluding 1 9 0. 34 0）	1.215 ±0.010 (1.205 ~ 1.225)
Alkaline	QKC(AM} QSC(AMH) QHC (AH -P) QFD(AH-S) Q F W (AHH) QFG (AHH)	1,170 ~ 1.230

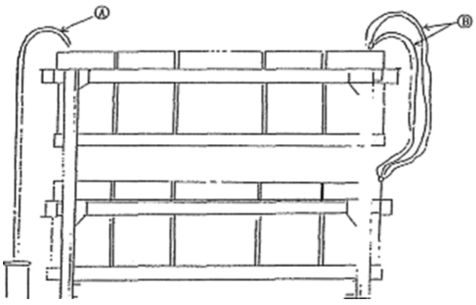
Method of measuring float charging current

Since it cannot be measured with the storage battery ammeter of the rectifier, measure with a clip-on ammeter.

(a) How to use the clip-on ammeter is based on the usage method indicated on the back of the lid of the instrument container.

(b) Measure the part by attaching a clip to the storage battery connection lead wire. (Measuring point A) However, when the lead wire is large and a clip cannot be attached, measure it with an intermediate jump wire (paralleled with 2-4 wires.) to obtain the composite value for the currents of each line. (Measuring point B)

(Example)



Precautions

(Note 15) If negative, check the maintenance status and for the presence of discharge.

(Note 16) Increase/decrease in specific gravity value due to increase/decrease in solution level shall be a change of 0.1 point as a reference value.

Work Content	Precautions
(c) To measure the AC component for CVCF, etc., set the clip-on ammeter to the AC range and measure in the same manner as above. (2) Judgment criteria (Note 17) It is acceptable if 1/100 CA or less. Hydrometer, thermometer (1) It is acceptable if the indicated value of in-liquid gravity meter and measured value of electrolytic specific gravity near the in-liquid specific gravity meter in the precision float type hydrometer are within ± 0.01. (Note 18) (2) It is acceptable as long as the indicated value of the hydrometer and the value of the electrolytic solution temperature measured with the rod-shaped alcohol thermometer are within ± 5 ℃. Solution loss warning electrode (1) Method (Note 19) (a) Remove the solution loss warning electrode from the vent plug and raise it above the level of the electrolytic solution. (b) If the solution reduction warning electrode cannot be removed, open one side of the lead wire. (2) Judgment criteria Check by turning on the alarm indicator lamp of the rectifier or monitoring panel.	Note 17) According to our technical documents, Lead-acid: 1/1000～1/2000Ｃ Alkaline: 1/500～1/1000 Ｃ.However, the judgment is based on the judgment criteria on the left. (Note 18) The old type (boomerang construction float) is not used as reference for judgment. (Note 19) A warning will be sent when the solution loss warning electrode is removed from the vent plug, so obtain consent in advance.

4. CS type lead storage battery lifetime deterioration diagnosis

Facility name / application	
Installation location	
Storage battery	
Inspection Date	

（Inspection result）

Standards of deterioration degree determination					Deterioration（Points）
Item				Deterioration（Points）	
Aged deterioration	Year of use C S type		6 years ～ less than 10 years	3	
			10 years ～ less than 14 years	6	
			14 years ～	8	
Characteristic deterioration	Floating voltage	C S： 2.1 less than or equal to the number of cells (%)	0.1～3%	2	
			3～10%	4	
			10% or more	1 0	
	Specific gravity	C S：2.1 less than or equal to the number of cells(%)	0.1～3%	2	
			3～10%	4	
			10% or more	10	
	Temperature	Number of cells 5 ℃ higher than the average temperature of each battery	0.1～3%	2	
			3～10%	4	
			10% or more	10	
Deterioration of appearance	The ⊕ pole of the cover is raised higher than the ⊖ pole.		1～2mm	2	
			2mm or more	4	
	Plate is Curved and deformation			2	
	Deposition of precipitate		5～10mm	2	
			10mm or more	4	
	Compound is cracking			2	
Other	The amount of water replenishment has increased more than 5 times the initial amount.			2	
Total number of degeneration					

The above Deterioration score when there is no item corresponding to each item of deterioration is 0 point.

（Diagnostic result）

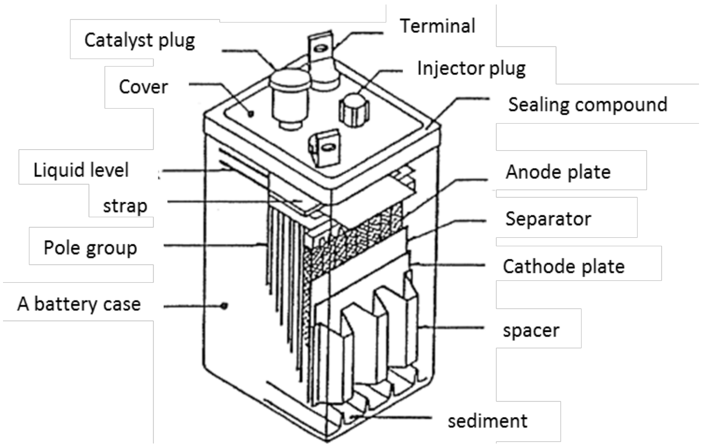
		Judgment
Degradation total score	12 or more	Aging is considerably advanced. As there is a danger of hindrance to the load, updating is necessary immediately.
	10～11	The aging phenomenon is clearly manifested. Please update immediately.
	6～9	Careful attention deterioration is progressing. Please continue to follow maintenance instructions and carefully check and maintenance.
	5 or less	It has not reached the end of its life. Please continue to follow maintenance instructions.

Estimated replacement time

10years

Average lifespan years

10 - 14 years



5. Storage battery report

Inspection date :	weather:	Temp: ℃	Humidity: %	Name :	
Measuring instrument spec	Model	Rating	Serial number	Made date	Manufacturer
Other measuring instruments: rod thermometer, specific gravity meter					

(Inspection, before adjustment)

Installation location :			Floating operation : Voltage ／ Current			Management target value	
Rectifier Model :			Input(3φ60HZ) :	V	A	Floating voltage :	V
Rectifier serial number :			整流器出力 :	V	A	Cell voltage :	2.15±0.05
Battery type :	Battery quantity :		Storage battery :	V	A		2.10 ～ 2.20
Made date :	Battery		Load :	V	A	Specific gravity :	1.215±0.01
Manufacturer :			Internal load :		A		1.205 ～ 1.225

測定記録

NO	Cell voltage	Specific gravity of electrolyte			NO	Cell voltage	Specific gravity of electrolyte			NO	Cell voltage	Specific gravity of electrolyte		
		Measured value	Liquid temp.	Converted value			Measured value	Liquid temp.	Converted value			Measured value	Liquid temp.	Converted value
	V	specific gravity	℃			V	specific gravity	℃			V	specific gravity	℃	
1					21					41				
2					22					42				
3					23					43				
4					24					44				
5					25					45				
6					26					46				
7					27					47				
8					28					48				
9					29					49				
10					30					50				
11					31					51				
12					32					52				
13					33					53				
14					34					54				
15					35					55				
16					36									
17					37									
18					38									
19					39									
20					40									

Remarks :			
Converted value (specific gravity) = (liquid temp. - 20) × 0.0007 + measured value			
Overall judgment	Good	NG	Converted value (specific gravity) ＝(liquid temp. －２０)×０．０００７＋measured value

6. Internal Resistance Measurement Method

Since a very small value is measured for internal resistance of the storage battery, if an error occurs during measurement, the influence on deterioration diagnosis will be significant. Therefore, please beware of the following items during measurement.

① Measure after zero point adjustment. Failure to do so will increase the measurement error. In addition, do not perform zero point adjustment on an iron plate.

② When measuring the internal resistance of medium/large capacity storage batteries (150 Ah or more), measure with the connecting conductors near the terminals.
If it is measured at the terminal, it cannot be measured accurately due to the influence of oxide film, etc. (See Figure 1) If the connecting conductor or terminal is whitened, polish both sides of the connecting conductor and the terminal, and measure the metal surface after exposing it.

③ For small capacity storage batteries and small valve regulated lead-acid storage batteries, measure at the terminals.
When the terminals are whitened, polish them and measure the metal surface after exposing it.

④ For the pin type, make sure it makes perpendicular contact with the part being measured. (See Figure-2)

⑤ If the connection is loose, the internal resistance will be high. If it is high, check for a loose connection. If it is loose, retighten it and remeasure.

⑥ When measuring the internal resistance, do not measure between the main unit and the measuring lead wire through the support of the cubicle, etc. It cannot be measured accurately due to the influence of eddy currents.

⑦ If the measured value is abnormal, do not judge by one measurement.
Rather, perform point zero adjustment again, change the measurement point, and remeasure. In addition, use the point where the smallest value is found as the measured value.

⑧ In order to see changes over time, measure at the same point every time. If the measurement points are different, the value may change.

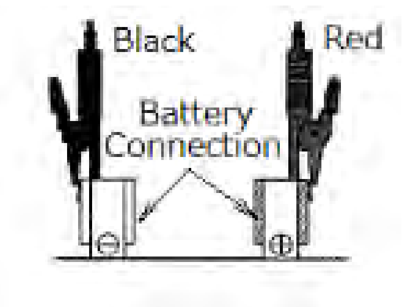


Figure 1 For clip type

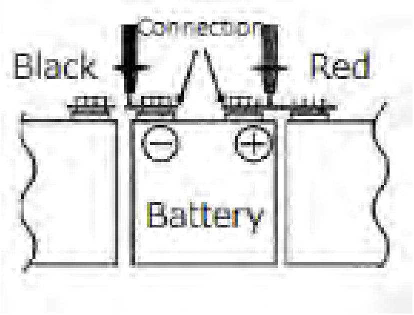


Figure-2 For pin type

Other precautions

① In general, the internal resistance measurement of the storage battery is measured in the float charging state. However, when measuring the storage battery connected to the UPS, the measured value may fluctuate due to the feedback current of the UPS which does not allow for accurate measurement.

If measurement is absolutely necessary, obtain consent from the customer and switch to bypass feeding and measure.

② If there is a discharge due to a power outage, etc. before measuring internal resistance, and measurement is performed with the storage battery in an unstable state, the error will be significant.

After a week or more, measure with the battery in a stable state.

③ The Internal resistance of vented stationary lead-acid batteries and alkaline storage batteries can also be measured, but since the change in internal resistance during their service life is small compared to valve regulated lead-acid batteries, it is difficult to use it as data for deterioration diagnosis.

Accordingly, diagnose deterioration by performing voltage/specific gravity measurements, appearance check, capacity test, etc. as usual.

Internal Resistance of the Storage Batteries and its Measuring Instruments

When compared with vented stationary lead-acid storage batteries, maintenance of valve regulated stationary lead-acid storage batteries does not require water replenishment, equal charge, etc.

However, it is more difficult to carry out deterioration diagnosis by appearance, specific gravity measurement, etc.

However, since internal resistance rises with the number of years used, as one method of diagnosing deterioration, the internal resistance has been increasingly measured during periodical inspections in recent years.

Figure 3 shows deterioration of internal resistance from aging and guidelines for diagnosing deterioration.

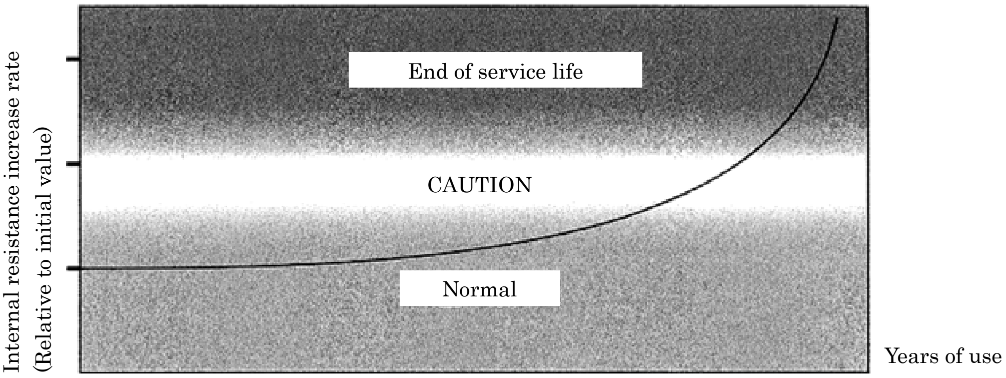


Figure-3 Deterioration of internal resistance from aging
(reference example of MSE type storage battery)

Since the judgment value for deterioration diagnosis is based on the judgment standard of each company, please contact the battery manufacturer.

There are two types of internal resistance measuring instruments and measuring terminals as shown in the photograph: a clip type (Photo 1) and those with a pin tip (Photo 2).

Photo 1 Example of internal resistance measuring instrument (clip type)

Photo 2 Pin type measuring terminals

7. Battery failure photo and manufacturers answer

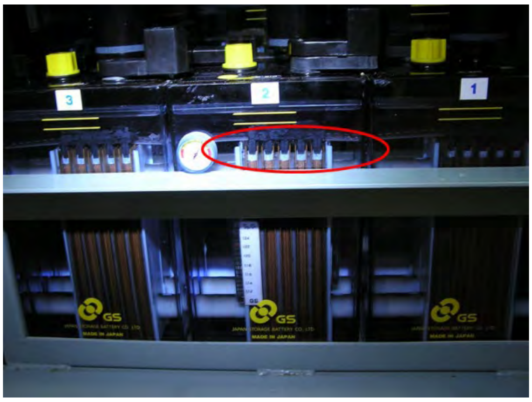


Photo1 Battery failure / Degraded matter

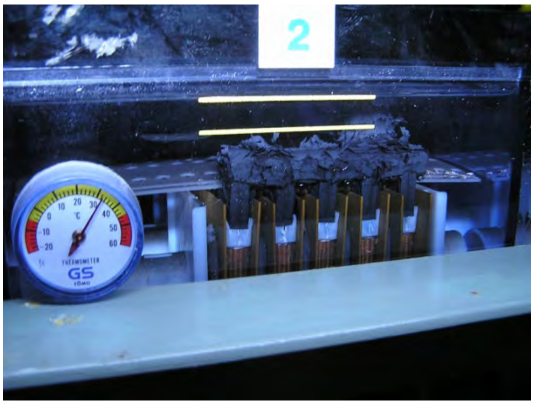


Photo2 Degraded matter

Description

Since the peeling phenomenon is seen in the electrode plate where the inside of the storage battery is deteriorated, there is a possibility that a peeling material will accumulate at the bottom and touch the positive electrode and the negative electrode plate to cause a short circuit.

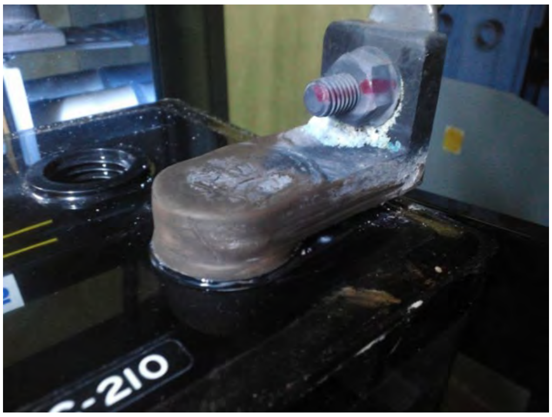


Photo3 Battery failure Terminal attachment

Description

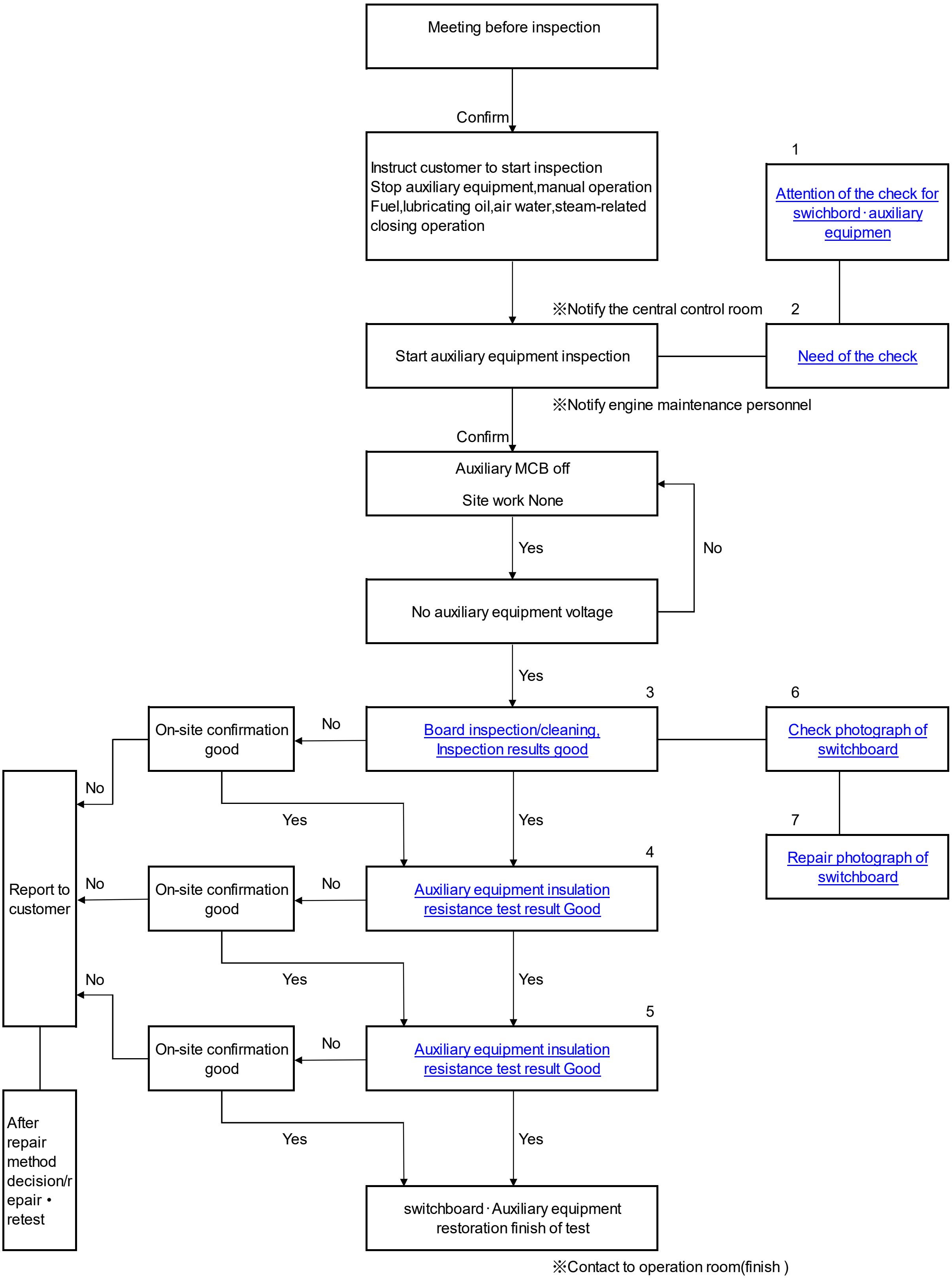
The substance at the base of the terminal of the storage battery is in a state where the oxide of the terminal portion is attached.

Important

The expected lifespan of the CS type storage battery is 10 to 14 years.If the expected life has passed, there is a possibility of malfunction such as capacity reduction.

End

7. Switchboard and Auxiliary equipment inspection



1. Precautions for switchboard or auxiliary equipment inspection

1. When checking the switchboard / auxiliary machines, it is often charged on the system, so check the system after understanding the system with drawings etc. well.
2. If the switchboard is charged at high voltage, inspect after stopping operation, electro scoping and discharging it and installing grounding wires. Even when receiving low voltage power, stopping operation is preferable, but if this is not possible, cover the surroundings to prevent electric shock, miss operation, etc.
3. When checking accessories, make sure that the circuit breaker etc. is "off" and that it is not working on site equipment side and inspect after electric inspection.
4. Use the tools and materials to be used by covering with insulation tapes etc.
5. When the switchboard inspection cleaning is also to make sure the interior of the state using the lighting and the like.
6. When resting or completing work, do not leave tools and materials on the switchboard and auxiliary equipment.

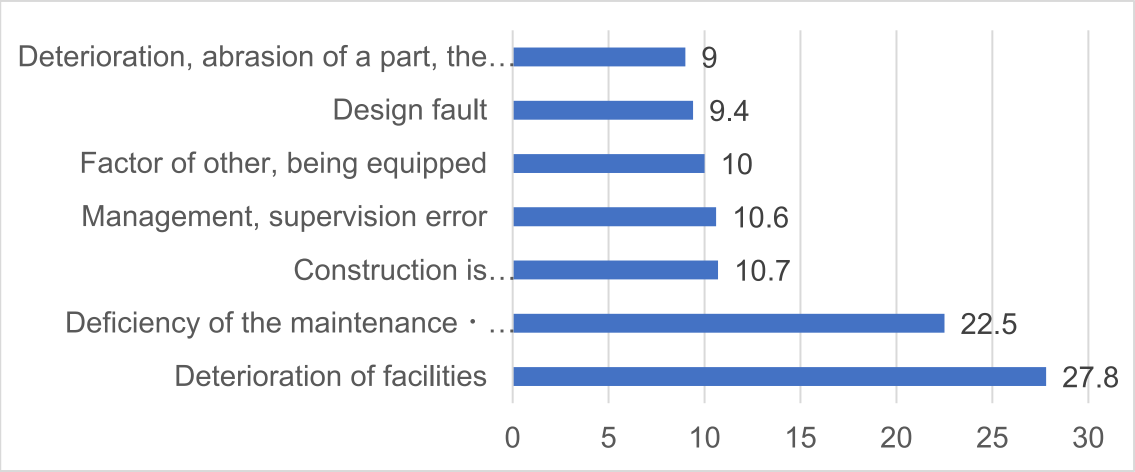
2. Need of the check

Electric facilities show various aspects depending on usage, environmental conditions, years of use,etc., up to the accident, but accidents have Beginning point that cause the accident.Maintenance is necessary in order to find this cause in advance, to prevent accidents beforehandand to continue using electric facilities.

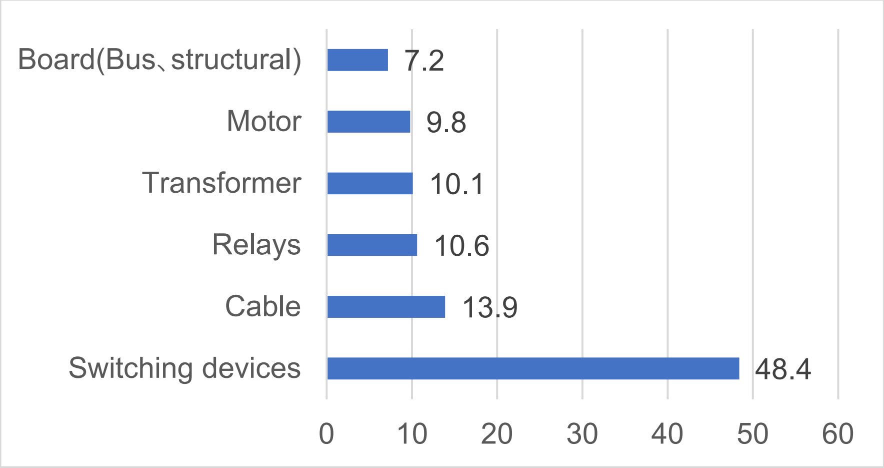
Accident statistics

Factor analysis of accidents and faults has analyzed that the aging of equipment is 32.7%, and the insufficiency / failure of maintenance, inspection and inspection is 22.5%. From this also, it can be said that maintaining or diagnosing electrical equipment is indispensable and appropriate response is necessary

Cause of an accident Number of response 670（multiple answers）



Outbreak point of an accident, the trouble　Number of response 635



Forming ARC of VCB main circuit part Grease solidification ⇒Heating⇒Alterration of contactor・spring ⇒ contactor melt･forming arc	
Insulation reduction of main circuit short circuit 、damage by afire in the board Fouling ⇒ Partial discharge ⇒ Insulation reduction ⇒ Ground fault･Short circuit ⇒ Outbreak of Ion Gas ⇒ Accident expansion by the arc (https://www.graphicproducts.com/articles/arc-flash-accident-reports/) **Clogging of air filter/Overheat damage by a fire of the board** Clogging of air filter ⇒ Increase of Fouling ⇒ Worse of Heat radiation effect ⇒ Temperature rising⇒ reduction of dielectric strenght ⇒Heating・Burning	 Damaged circuit breaker and position of level post-event
Looseness of coil rope / Burning of Stay coil Degradation over time Looseness of rope ⇒ Looseness of coil ⇒ Occurrence of worm powder ⇒ reduction of main insulation ⇒ reduction of dielectric ⇒ dielectric breakdown (https://www.easa.com/resources/booklet/typical-failures-three-phase-stator-windings)	

4. Auxiliary equipment operation ／Report of insulation resistance test

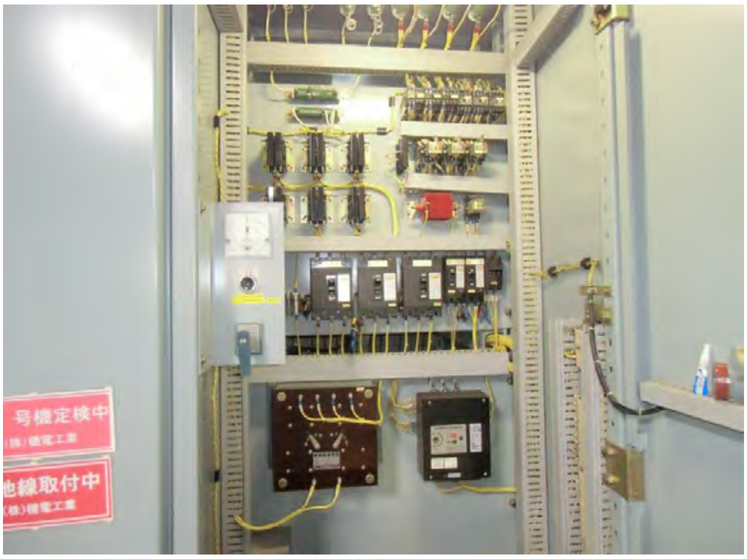
power plant issue

Start of measurring date	Month Day Year	Weather:	Temperature ℃	Humidity %
Stop of measurring date	Month Day Year	Weather:	Temperature ℃	Humidity %
測 定 実 施 者				

measuring equipment	manufacturer	type	manufacturing number	year of manufacture	rating

№	equipment name	rating （kV−V）	rated current （A）	thermal set point （A）	operation current（A）			**insulation resistance （MΩ）**	judgement good bad
					R phase	S phase	T phase		
1	lubricating oil priming pump	—							
2	secondary cooling water pump˚（A）	—							
3	secondary cooling water pump（B）	—							
4	Primary cooling water supply pump	—							
5	cooling tower fan	-							
6	Primary cooling water priming pump	-							
7	starting air compressor	-							
8	Generator space heater	—							
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									

note :

	6. Appearance check Appearance check burning、damage、change color Confirmation for Bad smell
	6. Appearance check mounting、 Internal check mounting、confirmation of wiring fastener Clean for equipment by brushes
	Wipe the insulation with a waste clothes and clean Copper bar bolting confirmation

	7. Auxiliary equipment board Repair / Board inside repair
	Board before reparation
	Board after reparation ①After rust remove rust resisting paint ②Put aluminum tape ③Sealing material filling ④Top coat
	Board after reparation ①After rust remove rust resisting paint ②Sealing material filling ③Top coat

8. Instrumentation inspection procedure manual

8.1 Test report
8.2 Measuring device list
8.3 Road Tool List
8.4 Pressure gauge inspection
8.5 Pressure switch inspection
8.6 Pressure transmitter inspection
8.7 Flow switch inspection
8.8 Temperature switch inspection
8.9 Digital panel meter inspection
8.10 Resistance temperature detector inspection (RTD)
8.11 Thermocouple inspection
8.12 Oil mist concentration meter disassembly inspection
8.13 Loop test

8.1 Test Report

weather	Temp ℃	Humidity %	P-1

Customer Name				Instrument Number	
Equipment name	BOOST AIR PRESSURE				
Range of Measurement	0 ～ 0.3 MPa				
Accuracy	±1.5% FS	Location		Machine Number	

Scale (%)	0.0	16.7	33.3	50.0	66.7	83.3	100.0
Input Value (MPa)							
Standard value (MPa)							
Before adjustment (MPa)							
Error (%)							
After adjustment (MPa)							
Error (%)							

Test Equipment Name	

Special Mention Work Content

Result	Good / Bad	

Test Day :	Tester :

Test Report

weather	Temp ℃	Humidity %	P-1

Customer Name				Instrument Number	
Equipment name	LUB.OIL PURESSURE				
Range of Measurement	0 ～ 1.0 MPa				
Accuracy	±1.5% FS	Location		Machine Number	

Scale (%)	0.0	20.0	40.0	60.0	80.0	100.0	
Input Value (MPa)							
	0.00	0.20	0.40	0.60	0.80	1.00	
Standard value (MPa)							
	0.00	0.20	0.40	0.60	0.80	1.00	
Before adjustment (MPa)							
Error (%)							
After adjustment (MPa)							
Error (%)							

Test Equipment Name	

Special Mention Work Content

Result	Good / Bad	

Test Day :

Tester :

Test Report

weather	Temp ℃	Humidity %	P-1

Customer Name				Instrument Number	
Equipment name	BOOST AIR PRESSURE TRANSMITTER				
Range of Measurement	IN 0～0.4 MPa OUT 4～20mA				
Accuracy	±1.5% FS	Location		Machine Number	

Scale (%)	0	25	50	75	100		
Input Value (MPa)							
	0.000	0.100	0.200	0.300	0.400		
Standard value (MPa)							
	4.00	8.00	12.00	16.00	20.00		
Before adjustment (MPa)							
Error (%)							
After adjustment (MPa)							
Error (%)							

Test Equipment Name	

Special Mention Work Content

Result	Good / Bad	

Test Day :   Tester :

Test Report

weather	Temp ℃	Humidity %	P-1

Customer Name				Instrument Number	
Equipment name	FUEL OIL PRESSURE TRANSMITTER				
Range of Measurement	IN 0～0.6 MPa OUT 4～20mA				
Accuracy	±1.5% FS	Location		Machine Number	

Scale (%)	0	25	50	75	100		
Input Value (MPa)							
	0.000	0.150	0.300	0.450	0.600		
Standard value (MPa)							
	4.00	8.00	12.00	16.00	20.00		
Before adjustment(MPa)							
Error (%)							
After adjustment (MPa)							
Error (%)							

Test Equipment Name	

Special Mention Work Content

Result	Good / Bad	

Test Day :

Tester :

Test Report

weather	Temp ℃	Humidity %	P-1

Customer Name				Instrument Number	
Equipment name	LUB.OIL PRESSURE TRANSMITTER				
Range of Measurement	IN 0～1.0 MPa OUT 4～20mA				
Accuracy	±1.5% FS	Location		Machine Number	

Scale (%)	0	25	50	75	100		
Input Value (MPa)							
	0.000	0.250	0.500	0.750	1.000		
Standard value (MPa)							
	4.00	8.00	12.00	16.00	20.00		
Before adjustment(MPa)							
Error (%)							
After adjustment (MPa)							
Error (%)							

Test Equipment Name	

Special Mention Work Content

Result	Good / Bad	

Test Day :

Tester :

Pressure Switch Test Report

Test Day：	Weather :	Temp : ℃	Humidity : %	Tester :

Equipment Name	Manufacturer Model	Location	Setting Value			Before Adjustment			After Adjustment			Remarks/Judgment	
LO.PRESS.LOW(1ST)	Danfoss	Engine Body	On Below	0.350	MPa	On		MPa	On		MPa	Cleaning	
Alarm 63Q1	MVC-5100		Allowable Value±0.01MPa			Off		MPa	Off		MPa	Result	Good
LO.PRESS.LOW(2ND)	Danfoss	Engine Body	On Below	0.350	MPa	On		MPa	On		MPa	Cleaning	
Engine stop 63Q2	MVC-5100		Allowable Value ±0.01MPa			Off		MPa	Off		MPa	Result	Good
LO. PRIMING FAILURE	Danfoss	Engine Body	On Below	0.350	MPa	On		MPa	On		MPa	Cleaning	
Priming pump driving 63QP	MVC-5100		Allowable Value ±0.01MPa			Off		MPa	Off		MPa	Result	Good
T/C LO. Press. Low	Danfoss	Engine Body	On Below	0.350	MPa	On		MPa	On		MPa	Cleaning	
Engine stop 63QT	MVC-5100		Allowable Value ±0.01MPa			Off		MPa	Off		MPa	Result	Good
HT Water press. Low (1st)	Danfoss	Engine Body	On Below	0.350	MPa	On		MPa	On		MPa	Cleaning	
Alarm 63WJ1	MVC-5100		Allowable Value ±0.01MPa			Off		MPa	Off		MPa	Result	Good
HT Water press. Low (2nd)	Danfoss	Engine Body	On Below	0.350	MPa	On		MPa	On		MPa	Cleaning	
Engine stop 63WJ2	MVC-5100		Allowable Value ±0.01MPa			Off		MPa	Off		MPa	Result	Good
Test Equipment Name													

Flow Switch Test Report

Test Day：	Weather :	Temp : ℃	Humidity : %	Tester :

Equipment Name	Manufacturer Model	Location	Setting Value			Before Adjustment			After Adjustment			Remarks/Judgment	
H.T.Water Flow Shortage	TAIYO VALVE	Primary Cooling Water Master Tube	On Below		L/min	On		L/min	On		L/min	Cleaning	
Engine Stop 69WJ	FCD-FR-REM		Off		L/min	Off		L/min	Off		L/min	Result	Good
H.T.Water Flow Shortage	TAIYO VALVE	Secondary Cooling Water Master Tube	On Below		L/min	On		L/min	On		L/min	Cleaning	
Alarm 69WJ	FCD-FR-REM		Off		L/min	Off		L/min	Off		L/min	Result	Good
Test Equipment Name													

Temperature Switch Test Report

Test Day：	Weather :	Temp :　　℃	Humidity :　　　%	Tester :

Equipment Name	Manufacturer Model	Location	Setting Value			Before Adjustment			After Adjustment			Remarks/Judgment	
HT Water Temp High(1st)			On Over		℃	On		℃	On		℃	Cleaning	
Alarm 26WJ1			Allowable Value+3℃、-2℃			Off			Off		℃	Result	
HT Water Temp High(2nd)			On Over		℃	On		℃	On		℃	Cleaning	
Engine stop 26WJ2			Allowable Value+3℃、-2℃			Off		℃	Off		℃	Result	
LO Temp High			On Over		℃	On		℃	On		℃	Cleaning	
Alarm 26Q			Allowable Value+3℃、-2℃			Off		℃	Off		℃	Result	
LT Water Temp High			On Over		℃	On		℃	On		℃	Cleaning	
Alarm 26WC			Allowable Value+3℃、-2℃			Off		℃	Off		℃	Result	
Test Equipment Name													

Test Report

weather	Temp ℃	Humidity %	P-1

Customer Name				Instrument Number	
Equipment name	BOOST AIR PRESSURE DM				
Range of Measurement	Input 4～20mADC / Inst 0～0.4 MPa				
Accuracy	±1.0%	Location		Machine Number	

Scale (%)	0	25	50	75	100		
Input Value (MPa)							
	4.00	8.00	12.00	16.00	20.00		
Standard value (MPa)							
	0.000	0.100	0.200	0.300	0.400		
Before adjustment(MPa)							
Error (%)							
After adjustment (MPa)							
Error (%)							

Test Equipment Name	

Special Mention Work Content

Result	Good / Bad	

Test Day : Tester :

Resistance Temperature Detector Inspection Report (Pt 100Ω)

weather	temp	hum	P-30
sun	30℃	65%	

Test Content:	＊Conduction check and insulation resistance test were carried out.

No.	NAME	AB resistance value	Insulation resistance value (5MΩ)	Judgment	Remarks
1	Primary cooling water temperature	OK	20 MΩ	Good	

Measurement Instrument	DDMM019 Digital multimeter (Yokogawa Denki、7544　F02、　No.99AF3008ZB、±0.04％) DMR005 Insulation meter(Yokogawa Denki、2406 33、№88LC0361、±5.0%)

Article

．＊As a result of inspection of RTD, there is no disconnection between terminals AB, insulation resistance is 5 MΩ or more,and there is no abnormality.

Date：　11 / JAN / 2019	Measurer:

Thermocouple Inspection Report

weather	temp	hum	P-30
sun	30℃	65%	

Electric Power Company Power Station Unit #					
Test content	＊Conduction check and insulation resistance test were carried out.				
No.	NAME	Continuity check	Insulation resistance value (5MΩ)	Judgment	
1	No.1 Cylinder outlet exhaust gas temperature thermocouple	OK	20 MΩ	Good	For field indicator
Measurement Instrument	DDMM019 Digital multimeter (Yokogawa Denki、7544　F02、No.99AF3008ZB、 ±0.04％) DMR005 Insulation meter(Yokogawa Denki、2406 33、№88LC0361、±5.0%)				
Article As a result of inspecting the thermocouple, there is no disconnection and insulation resistance is good.					
Date： 11 / JAN / 2019		Measurer:			

Oil Mist Density Meter

weather sun	temp 30℃	hum 65%	P-	

Manufacturer：Daihatsu	Model　:　MD-1M

No.	Inspection Items	Judgment	Condition
1	Source　Lamp	Good	Good confirmation
2	Rotary valve rotation / noise	Good	Good rotation, no noise
3	Injection motor rotation / noise	Good	Good rotation, no noise
4	Gear head rotation / noise	Good	Good rotation, no noise
5	Blower discharge pressure	Good	Good confirmation
6	Mist suction pressure	Good	Good confirmation
7	Zero point adjustable	Good	Good confirmation
8	Relay operation	Good	Good confirmation
9	Photo-cell (light receiver)	Good	Implement cleaning
10	Dirt of phototube	Good	Implement cleaning
11	Dirt on the lens	Good	Implement cleaning
12	Trouble lamp on	Good	Good confirmation
13	Mist Indicator (LED) Instruction	Good	Good confirmation
14	Connector part connection	Good	Good connection

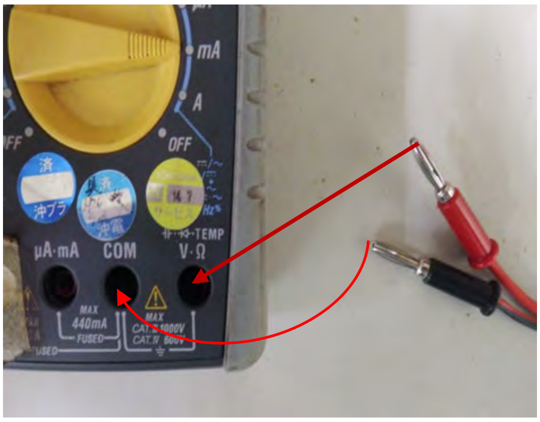
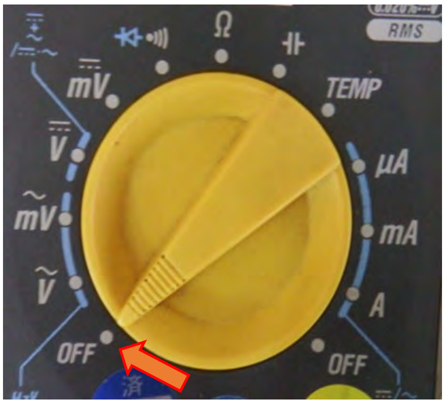
Remarks

Date：　day / manth / year　　Measurer：

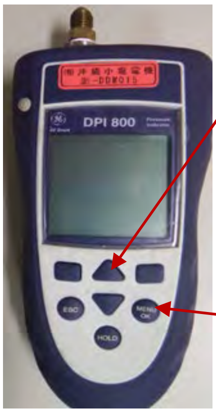
8.2 Measuring device list

	Digital manometer (or digital calibrator) (Pressure measuring device) Pressure gauge, pressure transmitter, pressure switch, for calibration The measurement range：0 ～ 3.5 MPa
	CA150 calibrator (DC voltage current generator, DC voltage current measuring device) Digital Panel Meter, transducers, for calibration DC４～20ｍA、DC1～5V、RTD（Pt100Ω） Output of thermocouple (K type), input possible
	Digital multimeter (Voltage, current, resistance measuring instrument) For checking the contact of the pressureswitch (Ω, buzzer) For signal measurement of pressure transmitter (DCmA) For confirmation of continuity of thermocouple / RTD (Ω)
	Digital thermometer Thermometer, temperature switch for calibration
	Insulation resistance meter (commonly known as megger) RTD, thermocouple insulation resistance measurement (range 250V)

8.2-1 How to use digital multimeter

 Digital multimeter, code	 Insert the cord clip into the measuring point
 Normally OFF	 In case of current measurement, mA · COM For voltage and resistance measurement, V · Ω and COM
 Voltage range (thermocouple inspection)	 Buzzer (Pressure switch test)
 Resistance range (continuity test)	 Current range (pressure transmitter, signal converter)

8.2-2 How to use pressure manometer and pressure pump

 Pressure manometer, air hose	 Pressure pump set
 UP、DOWN swich (Used when measuring range change) MENU switch (Use at 0 tone)	 Fine adjustment valve (Used when raising and lowering pressure a little) Closing valve (Close at Pressure pump body
 Combination of pressure pump, pressure manometer, air hose	 Before pressurization / After pressurization

8.2-3 How to use digital thermometer

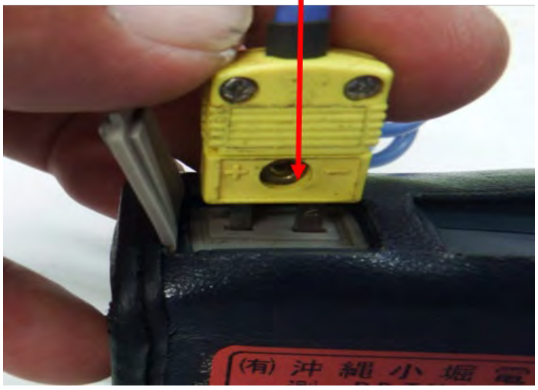
Digital thermometer body

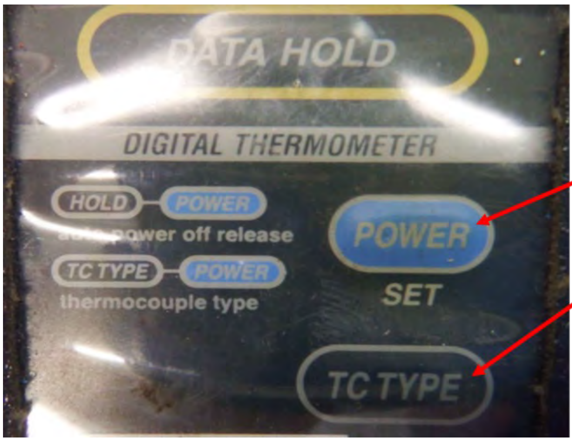
Thermosensitive part (K type sensor)

Connector slot

Sensor connector

Insert the sensor connector into the socket





Power switch

Select sensor type

(Choose K type here)

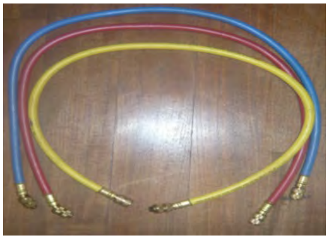
8.2-4 How to use insulation resistance meter (megger)

<table>
<tr>
<td>
Insulation resistance meter body</td>
<td></td>
</tr>
<tr>
<td> </td>
<td>Connect the red lead wire to the LINE
Connect black lead wire to EARTH
 </td>
</tr>
<tr>
<td colspan="2">Connect the lead wires to the connector on the back of the megger</td>
</tr>
<tr>
<td>
Set the measurement range to 250 V</td>
<td>
Ready for measurement</td>
</tr>
<tr>
<td colspan="2">Pull up MEAS lever and measure
 </td>
</tr>
</table>

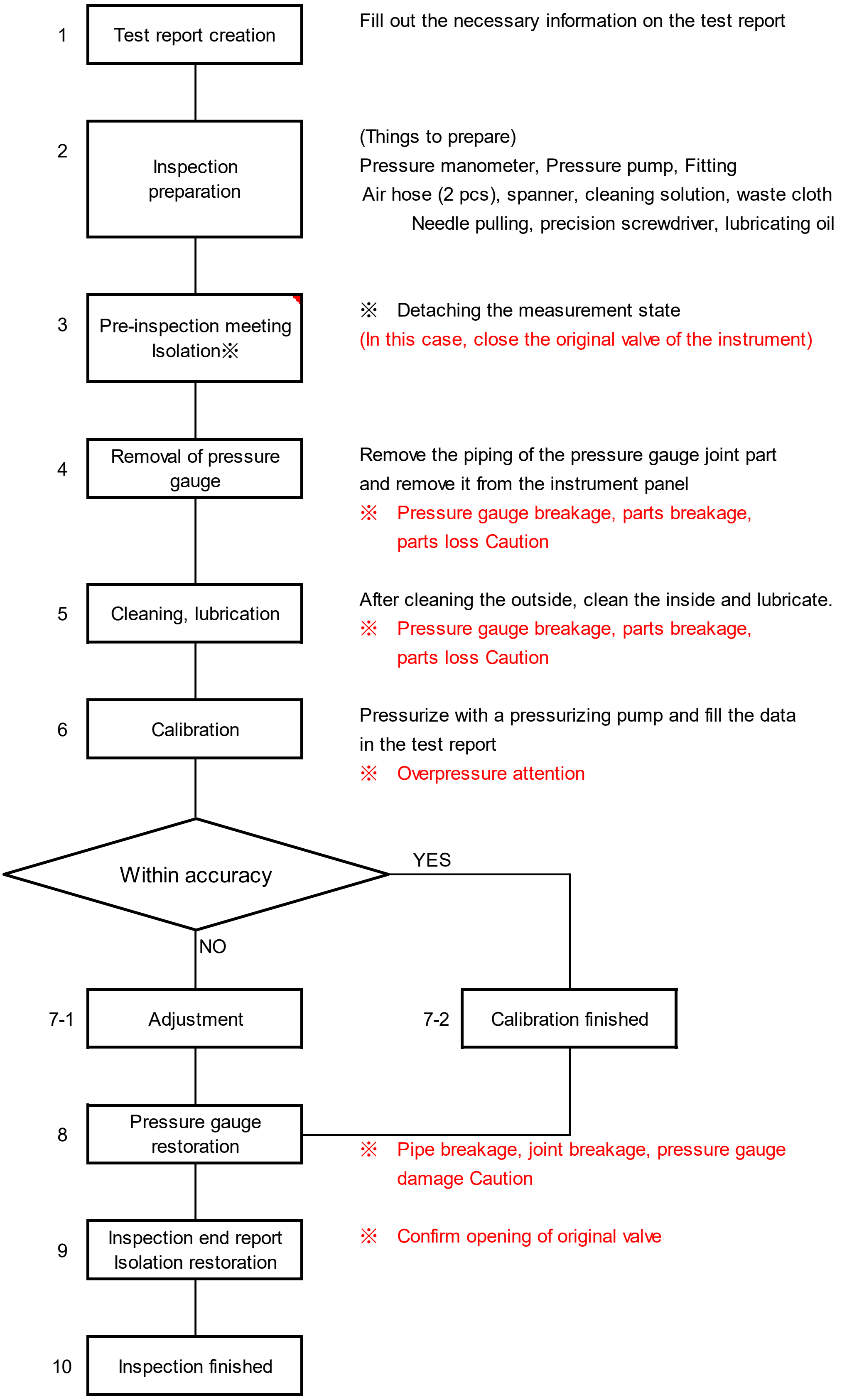
8.2-5 How to use Calibrator (CA 150)

 Portable Calibrator (CA 150) Body Lead wire	Connect red wire toH side of OUTPUT terminal and black lead wire to L side  OUTPUT terminal INPUT terminal The opposite side (clip side) of the lead wire is connected to the measuring instrument
 Press power switch	 DC voltage DC voltage current Ω TC（Thermocouple emf） RTD（Resistance temperature detector）
 ・Select a type with the FUNCTION button ・Press SOURCE button	 Output with UP, DOWN button (Note the number of digits)

8.3 List of Tools

 Pressure pump Use it in the test of 0 to 1.5 Mpa Pressure gauge, pressure switch, pressure transmitter calibration	 Electric pot used during thermometer test (Anything is acceptable as long as heating is possible)
 Air hose (Used for pressure related instrument test)	 Needle withdrawal (Used when adjusting pressure gauge)
 Fittings(Used when testing pressure related instruments)	 Lubricant, Cleaning solution (Clean the instrument, lubricate the shaft)
	Closure plug Closure plug (When removing the instrument, plug it so as not to leak water or oil)

8.4 Pressure gauge inspection



Fill out the necessary information on the test report

(Things to prepare)
Pressure manometer, Pressure pump, Fitting
Air hose (2 pcs), spanner, cleaning solution, waste cloth
Needle pulling, precision screwdriver, lubricating oil

※ Detaching the measurement state
(In this case, close the original valve of the instrument)

Remove the piping of the pressure gauge joint part and remove it from the instrument panel
※ Pressure gauge breakage, parts breakage, parts loss Caution

After cleaning the outside, clean the inside and lubricate.
※ Pressure gauge breakage, parts breakage, parts loss Caution

Pressurize with a pressurizing pump and fill the data in the test report
※ Overpressure attention

※ Pipe breakage, joint breakage, pressure gauge damage Caution

※ Confirm opening of original valve

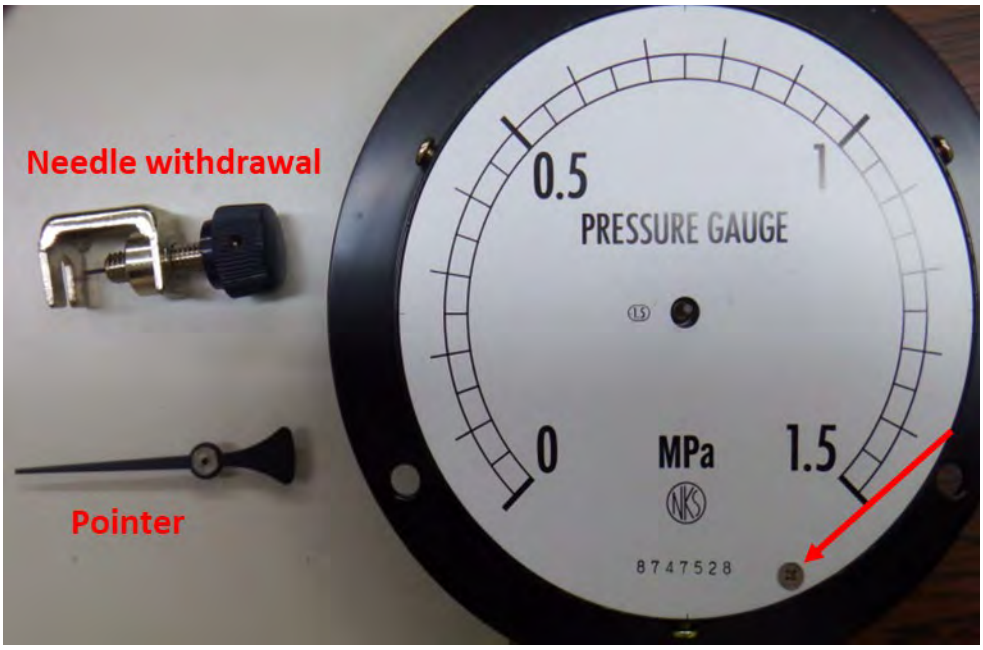
2. Inspection preparation

<table>
<tr><td colspan="6"></td></tr>
<tr><td colspan="2">
Pressure gauge</td><td colspan="2">
Fiting
There is a kind by the instrument
G1/2、G3/8、G1/4
PT1/2、PT3/8、PT1/4</td><td colspan="2">
Air hose</td></tr>
<tr><td> </td><td colspan="2">Pressure manometer
Selection by instrument
Left figure
MAX：For 3.5MPa</td><td colspan="2"> </td><td>Pressure pump
Selection by instrument
Left figure
MAX：For 1.5MPa</td></tr>
</table>

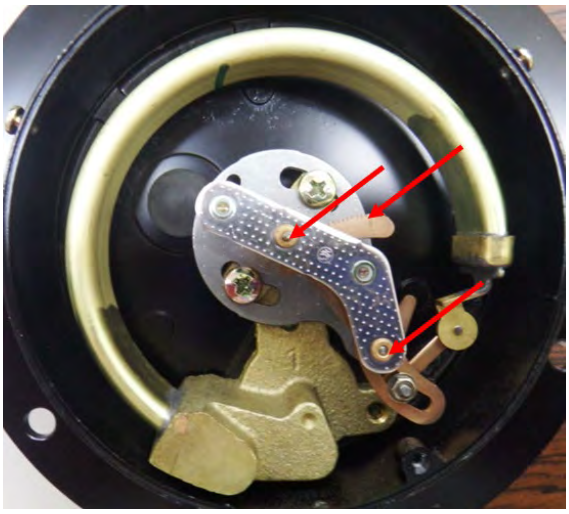
5. Pressure gauge inside and outside cleaning, lubrication

Loosen the cover mounting screws (3 places)

Remove pointer with Needle withdrawal.



Removing the scale plate by removing the fixing screw of the scale plate lower.



Lubricate the red arrows (bearings, gears).

After internal cleaning and lubrication, return the equipment in reverse order.

6. Calibration

1. Combine the equipment to calibrate the pressure gauge as shown in left picture.
2. Write the data before adjustment into the test report.
3. When the data is within the accuracy, the calibration is ended, and if it is outside the accuracy, adjustment is made.

7. Adjustment

7.1 Loosen the cover mounting screws (3 places)

7.2 Remove pointer with Needle withdrawal.

7.3 Pressurize 50% with pressurizing pump. (0.3 MPa in the case of 0 to 0.6 MPa)

7.4 Fix the pointer so that the indication is 50%.

7.5 Remove the pressure and collect data again as 0%, 25%, 50%, 75%, 100%.

7.6 Repeat steps 7-1 to 7-5 until it falls within accuracy.

Measurement principle of pressure gauge

(1) Direct acting elastic pressure gauge

When a measured pressure is introduced into a flat curved tube from one open end thereof, the curvature of bulging Bourdon tube changes and the sealed free end displaces in proportion to the pressure. This displacement is indicated by a sector, pinion to indicate the pressure value.

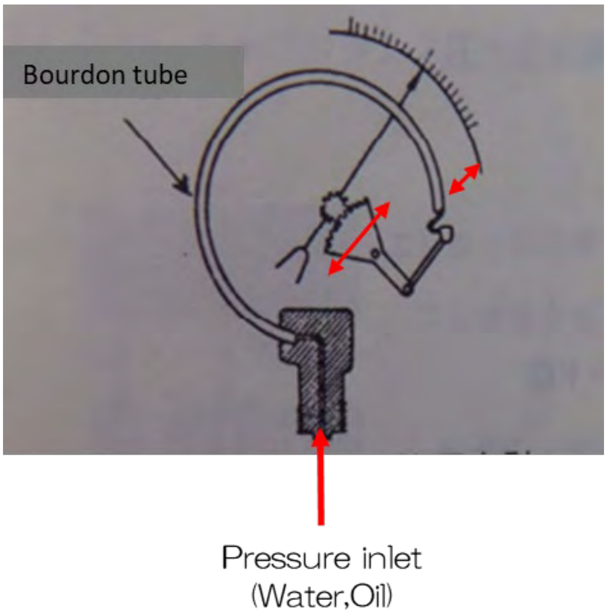
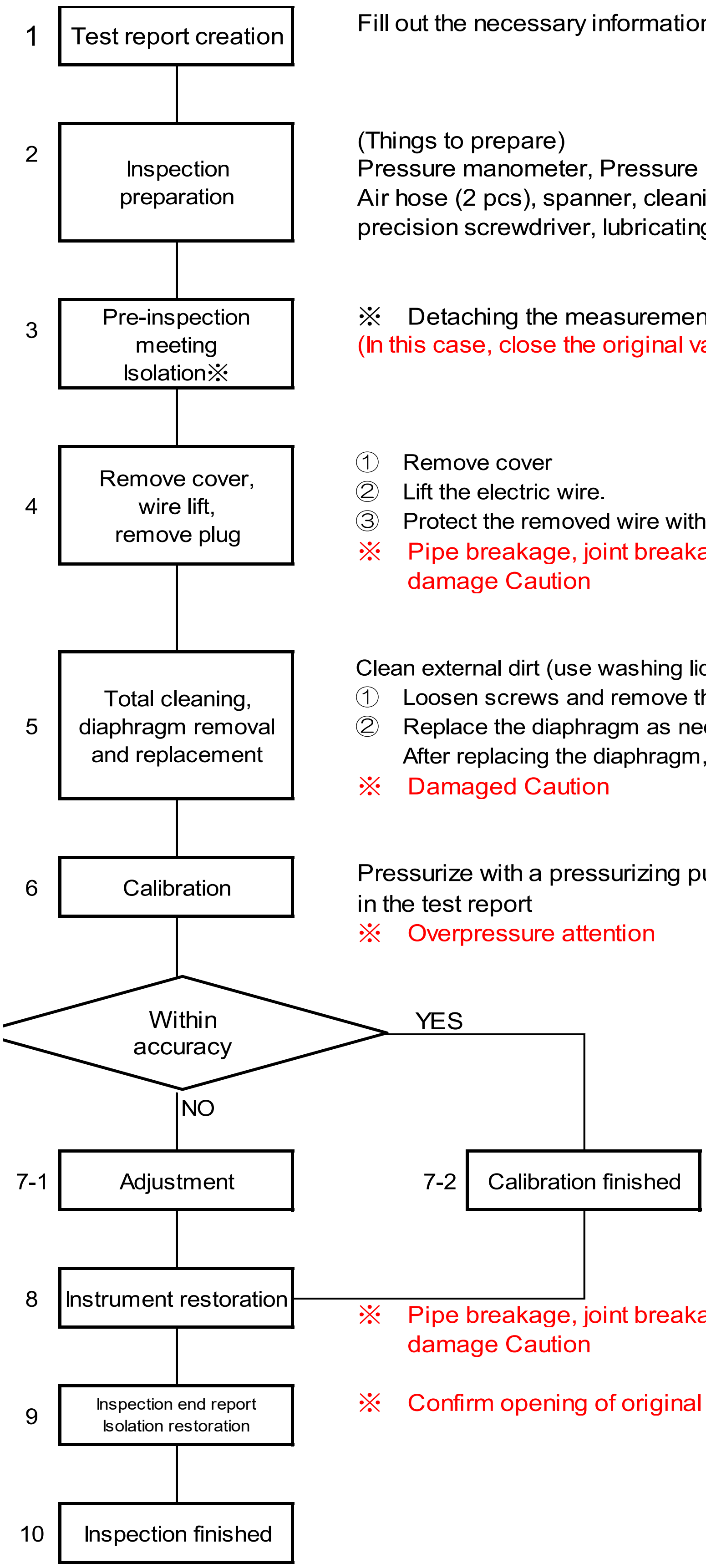


Figure 1 Bourdon tube pressure gauge

8.5 Pressure switch inspection



Fill out the necessary information on the test report

(Things to prepare)
Pressure manometer, Pressure pump, Fitting
Air hose (2 pcs), spanner, cleaning solution, waste cloth
precision screwdriver, lubricating oil

※ Detaching the measurement state
(In this case, close the original valve of the instrument)

① Remove cover
② Lift the electric wire.
③ Protect the removed wire with vinyl tape.
※ Pipe breakage, joint breakage, damage Caution

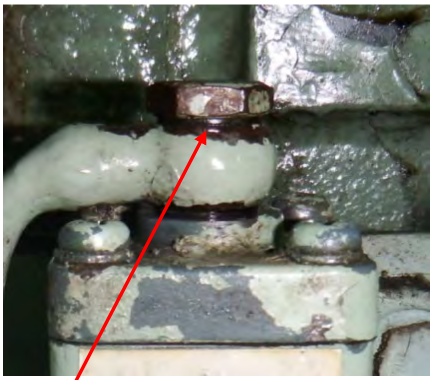
Clean external dirt (use washing liquid etc. as necessary)
① Loosen screws and remove them (4 places)
② Replace the diaphragm as necessary
After replacing the diaphragm, restore it.
※ Damaged Caution

Pressurize with a pressurizing pump and fill the data in the test report
※ Overpressure attention

※ Pipe breakage, joint breakage, damage Caution

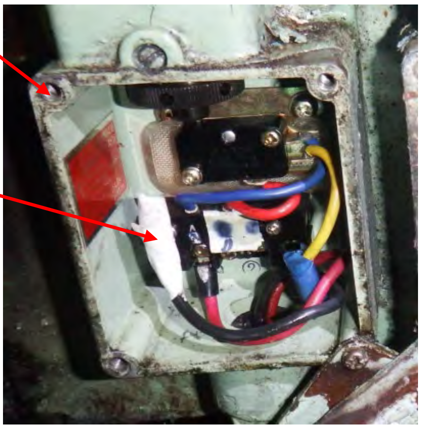
※ Confirm opening of original valve

4. Piping - Remove blind plug



④Remove the plug with a wrench

①Remove cover
②Lift the electric wire.
③Protect the removed wire
with vinyl tape.



5. Total cleaning, diaphragm removal and replacement

① Loosen screws and remove them
(4 places)

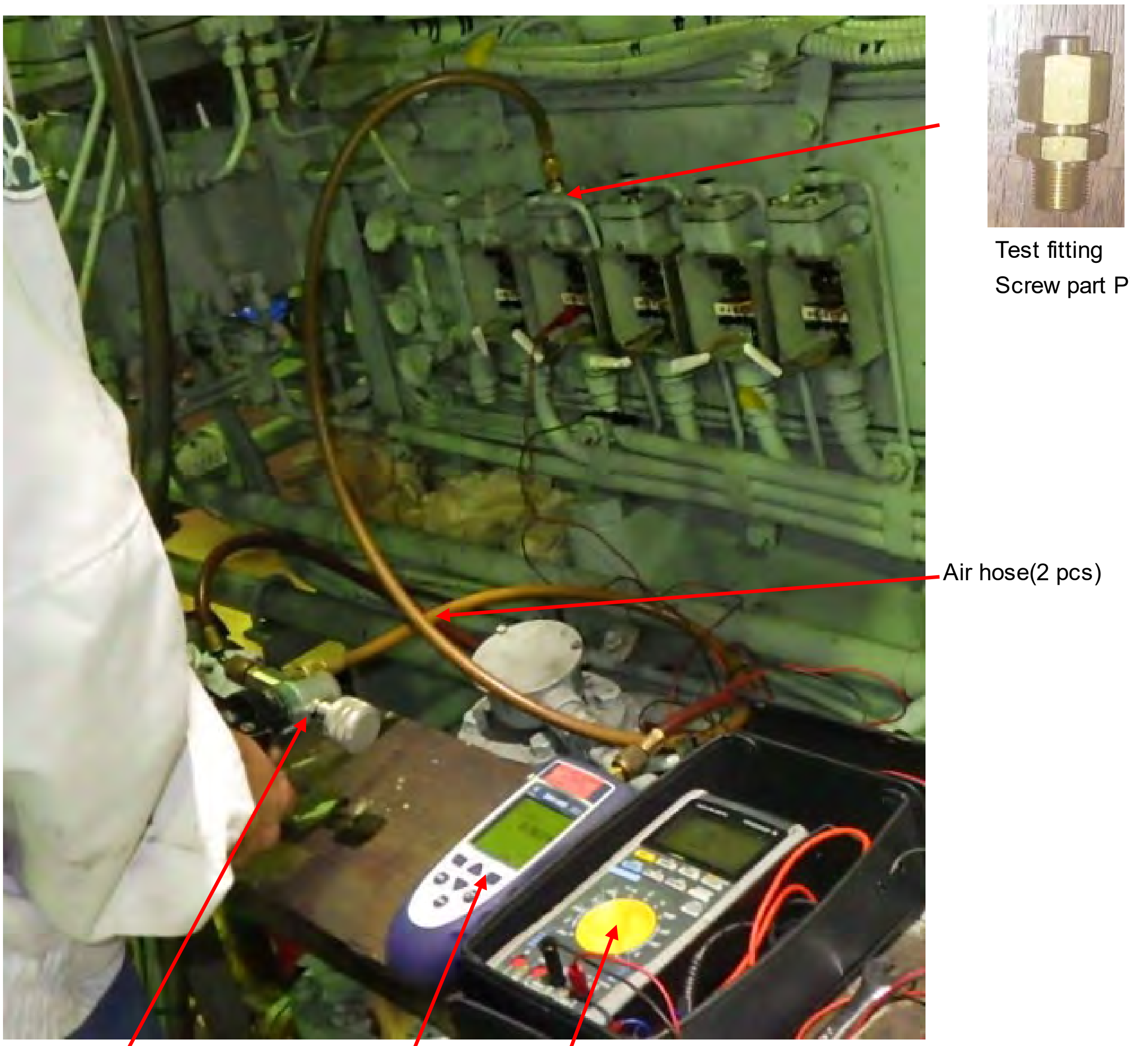
② Replace the diaphragm

Diaphragm（after use）

Diaphragm（new）

6. Calibration

① Attach test fitting, connect pressure switch, pressure pump, digital manometer with air hose.



② Connect the digital multimeter to the terminal unit.
(Measurement range is resistance range or buzzer)

③ Repeat pressurization and pressure reduction until the contact turns ON and OFF, and confirm the operation value.
※ For future life diagnosis, write the resistance value at the time of contact ON.
(Increasing the contact resistance will cause malfunction)

④ If the operation value is within the allowable value, the calibration is completed.
Adjust if it exceeds allowable value.

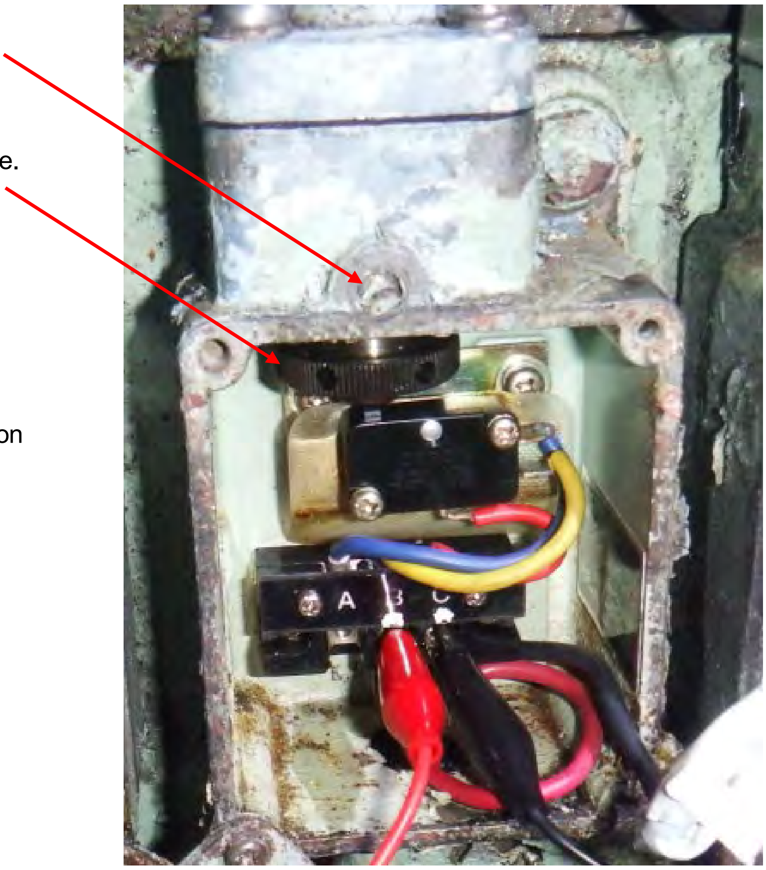
7. Adjustment

① Loosen the lock screw.

② Turn the pulley to either side.

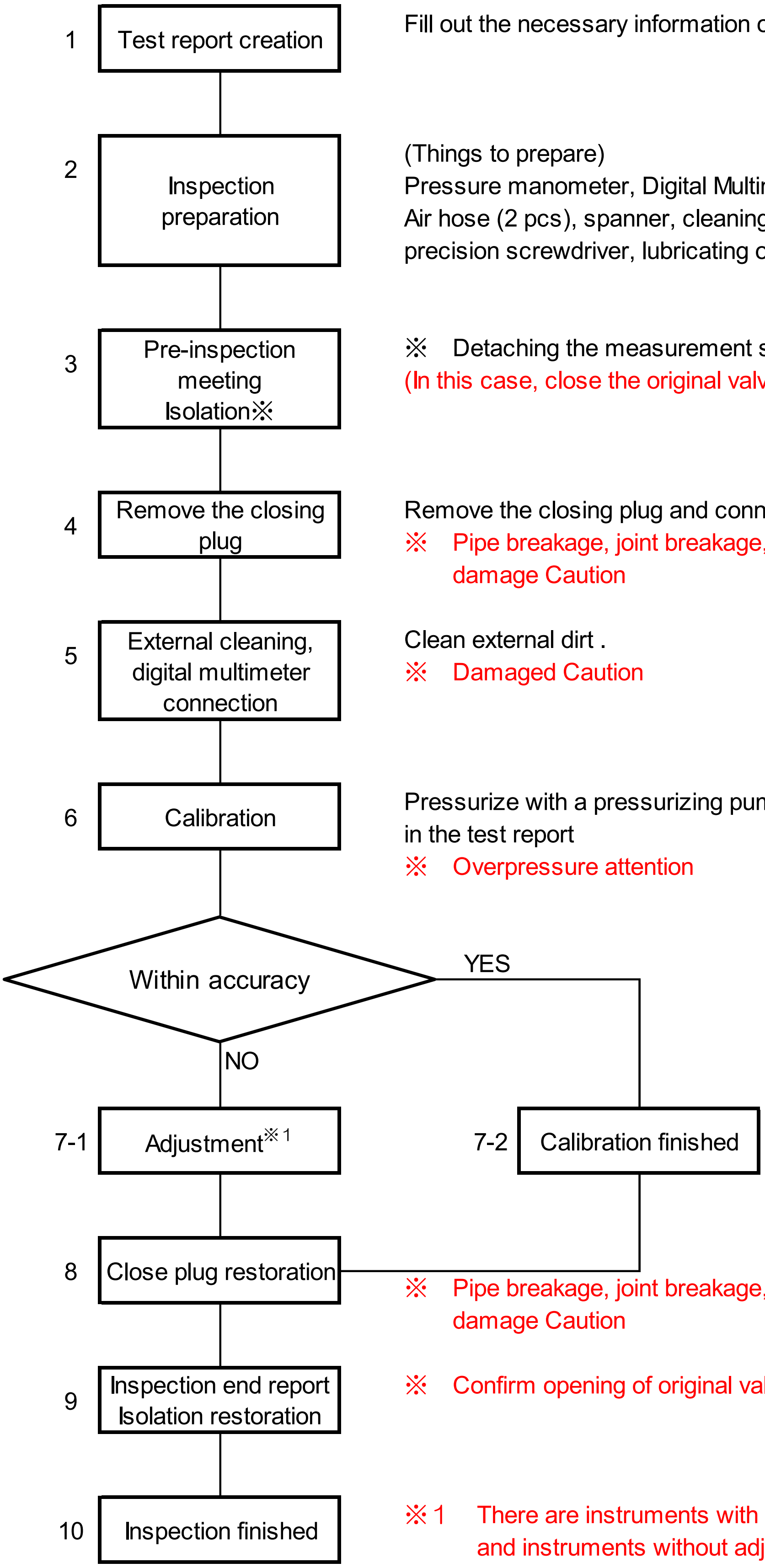
③ Tighten the lock screw。

④ 6. Perform ③ of calibration and check operation value.



Repeat steps ① to ④ until the operation value falls within the allowable range.

8.6 Pressure transmitter inspection



Fill out the necessary information on the test report

(Things to prepare)
Pressure manometer, Digital Multimeters, Pressure pump, Fitting
Air hose (2 pcs), spanner, cleaning solution, waste cloth
precision screwdriver, lubricating oil

※ Detaching the measurement state
(In this case, close the original valve of the instrument)

Remove the closing plug and connect the test fitting.
※ Pipe breakage, joint breakage,
damage Caution

Clean external dirt .
※ Damaged Caution

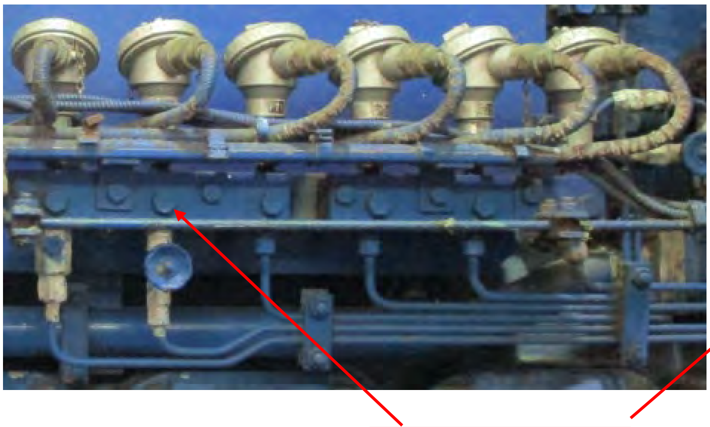
Pressurize with a pressurizing pump and fill the data in the test report
※ Overpressure attention

※ Pipe breakage, joint breakage,
damage Caution

※ Confirm opening of original valve

※1 There are instruments with adjustment function and instruments without adjustment, so if there is, adjust with ZERO, SPAN adjustment volume

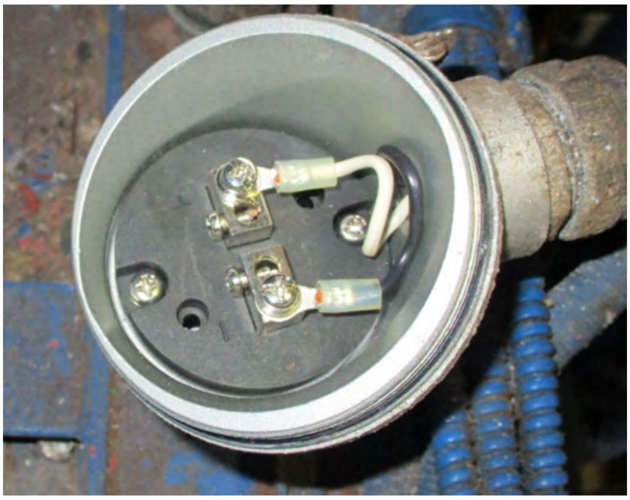
4. Piping and closing plug removal



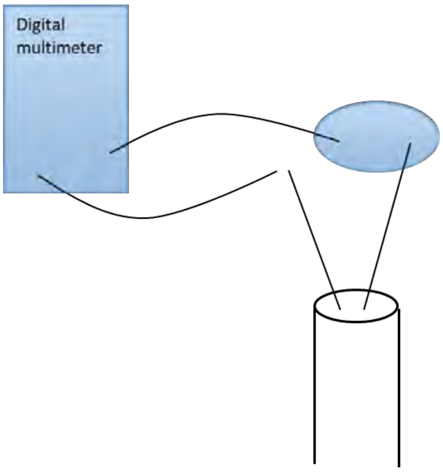
Remove the test closure plug and connect 1/4 test fitting.

Test fitting
Screw part 1/4

5. Digital multimeter connection



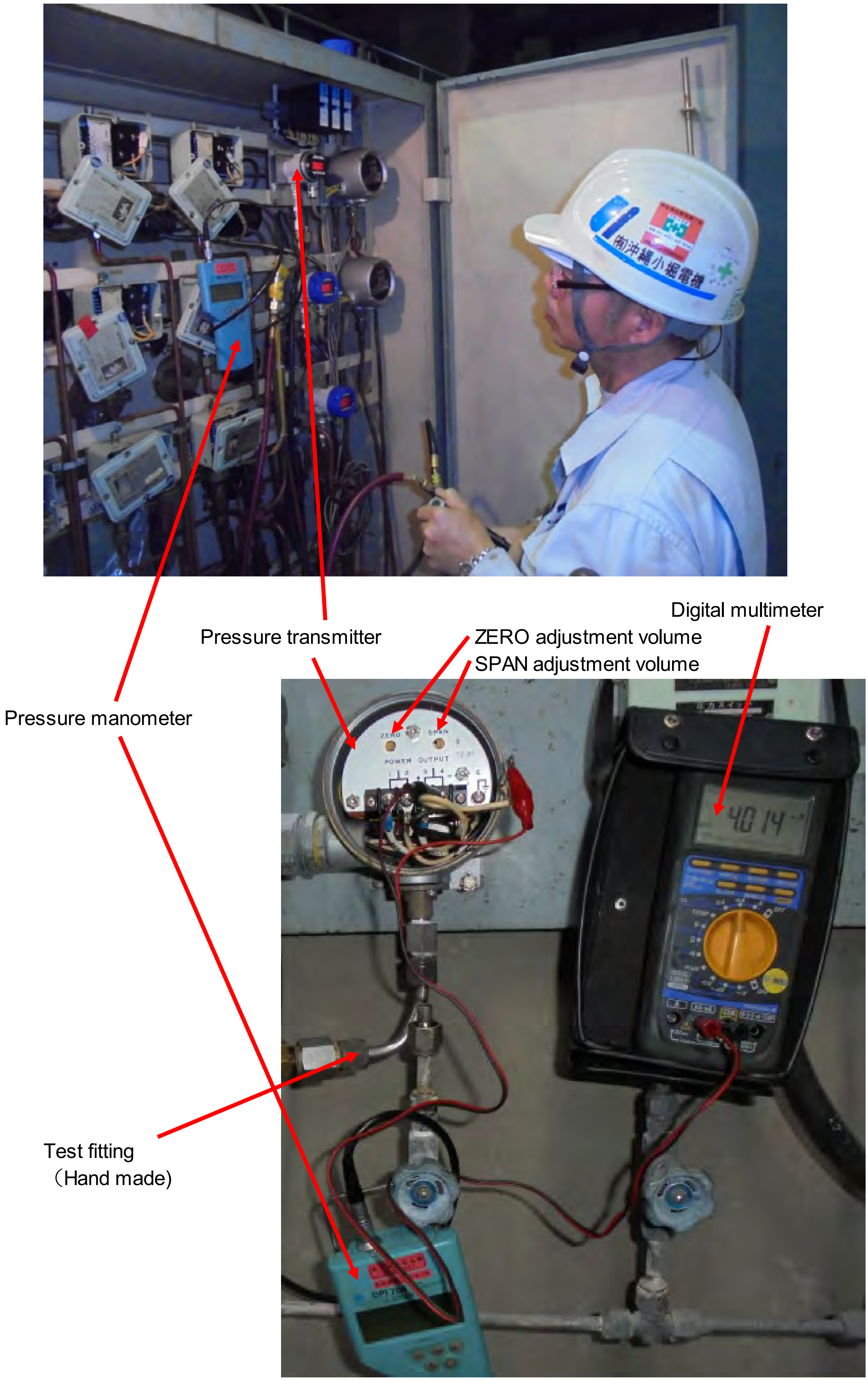
Disconnect one of the lines (+, -) and connect the digital multimeter shown on the right in series.



Cable

Digital multimeter

Calibration status



8.7 Flow switch inspection

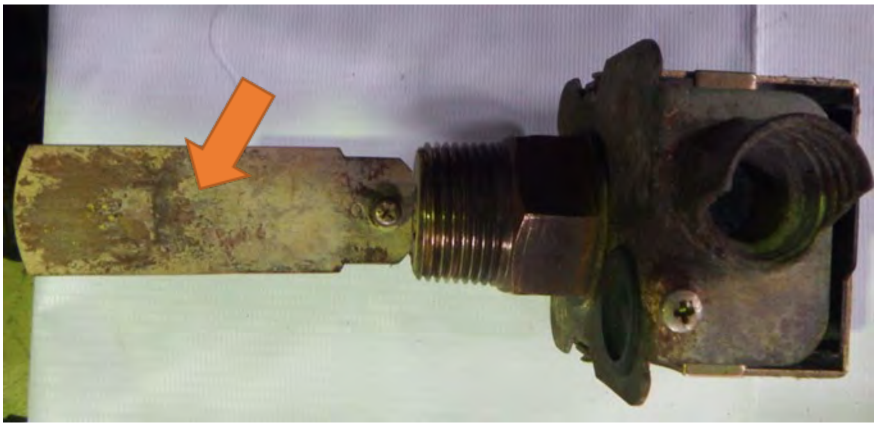
1	Test report creation	Fill out the necessary information on the test report
2	Inspection preparation	(Things to prepare) Wrench, waste, blind plug, sealing tape Cleaning solution, Scatch Bright, other cleaning tool
3	Pre-inspection meeting Isolation※	※ Detaching the measurement state (In this case, close the original valve of the instrument)
4	Cable removal	Remove the head cover and detach the cable. ※ Electric shock Caution (protect with vinyl tape)
5	Instrument removal	Remove the instrument from the piping with a wrench. ※ Damage caution, not to be caught between piping and instrument.
6	Cleaning	Clean the inside and outside of the instrument. ※ Rust, water screeing etc. to clean.
7	Operation check	Make sure to move the internal paddle (water catcher) to operate (Check the contact ON / OFF with a tester. By measuring the contact resistance at the time of ON, it is useful for diagnosing the life of the microswitch.) ※ Contact resistance tends to increase as the service life expires.
8	Instrument restoration	Restore instruments to piping. ※ Damage caution, not to be caught between piping
9	Cable restoration	Recover the detached cable. ※ Electric shock Caution
10	Inspection end report Isolation restoration	※ Confirm opening of original valve
11	Inspection finished	

4. Cable removal

	① Loosen screw cover (2 places) Remove the cover. ② Disconnect both cables. ③ Remove cable and conduit。 ※ Electric shock Cousion (Turn off the control power when it is possible)

5. Removal (loosen screw part from piping and remove main body)

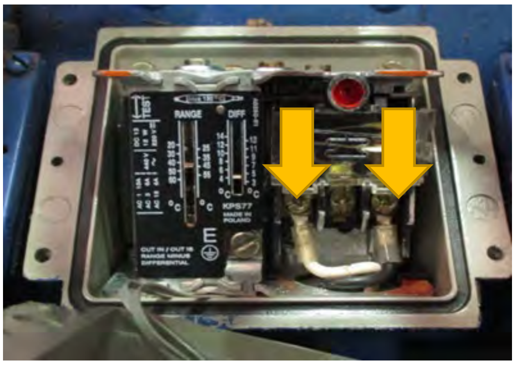
6. Cleaning

		Remove stain and rust of the paddle part
		Remove the screw and and carefully clean the back side of the paddle.

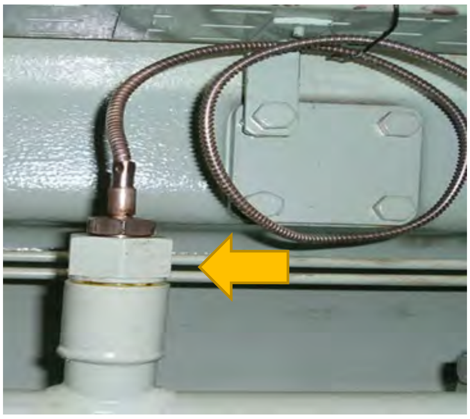
8.8 The temperature switch inspection

1	Test report creation	Fill out the necessary information on the test report.
2	Inspection preparation	(Things to prepare) Digital multimeter, Digital thermometer, Wrench, Pot Bucket, waste, cleaning solution
3	Pre-inspection meeting Isolation※	※ Detaching the measurement state （In this case, ask the control power supply to be turned off or have the valve on the pipe closed)
4	Cable removal	Remove the instrument cover and detach the cable. ※ Electric shock Caution (protect with vinyl tape)
5	Removal of temperature sensitive part	Remove temperature sensing part from piping. ※ Damege causion！If necessary, attach a closing plug to the temperature sensing part.
6	Exam preparation	Add water to the pot and heat it up to the temperature near the set value. Keep water in the bucket. ※ Beware of burns
7	Calibration	Temperature is up and down in the vicinity of set value and operation value is confirmed. If it is within the allowable value, it ends.Otherwise adjust.
8	Adjustment	If adjustment is necessary, turn the screw part and change the operation value.
9	Thermal part restoration	Restore the temperature sensing part to the piping. ※ Damege caution
10	Cable restoration	Recover the detached cable. ※ Electric shock Caution
11	Inspection end report Isolation restoration	
12	Inspection finished	

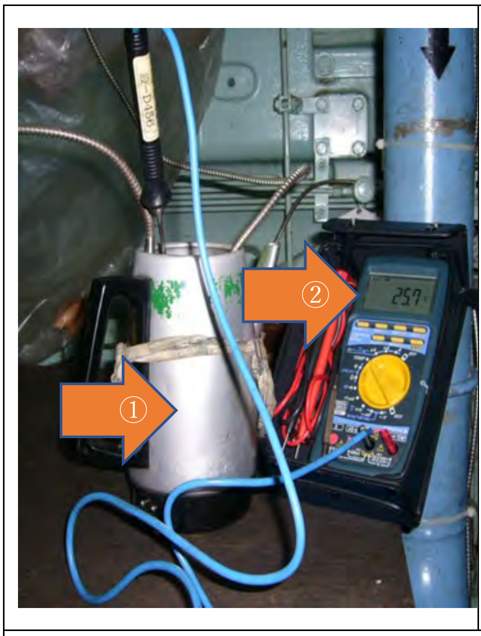
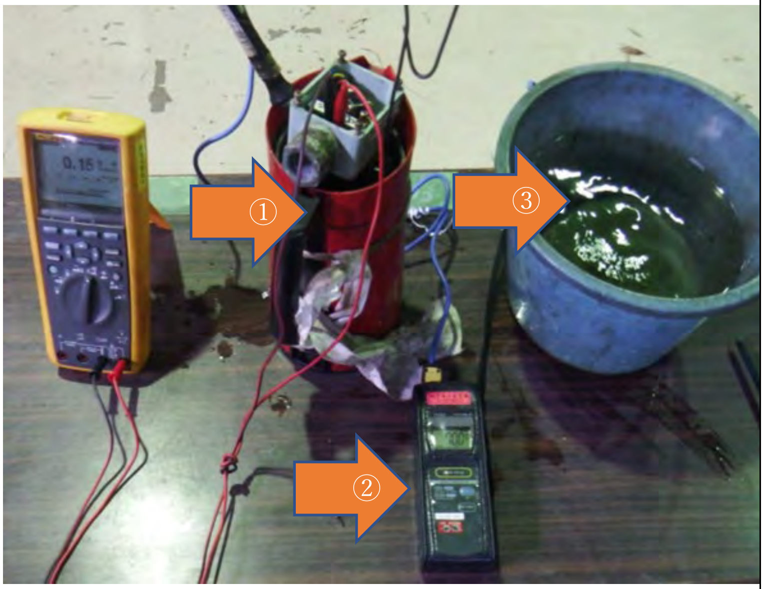
4. Cable removal

	Disconnect both cables. ※　Electric shock Caution！

5. Removal of temperature sensor

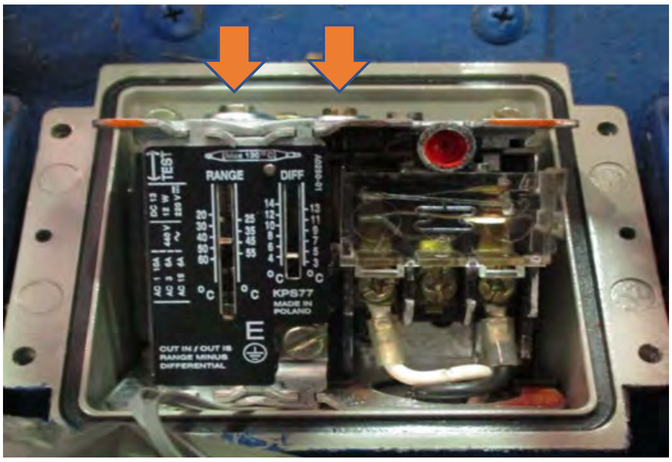
		Remove the temperature sensor. ※In the absence of protective tube, water and oil overflow, so plug it with a closing plug.

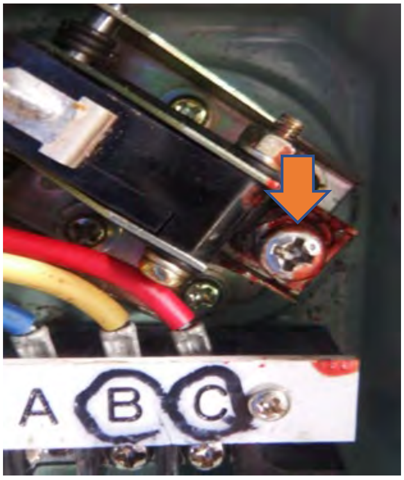
6. / 7. Exam preparation, Calibration

	
①Pot　　②Digital thermometer　　③Water (room temperature)	

8. Adjustment

Loosen the locking screw and turn the screw to adjust the operation value.



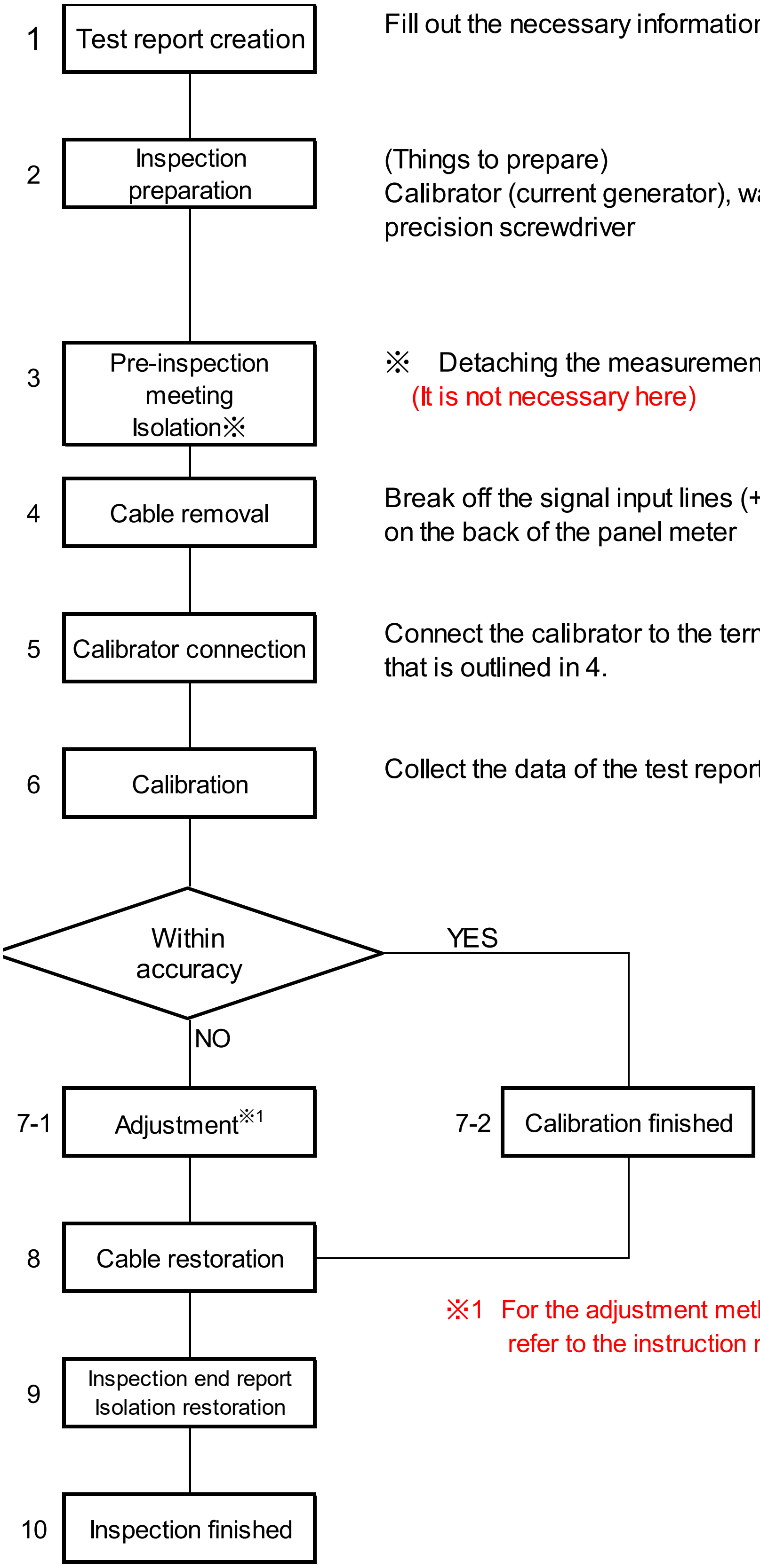


① After adjustment, fix the locking screw, up and down the temperature of water, confirm the ON / OFF of the contacts many times.
At this time, up and down of temperature should be carried out gently.
Otherwise, the operation values will vary.

② Measure the contact resistance when contact is ON.
If the contact resistance value increases, it will cause malfunction.
It becomes life diagnosis.

③ When it is confirmed that it operates according to the set value, lock paint is applied to the locking screw.

8.9 Digital panel meters inspection



Fill out the necessary information on the test report.

(Things to prepare)
Calibrator (current generator), waste cloth,
precision screwdriver

※ Detaching the measurement state
(It is not necessary here)

Break off the signal input lines (+, -)
on the back of the panel meter

Connect the calibrator to the terminal part
that is outlined in 4.

Collect the data of the test report with a calibrator.

※1 For the adjustment method,
refer to the instruction manual

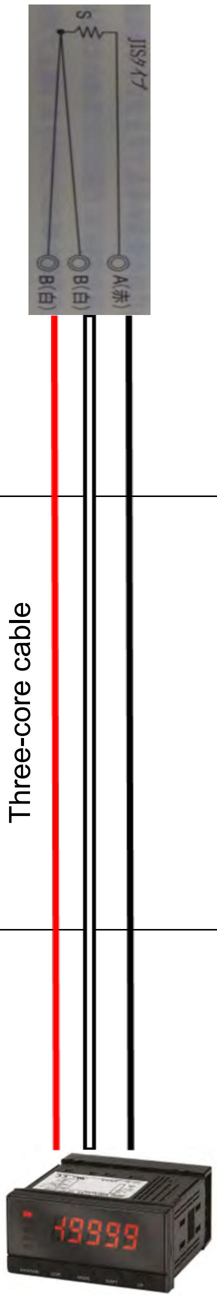
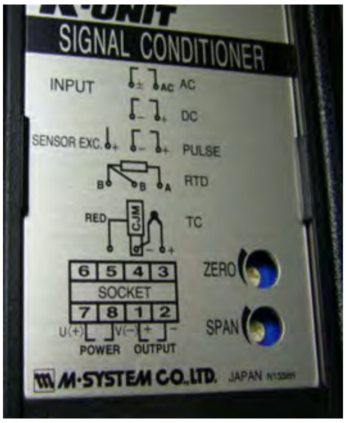
	Exterior view (front)
	Connect the calibrator by detaching the cable
	Test

8.10 Resistance temperature detector (RTD) inspection

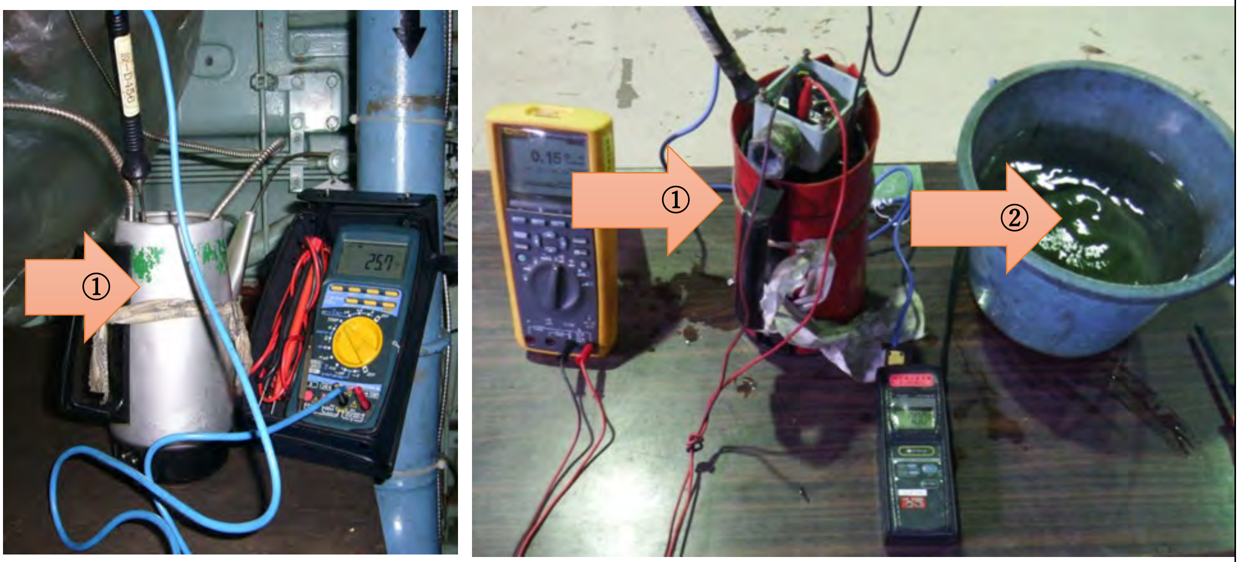
1	Test report creation	Fill out the necessary information on the test report.
2	Inspection preparation	(Things to prepare) Digital multimeter, digital thermometer, wrench, pot Bucket, waste, cleaning solution
3	Cable removal	Remove the instrument cover and detach the cable.
4	Remove RTD	Remove RTD main unit from connecting part (screw) ※ Damage Causion ! If necessary, attach a closing plug to the temperature sensing part
5	Continuity test Insulation resistance measurement	Measure the resistance between A and B and between B and B. (Measurement of conduction resistance) ※ The resistance value at room temperature is between A and B, and the value between B and B is close to 0Ω Measure the resistance between A - case and B - case. (Insulation resistance measurement) ※ Between A - Case and B - Case are 5 MΩ or more and normal (+ For terminals, - for case)
6	Exam preparation	Add water to the pot and heat it until it boils. Keep water in the bucket. ※ Beware of burns
7	Calibration Validity assessment	① Measure the resistance value of RTD at room temperature water ② RTD is put in boiling water and the resistance value is measured. ③ The measured resistance value is compared with the reference table to obtain an error. ④ If calibration is within tolerance, calibration is finished, if it is out of replacement.
8	RTD restoration	Recover from RTD ※ Damege causion
9	Cable restoration	Recover the detached cable. ※ Electric shock Caution
10	Inspection end report Isolation restoration	
11	Inspection finished	

3, 4 Cable removal, remove RTD

	Remove it with a wrench from this part
	Lift three wires from the terminal

Site side		 Lifting the cable at the terminal section and measuring the continuity resistance (resistance value measurement) with the digital multimeter Insulation resistance measurement (+ indicates terminal, - for case) (Insulation resistance measurement range is 250V)
Three-core cable		
Instrument set panel side or control room side		

7. Calibration



①Pot ②Water

① Prepare water at room temperature and boiling water in a pot.

② Measure the resistance value of RTD at room temperature water

③ RTD is put in boiling water and the resistance value is measured.

④ The measured resistance value is compared with the reference table to obtain an error

⑤ If calibration is within tolerance, calibration is finished, if it is out of replacement.

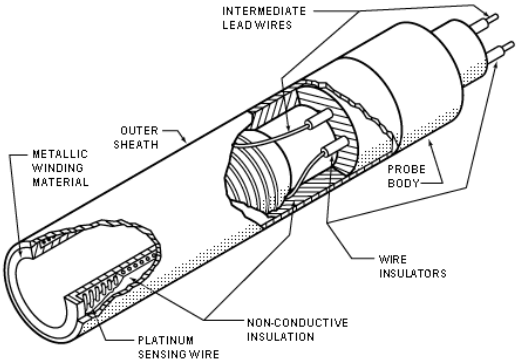
RTD reference resistance value table

Temp ℃	-100	0	Temp ℃	0	100	200	300	400	500	600	700	800	Temp ℃
0	60.26	100.00	**0**	100.00	138.51	175.86	212.05	247.09	280.98	313.71	345.28	375.70	**0**
-10	56.19	96.09	**10**	103.90	142.29	179.53	215.61	250.53	284.30	316.92	348.38	378.68	**10**
-20	52.11	92.16	**20**	107.79	146.07	183.19	219.15	253.96	287.62	320.12	351.46	381.65	**20**
-30	48.00	88.22	**30**	111.67	149.83	186.84	222.68	257.38	290.92	323.30	354.53	384.60	**30**
-40	43.88	84.27	**40**	115.54	153.58	190.47	226.21	260.78	294.21	326.48	357.59	387.55	**40**
-50	39.72	80.31	**50**	119.40	157.33	194.10	229.72	264.18	297.49	329.64	360.64	390.48	**50**
-60	35.54	76.33	**60**	123.24	161.05	197.71	233.21	267.56	300.75	332.79	363.67		**60**
-70	31.34	72.33	**70**	127.08	164.77	201.31	236.70	270.93	304.01	335.93	366.7		**70**
-80	27.10	68.33	**80**	130.90	168.48	204.90	240.18	274.29	307.25	339.06	369.71		**80**
-90	22.83	64.30	**90**	134.71	172.17	208.48	243.64	277.64	310.49	342.18	372.71		**90**
-100	18.52	60.26	**100**	138.51	175.86	212.05	247.09	280.98	313.71	345.28	375.70		**100**
Temp ℃	**-100**	**0**	**Temp ℃**	**0**	**100**	**200**	**300**	**400**	**500**	**600**	**700**	**800**	**Temp ℃**

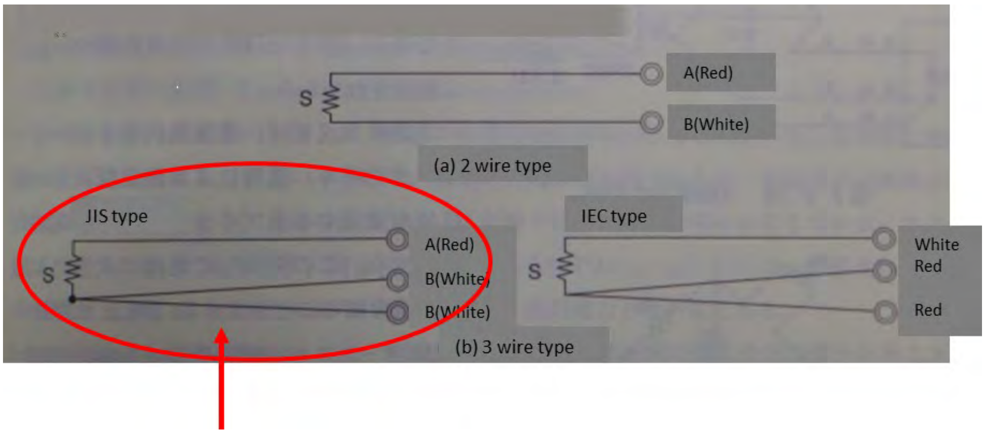
Common difference PT100 measurement temperature				
Measurement temperature(℃)	Common difference			
	Class A		Class B	
	℃	Ω	℃	Ω
-200	±0.55	±0.24	±1.3	±0.56
-100	±0.35	±0.14	±0.8	±0.32
0	±0.15	±0.06	±0.3	±0.12
100	±0.35	±0.13	±0.8	±0.30
200	±0.55	±0.20	±1.3	±0.48
300	±0.75	±0.27	±1.8	±0.64
400	±0.95	±0.33	±2.3	±0.79
500	±1.15	±0.38	±2.8	±0.93
600	±1.35	±0.43	±3.3	±1.06

Platinum resistance temperature detector (RTD) element shape

(http://www.rdfcorp.com/anotes/pa-r/pa-r_01.shtml)



Resistance temperature detector internal lead wire system



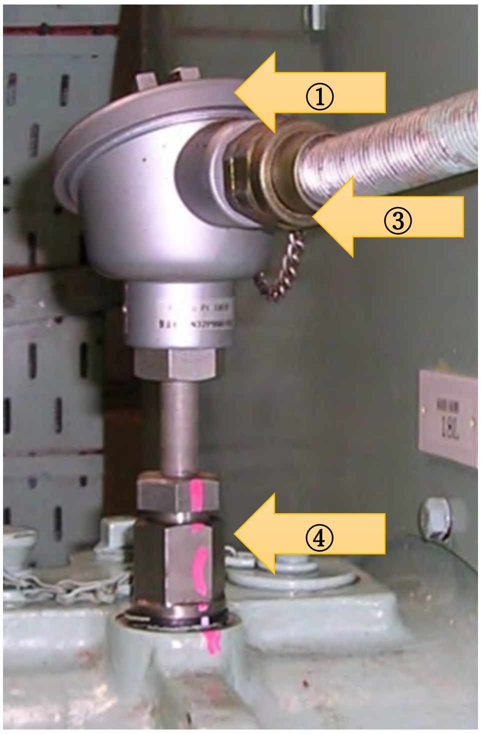
The RTD mainly used in Japan

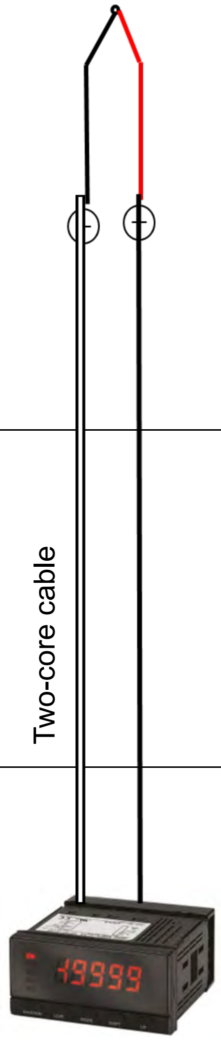
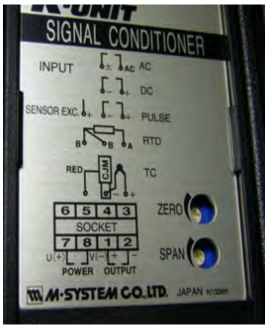
（Pt100Ω at 0℃）

8.11 Thermocouple inspection

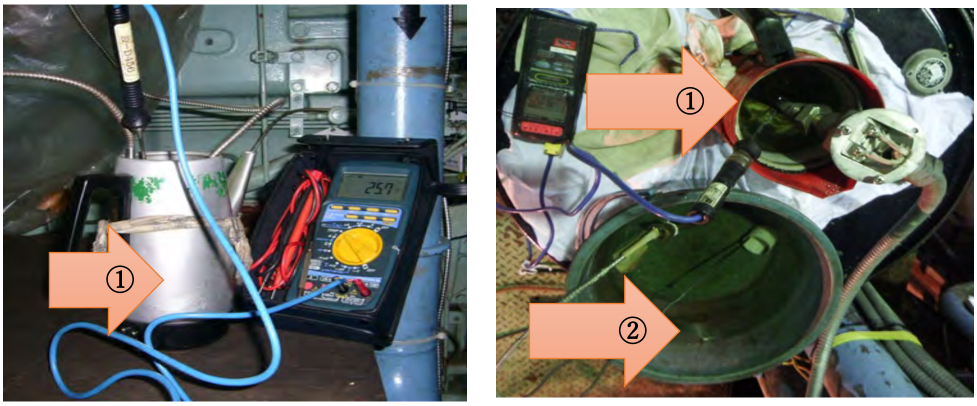
1	Test report creation	Fill out the necessary information on the test report.
2	Inspection preparation	(Things to prepare) Digital multimeter, digital thermometer, wrench, pot Bucket, waste, cleaning solution
3	Cable removal	Remove the instrument cover and lift both cables.
4	Remove thermocouple	Remove thermocouple main body from connecting part (screw) ※ Damage Caution！If necessary, attach a closing plug to the temperature sensing part
5	Continuity test Insulation resistance measurement	Measure the resistance between + (plus) and - (minus). (Measurement of conduction resistance) ※ The resistance value is close to 0Ω. Measure the resistance value between + (plus) and case. (Insulation resistance measurement) ※ + (Plus) to case, normal with 5 MΩ or more.
6	Exam preparation	Add water to the pot and heat it until it boils. Keep water in the bucket. ※ Beware of burns
7	Calibration Validity assessment	① Preparing the room temperature water and boiling water (room temperature water for cooling) ② Insert thermocouple in boiling water and measure mV ③ The measured electromotive force (mV) is compared with the electromotive force table to obtain an error. ④ If calibration is within tolerance, calibration is finished, if it is out of replacement.
8	Thermocouple restoration	Recover from thermocouple ※ Damege caution
9	Cable restoration	Recover the detached cable. ※ Electric shock Caution
10	Inspection end report Isolation restoration	
11	Inspection finished	

3., 4. Cable &b Thermocouple removal

	① Remove the cover ② Lift two wires from the terminal ③ Remove conduit ④ Remove it with a wrench
	

Site side	Measurement point 			
		Lifting the cable at the terminal section and measuring the continuity resistance (resistance value measurement) with the digital multimeter Insulation resistance measurement (+ indicates terminal, - for case) (Insulation resistance measurement range is 250V)		
Two-core cable				
Instrument set panel side or control room side	Digital Panel Meter	Signal converter 		

7. Calibration



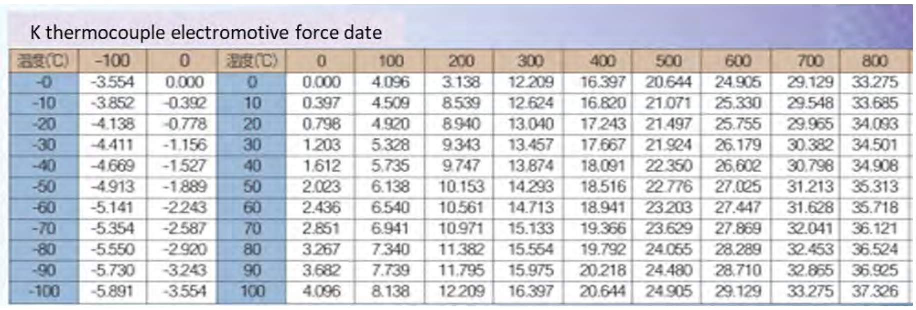
①Pot ②Water

① Preparing the room temperature water and boiling water.
(room temperature water for cooling)

② Insert thermocouple in boiling water and measure mV

③ The measured electromotive force (mV) is compared with the electromotive force table to obtain an error.

④ If calibration is within tolerance, calibration is finished,
if it is out of replacement.



K thermocouple electromotive force date

温度(℃)	-100	0	温度(℃)	0	100	200	300	400	500	600	700	800
-0	-3.554	0.000	0	0.000	4.096	3.138	12.209	16.397	20.644	24.905	29.129	33.275
-10	-3.852	-0.392	10	0.397	4.509	8.539	12.624	16.820	21.071	25.330	29.548	33.685
-20	-4.138	-0.778	20	0.798	4.920	8.940	13.040	17.243	21.497	25.755	29.965	34.093
-30	-4.411	-1.156	30	1.203	5.328	9.343	13.457	17.667	21.924	26.179	30.382	34.501
-40	-4.669	-1.527	40	1.612	5.735	9.747	13.874	18.091	22.350	26.602	30.798	34.908
-50	-4.913	-1.889	50	2.023	6.138	10.153	14.293	18.516	22.776	27.025	31.213	35.313
-60	-5.141	-2.243	60	2.436	6.540	10.561	14.713	18.941	23.203	27.447	31.628	35.718
-70	-5.354	-2.587	70	2.851	6.941	10.971	15.133	19.366	23.629	27.869	32.041	36.121
-80	-5.550	-2.920	80	3.267	7.340	11.382	15.554	19.792	24.055	28.289	32.453	36.524
-90	-5.730	-3.243	90	3.682	7.739	11.795	15.975	20.218	24.480	28.710	32.865	36.925
-100	-5.891	-3.554	100	4.096	8.138	12.209	16.397	20.644	24.905	29.129	33.275	37.326

Thermocouple common difference

K	Temperature range	-40℃ or higher + less than 375℃	-40℃ or higher + less than 333℃	-167℃ or higher + less than 40℃
	Common difference	±1.5℃	±2.5℃	±2.5℃
	Temperature range	-40℃ or higher + less than 375℃	-40℃ or higher + less than 333℃	-167℃ or higher + less than 40℃
	Common difference	±0.004･｜t｜	0.0075･｜t｜	±0.015･｜t｜
	Old class	0.4class	0.75class	1.5class

Types of thermocouples and constituent materials

Type Symbol	Constituent material	
	＋leg※	－leg※
B	Platinum rhodium alloy containing 30% rhodium	Platinum rhodium alloy containing 6% rhodium
R	Platinum rhodium alloy containing 13% rhodium	Platinum
S	Platinum rhodium alloy containing 10% rhodium	Platinum
N	Nickel, chromium and alloys mainly containing silicon	Alloys mainly made of nickel and chromium
K	Alloys mainly made of nickel and chromium	Nickel-based alloys
E	Alloys mainly made of nickel and chromium	Copper and nickel-based alloys
J	Iron	Copper and nickel-based alloys
T	Copper	Copper and nickel-based alloys

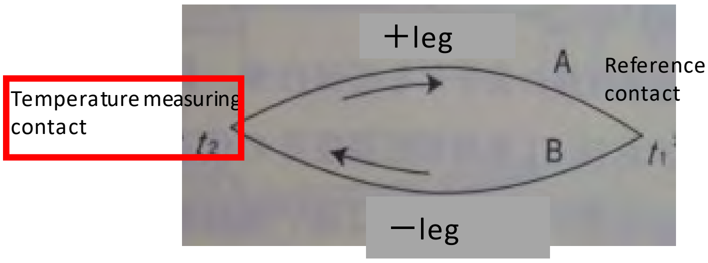
The +leg is The leg to be connected to The + terminal of The instrument that measures The thermoelectromotive force, The other one is called The - leg.

Mainly K type thermocouple is used.

Principle of thermocouple (thermocouple)

Thermocouple

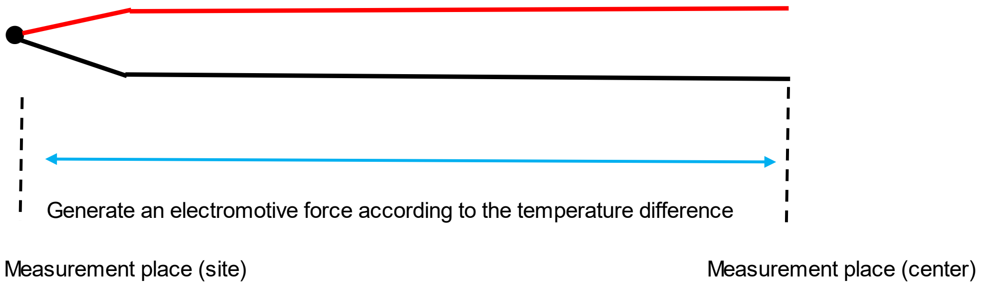
When a closed circuit is made with two kinds of different metal wires and the two contacts are kept at different temperatures, a thermoelectromotive force corresponding to the temperature difference is generated and a current flows in the closed circuit. (Seebeck effect)



The thermocouple (the arrow indicates the current direction in the case of t 2> t 1)

Figure1.Principle of thermocouple

By checking the relationship between this temperature and the thermoelectromotive force, it is possible to measure the temperature by connecting the DC voltmeter between the two terminals formed by opening one contact and measuring the thermoelectromotive force.

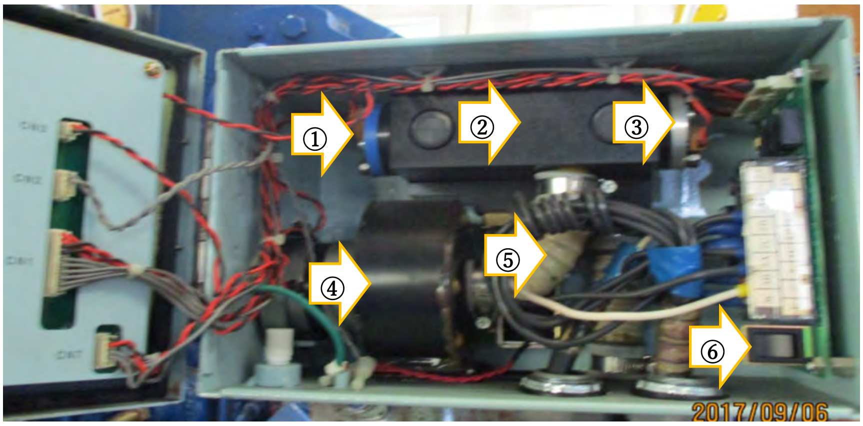


8.12 Oil mist concentration meter disassembly inspection

1	Power supply isolation	Have the power supply cut off at the instrument collecting board.
2	Inspection preparation	(Things to prepare) Waste, cleaning solution, precision screwdriver, hex wrench, Lubricant, brush
3	Cable removal	Power cables, heavy faults, light faults cable removal and cover with vinyl tape.
4	Detection pipe removal	Remove the detection piping (black rubber) from the engine. ※ Keep air purge the inside of the rubber hose.
5	Internal disassembly cleaning	Take pictures in advance and disassemble inside. Mist of lubricating oil adheres considerably, so wipe clean. ※ Be careful not to drop it because it is slippery with oil.
6	Consumables replacement※	※ Replace consumables if present (hose, o-ring)
7	Internal restoration	After cleaning, assemble disassembled internal parts. ※ Be careful with built-in mistakes
8	Cable restoration	Restore only the power cable.(For the test)
9	Power on, check operation	Have the power turned on and confirm the operation. ※ Operation of fan (air flow), automatic zero point adjustment. ※ For details, refer to the instruction manual.
11	Light failure cable recovery	Restore the cable for minor light fault and wait for trial operation (start up)
12	Span adjustment	Span adjustment is performed when the engine is 100% load. Adjust with the gain volume so that the indicated value will be 2 to 3.
13	Heavy failure cable recovery	Restore heavy fault cable when engine is stopped.
14	Inspection finished	

13. Oil mist concentration meter disassembly inspection

Internal Outline

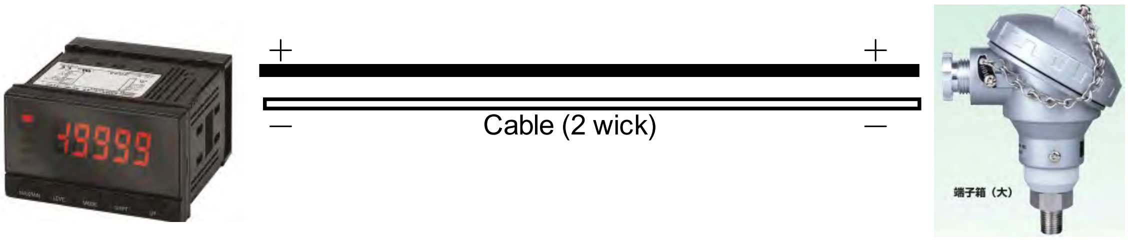
	① Floodlight ② Detection tube ③ Receiver ④ Suction fan ⑤ Hose ⑥ Power supply Switch

13. Oil mist concentration meter disassembly inspection

※ Since the inside details are dirty with oil mist, clean it thoroughly.
Replace expendable items
(O ring, hose) as much as possible.

8.13 Loop test

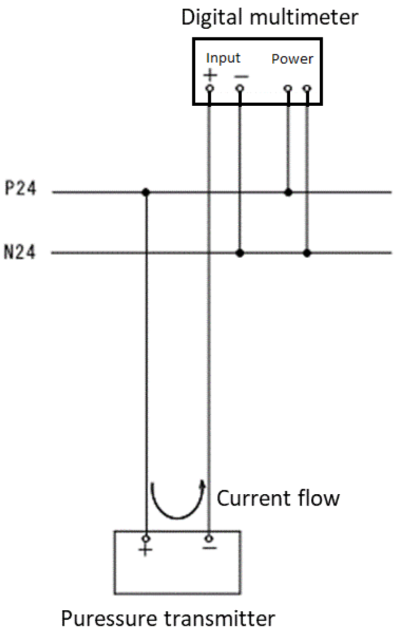
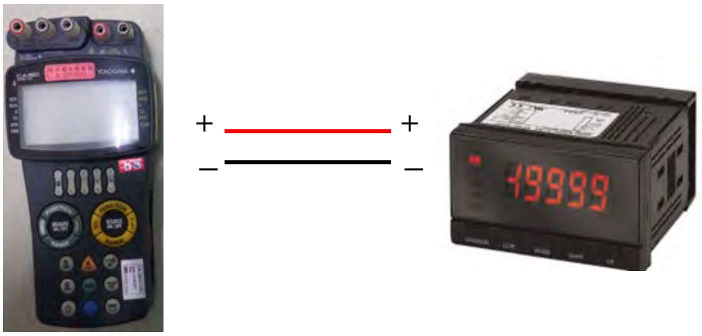
Pressure transmitter ～ Digital panel meter test and confirmation method



Instrument gathering board or center

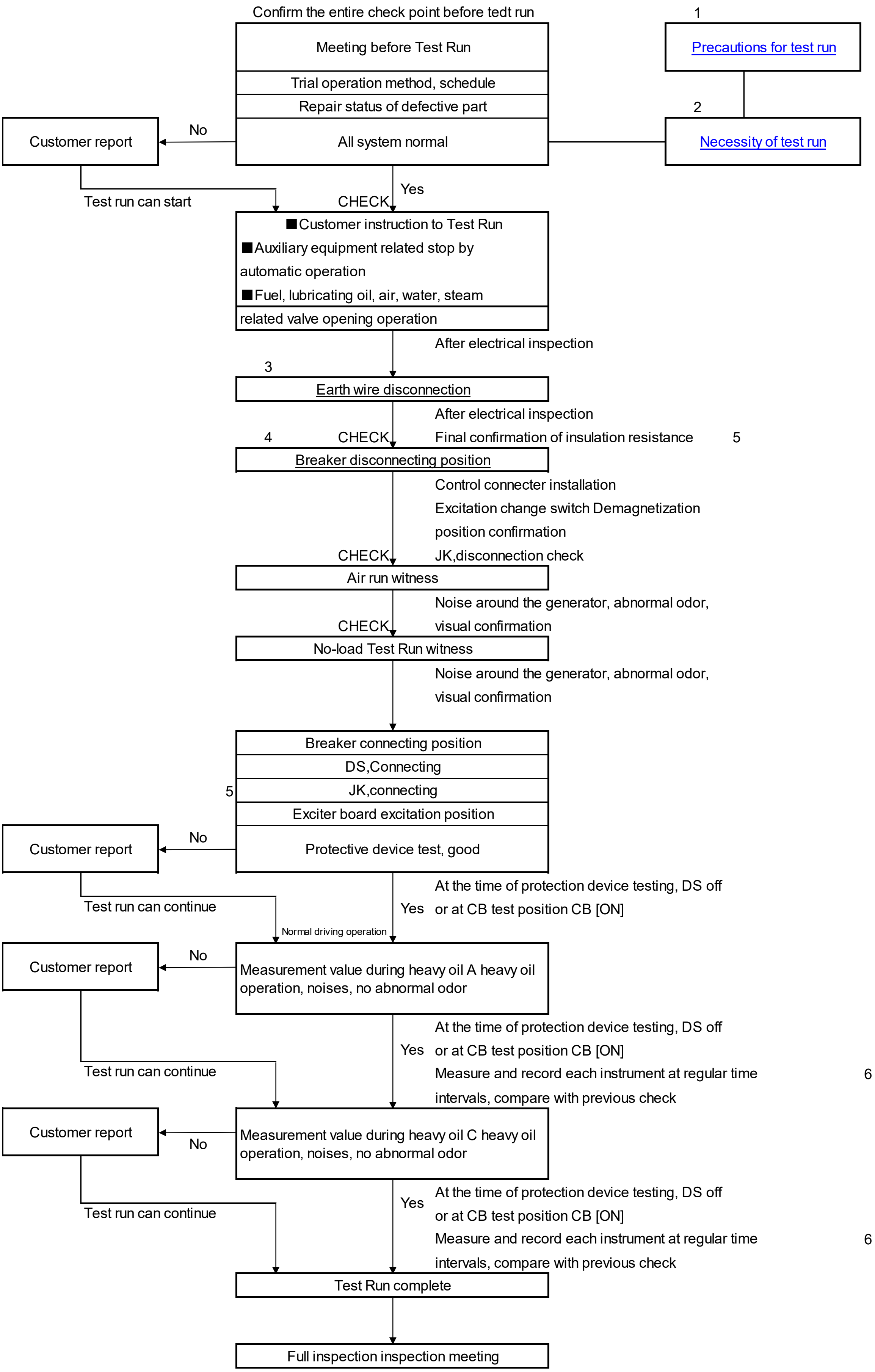
Pressure transmitter (site)

The loop confirmation method in the case of the measurement method as described above is described below.

	1. Connect a digital multimeter in series with the cable of the pressure transmitter and measure the current value. 2. When it is not the indicated value corresponding to the current signal. 2−①　Test the digital panel meter alone. (Calibrator is needed) 2-②　Giving a simulated pressure to the pressure transmitter and check with a digital panel meter. (Pressure manometer, pressurizing pump is necessary) 2−③　Enter the simulation signal in the digital multimeter and check it. (Calibrator is needed) ※Signal input from pressure transmitter side.
	Wire as described above, input DC - 4 to - 20mA with current input and confirm the indicated value.

With the above confirmation, it is possible to judge the quality of the pressure transmitter and judge the quality of the digital panel meter.

9.Test Run


Confirm the entire check point before tedt run
Meeting before Test Run
Trial operation method, schedule
Repair status of defective part
All system normal
1
Precautions for test run
2
Necessity of test run
No
Customer report
Test run can start
Yes
CHECK
■Customer instruction to Test Run
■Auxiliary equipment related stop by automatic operation
■Fuel, lubricating oil, air, water, steam related valve opening operation
After electrical inspection
3
Earth wire disconnection
After electrical inspection
4
CHECK
Final confirmation of insulation resistance
5
Breaker disconnecting position
Control connecter installation
Excitation change switch Demagnetization position confirmation
CHECK
JK,disconnection check
Air run witness
Noise around the generator, abnormal odor, visual confirmation
CHECK
No-load Test Run witness
Noise around the generator, abnormal odor, visual confirmation
Breaker connecting position
DS,Connecting
5
JK,connecting
Exciter board excitation position
No
Customer report
Protective device test, good
At the time of protection device testing, DS off or at CB test position CB [ON]
Test run can continue
Yes
Normal driving operation
No
Customer report
Measurement value during heavy oil A heavy oil operation, noises, no abnormal odor
At the time of protection device testing, DS off or at CB test position CB [ON]
Yes
Measure and record each instrument at regular time intervals, compare with previous check
6
Test run can continue
Customer report
No
Measurement value during heavy oil C heavy oil operation, noises, no abnormal odor
Yes
At the time of protection device testing, DS off or at CB test position CB [ON]
Test run can continue
Measure and record each instrument at regular time intervals, compare with previous check
6
Test Run complete
Full inspection inspection meeting

1. Precautions for test run

1. When test run is performed, understand the system and make procedures and others.
2. If there is a problem during inspection, reconfirm whether it was repaired.
3. Before test run, reconfirm all inspection points.
4. During the test run, we visit at regular time intervals and observe data acquisition, abnormal noise, odor by instruments etc. to prevent accidents etc beforehand.

2. Necessity of test run

The power station can demonstrate its performance only when many equipments and equipment constituting it perform soundly, and safety is secured.

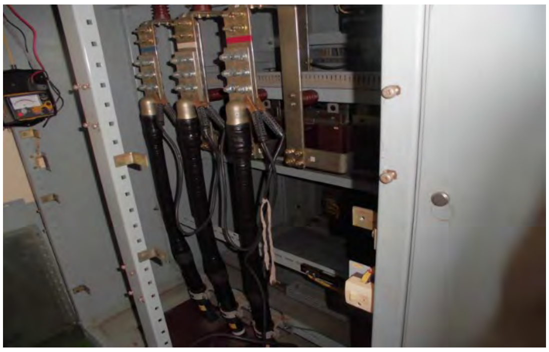
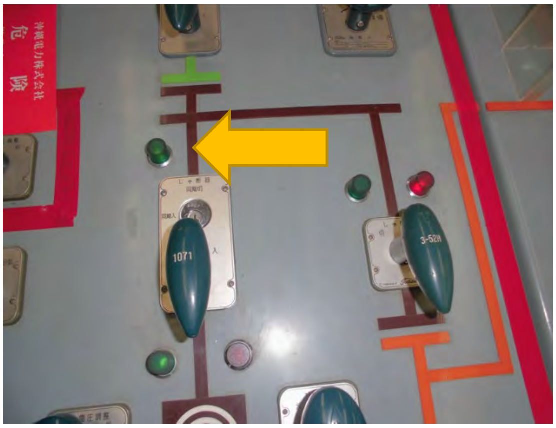
For this reason, all equipment and equipment tests, system tests and plant test runs of equipment and equipment are carried out.

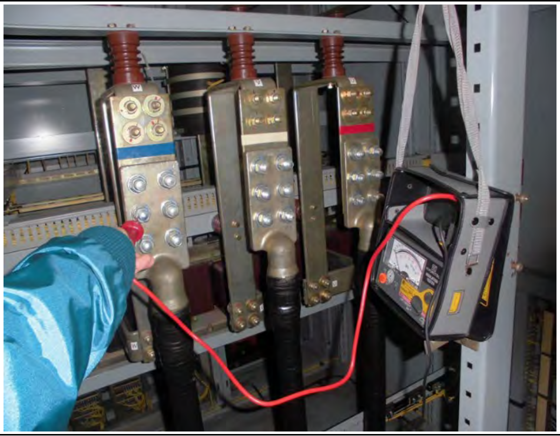
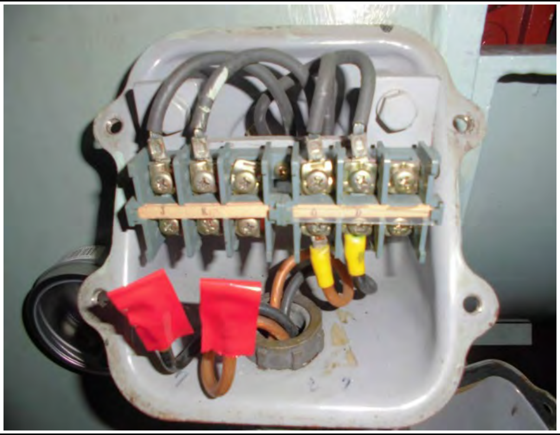
After conducting security device tests, etc., a generator was added, and the various dynamic characteristics of the plant simulating load fluctuation, plant trip etc., while sequentially increasing the output to 25%, 50%, 75%, 100% Repeat the test and output rise test etc. to confirm the health and safety of the plant.

Perform rated output continuous operation to check the stable operation performance of the plant.

3. Generator

	３． Generator Electroscopic inspection, Discharge round Exciter machine board Electroscopic inspection, status
	Discharge situation after inspection status

	Installation condition of grounding wire after discharge
	4. Generator circuit breaker Off indication in Generator control panel
	Generator breaker
	Generator breaker off Disconnecting position

	5. Insulation resistance High voltage circuit Measurement of insulation resistance
	Exciter terminal box side J, K removal
	Exciter side Low voltage circuit Measure insulation resistance

６. Test run report

Power plant unit Tenp. ℃ Humidity % Date month / day / year

Time	Air temp.			Bearing temp.		Stator temp.			output	Voltage	Current			Voltage	Current	Power	Rotation	Frequency
h : m	Intake		Exhaust	Eng side	Gen side	U	V	W	MW	kV	(kA)			EXV	EXA	factor	speed	Hz
	Eng	Gen									R	S	T			COSθ	min^{-1}	
Managed value																		
No load											—	—	—					
:	start																	
:																		
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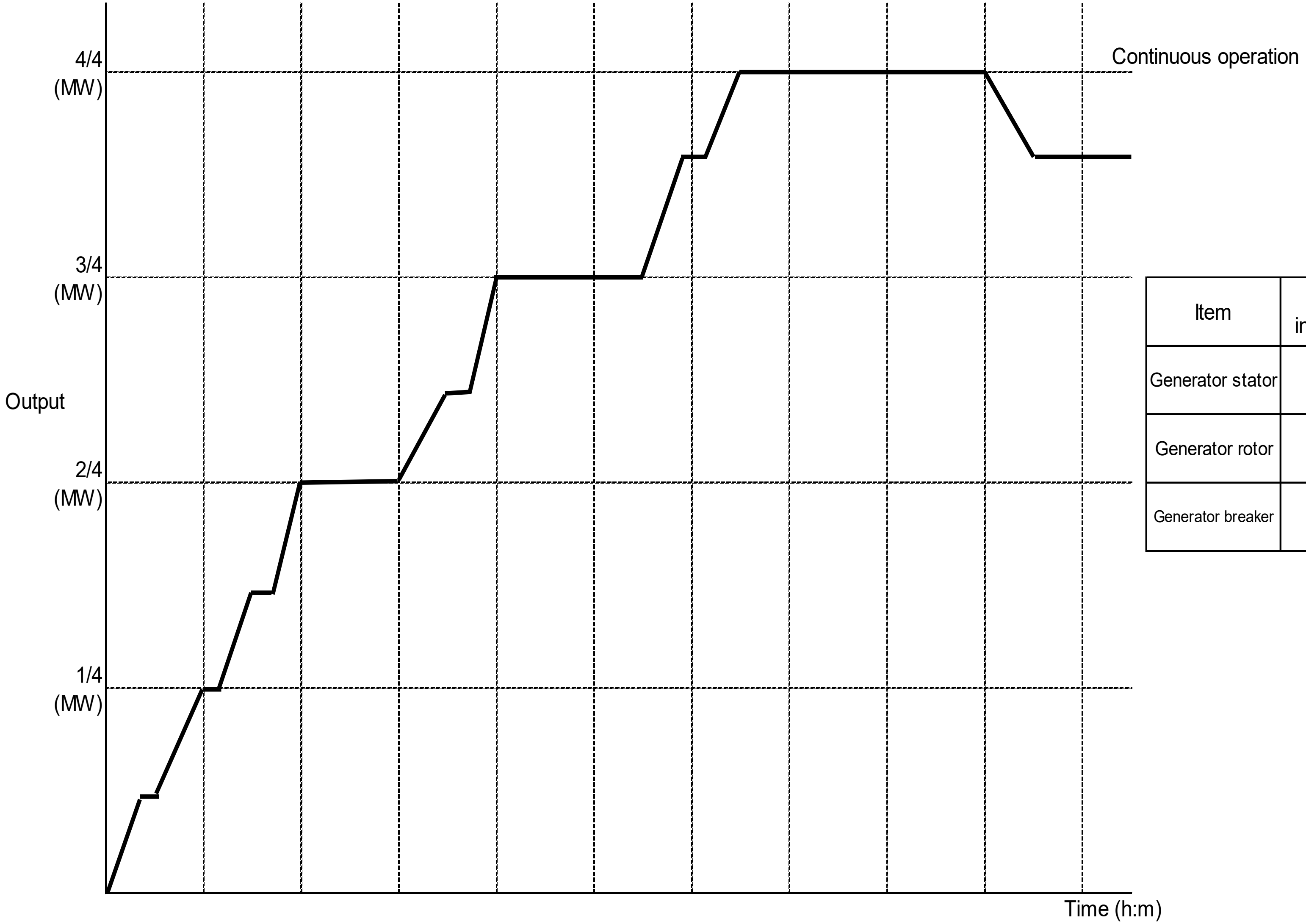
6. Test run report



Unit (MΩ)

Item	Before inspection	After inspection
Generator stator		
Generator rotor		
Generator breaker		

11.1.2 DG将来業務計画書

Diesel Generation Maintenance Plan

Kosrae Utilities Authority

June 2023

(Signature)____________________
Approved by
Fred Skilling
General Manager
Kosrae Utilities Authority (KUA)
Date 30 June 2023

June 2023

KUA (Kosrae) DG's Maintenance Plan

1. Objective

2. This plan has been prepared with the aim of contributing to the maintenance of reliable and affordable power generation by providing a guideline for the performing of future OH maintenance works on DGs units #9 and #10 of the KUA Power Plant. This plan has been prepared in accordance with the information provided by the KUA together with the advice of the JICA experts team. The results shown in this plan are for preliminary reference only, further periodic revisions are necessary to increase the accuracy of the results.

3. Preparation process for OH

The process to carry out the maintenance works are shown in the following flow chart.

1. Preparation of the maintenance schedule according to the running hours of each DG's (See attach.-1 Maintenance schedule)
2. Verification of the necessary spare parts according to the class of maintenance. (See attach-2 Spare parts list)
3. Request of quotation for spare parts and order according to the Maintenance schedule.
4. Verification of the necessary consumables and tools for maintenance works and order.
5. Maintenance works according to the manuals.

4. Conditions

In this plan are considered below conditions.

- This plan calculates the estimated costs for OH maintenance.
- Updating of each estimate to the actual values is preferable to increase accuracy in the results.
- Labor costs have not been accounted because the works is done by KUA maintenance staff and not extra cost is needed.

3.1 List of pilot DGs.

Unit No.	Manufacturer	Type	Rated capacity (kW)	Rotation speed (rpm)	Year manufactured	Remarks
9	Daihatsu	6DE-18	600	900	2017	
10	Daihatsu	6DE-18	600	900	2017	
	Total		1,200			

3.2. Type of Maintenance

Top OH：Upper cylinder overhaul every 12,000 hours of operation.

Major OH：DG overall overhaul every 24,000 hours of operation.

(See details in Daihatsu manual)

According to the above operation hours, maintenance is set as below.

Unit No.	2023	2024	2025	2026	2027
# 9	Top OH	Major OH	—	Top OH	Major OH
# 10	Top OH	—	Major OH	—	Top OH

※See Maintenance Schedule (2023-2027) for details.

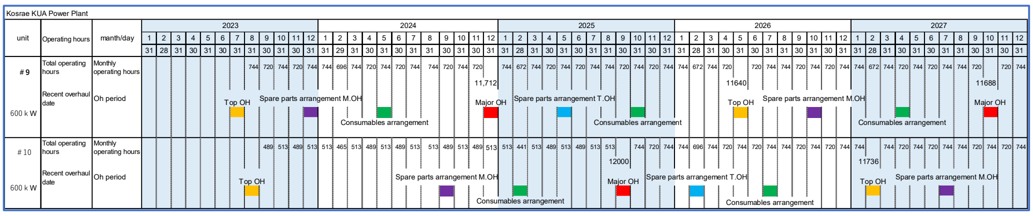
※Update the schedule for OH according to the operation hours of each DGs, which is influenced by the operation hours of the unit #11 (Caterpillar)

3.3. Ordering schedule for required parts and material for OH

To carry out the maintenance works without delaying, setting in the timing for order must be observed as below.

Spare Parts for Top and Major OH：Should be ordered 1 year in advance.

Consumables：Should be ordered 6 months in advance.



Kosrae KUA Power Plant

unit	Operating hours	manth/day	2023											
			1	2	3	4	5	6	7	8	9	10	11	12
			31	28	31	30	31	30	31	31	30	31	30	31
# 9 600 k W	Total operating hours	Monthly operating hours								744	720	744	720	744
	Recent overhaul date	Oh period							Top OH 🟨					Spare parts arrangement M.OH 🟪
# 10 600 k W	Total operating hours	Monthly operating hours									489	513	489	513
	Recent overhaul date	Oh period								Top OH 🟨				

unit	Operating hours	manth/day	2024											
			1	2	3	4	5	6	7	8	9	10	11	12
			31	29	31	30	31	30	31	31	30	31	30	31
# 9 600 k W	Total operating hours	Monthly operating hours	744	696	744	720	744	720	744	744	720	744	720	11,712
	Recent overhaul date	Oh period					Consumables arrangement 🟩							Major OH 🟥
# 10 600 k W	Total operating hours	Monthly operating hours	513	465	513	489	513	489	513	513	489	513	489	513
	Recent overhaul date	Oh period									Spare parts arrangement M.OH 🟪			

unit	Operating hours	manth/day	2025											
			1	2	3	4	5	6	7	8	9	10	11	12
			31	28	31	30	31	30	31	31	30	31	30	31
# 9 600 k W	Total operating hours	Monthly operating hours	744	672	744	720	744	720	744	744	720	744	720	744
	Recent overhaul date	Oh period					Spare parts arrangement T.OH 🟦					Consumables arrangement 🟩		
# 10 600 k W	Total operating hours	Monthly operating hours	513	441	513	489	513	489	513	513	12000	744	720	744
	Recent overhaul date	Oh period		Consumables arrangement 🟩							Major OH 🟥			

unit	Operating hours	manth/day	2026											
			1	2	3	4	5	6	7	8	9	10	11	12
			31	28	31	30	31	30	31	31	30	31	30	31
# 9 600 k W	Total operating hours	Monthly operating hours	744	672	744	720	11640	720	744	744	720	744	720	744
	Recent overhaul date	Oh period					Top OH 🟨					Spare parts arrangement M.OH 🟪		
# 10 600 k W	Total operating hours	Monthly operating hours	744	696	744	720	744	720	744	744	720	744	720	744
	Recent overhaul date	Oh period		Spare parts arrangement T.OH 🟦					Consumables arrangement 🟩					

unit	Operating hours	manth/day	2027											
			1	2	3	4	5	6	7	8	9	10	11	12
			31	28	31	30	31	30	31	31	30	31	30	31
# 9 600 k W	Total operating hours	Monthly operating hours	744	672	744	720	744	720	744	744	720	11688	720	744
	Recent overhaul date	Oh period				Consumables arrangement 🟩						Major OH 🟥		
# 10 600 k W	Total operating hours	Monthly operating hours	744	11736	744	720	744	720	744	744	720	744	720	744
	Recent overhaul date	Oh period	Top OH 🟨					Spare parts arrangement M.OH 🟪						

For details see attachment 01. DG Maintenance schedule.

5. Maintenance Cost Calculation

In this maintenance cost calculation, the cost of the necessary spare parts and consumables have been entered according to old information of OEPC, therefore is advisable to update mainly according to the local supplier's quotation. See Attachment 2.

Unit:USD

Year	Items	Qty	Unit Price	Total	Remarks
2023	Spere Parts Oder Major OH	1	USD 21,500.00	USD 21,500.00	for Unit#9
	Spere Parts Oder Top OH		USD 7,200.00	USD 0.00	
	Consumables Oder		USD 1,500.00	USD 0.00	
			Total	USD 21,500.00	
2024	Spere Parts Oder Major OH	1	USD 21,500.00	USD 21,500.00	for Unit#10
	Spere Parts Oder Top OH		USD 7,200.00	USD 0.00	
	Consumables Oder	1	USD 1,500.00	USD 1,500.00	for Unit#9
			Total	USD 23,000.00	
2025	Spere Parts Oder Major OH		USD 21,500.00	USD 0.00	
	Spere Parts Oder Top OH	1	USD 7,200.00	USD 7,200.00	for Unit#9
	Consumables Oder	2	USD 1,500.00	USD 3,000.00	for Unit#9, #10
			Total	USD 10,200.00	
2026	Spere Parts Oder Major OH	1	USD 21,500.00	USD 21,500.00	for Unit#9
	Spere Parts Oder Top OH	1	USD 7,200.00	USD 7,200.00	for Unit#10
	Consumables Oder	1	USD 1,500.00	USD 1,500.00	for Unit#10
			Total	USD 30,200.00	
2027	Spere Parts Oder Major OH	1	USD 21,500.00	USD 21,500.00	for Unit#10
	Spere Parts Oder Top OH		USD 7,200.00	USD 0.00	
	Consumables Oder	1	USD 1,500.00	USD 1,500.00	for Unit#9
			Total	USD 23,000.00	

Rate ¥140.25/USD(2023/6/5)

Table- 1　Maintenance Cost Calculation Table

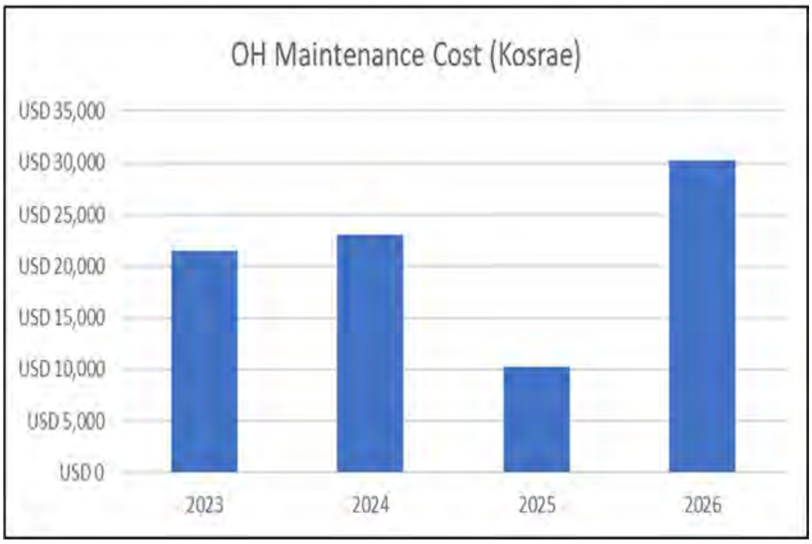


Chart- 1　Maintenance Cost Chart

6. Attachment

1 Maintenance Schedule(2023-2026)

2 Maintenance Cost Calculation Chart (Excel data)

3 Spare Parts List(Engine)

4 Spare Parts List(Electrical)

5 Consumables List

6 Tools and measuring equipment

7 Overhaul Schedule

End

Overhaul Schedule Draft

Kosrae KUA Power Plant

unit	Operating hours	manth/day	2023											
			1	2	3	4	5	6	7	8	9	10	11	12
			31	28	31	30	31	30	31	31	30	31	30	31
# 9	Total operating hours	Monthly operating hours								744	720	744	720	744
	Recent overhaul date	Oh period							Top OH					Spare parts arrangement M.OH
600 k W									🟨					🟪
# 10	Total operating hours	Monthly operating hours									489	513	489	513
	Recent overhaul date	Oh period								Top OH				
600 k W										🟨				

unit	Operating hours	manth/day	2024											
			1	2	3	4	5	6	7	8	9	10	11	12
			31	29	31	30	31	30	31	31	30	31	30	31
# 9	Total operating hours	Monthly operating hours	744	696	744	720	744	720	744	744	720	744	720	
														11,712
	Recent overhaul date	Oh period												Major OH
600 k W							🟩							🟥
							Consumables arrangement							
# 10	Total operating hours	Monthly operating hours	513	465	513	489	513	489	513	513	489	513	489	513
	Recent overhaul date	Oh period									Spare parts arrangement M.OH			
600 k W											🟪			

unit	Operating hours	manth/day	2025											
			1	2	3	4	5	6	7	8	9	10	11	12
			31	28	31	30	31	30	31	31	30	31	30	31
# 9	Total operating hours	Monthly operating hours	744	672	744	720	744	720	744	744	720	744	720	744
	Recent overhaul date	Oh period					Spare parts arrangement T.OH							
600 k W							🟦					🟩		
												Consumables arrangement		
# 10	Total operating hours	Monthly operating hours	513	441	513	489	513	489	513	513		744	720	744
											12000			
	Recent overhaul date	Oh period									Major OH			
600 k W				🟩							🟥			
				Consumables arrangement										

unit	Operating hours	manth/day	2026											
			1	2	3	4	5	6	7	8	9	10	11	12
			31	28	31	30	31	30	31	31	30	31	30	31
# 9	Total operating hours	Monthly operating hours	744	672	744	720		720	744	744	720	744	720	744
							11640							
	Recent overhaul date	Oh period					Top OH					Spare parts arrangement M.OH		
600 k W							🟨					🟪		
# 10	Total operating hours	Monthly operating hours	744	696	744	720	744	720	744	744	720	744	720	744
	Recent overhaul date	Oh period		Spare parts arrangement T.OH										
600 k W				🟦					🟩					
									Consumables arrangement					

unit	Operating hours	manth/day	2027											
			1	2	3	4	5	6	7	8	9	10	11	12
			31	28	31	30	31	30	31	31	30	31	30	31
# 9	Total operating hours	Monthly operating hours	744	672	744	720	744	720	744	744	720		720	744
												11688		
	Recent overhaul date	Oh period										Major OH		
600 k W						🟩						🟥		
						Consumables arrangement								
# 10	Total operating hours	Monthly operating hours	744		744	720	744	720	744	744	720	744	720	744
				11736										
	Recent overhaul date	Oh period		Top OH					Spare parts arrangement M.OH					
600 k W				🟨					🟪					

OH Maintenance cost

Unit:USD

Year	Items	Qty	Unit Price	Total	Remarks
2023	Spere Parts Oder Major OH	1	USD 21,500.00	USD 21,500.00	for Unit#9
	Spere Parts Oder Top OH		USD 7,200.00	USD 0.00	
	Consumables Oder		USD 1,500.00	USD 0.00	
			Total	USD 21,500.00	
2024	Spere Parts Oder Major OH	1	USD 21,500.00	USD 21,500.00	for Unit#10
	Spere Parts Oder Top OH		USD 7,200.00	USD 0.00	
	Consumables Oder	1	USD 1,500.00	USD 1,500.00	for Unit#9
			Total	USD 23,000.00	
2025	Spere Parts Oder Major OH		USD 21,500.00	USD 0.00	
	Spere Parts Oder Top OH	1	USD 7,200.00	USD 7,200.00	for Unit#9
	Consumables Oder	2	USD 1,500.00	USD 3,000.00	for Unit#9, #10
			Total	USD 10,200.00	
2026	Spere Parts Oder Major OH	1	USD 21,500.00	USD 21,500.00	for Unit#9
	Spere Parts Oder Top OH	1	USD 7,200.00	USD 7,200.00	for Unit#10
	Consumables Oder	1	USD 1,500.00	USD 1,500.00	for Unit#10
			Total	USD 30,200.00	
2027	Spere Parts Oder Major OH	1	USD 21,500.00	USD 21,500.00	for Unit#10
	Spere Parts Oder Top OH		USD 7,200.00	USD 0.00	
	Consumables Oder	1	USD 1,500.00	USD 1,500.00	for Unit#9
			Total	USD 23,000.00	

Rate ¥140.25/USD(2023/6/5)

- Spare Parts

Major OH : USD 21,500 (Approximately ¥3,000,000)
Top OH : USD 7,200 (Approximately ¥1,000,000)

- Consumables : USD 1,500 (Japan Reference Value)
- Superviser cost

Major OH : USD 15,000 (2weeks)
Top OH : USD 7,500 (1week)

JICA Team
July30,2021

List of Spare Parts for OH (Engine)

No.	Part No.	Name	MATERIAL	PER 1ENG	Quantity	Remarks
CYLINDER HEAD						
24	DE-18-052	CYL. HEAD ASSY (WITH VALVE)	ASSY	6	2	OUT.BOX
3	AE47056003	SEAT INTAKE VALVE	SPEC.CAST(E38)	12	48	BOX No.5
6	AE47056020	SEAT EXHAUST VALVE A	SCH3 STELLITE6	12	48	BOX No.4
7	AE47056007	SEAL EXHAUST VALVE	SPEC	12	48	BOX No.3
8	AE47056008	SEAL EXHAUST VALVE STEM	SPEC	12	48	BOX No.3
9		NOZZLE TIPS	SPEC	6	24	BOX No.3
33	AE47056010	O-RING G55	FP33	12	48	BOX No.7
34	AE47056011	O-RING S67	SILICON	12	48	BOX No.7
35	AE47056013	O-RING S44	NBR	12	48	BOX No.7
36	E205650300	O-RING G40(4D)	FPM	6	24	BOX No.7
37	Z560102235ZZ	O-RING P22A	NBR	6	24	BOX No.7
38	AE47056014	GASKET CYLINDER HEAD	SPCC	6	24	BOX No.7
39	AE47056003	STAT INTAKE VALVE	SPEC.CAST (E83)	12	48	BOX No.6
112	AE47056015	GASKET	HNBR SUS304	6	12	BOX No.5
113	Z560102235ZZ	O-RING P22A	NBR	6	12	BOX No.7
114	Z412005200ZZ	SNAP RING	SK5	6	12	BOX No.7
115	Z560103435ZZ	O-RING P34	NBR	1	2	BOX No.7
116	Z665030000CC	GASKET	SPCC-A MFZN-15microM-C	1	2	BOX No.7
117	Z665034000CC	GASKET 34	C1100P-0	1	2	BOX No.7
118	Z560101524ZZ	O-RING P15	NBR	6	12	BOX No.7
119	Z541103470AZ	GASKET	NON-AS.	6	12	BOX No.6
120	Z541106092AZ	GASKET (1) 60×92	NON-AS.	6	12	BOX No.6
INTAKE VALVE						
1	DE-18-001	INTAKE VALVE ASSY	ASSY	12	48	BOX No.1
2	AE47057011	INTAKE VALVE	SUH3	12	48	BOX No.1
EXHAUST VALVE						
4	DE-18-006	EXHAUST VALVE	ASSY	12	48	BOX No.2
5	AE47058002	EXHAUST VALVE	SCH3 STB	12	48	BOX No.2
FO INJECTION DEVICE						
19	DE-18-032	F.O.PUMP ASSY	ASSY	6	2×2	OUT.BOX
20	DE-18-033	PLUNGER & DELIVERY VALVE ASSY	ASSY	6	24	OUT.BOX
21	DE-18-034	F. O.INJECTION PIPE WITH JOINT	ASSY	6	12×2	BOX No.5,6
40	AE01062004	O-RING 24.6×5.7	FPM	6	60	BOX No.7
41	E206250120	O-RING 34×5.4	FPM	6	60	BOX No.7
42	Z560103235DZ	O-RING P32	FPM	6	60	BOX No.7
43	Z560104635DZ	O-RING P46	FPM	18	72	BOX No.7
44	Z560203031DZ	O-RING G30	FPM	6	60	BOX No.7
45	E206452160	O-RING	H 104 E85 700	6	24	BOX No.7

No.	Part No.	Name	MATERIAL	PER 1ENG	Quantity	Remarks
46	E206452300	O-RING	H 104 E85 690	6	24	BOX No.7
47	E206452360	O-RING	H 104 E85 680	18	72	BOX No.7
48	AE01064028	O-RING	F 01G 500 35U	6	24	BOX No.7
71	AE01062016	GASKET	PCHS	12	120	BOX No.7
74	Z560104635DZ	O RING	FPM	18	180	BOX No.7
76	Z565001920ZZ	GASKET 19	C1100P-0	6	60	BOX No.7
F.O. INJECTION PUMP						
60	AE01064007	DEFLECTOR	H 104 B33 850	12	48	BOX No.7
78	AE01064028	O-RING	H 01G S00 35U	6	24	BOX No.7
84	AE47064003	BACK UP RING	016410-0500	12	48	BOX No.7
81	AE47064004	BACK UP RING	016410-0400	12	48	BOX No.7
79	E206452160	O-RING	H 104 E85 700	12	48	BOX No.7
80	E206452300	O-RING	H 104 E85 690	6	24	BOX No.7
82	E206452360	O-RING	H 104 E85 680	18	72	BOX No.7
83	E206452610	SEAL RING	2 469 403 689	6	24	BOX No.7
85	E206452800	GASKET	H 104 E03 140	6	24	BOX No.7
86	Z560101824DZ	O-RING P18	FPM	14	56	BOX No.7
87	Z560102124DZ	O-RING P21	FPM	4	16	BOX No.7
88	Z560102335DZ	O-RING	FPM	2	8	BOX No.7
89	Z560203031DZ	O-RING G30	FPM	1	4	BOX No.7
F.O. FEED PUMP & FITTING						
145	C034402000	SEALING KIT HWTVB	00999161	1	2	BOX No.7
146	E203150130	GASKET 205/265	SPEC	1	2	BOX No.6
147	E211350270	CASTLE NUT WITH SEAT M20×1.5	SS400B-D	1	2	BOX No.3
148	Z300020000ZZ	FLAT WASHER 20	SPCC/SS4OOP	1	2	BOX No.7
149	Z320004040ZZ	SPLIT PIN 4×40	SWRM-12	1	2	BOX No.7
150	Z451163060ZZ	BEARING (1) 6306	PCHS	1	2	BOX No.7
151	Z451162060ZZ	BEARING (1) 6206	PCHS	1	2	BOX No.7
152	Z461406212SC	OIL SEAL SC406212	PCHS	1	2	BOX No.7
153	Z412006200ZZ	SNAP RING	SK5	1	2	BOX No.7
F.O. FILTER & FITTING PARTS						
27	Y529000301ZZ	ELEMENT ASSY 200ME	ASSY	2	2	BOX No.7
28	NN00496008	FILTER ELEMENT ROUND SHAPE	PCHS	19	19	BOX No.7
67	Y529000338ZZ	PACKING	EDP-22-TE	1	20	BOX No.7
68	Y529000113ZZ	PACKING	EDP-21-TE	2	20	BOX No.7
69	C060603430	O RING	G105-VI	2	20	BOX No.7
F.O. CONTROL & SHUTDOWN DEVICE						
198	NN00039059	SNAP RING	SWRH62A	4	8	BOX No.7
199	NN00039065	PACKING	FKM	2	4	BOX No.7
200	NN00039068	GASKET	FKM	2	4	BOX No.7
201	NN00039069	PACKING	FKM	2	4	BOX No.7
202	NN00039123	FILTER	SUS304	2	4	BOX No.7
F.O. PIPING						
154	AE01086017	PULSE ABSORBER	PCHS	2	4	BOX No.7

No.	Part No.	Name	MATERIAL	PER 1ENG	Quantity	Remarks
LUBRICANT OIL UNIT						
101	Z560105257ZZ	O-RING	NBR	2	8	BOX No.7
102	Z560107557ZZ	O-RING	NBR	4	16	BOX No.7
L.O. PUMP & FITTING						
31	DE-18-164	L.O.PUMP ASSY	ASSY	1	1	OUT.BOX
32	C03440030	OIL PUMP 208HWT031	SPEC	1	1	OUT.BOX
155	E170500470	BEARING LM4030×265	PCHS	5	10	BOX No.3
156	Z320005040ZZ	SPLIT PIN 5×40	SWRM-12	1	2	BOX No.7
157	Z400010025ZZ	KEY 10×25	S45/SF540	1	2	BOX No.7
158	Z412005000ZZ	SNAP RING	SK5	1	2	BOX No.7
159	Z412005500ZZ	SNAP RING	SK5	1	2	BOX No.7
160	Z461355511SC	OIL SEAL SC355511	SK5	1	2	BOX No.7
161	Z665010000ZZ	GASKET 10	C1100P-0	1	2	BOX No.7
162	Z665034000ZZ	GASKET 34	C1100P-0	1	2	BOX No.7
163	E203150130	GASKET 205/265	SPEC	1	2	BOX No.6
L.O. RELIEF VALVE						
164	AE47077005	GASKET	SPEC	1	2	BOX No.6
165	Z560108057ZZ	O-RING	NBR	2	4	BOX No.7
166	Z665012000ZZ	GASKET 12	C1100P-0	2	4	BOX No.7
L.O. THERMOSTAT VALVE						
167	Z560101124ZZ	O-RING	NBR	1	2	BOX No.7
168	Z560106557ZZ	O-RING	NBR	1	2	BOX No.7
169	Z560110557ZZ	O-RING	NBR	1	2	BOX No.7
170	Z665020000ZZ	GASKET	C1100P-0	1	2	BOX No.7
171	AE01079013	PELLET(1) 55C	SPEC	1	2	BOX No.7
CW PUMP & FITING						
29	AE47102002	GEAR CW PUMP Z26-HC	SCM415	1	1	OUT.BOX
30	NN00484002	C.W.PUMP 170-35	SPEC	1	1	OUT.BOX
172	AE01102008	O-RING 28×6.0-HT	NBR	1	2	BOX No.7
173	C038800660	CLAW WASHER	SUS304-CP	1	2	BOX No.7
174	AEO1102010	MECHANICAL SEAL (560-30)NT31	PCHS	1	2	BOX No.7
175	C038500570	BEARING 35	PCHS	2	4	BOX No.7
176	NN00484011	MOUSE RING 115	CAC403(BC3)	2	4	BOX No.7
177	Z319128054ZZ	CLAW WASHER	SPCC	1	2	BOX No.7
178	Z400007025DZ	KEY 7×25	SUS304	1	2	BOX No.7
179	Z400010028ZZ	KEY 10×28	S45C/SF540	1	2	BOX No.7
180	Z412007200ZZ	SNAP RING	SK5	1	2	BOX No.7
181	Z461456209TC	OIL SEAL TC456209	PCHS	1	2	BOX No.7
182	Z560110057ZZ	O-RING P100	NBR	2	4	BOX No.7
183	Z560114057ZZ	O-RING	NBR	1	2	BOX No.7
184	Z560203520ZZ	O-RING	NBR	1	2	BOX No.7
185	Z560217557ZZ	O-RING	NBR	1	2	BOX No.7
186	Z565001000EE	GASKET 10	SPCC NONAS COMPOUND	2	4	BOX No.7
187	Z565001700EE	GASKET 17	SPCC NONAS COMPOUND	2	4	BOX No.7

No.	Part No.	Name	MATERIAL	PER 1ENG	Quantity	Remarks
CW BY-PASS VALVE						
188	Z560100919ZZ	O-RING P9	NBR	1	2	BOX No.7
189	Z560101424ZZ	O-RING P14	NBR	1	2	BOX No.7
190	Z560102024ZZ	O-RING	NBR	1	2	BOX No.7
191	Z560104935ZZ	O-RING	NBR	1	2	BOX No.7
192	Z560107057ZZ	O-RING	NBR	2	4	BOX No.7
193	Z665012000ZZ	GASKET 12	C1100P-0	2	4	BOX No.7
CW THERMOSTAT VALVE						
194	AE47080004	THERMOSTAT VALVE	PCHS	2	4	BOX No.7
103	Z560105057ZZ	O-RING P50A	NBR	1	4	BOX No.7
104	Z560108057ZZ	O-RING	NBR	1	4	BOX No.7
105	Z560208531ZZ	O-RING	NBR	2	8	BOX No.7
106	Z560209531ZZ	O-RING G95	NBR	2	8	BOX No.7
EXHAUST GAS PIPE						
59	AE47021081	BELLOWS	SPEC	3	12	OUT.BOX
121	AE47021014	GASKET EXHAUST PIPE1	SUS-DP	6	12	BOX No.3
122	AE47021015	GASKET EXHAUST PIPE2	SUS 304 CERAMIC	6	12	BOX No.7
CYLINDER LINER						
26	DE-18-056	CYLINDERL LINER	ASSY	6	2	OUT.BOX
PISTON						
25	DE-18-054	PISTON ASSY	ASSY	6	1	OUT.BOX
10	AE47051003	PISTON RING 1ST	SPEC	6	24	BOX No.3
11	AE47051004	PISTON RING 2ND	SPEC	6	24	BOX No.3
12	AE47051005	PISTON RING 3RD	SPEC	6	24	BOX No.3
13	AE47051006	OIL RING	SPEC	6	24	BOX No.3
126	AE47051006	OIL RING	SPEC	6	12	BOX No.3
127	AE47051009	SNAP RING C TYPE	SWRH62-72	12	24	BOX No.3
CONNECTING ROD						
14	AE47052003	PISTON PIN BUSH	CAC603 S 10C	6	24	BOX No.4
15	AE47052006	BEARING CRANK PIN A40	A40 DS10	6	12×2	BOX No.5,6
MAIN BEARING						
16	DE-18-024	CRANK PIN BOLT ASSY	ASSY	6	12×2	BOX No.3,4
17	AE47007001	MAIN BEARING	A40 DS10	7	7	BOX No.7
18	AE47007002	BEARING	A40 S10C	2	8	BOX No.4
AIR COOLER						
49	NN00598008	GASKET	NON-ASBESTOS	1	4	OUT.BOX
50	NN00598009	GASKET	NON-ASBESTOS	1	4	OUT.BOX
51	NN00598013	PACKING	CU	10	40	BOX No.7
52	NN00598010	GASKET	NON-ASBESTOS	2	8	OUT.BOX
90	NN00598008	GASKET	NON-ASBESTOS	1	4	OUT.BOX
94	AE47026002	AIR COOLER INLET GASKET	SPEC	1	4	OUT.BOX
95	AE47026007	GASKET	SPEC	2	8	BOX No.6

No.	Part No.	Name	MATERIAL	PER 1ENG	Quantity	Remarks
96	AE47026012	AIR COOLER OUTLET GASKET	SPEC	1	4	OUT.BOX
97	Z560230057ZZ	O-RING G300	NBR	1	4	BOX No.7
98	Z565002100EE	GASKET 21	SPCC NONAS COMPOUND	1	4	BOX No.7
99	AE47090011	GASKET	SPEC	1	4	BOX No.6
100	AE47090023	GASKET	SPEC	2	8	BOX No.6
STARTING VALVE						
22	DE-18-037	STARTING VALVE ASSY	ASSY	6	2	BOX No.3
132	S108600100	SPLIT PIN 2.5×2 5	SUS	1	2	BOX No.7
133	S108600250	SPLIT PIN 2×18		1	2	BOX No.7
134	Z560001218ZZ	O-RING	NBR	1	2	BOX No.7
135	Z560100919ZZ	O-RING P9	NBR	1	2	BOX No.7
136	Z560101019ZZ	O-RING P10	NBR	1	2	BOX No.7
137	Z560101324ZZ	O-RING	NBR	1	2	BOX No.7
138	Z560102435ZZ	O-RING P24	NBR	1	2	BOX No.7
139	Z560103435ZZ	O-RING P34	NBR	1	2	BOX No.7
140	Z560204531ZZ	O-RING G45	NBR	1	2	BOX No.7
141	Z560205531ZZ	O-RING G55	NBR	2	4	BOX No.7
142	Z565003400EE	GASKET 34	SPCC NONAS COMPOUND	3	6	BOX No.7
53	Z665030000CD	GASKET 30	C1100P-0	6	24	BOX No.7
54	Z665034000ZZ	GASKET 34	C1100P-0	6	24	BOX No.7
STARTING ROTARY VALVE						
143	Z560205531ZZ	O-RING G55	NBR	1	2	BOX No.7
144	Z560207531ZZ	O-RING G75	NBR	1	2	BOX No.7
GOV. FITTING						
128	AEOI045013	DISTANCE PIECE	SS400B	1	2	BOX No.3
129	AEOI045017	GASKET	5LS	1	2	BOX No.6
130	Z451162050ZZ	BEARING (1) 6205	PCHS	2	4	BOX No.7
131	Z320004030ZZ	SPLIT PIN	SWRM-12	1	2	BOX No.7
CONTROL MAGNETIC VALVE						
197	Z560000415ZZ	O-RING	NBR	8	16	BOX No.7
INDICATOR & SAFTY VALVE						
23	NN00002045	INDICATOR & SAFTY VALVE ASSY 12	ASSY	6	26	BOX No.5,6
55	Z565001700ZZ	GASKET 17	C1100P-0	6	24	BOX No.7
56	Z565002300ZZ	GASKET	C1100P-0	18	72	BOX No.7
57	NN00002016	SEAT	SS400B	6	24	BOX No.7
58	Z565002300ZZ	GASKET	C1100P-0	6	24	BOX No.7
GAUGE						
61	AQL20017367B	PRESS. GAUGE FOR COMBUSTION AIR	NAGANO KEIKI	1	1	BOX No.7
62	AQL20017367B	PRESS. GAUGE FOR ENGINE LUBRICATING OIL	NAGANO KEIKI	1	1	BOX No.7
63	AQL20017367B	PRESS. GAUGE FOR TURBO-CHARGER LUBRICATING OIL	NAGANO KEIKI	1	1	BOX No.7
64	AQL20017367B	PRESS. GAUGE FOR ENGINE HT WATER	NAGANO KEIKI	1	1	BOX No.7
65	AQL20017367B	PRESS. GAUGE FOR ENGINE LT WATER	NAGANO KEIKI	1	1	BOX No.7
66	AQL20017367B	PRESS. GAUGE FOR ENGINE FUEL OIL	NAGANO KEIKI	1	1	BOX No.7

No.	Part No.	Name	MATERIAL	PER 1ENG	Quantity	Remarks
SEAL POT						
107	NN0003002	PCH ETHILENE GLYCOL	PCHS	1	4	OUT.BOX
108	NN00295003	MOLYKOTE 1000 300ML	SPEC	-	16	OUT.BOX
Others						
203	Z565001000CZ	GASKET	SPCC-A	-	100	BOX No.7
204	Z565001300ZZ	GASKET 13	C1100P-0	-	200	BOX No.7
205	Z565001700ZZ	GASKET 17	C1100P-0	-	200	BOX No.7
206	Z565002100ZZ	GASKET 21	C1100P-0	-	100	BOX No.7
207	Z565002700ZZ	GASKET 27	C1100P-0	-	100	BOX No.7
208	Z565002700ZZ	SPARE PARTS BOX TYPE 12(STEEL)	SS400	-	7	BOX No.1-7

JICA Team
July30,2021

List of Spare Parts for OH (ELECTRICAL EQUIPMENT)

No.	Name	TYPE	RATING	PER 1ENG	Quantity	Part No.	Remarks
13.8kV SWICHGEAR							
1	VCB	20-VPR-16D	24kV 600A 12.5kA		1		
2	DRAW OUT HANDLE	FOR "VCB"			7		
3	ACCUMULATE HANDLE	FOR "VCB"			7		
4	LBS FUSES	ISA	24kV 63kA		3		
5	VT FUSES	PL-JB	15kV TIA 40kA		28		
6	EVT FUSES	PL-JB	15kV TIA 40kA		3		
7	LIFTER	FOR "VCB","EVT"			1		
8	OPERATING HANDLE	FOR "LBS"			1		
9	LED LAMP	FOR "(G)"			8		
10	LED LAMP	FOR "(R)"			8		
11	LAMP LENS	FOR "(G)"			8		
12	LAMP LENS	FOR "(R)"			8		
13	CONTROL CIRCUIT FUSE		2A		2		
14	OPERATING HANDLE	FOR "ES of VCB"			7		
STAITION TRANSFORMER							
1	HORIZONTAL TABLE	FOR "STR"			1		
NATIONAL GROUNDING PANEL							
1	OPERA TING HANDLE	FOR "DS"			1		
2	LED LAMP	FOR "(G)"			4		
3	LED LAMP	FOR "(R)"			4		
4	LAMP LENS	FOR "(G)"			4		
5	LAMP LENS	FOR "(R)"			4		
6	CONTROL CIRCUIT FUSE		2A		8		
PROTECTION PANEL							
1	DC RELAY	COC3-A01D1			1		
2	UV RELAY	CBV2-A01D1			1		
3	CONTROL CIRCUIT FUSE		2A		6		
4	RELAY TEST CASE	D1			1		
5	TEST PULG	KTQ-A4 KTQ-V3			2		
PROTECTION PANEL							
1	MOLDED-CASE CIRCUIT-BREAKER	MITSUBISHI	NF250-SV 4P 150AT F-F WITH AL	1	1		
2	UV RELAY	MITSUBISHI	NF125-SV 4P 75AT F-F WITH AL	1	1		
3	MOLDED-CASE CIRCUIT-BREAKER	MITSUBISHI	NF125-SV 4P 15AT F-F WITH AL	1	1		
4	MOLDED-CASE CIRCUIT-BREAKER	MITSUBISHI	NF125-SV 4P 20AT F-F WITH AL	1	1		
5	MOLDED-CASE CIRCUIT-BREAKER	MITSUBISHI	NF125-SV 4P 30AT F-F WITH AL	1	1		
6	MOLDED-CASE CIRCUIT-BREAKER	MITSUBISHI	NF125-SV 3P 20AT F-F WITH AL	1	1		
7	MOLDED-CASE CIRCUIT-BREAKER	MITSUBISHI	NF125-SV 3P 15AT F-F WITH AL	1	1		
8	MOLDED-CASE CIRCUIT-BREAKER	MITSUBISHI	NF125-SV 3P 50AT F-F WITH ALAX	1	1		

No.	Name	TYPE	RATING	PER 1ENG	Quantity	Part No.	Remarks
9	MOLDED-CASE CIRCUIT-BREAKER	MITSUBISHI	NF125-SV 3P 30AT F-F WITH ALAX	1	1		
10	MOLDED-CASE CIRCUIT-BREAKER	MITSUBISHI	NF125-SV 3P 20AT F-F WITH ALAX	1	1		
11	MOLDED-CASE CIRCUIT-BREAKER	MITSUBISHI	NF125-SV 3P 15AT F-F WITH ALAX	1	1		
12	MOLDED-CASE CIRCUIT-BREAKER	MITSUBISHI	NF125-SV 2P 15AT F-F WITH ALAX	1	1		
13	MOLDED-CASE CIRCUIT-BREAKER	MITSUBISHI	NF125-SV 2P 30AT F-F WITH AL	1	1		
14	MOLDED-CASE CIRCUIT-BREAKER	MITSUBISHI	NF125-SV 2P 15AT F-F WITH AL	1	1		
15	MOLDED-CASE CIRCUIT-BREAKER	MITSUBISHI	NF32-SV 2P 30AT F-F WITH AL	1	1		
16	MOLDED-CASE CIRCUIT-BREAKER	MITSUBISHI	NF32-SV 2P 10AT F-F WITH AL	1	1		
17	MOLDED-CASE CIRCUIT-BREAKER	MITSUBISHI	NF32-SV 2P 5AT F-F WITH	1	1		
18	CIRCUIT-PROTECTER	MITSUBISHI	CP30-BA 2P 9M 5A WITH AL	1	1		
19	CIRCUIT-PROTECTER	MITSUBISHI	CP30-BA 2P 9M 10A WITH AL	1	1		
20	THERMAL RELAY	MITSUBISHI	TH-T25KP 0.35A(0.28-0.42A) AUTO RESET	1	1		
21	THERMAL RELAY	MITSUBISHI	TH-T25KP 1.3A(1-1.5A) AUTO RESET	1	1		
22	THERMAL RELAY	MITSUBISHI	TH-T25KP 1.7A(1.4-2A) AUTO RESET	1	1		
23	THERMAL RELAY	MITSUBISHI	TH-T25KP 2.5A(2-3A) AUTO RESET	1	1		
24	THERMAL RELAY	MITSUBISHI	TH-T25KP 5A(4-6A) AUTO RESET	1	1		
25	THERMAL RELAY	MITSUBISHI	TH-T25KP 6.5A(6.2-8A) AUTO RESET	1	1		
26	THERMAL RELAY	MITSUBISHI	TH-T25KP 11A(9-13A) AUTO RESET	1	1		
27	THERMAL RELAY	MITSUBISHI	TH-T25KPSR 22A(18-26A) AUTO RESET	1	1		
28	AUXILIARY RELAY	MITSUBISHI	SR-T5 AC100V 4a1b	1	1		
29	EARTH LEAKAGE RELAY	MITSUBISHI	NV-ZBA AC100･200V 30mA 0.1sec	1	1		
30	EARTH LEAKAGE RELAY	MITSUBISHI	NV-ZBA AC100･200V 100mA 0.1sec	1	1		
31	VT FUSE	MITSUBISHI	PL-G 0.6kV T2A	18	18		
32	AUXILIARY RELAY	OMRON	G2R-2-SN AC100V 2sec	1	1		
33	TIMER	OMRON	H3Y-2 AC100-120V 10sec	1	1		
34	CONTOROL CIRCUIT FUSE	FUJI	FCF2-3 3A	9	9		
35	CONTOROL CIRCUIT FUSE	FUJI	FCF2-1 1A	88	88		
CT PANEL							
1	FUSE 5A		P1 AC500V DC250V NPN23731P00	4	4		

No.	Name	TYPE	RATING	PER 1ENG	Quantity	Part No.	Remarks
AC DISTRIBUTION PANEL							
1	FUSE 3A		P1 AC500V DC250V NPN23731P00	3	3		
2	FUSE 5A		P1 AC500V DC250V NPN23731P00	4	4		
3	FLUORESCENT		MLW-100GM-TB-DS2A AC100/110V 6W 50/60Hz NPN23072P002	1	1		
4	MOLDED-CASE CIRCUIT-BREAKER		NF400-SW-4P-	1	1		
5	MOLDED-CASE CIRCUIT-BREAKER		NF250-SV-4P-S	1	2		
6	MOLDED-CASE CIRCUIT-BREAKER		NF125-SV-4P-S	1	1		
7	MOLDED-CASE CIRCUIT-BREAKER		NF125-SV-4P-S	1	1		
8	MOLDED-CASE CIRCUIT-BREAKER		NF-125-SV-3P-	1	1		
9	MOLDED-CASE CIRCUIT-BREAKER		NF125-SV-3P-S	1	1		
10	MOLDED-CASE CIRCUIT-BREAKER		NF125-SV-3P-S	1	2		
BUILDING AUXILIARY PANEL							
1	FUSE 3A		PC1 AC500V DC250V NPN23731P00	3	3		
2	FUSE 5A		PC1 AC500V DC250V NPN23731P00	5	5		
3	FLUORESCENT		MLW-100GM-TB-DS2A AC100/110V 6W 50/60Hz NPN23072P002	1	1		
4	MOLDED-CASE CIRCUIT-BREAKER		NF125-SV-3P-S	1	1		
5	MOLDED-CASE CIRCUIT-BREAKER		NF63-SVF-3P-S	1	2		
6	MOLDED-CASE CIRCUIT-BREAKER		NF63-SVF-3P-S	1	1		
7	MOLDED-CASE CIRCUIT-BREAKER		NF63-SVF-2P-S	1	17		
8	MOLDED-CASE CIRCUIT-BREAKER		NF63-SVF-2P-S	1	4		
9	MOLDED-CASE CIRCUIT-BREAKER		NF63-SVF-2P-S	1	3		
10	MOLDED-CASE CIRCUIT-BREAKER		NF63-SV-2P-SF	1	3		
COMMON CONTROL DESK							
1	FUSE 3A		PC1 AC500V DC250V NPN23731P00	1	1		
2	LED UNIT RED		UA-37FD6-R (KFA-37F)	5	5		

No.	Name	TYPE	RATING	PER 1ENG	Quantity	Part No.	Remarks
3	LED UNIT RED		TS-LEDA-R (WSPA)	1	1		
4	LED UNIT GREEN		TS-LEDA-G (WSPA)				
EXISTING GENERATOR CONTROL DESK							
1	FUSE 3A		PC1 AC500V DC250V NPN23731P00	1	1		
2	LED UNIT RED		UA-37FD6-R (KFA-37F)	8	8		
3	LED UNIT WHITE		UA-37FD8A-W (KFE-37F)	1	1		
4	LED UNIT RED		TS-LEDA-R (WSPA)	2	2		
5	LED UNIT GREEN		TS-LEDA-G (WSPA)	2	2		
6	AUX. RELAY		MY4N-D2 DC100/110V NPN21026P255	1	1		
7	AUX. RELAY		MY4N DC100/110V NPN21026P165	1	2		
8	TIMER		H3CR-A8 AC100-240V DC100-125V NPN21443P031	1	1		
SYNCRONOUS CONTROL DESK							
1	FUSE 3A		PC1 AC500V DC250V NPN23731P00	5	5		
2	LED UNIT RED		UA-37FD6-R (KFA-37F)	4	4		
3	LED UNIT ORANGE		UA-37FD6A-O (KFE-37F)	34	34		
4	LED UNIT WHITE		UA-37FD8A-W (KFE-37F)	8	8		

No.	Name	TYPE	RATING	PER 1ENG	Quantity	Part No.	Remarks
5	LED UNIT RED		TS-LEDA-R (WSPA)	1	1		
6	LED UNIT GREEN		TS-LEDA-G (WSPA)	1	1		
7	LAMP		E-10, T-10 110V 2W (BT-16HHB-C)	5	5		
8	AUX. RELAY		MY4N DC100/110V NPN21026P175	1	3		
9	TIMER		H3CR-A8 AC100-240V DC100-125V NPN21443P031	1	1		
GENERATOR CONTROL DESK							
1	FUSE 3A		PC1 AC500V DC250V NPN23731P00	2	2		
2	LED UNIT RED		UA-37FD6-R (KFA-37F)	48	48		
3	LED UNIT ORANGE		UA-37FD6-O (KFE-37F)	56	56		
4	LED UNIT WHITE		UA-37FD8A-W (KFE-37F)	18	18		
5	LED UNIT RED		TS-LEDA-R (WSPA)	12	12		
6	LED UNIT GREEN		TS-LEDA-G (WSPA)	4	4		
7	AUX. RELAY		MY4N DC100/110V NPN21026P175	1	14		
8	AUX. RELAY		MY4N-D2 AC100-240V DC100-125V NPN21026P255	1	4		
9	TIMER		H3CR-A8 AC100-240V DC100-125V NPN21443P031	1	4		
GENERATOR PROTECTION DESK							
1	FUSE 3A		PC1 AC500V DC250V NPN23731P00	14	14		
2	AUX. RELAY		MY4N DC100/110V NPN21026P175	1	62		
3	AUX. RELAY		MY4N-D2 DC100/110V NPN21026P255	1	8		
4	AUX. RELAY		MY4N DC100/110V NPN21026P165	1	6		
5	TIMER		H3CR-A8 AC100-240V DC100-125V NPN21443P031	1	50		

No.	Name	TYPE	RATING	PER 1ENG	Quantity	Part No.	Remarks
6	FLICKER TIMER RELAY		H3CR-F8 AC100-240V DC100-125V NPN21443P101	1	2		
7	AUX. RELAY		MM2XPN DC100/110V NPN21046P115	1	14		
8	AUX. RELAY		MM2XPN DC100/110V NPN21046P105	1	2		
9	AUX. RELAY		MM4XPN-D DC100/110V NPN21063P015	1	4		
10	KEEP RELAY		G7K-412S DC110V NPN21043P014	1	16		
11	AUX. RELAY		KA3-E28P	1	34		
12	MULTI RELAY		CGP1-A03D2	1	2		
13	MULTI RELAY		CGP2-A01D2	1	2		
14	LOCK-OUT RELAY		KA15-PB4T DC110V	1	4		
15	TIMER		H3CR-A8 AC24-48V DC12-48V NPN21443P032	1	4		
FEEDER PROTECTION DESK							
1	FUSE 3A		PC1 AC500V DC250V NPN23731P00	12	12		
2	AUX. RELAY		MY4N DC100/110V NPN21026P175	1	42		
3	AUX. RELAY		MY4N-D2 DC100/110V NPN21026P255	1	6		
4	AUX. RELAY		MY4N DC100/110V NPN21026P165	1	4		
5	TIMER		H3CR-A8 AC100-240V DC100-125V NPN21443P031	1	22		
6	AUX. RELAY		MM2XPN DC100/110V NPN21046P115	1	10		
7	AUX. RELAY		MM4XPN DC100/110V NPN21046P155	1	4		
8	KEEP RELAY		G7K-412S DC110V NPN21043P014	1	16		
9	GROUND OVER CURRENT RELAY		LEG-190L-DC	1	1		
10	GROUND OVER CURRENT RELAY		COC1-A01D1	1	1		

No.	Name	TYPE	RATING	PER 1ENG	Quantity	Part No.	Remarks
11	UNDER VOLTAGE RELAY		CBV2-A01D1	1	3		
12	OVER CURRENT RELAY GROUND OVER CURRENT RELAY		COC4-A02D1	1	3		
13	UNDER VOLTAGE RELAY GROUND OVER VOLTAGE RELAY		CBV4-A01D1	1	1		
GENERATOR PANEL							
1	TEST PLUG (CT 2ND.)		KTP-A4 NPN37739P204		1		
2	TEST PLUG (VT 2ND.)		KTP-V3 NPN37739P208		1		
3	TEST PLUG (VT 2ND.)		KTP-V4 NPN37739P209		1		
4	DOOR KEY		KEY No. 200		1		
5	TEST PLUG (CT 2ND.)		KTP-A3 NPN37739P203				
6	TEST PLUG (CT 2ND.)		KTP-A4 NPN37739P204				
7	TEST PLUG (CT 2ND.)		KTP-A8 NPN37739P206				
8	TEST PLUG (VT 2ND.)		KTP-V3 NPN37739P208				
9	TEST PLUG (VT 2ND.)		KTP-V4 NPN37739P209				
10	DOOR KEY		KEY No. 200				
DC POWER SUPPLY PANEL							
1	FUSE		BLA003 3A		2		
2	FUSE		BLA015 15A		6		
3	FUSE		P-413 1.3A		8		
4	FUSE		P-430 3.0A		6		
5	FUSE		FCK-60 60A		4		
6	LED MODULE		PXL-LED220-W		1		
7	LED MODULE		PXL-LED024-R		1		
8	DC VOLTMETER		DVF-11 0-200V		1		
9	DC AMMETER		DVF-11 0-30A 60mV		1		
10	DC AMMETER		DVF-11 0-50A 60mV		1		

No.	Name	TYPE	RATING	PER 1ENG	Quantity	Part No.	Remarks
11	VOLT SELECTER		JSBN-4X-VO-C-HKKK-N		1		
12	MCB		BW32AAG-2P		1		
13	MCB		BW125JAG-3P015KFKA TC：AC200V		1		
14	MCB		BW50SBG-2P		1		
15	MCB		BW32SBG-2P		1		
16	MCB		BW32SBG-2P		1		
17	AUX. RELAY		MY2-CR AC2		1		
18	AUX. RELAY		MY4-D AC24		1		
19	AUX. RELAY		SH4 AC200V		1		
20	DC GROUND RELAY		VG-NF3-110		1		
ACCESSARIES OF RECTIFIRE							
21	ANCHOR VOLT		C-1290		4		
22	DEHUMIDICATION AGENT		[A-UN] Silicag		2		
23	LED CHARGING TOOL		XL-NQ		1		
24	FIXING VOLT		M20×35		4		
ACCESSARIES OF RECTIFIRE							
25	SPANNER(No.10)				1		
26	DC VOLTMETER		Voltage range 0-40V Portable type, Digital meter with leads and		1		
27	MENTENANCE TOOL BOX				1		
PV INVERTER CONTROL PANEL							
1	AUXILIARY RELAY		MY2N AC100V		1		
2	REPAIR PAINT		COLOR：5Y7/1 (SEMI-GLOSS) 200cc		1		
600kW A. C. GENERATOR							
1	RECTIFIER ELEMENT		4G27187G1 SKR133/12	12	12		
2	RECTIFIER ELEMENT		4G27187G2 SKR133/12	12	12		
3	SPARE PARTS BOX		STEEL BOX NU-9189		1		
4	GAP GAURGE		NPN70076P1		1		
5	SPANNER		NPN4271P17 M30		1		

No.	Name	TYPE	RATING	PER 1ENG	Quantity	Part No.	Remarks
6	SUB SHAFT		4GE5364G1 (HEXAGON HEAD BOLTS： M24×140SZ3 WITH PLAINE		1		
7	SUB SHAFT		4GE5365G1 (HEXAGON HEAD BOLTS： M24×130SZ3 WITH PLAINE		1		
8	SPARE PARTS BOX		STEEL BOX NU-9189		1		

List of Consumables for Overhaul Works

for 1 unit 19-Jul-19

	Consumable name	Qty	Comments
1	Ply wood 3～5mm thickness	20 sheets	
2	Gum tape	10 rolls	
3	Polyethylene sheet		
4	Wash oil or Kerosene	100 liters	
5	Sponge	5	
6	Waste cloth	20 kilogram	
7	Scoth bright	30 sheets	
8	Sheet Grinder		
9	Thunder wheel		
10	Sand paper	30 sheets	
11	Roll paper	1 roll	
12	Paper		
13	Cup brush	3 unit	
14	Color check	3 unit	
15	Compound carborundum	medium 1 can	
16	Piccard	1	
17	Kohmira	1	
18	Blue sheet(swiss tarp)5×5m	3	
19	Smokon (Anti Seizing compound)	1 can	
20	Molykote（1207）	1 can	
21	Three bond	3本	
22	Heaper base sheet (gasket)	1m	
23	Rubber sheet (gasket)	1m	
24	Oil sheet 0.8 t	1m	
25	Wire	1 roll	
26	Marker (0ily)	20 pens	
27	Gloves (common)	20	
28	Gloves (leather)	20	
29	Gloves (vinyl)	20	
30	Detergent (carbon removal)	5	
31	Wood(square bar ☐100×L1000	some	
32	Welding rods	some	
33	Others(Bucket and brush)	2 set	
34	Rust-proof paint	1 can	
35	Cleaner（Dye PT test use)	24 aerosol	
36	Molykote 1000 (spray)	3 cans	
37	Wire brush	10	
38	Silicon	3 tube	
39	Pallets	6	
40	Box for bolts and small parts	20	
41	High pressure washing machine	1	
42	Bowl (for parts washing)	4	
43	Scaffold(engine exhaust pipe side)		
44	Scraper	5	

JICA Team
July30,2021

List of Equipment and tools for OH (Kosrae)

No.	Name	MATERIAL	PER 1ENG	Quantity	Part No.	Remarks
1	STANO HYDRAULIC JACK CAP	SCM435		2	AE47195003	
2	STANO HYDRAULIC JACK CAP	SCM435		4	AE47195004	
3	HYDRAULIC JACK JOINT BOLT M36X3	SCM435		4	AE47195005	
4	STANO HYDRAULIC JACK RDD&	S45C		2	AE47195007	
5	HYDRAULIC JACK M36X3.0	ASSY		5	AE47195008	
6	HANDLE JACK	SCM435		2	AE47195006	
7	HYDRAULIC JACK M30X3.0	SCM435		2	AE47195013	
8	HAND HYDRAULIC JACK	SCM435-D		4	AE02195010	
9	PISTON INSERT	FC200		1	AE47199001	
10	NOZZLE TEST	S45C		1	AE47199005	
11	L. O. FILTER SAUCER	SPCC SS400		1	AE47199006	
12	UAIN BEARING CAP	SS400P		1	AE47199007	
13	VALVE SPRIN0 BASE	SS400P		1	AE47199018	
14	VALVE SPRING PLATE	SS400P		1	AE47199009	
15	NOZZLE HOLDER REMOVER	SS400		1	AE47199020	
16	SOCKET 24 ROCKR ARM SHAFT HOLDE	PCHS SS400		1	AE47199023	
17	CYLINDER LINER PULL&INSERT	ASSY		1	AE47199024	
18	PROTECT RING TOOL	ASSY		1	AE47199025	
19	EX. VALVE SEAT REMOVER	ASSY		1	AE47199026	
20	EX. VALVE SEAT COOLING	ASSY		1	AE47199027	
21	BIG END REMOVER	SS400		1	AE47199028	
22	RING HEAD LCR 1819	PCHS		1	AE47199029	
23	MEASUREMENT TOOL CYLINDE	SS400P		1	AE47199034	
24	VALVE GRINOINGSPRING 1.8×1	SWPA		1	AE47199035	

No.	Name	MATERIAL	PER 1ENG	Quantity	Part No.	Remarks
25	INSERT STEM SEAL INTAKE	S45C		1	AE47199036	
26	INSERT STEM SEAL EXHAUST	S45C		1	AE47199037	
27	TOOL PISTON RING	ASSY		1	AE47199041	
28	NUT FLANGE M12×1.75	JIS B1190/B1181		2	AE01003009	
29	SNAP RING PLIER	PCHS		1	AE01199003	
30	PIN MAIN BEARING	SS400B		1	AE01199014	
31	MAIN BEARING CAP2	S45S		1	AE01199030	
32	MAIN BEARING CAP3	SS400B		2	AE01199031	
33	NOZZLE TEST TOOL	S45S		1	AE01199035	
34	TORQUE WRENCH N1800LCK	PCHS		1	AE01199039	
35	RACHET HEAD LQ4080	PCHS		1	AE01199040	
36	NOZZLE TEST PUMP	ASSY		1	AE01199052	
37	SOCKET 27×19×L100	PCHS		1	AE01199056	
38	VALVE GRINDING	PCHS		1	AE01199057	
39	THICKNESS GAUGE 70M	PCHS		1	AE01199059	
40	MAX. PRESS. GAUGE MT31-25M	PCHS		1	AE01199058	
41	INSIDE MICROMETETER 175-200	PCHS		1	C091870030	
42	TORQUE WRENCH N5600QLK	PCHS		1	C092070020	
43	EYE BOLT M12	PCHS		2	Z270012000ZZ	
44	BOLT M12×1.75×20	SS400B-D		2	X200012000ZZ	
45	FLAT WASHER	SPCC/SS400P		2	Z300012000ZZ	
46	EYE BOLT M16	PCHS		1	Z270016000ZZ	
47	BOLT M10×1.5×100	SS400B-D		2	Z270016000ZZ	
48	BOLT MI6×2.0×135	SS401B-D		1	Z200010100ZZ	
49	EYE BOLT M10	PCHS		1	Z270010000ZZ	
50	EXTENSION BAR 12.7×250	PCHS		1	Z915712250ZZ	
51	O-RING	NBR		1	Z560100919ZZ	

No.	Name	MATERIAL	PER 1ENG	Quantity	Part No.	Remarks
52	NUT M16×2.0	SS400B-D		2	X220016000ZZ	
53	NUT M12×1.75	SS400B-D		5	X220012000ZZ	
54	BOLT M16×2.0×55	SS400B-D		1	X220016055ZZ	
55	BOX-12TYPE WITH PAD LOCK	SS400		1	Y910148300ZA	
56	Spanner 8×10	PCHS		1	Z900208100ZZ	
57	Spanner 11×13	PCHS		1	Z900211130ZZ	
58	Spanner 17×19	PCHS		1	Z900217190ZZ	
59	Spanner 22×24	PCHS		1	Z900222240ZZ	
60	Spanner 27×30	PCHS		1	Z900227300ZZ	
61	Offset Wrench 7×19	PCHS		1	Z904117190LZ	
62	Box Spanner 9×300	PCHS		1	Z910119300ZZ	
63	Box Spanner 4×300	PCHS		1	Z910124300ZZ	
64	Socket 19×12	PCHS		1	Z915119000ZZ	
65	Socket 24×12	PCHS		1	Z915124000ZZ	
66	Socket 30×19	PCHS		1	Z915230000ZZ	
67	Socket 41×19	PCHS		1	Z915241000ZZ	
68	Ajust. Angle Wrench 250	PCHS		1	Z920025000ZZ	
69	Hex. Wrench Key 4	PCHS		1	Z925004000ZZ	
70	Hex. Wrench Key 5	PCHS		1	Z925005000ZZ	
71	Hex. Wrench Key 6	SCM435/SNCM240		1	Z925006000ZZ	
72	Hex. Wrench Key 10	PCHS		1	Z925010000ZZ	
73	Hex. Wrench Key	PCHS		1	Z925012000ZZ	
74	SCREW DRIVER	PCHS		1	Z928008150ZZ	
75	PLUS SCREW DRIVER	PCHS		1	Z930100200ZZ	
76	OIL FEEDER 150ML	PCHS		1	Z938501500ZZ	
77	NOZZLE CLEANING TOOL	PCHS		1	Z940019313ZZ	
78	LO PLATE COOLER SET UP TOC	PCHS		2	NN00596013	

No.	Name	MATERIAL	PER 1ENG	Quantity	Part No.	Remarks
79	NOZZLE HOLDER GUIDE	ASSY		1	AE47199048	
80	SNAP RING PRIER CH-4A	PCHS		1	E279880440	
81	HYDRAULIC PUMP	PCHS		1	AE36199032	
82	DEFLECTION GUIDE E69-90 ASS	ASSY		1	AE01199076	
83	LUBRICATING OIL ANALYSER	ASSY		1	AQL20017835	
84	TURNING BAR 34×1000	STPG370(SCH80)		2	NN00053002	
85	HAMMER			1	Z932612000	
86	CALIPPER			1	AQL20017552	
87	HAND PALLET			1	(TPSC)	
88	LADDER			1	(TPSC)	
89	CHAIN BLOCKS　1.0TON/2.5TON			1	(TPSC)	
90	LIFTING WIRES (φ8）			1	(TPSC)	

JICA Team
July30,2021

List of Equipment and tools for OH (Kosrae)

No.	Name	MATERIAL	PER 1ENG	Quantity	Part No.	Remarks
1	GAP GUGE			1	NPN70076P1	
2	SPANNER			1	NPN70076P1 M3	
3	SUB SHAFT			1		
4	TOOL BOX			1	NU-9189	STEEL BOX

JICA Team
July30,2021

List of Equipment and tools for OH (Kosrae)

No.	Name	MATERIAL	PER 1ENG	Quantity	Part No.	Remarks
1	Hex. Bolt M6×65	Rolled Steel (SS400)		2	T-13 N36-101-0039	
2	Starting Bolt for Draw-out tube M10X50	Rolled Steel (SS400)		1	T-23 N36-Y02-5005	
3	Puller	Rolled Steel (SS400)		1	T-45 N36-982-5001	
4	Slinging Device	Rolled Steel (SS400)		1	T-76 N36-Y02-5003	
5	Starting Bolt	Rolled Steel (SS400)		1	T-121 N36-Y00-5004-A	

JICA Team
July30,2021

List of Equipment and tools for OH (Kosrae)

No.	Name	MATERIAL	PER 1ENG	Quantity	Part No.	Remarks
1	Electric circuit tester			2		Analogportabletype,range:ACV,DCV,DCA,Ohm
2	DC voltmeter			2		range 0~300V
3	Battery type insulation resistance tester (500V)			2		Portabletype, 500Vrange: 1000Mohm
4	Battery type insulation resistance tester (2500V)			2		Portabletype, 2500Vrange: 100Gohm
5	Earth resistance meter			2		Portable type,0ohm-1000ohm, voltage0-30V
6	Low-voltage phase rotation meter			2		AC110V-480V, portable type, with 1amp-type missing phase detection function
7	Relay tester			2		Relay tester corresponding to the protection relays to be supplied in the Project
8	Low-voltage electroscop			2		Measurement range AC50V-600V, sound and light confirmatio
9	13.8 kV electroscop			2		Measurement range AC3kV-20kV, sound and light confirmation
10	Digital multi meter			2		Portabletype,digita type, DCV,DCA,ACV, ACA,ohm
11	AC/DC clamp mete			2		Portabletype,digital type, DCV, DCAACV, ACA,Hz
12	Grounding tools for maintenanc			1		Grounding tools with 3 phase insulation rod,applicable voltage 11kV
13	Withstand voltage teste			1		DC36kV,power supply AC240V-50Hz
14	Circuit breaker pull-out tools			1		Lifter type
15	Tool set			2		For electical engineer
16	Digital sound level meter					Measuring range 32-130dB, 31.5-8kHz, English display,Portable type
17	Flue gas analyser					Measuring gas 02, N02, S02, Measuring temperature 0-650℃, English display,Portable type

Kosrae Utilities Authority

Major Overhaul Schedule

Saite of work	
Person in Charge	
Workinng Days	
No. MainPower	

Site Name		Engine Serial No.	
Engine Model		Plant No.	
Type of Engine		Installed Date	
Subject	24,000hr Preventive Maintenance		

Major Overhaul Works

NO.	Job Description		Man	Tue	Wed	Thu	Fri	Sat	Sun	Man	Tue	Wed	Thu	Fri	Sat	Sun	Man	Tue	Wed	Thu	Fri	Sat	Sun	Man	Tue	Wed	Thu	Fri	Sat	Sun	Man	Tue	Wed	Thu	Fri
			Day 1	Day 2	Day 3	Day 4	Day 5			Day 6	Day 7	Day 8	Day 9	Day 10			Day 11	Day 12	Day 13	Day 14	Day 15			Day 16	Day 17	Day 18	Day 19	Day 20			Day 21	Day 22	Day 23	Day 24	Day 25
1	On site discussion & preparation	🟥	🟥																																
2	Check spare parts & special tools	🟥	🟥																																
3	Check crankshaft deflection, F.O injection timing, Valve Clearance	🟥	🟥																																
4	Open & Clean all filters (F.O, L.O, CW)	🟥	🟥																																
5	Remove Cylinder Heads, F.O Injection pumps, Pistion/Conrods & Liners		🟥	🟥	🟥	🟥	🟥																												
6	Open, Clean, calibrate & Overhaul (Cyl. Heads, F.O Injection pumps, injectors & Piston)		🟥	🟥	🟥	🟥	🟥																												
7	Remove all attached pumps F.O, L.O, CW & overhaul		🟥	🟥	🟥	🟥	🟥																												
8	Extract protection ring, clean & calibrate									🟥	🟥	🟥	🟥	🟥																					
9	Clean cylinder linear clean, visual insppection & calibrate									🟥	🟥	🟥	🟥	🟥																					
10	Clean clinder heads & FO pump seating area. Clean liner area (Engine Block)									🟥	🟥	🟥	🟥	🟥																					
11	Caliberate crank pin journal									🟥	🟥	🟥	🟥	🟥																					
12	Open & check main bearing & thrust bearing (replace if necessary)									🟥	🟥	🟥	🟥	🟥																					
13	Check tightning balance weight bolts inspect and repalce if necessary																🟥	🟥	🟥	🟥	🟥														
14	Move camshaft & check camshaft bearing ondition (replace if necessary)																🟥	🟥	🟥	🟥	🟥														
15	Check gear trains (Backlash,visual condition, tightning bolts)																🟥	🟥	🟥	🟥	🟥														
16	Removed all coolers (L.O,Air cooler, FW) do cleaning																🟥	🟥	🟥	🟥	🟥														
17	Remove T/C & Overhaul																🟥	🟥	🟥	🟥	🟥														
18	Remover Governr and send to authorized service agent																							🟥	🟥	🟥	🟥	🟥							
19	Overhaul main air starting valve,air rotary, air control valve, & FO shut down device																							🟥	🟥	🟥	🟥	🟥							
20	Replace o-ring all relive valves																							🟥	🟥	🟥	🟥	🟥							
21	Installed Linear, Pistons, Cyl. Head, FO Injection pumps, L.O, CW FO pumps																							🟥	🟥	🟥	🟥	🟥							
22	Install Coolers, Isolation rubber & T/C																							🟥	🟥	🟥	🟥	🟥							
23	Check cranshaft deflection, F.O injection timimg, Valve Clearance																														🟥	🟥	🟥	🟥	🟥
24	Leak Test, LO free flow check																														🟥	🟥	🟥	🟥	🟥
25	Engine running test, Protection device test & Load test																														🟥	🟥	🟥	🟥	🟥
26	Uninstalling DEG#3 sensors		🟨	🟨																															
27	RTD inspection		🟨	🟨						🟨																									
28	Themo switch inspection									🟨																									
29	Pressure switch inspection										🟨	🟨																							
30	Oil Mist detector inspection										🟨	🟨																							
31	Flow switch inspection												🟨	🟨																					
32	Float/Level switch inspection												🟨	🟨																					
33	VCB inspection																🟨	🟨																	
34	DEG#3 Electrical Panel and juction boxes inspection																🟨	🟨																	
35	AVR inspection																		🟨	🟨															
36	Speed detector inspection																		🟨	🟨															
37	DEG#3 auxiliary inspection																				🟨			🟨											
38	Installing DEG#3 sensor																				🟨			🟨											
39	Electrical meter calibration																								🟨	🟨									
40	Alarm simulate test																								🟨	🟨									

11.1.3　DG点検シート

Daily Inspection

Activity No.	Engine Parts to be Inspected	Description	TICK BELOW		Remarks
			Done	Not Done	
1	Engine Appearance	Check lose parts and Leaks			
2	Piping Systems	Check lose parts and Leaks			
3	Governor	Check and supply hydraulic oil if required			
4	Starting Air Tank	Check Pressure			
5	Engine Oil Sump	Check oil level & Supply oil			
6	Gauge Board	Check pressure reading on all pressure gauge with normal position (Blue Zone)			
7	Thermometers	Check all thermometers on Engine Parameter			
8	Radiator	Check carefully that there are no any foreign mateial around intake and delivery port			
9	Fuel Oil Service Tank	Check the float gauge			
10	Abnormal Sound	Listen carefully to the sound in the engine parts for any abnormal noise, gas leakage,abnormal mechanical noise,abnormal combustion noise			
11	Blower Room	Check the working condition of ventilation and confirm the fan is normal			
12	Exhaust Colour	Check for abnormal exhaust gas colour(Black or White)			
13	Air Compressor	check oil level & supply if required			
14	Leak off Tank	Check the level of liquid on the gauge reading			

Weekly Service

Activity No.	Engine Parts to be Inspected	Description	Tick Below		Spare Part			Remarks
			Done	Done	Part No.	Used	Instock	
	Fuel Oil System							
1	Fuel injection Pumps	Lubricate pump racks						
2	Engine Fuel Filters	Clean and check O-rings Condition						
3	Fuel Control Link	Inspect, adjust and Lubricate						
	Lubricating Oil System							
4	Lubricating oil Filters	Clean and check O-rings Condition						
	Intake & Exhaust Air System							
5	Turbo-Charger oil filters	Clean and check O-rings Condition						
6	Turbo-Charger Turbine side	Flush Blower side						
7	Turbo-Charger Air Filter	Wash pre-filter						
	Cooling Water System							
8	Jack Water cooling Tank	Check cooling water level						
		Test water quality						
	Auxilliaries Systems							
9	Oil Purifying & Filtering System	check and clean sludge bucket						
10	Lubricating Oil Cooler	Check for leak						
11	Air Cooler	Check for leak						
12	Air Compressor	Check,Clean and top up oil level & drain condensate in the system						
	Generator side							
13	Bearing Thermometer	Visually check thermometer						
14	oil ring	Visual check the work condition of the oil ring						
15	Alternator & VCB	Check and Clean						

Monthly [500hrs] Service

Activity No.	Engine Parts to be Inspected	Description	Tick Below		Spare Part			Remarks
			Done	Done	Part No.	Used	Instock	
	CyLinder Heads							
1	Indicator & Safety Valve	Check & repair for leakage						
	Fuel System							
2	Fuel Injection Pump	Check & Reapir for leakage						
		Check rack graduation position						
4	Storage Tank Fuel Filter	Clean and remove impurities						
	Cooling System							
5	Radiator	Clean radiators heat exchanger						
		Check condition of exchanger fins						
		check for corrossion						
6	Radiator Expansion Tank	Check water level						
8	Fresh water full flow filter	Diassemble and clean						
	Lubricating System							
9	Oil Filter (notch wire type)	Disassemble and clean						
	Main Moving Parts							
10	Camshaft	inspect cam and roller fitting						
	Auxillaries & Gauges							
11	Protective devices	Inspect ,test and adjust						
	Starting Neumatic System							
12	Starting rotary valve	Drain condensate						
	Generator Side							
13	Generator Body	Clean and remove dirty						
14	AC Generator	Check all wiring connection						

Quaterly [1500hr] Service

Activity No.	Engine Parts to be Inspected	Description	Tick Below		Spare Part			Remarks
			Done	Not Done	Part No.	Used	Instock	
Cylinder Head								
1	Valve End Clearance	Check and adjust Intake Valve Clearance(0.5mm),Exhaust Valve Clearance(0.5mm)						
2	Maximum Combustion Pressure	Check and Adjust Full Load (15.7 Mpa) Difference Between cylinders(0.6MPa)						
Fuel System								
3	Fuel Injection Pump	Check and adjust injection Timing						
4	Fuel Nozzle	extraction and adjust fuel injection pressure 34 MPa						
Main Moving Parts								
5	Crankshaft Deflection	Deflection measurement						
Gauges								
6	Pressure & Thermometer	Inspection & calibration of pressure gauges and tachnometer						
Luburicating Oil System								
7	Lub.Oil Cooler	Inspect & replace protective zinc						
Radiator								
8	Axilal Flow Fan	Check noise & vibration						
9	Motor	Check noise & vibration						
10	Heat Exchanger	Check leadk of fluid and air vent						
Oil Purifyer & Filtering System								
11	Seperator	Check for vibration & noise						
		Check smooth operation						
		Check pump condition						
12	CJC Filter	0.2MPa						
		Check for leaks						
Centrifugal Pump								
13	Ball Bearing	Check & lubricate						
14	Gland Packing	Check up condition of fitting and amount of leakage.						
Oil Mist Dectector								
15	Oil Mist Dectector	Check body for exraordinary heat generation vibration and noise						

16	Mist Indicator Lightning	Check mist indicator to see that an extraordinarily large number od LED do not light up and the indicator does not keep indicating 0						
		Check the relation between the engine load factor and the mist indicator LEDs from start-up to normal						
Blower Room								
17	Fan Motor	Check and clean						
18	Ventilation Filters	clean and wash all air filters						
19	Motor Drive Belt	Check and adjust						
Camshaft								
20	Swing arm	Check and adjust tappet roller clearance not to exceed 0.2mm						
Protection Panel								
21	Protection Relay	Inspect and Check working condition						
22	Speed Realy	Inspect and Check working condition						
23	AVR	Inspect and Check working condition						
24	Generator Control Desk	Check and Inspect each meter, Indicator,and switch						

Bi -Annual [3000hr] Service

Activity No.	Engine Parts to be Inspected	Description	Tick Below		Spare Part			Remarks
			Done	Done	Part No.	Used	Instock	
1	Cylinder Head Bolt	check and retighten head bolts specify torque 83.4 Mpa						
2	Connecting Rod Bolt	Mpa						
3	Crankshaft	Measure Deflection						
4	Governor	Check, replace working fliud						
5	Gauges	Inspect pressure gauge & thermometers						
		Inspect gauge board vibration insulting rubber						
6	Starting Air Valve	Inspect and repair for air leak						
7	Y-type strainer	Disassemble and clean						
8	Lub.Oil Thermostat	Inspect element						
9	intercooler	Inspect and replace protective zinc						
10	Fuel Pump	Check and fuel injection timimg						
11	Cylinder Head	Valve rotator disassembly and inspection						
		Valve spring cotter inspection						
	Radiator							
12	Axial Flow Fan	Check and fastening of bolts						
13	Motor	bolts						
14	Heat Excahnger	Check fastening of bolts and remove dirt on the fin						
	Oil Mist Detector							
15	Alarm Check	Check the alarm output relay operation						
16	Trouble Check	Test and confirm working condition of the trouble lamp indicator and output relay						
	Fuel System							
17	Fuel Service Tank	Empty and remove sludge from tank						
18	Fuel Flow Meter	Disassemble and clean						
	CB Room							
19	Generator CB Panel	check and remove dust						
20	Generator Neutral Panel	check and remove dust						
21	11KV Bus interconnection Panel	Inspect and check condition						

11.1.4　DG日常パトロールシート

Inspection check sheet

KUA Power Station

◆ **Electrical Inspection (2)**

Date :

No.	inspection item	Limit Value	Inspection hour / unit																		Coments
			3:00			7:00			11:00			15:00			19:00			23:00			
			#3	#4	#5	#3	#4	#5	#3	#4	#5	#3	#4	#5	#3	#4	#5	#3	#4	#5	
DC Power supply Device																					
1	DC power supply (voltage / current, test lamp)	light op																			
2	Rectifier output voltage (V)	indication																			
3	Rectifier output current (A)	indication																			
4	DC voltage (V)	indication																			
5	Battery (A)	indication																			
6	Battery (odour, sound, temperature)																				
7	Battery terminal slack																				
8	Panel inside cleaning																				
11kV Station Power Transformer Panel																					
1	Ground fault indication lamp	operation																			
2	Station power voltage 415V (R・S)	indication																			
3	Station power voltage 416V (S・T)	indication																			
4	Station power voltage 417V (T・R)	indication																			
5	Main Feeder 11kV (R・S)	indication																			
6	Main Feeder 11kV (S・T)	indication																			
7	Main Feeder 11kV (T・R)	indication																			
8	Station power current (A) R	indication																			
9	Station power current (A) S	indication																			
10	Station power current (A) T	indication																			
11	Panel inside cleaning																				
REMARKS ・abnormality ・reparation		operator name																			

Inspection check sheet

KUA Power Station

◆ **Electrical Inspection (1)**

Date :

No.	inspection item	Limit Value	Inspection hour / unit																		Coments
			3:00			7:00			11:00			15:00			19:00			23:00			
			#3	#4	#5	#3	#4	#5	#3	#4	#5	#3	#4	#5	#3	#4	#5	#3	#4	#5	
Power Station General																					
1	Electrical panel room cleaning																				
2	Operation of the meters																				
3	Electric motors temperature (auxiliary devices)																				
4	Confirmation inside the generator panel (breaker leakage oil)																				
5	Confirmation inside high-voltage switchboard (breaker leakage oil)																				
6	Electrical panel inside cleaning																				
7	Indication lamp of the electrical panels																				
Generator / Exciter																					
1	Apearance / Cleaning																				
2	Generator shaft bearing temperature(engine side)	＜85℃																			
3	Generator shaft bearing temperature(exciter side)	＜85℃																			
4	Generator stator winding temperature (U)	≦120℃																			
5	Generator stator winding temperature (V)	≦120℃																			
6	Generator stator winding temperature (W)	≦120℃																			
7	Continuos current voltage	25.5～28V																			
8	Generator bearing oil level check																				
REMARKS ・abnormality ・reparation		operator name																			

NOTICE

KUA Power Station

Date:

1st shift

0perator:

2nd shift

Operator:

3rd shift

Operator:

Daily inspection check sheet

KUA Power Station

● Power house, Engine & comon devices inspection

Date :

No.	inspection item	Limit Value	Inspection hour / unit																		Coments
			3:00			7:00			11:00			15:00			19:00			23:00			
			#3	#4	#5	#3	#4	#5	#3	#4	#5	#3	#4	#5	#3	#4	#5	#3	#4	#5	
1	Outside temperature	–																			
2	Control room temperature	below 28℃																			
3	Engine room temperature (ventilation)																				
4	Blower room																				
5	Engine room pit sump basin condition	overflow																			
6	Oil / water separation pool condition	overflow																			
7	Oil leak in the waste oil storage site	No leak																			
8	Cleaning																				
9																					
10	Engine appearance																				
11	Piping systems (lose parts & leaks)																				
12	Governor oil check / pin / nuts																				
13	Engine oil sump level																				
14	Gauge board pressure reading normal position																				
15	Thermometers in engine parameters																				
16	Exhaust gas color																				
17	Exhaust duct leaks																				
18	Abnormal sound / odour / vibration																				
19	Cylinder head cover exhaust gas leak																				
21	Turbocharger air pressure (Mpa)	≦0.3																			
20																					
REMARKS ・abnormality ・reparation		operator name																			

Daily inspection check sheet

KUA Power Station

■ **Fuel oil & Lube oil system inspection**

Date :

No.	inspection item	Limit Value	Inspection hour / unit																		Coments
			3:00			7:00			11:00			15:00			19:00			23:00			
			#3	#4	#5	#3	#4	#5	#3	#4	#5	#3	#4	#5	#3	#4	#5	#3	#4	#5	
	Fuel oil System																				
1	Fuel storage tank level																				
2	Service tank level																				
3	Piping system lose parts an leaks																				
4	Fuel oil pressure	≦0.44Mpa																			
	Lube Oil System																				
1	No oil leak in lubricating oil storage area																				
2	Piping system lose parts an leaks																				
3	Lubricating oil pressure (bearing) (Mpa)	0.35≦																			
4	Lubricating oil pressure (Turbocharger) (Mpa)	0.09≦																			
5	Engine inlet lubricating oil temperature (℃)	≦65																			
6	Lubricating oil cooler inlet oil temperature (℃)	≦85																			
7	Lubricating oil cooler outlet oil temperature (℃)	≦61																			
8	Lubricating oil cooler secondary cooling water inlet temperature(℃)	≦51																			
9	Lubricating oil cooler secondary cooling water outlet temperature(℃)	≦55																			
10	CJC filter leaks and pressure (Mpa)	0.2																			
REMARKS ・abnormality ・reparation		operator name																			

Daily inspection check sheet

KUA Power Station

☆Cooling System inspection

Date :

No.	inspection item	Limit Value	Inspection hour / unit																		Coments
			3:00			7:00			11:00			15:00			19:00			23:00			
			#3	#4	#5	#3	#4	#5	#3	#4	#5	#3	#4	#5	#3	#4	#5	#3	#4	#5	
	Cooling System																				
1	Radiators condition (leaks, corrosion, etc.)																				
2	Expantion tank water level																				
3	Primary cooling water pressure(Mpa)	0.15≦																			
4	Secondary cooling water pressure(Mpa)	0.1≦																			
5	Cylinder outlet CW temperature-1	≦85																			
6	Cylinder outlet CW temperature-2																				
7	Cylinder outlet CW temperature-3																				
8	Cylinder outlet CW temperature-4																				
9	Cylinder outlet CW temperature-5																				
10	Cylinder outlet CW temperature-6																				
11	Clean water intercooler primary CW inlet temp	≦85																			
12	Clean water intercooler primary CW outlet temp	≦74																			
13	Clean water intercooler secondary CW inlet temp	＜55℃																			
14	Clean water intercooler secondary CW outlet temp	＜55℃																			
15	Primary CW pump /leak from the seal																				
16	Secondary CW pump / water from the packing																				
17	Air intercooler / secondary CW inlet temp.	＜45℃																			
18	Air intercooler / secondary CW outlet temp.	＜50℃																			
19	Lube oil intercooler / secondary CW inlet temp	＜50℃																			
20	Lube oil intercooler / secondary CW outlet temp	＜50℃																			
21																					
REMARKS ・abnormality ・reparation		operator name																			

Daily inspection check sheet

KUA Power Station

◆ Air / Exhaust gas system inspection

Date :

No.	inspection item	Limit Value	Inspection hour / unit																		Coments
			3:00			7:00			11:00			15:00			19:00			23:00			
			#3	#4	#5	#3	#4	#5	#3	#4	#5	#3	#4	#5	#3	#4	#5	#3	#4	#5	
	Air System																				
1	Compressor operation																				
2	Air tank (lose parts or leaks) pressure(Mpa)	0.19																			
3	Piping system lose parts an leaks																				
4	Air intercooler/ air outlet temperature (℃)	≦74																			
5	Turbocharger rpm	39000																			
6	Turbocharger oil level																				
	Exhaust Gas System																				
1	Turbocharger inlet temperature (℃)	≦500																			
2	Exhaust gas temperature－cyl 1	＜500℃																			
3	Exhaust gas temperature－2	＜500℃																			
4	Exhaust gas temperature－3	＜500℃																			
5	Exhaust gas temperature－4	＜500℃																			
6	Exhaust gas temperature－5	＜500℃																			
7	Exhaust gas temperature－6	＜500℃																			
8	Turbocharger exhaust gas temperature No.1・2・3	440℃																			
9	Turbochargerexhaust gas temperature No.1・2・4	440℃																			
	Silencer appearance																				
	Chimney appearance																				
REMARKS ・abnormality ・reparation		operator name																			

Generator / Power internal consume Diary

Date 2018, May

Parameter	shift	Operation shift	Generator											Remarks
			measure	Load	Current （A）			Voltage （V）			cosϕ	Excitator		
			hour	kW	R	S	T	R･S	S･T	T･R	%	A	V	
Date		—	—											—
	1st	#6	:											
		#7	:											
		#8	:											
	2nd	#6	:											
		#7	:											
		#8	:											
	3rd	#6	:											
		#7	:											
		#8	:											
	1st	#6	:											
		#7	:											
		#8	:											
	2nd	#6	:											
		#7	:											
		#8	:											
	3rd	#6	:											
		#7	:											
		#8	:											
	1st	#6	:											
		#7	:											
		#8	:											
	2nd	#6	:											
		#7	:											
		#8	:											
	3rd	#6	:											
		#7	:											
		#8	:											
	1st	#6	:											
		#7	:											
		#8	:											
	2nd	#6	:											
		#7	:											
		#8	:											
	3rd	#6	:											
		#7	:											
		#8	:											

Transmission Line Diary

Date 2018, May

	勤務体制		Voltage （ V ）			(F 1)Line				(F 2) Line							
		測 定 時 刻				Active Power	Current （ A ）			Active Power	Current （ A ）			Active Power	Current （ A ）		
			R･S	S･T	T･R	kW	R	S	T	kW	R	S	T	kW	R	S	T
Parameter	—	—	6400～6800	6400～6800	6400～6800	≦320	≦32	≦32	≦32	≦320	≦32	≦32	≦32	≦320	≦32	≦32	≦32
year	1shift	08:00															
month	2shift	14:00															
day	3shift	20:00															
year	1shift	08:00															
month	2shift	14:00															
day	3shift	20:00															
year	1shift	08:00															
month	2shift	14:00															
day	3shift	20:00															
year	1shift	08:00															
month	2shift	14:00															
day	3shift	20:00															
year	1shift	08:00															
month	2shift	14:00															
day	3shift	20:00															
year	1shift	08:00															
month	2shift	14:00															
day	3shift	20:00															
year	1shift	08:00															
month	2shift	14:00															
day	3shift	20:00															

11.1.5　スペアパーツリスト

JICA Team

July30,2021

List of Spare Parts for OH (Engine)

No.	Part No.	Name	MATERIAL	PER 1ENG	Quantity	Remarks
CYLINDER HEAD						
24	DE-18-052	CYL. HEAD ASSY (WITH VALVE)	ASSY	6	2	OUT.BOX
3	AE47056003	SEAT INTAKE VALVE	SPEC.CAST(E38)	12	48	BOX No.5
6	AE47056020	SEAT EXHAUST VALVE A	SCH3 STELLITE6	12	48	BOX No.4
7	AE47056007	SEAL EXHAUST VALVE	SPEC	12	48	BOX No.3
8	AE47056008	SEAL EXHAUST VALVE STEM	SPEC	12	48	BOX No.3
9		NOZZLE TIPS	SPEC	6	24	BOX No.3
33	AE47056010	O-RING G55	FP33	12	48	BOX No.7
34	AE47056011	O-RING S67	SILICON	12	48	BOX No.7
35	AE47056013	O-RING S44	NBR	12	48	BOX No.7
36	E205650300	O-RING G40(4D)	FPM	6	24	BOX No.7
37	Z560102235ZZ	O-RING P22A	NBR	6	24	BOX No.7
38	AE47056014	GASKET CYLINDER HEAD	SPCC	6	24	BOX No.7
39	AE47056003	STAT INTAKE VALVE	SPEC.CAST (E83)	12	48	BOX No.6
112	AE47056015	GASKET	HNBR SUS304	6	12	BOX No.5
113	Z560102235ZZ	O-RING P22A	NBR	6	12	BOX No.7
114	Z412005200ZZ	SNAP RING	SK5	6	12	BOX No.7
115	Z560103435ZZ	O-RING P34	NBR	1	2	BOX No.7
116	Z665030000CC	GASKET	SPCC-A MFZN-15microM-C	1	2	BOX No.7
117	Z665034000CC	GASKET 34	C1100P-0	1	2	BOX No.7
118	Z560101524ZZ	O-RING P15	NBR	6	12	BOX No.7
119	Z541103470AZ	GASKET	NON-AS.	6	12	BOX No.6
120	Z541106092AZ	GASKET (1) 60×92	NON-AS.	6	12	BOX No.6
INTAKE VALVE						
1	DE-18-001	INTAKE VALVE ASSY	ASSY	12	48	BOX No.1
2	AE47057011	INTAKE VALVE	SUH3	12	48	BOX No.1
EXHAUST VALVE						
4	DE-18-006	EXHAUST VALVE	ASSY	12	48	BOX No.2
5	AE47058002	EXHAUST VALVE	SCH3 STB	12	48	BOX No.2
FO INJECTION DEVICE						
19	DE-18-032	F.O.PUMP ASSY	ASSY	6	2×2	OUT.BOX
20	DE-18-033	PLUNGER & DELIVERY VALVE ASSY	ASSY	6	24	OUT.BOX
21	DE-18-034	F. O.INJECTION PIPE WITH JOINT	ASSY	6	12×2	BOX No.5,6
40	AE01062004	O-RING 24.6×5.7	FPM	6	60	BOX No.7
41	E206250120	O-RING 34×5.4	FPM	6	60	BOX No.7
42	Z560103235DZ	O-RING P32	FPM	6	60	BOX No.7
43	Z560104635DZ	O-RING P46	FPM	18	72	BOX No.7
44	Z560203031DZ	O-RING G30	FPM	6	60	BOX No.7
45	E206452160	O-RING	H 104 E85 700	6	24	BOX No.7

No.	Part No.	Name	MATERIAL	PER 1ENG	Quantity	Remarks
46	E206452300	O-RING	H 104 E85 690	6	24	BOX No.7
47	E206452360	O-RING	H 104 E85 680	18	72	BOX No.7
48	AE01064028	O-RING	F 01G 500 35U	6	24	BOX No.7
71	AE01062016	GASKET	PCHS	12	120	BOX No.7
74	Z560104635DZ	O RING	FPM	18	180	BOX No.7
76	Z565001920ZZ	GASKET 19	C1100P-0	6	60	BOX No.7
F.O. INJECTION PUMP						
60	AE01064007	DEFLECTOR	H 104 B33 850	12	48	BOX No.7
78	AE01064028	O-RING	H 01G S00 35U	6	24	BOX No.7
84	AE47064003	BACK UP RING	016410-0500	12	48	BOX No.7
81	AE47064004	BACK UP RING	016410-0400	12	48	BOX No.7
79	E206452160	O-RING	H 104 E85 700	12	48	BOX No.7
80	E206452300	O-RING	H 104 E85 690	6	24	BOX No.7
82	E206452360	O-RING	H 104 E85 680	18	72	BOX No.7
83	E206452610	SEAL RING	2 469 403 689	6	24	BOX No.7
85	E206452800	GASKET	H 104 E03 140	6	24	BOX No.7
86	Z560101824DZ	O-RING P18	FPM	14	56	BOX No.7
87	Z560102124DZ	O-RING P21	FPM	4	16	BOX No.7
88	Z560102335DZ	O-RING	FPM	2	8	BOX No.7
89	Z560203031DZ	O-RING G30	FPM	1	4	BOX No.7
F.O. FEED PUMP & FITTING						
145	C034402000	SEALING KIT HWTVB	00999161	1	2	BOX No.7
146	E203150130	GASKET 205/265	SPEC	1	2	BOX No.6
147	E211350270	CASTLE NUT WITH SEAT M20×1.5	SS400B-D	1	2	BOX No.3
148	Z300020000ZZ	FLAT WASHER 20	SPCC/SS4OOP	1	2	BOX No.7
149	Z320004040ZZ	SPLIT PIN 4×40	SWRM-12	1	2	BOX No.7
150	Z451163060ZZ	BEARING (1) 6306	PCHS	1	2	BOX No.7
151	Z451162060ZZ	BEARING (1) 6206	PCHS	1	2	BOX No.7
152	Z461406212SC	OIL SEAL SC406212	PCHS	1	2	BOX No.7
153	Z412006200ZZ	SNAP RING	SK5	1	2	BOX No.7
F.O. FILTER & FITTING PARTS						
27	Y529000301ZZ	ELEMENT ASSY 200ME	ASSY	2	2	BOX No.7
28	NN00496008	FILTER ELEMENT ROUND SHAPE	PCHS	19	19	BOX No.7
67	Y529000338ZZ	PACKING	EDP-22-TE	1	20	BOX No.7
68	Y529000113ZZ	PACKING	EDP-21-TE	2	20	BOX No.7
69	C060603430	O RING	G105-VI	2	20	BOX No.7
F.O. CONTROL & SHUTDOWN DEVICE						
198	NN00039059	SNAP RING	SWRH62A	4	8	BOX No.7
199	NN00039065	PACKING	FKM	2	4	BOX No.7
200	NN00039068	GASKET	FKM	2	4	BOX No.7
201	NN00039069	PACKING	FKM	2	4	BOX No.7
202	NN00039123	FILTER	SUS304	2	4	BOX No.7
F.O. PIPING						
154	AE01086017	PULSE ABSORBER	PCHS	2	4	BOX No.7

No.	Part No.	Name	MATERIAL	PER 1ENG	Quantity	Remarks
LUBRICANT OIL UNIT						
101	Z560105257ZZ	O-RING	NBR	2	8	BOX No.7
102	Z560107557ZZ	O-RING	NBR	4	16	BOX No.7
L.O. PUMP & FITTING						
31	DE-18-164	L.O.PUMP ASSY	ASSY	1	1	OUT.BOX
32	C03440030	OIL PUMP 208HWT031	SPEC	1	1	OUT.BOX
155	E170500470	BEARING LM4030×265	PCHS	5	10	BOX No.3
156	Z320005040ZZ	SPLIT PIN 5×40	SWRM-12	1	2	BOX No.7
157	Z400010025ZZ	KEY 10×25	S45/SF540	1	2	BOX No.7
158	Z412005000ZZ	SNAP RING	SK5	1	2	BOX No.7
159	Z412005500ZZ	SNAP RING	SK5	1	2	BOX No.7
160	Z461355511SC	OIL SEAL SC355511	SK5	1	2	BOX No.7
161	Z665010000ZZ	GASKET 10	C1100P-0	1	2	BOX No.7
162	Z665034000ZZ	GASKET 34	C1100P-0	1	2	BOX No.7
163	E203150130	GASKET 205/265	SPEC	1	2	BOX No.6
L.O. RELIEF VALVE						
164	AE47077005	GASKET	SPEC	1	2	BOX No.6
165	Z560108057ZZ	O-RING	NBR	2	4	BOX No.7
166	Z665012000ZZ	GASKET 12	C1100P-0	2	4	BOX No.7
L.O. THERMOSTAT VALVE						
167	Z560101124ZZ	O-RING	NBR	1	2	BOX No.7
168	Z560106557ZZ	O-RING	NBR	1	2	BOX No.7
169	Z560110557ZZ	O-RING	NBR	1	2	BOX No.7
170	Z665020000ZZ	GASKET	C1100P-0	1	2	BOX No.7
171	AE01079013	PELLET(1) 55C	SPEC	1	2	BOX No.7
CW PUMP & FITING						
29	AE47102002	GEAR CW PUMP Z26-HC	SCM415	1	1	OUT.BOX
30	NN00484002	C.W.PUMP 170-35	SPEC	1	1	OUT.BOX
172	AE01102008	O-RING 28×6.0-HT	NBR	1	2	BOX No.7
173	C038800660	CLAW WASHER	SUS304-CP	1	2	BOX No.7
174	AEO1102010	MECHANICAL SEAL (560-30)NT31	PCHS	1	2	BOX No.7
175	C038500570	BEARING 35	PCHS	2	4	BOX No.7
176	NN00484011	MOUSE RING 115	CAC403(BC3)	2	4	BOX No.7
177	Z319128054ZZ	CLAW WASHER	SPCC	1	2	BOX No.7
178	Z400007025DZ	KEY 7×25	SUS304	1	2	BOX No.7
179	Z400010028ZZ	KEY 10×28	S45C/SF540	1	2	BOX No.7
180	Z412007200ZZ	SNAP RING	SK5	1	2	BOX No.7
181	Z461456209TC	OIL SEAL TC456209	PCHS	1	2	BOX No.7
182	Z560110057ZZ	O-RING P100	NBR	2	4	BOX No.7
183	Z560114057ZZ	O-RING	NBR	1	2	BOX No.7
184	Z560203520ZZ	O-RING	NBR	1	2	BOX No.7
185	Z560217557ZZ	O-RING	NBR	1	2	BOX No.7
186	Z565001000EE	GASKET 10	SPCC NONAS COMPOUND	2	4	BOX No.7
187	Z565001700EE	GASKET 17	SPCC NONAS COMPOUND	2	4	BOX No.7

No.	Part No.	Name	MATERIAL	PER 1ENG	Quantity	Remarks
CW BY-PASS VALVE						
188	Z560100919ZZ	O-RING P9	NBR	1	2	BOX No.7
189	Z560101424ZZ	O-RING P14	NBR	1	2	BOX No.7
190	Z560102024ZZ	O-RING	NBR	1	2	BOX No.7
191	Z560104935ZZ	O-RING	NBR	1	2	BOX No.7
192	Z560107057ZZ	O-RING	NBR	2	4	BOX No.7
193	Z665012000ZZ	GASKET 12	C1100P-0	2	4	BOX No.7
CW THERMOSTAT VALVE						
194	AE47080004	THERMOSTAT VALVE	PCHS	2	4	BOX No.7
103	Z560105057ZZ	O-RING P50A	NBR	1	4	BOX No.7
104	Z560108057ZZ	O-RING	NBR	1	4	BOX No.7
105	Z560208531ZZ	O-RING	NBR	2	8	BOX No.7
106	Z560209531ZZ	O-RING G95	NBR	2	8	BOX No.7
EXHAUST GAS PIPE						
59	AE47021081	BELLOWS	SPEC	3	12	OUT.BOX
121	AE47021014	GASKET EXHAUST PIPE1	SUS-DP	6	12	BOX No.3
122	AE47021015	GASKET EXHAUST PIPE2	SUS 304 CERAMIC	6	12	BOX No.7
CYLINDER LINER						
26	DE-18-056	CYLINDERL LINER	ASSY	6	2	OUT.BOX
PISTON						
25	DE-18-054	PISTON ASSY	ASSY	6	1	OUT.BOX
10	AE47051003	PISTON RING 1ST	SPEC	6	24	BOX No.3
11	AE47051004	PISTON RING 2ND	SPEC	6	24	BOX No.3
12	AE47051005	PISTON RING 3RD	SPEC	6	24	BOX No.3
13	AE47051006	OIL RING	SPEC	6	24	BOX No.3
126	AE47051006	OIL RING	SPEC	6	12	BOX No.3
127	AE47051009	SNAP RING C TYPE	SWRH62-72	12	24	BOX No.3
CONNECTING ROD						
14	AE47052003	PISTON PIN BUSH	CAC603 S 10C	6	24	BOX No.4
15	AE47052006	BEARING CRANK PIN A40	A40 DS10	6	12×2	BOX No.5,6
MAIN BEARING						
16	DE-18-024	CRANK PIN BOLT ASSY	ASSY	6	12×2	BOX No.3,4
17	AE47007001	MAIN BEARING	A40 DS10	7	7	BOX No.7
18	AE47007002	BEARING	A40 S10C	2	8	BOX No.4
AIR COOLER						
49	NN00598008	GASKET	NON-ASBESTOS	1	4	OUT.BOX
50	NN00598009	GASKET	NON-ASBESTOS	1	4	OUT.BOX
51	NN00598013	PACKING	CU	10	40	BOX No.7
52	NN00598010	GASKET	NON-ASBESTOS	2	8	OUT.BOX
90	NN00598008	GASKET	NON-ASBESTOS	1	4	OUT.BOX
94	AE47026002	AIR COOLER INLET GASKET	SPEC	1	4	OUT.BOX
95	AE47026007	GASKET	SPEC	2	8	BOX No.6

No.	Part No.	Name	MATERIAL	PER 1ENG	Quantity	Remarks
96	AE47026012	AIR COOLER OUTLET GASKET	SPEC	1	4	OUT.BOX
97	Z560230057ZZ	O-RING G300	NBR	1	4	BOX No.7
98	Z565002100EE	GASKET 21	SPCC NONAS COMPOUND	1	4	BOX No.7
99	AE47090011	GASKET	SPEC	1	4	BOX No.6
100	AE47090023	GASKET	SPEC	2	8	BOX No.6
STARTING VALVE						
22	DE-18-037	STARTING VALVE ASSY	ASSY	6	2	BOX No.3
132	S108600100	SPLIT PIN 2.5×2 5	SUS	1	2	BOX No.7
133	S108600250	SPLIT PIN 2×18		1	2	BOX No.7
134	Z560001218ZZ	O-RING	NBR	1	2	BOX No.7
135	Z560100919ZZ	O-RING P9	NBR	1	2	BOX No.7
136	Z560101019ZZ	O-RING P10	NBR	1	2	BOX No.7
137	Z560101324ZZ	O-RING	NBR	1	2	BOX No.7
138	Z560102435ZZ	O-RING P24	NBR	1	2	BOX No.7
139	Z560103435ZZ	O-RING P34	NBR	1	2	BOX No.7
140	Z560204531ZZ	O-RING G45	NBR	1	2	BOX No.7
141	Z560205531ZZ	O-RING G55	NBR	2	4	BOX No.7
142	Z565003400EE	GASKET 34	SPCC NONAS COMPOUND	3	6	BOX No.7
53	Z665030000CD	GASKET 30	C1100P-0	6	24	BOX No.7
54	Z665034000ZZ	GASKET 34	C1100P-0	6	24	BOX No.7
STARTING ROTARY VALVE						
143	Z560205531ZZ	O-RING G55	NBR	1	2	BOX No.7
144	Z560207531ZZ	O-RING G75	NBR	1	2	BOX No.7
GOV. FITTING						
128	AEOI045013	DISTANCE PIECE	SS400B	1	2	BOX No.3
129	AEOI045017	GASKET	5LS	1	2	BOX No.6
130	Z451162050ZZ	BEARING (1) 6205	PCHS	2	4	BOX No.7
131	Z320004030ZZ	SPLIT PIN	SWRM-12	1	2	BOX No.7
CONTROL MAGNETIC VALVE						
197	Z560000415ZZ	O-RING	NBR	8	16	BOX No.7
INDICATOR & SAFTY VALVE						
23	NN00002045	INDICATOR & SAFTY VALVE ASSY 12	ASSY	6	26	BOX No.5,6
55	Z565001700ZZ	GASKET 17	C1100P-0	6	24	BOX No.7
56	Z565002300ZZ	GASKET	C1100P-0	18	72	BOX No.7
57	NN00002016	SEAT	SS400B	6	24	BOX No.7
58	Z565002300ZZ	GASKET	C1100P-0	6	24	BOX No.7
GAUGE						
61	AQL20017367B	PRESS. GAUGE FOR COMBUSTION AIR	NAGANO KEIKI	1	1	BOX No.7
62	AQL20017367B	PRESS. GAUGE FOR ENGINE LUBRICATING OIL	NAGANO KEIKI	1	1	BOX No.7
63	AQL20017367B	PRESS. GAUGE FOR TURBO-CHARGER LUBRICATING OIL	NAGANO KEIKI	1	1	BOX No.7
64	AQL20017367B	PRESS. GAUGE FOR ENGINE HT WATER	NAGANO KEIKI	1	1	BOX No.7
65	AQL20017367B	PRESS. GAUGE FOR ENGINE LT WATER	NAGANO KEIKI	1	1	BOX No.7
66	AQL20017367B	PRESS. GAUGE FOR ENGINE FUEL OIL	NAGANO KEIKI	1	1	BOX No.7

No.	Part No.	Name	MATERIAL	PER 1ENG	Quantity	Remarks
SEAL POT						
107	NN0003002	PCH ETHILENE GLYCOL	PCHS	1	4	OUT.BOX
108	NN00295003	MOLYKOTE 1000 300ML	SPEC	-	16	OUT.BOX
Others						
203	Z565001000CZ	GASKET	SPCC-A	-	100	BOX No.7
204	Z565001300ZZ	GASKET 13	C1100P-0	-	200	BOX No.7
205	Z565001700ZZ	GASKET 17	C1100P-0	-	200	BOX No.7
206	Z565002100ZZ	GASKET 21	C1100P-0	-	100	BOX No.7
207	Z565002700ZZ	GASKET 27	C1100P-0	-	100	BOX No.7
208	Z565002700ZZ	SPARE PARTS BOX TYPE 12(STEEL)	SS400	-	7	BOX No.1-7

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List of Spare Parts for OH (Turbo Charger)

No.	Name	Material	PER 1ENG	Quantity	Part No.	Remarks
MET18SRC						
1	THRUST BEARING (TURBINE SIDE)	Carbon Steel & Leaded Tin Bronze Casting (S25C,LBC)	1	4	N36-J12-4007-A Part No.71	OUT.BOX
2	THRUST BEARING(BLOWER SIDE)	Carbon Steel & Leaded Tin Bronze Casting (S25C,LBC)	1	4	N36-J12-4012-A Part No.73	OUT.BOX
3	JOURNAL BEARING	Carbon Steel & Leaded Tin Bronze Casting (S45C,LBC)	2	8	N36-J02-4008-A Part No.70	OUT.BOX
4	THRUST COLLER	Cr-Mo Steel (SCM415)	1	4	N36-852-4008-1 Part No.63	OUT.BOX
5	AIR FILTER	Polyester	1	4	N36-782-8006-1 Part No.55	OUT.BOX
6	O-RING	Rubber (4D)	1	4	N36-361-0063-1 Part No.306	OUT.BOX
7	O-RING	Rubber (4D)	1	4	N36-361-0064-1 Part No.472	OUT.BOX
8	O-RING	Rubber (4D)	1	4	361-031-090-6 Part No.362	OUT.BOX
9	O-RING	Rubber (4D)	1	4	361-031-045-6 Part No.373	OUT.BOX
10	O-RING	Rubber (4D)	1	4	N36-361-0110-1 Part No.358	OUT.BOX
11	GASKET	SPCC	1	4	N36-362-0161-1 Part No.309	OUT.BOX
12	GASKET	SPCC	1	4	N36-362-0310-1 Part No.357	OUT.BOX
13	SPRING WASHER	Hard Steel Wire (SWRH62)	4	16	168-400-106-2 Part No.373	OUT.BOX
14	GAS SEAL RING	Spheroidal Graphite iron Casting	1	4	N36-702-4001-1 Part No.605	OUT.BOX

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List of Spare Parts for OH (Motor)

No.	Name	Material	PER 1ENG	Quantity	Part No.	Remarks
1	FUEL OIL TRANSFER PUMP AND MOTOR			1	AQL20017188	OUT.BOX
2	FUEL OIL DRAIN DISCHARGE PUMP AND MOTOR			1	AQL20017189	OUT.BOX
3	WASTE OIL DISCHARGE PUMP AND MOTOR			1	AQL20017190	OUT.BOX
4	LOW-TEMPERATURE CIRCULATING PUMP AND MOTOR			1	AQL20017187	OUT.BOX
5	LUBRICATING OIL PRIMING PUMP AND MOTOR			1	AQL20018176	OUT.BOX

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List of Spare Parts for OH (Filter)

No.	Name	Material	PER 1ENG	Quantity	Part No.	Remarks
FUEL OIL & SLUDGE TREATMENT						
1	INLET OF FO TRANSFER PUMP		1	2		OUT.BOX
2	INLET OF FLOW METER(FUEL PRIMARY FILTER)		1	4		OUT.BOX
3	INLET OF FO DRAIN DISCHARGE PUMP		2	2		OUT.BOX
4	WASTE OIL DISCHARGE PUMP		1	1		OUT.BOX
5	INLET OF SLUDGE DISCHARGE PUMP		1	1		OUT.BOX
6	INLET OF OIL WATER TRANSFER PUMP		1	1		OUT.BOX
7	INLET OF SLUDGE TRANSFER PUMP		1	1		OUT.BOX
LUBRICANT OIL SYSTEM						
8	INLET OF LO CLEANING DEVICE		2	2		OUT.BOX
COOLING WATER						
9	INLET OF WATER TREATMENT UNIT		1	1		OUT.BOX

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List of Spare Parts for OH (Pump)

No.	Name	Material	PER 1PUMP	Quantity	Part No.	Remarks
FUEL OIL TRANSFER PUMP MODEL：ALG-40N　3 SETS						
1	BEARING METAL	CAC603	4	1	99DS0582 / Part No.201	OUT.BOX
2	MECHANICAL SEAL		1	1	99DS0582 / Part No.520	OUT.BOX
3	PRESSURE GAUGE(0~0.6MPa)		1	3		OUT.BOX
FUEL OIL DRAIN DISCHARGE PUMP MODEL：TLG-2　3 SETS						
1	BALL BEARING		1	1	A0DS0225 / Part No.201	OUT.BOX
2	BALL BEARING		1	1	A0DS0225 / Part No.202	OUT.BOX
3	OIL SEAL	RUBBER	2	1	A0DS0225 / Part No.531	OUT.BOX
4	PRESSURE GAUGE		1	3		OUT.BOX
LUBRICANTING OIL PRIMING PUMP MODEL：ALG-40N　3 SETS						
1	BEARING METAL	CAC603	4	1	99DS0582 / Part No.201	OUT.BOX
2	MECHANICAL SEAL		1	1	99DS0582 / Part No.520	OUT.BOX
COOLING WATER SUPPLY PUMP MODEL：BHR-32　2 SETS						
1	MECHANICAL SEAL		1	1	A0DS0193 / Part No.201	OUT.BOX
2	PRESSURE GAUGE		1	2		OUT.BOX
WASTE OIL DISCHARGE PUMP MODEL：AE1N-25-ID　2 SETS						
1	BALL BEARING	NO.6204Z	1	1	B2DS0334 / Part No.103	OUT.BOX
2	BALL BEARING	NO.3204	1	1	B2DS0334 / Part No.104	OUT.BOX
3	GLAND PACKING	NON ASBESTOS FIBER	1	1	B2DS0334 / Part No.207	OUT.BOX
4	PRESSURE GAUGE(0~0.6MPa)		1	2		OUT.BOX
OIL-WATER TRANSFER PUMP MODEL：AE1N-25-ID　1 SETS						
1	BALL BEARING	NO.6204Z	1	1	B2DS0334 / Part No.103	OUT.BOX
2	BALL BEARING	NO.3204	1	1	B2DS0334 / Part No.104	OUT.BOX
3	GLAND PACKING	NON ASBESTOS FIBER	1	1	B2DS0334 / Part No.207	OUT.BOX
4	PRESSURE GAUGE(0~0.6MPa)		1	1		OUT.BOX
SLUDGE DISCHARGE PUMP MODEL：AE1N-25-ID　1 SETS						
1	BALL BEARING	NO.6204Z	1	1	B2DS0334 / Part No.103	OUT.BOX
2	BALL BEARING	NO.3204	1	1		OUT.BOX
3	GLAND PACKING	NON ASBESTOS FIBER	1	1	B2DS0334 / Part No.207	OUT.BOX
4	PRESSURE GAUGE(0~0.6MPa)		1	1		OUT.BOX
SLUDGE TRANSFER PUMP MODEL：AE1N-25-ID　1 SETS						
1	BALL BEARING	NO.6204Z	1	1	B2DS0334 / Part No.103	OUT.BOX
2	BALL BEARING	NO.3204	1	1	B2DS0334 / Part No.104	OUT.BOX
3	GLAND PACKING	NON ASBESTOS FIBER	1	1	B2DS0334 / Part No.207	OUT.BOX
4	PRESSURE GAUGE(0~0.6MPa)		1	1		OUT.BOX
LT WATER CIRCULATING PUMP MODEL：CRD-65　3 SETS						
1	MECHANICAL SEAL		1	1	A0DS0012 / Part No.520	OUT.BOX
2	PRESSURE GAUGE(0~0.6MPa)		1	3		OUT.BOX
LUBRICANTING OIL TRANSFER PUMP MODEL：ALG-40N　1 SETS						
1	BEARING METAL	CAC603	4	1	99DS0582 / Part No.201	OUT.BOX
2	MECHANICAL SEAL		1	1	99DS0582 / Part No.520	OUT.BOX
3	PRESSURE GAUGE(0~0.6MPa)		1	1		OUT.BOX

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List of Spare Parts for OH (Waste Oil Incinerator)

No.	Name	Material	PER 1PUMP	Quantity	Part No.	Remarks
AUXILIARY BURNER (Model：LT-35W)						
1	FLAME-EYE			4		OUT.BOX
2	NOZZLE			2		OUT.BOX
3	IGNITION TRANS			1		OUT.BOX
4	SPARK ROD			2		OUT.BOX
5	HIGH TENSION WIRE			4		OUT.BOX
6	PRESSURE GAUGE			1		OUT.BOX
7	SOLENOID VALVE			2		OUT.BOX
8	DIFFUSER			1		OUT.BOX
9	RUBBER COUPLING			1		OUT.BOX
10	OIL PUMP			1		OUT.BOX
11	FAN& SHAFT			1		OUT.BOX
12	DUMPER MOTOR			1		OUT.BOX
13	13.MOTOR			1		OUT.BOX
WASTE-OIL BURNER (Model：SW-2B)						
1	OIL COCK			1		OUT.BOX
2	FLAME-EYE			4		OUT.BOX
3	INSIDE OIL PIPE			1		OUT.BOX
4	NOZZLE TOP			1		OUT.BOX
5	FRONT BEARING			1		OUT.BOX
6	REAR BEARING			1		OUT.BOX
7	OIL SEAL			1		OUT.BOX
8	OIL SPRAY SUPPLY CUP			1		OUT.BOX
9	HEAT INSULATION PLATE			1		OUT.BOX
10	MOTOR（with Case)			1		OUT.BOX
TEMPERATURE SENSOR						
1	THERMOCOUPLE	JIS K-Grade (with SUS310S Guard		4		OUT.BOX
COMBUSTION BLOWER (Model：TFM-075SSL)						
1	MOTOR			1		OUT.BOX
CONTROL PANEL						
1	BURNER CONTROLLER					OUT.BOX
2	CONTROL RELAY					OUT.BOX
LINE HEATER						
1	THERMOMETER			1		OUT.BOX
2	THERMOSTAT			4		OUT.BOX
3	FRANGE PACKING					
INCINERATOR						
1	CASTABLE			100kg		OUT.BOX
2	CERAMIC SEAL			5		OUT.BOX

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List of Spare Parts for OH (ELECTRICAL EQUIPMENT)

No.	Name	TYPE	RATING	PER 1ENG	Quantity	Part No.	Remarks
13.8kV SWICHGEAR							
1	VCB	20-VPR-16D	24kV 600A 12.5kA		1		
2	DRAW OUT HANDLE	FOR "VCB"			7		
3	ACCUMULATE HANDLE	FOR "VCB"			7		
4	LBS FUSES	ISA	24kV 63kA		3		
5	VT FUSES	PL-JB	15kV TIA 40kA		28		
6	EVT FUSES	PL-JB	15kV TIA 40kA		3		
7	LIFTER	FOR "VCB","EVT"			1		
8	OPERATING HANDLE	FOR "LBS"			1		
9	LED LAMP	FOR "(G)"			8		
10	LED LAMP	FOR "(R)"			8		
11	LAMP LENS	FOR "(G)"			8		
12	LAMP LENS	FOR "(R)"			8		
13	CONTROL CIRCUIT FUSE		2A		2		
14	OPERATING HANDLE	FOR "ES of VCB"			7		
STAITION TRANSFORMER							
1	HORIZONTAL TABLE	FOR "STR"			1		
NATIONAL GROUNDING PANEL							
1	OPERA TING HANDLE	FOR "DS"			1		
2	LED LAMP	FOR "(G)"			4		
3	LED LAMP	FOR "(R)"			4		
4	LAMP LENS	FOR "(G)"			4		
5	LAMP LENS	FOR "(R)"			4		
6	CONTROL CIRCUIT FUSE		2A		8		
PROTECTION PANEL							
1	DC RELAY	COC3-A01D1			1		
2	UV RELAY	CBV2-A01D1			1		
3	CONTROL CIRCUIT FUSE		2A		6		
4	RELAY TEST CASE	D1			1		
5	TEST PULG	KTQ-A4 KTQ-V3			2		
PROTECTION PANEL							
1	MOLDED-CASE CIRCUIT-BREAKER	MITSUBISHI	NF250-SV 4P 150AT F-F WITH AL	1	1		
2	UV RELAY	MITSUBISHI	NF125-SV 4P 75AT F-F WITH AL	1	1		
3	MOLDED-CASE CIRCUIT-BREAKER	MITSUBISHI	NF125-SV 4P 15AT F-F WITH AL	1	1		
4	MOLDED-CASE CIRCUIT-BREAKER	MITSUBISHI	NF125-SV 4P 20AT F-F WITH AL	1	1		
5	MOLDED-CASE CIRCUIT-BREAKER	MITSUBISHI	NF125-SV 4P 30AT F-F WITH AL	1	1		
6	MOLDED-CASE CIRCUIT-BREAKER	MITSUBISHI	NF125-SV 3P 20AT F-F WITH AL	1	1		
7	MOLDED-CASE CIRCUIT-BREAKER	MITSUBISHI	NF125-SV 3P 15AT F-F WITH AL	1	1		
8	MOLDED-CASE CIRCUIT-BREAKER	MITSUBISHI	NF125-SV 3P 50AT F-F WITH ALAX	1	1		

No.	Name	TYPE	RATING	PER 1ENG	Quantity	Part No.	Remarks
9	MOLDED-CASE CIRCUIT-BREAKER	MITSUBISHI	NF125-SV 3P 30AT F-F WITH ALAX	1	1		
10	MOLDED-CASE CIRCUIT-BREAKER	MITSUBISHI	NF125-SV 3P 20AT F-F WITH ALAX	1	1		
11	MOLDED-CASE CIRCUIT-BREAKER	MITSUBISHI	NF125-SV 3P 15AT F-F WITH ALAX	1	1		
12	MOLDED-CASE CIRCUIT-BREAKER	MITSUBISHI	NF125-SV 2P 15AT F-F WITH ALAX	1	1		
13	MOLDED-CASE CIRCUIT-BREAKER	MITSUBISHI	NF125-SV 2P 30AT F-F WITH AL	1	1		
14	MOLDED-CASE CIRCUIT-BREAKER	MITSUBISHI	NF125-SV 2P 15AT F-F WITH AL	1	1		
15	MOLDED-CASE CIRCUIT-BREAKER	MITSUBISHI	NF32-SV 2P 30AT F-F WITH AL	1	1		
16	MOLDED-CASE CIRCUIT-BREAKER	MITSUBISHI	NF32-SV 2P 10AT F-F WITH AL	1	1		
17	MOLDED-CASE CIRCUIT-BREAKER	MITSUBISHI	NF32-SV 2P 5AT F-F WITH	1	1		
18	CIRCUIT-PROTECTER	MITSUBISHI	CP30-BA 2P 9M 5A WITH AL	1	1		
19	CIRCUIT-PROTECTER	MITSUBISHI	CP30-BA 2P 9M 10A WITH AL	1	1		
20	THERMAL RELAY	MITSUBISHI	TH-T25KP 0.35A(0.28-0.42A) AUTO RESET	1	1		
21	THERMAL RELAY	MITSUBISHI	TH-T25KP 1.3A(1-1.5A) AUTO RESET	1	1		
22	THERMAL RELAY	MITSUBISHI	TH-T25KP 1.7A(1.4-2A) AUTO RESET	1	1		
23	THERMAL RELAY	MITSUBISHI	TH-T25KP 2.5A(2-3A) AUTO RESET	1	1		
24	THERMAL RELAY	MITSUBISHI	TH-T25KP 5A(4-6A) AUTO RESET	1	1		
25	THERMAL RELAY	MITSUBISHI	TH-T25KP 6.5A(6.2-8A) AUTO RESET	1	1		
26	THERMAL RELAY	MITSUBISHI	TH-T25KP 11A(9-13A) AUTO RESET	1	1		
27	THERMAL RELAY	MITSUBISHI	TH-T25KPSR 22A(18-26A) AUTO RESET	1	1		
28	AUXILIARY RELAY	MITSUBISHI	SR-T5 AC100V 4a1b	1	1		
29	EARTH LEAKAGE RELAY	MITSUBISHI	NV-ZBA AC100・200V 30mA 0.1sec	1	1		
30	EARTH LEAKAGE RELAY	MITSUBISHI	NV-ZBA AC100・200V 100mA 0.1sec	1	1		
31	VT FUSE	MITSUBISHI	PL-G 0.6kV T2A	18	18		
32	AUXILIARY RELAY	OMRON	G2R-2-SN AC100V 2sec	1	1		
33	TIMER	OMRON	H3Y-2 AC100-120V 10sec	1	1		
34	CONTOROL CIRCUIT FUSE	FUJI	FCF2-3 3A	9	9		
35	CONTOROL CIRCUIT FUSE	FUJI	FCF2-1 1A	88	88		
CT PANEL							
1	FUSE 5A		P1 AC500V DC250V NPN23731P00	4	4		

No.	Name	TYPE	RATING	PER 1ENG	Quantity	Part No.	Remarks
AC DISTRIBUTION PANEL							
1	FUSE 3A		P1 AC500V DC250V NPN23731P00	3	3		
2	FUSE 5A		P1 AC500V DC250V NPN23731P00	4	4		
3	FLUORESCENT		MLW-100GM-TB-DS2A AC100/110V 6W 50/60Hz NPN23072P002	1	1		
4	MOLDED-CASE CIRCUIT-BREAKER		NF400-SW-4P-	1	1		
5	MOLDED-CASE CIRCUIT-BREAKER		NF250-SV-4P-S	1	2		
6	MOLDED-CASE CIRCUIT-BREAKER		NF125-SV-4P-S	1	1		
7	MOLDED-CASE CIRCUIT-BREAKER		NF125-SV-4P-S	1	1		
8	MOLDED-CASE CIRCUIT-BREAKER		NF-125-SV-3P-	1	1		
9	MOLDED-CASE CIRCUIT-BREAKER		NF125-SV-3P-S	1	1		
10	MOLDED-CASE CIRCUIT-BREAKER		NF125-SV-3P-S	1	2		
BUILDING AUXILIARY PANEL							
1	FUSE 3A		PC1 AC500V DC250V NPN23731P00	3	3		
2	FUSE 5A		PC1 AC500V DC250V NPN23731P00	5	5		
3	FLUORESCENT		MLW-100GM-TB-DS2A AC100/110V 6W 50/60Hz NPN23072P002	1	1		
4	MOLDED-CASE CIRCUIT-BREAKER		NF125-SV-3P-S	1	1		
5	MOLDED-CASE CIRCUIT-BREAKER		NF63-SVF-3P-S	1	2		
6	MOLDED-CASE CIRCUIT-BREAKER		NF63-SVF-3P-S	1	1		
7	MOLDED-CASE CIRCUIT-BREAKER		NF63-SVF-2P-S	1	17		
8	MOLDED-CASE CIRCUIT-BREAKER		NF63-SVF-2P-S	1	4		
9	MOLDED-CASE CIRCUIT-BREAKER		NF63-SVF-2P-S	1	3		
10	MOLDED-CASE CIRCUIT-BREAKER		NF63-SV-2P-SF	1	3		
COMMON CONTROL DESK							
1	FUSE 3A		PC1 AC500V DC250V NPN23731P00	1	1		
2	LED UNIT RED		UA-37FD6-R (KFA-37F)	5	5		

No.	Name	TYPE	RATING	PER 1ENG	Quantity	Part No.	Remarks
3	LED UNIT RED		TS-LEDA-R (WSPA)	1	1		
4	LED UNIT GREEN		TS-LEDA-G (WSPA)				
EXISTING GENERATOR CONTROL DESK							
1	FUSE 3A		PC1 AC500V DC250V NPN23731P00	1	1		
2	LED UNIT RED		UA-37FD6-R (KFA-37F)	8	8		
3	LED UNIT WHITE		UA-37FD8A-W (KFE-37F)	1	1		
4	LED UNIT RED		TS-LEDA-R (WSPA)	2	2		
5	LED UNIT GREEN		TS-LEDA-G (WSPA)	2	2		
6	AUX. RELAY		MY4N-D2 DC100/110V NPN21026P255	1	1		
7	AUX. RELAY		MY4N DC100/110V NPN21026P165	1	2		
8	TIMER		H3CR-A8 AC100-240V DC100-125V NPN21443P031	1	1		
SYNCRONOUS CONTROL DESK							
1	FUSE 3A		PC1 AC500V DC250V NPN23731P00	5	5		
2	LED UNIT RED		UA-37FD6-R (KFA-37F)	4	4		
3	LED UNIT ORANGE		UA-37FD6A-O (KFE-37F)	34	34		
4	LED UNIT WHITE		UA-37FD8A-W (KFE-37F)	8	8		

No.	Name	TYPE	RATING	PER 1ENG	Quantity	Part No.	Remarks
5	LED UNIT RED		TS-LEDA-R (WSPA)	1	1		
6	LED UNIT GREEN		TS-LEDA-G (WSPA)	1	1		
7	LAMP		E-10, T-10 110V 2W (BT-16HHB-C)	5	5		
8	AUX. RELAY		MY4N DC100/110V NPN21026P175	1	3		
9	TIMER		H3CR-A8 AC100-240V DC100-125V NPN21443P031	1	1		
GENERATOR CONTROL DESK							
1	FUSE 3A		PC1 AC500V DC250V NPN23731P00	2	2		
2	LED UNIT RED		UA-37FD6-R (KFA-37F)	48	48		
3	LED UNIT ORANGE		UA-37FD6-O (KFE-37F)	56	56		
4	LED UNIT WHITE		UA-37FD8A-W (KFE-37F)	18	18		
5	LED UNIT RED		TS-LEDA-R (WSPA)	12	12		
6	LED UNIT GREEN		TS-LEDA-G (WSPA)	4	4		
7	AUX. RELAY		MY4N DC100/110V NPN21026P175	1	14		
8	AUX. RELAY		MY4N-D2 AC100-240V DC100-125V NPN21026P255	1	4		
9	TIMER		H3CR-A8 AC100-240V DC100-125V NPN21443P031	1	4		
GENERATOR PROTECTION DESK							
1	FUSE 3A		PC1 AC500V DC250V NPN23731P00	14	14		
2	AUX. RELAY		MY4N DC100/110V NPN21026P175	1	62		
3	AUX. RELAY		MY4N-D2 DC100/110V NPN21026P255	1	8		
4	AUX. RELAY		MY4N DC100/110V NPN21026P165	1	6		
5	TIMER		H3CR-A8 AC100-240V DC100-125V NPN21443P031	1	50		

No.	Name	TYPE	RATING	PER 1ENG	Quantity	Part No.	Remarks
6	FLICKER TIMER RELAY		H3CR-F8 AC100-240V DC100-125V NPN21443P101	1	2		
7	AUX. RELAY		MM2XPN DC100/110V NPN21046P115	1	14		
8	AUX. RELAY		MM2XPN DC100/110V NPN21046P105	1	2		
9	AUX. RELAY		MM4XPN-D DC100/110V NPN21063P015	1	4		
10	KEEP RELAY		G7K-412S DC110V NPN21043P014	1	16		
11	AUX. RELAY		KA3-E28P	1	34		
12	MULTI RELAY		CGP1-A03D2	1	2		
13	MULTI RELAY		CGP2-A01D2	1	2		
14	LOCK-OUT RELAY		KA15-PB4T DC110V	1	4		
15	TIMER		H3CR-A8 AC24-48V DC12-48V NPN21443P032	1	4		
FEEDER PROTECTION DESK							
1	FUSE 3A		PC1 AC500V DC250V NPN23731P00	12	12		
2	AUX. RELAY		MY4N DC100/110V NPN21026P175	1	42		
3	AUX. RELAY		MY4N-D2 DC100/110V NPN21026P255	1	6		
4	AUX. RELAY		MY4N DC100/110V NPN21026P165	1	4		
5	TIMER		H3CR-A8 AC100-240V DC100-125V NPN21443P031	1	22		
6	AUX. RELAY		MM2XPN DC100/110V NPN21046P115	1	10		
7	AUX. RELAY		MM4XPN DC100/110V NPN21046P155	1	4		
8	KEEP RELAY		G7K-412S DC110V NPN21043P014	1	16		
9	GROUND OVER CURRENT RELAY		LEG-190L-DC	1	1		
10	GROUND OVER CURRENT RELAY		COC1-A01D1	1	1		

No.	Name	TYPE	RATING	PER 1ENG	Quantity	Part No.	Remarks
11	UNDER VOLTAGE RELAY		CBV2-A01D1	1	3		
12	OVER CURRENT RELAY GROUND OVER CURRENT RELAY		COC4-A02D1	1	3		
13	UNDER VOLTAGE RELAY GROUND OVER VOLTAGE RELAY		CBV4-A01D1	1	1		
GENERATOR PANEL							
1	TEST PLUG (CT 2ND.)		KTP-A4 NPN37739P204		1		
2	TEST PLUG (VT 2ND.)		KTP-V3 NPN37739P208		1		
3	TEST PLUG (VT 2ND.)		KTP-V4 NPN37739P209		1		
4	DOOR KEY		KEY No. 200		1		
5	TEST PLUG (CT 2ND.)		KTP-A3 NPN37739P203				
6	TEST PLUG (CT 2ND.)		KTP-A4 NPN37739P204				
7	TEST PLUG (CT 2ND.)		KTP-A8 NPN37739P206				
8	TEST PLUG (VT 2ND.)		KTP-V3 NPN37739P208				
9	TEST PLUG (VT 2ND.)		KTP-V4 NPN37739P209				
10	DOOR KEY		KEY No. 200				
DC POWER SUPPLY PANEL							
1	FUSE		BLA003 3A		2		
2	FUSE		BLA015 15A		6		
3	FUSE		P-413 1.3A		8		
4	FUSE		P-430 3.0A		6		
5	FUSE		FCK-60 60A		4		
6	LED MODULE		PXL-LED220-W		1		
7	LED MODULE		PXL-LED024-R		1		
8	DC VOLTMETER		DVF-11 0-200V		1		
9	DC AMMETER		DVF-11 0-30A 60mV		1		
10	DC AMMETER		DVF-11 0-50A 60mV		1		

No.	Name	TYPE	RATING	PER 1ENG	Quantity	Part No.	Remarks
11	VOLT SELECTER		JSBN-4X-VO-C-HKKK-N		1		
12	MCB		BW32AAG-2P		1		
13	MCB		BW125JAG-3P015KFKA TC：AC200V		1		
14	MCB		BW50SBG-2P		1		
15	MCB		BW32SBG-2P		1		
16	MCB		BW32SBG-2P		1		
17	AUX. RELAY		MY2-CR AC2		1		
18	AUX. RELAY		MY4-D AC24		1		
19	AUX. RELAY		SH4 AC200V		1		
20	DC GROUND RELAY		VG-NF3-110		1		
ACCESSARIES OF RECTIFIRE							
21	ANCHOR VOLT		C-1290		4		
22	DEHUMIDICATION AGENT		[A-UN] Silicag		2		
23	LED CHARGING TOOL		XL-NQ		1		
24	FIXING VOLT		M20×35		4		
ACCESSARIES OF RECTIFIRE							
25	SPANNER(No.10)				1		
26	DC VOLTMETER		Voltage range 0-40V Portable type, Digital meter with leads and		1		
27	MENTENANCE TOOL BOX				1		
PV INVERTER CONTROL PANEL							
1	AUXILIARY RELAY		MY2N AC100V		1		
2	REPAIR PAINT		COLOR：5Y7/1 (SEMI-GLOSS) 200cc		1		
600kW A. C. GENERATOR							
1	RECTIFIER ELEMENT		4G27187G1 SKR133/12	12	12		
2	RECTIFIER ELEMENT		4G27187G2 SKR133/12	12	12		
3	SPARE PARTS BOX		STEEL BOX NU-9189		1		
4	GAP GAURGE		NPN70076P1		1		
5	SPANNER		NPN4271P17 M30		1		

No.	Name	TYPE	RATING	PER 1ENG	Quantity	Part No.	Remarks
6	SUB SHAFT		4GE5364G1 (HEXAGON HEAD BOLTS： M24×140SZ3 WITH PLAINE		1		
7	SUB SHAFT		4GE5365G1 (HEXAGON HEAD BOLTS： M24×130SZ3 WITH PLAINE		1		
8	SPARE PARTS BOX		STEEL BOX NU-9189		1		

11.1.6　工具と測定器リスト

JICA Team
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List of Equipment and tools for OH (Kosrae)

No.	Name	MATERIAL	PER 1ENG	Quantity	Part No.	Remarks
1	STANO HYDRAULIC JACK CAP	SCM435		2	AE47195003	
2	STANO HYDRAULIC JACK CAP	SCM435		4	AE47195004	
3	HYDRAULIC JACK JOINT BOLT M36X3	SCM435		4	AE47195005	
4	STANO HYDRAULIC JACK RDD&	S45C		2	AE47195007	
5	HYDRAULIC JACK M36X3.0	ASSY		5	AE47195008	
6	HANDLE JACK	SCM435		2	AE47195006	
7	HYDRAULIC JACK M30X3.0	SCM435		2	AE47195013	
8	HAND HYDRAULIC JACK	SCM435-D		4	AE02195010	
9	PISTON INSERT	FC200		1	AE47199001	
10	NOZZLE TEST	S45C		1	AE47199005	
11	L. O. FILTER SAUCER	SPCC SS400		1	AE47199006	
12	UAIN BEARING CAP	SS400P		1	AE47199007	
13	VALVE SPRIN0 BASE	SS400P		1	AE47199018	
14	VALVE SPRING PLATE	SS400P		1	AE47199009	
15	NOZZLE HOLDER REMOVER	SS400		1	AE47199020	
16	SOCKET 24 ROCKR ARM SHAFT HOLDE	PCHS SS400		1	AE47199023	
17	CYLINDER LINER PULL&INSERT	ASSY		1	AE47199024	
18	PROTECT RING TOOL	ASSY		1	AE47199025	
19	EX. VALVE SEAT REMOVER	ASSY		1	AE47199026	
20	EX. VALVE SEAT COOLING	ASSY		1	AE47199027	
21	BIG END REMOVER	SS400		1	AE47199028	
22	RING HEAD LCR 1819	PCHS		1	AE47199029	
23	MEASUREMENT TOOL CYLINDE	SS400P		1	AE47199034	
24	VALVE GRINOINGSPRING 1.8×1	SWPA		1	AE47199035	

No.	Name	MATERIAL	PER 1ENG	Quantity	Part No.	Remarks
25	INSERT STEM SEAL INTAKE	S45C		1	AE47199036	
26	INSERT STEM SEAL EXHAUST	S45C		1	AE47199037	
27	TOOL PISTON RING	ASSY		1	AE47199041	
28	NUT FLANGE M12×1.75	JIS B1190/B118		2	AE01003009	
29	SNAP RING PLIER	PCHS		1	AE01199003	
30	PIN MAIN BEARING	SS400B		1	AE01199014	
31	MAIN BEARING CAP2	S45S		1	AE01199030	
32	MAIN BEARING CAP3	SS400B		2	AE01199031	
33	NOZZLE TEST TOOL	S45S		1	AE01199035	
34	TORQUE WRENCH N1800LCK	PCHS		1	AE01199039	
35	RACHET HEAD LQ4080	PCHS		1	AE01199040	
36	NOZZLE TEST PUMP	ASSY		1	AE01199052	
37	SOCKET 27×19×L100	PCHS		1	AE01199056	
38	VALVE GRINDING	PCHS		1	AE01199057	
39	THICKNESS GAUGE 70M	PCHS		1	AE01199059	
40	MAX. PRESS. GAUGE MT31-25M	PCHS		1	AE01199058	
41	INSIDE MICROMETETER 175-20	PCHS		1	C091870030	
42	TORQUE WRENCH N5600QLK	PCHS		1	C092070020	
43	EYE BOLT M12	PCHS		2	Z270012000ZZ	
44	BOLT M12×1.75×20	SS400B-D		2	X200012000ZZ	
45	FLAT WASHER	SPCC/SS400P		2	Z300012000ZZ	
46	EYE BOLT M16	PCHS		1	Z270016000ZZ	
47	BOLT M10×1.5×100	SS400B-D		2	Z270016000ZZ	
48	BOLT MI6×2.0×135	SS401B-D		1	Z200010100ZZ	
49	EYE BOLT M10	PCHS		1	Z270010000ZZ	
50	EXTENSION BAR 12.7×250	PCHS		1	Z915712250ZZ	
51	O-RING	NBR		1	Z560100919ZZ	

No.	Name	MATERIAL	PER 1ENG	Quantity	Part No.	Remarks
52	NUT M16×2.0	SS400B-D		2	X220016000ZZ	
53	NUT M12×1.75	SS400B-D		5	X220012000ZZ	
54	BOLT M16×2.0×55	SS400B-D		1	X220016055ZZ	
55	BOX-12TYPE WITH PAD LOCK	SS400		1	Y910148300ZA	
56	Spanner 8×10	PCHS		1	Z900208100ZZ	
57	Spanner 11×13	PCHS		1	Z900211130ZZ	
58	Spanner 17×19	PCHS		1	Z900217190ZZ	
59	Spanner 22×24	PCHS		1	Z900222240ZZ	
60	Spanner 27×30	PCHS		1	Z900227300ZZ	
61	Offset Wrench 7×19	PCHS		1	Z904117190LZ	
62	Box Spanner 9×300	PCHS		1	Z910119300ZZ	
63	Box Spanner 4×300	PCHS		1	Z910124300ZZ	
64	Socket 19×12	PCHS		1	Z915119000ZZ	
65	Socket 24×12	PCHS		1	Z915124000ZZ	
66	Socket 30×19	PCHS		1	Z915230000ZZ	
67	Socket 41×19	PCHS		1	Z915241000ZZ	
68	Ajust. Angle Wrench 250	PCHS		1	Z920025000ZZ	
69	Hex. Wrench Key 4	PCHS		1	Z925004000ZZ	
70	Hex. Wrench Key 5	PCHS		1	Z925005000ZZ	
71	Hex. Wrench Key 6	SCM435/SNCM240		1	Z925006000ZZ	
72	Hex. Wrench Key 10	PCHS		1	Z925010000ZZ	
73	Hex. Wrench Key	PCHS		1	Z925012000ZZ	
74	SCREW DRIVER	PCHS		1	Z928008150ZZ	
75	PLUS SCREW DRIVER	PCHS		1	Z930100200ZZ	
76	OIL FEEDER 150ML	PCHS		1	Z938501500ZZ	
77	NOZZLE CLEANING TOOL	PCHS		1	Z940019313ZZ	
78	LO PLATE COOLER SET UP TOO	PCHS		2	NN00596013	

No.	Name	MATERIAL	PER 1ENG	Quantity	Part No.	Remarks
79	NOZZLE HOLDER GUIDE	ASSY		1	AE47199048	
80	SNAP RING PRIER CH-4A	PCHS		1	E279880440	
81	HYDRAULIC PUMP	PCHS		1	AE36199032	
82	DEFLECTION GUIDE E69-90 ASS	ASSY		1	AE01199076	
83	LUBRICATING OIL ANALYSER	ASSY		1	AQL20017835	
84	TURNING BAR 34×1000	STPG370(SCH80)		2	NN00053002	
85	HAMMER			1	Z932612000	
86	CALIPPER			1	AQL20017552	
87	HAND PALLET			1	(TPSC)	
88	LADDER			1	(TPSC)	
89	CHAIN BLOCKS 1.0TON/2.5TON			1	(TPSC)	
90	LIFTING WIRES (φ8）			1	(TPSC)	

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List of Equipment and tools for OH (Kosrae)

No.	Name	MATERIAL	PER 1ENG	Quantity	Part No.	Remarks
1	GAP GUGE			1	NPN70076P1	
2	SPANNER			1	NPN70076P1 M3	
3	SUB SHAFT			1		
4	TOOL BOX			1	NU-9189	STEEL BOX

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List of Equipment and tools for OH (Kosrae)

No.	Name	MATERIAL	PER 1ENG	Quantity	Part No.	Remarks
1	Hex. Bolt M6×65	Rolled Steel (SS400)		2	T-13 N36-101-0039	
2	Starting Bolt for Draw-out tube M10X50	Rolled Steel (SS400)		1	T-23 N36-Y02-5005	
3	Puller	Rolled Steel (SS400)		1	T-45 N36-982-5001	
4	Slinging Device	Rolled Steel (SS400)		1	T-76 N36-Y02-5003	
5	Starting Bolt	Rolled Steel (SS400)		1	T-121 N36-Y00-5004-A	

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List of Equipment and tools for OH (Kosrae)

No.	Name	MATERIAL	PER 1ENG	Quantity	Part No.	Remarks
1	Electric circuit tester			2		Analogportabletype,range:ACV,DCV,DCA,Ohm
2	DC voltmeter			2		range 0~300V
3	Battery type insulation resistance tester (500V)			2		Portabletype, 500Vrange: 1000Mohm
4	Battery type insulation resistance tester (2500V)			2		Portabletype, 2500Vrange: 100Gohm
5	Earth resistance meter			2		Portable type,0ohm-1000ohm, voltage0-30V
6	Low-voltage phase rotation meter			2		AC110V-480V, portable type, with 1amp-type missing phase detection function
7	Relay tester			2		Relay tester corresponding to the protection relays to be supplied in the Project
8	Low-voltage electroscop			2		Measurement range AC50V-600V, sound and light confirmatio
9	13.8 kV electroscop			2		Measurement range AC3kV-20kV, sound and light confirmation
10	Digital multi meter			2		Portabletype,digita type, DCV,DCA,ACV, ACA,ohm
11	AC/DC clamp mete			2		Portabletype,digital type, DCV, DCAACV, ACA,Hz
12	Grounding tools for maintenanc			1		Grounding tools with 3 phase insulation rod,applicable voltage 11kV
13	Withstand voltage teste			1		DC36kV,power supply AC240V-50Hz
14	Circuit breaker pull-out tools			1		Lifter type
15	Tool set			2		For electical engineer
16	Digital sound level meter					Measuring range 32-130dB, 31.5-8kHz, English display,Portable type
17	Flue gas analyser					Measuring gas 02, N02, S02, Measuring temperature 0-650°C, English display,Portable type

11.1.7　消耗品リスト

List of Consumables for Overhaul Works

for 1 unit 19-Jul-19

	Consumable name	Qty	Comments
1	Ply wood 3～5mm thickness	20 sheets	
2	Gum tape	10 rolls	
3	Polyethylene sheet		
4	Wash oil or Kerosene	100 liters	
5	Sponge	5	
6	Waste cloth	20 kilogram	
7	Scoth bright	30 sheets	
8	Sheet Grinder		
9	Thunder wheel		
10	Sand paper	30 sheets	
11	Roll paper	1 roll	
12	Paper		
13	Cup brush	3 unit	
14	Color check	3 unit	
15	Compound carborundum	medium 1 can	
16	Piccard	1	
17	Kohmira	1	
18	Blue sheet(swiss tarp)5×5m	3	
19	Smokon (Anti Seizing compound)	1 can	
20	Molykote（1207）	1 can	
21	Three bond	3 本	
22	Heaper base sheet (gasket)	1m	
23	Rubber sheet (gasket)	1m	
24	Oil sheet 0.8 t	1m	
25	Wire	1 roll	
26	Marker (0ily)	20 pens	
27	Gloves (common)	20	
28	Gloves (leather)	20	
29	Gloves (vinyl)	20	
30	Detergent (carbon removal)	5	
31	Wood(square bar □100×L1000	some	
32	Welding rods	some	
33	Others(Bucket and brush)	2 set	
34	Rust-proof paint	1 can	
35	Cleaner（Dye PT test use)	24 aerosol	
36	Molykote 1000 (spray)	3 cans	
37	Wire brush	10	
38	Silicon	3 tube	
39	Pallets	6	
40	Box for bolts and small parts	20	
41	High pressure washing machine	1	
42	Bowl (for parts washing)	4	
43	Scaffold(engine exhaust pipe side)		
44	Scraper	5	

11.2　再エネマニュアルおよび将来業務計画書
（Integration,O&M）

11.2.1　再エネマニュアルおよび将来業務計画書
(Integration,O&M)

Integration of RE & PV Facilities O & M

Manual

KOSRAE UTILITIES AUTHORITY (KUA)

June 2023

(Signature)____________________
Approved by
Fred Skilling
General Manager
KOSRAE UTILITIES AUTHORITY
(KUA)
Date: 30 June 2023

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Chapter 1 Renewable Energy Integration

Chapter 1 Renewable Energy Integration

1. Introduction

This Manual provide Guidelines that refers to the installation of renewable energy (RE) generation systems, grid connected solar photovoltaic (PV) system connected to the Kosrae Utilities Authority (KUA) central grid.

Kosrae, formerly known as Kusaie, is one of the four states of the Federated States of Micronesia. Located 5 ◦9’north latitude and 163◦east longitude, Kosrae is the eastern-most state in the FSM. Although Kosrae is the smallest out of the four FSM States in terms of total landmass and population, it is the second largest single island in the FSM.

The power system in the island is provided by Kosrae Utilities Authority (KUA) by operating the main power plants with diesel fed Generating units and two (2) main grid connected PV solar systems rated 200 KW and 100 KW respectively.

The power system is composed of three main feeders (Malem/Utwa, Lelu and Tafunsak). The main feeders are rated at 13.8 KV, 60 Hz, 4 Wires Overhead Power Conductors. The solar PV systems were developed with the assistance from Japan Government (PEC Fund) and European Union (EU). The Kosrae State envisions a Renewable Energy contribution of 30% to the power supply with various Renewable Energy sources mainly from Solar PV strings and arrays to be developed at the island.

A PV string is a group of solar photovoltaic modules (panel) wired together in series generating direct current (DC) electricity when exposed to sunlight. A PV array can consist of one or more PV strings and is typically secured with mounting frame.

The grid-connected inverter converts the DC electricity to alternating current (AC) electricity and ensures the Voltage matches that supplied by the electrical distribution network (the grid). If electricity from the grid is switched off or fails, the inverter will shut down for safety reasons.

A solar photovoltaic system is a powerful electricity generator. Both DC and AC electricity are potentially fatal hazards and fire risks. Solar PV must be designed and installed by appropriately qualify people. Protective devices, including both DC and AC isolators plus circuit breakers are required for safety, emergency shutdown and to enable maintenance.

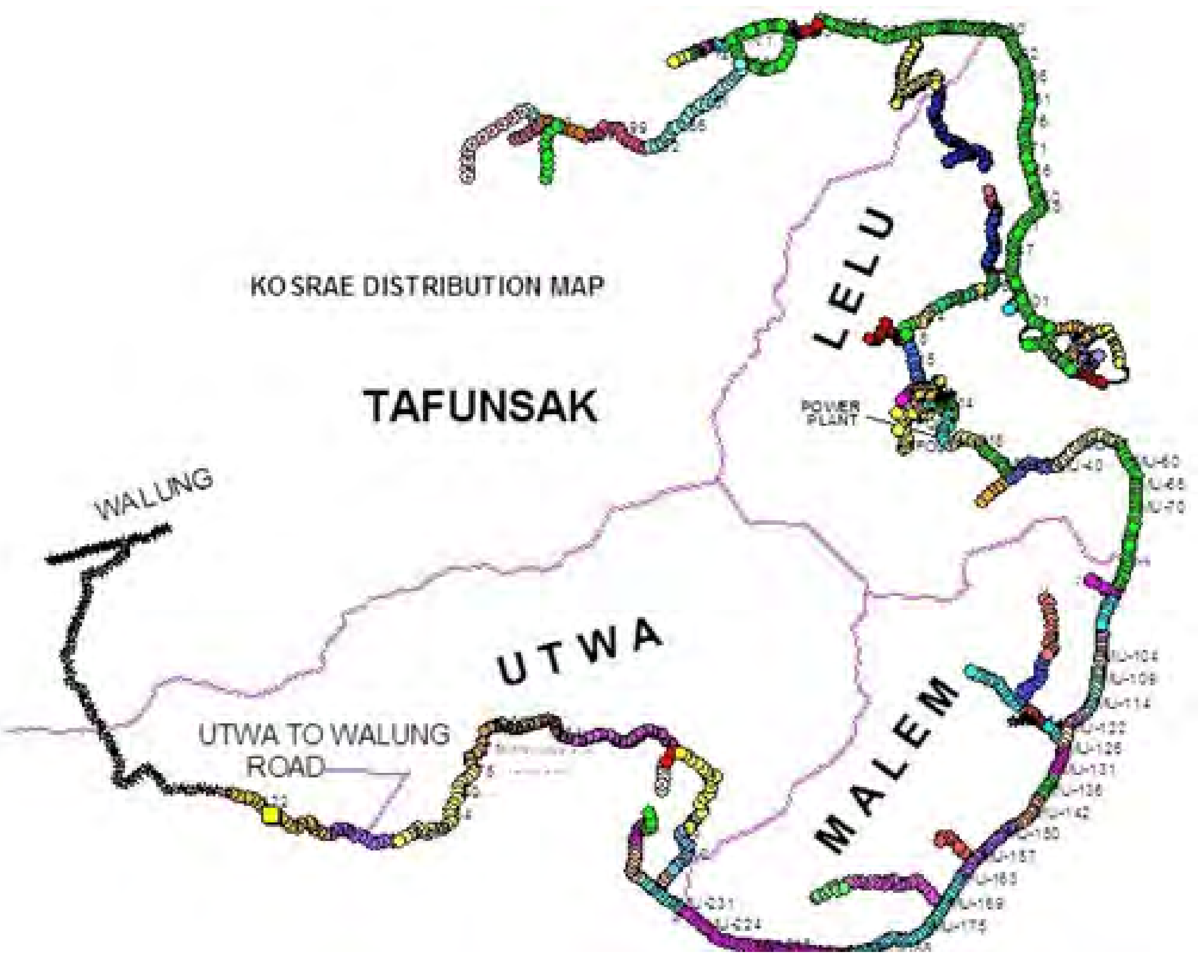


Figure1.1 Schematic of Kosrae Distribution System
13, 800 VOLTS, 4 wires, Overhead System, 60 HZ

2. DUTIES IN THE RENEWABLE ENERGY MANUAL

2.1 Inventory of Duties

The manual will serve as guideline for KUA to use in the installation of Renewable Energy System in Kosrae. Such system will be but not inclusive as to Solar Grid connected systems, Wind, Ocean Wave and Tidal power systems, small scale river water flow systems. OTEC, Flywheel Storage systems and the like. These systems are to augment the existing fossil fuel powered generation plants in Kosrae.

2.2 Duties related to power quality.

This manual will be utilized in carrying out operational procedures and to ensure the delivery of clean power to customers in terms of standard voltage and frequency for all types of power consumers of KUA.

2.3 Duties related to residential PV interconnection.

This manual will serve as service guideline and policy for private customers who will provide their own solar power system or any other renewable energy systems for their domestic or commercial installation. Such policy is intended to provide safe and efficient power installation for both the power service provider (KUA) and individual customer.

2.4 Relevant Regulations (laws, rules, guidelines, manual, company regulation)

2.4.1 Law

The manual will be in compliance with Kosrae State Law no.5-38, creating Kosrae Utilities Authority (KUA) to provide electric power service to the island of Kosrae.

2.4.2 Guideline

Kosrae Utilities follow the United States of America's National Electrical Code (NEC) as the main technical guide in its operation, maintenance and construction activities. The manual will be compliant with the provisions stated in the NEC, as well as relevant standards from Australia, New Zealand, Japan, Canada, and others.

2.4.3 Rules

The manual will establish regulations in compliance with State law no. 5-38, KUA Technical Policies and standards, Administrative and power connection policies of KUA, FSM National Laws and Kosrae State and Municipality regulations.

2.4.4 Standards

All Renewable Energy generation systems shall be installed in accordance with: The latest edition of the US **National Electrical Code**;, Australia, New Zealand, Japan, Canada, and IEEE 1547: Standards for Interconnecting Distributed Resources with Electric Power System.

All RE generation system must be interconnected with the grid via an inverter.

3. Renewable energy generation system disconnection means

At the point of common coupling, the output from the RE generation system's supply inverter must be a dedicated circuit breaker or fusible disconnecting means.

The connection in the panel/switchboard via the inverter shall be positioned at the opposite end (the load end) from the input feeder or main circuit location.

ON the distribution board to which the inverter is connected, there shall be a sign indicating that there are multiple sources supplying that distribution board and the sources should be listed.

Since the circuit breaker (or fusible disconnecting means) is also being used as a disconnector, and not just for cable protection it shall be:

- Rated for the full current of the inverter.
- Externally operable to contact with live parts.
- Simultaneously disconnect all ungrounded conductors.
- Plainly indicate whether it is open (off) or closed (on); and
- Capable of being locked in the open (off) position.

4. Inverters

Ideally the inverter shall be located in an accessible location. However, the NEC does allow the inverter to be located in any suitable location such as exterior areas or on roofs provided all the requirements are met.

If the inverter enclosure is not (weatherproof equivalent of an IP 54rating or the equivalent NEMA rating), the inverters should be located either inside a building or in an appropriate weatherproof enclosure. The inverter heat sink must be positioned so that it is clear of any obstacles to facilitate cooling of the inverter. The manufacture's recommendations for these clearances must be followed.

4.1 DC disconnecting means

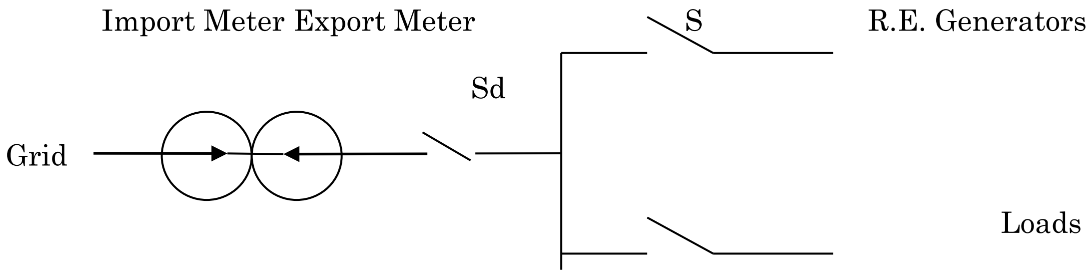
A suitable rated DC disconnecting means shall be mounted within sight of the inverter. This could be integral to the inverter or separate to it.

4.2 AC disconnecting means

A suitably rated disconnecting means shall be mounted within sight of the inverter. If it is in line of sight of the inverter, this could be the RE generation system's disconnecting means and the rating shall be based on the output rating of the inverter.

4.3 Metering

A meter shall be installed in series with the existing meter in Figure 4.1 The purpose of this meter is to record the energy which is supplied from the RE generation system to the figure 4.1 Schematic of separate import and export meter.



The existing meter could be replaced by a dual electronic meter as depicted in Figure 2.

Figure 4.1: Import meter and Export meter

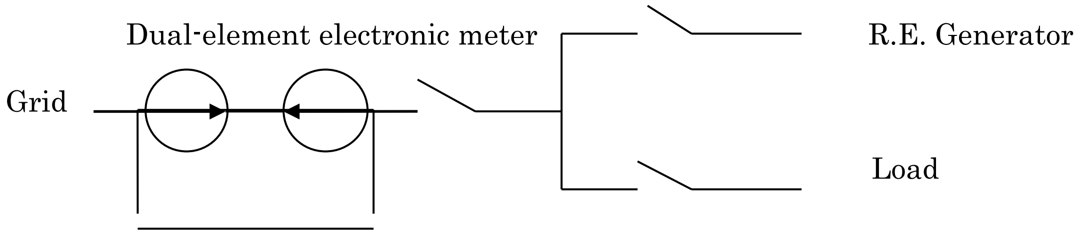


Figure 4.2: Dual element electronic import and export meter

5. Anti-islanding requirements

Islanding is a situation where one or more inverters maintain a supply to the distribution system after the distribution system supply has been isolated. Isolation of grid supply may be unplanned (power outage) or planned (for maintenance work on the grid).

Islanding creates serious safety issues, quality of supply problems for other customers and the possibility of equipment damage.

The protection equipment associated with the RE generation system must be designed , installed, and tested to ensure that islanding does not occur. The protection equipment must be part of the inverter.

5.1 Active (anti-islanding) protection

Active anti-islanding protection isolates the generation source from the distribution system in the event of a distribution system supply outage. The inverter's active component ensures that either the voltage or typically the frequency is unstable when not connected to the grid such that the passive anti-islanding described below will operate.

The inverter shall have been tested and approved in accordance with all the anti-islanding requirements of UL Standard 1741.

5.2 Passive protection

For the passive anti-islanding protection to operate, the customer's generation facilities must have the following minimum protection (part of the inverter):

a. Over/under frequency: and
b. Over/under voltage

The inverter shall also include the following protection over current and short circuit protection. The over/under voltage and frequency protection settings shall be in accordance with Table 5.1

Table 5.1: Over/Under Protection Setting Limits

Parameter	Minimum	Maximum
60 HZ +/- 2%	58.8Hz	61.2Hz
Voltage (120/240 V Utility Supply) +/- 5%	114 V 228 V	126 V 252 V
200 V above +/- 7% (Commercial and industrial)	186 V	214 V
13.8 kV +/- 7%	12,834 V	14,766 V

Table 5.2 details the maximum trip time for the various voltages.

Voltage at Connection Point	**Maximum Trip Time**
V<60 (V < 50%)	6 cycles
60 ≤ V ≤ 105.6 (50% ≤V≤88%)	120 cycles
105.8 ≤V ≤ 132 (88% ≤V ≤ 110%)	Normal Operation
132 <165 (110% < V < 137%)	120 cycles
165 ≤V (137% ≤ V)	2 cycles

Source IEEE929-2000

Table 5.3 details the system response times to abnormal frequency as detailed in IEEE1547-2003.

The logic of these settings at the time of writing was so that the renewable power generating system is removed from the distribution system if the frequency drifted outside a very tight frequency band. The main objective was to use these settings to disconnect from the grid quickly, in particular when the distribution power had failed.

However, field experience has since shown that, in particular on diesel powered grid where the frequency can vary, such a tight frequency band is too restrictive resulting in regular 'tripping off" occurrences and high penetration actually are causing power fluctuations on the distribution system. There is now provision for a wider range of frequency windows and the maximum time allowed (usually cycles) for a distribution system with frequencies outside any limited range, so that these fluctuation in the grid do not cause the inverter to 'nuisance' trip.

Therefore Table 5.1 recommends a window of 58 to 62 Hz with times shown in Table 5.4

Table 5.3: Interconnection System Responses to Abnormal Frequencies

Renewable Generator Size	**Frequency Range (Hz)**	**Clearing Time (s)**
≤30 kW	>60.5	0.16
	<59.3	0.15
>30 kW	>60.5	0.16
	59.8 to 57.0 (adjustable)	Adjustable 0.16 to 300
	< 57	0.16

Source: IEEE1547-2003

Table 5.4: Recommend Clearing Times for Frequency Variation

Frequency (Hz)	**Clearing time**
>62	0.16
58 ≤ f ≤ 62	Normal Operation
< 58	0.16

6. Kosrae Solar photovoltaic systems

Kosrae is located at latitude 5.306 degrees North, and the following Section refers to solar PV systems connected to the central grid in Kosrae. There are two (2) Grid connected Solar PV Systems in Kosrae. One is at the Kosrae Utilities Authority compound and is rated at 200

KW. This was installed by Mitsubishi Singapore in 2015. Fund for the project was provided by PEC. The system provides its power to the Malem/Utwa Primary Feeder.

The other grid connected solar PV system is installed at the parking area of the Kosrae State Government Building in Tofol, Kosrae. The system is rated at 100 KW and was installed by CBS Company thru the funding from the European Union. This system is connected to the Tafunsak Primary Feeder.

6.1 SOLAR PV FACILITIES

№	Facility name	Output (kW)	Picture	DONOR
1	Parking area of Kosrae state government offices	100		2015 / EU
2	Rooftop of Kosrae state government offices	9.4		2008 / EU
3	Tofol Power Plant premises	200		2015 / PEC
4	KUA car park roof	4.8		2008 / EU

5	Roof of entrance to Kosrae International Airport	6.5		2008 / EU

6.2 Solar PV array frames

Solar PV arrays consist of a number of solar PV modules wired together. In grid connected systems, the solar PV array is generally mounted:

- fixed on a frame ‘flat’ to the roof, meaning parallel to the roof area slope; or
- fixed on a frame that is tilted to fix the array at a preferred angle above horizontal, used for the flat roofs, ground mounts and car park shading arrays; or
- integrated into the new building.

6.3 Solar PV arrays orientation and tilt

Considering the sun’s path throughout the year, the theoretical, optimal year-round performances for a fixed PV array in Kosrae, would be achieved by mounting facing true south at an inclination above horizontal equal to the latitude angle (5°). However, this does not consider seasonal cloud patterns, local shading and other environmental factors such as dust, local vegetation and bird droppings.

A minimum inclination above the horizontal (tilt angle) of 10° is recommended to enhance self-cleaning during rain periods.

In addition, the tilt angle should be approximately 5°. However, because of the cloud cover in the wet season a tilt angle of 20 degrees above horizontal is recommended.

It should also be noted that for optimal performance PV modules that are electrically wired together in the same string must all be at the same orientation and tilt.

6.4 Roof mounting

- It is preferable to allow sufficient space below the PV array (> 2 inches) for ventilation cooling, particularly for crystalline PV modules but also for thin-film PV modules.
- It is important to allow sufficient clearance behind the PV array to facilitate self-cleaning of the roof and to prevent the build-up of leaves and other debris. If fauna is a problem in the vicinity of the installation, consideration should be given to prevent any animals gaining access to the underneath of the array.

-All supports, brackets, screws, and other metal parts should be of a similar material or Stainless steel to minimize corrosion. If dissimilar metals (based on their galvanic Rating) are used, the two surfaces of the metals should be separated by using rubber washers or similar materials. Kosrae has a marine environment with high humidity, so materials must be selected to be suitable in this environment.

-Where timber is used, it must be suitable for long-term external use and fixed so that Trapped moisture cannot cause corrosion of the roof and or rotting of the timber. The expected replacement time for these materials should be stated in the system Documentation.

-Any roof penetrations must be suitably sealed and waterproofed for the expected life of the system. If this is not possible, this item must be detailed in the Maintenance Schedule.

-All fixings must ensure structural security when subject to the highest wind speeds for the region and local terrain. This may require specific tests of the fixing/substrate combination for that roof.

-The installer shall ensure that the PV array frame that they install has applicable Engineering Certificates to verify that the array frame meets wind loadings for that particular location.

-The installer must follow the array frame supplier/manufacture's recommendations when mounting the array to the roof support structure to ensure that the array structures meet wind loading certification.

-The solar PV array modules must be rated for the static wind load of that region.

6.5 Free standing PV arrays

All components must be wind rated to meet the wind loading for the region. This includes footings and/or piles, mounting structures, frames, and the solar PV panels.

6.6 Disconnection means and protection.

According to the National Electrical Code, Article 690.15, PV arrays must have a disconnecting means to isolate the inverter from the PV power source. Utility grid-tie inverters that utilize PV arrays with voltages above 250V DC require a disconnection device rated for 600V DC to perform this function.

The DC disconnecting means is used to safely interrupt the flow of electricity from the PV array. This is an essential component when system maintenance or troubleshooting is required. The disconnection enclosure houses an electrical switch rated for use in DC circuits. It also may integrate either circuit breakers or fuses, if needed.

The disconnecting device shall be rated at 1.25 x the total short circuit current of the PV output that is connected to the device. With reference to NEC –

6.7 Solar PV array AC disconnecting means at the inverter

If the inverter is not in a readily accessible location, an AC disconnecting means located at the inverter shall be installed.

It is recommended that , even if the inverter is mount in a readily accessible location , an AC disconnecting means is installed unless is line of sight of the renewable generator supply disconnecting means. This to allow isolation of the AC supply while a person is undertaking any servicing of the inverter.

The current rating of the disconnecting means shall be based on the inverter continuous output current rating.

6.8 String Protection

Series string fuses are used to protect PV modules from overcurrent under fault conditions. PV modules are rated by the manufacturer to withstand a certain number of amps. This rating is known as the 'maximum series fuse rating' or reverse current rating' and is typically listed on the module specification sheet. An excess of current flowing through the module (for example current back-fed from paralleled modules or paralleled strings of modules) could damage the PV module if the module/string is not protected by an appropriately rated overcurrent device. Back-feeding from other strings is most likely to exist if one series string of PV modules stops producing power due to shading or a damaged circuit.

Because PV modules are current-limited sources, there are some cases where series fusing may not be needed. When there is only one string, there is nothing that is able to back-feed current, and no series string fuse needed. In the case of two series strings, if one string stops producing power and the other string back-feeds current through it, no fuse is needed because each module is designed to handle the current from one string. Some PV systems allow for three strings or more with no series fuses. This is allowable by NEC Article 690.9.

Each solar PV module has a maximum reverse current provided by the manufacturer. If the array consists of parallel strings such that the reverse current flow into the string with a fault is greater than the maximum reverse current for the modules in that string, protection shall be provided in each string. The protection can either be DC rated fuses or non-polarized DC rated circuit breakers.

Series string protection is required when the number of parallel strings is such that:

(Number of parallel strings – 1) x short circuit current of module > Module's maximum reverse current

Example: The reverse current rating for a module is 15A while the short circuit current is 5.4A. If the PV array consists of 3 parallel strings and a fault occurs in one string, the potential fault current will come from the other 2 strings in parallel, which equal 10.8A combined (2 x 5.4A). This figure of 10.8A is less than the reverse current rating of 15A, so no protection is required.

However, if the array consists of 4 parallel strings, the fault current could come from the other 3 parallel strings of the array. The current from these 3 strings is 16.2A (3 x 5.4A) and is now greater than the reverse current rating of the module (15A). Protection is now required in each parallel string.

The fuses or DC circuit breakers shall have the following current rating:

$$1.25 \times I_{sc\ mod} < \text{Fuse Rating} < 2.0 \times I_{sc\ mod}$$

If the array consists of sub-arrays, then each sub array shall be protected by a fuse or circuit breaker with the following rating:

$$1.25 \times I_{sc\ sub\text{-}array} < \text{Fuse Rating} < 2.0 \times I_{sc\ sub\text{-}array}$$

6.9 External mounted disconnection and junction boxes

The NEC, Article 690.14 © does not required a disconnecting means at the PV array. However, if string overcurrent devices (fuses) are required, disconnecting means might be required (Article 690.16) if the fuse holders cannot be isolated from energized circuits so that they can be worked on. Therefore, these could be externally mounted (e.g. on roof) disconnection and /or junction boxes.

Where mounted isolators (disconnection devices) and/or array junction boxes are mounted on the roof (or in any external location), the installer must that the integrity of the IP (or NEMA) rating in maintain, and that no moisture can enter the isolator or junctions' boxes.

The external isolator should be mounted vertically, that is, the switch is in vertical position. The conduit entry points should be on the bottom face of the isolator.

It is recommended that Junction boxes are mounted so that the access to the junction box is vertical not horizontal. The conduit entry points should be on the bottom face of the isolator.

6.10 Cabling

All cables shall be installed in a neat and tidy manner and in accordance with the National Electrical Code and any specific rules required by KUA.

Correctly sized cables in an installation will produce the following outcomes:

1. There is no excessive voltage drop (which will equate to an equivalent power loss) in the cable.
2. The current in the cables will not exceed the safe current handling capability of the selected cables known as current carrying capacity (CCC) or ampacity.

6.11 Selection PV string cables

If the fault current protection device is located in the string, the string must be rated to carry at least that current. For example, if the fault current protection device is rated at 8A, the string cable will need to be rated at a minimum of 8A.

If no fault protection is provided, then the string cable will be rated as:

$$CCC \geq 1.25 \times I_{sc\ mod} \times (\text{Number of strings} - 1)$$

6.12 Selection of PV array cables

The PV array cable should be rated according to:

$$CCC \geq 1.25 \times I_{sc\ array}$$

6.13 Voltage drop.

Losses in the cabling between the PV array and the inverter should be kept to a minimum, consistent with cable size and cost decisions, and to maximize system output it is recommended that the voltage drop is a maximum of 3%.

It is recommended that the voltage drop between the inverter and the point of connection of AC supply should be kept to a minimum (recommended < 1%) so as to minimize voltage rise within the installation and to limit inverter disconnection in areas where the grid voltage may be high in order to decrease incidents of overvoltage trips for inverters.

6.14 Cabling/Conduit installation

Cables connected to the inverter must be mechanically secured in such a manner that they cannot be inadvertently unplugged from the inverter. This mechanical securing can be achieved by:

1 Having the inverter housed in an enclosed (with cables suitably supported); or
2 The use of an inverter which has the cable connection area of the inverter.
covered by a removable closure/cover which protects the supported cables.
so that there is no exposed unsupported cable loops.
3 The use of conduit and secure wall fittings.

6. 15 Wiring PV arrays

To prevent the possibility of an installer coming in contact with live wires, it is recommended practice that one of the interconnecting cables in the middle of each string is left disconnected until all the wiring has been completed between the array and the inverter. Once all the isolators and other hard-wired connections are completed, the interconnections in the middle of the array can be connected.

The installer shall ensure that all connectors used are waterproof and connected securely to avoid the possibility of a loose connection. The connectors shall be of the latching or locking type. Only connectors of the same from the same manufacturer are allowed to be mated at a connection point.

Solar PV module interconnecting cables must be supported clear of the roof surface to prevent debris build up or damage to insulation.

In accordance with NEC690.33 (E):
The connectors shall be either (1) or (2):

(1) Be rated for interrupting current without hazard to the operator:
(2) Be a type that requires the use of a tool to open and marked: " Do not disconnect under load" or "Not for current interrupting.

6.16 Wiring from PV arrays to DC disconnecting means near inverter

The PV array cable shall be clearly identified as 'DC solar cable' to ensure that it Cannot be mistaken for AC cable.

To avoid confusion, it is recommended that, between the PV array and the inverter, single core double insulated solar cable is used. This cable is similar to that for interconnecting the solar modules in the array.

It is recommended that the cable is sized so that the maximum voltage drop between the array and the inverter is less than 3%.

6.17 Grounded PV arrays

Except where the PV system meets all the requirements of Article 690.35 (8.4.3), one conductor of a 2 wire PV system (unless system voltage is less than 50V) shall be solidly grounded. Note: Article 690.35 basically refers to systems using transformerless inverters.

There shall be one DC grounding point on the PV output circuit.

Grounding PV arrays shall be provided with ground fault protection. In summary, the ground fault protection device shall be of; detecting a ground fault current; interrupting the flow of current; and providing an indication of the fault.

6.18 Ungrounded PV arrays

Ungrounded PV arrays are permitted when all the paragraphs (A) through to (G) in NEC Article 690.35 are met.

The PV source and output circuits shall be provided with ground fault protection device/system that:

(1) Detects a ground fault.
(2) Indicates that a ground fault has occurred.
(3) Automatically disconnects all conductors or causes the inverter to automatically cease supplying power to the output circuits. Typically, the inverter turns off and disconnects from the PV array.

6.19 Shutdown procedure

A shutdown procedure shall be installed near the inverter or main distribution board to ensure safe de-energization of the system.

The procedure should be:

- Turn off the AC disconnecting means at the distribution equipment where the point of common coupling has occurred and then the AC disconnecting means at the inverter
- Then turn off the DC disconnecting means at the inverter.

When undertaking any work on the array cabling between the array and inverter, good practice is to disconnect a plug in the middle of each string so that the array is then de-energized.

6.20 Commissioning renewable energy generation systems

The installer shall undertake commissioning of the system at the completion of the RE generation system installation. The installer should prepare standard commissioning sheets. A copy shall be provided to KUA in the system documentation and a copy retained by the installer.

6.21 Documentation

All complex system required a user manual for KUA. The documentation for the system installation that must be provided is:

- List of equipment supplied.
- Shutdown and isolation procedure for emergency and maintenance.
- Maintenance procedure and timetable.
- Commissioning sheet and installation checklist.
- Warranty information.
- System connection diagram.
- performance estimate.

- Equipment manufacturers documentation.
- Handbooks for all equipment supplied.

6.22 Standards

The components and installation of all energy generating system shall be in accordance with the National Electrical Code and all relevant Standards.

1) Quality of supply
2) Islanding prevention
3) Connection point for renewable energy power source generating system
4) Balancing of phases
5) Metering application.

6.23 Conclusion

These regulation manuals relate to the installation of all renewable energy generating system that are connected to the KUA distribution system via inverter. The renewable energy generation system is most commonly solar PV arrays, but these regulations also apply to wind generators.

7. DESCRIPTIONS AND CAPACITIES OF POWER PLANTS IN KOSRAE

7.1. Diesel Generator Power Plants

Plant Name	Connection Point	Rating (MW) @ 0.8 Power Factor	Maximum Power, de-rated MW	Minimum Power MW	Governor Characteristics	AFC range	Note
JICA (G 9)	All Feeders	0.60	.60	30%	Isochronous	n/a	
JICA (G 10)	All Feeders	0.60	0.60	30%	Isochronous	n/a	
OLD Plant							
(G-8)	All Feeders	1.0	0.8	30%	Isochronous	n/a	
WORLD BANK GENSET (G -11)	All Feeders	0.6	0.6	30 %	Iso/ Droop	n/a	
(G-6) Under Repair	All Feeders	1.5	1.2	30%	Isochronous	n/a	
Total capacity		4.3					

7.2. Renewable Energy Systems in Kosrae

System Name	No	Rated Capacity	Location	Note
PEC SOLAR PV	1	200 kW	Tofol	Built in 2015, PEC Fund
EU SOLAR PV	1	100 KW	Tofol	Built in 2015, EU fund
ADB SOLAR PV	1	1.2 MW	Tofol	Planned., Under ADB Funding
WB BESS	1	1MWH	Tofol	Planned. BESS , Under WB Funding
ADB MINI GRID (OFF GRID)	1	To Be Determined	**Walung**	Planned. To be for households in Walung, ADB Funding

8. 200 KW SOLAR PV GRID CONNECTED SYSTEM IN KUA POWER PLANT COMPOUND (PEC FUNDED)

9. 100 KW SOLAR PV GRID CONNECTED SYSTEM IN THE GOVERNOR'S BUILDING IN TOFOL (EU FUNDED)

10. GRAPHICAL PRESENTATION OF KOSRAE EXISTING POWER CONDITIONS

10.1 POWER PLANT AND SOLAR PV COMBINED

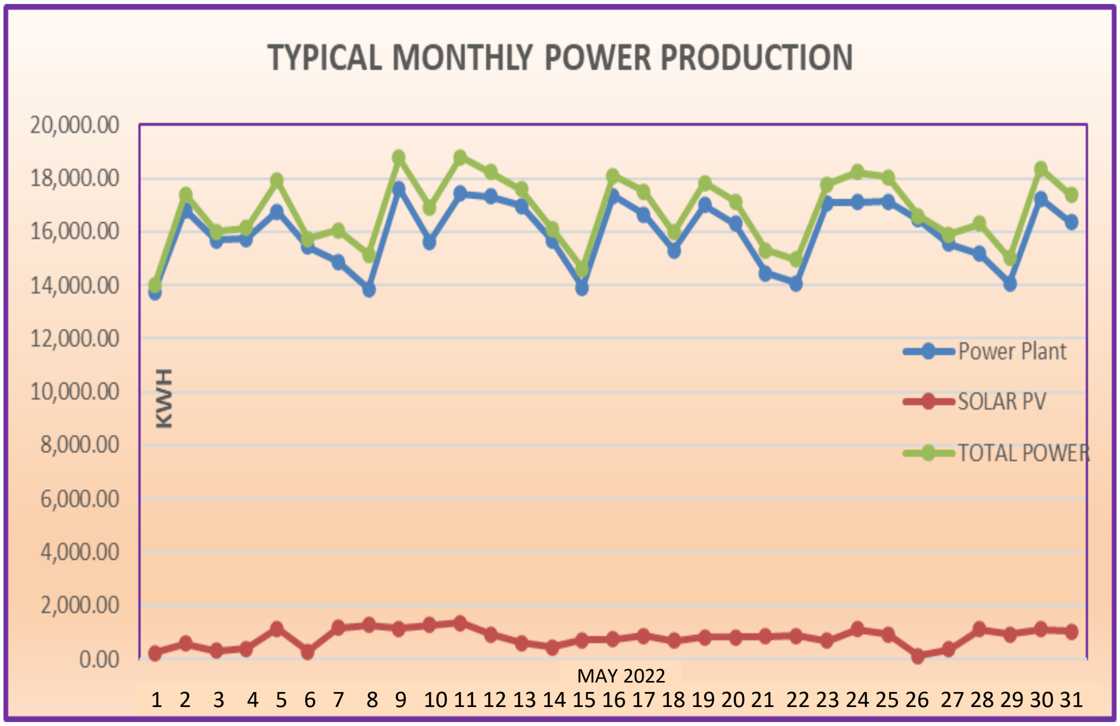


Figure10.1 TYPICAL MONTHLY POWER PRODUCTION FOR KOSRAE

10,2 TYPICAL DAILY LOADING OF GENERATORS DURING WEEKDAYS

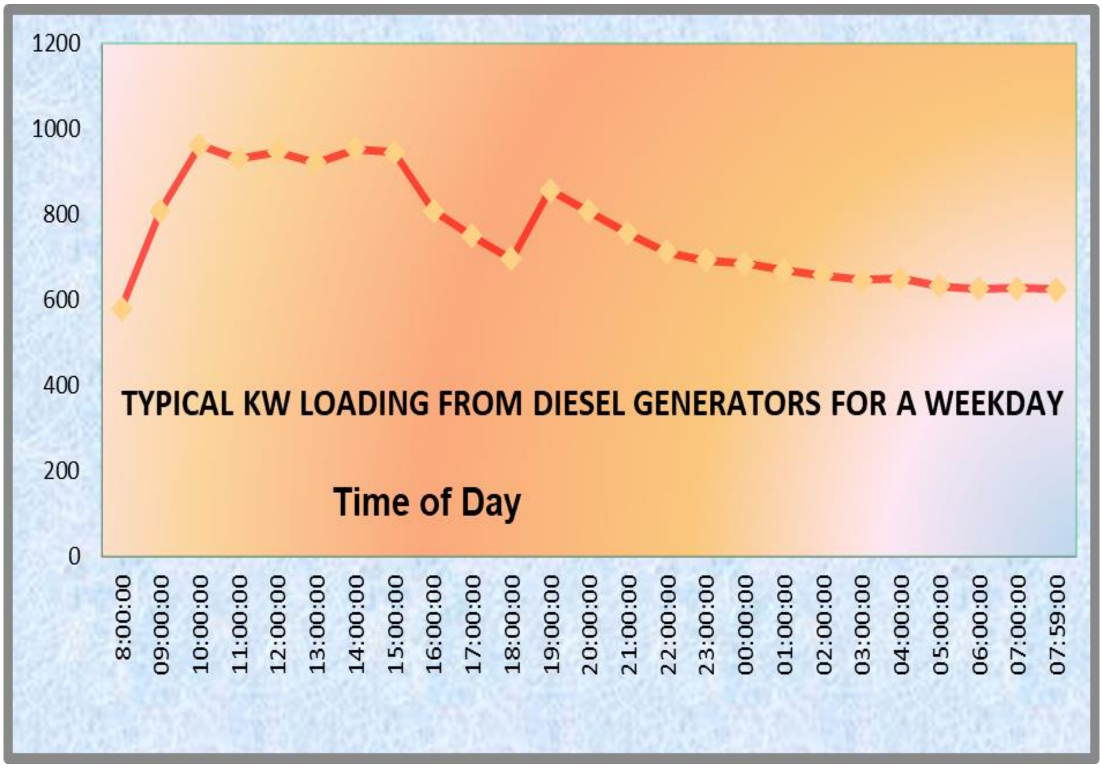


Figure10.2 TWO (2) 600 KW GENERATORS ARE ONLINE TO PROVIDE THE POWER DEMAND

10.3 TYPICAL POWER GENERATION OF THE DIESEL GENERATORS FOR A WEEKEND

Figure10.3 TWO (2) 600 KW GENERATORS ARE OPERATED CONTINOUSLY TO SUPPLY THE DEMAND

10.4 COMBINED GENERATION OF POWER FROM POWER PLANT ANDSOLAR PV SYSTEMS

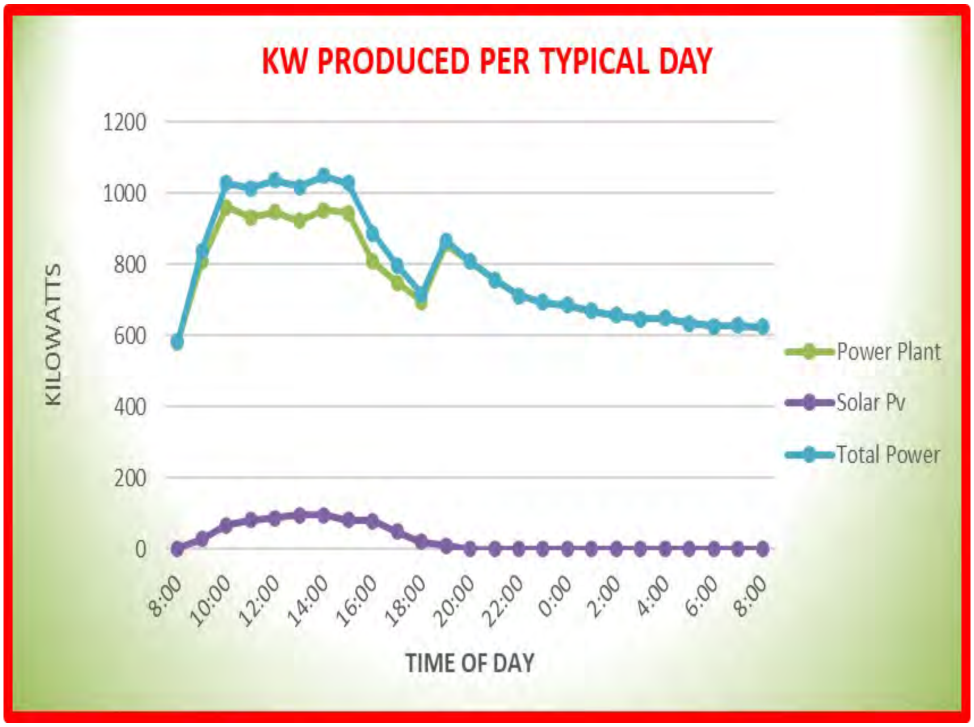


Figure10.4 TWO (2) 600 KW GENERATORS AND COMBINED 300 KW SOLAR PV SYSTEMS

10.5 PEAK AND LOW LOADS TYPICAL FOR A MONTH

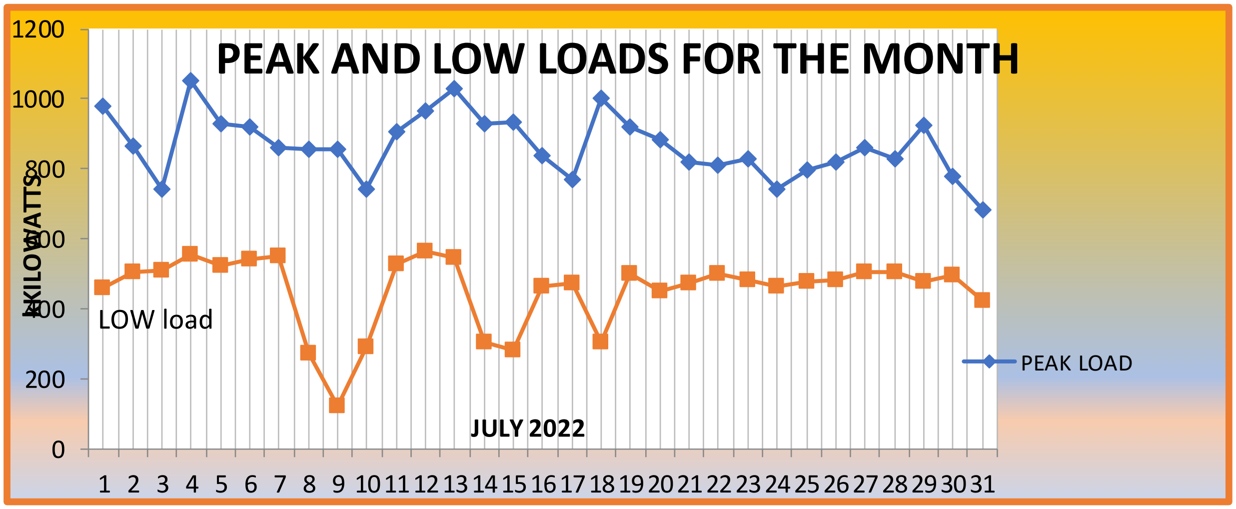


Figure10.5 PEAK AND LOW LOADS TYPICAL FOR A MONTH

10.6 POWER PRODUCTION FROM THE SOLAR PV SYSTEMS IN KOSRAE

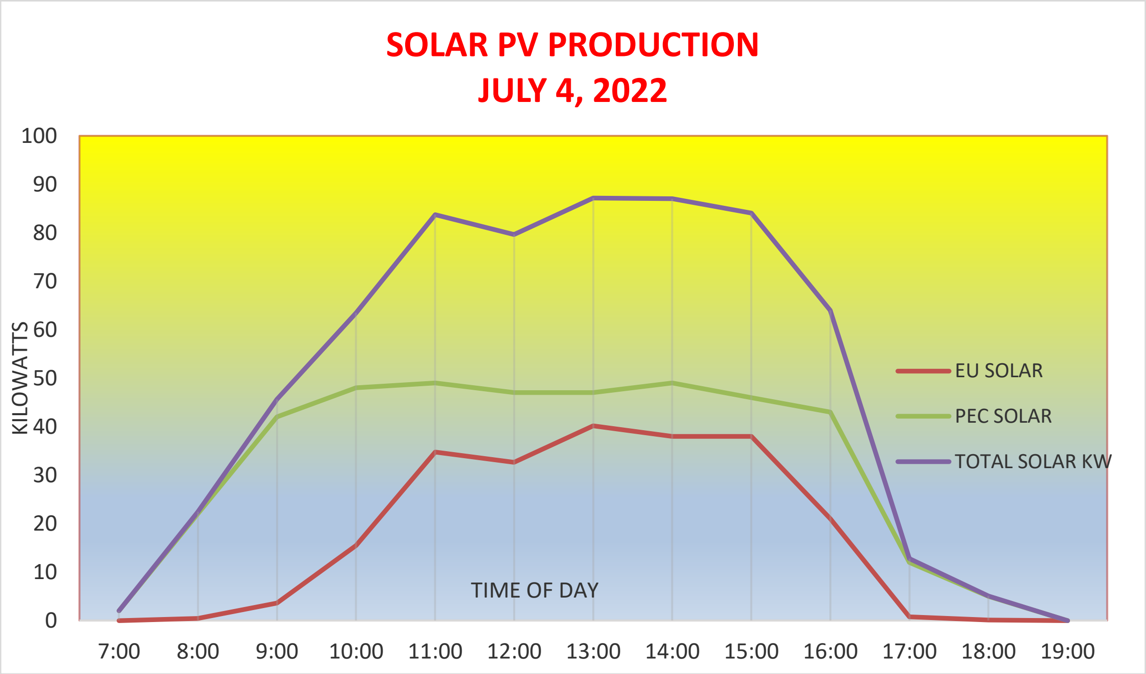


Figure10.6 FOR A PARTICULAR DAY (JULY 4, 2022) RAINS WERE ENCOUNTERED

10.7 COMPARISON OF POWER CONTRIBUTION TO THE GRID BETWEEN THE SOLAR PV

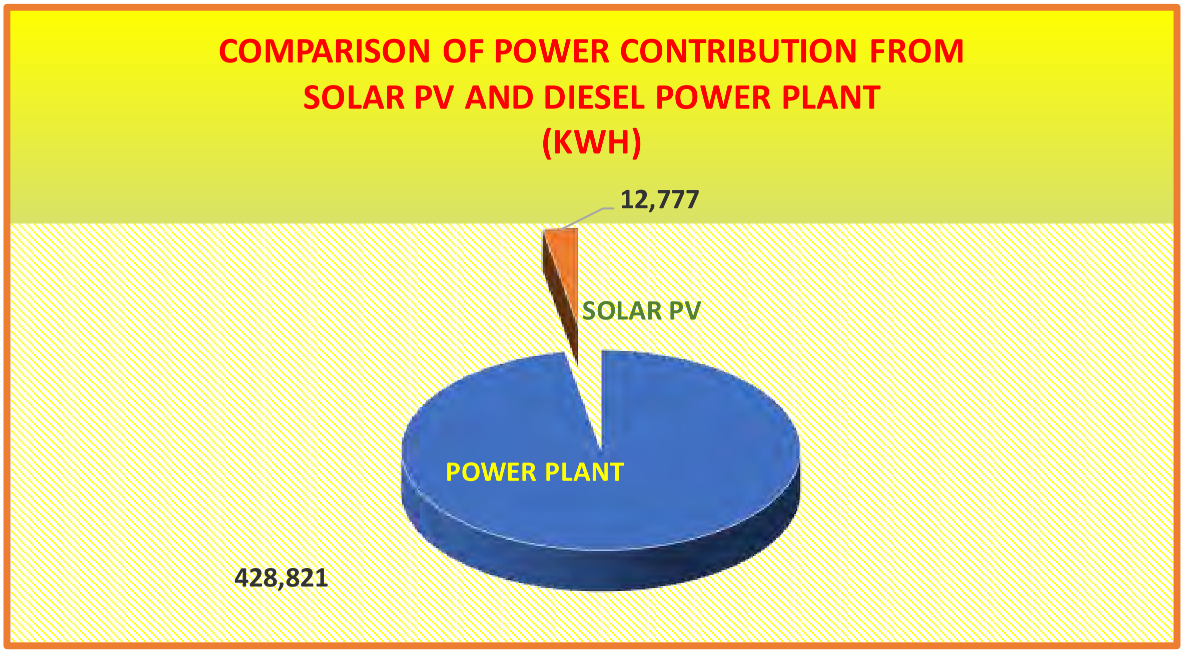
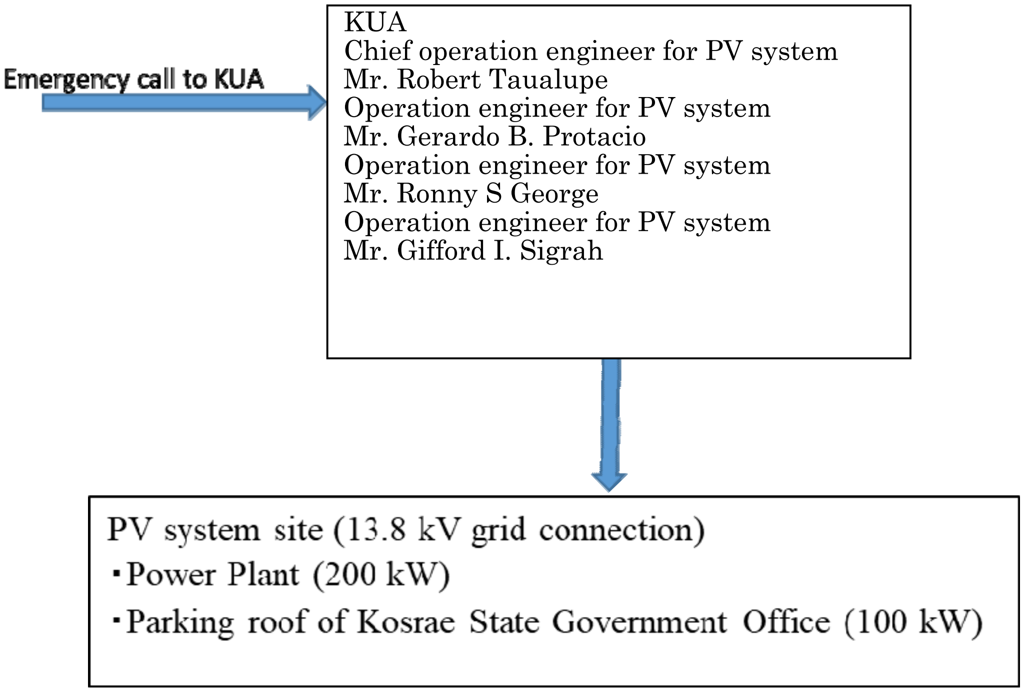


Figure10.7 SYSTEMS AND DIESEL POWER GENERATORS FOR THE MONTH OF JULY 2022

CHAPTER 2
PV OPERATION AND MAINTENANCE

1. PV Operation and Maintenance Structure for KUA

Table 1.1 PV Operation and Maintenance Structure for KUA



KUA
Chief operation engineer for PV system
Mr. Robert Taualupe
Operation engineer for PV system
Mr. Gerardo B. Protacio
Operation engineer for PV system
Mr. Ronny S George
Operation engineer for PV system
Mr. Gifford I. Sigrah

PV system site (13.8 kV grid connection)
･Power Plant (200 kW)
･Parking roof of Kosrae State Government Office (100 kW)

2. PV TEAM DUTIES

Table 2.1 Structure in charge in O&M of PV system

Professional Position	No	Duties	Working system	Note
Manager (R Taualupe)	1	Responsible person in charge of the operation and maintenance of all PV facilities	Work on a daily basis. Call in case of emergency at night or on holiday.	Overall Operations Manager
Operator (G. Sigrah) (R. George)	1	In charge of the operation of PV facilities, monitoring, daily patrol, advise in reparation or maintenance.	Work on a daily basis. (7:30 to 16:30)	Part of Distribution Team
Maintenance staff (G. Sigrah) (R. George)	2	Staff in charge of maintenance works, periodical inspections, Procedures to get necessary budget for maintenance.	Work on a daily basis. (7:30 to 16:30)Call in case of emergency at night or on holiday.	Part of Distribution Team

Assistant Worker (●●●●) (●●●●)	0	Staff to support the maintenance staff in secondary task like cleaning of panels, Mowing, etc.	Work on a daily basis. (7:30 to 16:30)	Will avail of Distribution team members as situation calls for
Office worker (G Protacio)	1	Person in charge of documentation, parts order, managing of maintenance reports, etc.	Work on a daily basis. (7:30 to 16:30) Call in case of emergency at night or on holiday.	Can only work part time with the group. Attached to the Eng. and Planning Division.
Total	5			

Revision : 2023/3/24

3. INSPECTION SCHEDULE

Detail Refer to the Attachment; KOSRAE PV SYSTEM SCHEDULE OF MAINTENANCE CHECKLIST

Table 3.1 PV SYSTEM SCHEDULE OF MAINTENANCE

Item	Check point		Daily	Monthly	Annual
PV array	Visual check	Abnormal smell, smoke, etc.	○		
		Corrosion and/or Breakage		○	○
		Broken glass		○	○
		Cable connector disconnection		○	○
		Damage on the cable		○	○
		Loosened fixing bolt		○	○
		Damage on grounding conductor		○	○
		Loosened of a connector terminal		○	○
	Measurement	Photovoltaic circuit insulation resistance			○
Junction box Collecting box	Visual check	Abnormal sound, smell, smoke, etc.	○		
		Corrosion and/or Breakage of a frame		○	○
		Damage on external wirings		○	○
		Loosened fixing bolt and screws		○	○

		Damage on grounding conductor		○	○
		Loosened of a connector terminal		○	○
		Replacement of surge arrester (if necessary)			○
	Measurement	Insulation resistance			○
		I-V curve			○
		Photovoltaic circuit open voltage			○
Power conditioner	Visual check	Abnormal sound, smell, smoke, etc.	○		
		Corrosion and/or Breakage of a frame		○	○
		Damage on external wirings		○	○
		Loosened fixing bolt and screws		○	○
		Damage on grounding conductor		○	○
		Loosened of a connector terminal		○	○
		Abnormal indication lumps	○		

Please see the inspection schedule form below. Inspection plans and inspection results are input and managed on a case-by-case basis.

Basically, the inspection schedule plan should be prepared before the start of the fiscal year. The plan for 12 months, should include all PV facilities by assigning a responsible staff for each, and the necessary staff and days numbers.

Whenever there is a change, the plan must be reviewed and kept in a designated place in the office.

After the inspection is conducted, the results must be noted, and the revised version kept in the same place.

The designated keeping place must include the measurement instruments and for the data the common PC for RE maintenance staff.

Table 3.2 INSPECTION SCHEDULE form

[Annual Work Schedule]

PV System Maintenance

Country name: Kosrae, FSM

						January																							February							December						
NO	Site name	PV capacity		No. of inspectors	Inspector name	1	～	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	～	30	31	1	2	3	～	26	27	28	1	2	3	～	29	30	31
1	PEC PV	200KW	Plan	2	Ronnie, Gerry				■	■	■	■	■	■		■	■	■																								
			Conducted	2	Robert, Gifford				🟥	🟥	🟥	🟥	🟥	🟥							🟥	🟥	🟥	🟥																		
2	EU PV	100 KW	Plan	2	Robert, Gerry																																					
			Conducted	2	Robert, Gifford																																					
3	C		Plan																																							
			Conducted																																							
4	D		Plan																																							
			Conducted																																							
5	E		Plan																																							
			Conducted																																							
6			Plan																																							
			Conducted																																							

Remarks

Plan ■

Conducted 🟥

* Estimated No. of inspectors		* Estimated inspection period
• Up to 100 kW	1-2 inspectors	1-2 days
• 100-500 kW	2-3 inspectors	2-3 days
• 500 kW-1 MW	3-4 inspectors	4-6 days

4. INSPECTION SHEET FORM

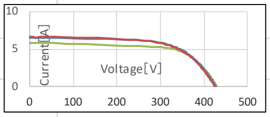
Table 4.1 INSPECTION SHEET FORM

Array Measurement Records

（place）

Date		Humidity	56 %	**Measuring Instrument**	Digital multimeter **Kyoritsu KEW 1021R**	String Tracer Togami SPST-A2A-Y1	Meggar Kyoritsu KEW 3021	**Measurer**	ry/Rob/Rin/Ro			**Person in charge**	Approval	Confirmation	Confirmation
Weather	Sunny/w cloudy	Solar radiation											**Robert**	**Gerry**	
Temperature	48.6 ℃														

EU PV

Junction Box Number	Combiner Box Number	Circuit/ Breaker No.	Measurement time	Number of panels	Open circuit voltage (1 panel)	Theoretical Voc (string)	Circuit Voc (1 String)	P-side	N-side	I-V measurement	NFB		Comprehensive judgment	Remarks		
							Difference no larger than voltage of one panel	0.2 MΩ or more at DC 500V	0.2 MΩ or more at DC 500V	Presence of abnormal string	Start	Finish				
	1	1	13:50	13	40.075	520.975	432	44.3	88.1	Good	OP	cL	Good	Rdgs. Taken on 3-23-23		
		2	13:50	13	40.075	520.975	427	41.9	110	Good	OP	cL	Good			
		3	13:50	13	40.075	520.975	425	39.6	93.9	Good	OP	cL	Good	Ref 49		

(Refer to Attachment "KOSRAE PV SYSTEM MAINTENANCE CHECKLIST")

5. Measurements Standards

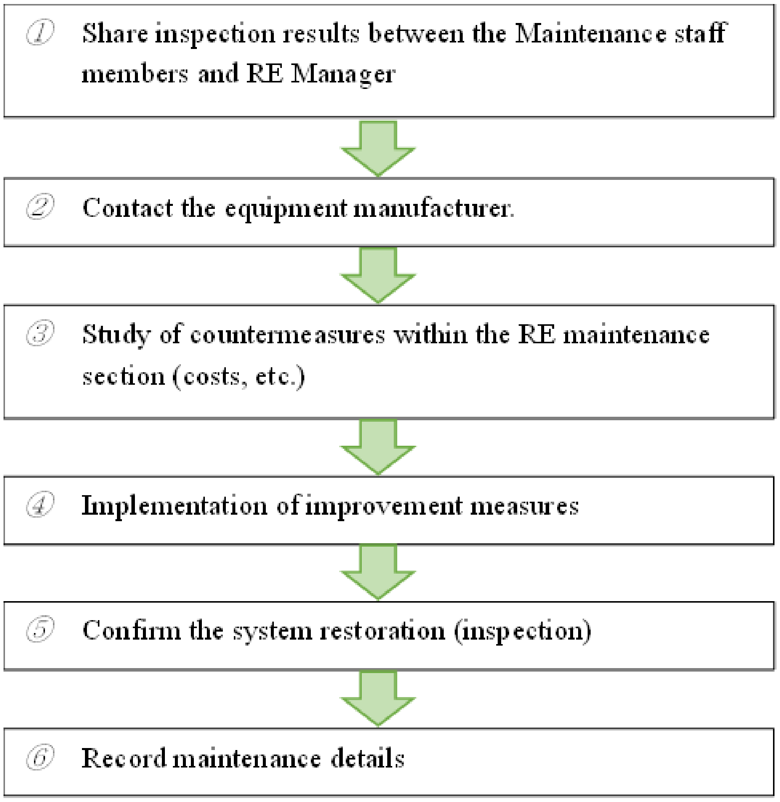
The criteria for judgment for measurement shall be follows below set values.

Table 2.5 Criteria for Judgment of Measurements

Measured Value Item	Judgment criteria	Note
1.Insulation resistance [MΩ] [V]	>0.2 [MΩ]	As Refer to the Japanese standard.
2.Open circuit voltage [V] (1 String) Circuit Voc (1 String)	Difference in Voc between strings should not be larger than the voltage of one panel	
3.I-V Curve	Check the I-V curve table Attachment	Refer to Attachment. (Interpretation of the I-V curve shape)
4.Guideline for visual inspection (Panel is affected by shadows, equipment is damaged, etc.)	See table of items to be checked for visual inspection.	Refer to Attachment (Recommended checkpoints during patrol)

6. Responses when maintenance is required

After confirming the inspection results, if maintenance is required, consider improvement according to the following procedure.



① Share inspection results between the Maintenance staff members and RE Manager

② Contact the equipment manufacturer.

③ Study of countermeasures within the RE maintenance section (costs, etc.)

④ Implementation of improvement measures

⑤ Confirm the system restoration (inspection)

⑥ Record maintenance details

7. Monitoring of the Performance Ratio (PR)

Currently, the PR is a good reference to evaluate the condition of the PV solar generation facility so necessary check every month. The PR value indicates how much power has been generated relative to the nominal maximum power (Pmax) of the solar cell. The PR can be calculated using the following equation and the calculation results should be recorded, and it should be kept in the assigned place for analysis or confirmation.

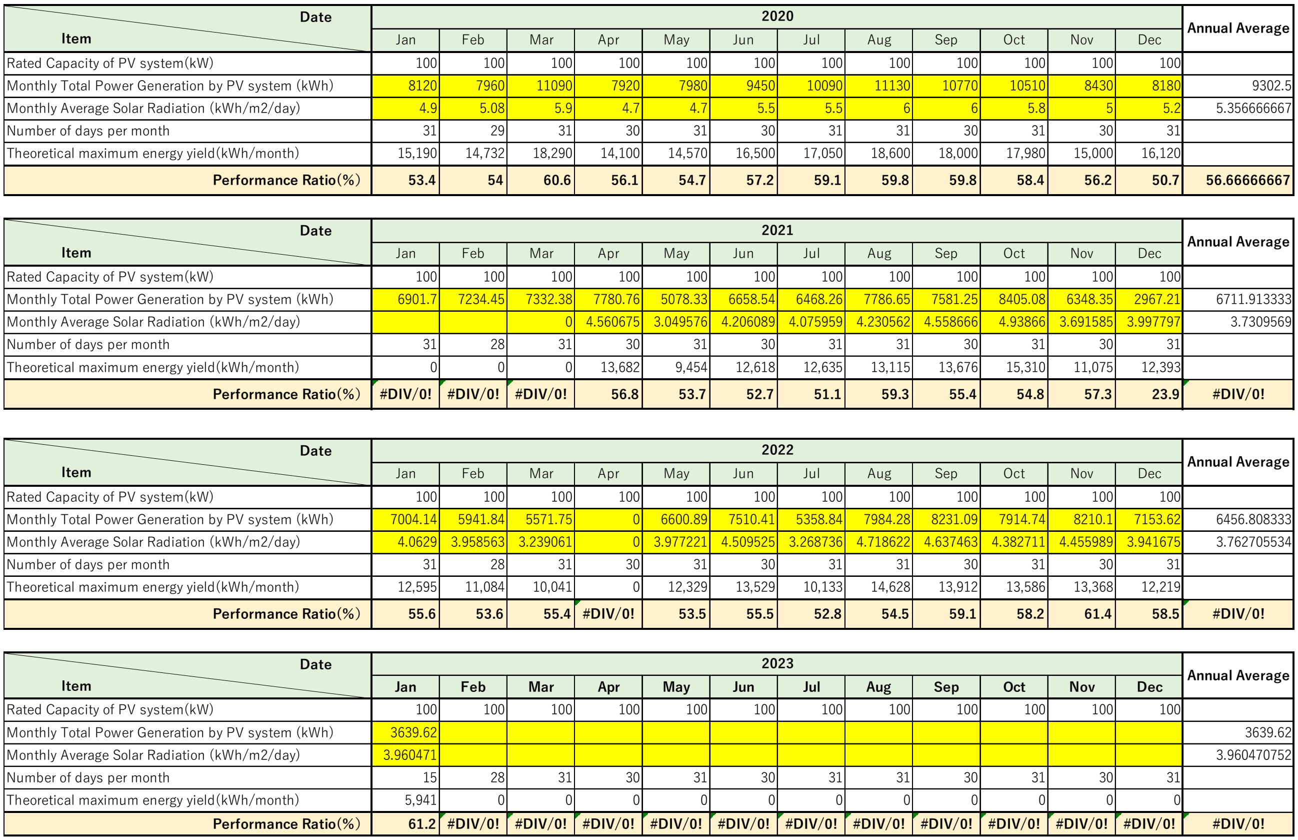
Performance ratio = Actual annual average energy yield (kWh/year) ÷ ***Theoretical*** *maximum energy yield (kWh/year)*

Theoretical maximum energy yield(kWh/month)

=Rated Capacity of PV system(kW)× Monthly Average Solar Radiation (kWh/m2/day)× Number of days per month

For each site, review the monthly power generation and solar irradiance measurements. PR values can then be calculated using the Excel sheet below and entering the measured values. For CPUC main PV facilities benchmarks are shown in below table.

EU Fund PV Performance Ratio



Item \ Date	2020												Annual Average
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Rated Capacity of PV system(kW)	100	100	100	100	100	100	100	100	100	100	100	100	
Monthly Total Power Generation by PV system (kWh)	8120	7960	11090	7920	7980	9450	10090	11130	10770	10510	8430	8180	9302.5
Monthly Average Solar Radiation (kWh/m2/day)	4.9	5.08	5.9	4.7	4.7	5.5	5.5	6	6	5.8	5	5.2	5.356666667
Number of days per month	31	29	31	30	31	30	31	31	30	31	30	31	
Theoretical maximum energy yield(kWh/month)	15,190	14,732	18,290	14,100	14,570	16,500	17,050	18,600	18,000	17,980	15,000	16,120	
Performance Ratio(%)	**53.4**	**54**	**60.6**	**56.1**	**54.7**	**57.2**	**59.1**	**59.8**	**59.8**	**58.4**	**56.2**	**50.7**	**56.66666667**

Item \ Date	2021												Annual Average
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Rated Capacity of PV system(kW)	100	100	100	100	100	100	100	100	100	100	100	100	
Monthly Total Power Generation by PV system (kWh)	6901.7	7234.45	7332.38	7780.76	5078.33	6658.54	6468.26	7786.65	7581.25	8405.08	6348.35	2967.21	6711.913333
Monthly Average Solar Radiation (kWh/m2/day)			0	4.560675	3.049576	4.206089	4.075959	4.230562	4.558666	4.93866	3.691585	3.997797	3.7309569
Number of days per month	31	28	31	30	31	30	31	31	30	31	30	31	
Theoretical maximum energy yield(kWh/month)	0	0	0	13,682	9,454	12,618	12,635	13,115	13,676	15,310	11,075	12,393	
Performance Ratio(%)	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**56.8**	**53.7**	**52.7**	**51.1**	**59.3**	**55.4**	**54.8**	**57.3**	**23.9**	**#DIV/0!**

Item \ Date	2022												Annual Average
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Rated Capacity of PV system(kW)	100	100	100	100	100	100	100	100	100	100	100	100	
Monthly Total Power Generation by PV system (kWh)	7004.14	5941.84	5571.75	0	6600.89	7510.41	5358.84	7984.28	8231.09	7914.74	8210.1	7153.62	6456.808333
Monthly Average Solar Radiation (kWh/m2/day)	4.0629	3.958563	3.239061	0	3.977221	4.509525	3.268736	4.718622	4.637463	4.382711	4.455989	3.941675	3.762705534
Number of days per month	31	28	31	30	31	30	31	31	30	31	30	31	
Theoretical maximum energy yield(kWh/month)	12,595	11,084	10,041	0	12,329	13,529	10,133	14,628	13,912	13,586	13,368	12,219	
Performance Ratio(%)	**55.6**	**53.6**	**55.4**	**#DIV/0!**	**53.5**	**55.5**	**52.8**	**54.5**	**59.1**	**58.2**	**61.4**	**58.5**	**#DIV/0!**

Item \ Date	2023												Annual Average
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	
Rated Capacity of PV system(kW)	100	100	100	100	100	100	100	100	100	100	100	100	
Monthly Total Power Generation by PV system (kWh)	3639.62												3639.62
Monthly Average Solar Radiation (kWh/m2/day)	3.960471												3.960470752
Number of days per month	15	28	31	30	31	30	31	31	30	31	30	31	
Theoretical maximum energy yield(kWh/month)	5,941	0	0	0	0	0	0	0	0	0	0	0	
Performance Ratio(%)	**61.2**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**

(Remarks) 1. Input yellow cells.

2. Usual Performacne Ratio is between 70 and 85%.

3. 2016 Baseline Perfomance Ratio =56%

Facility Name	Performance	Comments
1. PEC Solar PV	66 %	
2. EU Solar PV	56 %	

8. Recommended spares

Table 2.6 List of needed spare parts for O&M of solar PV facilities

Spare	When	Reason and frequency	Quantity
PV modules	Availability of spares	Module will be difficult to procure after more than 20 years of operation.	Quantity is derived from probability of damage due to thrown stone and failure in internal element and circuit, which vary depending on site conditions and module type. About 0.1% of the whole quantity for the moment. In consideration of damage conditions during 1 to 2 years after commissioning, it is necessary to consider early procurement based on failure rate.
DC Circuit Breakers for the termination of PV circuit	Abnormal event occurs.	If quick procurement is difficult upon failure, it has significant effect on operation.	1 unit for each kind
Fuse for PCS	Abnormal event occurs.	Failure rate may be high. Keeping spares is effective for the quick power restoration because on-site workers can take recovering action.	1 or more for each kind Note some PCS manufacturers don't allow the client to open the panel and change equipment inside the panel. Check your manufacturer first!
Condensers, Touch Panels, Batteries of touch panels, Fans for PCS	Replacement is necessary before life (5 to 10 years) or abnormal event occurs.	Failure rate may be high. In addition, regular inspection may show that component should be replaced. Periodical procurement is necessary according to life of each component.	
Circuit boards for PCS	Abnormal event occurs.	Circuit board has significant effect on operation and quick procurement is difficult.	

PCS (Whole equipment)	Abnormal event occurs.	If an engineer responsible for replacing parts judges that quick procurement is impossible for the site, a set of PCS shall be reserved to be replaced as a whole.	1 set Cool and secure storage space need to be prepared.

(See Attachment)

9. Recommended tools and equipments

Table 2.7 List of measuring instruments for PV O&M

Items	quantity	main usage
Digital multi meter	1	General measurement for circuit condition
Voltage detector	1	
Clamp meter	1	
Terminal boards & wire clips	1 set	To make circuits for inspections
Insulation Resistance Tester (Megger)	1	measurement for insulation condition of the circuit from PV to switching board
Grounding resistance tester	1	measurement for circuit condition
I-V Curve tracer	1	Judgment of the condition of cells and the circuit
Infrared camera	1	Judgment of the condition of cells and wiring in modules
Current path detector	1	Detection of disconnection wiring in modules
Step Ladder	1	To reach high places
Various Hamd Tools	SET	Perform operations

(See Attachment)

Table 2.8 List of tools needed for renewable energy O&M

Items	quantity (ex)		Specifications
Screwdriver (+ and -)	2	set	
Terminals board & wire clips	1	set	
Cutting nipper	2		
Cutting Plier	2		
Hammer	2		
Card tester	2		

Socket wrench	1	set	
Paint	2	cans	
Anti-corrosive paint	2	cans	
Tool cabinet with door	1	unit	

(See Attachment)

10. Related regulations

The following is a list of laws and regulations related to the maintenance and management of photovoltaic power generation facilities.

- Laws : Kosrae State Law 5 -38
- Guidelines : KUA Policy and Standard for Electrical Installation
- Rules : KUA Internal Rules and Policies, USA National Electrical Code
- Measuring equipment manual Not Data
- Donors manual Not Data

11. Documents related to each renewable energy facility

Specifications and manuals for each renewable energy facility are shown below.
Each document shall be stored in the "General Files at Power Plant File racks".

(1) PEC 200 KW- To be added

- Facility specifications (Attached as Attachment A)
- Equipment operation manual (Attached as Attachment A)

(2) EU 100 KW- To be added

- Equipment specifications
- Equipment operation manual

12. General PV Systems Safety

Working with photovoltaic modules for any work on photovoltaic modules, it is highly recommended to cover all the modules or the considered string / PV field with packaging boxes. The generated current can cause injury when the voltage exceeds 120V DC. The open circuit voltage of up to 600V is expected for this system. It is highly important to prevent all electrical hazards. Therefore, personal safety protections are compulsory. ・

Electrical shock may occur (1) High voltage and / or high current. Do not touch the connectors and terminals without the adequate insulating protection. Use insulated tools only. Remove any item (jewelry, watch, etc.) that may lead to short circuit. Always check for the presence of AC and DC voltages prior to servicing. ・

(2) The inverter contains energy storage devices (capacitors) that require fifteen minutes to discharge after all sources have been disconnected. Do not service equipment until AC and DC power sources have been disconnected and locked out for a period of fifteen minutes.

13. Safety protections

The modules should be covered during any electrical work (modules packaging boxes, blankets, etc.)

Reasons: For prevention of electrical shocks.

Caution: Avoid scratches to the glass surface of the modules. Safety gloves and shoes are mandatory when being on site.

Reasons: For prevention of injury during materials / goods handling.

Protective clothes are recommended. Synthetic clothes should be avoided. Prefer cotton clothes covering the entire body.

Reasons: For protection against the exposure to UV rays from the sun and reduce the possibility of electric shocks.

Safety goggles Helmet Clothes covering the entire body Safety belt Safety shoes Clothes covering the entire body are recommended.

14. Maintenance of 200 kWp PV system at the KUA Power plant compound

System Overview The photovoltaic systems installed on roof, with maximum power rating of 198.00 kWp. The photovoltaic modules are configured to a solar array with modules electrically connected 11 in series. The output from each string is led to a set of fuses located in a DC Box with DC surge suppressor.

On the AC side, the inverter is connected through a circuit breaker, protected with an AC surge suppressor, and connected to grid through a delicate pole transformer stepping down to 208 V from 13.8 kV transmission line. The operating circuitry is earthed, upon leakage to earth is detected and the inverter automatically disconnected from the grid. PV modules frames, mounting structure, DC box, AC box and inverter housings are earthed and bonded to the grid neutral.

・Solar PV Modules (1) The PV array consists of 225Wp modules and mounted on the ground.

Stainless steel mounting brackets are used to secure the PV modules. All modules tilt in similar angle of 20 degrees on the ground and the array consist of a total of 880 PV modules physically installed and electrically connected. Source: Prepared by JICA Experts team.

Solar PV Modules (2) Issued with a performance guarantee of not less than 90% of minimum rated power for a period of 10 years from date of purchase and not less than 80% of minimum rated power for a period of 25 year.

15. Solar PV modules maintenance

Cleaning out any foreign objects at the back of the panel also after any windstorm. Leaves, branches, papers, plastic, and other materials may be blown onto the panel and become lodged under the panels blocking the air flow under the panels and causing increased heating and lower electrical output.

Check panels for a tight connection to the mounting structure that does not twist or otherwise stress the panels. Note that drilling any holes in panel frames may void the warranty because it can change the strength characteristics of the panel so only use existing holes for mounting or for attaching cables.

Check for excessively tight or loose cables, both conditions can result in damage to their insulation or open connections. If string output is reduced, check connectors in that string for tight seals and for open, loose, corroded, or arcing contacts.

Almost all problems with solar panels are a result of problems with the packaging of the cells, not with the cells themselves. Since it is rare that a panel fails outright, most panel problems result in lowered output and the primary indicator of panel problems is that the string with the problem panels has a consistently lower than the other strings.

Most causes of reduced string output are not related to the panels but to the wiring. Although very unlikely for laminated cells to fail, the panels in the string should be inspected to look for changes in the color of the panels, cells that are separating from the glass (delamination) and corrosion in the cell wiring and on its surface.

16. DC Box

Panels are connected in series and parallel by means of weatherproof cable and connection plugs or connection boxes. They are thoroughly insulated and protected against the weather, UV damage and minor mechanical damage. Checking at the connection box for that string may be necessary. This procedure should be done by qualified engineer.

The DC box connects a total of 4 PV strings. The positive and negative terminals of each string are protected by disconnection fuses. The 4 strings are parallel connected in the box into groups. Each of the parallel groups is protected by two surge arresters to dissipate high induced voltage from lightning to earth. ・

17. DC Box maintenance

(1) Check for overly tight or loose connections.

Check each surge arrester unit for its status indicator. When the status indicates non-functioning, it implies that the arrester must be replaced. The surge arresters are design to dissipated surge voltages and protect equipment up to 1000 V. Overtime, the surge arrester protection capacity will be used up to dissipate high induced voltage from lightning. Status indicator will indicate that the surge protector if it is.

(2) Check the current through each string.

The current through each individual string can be measured with a clamp-meter during operation. In case of more than 25% deviation from other strings checked at the same time, check for shading or objects on the panels, check the DC connections, and check for damage to panels.

To check the voltage, always disconnect the AC connection to the grid first. Then open the DC disconnecting fuse at the surge arrester. In case of more than 25% deviation from string to string, check cables and contacts in DC connection boxes, and check the panels for damage or severe shading. Source: Prepared by JICA Expert team SPD (Surge Protection Device, Surge arrester) MCCB Each string due for change.

18. Inverters (Power conditioner)

A total of 2 inverter are installed each with the capacity of 100 kW. Each of the inverter used are connected designed for 3-phase electrical system.

Each inverter constantly monitors both the AC and DC values for irregularities, leakage etc. and if an irregularity is seen the control circuitry will shut down the inverter. They will automatically stop operating when the AC is disconnected and at night and will resume work automatically when the proper grid voltage and solar electricity input is present.

The inverters display the important operational parameters and warn in case of problems with error messages either displayed on the LCD screen or using error codes shown after pressing status button on the LCD touch screen on the front of the inverter panel.

The room housing the inverters should remain cool and clean. Inverter require a weekly check for their operation on site using the LCD touch screen.

19. Power conditioner maintenance

The power conditioner uses highly reliable circuit parts; Its main conversion unit and control circuit have been made contactless, and this contributes to an even higher level of reliability. It is advisable to enhance reliability of the power conditioner by checking the status of the inverter using the touch screen LCD weekly.

20. AC Box

In case of over current or electrical fault at AC side, the circuit breaker will automatically break the circuit to protect the inverter. The circuit breaker must be manually reconnected in the event of trip. The AC breaker is rated at 400 A for each inverter.

21. AC Box maintenance

Check for breaker status and remove any debris inside the box (if any)

22. General troubleshooting procedure

If the PV system is not working as expected, this general guideline will help determine and repair the problem. These service instructions are for use by qualified personnel only. To reduce the risk of electric shock, do not perform any servicing other than that contained in the operating instructions unless you are qualified to do so. This equipment is connected to potentially lethal voltages from multiple sources. AC and DC disconnecting devices should be opened and locked out prior to any service. Always check for presence of AC or DC voltage prior to servicing.

Visually inspection of modules, controller and inverters for any obvious problems such as broken modules, disconnected wires, or other signs of distress. Check for dirt on the modules. Dirty modules will have a reduced output of 1-20% depending on how long it has been since the last rain or washing.

If modules are broken, they must be replaced. Do not attempt to clean or come in contact with a module with a broken glass surface. Arrays are at hazardous voltage when illuminated even when not connected to any loads.

If modules are dirty, clean with water spray. If they are extremely dirty they may be washed with a mild detergent and water. Follow appropriate electrical safety procedures to ensure that personnel cleaning the array do not contact live parts with the water spray. Always use PPE (Personal protective equipment) to minimize shock hazard.

Check the inverter display indications for any sign of an error.

If errors are displayed, always refer to the inverter manuals trouble-shooting list

23. Array troubleshooting

If array problems are suspected, take the following steps to ensure the PV array is working properly.

Check all disconnect switches, circuit breakers, and fuses.

If fuses or circuit breakers are blown, tripped, or cleared, determine the cause before replacing fuse or re-engaging the circuit breaker.

Check the physical condition of the PV array. All glass surfaces should be unbroken and reasonably clean. Module frames should be intact and be corrosion free. Note any other physical damage or vandalism that has occurred.

Use an ohmmeter to confirm the electrical continuity through the entire equipment grounding system. Only by qualified persons. Do this only when all fuses and switches in the disconnected position.

All modules should be un-shaded throughout the day. "Spot" shading of a few cells or modules in the entire array must be minimized or eliminated. Spot shading can drastically affect the output of modules connected in a series circuit and may result in component failure.

Check all the mounting hardware for loose fasteners or connections to the mounting surface. Corrosion, vandalism, or other damage should be recorded for later repair.

Conduit and connections must be tight and undamaged. Look for loose, broken, corroded, vandalized, and otherwise damaged components. Check equipment close to the ground for animal damage. If conduit is not used, carefully check cable insulation.

Open box covers to check wiring and wiring connections for similar damage or degradation. Look for burned wiring or terminals.

Confirm that there are no short circuits or ground faults in the system.

In some cases, ground or phase to phase faults may only occur when a higher voltage is connected in series to the array. Testing with an insulation resistance tester is recommended.

24. System repair procedure

Module replacement. In doubt of module performance, please contact Mitsubishi Electric.

Inverter (Power conditioner) All inverter components should be handled using standard industry normal electrical procedures. Follow the instructions illustrated in the inverter manual.

System repair record Please record all system repairs in the Maintenance record.

25. Measurements

Unless necessary, measurement should not be done.

Measurement can only be done by qualified PV personal during maintenance of PV system.

Check list prior to measurement.

1. Only done by qualified installer or persons
2. Read and understand the instruction manual before operating
3. Right polarity at all cable connections (cable marking)
4. Check tightness of all cable connections
5. Check tightness of screws and terminal connection

Before carrying the modules test, ensure that the MCCBs are in the open circuit position.

System output testing involves exposure to live wires that may contain high voltage. Touching these wires may cause injury or death. Only qualified electricians with proper PPE safety gear should conduct these tests.

Always disconnect AC and DC power before disconnecting the DC fuse holders. The DC fuse holders are not rated to be disconnected under load. ・This equipment contains energy storage devices capacitors that require fifteen minutes to discharge after all sources have been disconnected

Do not service until AC and DC power sources have been disconnected and locked out for a period of fifteen minutes.

26. Health and safety

Potential hazards associated with the system.

Hazards Suggested and precautions.

26.1. Electrical shock from PV modules – PV modules are always live if daylight is falling on them.

Only qualified personnel should make modifications to the PV system, appropriate precautions should be taken to ensure live terminals are not touched.

26.2 .Electrical shock from DC or AC voltage – If any damages occurs to cables or equipment, live conductors could be exposed.

Precautions:

Carry out regular maintenance on the system. Report any damage which occurs to maintenance personnel so repair work can be carried out promptly.

26.3. DC cables are live during daylight, even when main AC isolator is switched off.

Precautions:

Any persons carrying out work should be made aware of the existence of the system and location of components.

26.4. Fire –

As with all electrical equipment, heat generated in arc, high resistance joints or damaged cables can cause surrounding materials to reach ignition temperature and burn.
Precautions:
Keep flammable materials away from system components; keep cables away from sharp edges. Ensure regular checks of system.

27. Risks

The photovoltaic system contains dangerous high voltages which can cause severe injury.
The PV arrays generate DC voltage and cannot be turned off during daytime.
To prevent an accident, all electric boxes, such as Junction box should be locked.
When work at high place, be careful and take safety measures not to drop off. (To prevent the using electrical power tools, etc. from dropping, the tools should be tied with something such as rope to your body.)
When working in the confined place, wear the helmet, also in order to protect from the falling objects.
Do not climb up the PV arrays installed at rooftop under a bad weather condition such as after raining.
The PV modules are designed to absorb the sun energy therefore become extremely hot in daytime.

28. Attachments

(1) KOSRAE PV SYSTEM SCHEDULE OF MAINTENANCE CHECKLIST
(2) KOSRAE PV SYSTEM MAINTENANCE CHECKLIST
(3) Inspection Schedule Form
(4) Visual Inspection Record (Form)
(5) Measurement Inspection Record (Form)
(6) Instruction manual Sting tracer instruction manual Cell line checker instruction manual.
(7) Interpretation of the I-V curve shape
(8) Recommended checkpoints during patrol
(9) List Form(Measuring instruments, Spare, parts, Tools for O&M of solar PV facilities)

29. Revision History

27/3/2023 : First edition v0
DD/MM/YY : Revision v1

30. Operation and updating of this manual

- The person in charge of managing the manual: G.B. Protacio.
- Update cycle : One time a year
- Person in charge of updating : G.B.Protacio
- Location of manual storage : KUA Main Office Building

（Attchment1） KOSRAE PV SYSTEM SCHEDULE OF MAINTENANCE CHECKLIST

Kosrae Utilities Authority
P.O.Box KUA
Tofol
Kosrae State, FM 96944

Date:________________

KOSRAE PV SYSTEM SCHEDULE OF MAINTENANCE CHECKLIST:

No.	Item	Daily Check	Weekly check	Monthly check	Twice yearly check	Annual check
A	**Solar Module Equipments:**					
1	PV Modules			x		
2	PV Modules mounting structures				x	
3	Array Junction Box			x		
4	Circuit Boxes			x		
5	Terminal Boxes			x		
6	Inverter				x	
B	**PV Rack Components:**					
7	All racking hardware and components for abnormal wear and					x
	excessive corrosion					
8	All ground mounts, visual inspection of structural footings					x
9	Continuity tests to ground throughout the structure of the arrays					x
C	**Monitoring System:**					
10	Error/Alarm signals	x	x			
11	DC Output Voltage/ Current	x	x			
12	AC Output Voltage/ Currewnt	x	x			
13	Sensor Condition	x	x			
14	Daily Sum Power Output	x	x			
15	Inspect and maintain all meters, sensors and communication point					x
16	Clean/ service Pyranometer					x
D	**Inverter:**					
17	Direct rays of sunlight	x	x			
18	Cablings Connection	x	x			
19	Abnormal operating temperature	x	x			
20	Record and validate all voltages and production values from the	x	x			
	HMI display	x	x			
21	Clean filters	x	x			
22	test fans for proper operation	x	x			
23	Check torque on terminations	x	x			
24	Check integrity of lighting arrestors	x	x			
25	check of continuity of system ground and equipment ground	x	x			
26	Other critical parts involved during inspection	x	x			
27	Service of all internal components as per manufacture's guideline					x
28	Replacement of air filters					x
29	Cleaning air intake and vent ducts					x
30	Record all internal faults codes and process as necessary					x

(Attchment2）KOSRAE PV SYSTEM MAINTENANCE CHECKLIST

Kosrae Utilities Authority
P.O.Box KUA
Tofol
Kosrae State, FM 96944

Date:________________

KOSRAE PV SYSTEM SCHEDULE OF MAINTENANCE CHECKLIST:

	MONTHLY MAINTENANCE	PASS	FAIL	Remarks
INVERTER 1				
1	Ensure MCCB11 is in "ON" Position			
2	Ensure MCCB51 is in "ON" Position			
3	Ensure ALARM LED is "OFF"			
INVERTER 2				
1	Ensure MCCB11 is in "ON" Position			
2	Ensure MCCB51 is in "ON" Position			
3	Ensure ALARM LED is "OFF"			
VENTILATION FAN				
1	Ensure at least 1 FAN in operation			
2	Ensure Timer Accuracy in DB Box			
3	Ensure Air Vent not dusty or blocked			
MAIN AC BOX				
1	**Ensure MAIN BREAKER is in "ON" Position**			
2	Ensure INVERTER 1 AC BREAKER is in "ON" Position			
3	Ensure INVERTER 2 AC BREAKER is in "ON" Position			
DC MAIN COMBINER BOX 1				
1	Ensure DC breaker is in "ON" position			
DC MAIN COMBINER BOX 2				
1	Ensure DC breaker is in "ON" position			
AC DB BOX				
1	Ensure ALL breakers in "ON" position			
Record Production Figures				
1	Activate Monitoring PC from sleep mode using keyboard			
2	kWh production for the Month:________________________kwh			
Housekeeping				
1	Ensure PV Control Station interior is clean and tidy			

* If any of the above check fails, conduct a shutdown and turn on procedure

Kosrae Utilities Authority
P.O.Box KUA
Tofol
Kosrae State, FM 96944

Date:_______________

KOSRAE PV SYSTEM SCHEDULE OF MAINTENANCE CHECKLIST:

	BI-ANNUAL MAINTENACE	PASS	FAIL	Remarks
ARRAY NO:_______				
0	Random check 20 Button Cap Bolts at top side of a array			
	Rasndom check 10 Hexagonal Nuts at bottom side of array			
	* Fail if any 1 lose			
1	TURN OFF DC breaker inside DC JUNCTION BOX			
2	Measure DC Bus Bar Voltage:__________ VDC (600V max)			
3	Disengage Fuse 1 to 4			
4	Check Fuse Connectivity 1 to 4			
5	**Fuse 1 to 4 remain disengaged**			
6	Rinse PV Modules with clean water. Do not use clening products			
7	Measure and Record: String 1 voltage:_____________ VDC String 2 voltage:_____________VDC String 3 Voltage:_____________VDC String 4 Voltage:_____________VDC			
8	Engage Fuse 1 to 4			
9	Measure DC Bus Bar Voltage:____________VDC (600V max)			
10	TURN ON DC breaker inside DC JUNCtION BOX			

Equipment Needed: (1) Ladder for array access (2) 5mm Allen Keys (3) Size 13 wrench (4) DC Junction Box Keys (5) Voltmeter for DC measurement and connectivity check (6) water for washing (7) Mop for stubborn debris on PV modules.

2.5 PV facility maintenance inspection item check sheet

No.	Target	PV facility maintenance inspection item check sheet			Check / comments	
1	**PV array racking**	Visual inspection	Dirtying of and damage to the PV module	Significant dirt on the surface		
				No scratches or damage		
				No significant dirt, scratches, or damage on the back side (back seat)		
				Sites receiving external forces due to strong winds		Cell line checker
			Thermal image for viewing terminal box, cell variation, internal connections, and partial operation	Perform to check status during times of high insolation		Cell line checker
			PV module frame	No damage and significant deformation to the frame		
			Status of racking and foundation	No remarkable distortion, damage, cracks etc. of the foundation		Schmidt hammer
			PV module frame	No damage and significant deformation to the frame		
			Status of racking and foundation	No remarkable distortion, damage, cracks etc. of the foundation		
				No deformation, scratches, dirt, rust, corrosion, or damage on the racking (No rust progression, excluding rusting at the end of the plated steel sheet)		
				Check for unequal sedimentation, interfacial corrosion, expansion deformation due to multiple connections to racking		
			PV modules and fixing to racking	No loose nuts and bolts		Torque wrench
			Surrounding conditions	The status of shadows, bird's nests, weeds, trees, etc. have no significant influence on power generation performance		
			Grounding of PV modules and racking	No significant scratches, damage, etc. on the grounding wire, and it is correctly connected		
			Waterproofing	No abnormality in the caulking		
			Damage to wiring and conduits	Connectors have no damage and are securely connected		
				Excessive tension is not applied		
				No excess slack		
				No significant defects or damage on the wiring		

				No abnormal heat in the wiring		
				No significant scratches, dirt, rust, corrosion, damage, or deformation on the conduit.		
				Check the support and fixing of the piping		
2	**Junction box**	Visual inspection and operation	Corrosion and damage of outer case	No significant corrosion, rust, scratches, or damage in appearance that may impair function		
			Opening, closing, and locking of the door	No abnormality in the opening and closing of the door		
				Can be locked		
			Condition inside the outer case	No dust, rain water, insects, small animals, etc. has entered		
				No significant dirt, corrosion, rust, damage, deformation		
			Installation status	No looseness in the mounting bolts, etc. of the outer case, and it is securely mounted		Torque wrench
				No significant defects or damage on the wiring		
				No abnormal heat in the wiring		
			Waterproofing	Adequate waterproofing and caulking		
				Water drain holes, etc. have been treated		
			Loss of internal equipment	No loss of internal equipment		
			Damage to conduit	No significant defects, corrosion, etc. of the wiring		
			Loose screws of the terminal block and internal equipment	No looseness in the screw of the terminal block and internal equipment		
				No abnormal heat generated		
			State of the switch	Final control elements such as a handle if any, can operate reliably		
			Check grounding	No significant scratches or damage on the grounding wire, and it is correctly connected		
			Check lightning countermeasures	No deterioration in surge protection device (SPD) and varistor		
		Measurement	Insulation resistance (between PV modules and ground)	Insulation resistance value measured for each string is equal to or greater than the specified value		Ohmmeter
			Insulation resistance (between the junction box output terminal and ground)	Insulation resistance value is equal to or greater than the prescribed value		Ohmmeter

			Ground Resistance	Less than the prescribed ground resistance value		Ohmmeter
			Open circuit voltage	No abnormality in the voltage measured for each string		String tracer
			I - V curve	No abnormality in the IV curve		String tracer
				String Voc measured for baseline comparison		
3	**PCS**	Visual inspection	Corrosion and damage of outer case	No significant corrosion, rust, scratches, or damage in appearance that may impair function		
			Opening, closing, and locking of the door	No abnormality in the opening and closing of the door		
				Can be locked		
			Installation status	No looseness in the mounting bolts, etc. of the outer case, and it is securely mounted		Torque wrench
			Status of racking and foundation	No remarkable distortion, damage, cracks etc. of the foundation		Schmidt hammer
				No deformation, scratches, dirt, rust, corrosion, or damage on the racking (No rust progression, excluding rusting at the end of the plated steel sheet)		
				Check for unequal sedimentation, interfacial corrosion		
			Waterproofing	No rain water has entered		
			Falling of parts	No parts inside or outside the PCS have fallen		
			Damage to external wiring or looseness in connection terminal	No significant defects or damage on the wiring		
				No abnormal heat in the wiring		
				No loose screws		
				No discoloration of terminals and caps		
			Damage to ground wire or looseness in connection terminal	No significant scratches or damage on the grounding wire, and it is correctly connected		
				No loose screws		
			Damage to conduit	No significant defects, corrosion, etc. of the wiring		
			Check ventilation (vents, ventilation filters, etc.)	Do not block the vents		
				Ventilation filter is not clogged		
			Abnormal sounds, etc.	No abnormal sound, abnormal vibration, unusual odor, or abnormal overheating during operation		
		Measurement	Insulation resistance (between PCS input/output	Insulation resistance value is equal to or greater than the prescribed value		Ohmmeter

			terminal and ground)			
			Ground Resistance	Less than the prescribed ground resistance value		
			Measurement of system voltage			
4	**Others (step-up transformer, switch, WH, etc.)**	Visual inspection and operation	Damage to equipment	No significant rust, scratches, or damage that may impair function		
			Attachment of dust, oil, etc.	No significant dirt around the terminal		
			Status of final control elements	Final control elements such as a handle if any, can operate reliably		
			Overheating of equipment	No deformation, etc. of insulating case or terminal due to heating from abnormal temperatures		
			Installation status	Securely attached		
			Damage to wiring	No significant defects or damage on the wiring		
				No abnormal heat in the wiring		
			Loose screws of the terminal block and internal equipment	No looseness in the screws of the terminal block and internal equipment		
			Status of racking and foundation	No remarkable distortion, damage, cracks etc. of the foundation		Schmidt hammer
				No looseness in the mounting bolts, etc. of the outer case, and it is securely mounted		Torque wrench
				No deformation, scratches, dirt, rust, corrosion, or damage on the racking (No rust progression, excluding rusting at the end of the plated steel sheet)		
				Check for unequal sedimentation, interfacial corrosion		
5		Visual inspection	Sensor adjustment	Confirmation of cleanliness and ventilation		Pyranometer, thermometer
				Periodical calibration		Pyranometer, thermometer
				No abnormal heat generated		
6	**Operation/stop**	Visual inspection and	Operation	When stopped, turn the operation switch "ON," and it runs in interconnected mode		
				Displays OPERATING or and indicator indicates operation during interconnected		

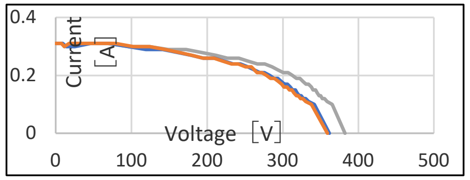
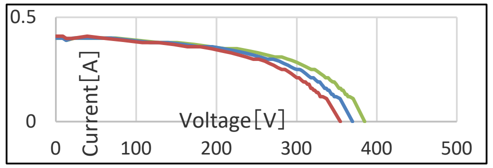
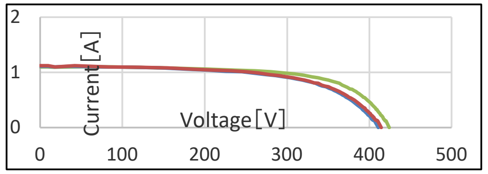
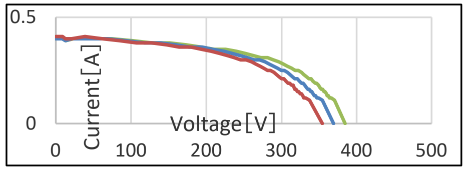
		operation		operation		
			Stop	When operating, turn the operation switch to “OFF,” and it stops instantly		
				Displays STOP or an indicator indicates stop when stopped		
			Confirmation of operation and anti-islanding during power outage	Stops instantly when the service entrance switch is opened		
				Also, when power is restored, it is automatically restored after the prescribed time.		
			Time limit timer operation test	1) Set PCS to interconnected operation and disconnect service entrance switch is to stop operation		
				2) After confirming that the protective device works and the PCS stops immediately, reconnect it. Measure the time from connecting to PCS automatic restoration. This is the prescribed time.		
			Autonomous operation	If it has autonomous operation function, voltage specified by manufacturer is output from the autonomous operation dedicated terminal when switching to autonomous operation		
			Confirm operation confirmation of display	Confirm that the PCS is operating normally by confirming the display for status of the PCS operation/stop, output, generated energy, etc.		
				1) Switch PCS from operating to stop and check the status display for operation, stop, etc.		
				2) Confirm display of PCS for output, generated energy, etc. during operation		
				3) Confirm display of PCS status, output, generated energy, etc. and display of monitoring device and data collecting device		
				Compared with the simulation values, the generated energy is not significantly less		
7	**Output**	Visual inspection	Energy meter	Meter is working properly		

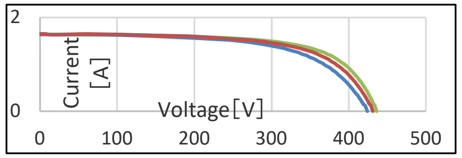
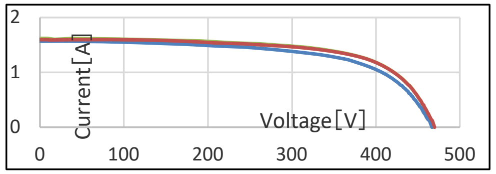
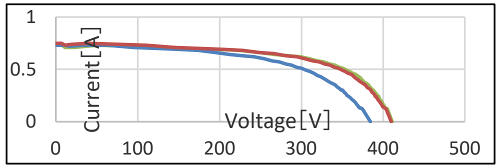
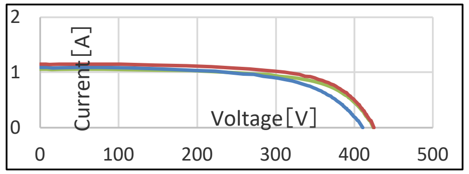
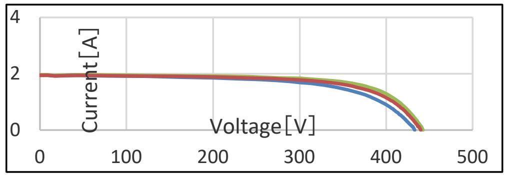
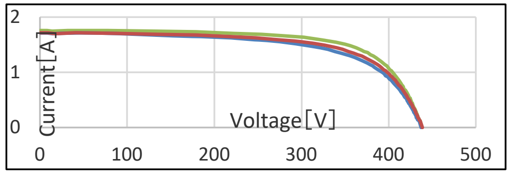
Array Measurement Records

(place)

Date		Humidity	56 %	**Measuring Instrument**	Digital multimeter Kyoritsu KEW 1021R	String Tracer Togami SPST-A2A-Y1	Meggar Kyoritsu KEW 3021	**Measurer**	Gerry/Rob/Rin/Ronnie	**Person in charge**	Approval **Robert**	Confirmation **Gerry**	Confirmation
Weather	Sunny/w cloudy	Solar radiation											
Temperature	48.6 ℃												

EU PV

Junction Box Number	Combiner Box Number	Circuit/ Breaker No.	Measurement time	Number of panels	Open circuit voltage (1 panel)	Theoretical Voc (string)	Circuit Voc (1 String) Difference no larger than voltage of one panel	P-side 0.2 MΩ or more at DC 500V	N-side 0.2 MΩ or more at DC 500V	I-V measurement Presence of abnormal string	NFB		Comprehensive judgment	Remarks
											Start	Finish		
	1	1	10:45	13	40.075	520.975	369	4.39	3.5	Good	OP	cL	Good	Cody/Rains 
		2	10:45	13	40.075	520.975	345	4.48	5.5	Good	OP	cL	Good	
		3	10:45	13	40.075	520.975	339	4.34	5.5	Good	OP	cL	Good	Ref 09
	2	4	10:50	13	40.075	520.975	365	4.6	5.6	Good	OP	cL	Good	
		5	10:51	13	40.075	520.975	347	5	4.6	Good	OP	cL	Good	Ref 10
		6	10:51	13	40.075	520.975	330	5.2	5	Good	OP	cL	Good	
	3	7	11:02	13	40.075	520.975	406	4.25	8.4	Good	OP	cL	Good	
		8	11;)2	13	40.075	520.975	387	4.3	6.1	Good	OP	cL	Good	Ref 11
		9	11:02	13	40.075	520.975	392	4.5	6.6	Good	OP	cL	Good	
	4	10	11:12	13	40.075	520.975	419	1.7	3	Good	OP	cL	Good	
		11	11:12	13	40.075	520.975	401	4.3	3.8	Good	OP	cL	Good	Ref 12
		12	11:12	13	40.075	520.975	413	3.5	4.27	Good	OP	cL	Good	

5	13	11:21	13	40.075	520.975	468	4.5	3.89	Good	OP	cL	Good	Ref 13 / 14	
	14	11:21	13	40.075	520.975	454	4.6	5.6	Good	OP	cL	Good		
	15	11:21	13	40.075	520.975	451	4.05	8.1	Good	OP	cL	Good		
6	16	11:30	13	40.075	520.975	456	4.2	4.7	Good	OP	cL	Good	Ref 15	
	17	11:30	13	40.075	520.975	454	3.9	5.4	Good	OP	cL	Good		
	18	11:30	13	40.075	520.975	459	3.8	6.4	Good	OP	cL	Good		
7	19	11:37	13	40.075	520.975	431	2.6	4.6	Good	OP	cL	Good	Ref 16	
	20	11:37	13	40.075	520.975	410	4.3	7.6	Good	OP	cL	Good		
	21	11:37	13	40.075	520.975	427	4.1	4.7	Good	OP	cL	Good		
8	22	11:43	13	40.075	520.975	416	4.2	4.3	Good	OP	cL	Good	Ref 17	
	23	11:43	13	40.075	520.975	398	3.5	5.7	Good	OP	cL	Good		
	24	11:43	13	40.075	520.975	414	4.5	3.4	Good	OP	cL	Good		
9	25	11:49	14	40.075	520.975	440	3.9	7	Good	OP	cL	Good	Ref 18	
	26	11:49	14	40.075	520.975	430	4	7.6	Good	OP	cL	Good		
	27	11:49	14	40.075	520.975	439	4	8.7	Good	OP	cL	Good		
10	28	11:54	14	40.075	520.975	440	3.7	5.9	Good	OP	cL	Good	Ref 19	
	29	11:54	14	40.075	520.975	439	3.8	4.3	Good	OP	cL	Good		
	30	11:54	14	40.075	520.975	440	4.1	5.2	Good	OP	cL	Good		

3.1 *Photovoltaic Module Fault Detectors*

For the inspection and fault location of the photovoltaic modules

PV Doctor

Togami

String Tracer (I-V curve tracer)

Cell LineChecker (Fault module detector)

Feb. 2017

Catalog No. C0234d

Togami Electric Mfg.Co.,Ltd.

PV Doctor Togami has solutions!

Do you have any of the following issues in your PV system?

- I don’t know how to invest the cause of declining the power output.
- I don’t know which tool is suitable for the detailed module inspection.
- There is no tool to check the photovoltaic module condition.
- I’m looking for a tool which is cheap and easy to use.

If you have these issues and leave them unsolved, you may have the unexpected troubles, such as...

- ◆ Unexpected decline of power output which may lead to the compensation issue of electricity sales to the grid.
- ◆ Accidents, such as fire, caused by photovoltaic module, etc.

Japan Photovoltaic Energy Association <Guideline for maintenance and inspection of small-scale photovoltaic generation system>

Periodic Inspection

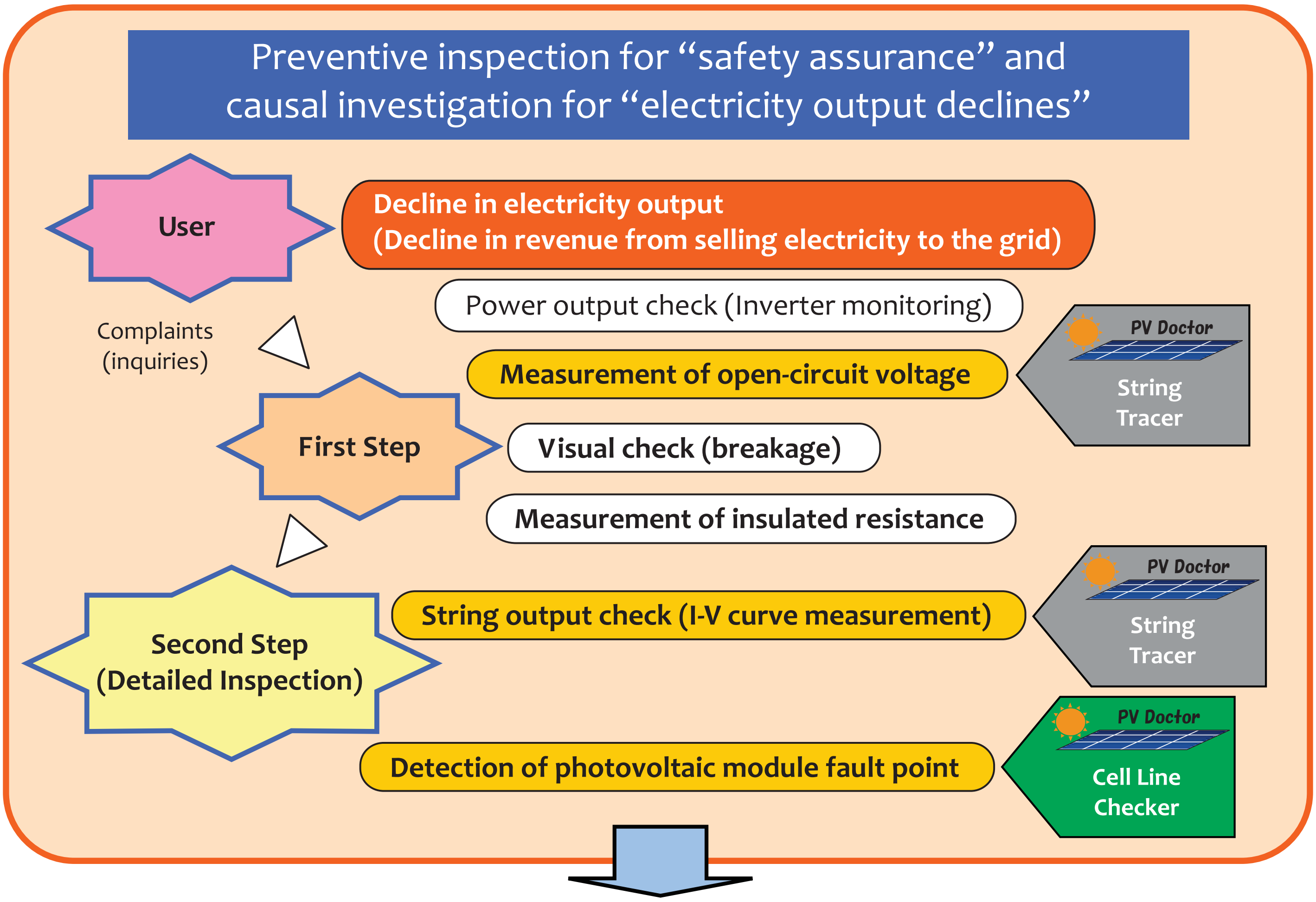
- Visual check (breakage, etc.)
- Power output check (Inverter monitoring)
- Measurement of ground resistance.
- Measurement of open-circuit voltage (Voc)
- Measurement of insulation resistance
- Check self-consumption function.

Guideline recommends the I-V curve measurement by the curve tracer other than Voc measurement.

Daily Inspection

- Visual check (breakage, etc.)
- Power output check (Inverter monitoring)

PV Doctor Series solve your problem!



Preventive inspection for "safety assurance" and causal investigation for "electricity output declines"

User

Complaints (inquiries)

Decline in electricity output (Decline in revenue from selling electricity to the grid)

Power output check (Inverter monitoring)

First Step

Measurement of open-circuit voltage

Visual check (breakage)

Measurement of insulated resistance

Second Step (Detailed Inspection)

String output check (I-V curve measurement)

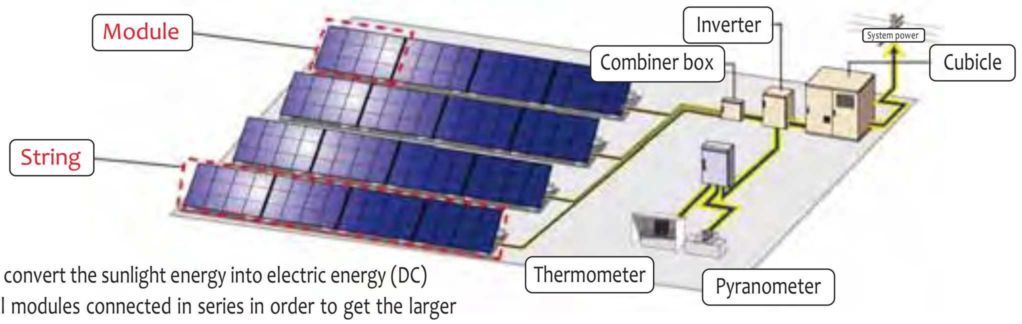
Detection of photovoltaic module fault point

Causal investigation will bring the following benefits to each party!

PV home builders, etc.	Even if any failure, such as decline in electricity output, occurs **within the warranty period**, only the defective module(s) should be changed. Therefore, warranty expense can be minimized.
PV contractors, Electrical contractors, etc.	･Fault point identification will lead to the advantageous negotiation with both user and manufacturer. ･New business expansion in the maintenance and inspection may differentiate from the competitors.
User	Even if any failure, such as decline in electricity output, occurs **after the warranty period**, you may only exchange the defective module(s), which enables to minimize the maintenance expense.

"Enhance safety" and "maintain relevant power output" as power generation system.

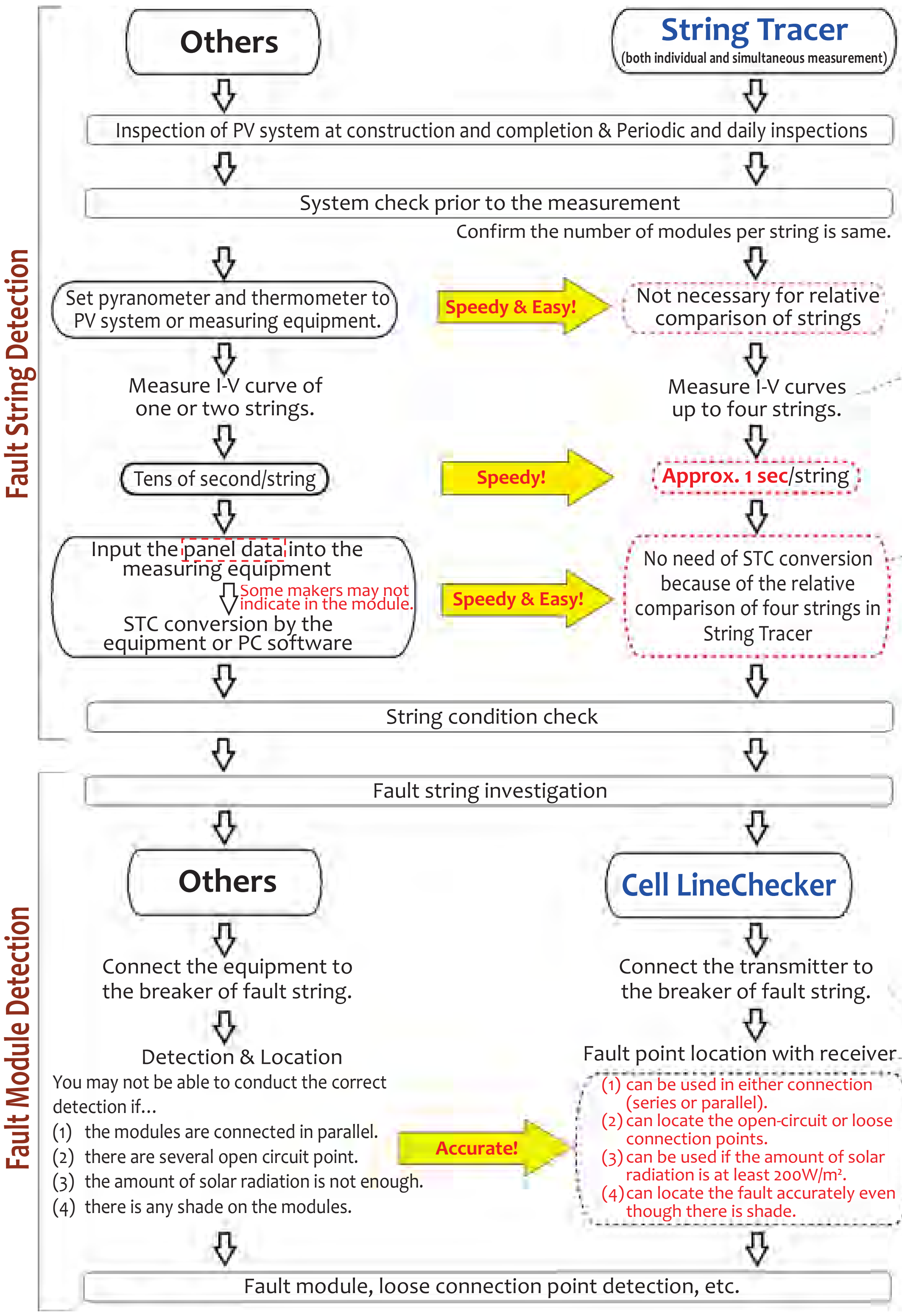
Photovoltaic power generation system



Module: Panel to directly convert the sunlight energy into electric energy (DC)

String: A unit of several modules connected in series in order to get the larger power output

Features of PV Doctor from Togami and comparison with other equipment



Fault String Detection

Others		**String Tracer** (both individual and simultaneous measurement)
Inspection of PV system at construction and completion & Periodic and daily inspections		Inspection of PV system at construction and completion & Periodic and daily inspections
System check prior to the measurement		System check prior to the measurement Confirm the number of modules per string is same.
Set pyranometer and thermometer to PV system or measuring equipment.	**Speedy & Easy!**	Not necessary for relative comparison of strings
Measure I-V curve of one or two strings.		Measure I-V curves up to four strings.
Tens of second/string	**Speedy!**	Approx. 1 sec/string
Input the panel data into the measuring equipment Some makers may not indicate in the module. STC conversion by the equipment or PC software	**Speedy & Easy!**	No need of STC conversion because of the relative comparison of four strings in String Tracer
String condition check		String condition check

Fault Module Detection

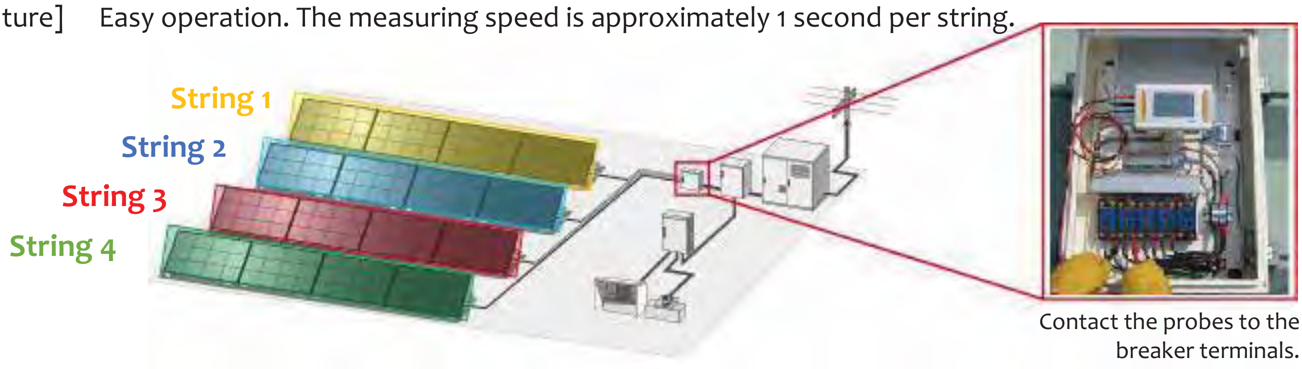
Fault string investigation		Fault string investigation
Others		**Cell LineChecker**
Connect the equipment to the breaker of fault string.		Connect the transmitter to the breaker of fault string.
Detection & Location You may not be able to conduct the correct detection if… (1) the modules are connected in parallel. (2) there are several open circuit point. (3) the amount of solar radiation is not enough. (4) there is any shade on the modules.	**Accurate!**	Fault point location with receiver (1) can be used in either connection (series or parallel). (2) can locate the open-circuit or loose connection points. (3) can be used if the amount of solar radiation is at least 200W/m². (4) can locate the fault accurately even though there is shade.
Fault module, loose connection point detection, etc.		Fault module, loose connection point detection, etc.

Combiner box

Combiner box

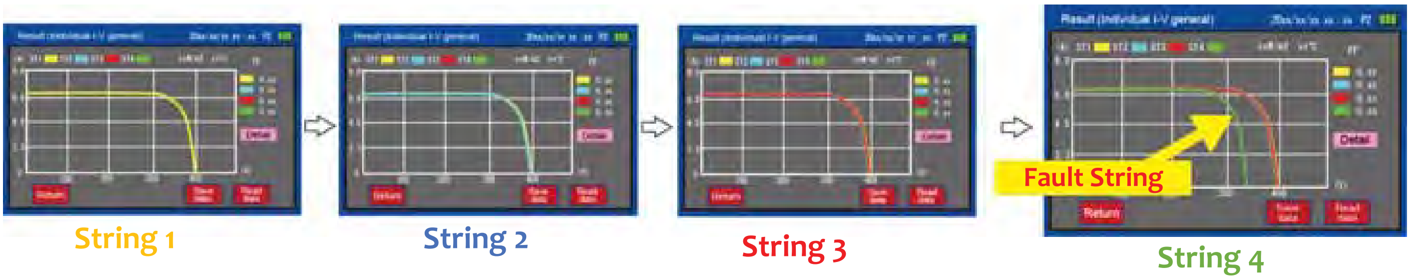
String Tracer (I-V curve tracer)

[Function] Fault module can be detected by the relative comparison of up to 4 strings in a screen.
[Feature] Easy operation. The measuring speed is approximately 1 second per string.



Contact the probes to the breaker terminals.

[Screen]



Cell LineChecker (Fault module detector)

[Function] (1) Module configuration per string
(2) Fault point location
[Feature] Fault module can be identified.

(1) Checking the module configuration per string

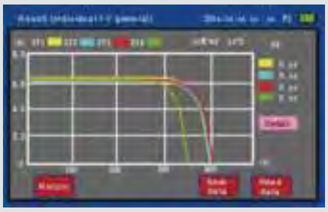
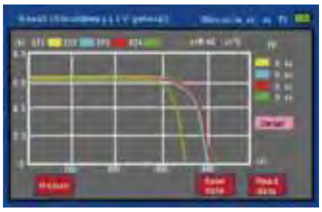
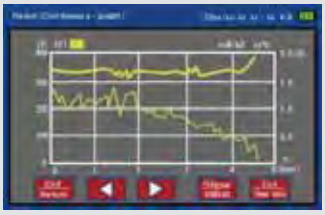
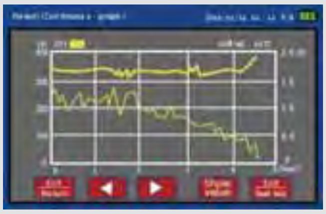
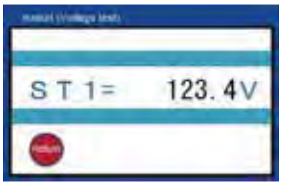
Connect the transmitter to the breaker terminal of the string.	On the surface of modules connected to the signal input string, receiver detects the signal and shows response by light and sound.	Confirm the module configuration of the string.
		

(2) Locating the fault point

Connect the transmitter to the breaker terminal of the fault string.	Conduct the fault location on the fault string.	Confirm the fault module.
		 On the surface of normal module, receiver detects and shows the signal input from transmitter by light and sound. However, on the fault point, no signal can be detected. * For bypass diode open-circuit check, you need a special procedure.

PV Doctor

String Tracer (I-V curve tracer)

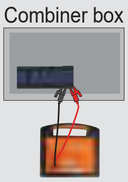
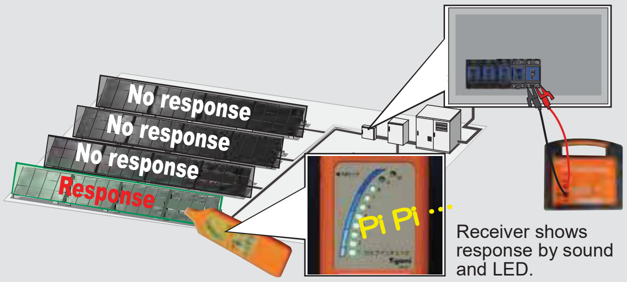
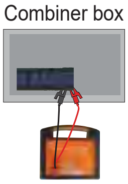
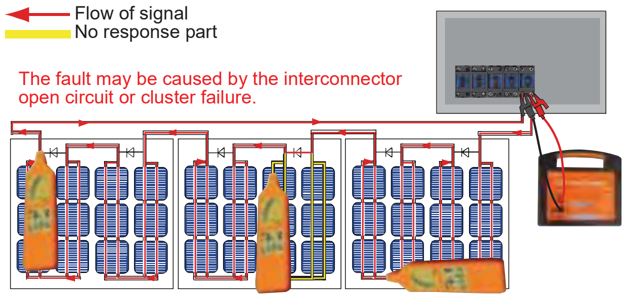
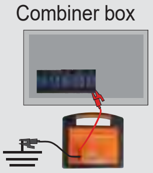
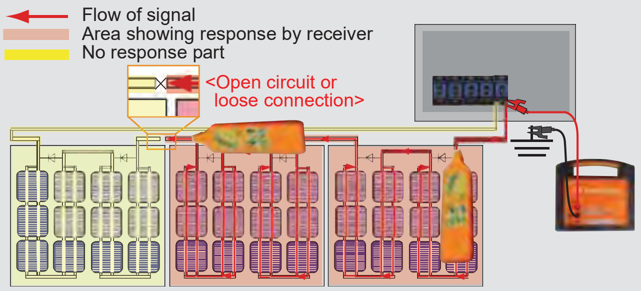
			
Type		SPST-A1A-Y1	SPST-A2A-Y1
Voltage measuring Range		[General (c-Si, CIS, etc.)] 20.0Vdc to 700.0Vdc [Hybrid (Si-HJT)] 20.0Vdc to 600.0Vdc	[General (c-Si, CIS, etc.)] [Hybrid (Si-HJT)] 20.0Vdc to 1000.0Vdc
Current measuring Range		[General (c-Si, CIS, etc.)] 0.5Adc to 10.0Adc [Hybrid (Si-HJT)] 0.5Adc to 7.0Adc	[General (c-Si, CIS, etc.)] [Hybrid (Si-HJT)] 0.5Adc to 10.0Adc
Power measuring Range		[General (c-Si, CIS, etc.)] 10W to 4900W [Hybrid (Si-HJT)] 10W to 2900W	[General (c-Si, CIS, etc.)] [Hybrid (Si-HJT)] 10W to 8000W
Rated power voltage		[AC adopter] 100V to 240Vac, 50/60Hz [Size AA battery×4] 6.0Vdc (Range: 4.8 to 7.2Vdc)	
Accuracy		Voltage:±1%rdg ±5dgt Current:±1%rdg ±5dgt	
Dimensions		195×115×70mm	
Weight		690g (excl. batteries)	600g (excl. batteries)
Measuring speed		Approx. 100ms (per string)	
Functions	Individual I-V curve measurement	 Measure and display up to 4 strings	
	Simultaneous I-V curve measurement	 Measure and display up to 4 strings	 Measure and display up to 2 strings
	String voltage/current Measurement * Clamp CT is necessary for the measurement.	 Measure up to 4 strings	 Measure up to 2 strings
	Voltage test	 ST1= 123.4V	(Voc measurement)
	STC conversion *1	N/A (Accompanied PC software can conduct STC conversion.)	String Trace main unit can conduct STC conversion.
Detailed specification page		7 to 10	

*1 Pyranometer and thermometer (optional) is necessary for STC conversion.

PV Doctor

Cell LineChecker (Fault module detector)

Type			SPLC-B-Y
Transmitter	Rated power voltage		9.0Vdc(Range: 6.5 to 9.0Vdc)
	Applicable voltage range	Magnetic field mode	15.0Vdc to 1000.0Vdc
		Electric field mode	0V to 1000.0Vdc (0V for open-circuit fault detection)
	Detecting method		Current consumption (Magnetic field mode) Signal input (Electric field mode)
	Signal frequency		5kHz
	Dimensions		205 x 222 x 80mm
	Weight		Approx. 1000g (with battery)
Receiver	Rated power voltage		9.0Vdc (Range: 6.5 to 9.0Vdc)
	Receiver sensitivity level		Select from 5 levels. Each level has 5 level adjust from -20% to +20%.
	Receiver display		Receiving level display: Flashing 10 green LEDs Alarm sound synchronized with LED flash
	Dimensions		235 x 60 x 30mm
	Weight		Approx. 160g (with battery)

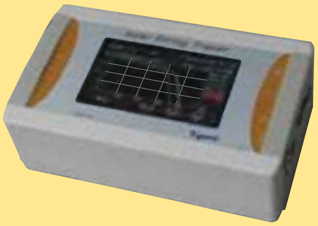
			Procedure		
	Phenomenon	Function	CB	Transmitter	Response of receiver
Functions	No system map and no information on configuration per string	[Magnetic field mode] Configuration check of the string	Off	 Combiner box Connect to breaker for string configuration check.	 No response No response No response Response Pi Pi ··· Receiver shows response by sound and LED.
	Output drop e.g.) cluster failure e.g.)interconnector open-circuit	[Magnetic field mode] Fault point location		 Combiner box Connect to breaker of fault string.	 Flow of signal No response part The fault may be caused by the interconnector open circuit or cluster failure.
	Voc=0 by I-V curve tracer or tester	[Electric field mode] Open-circuit between modules and loose connection, etc.		 Combiner box Connect plus terminal to breaker and minus terminal to earth.	 Flow of signal Area showing response by receiver No response part <Open circuit or loose connection>
Detailed specification page			11 to 14		

PV Doctor

String Tracer

(I-V curve tracer)

SPST-A1A-Y



SPST-A2A-Y1

☆Displaying 4-string I-V curves in a screen

☆Easy determination of faulty module by the relative comparison of strings

☆Usable at the installation inspection

Purpose

Electrical failure of module at string level can be detected in the residential, industrial, and utility-scale PV power generation systems.
Installation inspection and maintenance check can be conducted effectively.

Features

- **Four measuring modes: Individual I-V measurement, simultaneous I-V measurement, string voltage/current measurement, and voltage test**
- **Relative comparison of I-V curves of each string makes the performance check quick and easy.**
- **Measured data can be saved on SD card and used on PC.**

***The data management software is Windows 7 compatible.**

- **For relative comparison among strings, pyranometer and thermometer are not necessary.**
- **For STC conversion, pyranometer and thermometer (options) are necessary.**

Functions

Function	Detail of function
Individual I-V curve measurement CB in the combiner box shall be "OFF".	String I-V curve can be measured by 1 channel at a time. Measured results, up to 4 strings, can be displayed in a graph, and each string condition can be compared relatively. Needle type probes for 1 channel shall be contacted with the terminals of a string at a time; therefore, there is no need to clamp the leads to the terminals.
Simultaneous I-V curve measurement & String condition check CB in the combiner box shall be "OFF".	String I-V curves up to 4 strings for SPST-A1A-Y1 and 2 strings for SPST-A2A-Y1 can be measured at a time, and measured data can be saved. All measured results (max. 4 strings for SPST-A1A-Y1 and 2 strings for SPST-A2A-Y1) can be displayed in a graph, and strings can be compared relatively to check the conditions. V_{OC} is measured to judge whether the relative comparison of I-V curves is effective by checking the string circuit failure, number of string modules, etc.
String voltage/current measurement CB in the combiner box shall be "ON", and inverter shall be under operation.	In a certain intervals, voltage and current of the strings (max. 4 strings for SPST-A1A-Y1 and 2 strings for SPST-A2A-Y1) can be measured at a time, and the data can be saved. ・ Measuring item (voltage/current) and strings can be selected. ・ Continuous measurement up to 7 days is possible. Results can be displayed in either "numerical data" or "graphs" in the screen. * When continuous measurement mode is selected, make sure to use the accompanied AC adapter.
Voltage test (V_{OC} measurement)	Open circuit voltage of a string can be measured.

Specifications

Voltage measuring range	SPST-A1A-Y1	[General (c-Si, CIS, etc.)] *1 20.0V to 700.0Vdc [Hybrid (Si-HJT)] *1,*7 20.0V to 600.0Vdc
	SPST-A2A-Y1	20.0V to 1000.0Vdc
Current measuring range	SPST-A1A-Y1	[General (c-Si, CIS, etc.)] *1 0.5A to 10.0Adc [Hybrid (Si-HJT)] *1,*7 0.5A to 7.0Adc
	SPST-A2A-Y1	0.5A to 10.0Adc
Power measuring range	SPST-A1A-Y1	[General (c-Si, CIS, etc.)] *1 10W to 4900W [Hybrid (Si-HJT)] *1,*7 10W to 2900W
	SPST-A2A-Y1	10W to 8000W
Rated power voltage	[AC adapter] 100V to 240Vac, 50/60Hz [Size AA battery×4] 6.0Vdc (Range: 4.8 to 7.2Vdc) *2, *3	

Accuracy	Voltage: ±1%rdg ±5dgt Current: ±1%rdg ±5dgt	
Measuring points	100 points (per string)	
Measuring time	Approx. 100ms (per string) *4	
Max. continuous use (LCD brightness set: +10) *5	- LCD display on: Approx. 9 hours - Touch screen operation: Approx. 6 hours - I-V measurement: Approx. 4 hours	
Savable data	500 files/day x 100 days = Max. 50,000 files Manage the data with the software in case the number of files exceeds the above. Delete the data in the SD card.	
Other functions	Automatic power off (5 minutes)	
Dimensions	195×115×70mm	
Weight	SPST-A1A-Y1	690g (excl. batteries)
	SPST-A2A-Y1	600g (excl. batteries)
Accessories	Clamp probe, Needle probe: 1set, I-V test lead, SD card *6, AC adapter, Instruction manual, Shoulder belt, Size AA battery: 4, and Carrying case	

*1 Measuring ranges are different depending on the module types.
*2 If battery level is decreased, measurement will stop because the inrush current causes the instant voltage drop.
*3 Battery can be NiMH rechargeable battery or alkaline battery.
*4 I-V curve measurement (individual mode) takes 3.1 sec to measure a string: 1sec for probe contact check + 100ms for I-V measurement + 2 sec for the interval until the next measurement
I-V curve measurement (simultaneous mode) needs 5 sec interval between measurements. Within 5 sec after a string measurement, start selection button will not be shown on the screen.
*5 Hours are based on the continuous use of full charged four(4) 1900mAh NiMH batteries.
*6 SD card contains the data management software and software installation manual.
*7 "Hybrid (mode)" can measure heterojunction modules including HIT modules.
In case the amount of solar radiation is more than 1000w/m^2, this product may not be able to use.
Not at all modules can be measured with this product.

Accessories


Clamp probes
(SPST-A1A-Y1: 4 sets)
(SPST-A2A-Y1: 2 sets)


Needle probes


I-V test leads
(SPST-A1A-Y1: 4 sets)
(SPST-A2A-Y1: 2 sets)


AA alkaline batteries


SD card


AC adapter


Carrying case

Options


Clamp sensor

Type	SPST-A-F1
Measuring range (accuracy)	0 to 10.0A (±1%rdg ±5dgt)
Length of cable	1.5 meters
Weight	80g/unit


Pyranometer & thermometer

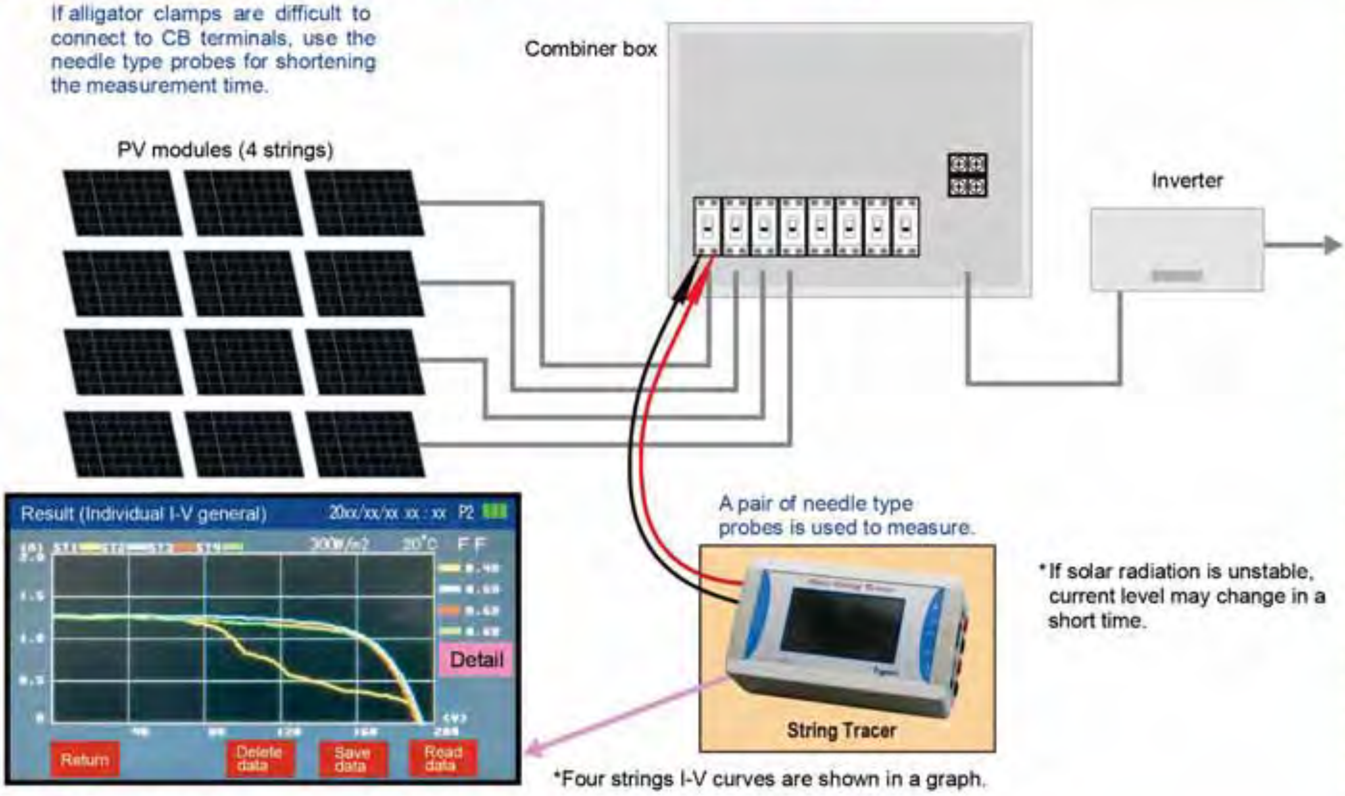
Type	SPST-A-F2
Measuring range (accuracy)	0 to 1200W/m^2(±5%rdg ±5dgt) -20 to 100℃(±1%rdg ±2dgt)
Length of cable	10 meters
Dimensions	Pyranometer: 40x100x80(mm) Thermometer: 50x70x6(mm)
Weight	Pyranometer: 700g Thermometer & cable: 720g


Magnetic test probe

Type	SPST-A-F4
Length of cable	1.5 meters
Withstand voltage	1000V CATIII

I-V curve measurement modes

(1)Individual mode (CB in combiner box: OFF)



If alligator clamps are difficult to connect to CB terminals, use the needle type probes for shortening the measurement time.

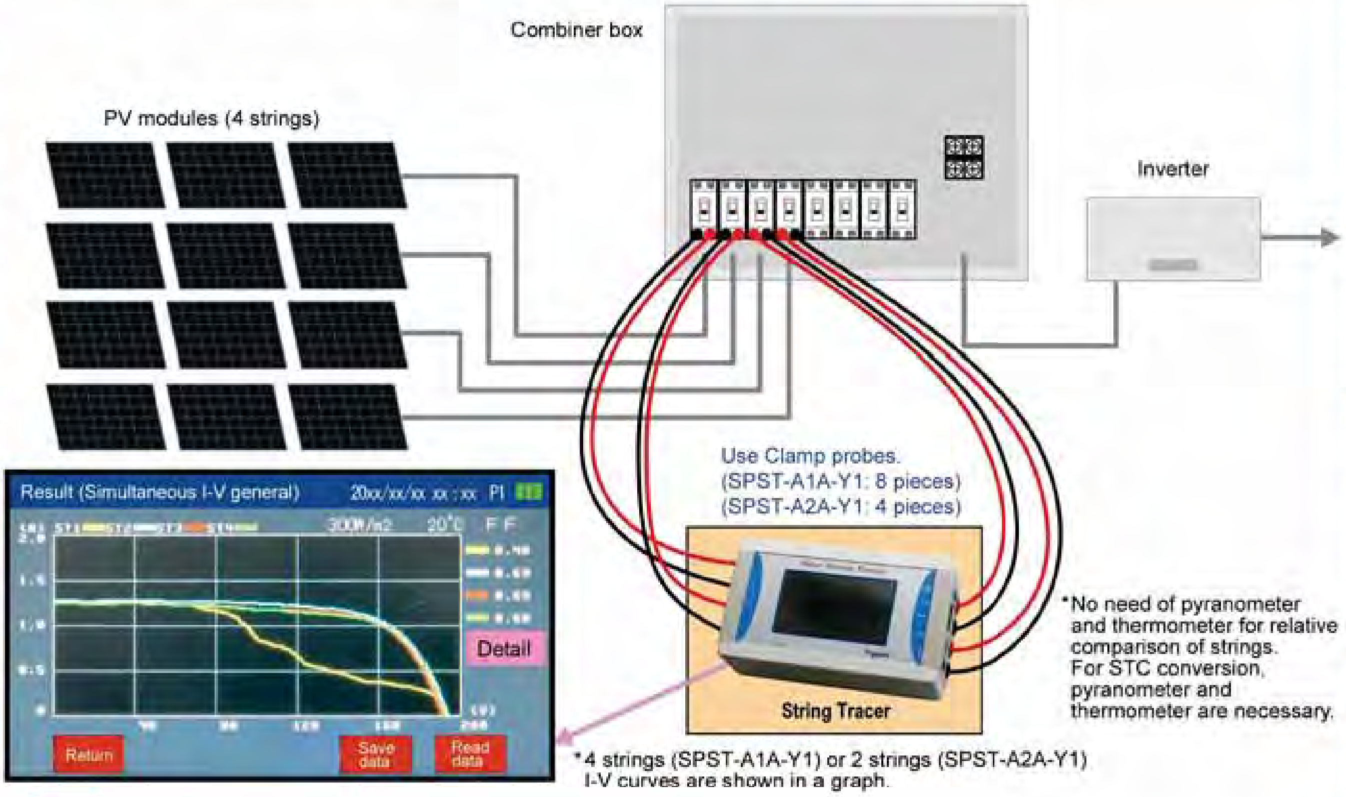
A pair of needle type probes is used to measure.

*If solar radiation is unstable, current level may change in a short time.

*Four strings I-V curves are shown in a graph.

If **Detail** is selected, measured results: V_{oc} (V) open-circuit voltage, I_{sc} (A) short-circuit current, P_{max} (W) Maximum power, and FF value are shown.

(2) Simultaneous mode (CB in combiner box: OFF)



Use Clamp probes.
(SPST-A1A-Y1: 8 pieces)
(SPST-A2A-Y1: 4 pieces)

*No need of pyranometer and thermometer for relative comparison of strings. For STC conversion, pyranometer and thermometer are necessary.

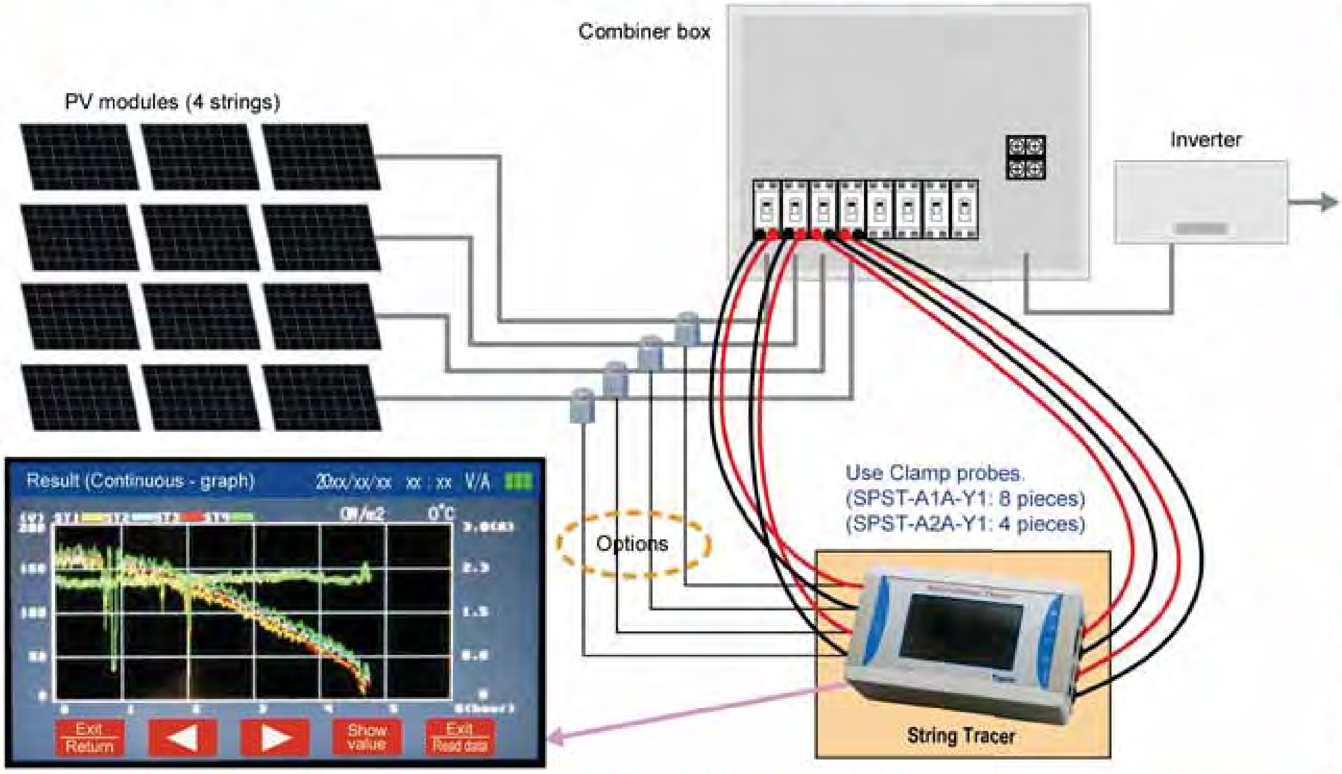
*4 strings (SPST-A1A-Y1) or 2 strings (SPST-A2A-Y1) I-V curves are shown in a graph.

If **Detail** is selected, measured results: V_{oc} (V) open-circuit voltage, I_{sc} (A) short-circuit current, P_{max} (W) Maximum power, and FF value are shown.

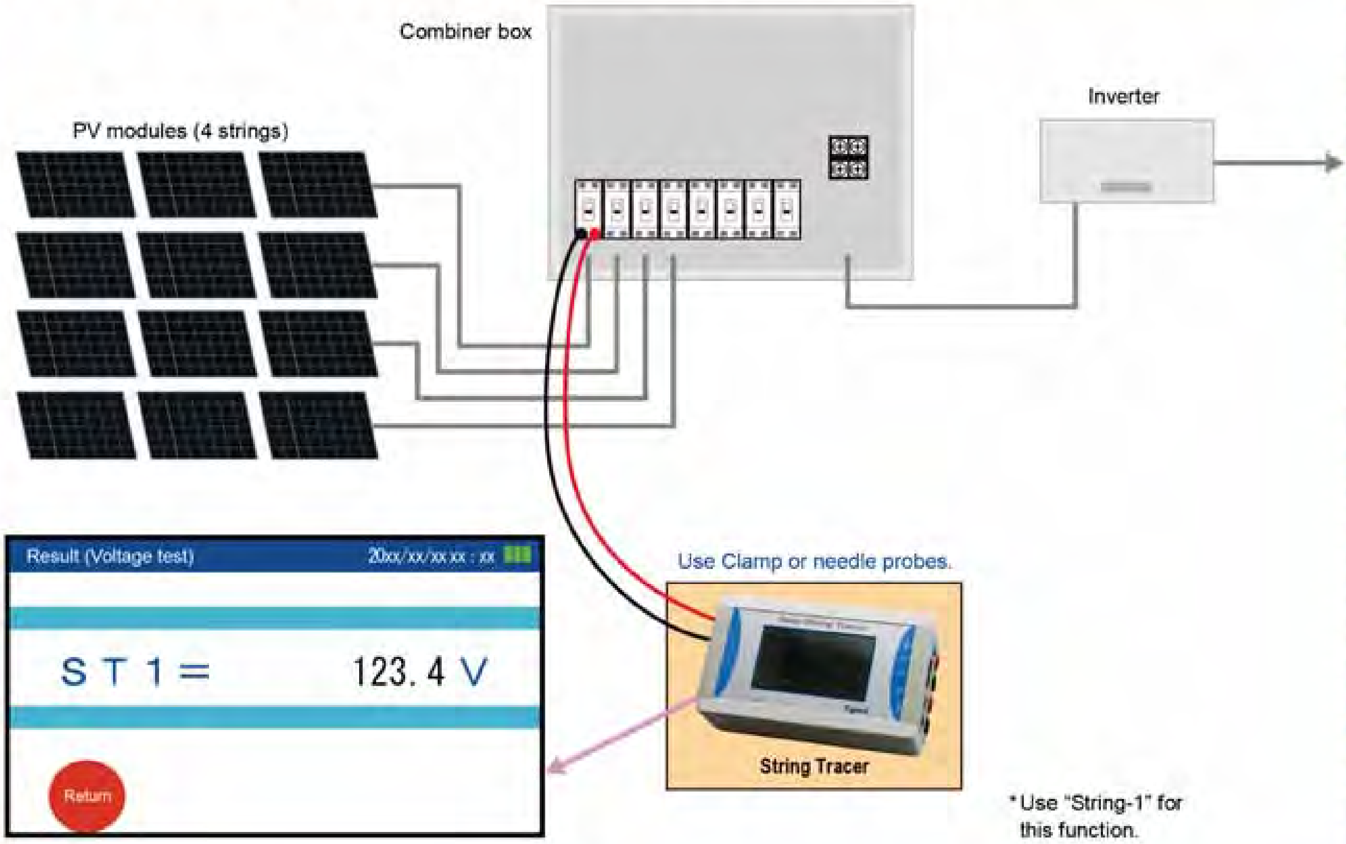
(3) String voltage/current measurement

(CB in combiner box: ON & Inverter: operation)

In a certain intervals, voltage and current of the strings (max. 4 strings for SPST-A1A-Y1 and 2 strings for SPST-A2A-Y1) can be measured at a time, and the data can be saved for maximum 7 days. * Clamp CT sensors (option) are necessary.



(4) Voltage test (Open-circuit voltage measurement)



Result (Voltage test) 20xx/xx/xx xx : xx

ST1 = 123.4 V

* Use "String-1" for this function.

PV Doctor

Cell LineChecker

(Fault module detector)

SPLC-B-Y

☆String configuration can be identified.
☆Fault point (wiring failure) can be detected.
☆Shadow on the module will not affect the results.
☆Installation inspection is effectively conducted.
☆Detection can be conducted on the rear surface of modules.

■ Purpose

Detect the string configuration and fault module and cell at the time of PV systems maintenance.

■ Features

➢ **Cluster failure and bypass diode open circuit can be easily detected.**	[Magnetic field mode]
➢ **Open circuit or loose connector between modules can be detected.**	[Electric field mode]
➢ **Detection can be conducted under the cloudy weather.**	
➢ **Cell interconnector failure can be detected; therefore, module power output reduction is possibly predicted.**	[Magnetic field mode]

[Magnetic field mode]
- Identification of a string configuration
- Detection of fault modules, clusters, and cells
- Detection of the fault bypass diode in a module

[Electric field mode]
- Detection of the broken/disconnected wire between modules
- Detection of the connecter between modules having fault continuity

Quality of installation of PV system can be enhanced because Cell LineChecker can detect the wiring and connector failures between modules.

Detailed functions depending on module fault causes

Phenomenon	Details of failure phenomenon	Causes	Applicable functions
Decline of power output	**No output from the string** *Series circuit in a string is disconnected.	(1) Broken/loose connector or disconnected wire between modules (2) Damaged bypass diode and disconnected busbar, disconnected interconnector, or damaged cell	[Magnetic field mode] ・Detection of fault module ・Detection of wiring failure between modules [Electric field mode] ・Detection of connector having defective continuity or wiring disconnection
	Declined output from the string *Series circuit in module is disconnected.	(1) Fault busbar (2) Complete interconnector disconnection (3) Cell damage (severe)	[Magnetic field mode] ・Detection of fault module ・Detection of fault cluster in the fault module ・Detection of fault cell in the fault module ・Detection of fault bypass diode
	Declined output from the string *Part of series circuit in module is damaged.	(1) Disconnection of one of interconnectors (2) Cell damage (light)	

Specifications

【Transmitter】

Rated power voltage	9.0Vdc (Range: 6.5 to 9.0Vdc) *1	
Applicable voltage range	Magnetic field mode	15.0Vdc to 1000.0Vdc
	Electric field mode	0V to 1000.0Vdc (0V for connection fault detection)
Detecting method	Current consumption (Magnetic field mode) Signal input (Electric field mode)	
Signal frequency	5kHz	
Display	Green or Blue LED by flashing or ON	
Dimensions	205 x 120 x 50mm	
Weight	Approx. 1000g (with battery)	
Other functions	Auto-power off *2	

【Receiver】

Rated power voltage	9.0Vdc (Range: 6.5 to 9.0Vdc) *1
Receiver sensitivity level	Select from 5 levels. Each level has 5 level adjust from -20% to +20%.
Receiver display	Receiving level display: Flashing 10 green LEDs Alarm sound synchronized with LED flash
Built-in sensor	Coil sensor: 1 Electrode sensor: 1
Dimensions	235 x 60 x 30mm
Weight	Approx. 160g (with battery)
Other functions	Auto-power off and Silent mode *3

*1 One 9V battery is used. (Manganese or alkaline battery)
*2 [Magnetic field mode] The power is automatically turned off when input voltage gets less than 10V and non-operated duration exceeds 10min.
[Electric field mode] The power is automatically turned off when non-operated duration exceeds 2hr.
*3 The power is automatically turned off when no signal input and non-operated duration continues 10min.

Accessories

Clamps and test leads

Rubber sheet

Carrying case

Options

Rod sensor

Type	SPLC-B-F1Y
Built-in sensor	2 coil sensors (horizontal & vertical)
Rod length when detecting	Max. 2meters (0.92meter when storing)
Dimensions when storing	920(H)×70(W)×60(D) (mm)
Weight	Approx. 850g (without receiver)
Other function	Angle adjustable sensor head
Accessories	Storage bag and shoulder belt

Needle probe

Type	SPST-A-F3
Withstand voltage	1000V CATIII

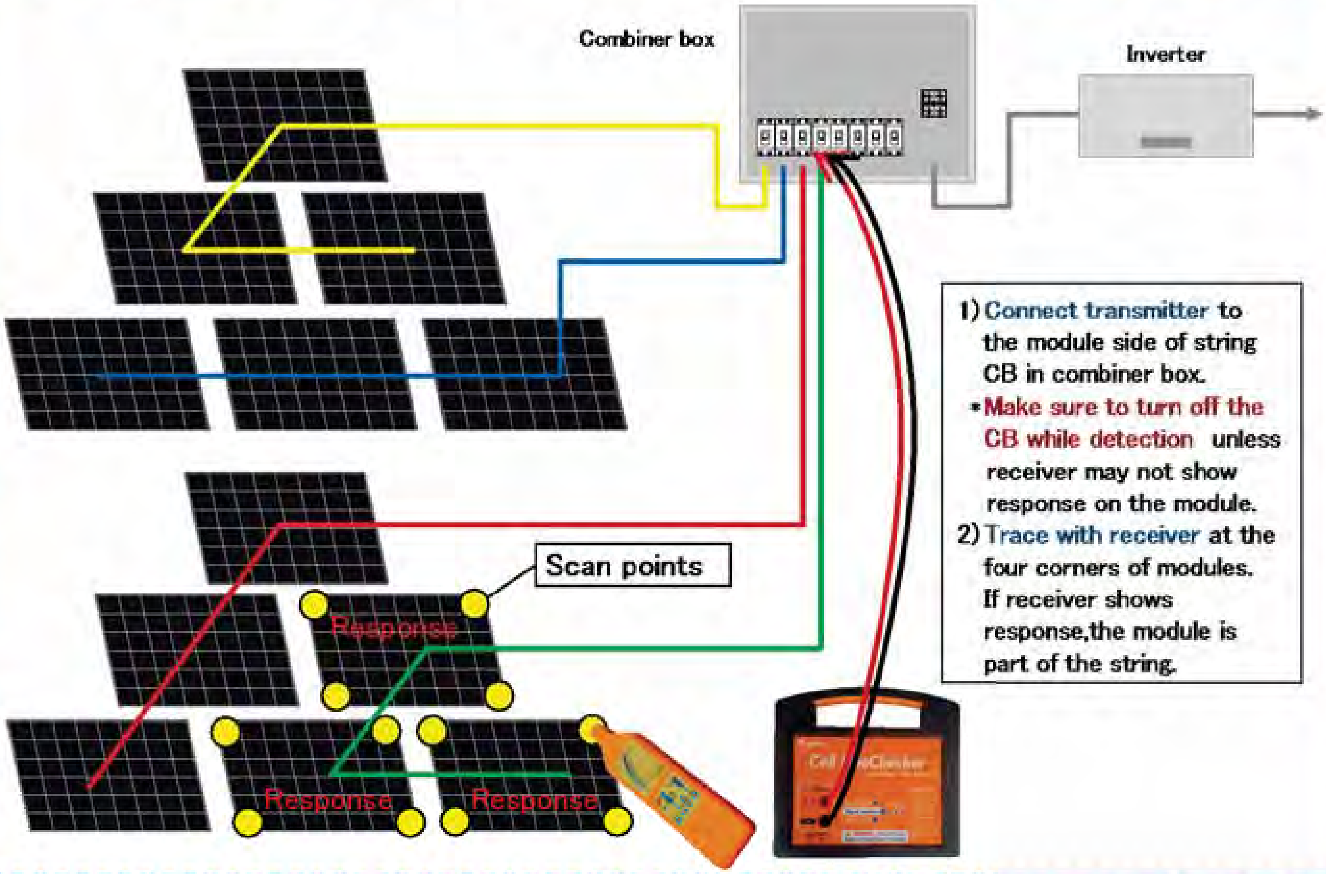
Magnetic test probe

Type	SPST-A-F4
Length of cable	1.5 meters
Withstand voltage	1000V CATIII

Example of detection

<String configuration check>

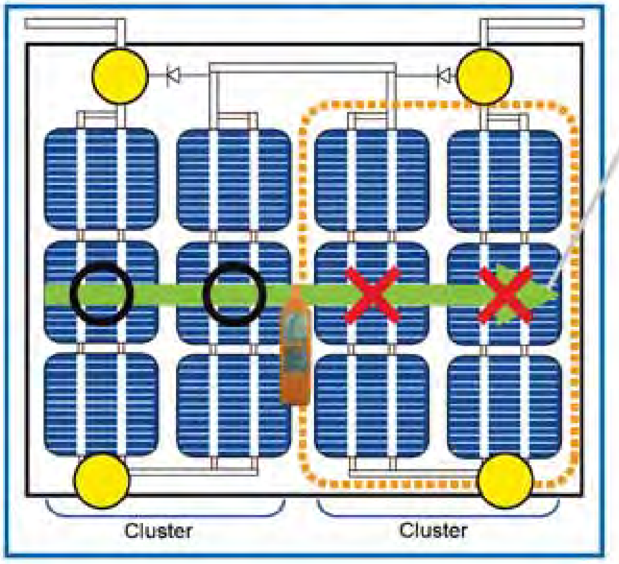
【Magnetic field mode】



1) Connect transmitter to the module side of string CB in combiner box.
*Make sure to turn off the CB while detection unless receiver may not show response on the module.
2) Trace with receiver at the four corners of modules. If receiver shows response,the module is part of the string.

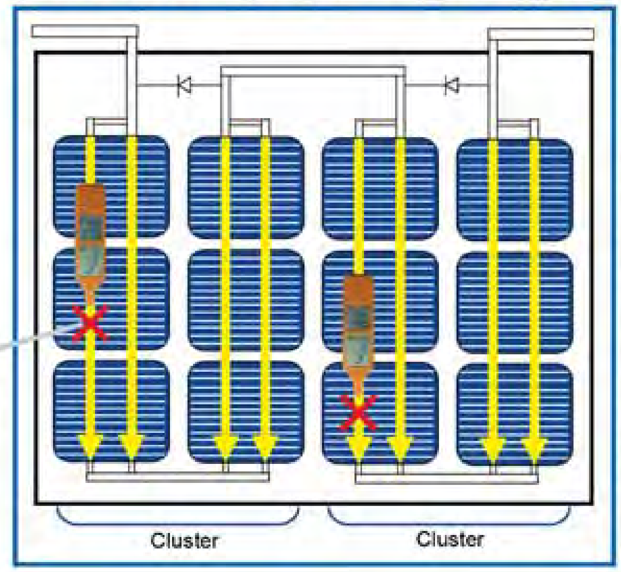
<Detection of fault (non-generating) module>

[Magnetic field mode]



1) Trace with receiver across the clusters in a module. If there is any module which does not show any response with receiver, the module/cluster has failure.
* If the module has 2 clusters, trace the module at the four corners. If there is any corner which does not show response, the module/cluster has failure.

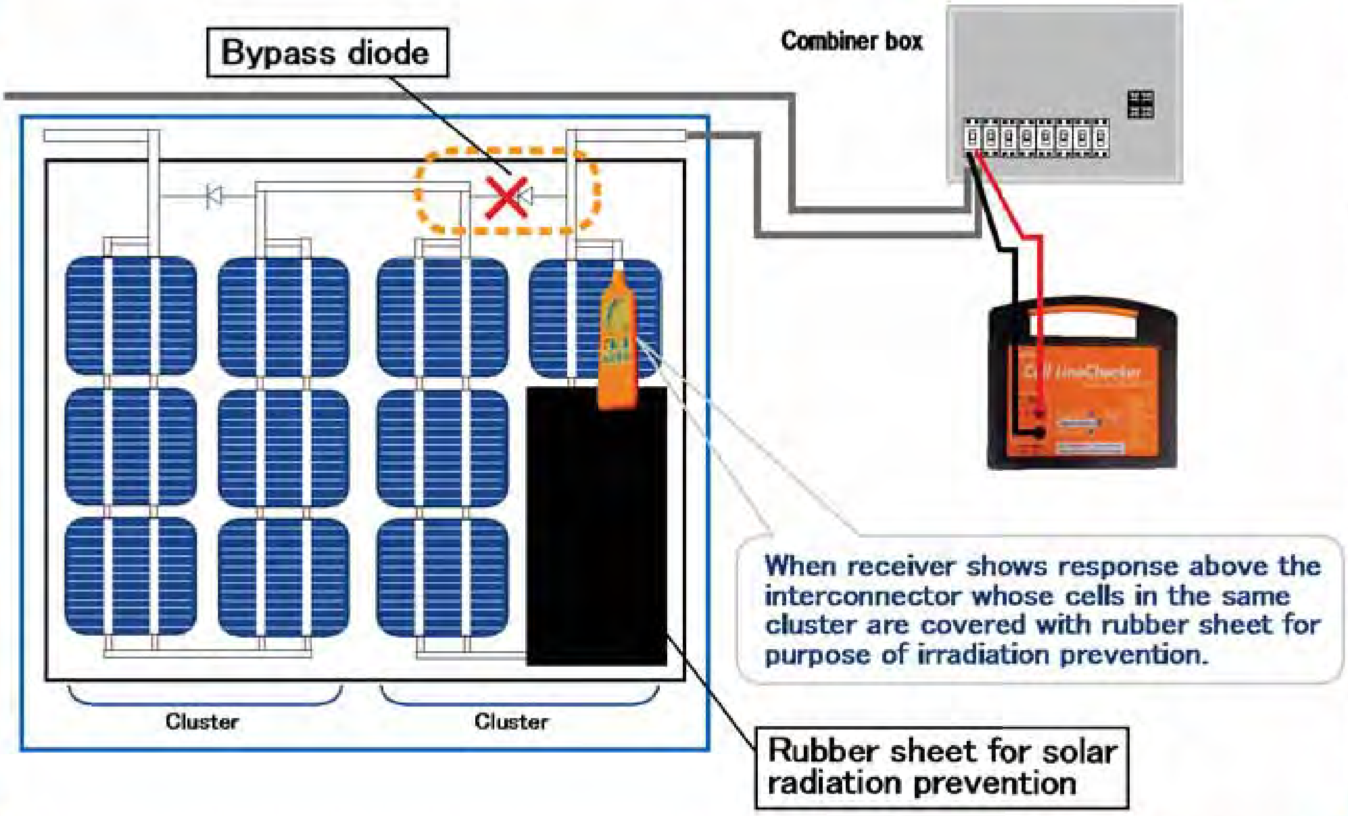
<Detection of fault (low-generating/heating) cell>



1) Trace along the interconnectors. If there is any interconnector which does not show any response, the interconnector has failure.

<Detection of fault module (bypass diode open circuit failure)>

【Magnetic field mode】



When receiver shows response above the interconnector whose cells in the same cluster are covered with rubber sheet for purpose of irradiation prevention.

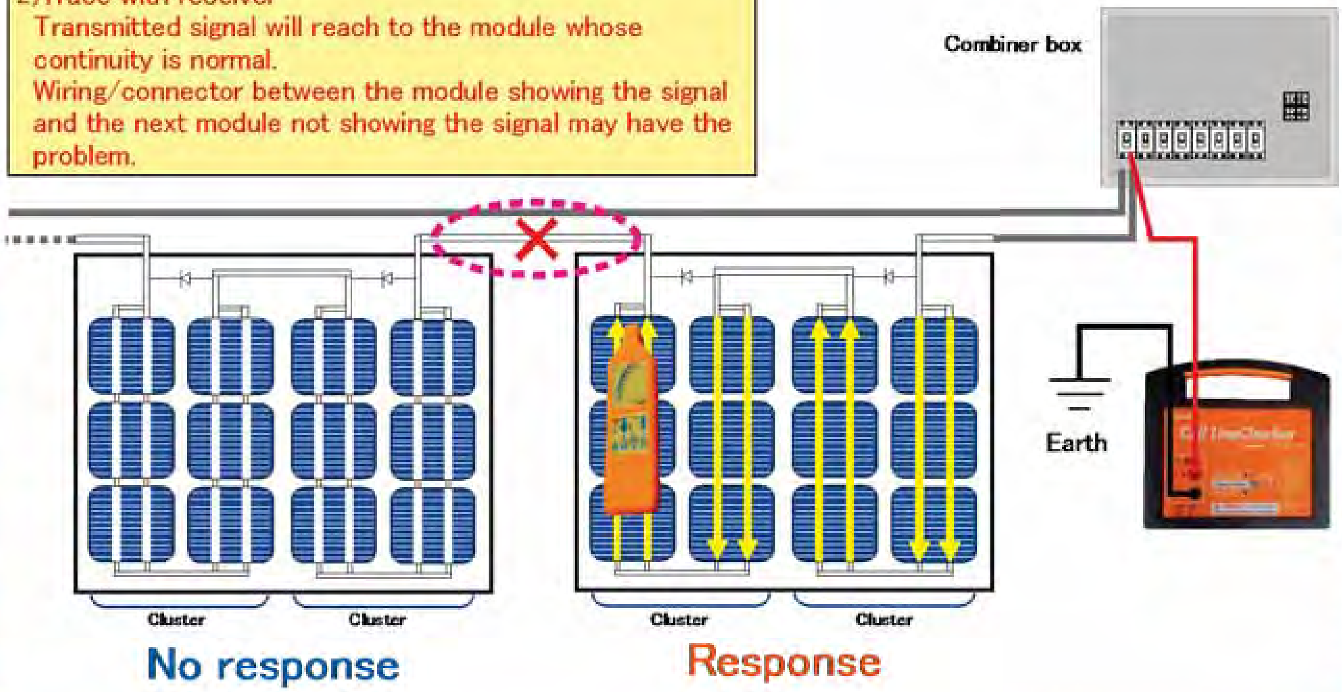
Rubber sheet for solar radiation prevention

<Detection of wiring/connector failure between modules>

【Electric field mode】

1)Connect transmitter
Connect the plus terminal of transmitter to one of the string CB terminals and the minus terminal to the earth.

2)Trace with receiver
Transmitted signal will reach to the module whose continuity is normal.
Wiring/connector between the module showing the signal and the next module not showing the signal may have the problem.



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03.2 Togami String Tracer instruction manual

INSTRUCTION MANUAL

String Tracer Model: SPST-A2A-Y1

- This instruction manual describes the operation and maintenance for the correct and safe use of String Tracer.
  Thoroughly read and understand the information contained in this instruction manual before operating String Tracer.
- After reading, keep this instruction manual for future reference.

Instruction manual
No. 01147

Togami Electric Mfg.Co.,Ltd.

Contents

1. Safety Precautions

- In order to prevent accident and injury, the following points should always be observed. Please be proficient in the knowledge of product, safety information, and precautions before operating String Tracer. After reading, please keep this instruction manual at hand and refer to it when necessary.

⚠ DANGER If mishandled, dangerous situations leading to fatal or serious injuries may occur.

- To avoid electric shock, always wear rubber insulated gloves and electrical safety shoes when connecting the I-V test probes to the equipment.
- To avoid electric shock, remove I-V test probes when replacing the batteries.
- To avoid electric shock, damage, and fire, never use this equipment with the PV module or string having higher output ratings (Voc) than the ratings of the equipment.
- To avoid electric shock and damage, never disassemble or modify the equipment.
- To avoid electric shock and damage, never use this equipment in wet conditions or damp locations.
- To avoid electric shock, never connect any cables or other equipment to this equipment other than those provided by the manufacturer.
- To avoid electric shock and damage, make sure to turn on and off the string circuit breakers depending on the detection.
- To avoid electric shock and damage, never measure the circuit breakers of main power source with this equipment.

⚠ CAUTION If mishandled, dangerous situations leading to minor injuries or physical damages or damages to the equipment may occur.

- To avoid damage, use the enclosed AC adapter.
- To avoid damage, if it is not used for a long time, please remove the battery for proper keeping.
- To avoid electric shock and damage, if the equipment is dropped, check whether there is no damage to the case or it does not show abnormal function prior to use. For the possibility of internal damage, request for inspection.
- To avoid damage, never use this equipment other than the I-V curve measurement of photovoltaic modules.
- To avoid damage, if any kind of voltage step-up device is equipped in the string to be measured, disconnect the device from the string.
- To avoid waveform turbulence and damage, make sure that the I-V test probe is firmly in contact with the terminals.

2. Product overview

String Tracer is designed to detect the electrical characteristic degradation and failure of photovoltaic module and string.

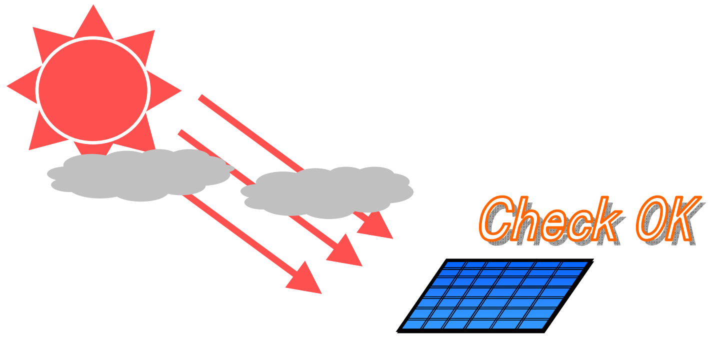
Maximum 4 measured I-V characteristic curves can be displayed in a graph, which enables to compare the condition of PV module relatively among strings under the approximately same conditions. At the installation site of PV systems, inspection at installation and periodical inspection can be conducted in a short time. (For individual I-V curve measurement)

Since I-V curve and voltage/current measurement can be done simultaneously in 2 strings, it enables to easily determine the failures of specific string by relative comparison among several strings regardless of changes in the weather. (For simultaneous I-V curve measurement)

When pyranometer and thermometer (options) are used, the conversion of the measured data to standard testing condition (STC) with the data of solar irradiance and PV module temperature during measurement is possible in the PC software. (The equipment itself can convert only the value.)

* This I-V curve tracer is designed to be less affected by the change in solar irradiance and focused on the workability in the field to quickly measure the I-V curve. Therefore, it is not suitable to be used to measure and detect a slight change in the module characteristics as the research application. Use an appropriate I-V curve measuring equipment for such usage.

Check the module condition without being affected by weather.



3. Features

- Individual measuring mode enables to quickly measure the I-V curves by bringing the probes into contact with the terminals, which shortens the measurement time even in the large-scale solar systems having numerous strings.

- Simultaneous measuring mode enables to measure I-V curves of 2 strings at the same time and to detect the properties degradation of modules without using pyranometer and thermometer.

- Measured data are displayed in a same graph for easy relative comparison.

- String voltage and string current can be measured. (Maximum of 7 days continuous measurement)
  * String current measurement requires an optional clamp CT sensors.

- Measured results are save on the memory card (SD card/multi-media card) and can be used in the PC as CSV file without connecting String Tracer to the computer.

- Battery powered and compact size main part enables its portability.
  * Continuous string voltage and current measurements require AC adapter.
    (When the equipment is powered by the battery, the measurement can be stopped before reaching to the set period due to voltage drop of battery.)

- I-V curve of a single module can be measured.
  * Some module whose specification is other than IEC standard may not be able to be measured. Be sure that the module to be measured conforms to specification of the string tracer shown on P8.

- Open-circuit voltage (Voc) can be measured like a voltage tester.

4. Product components

Upon delivery, unpack and inspect the components and for any damage. If any damage or lack of component is discovered, please contact our distributor/manufacturer. Components are indicated in the table below.

No.	Part	Function/purpose	Quantity
①	String Tracer	Main body of String Tracer containing touch screen LCD and input terminals for setting the measurement condition and conducting measurement	1 pc
②	Clamp probe	Probe to connect to ④I-V test lead for simultaneous measuring mode (2 string for simultaneous measurement of I-V curve) and voltage measurement 1set: red and black	2 sets (4 pcs)
③	Needle probe	Probe to connect to ④I-V test lead for individual measuring mode (1 string for each measurement of I-V curve) 1set: red and black	1 set (2 pcs)
④	I-V test lead	Connect to the String Tracer, install② or③ probe and connect to PV module 1set: 1.5 m red and black	2 sets (4 pcs)
⑤	SD card (2 GB)	- For measured data saving and update of program - Containing the data management software [*1 & *2] Containing the -instruction manual of String Tracer and data management software and the software installation procedure to PC.	1 pc
⑥	AC adapter (6.0 Vdc)	For power supply to String Tracer (Not for charging the batteries inserted into the main body)	1 pc
⑦	Instruction manual	Precaution and instruction of String Tracer⑤SD card also contains its PDF version.	1 pc
⑧	Shoulder belt	Belt for String Tracer and Carrying case	1 pc
⑨	AA alkaline battery	For power supply of String Tracer	4 pcs
⑩	Carrying case	For storing the items of ① to ⑨ above	1 pc

*1 PC software and instruction manual are recommended to be saved in your computer as backup copies in case of SD card loss.

*2 Check whether your software is the latest version on our website. If needed, download the latest version.

Figure 4-1: Standard scope of supply

(The numbers indicated above correspond to the table in the previous page.)

【Option】

Model No./name	Purpose
SPST-A-F1-Y1 /Clamp CT sensor	- For current measurement with the inverter operated - Purchase the required number of sensors, depending on the number of strings to be measured simultaneously (up to 2 strings) - For measuring the output power
SPST-A-F2-Y1 /Pyranometer and thermometer	- For measuring the solar irradiance and temperature when measuring the I-V curves - By measuring the solar irradiance and the temperature at the back of the module, measured I-V curves can be converted to the value at the standard testing condition (STC) of the string. STC conversion can be conducted in the PC software. (PC software can convert both the carve and value and the String Tracer itself can convert ony the value.)
SPST-A-F4 /Magnetic probe with test lead	- For the Simultaneous measuring mode and voltage measurement but cannot be connected to the screws made from stainless or brass 1set: red and black

5. Specifications

5.1 Condition of use

Item	Condition
Environment	Avoid using in the rain
Temperature range	-10 to 50°C (14 to 122°F)
Humidity range	Relative humidity: 80% or less (No condensation)
Storage temperature range	-20°C to 60°C (-4°F to 140°F)

5.2 Ratings

Item		Condition
Rated power voltage	AC adapter	100Vac to 240Vac, 50Hz/60Hz
	AA type battery	6.0Vdc (4 AA type batteries) Operation range: 4.8Vdc to 7.2Vdc *1&*2

*1 When the battery level drops, measurement will be stopped because inrush current at the measurement temporarily lowers the voltage.

*2 Nickel metal-hydride rechargeable battery and alkaline battery can be use.

Item	Module type	
	General (Silicone and compound)	Hybrid
Voltage range	20.0 to 1000.0Vdc	
Current range	0.5 to 10.0A	
Power range	10 to 8000W	

Measurement ranges are different from the module type.

⚠ DANGER

Voltage and current ranges indicate the open-circuit voltage (Voc) and short-circuit current (Isc) respectively. Using the equipment in the ranges other than indicated above may cause damage to the equipment. For safety reasons, use the equipment within the rated ranges.

5.3 Ratings (String Tracer)

Accuracy	Voltage: ±1%rdg ±5dgt Current: ±1%rdg ±5dgt
Measuring points	100 points (per string)
Measuring time	Approx. 100ms (per string) [*1]
Battery life [*2] (LCD brightness set as +10)	- Continuous LCD display on : Approx. 9 hours - Continuous touch screen operation : Approx. 6 hours - Continuous I-V measurement : Approx. 4 hours
Protection functions	- Measurement stop by detecting the voltage above the rating - Measurement stop by detecting the current above the rating - Measurement stop by detecting the power above the rating - Heat protection and message display for 30sec if the measuring power gets above 4000W[*3]
Savable data	500 files/day × 100 days = Max. 50,000 files Manage the data with the software in case the number of files exceeds the above. Delete the data in the SD card so it does not exceed the above mentioned numbers.
Other functions	Automatic power off (5 minutes)
Dimensions	195 × 115 × 70mm (7.7 × 4.5 × 2.8 in)
Weight	690g (24.4oz) without batteries

*1 I-V curve measurement (individual mode) takes approximately 3s to measure a string: 1s for probe contact check + 100ms for I-V measurement + 2s for the interval until the next measurement.

I-V curve measurement (simultaneous mode) needs 5s interval between measurements.

Within 5s after a string measurement, “Start” will not be displayed on the screen.

*2 Hours are based on the continuous use of full charged 4 pieces of 1900mA/h NiMH batteries.

Note: When using a small capacity battery, such as alkaline batteries, the maximum continuous use duration gets shorter.

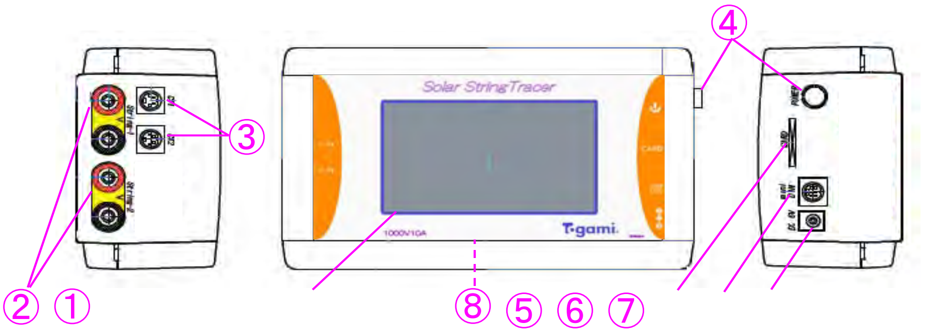
5.4 Ratings (options)

Clamp CT sensor	Measuring range (accuracy)	0 to 10.0A (±1%rdg ±5dgt)
	Length of cable	1.5 m (4.9ft)
	Weight	80g/unit
Pyranometer [*1] & thermometer [*2]	Measuring range (accuracy)	0 to 1200W/m^2 (±5%rdg ±5dgt) -20 to 100 °C (±1%rdg ±2dgt)
	Length of cable	10.0 m (33ft)
	Dimensions	Pyranoometer: 140 × 100 × 80 mm (5.5 × 3.9 × 3.2 in) Thermometer: 50 × 70 × 6 mm (2 × 2.8 × 0.2 in)
	Weight	Pyranometer: 700g (24.7oz) Thermometer & cable: 720g (25.4oz)
Magnetic probe with test lead	Length of cable	1.5 m (4.9ft)
	Withstand voltage	1000V CATIII

*1 When using pyranometer, leave it under the sun for more than 30s until the start of measurement. (Response time of pyranometer: within 30 s)

*2 Thermometer shall be left under the sun until the measuring temperature gets stable. (Wait until the temperature of meter installation bracket and the modules are approximately the same.)

6. Name and function of each parts



No.	Name	Function
1	LCD touch screen	For setting and displaying measurement results
2	I-V connecter	For connecting I-V test leads used for the measurement of voltage and I-V curves - Red test leads shall be connected to positive terminals of the PV modules and the black one to the negative.
3	Clamp CT sensor connecter	For connecting optional clamp CT sensors used for the measurement of string current *Make sure of its insertion direction.
4	POWER button	For turning on and off the power - Push and hold this button for more than 2s to turn on and off.
5	SD card slot	For SD card insertion to save the result data
6	miniDIN connecter	For connecting the optional pyranometer/thermometer used to measure the solar irradiance and temperature of PV module at the time of I-V curve measurement. *Make sure of its insertion direction.
7	DC plug	For AC adapter (6Vdc) connection used when conducting the continuous measurement (max. 7 days) and using the equipment without AA batteries * Never use the AC adapter other than provided.
8	Battery box (rear side)	For storing 4 AA batteries as the power source (The voltage of 1.2V to 1.5V AA batteries can be used.)

7. Usage

⚠ CAUTION
⚠ DANGER
Thoroughly read the followings for correct use.

7.1 Precautions

(1) Power on and off

⚠ CAUTION - Press and hold the power button for 2s or more to turn on and off the power.

(2) Connection

⚠ DANGER - To avoid electric shock accident, always use the insulation protection tools when connect I-V probe and String Tracer.

⚠ CAUTION - Perform the measurement with the voltage step-up device disconnected if such a device is connected to the measuring strings.

⚠ CAUTION - To avoid contact failure, insert each connector firmly.

(3) Operation

⚠ CAUTION - LCD touch screen is pressure-sensitive. To avoid any malfunction, do not apply excessive pressure to the screen.

⚠ CAUTION - LCD touch screen cannot respond to simultaneous touches at 2 points or more.

⚠ CAUTION - Power of the equipment automatically turns off if it is left unoperated for 5 minutes.

(4) Handling

⚠ CAUTION - If the equipment is dropped to the ground, use after checking the damage to the case and operating malfunctions.

⚠ CAUTION - Change the batteries as soon as possible, if low battery sign is displayed.

(5) Data saving

⚠ CAUTION - Recommended capacity of SD card and multimedia cards is 2GB or less.
*The saved data may not be able to be read when the capacity is more than 2GB.

(6) Measuring I-V curves

⚠ CAUTION - Select the right module type on the condition setting screen, and measure I-V curves. Module type shall be selected either General or Hybrid.
* See P14 (9) for further details regarding the selection of module type.

(7) Results of measurement

⚠ CAUTION This product is the indicator of output performance of a PV system through tracing. It can't be determined whether there is any abnormality or fault on the system. The final judgement whether it is normal or abnormal shall follow the user's standard.

* Fully understand and consider the influence of measurement circumstance on the measured result in case of abnormality determination based on the results of this product. There are various aspects on output characteristic of PV system. The characteristic is easily changed by the circumstance which every single PV system has each own. For example, natural condition, such as irradiation and temperature, level of pollution on PV modules, bird and animal damages etc. Furthermore, the output of each string is different, if not all strings in a power collection or a combiner box have the same structure.

(See to P68 for the typical aspects of the abnormalities.)

(8) Effect of electrostatic capacitance

⚠ CAUTION In case of measurement of hybrid modules, such as heterojunction and back contact type, the string tracer executes its fail-safe feature due to overcurrent to prevent damage, even if the specifications of these module satisfy the applicable range of the string tracer.

Transient current of such modules, can be extremely large due to the influence of electrostatic capacitance inside the module. This transient current may be more than the rated short-circuit current (I_{SC}), such as 10A or more, shown on the specification of the module.

(9) Selection of module type

[ATTENTION]

If the PV module type is not selected properly, the following may occur;

1. Measurement error will increase, and,
2. Measurement will be suspended.

[General]

- The default setting after turning on this product is "General".
- "General" modules are mono- and poly-crystalline silicone and compound based modules. Influence of transient current by electrostatic capacitance upon those modules is relatively low. This influence is shown on P13 (8).

※ We have recently faced on the report that these electrostatic capacitance may influence even these General modules.

If the module to be measured is not the following mentioned hybrid type and the result of the measurement causes an error due to excessive ratings, such as Isc error, try the following measurement for "Hybrid" modules.

[Hybrid]

- The modules with large electrostatic capacitance, such as heterojunction and back contact type, shall be measured by "Hybrid" mode.

※ If electrostatic capacity exceeding the allowable capacity of this product is accumulated due to progress in module performance, the product may not be able to measure properly.

When Isc error is indicated on the display, follow the procedure shown on P66. If this procedure doesn't resolve the error, contact to our customer service indicated on the back cover of this manual.

7.2 Overview of functions

(1) The overview of main screen and operation buttons are indicated below.

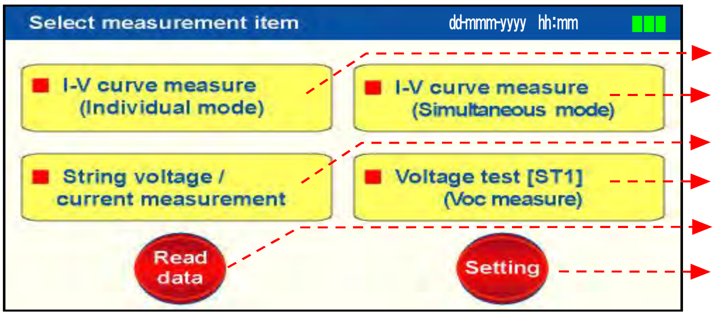
Press "Return" to go back to the previous screen of each screen.

【Screen 1】

This screen is displayed for 3 seconds when the power turns on.

【Screen 2】

Selecting measurement options:



【Refer to clause 7.3】
【Refer to clause 7.4】
【Refer to clause 7.5】
【Refer to clause 7.6】
【Refer to clause 7.7】
【Refer to clause 8】

(2) The measurable inverter status in each measurement mode are indicated in the tables below. Inverter status must be checked and confirmed before starting the measurement to avoid an invalid measurement or damages to the equipment.

/ Combiner box with blocking diodes. (In other words, the current doesn't sneak from non-measured strings to the measured strings.)

The blocking diode is a diode that can avoid an adverse current from inverters or other strings.

	Inverter operation stop	Inverter under operation
I-V curve measurement (Individual mode)	1 or 2 channel use only	1 or 2 channel use only
I-V curve measurement (Simultaneous mode)	1 to 2 channels simultaneous use	Not measurable
String voltage measurement	1 to 2 channels simultaneous use	1 to 2 channels simultaneous use
String current measurement	Not measurable	1 to 2 channels simultaneous use
Voltage test	1 channel use only	1 channel use only

ii. Combiner box without the blocking diode[*1]

	Inverter operation stop	Inverter under operation
I-V curve measurement (Individual mode)	1 or 2 channel use only	Not measurable
I-V curve measurement (Simultaneous mode)	1 to 2 channels simultaneous use	Not measurable
String voltage measurement	1 to 2 channels simultaneous use	1 to 2 channels simultaneous use[*1]
String current measurement	Not measurable	1 to 2 channels simultaneous use
Voltage test	1 channel use only	1 channel use only[*2]

[*1] In case of a combiner box with fuses, the box doesn't contain blocking diodes. Remove fuses from the box before IV measurement.

[*2] Measurement is possible, but its result may not be accurate due to the sneaking current from non-measured strings.

7.3 I-V curve measurement (Individual mode) 【Inverter: stop or under operation】

Purpose

Measuring I-V curves up to 4 strings in order and displaying the results on the same graph. Conditions of strings can be determined by comparing the I-V curves.
This method is useful when the clamp type I-V probes are difficult to connect to the circuit breakers equipped in the combiner box and the solar irradiance is stable.

Important notes for individual mode

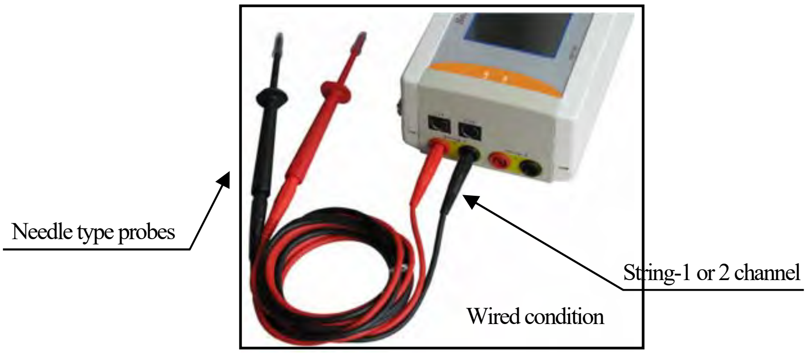
- If the solar radiation changes frequently, the maximum string output current changes significantly in a short time, which leads to an erroneous determination of fault string.
- If the status is set as the inverter "system interconnected" in "8.4 Measurement condition setting," the measurement would stop when the measuring voltage gets higher than the set value.
- The measured data may not be as accurate with the inverter operated when measuring the hybrid type modules.

【Preparation】

(1) Connect the needle type I-V probes to the I-V test leads.

(2) Connect I-V test leads to the connecters of String-1 channel or -2 channel of String Tracer.

* Make sure to always hold the connecter when inserting the connecter into or removing it from the string tracer.

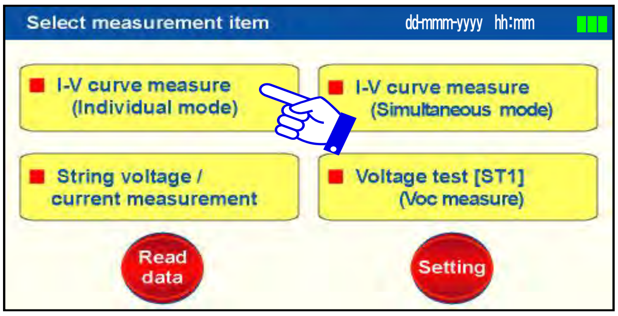


【Measurement】

(1) "Turn off "the string circuit breaker.

(2) Turn on the power of String Tracer by pressing and holding the power button for 2 seconds or more.

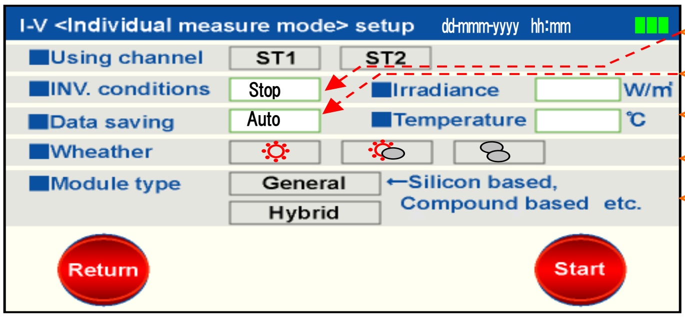
(3) Meas ment item selection screen【Screen 3】is displayed, then select "I-V curve measure (Individual mode)" button.



【Screen 3】

(4) When【Screen 4】is displayed, select each item on the screen.
- Select the channel prove is connected.

【Screen 4】



I-V <Individual measure mode> setup dd-mmm-yyyy hh:mm

Using channel: ST1 ST2

INV. conditions: Stop

Data saving: Auto

Irradiance W/㎡

Temperature ℃

Wheather

Module type: General ←Silicon based, Compound based etc.; Hybrid

(4)-1 Select inverter status.

(4)-2 Select data saving option.

(4)-3 Input solar irradiance & temperature.

(4)-4 Select weather condition.

(4)-5 Select module type.

(4)-1 Select inverter status.

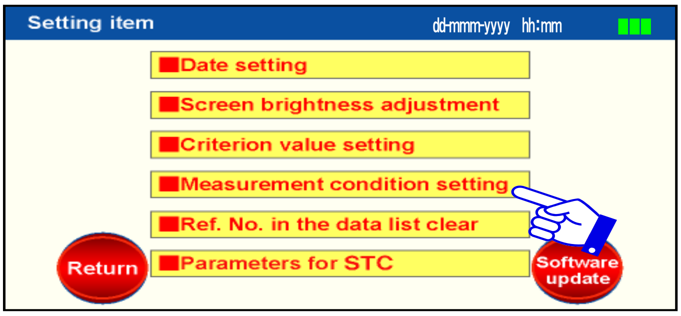
The initial setting shall be "Stop," and the equipment remembers its previous setting.

If "Oper." (Operation) is selected, change the setting for the measurement stop voltage of inverter according to the following procedure.

1) Select "Return" button in the【Screed 4】.

2) When【Screen 3】is displayed, select "Setting" button.

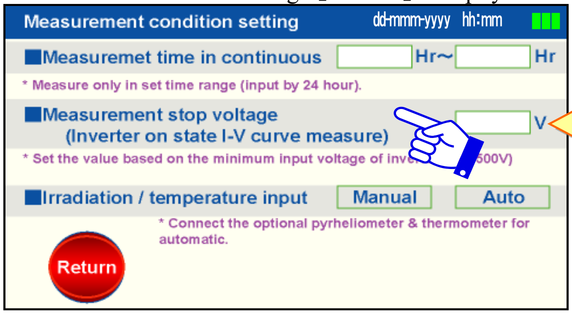
3) Setting item【Screen 5】is displayed, then select "Measurement condition setting."



Setting item dd-mmm-yyyy hh:mm

【Screen 5】

4) The screen of measurement settings【Screen 6】is displayed.



Measurement condition setting dd-mmm-yyyy hh:mm

Measuremet time in continuous Hr~ Hr

* Measure only in set time range (input by 24 hour).

Measurement stop voltage (Inverter on state I-V curve measure) V

* Set the value based on the minimum input voltage of inv 500V)

Irradiation / temperature input: Manual Auto

* Connect the optional pyrheliometer & thermometer for automatic.

【Screen 6】

Input value.

5) Input the voltage to stop measurement when performing the measurement with system connected.

Confirm the minimum input voltage (0 to 500V) of inverter to its manufacturer. In order not to stop its operation by the voltage drop when measuring with String Tracer, the voltage to stop measurement shall be set higher than its minimum input voltage. Enter the measurement stop voltage, then display【Screen 4】again by "Return" button.

(4)-2 Select the data saving option.

The initial setting is automatic, and the previous setting is stored.

If automatic is selected, measured data are automatically saved after measuring 4 strings, and the screen changes to measure the next strings.

If manual saving is selected, the measured data can be saved by selecting "Save data" button after every measurement.

(4)-3 Input solar irradiance and temperature. (These items cannot be entered if the solar irradiance and temperature data saving options are set as automatic in "8.4 Measurement condition setting.")
These items are not required but only a recording reference of weather conditions at the time of measurement. However, it is necessary for converting the measured data into the standard testing condition.

* In case of using pyranometer and thermometer (optional), measured data by these sensors are automatically saved by selecting "automatic input" in the measurement setting.

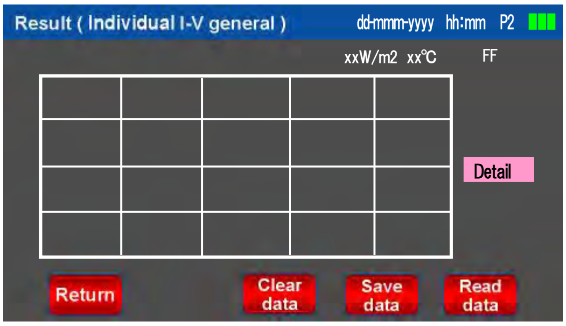
* When using pyranometer, leave it under the sun for more than 30 seconds until the start of measurement. (Response time of pyranometer: within 30 seconds)

* Thermometer shall be left under the sun until the measuring temperature gets stable. (Wait until the temperature of meter installation bracket and the modules are approximately the same.)

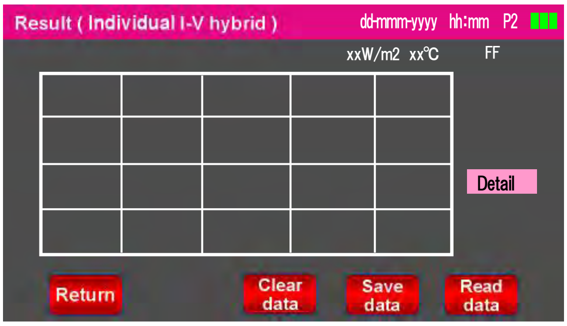
(4)-4 Select weather condition.
This is not a mandatory. The weather condition can be recorded at the time of measurement for the reference and displayed in the PC software.

(4)-5 Select the module type.
Select the module type between General and Hybrid according to the type of a module to be measured. See P14 (9) for details on this selection.

(5) Select "Start" button.
【Screen 7】 or 【Screen 8】 is displayed.
Depending on the module type, the color at the top of the screen will be different: General: Blue, Hybrid: Pink.



【Screen 7】



【Screen 8】

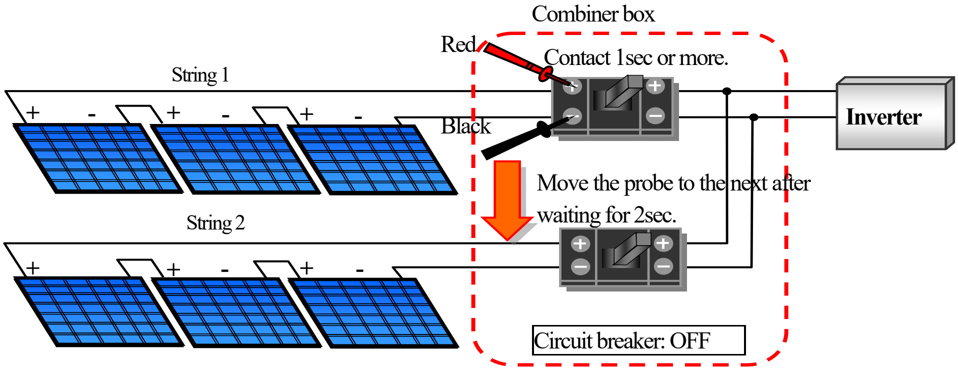
(6) Contact the needle type I-V probes to the string circuit breaker terminals of module side for 1 second or more. (Contacting the I-V probes for at least 1 second confirms no poor contact.)

* Make sure to firmly push the probe against the terminal. Poor contact may cause disturbance in the measured waveform or damage to the equipment.

Contact the I-V probes to the terminals firmly, and do not move. When the equipment detects the voltage (more than 10Vdc), the measurement is started and beeps when the measurement is completed. Do not move or release the probes until you hear the beep.

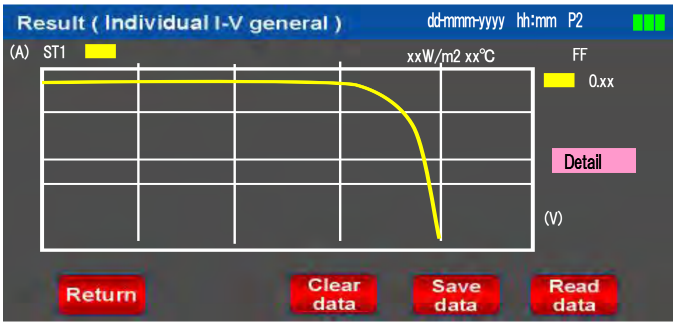
2 seconds interval to the next measurement is necessary after a measurement. Beeps “Pi-Pi” informs the completion of a measurement.

If there are four strings, repeat the procedure four times.



(7) After the first measurement, an I-V curve of string 1 (ST1)【Screen 9】is displayed .

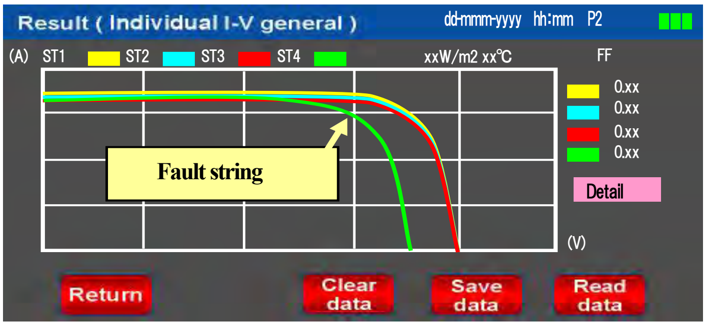
■ Display after ST1 measurement



【Screen 9】

Range of current and voltage displayed on the graph shall be optimized automatically.

■ Display after four-string measurement



【Screen 10】

One string (ST4) shows the different I-V characteristics, which can be determined the string has some fault.

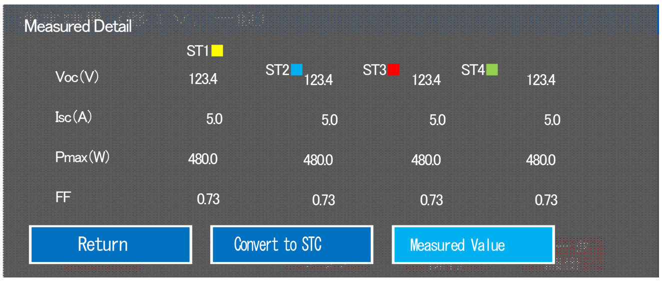
“Detail” button

If “Detail” button is selected, each measured results are shown in numbers.

The following items are displayed on the screen.

【Screen 11】: Voc (open-circuit voltage), Isc (short-circuit current), Pmax (maximum power), and FF (fill factor)

The data converted according to STC is also displayed. See “7.8 STC conversion” for further detail,



Measured Detail

	ST1 🟨	ST2 🟦	ST3 🟥	ST4 🟩
Voc(V)	123.4	123.4	123.4	123.4
Isc(A)	5.0	5.0	5.0	5.0
Pmax(W)	480.0	480.0	480.0	480.0
FF	0.73	0.73	0.73	0.73

【Screen 11】

【Measured data saving】

(1) Automatic data saving

After 4-string I-V measurements are completed and the results are saved automatically, next group of 4-string I-V measurements can be performed.

If 1 to 3 strings should be saved randomly, press “Save data”, and save the results. After saving the data individually, a new group of measurements can be performed.

(2) Manual data saving

Select manual data saving in case every result should be checked before saving.

After measuring the random number of strings, press “Save data” button. After the measured results are saved, the next 4-string measurements can be performed.

After the 4-string measurement, make sure to save the results. The new measurement cannot be performed unless the measured results are saved.

Saved data can be checked on the screen by pressing “Read data” button.

For details, refer the clause “7.7 Measured data readout.”

[Termination of measurement]

Select “Return” or “Read data” button for terminating the measurement.

⚠ CAUTION

[Notes for measuring with a probe]

Using probes for measurement, surely push the leads against the circuit breaker terminals. Its poor connection may cause an arc. This arc can lead to the disturbance of the measured waveform. Repeated measurements may damage the electronic component inside the String Tracer and its measurement may become impossible.

[Notes for measuring with inverter operated]

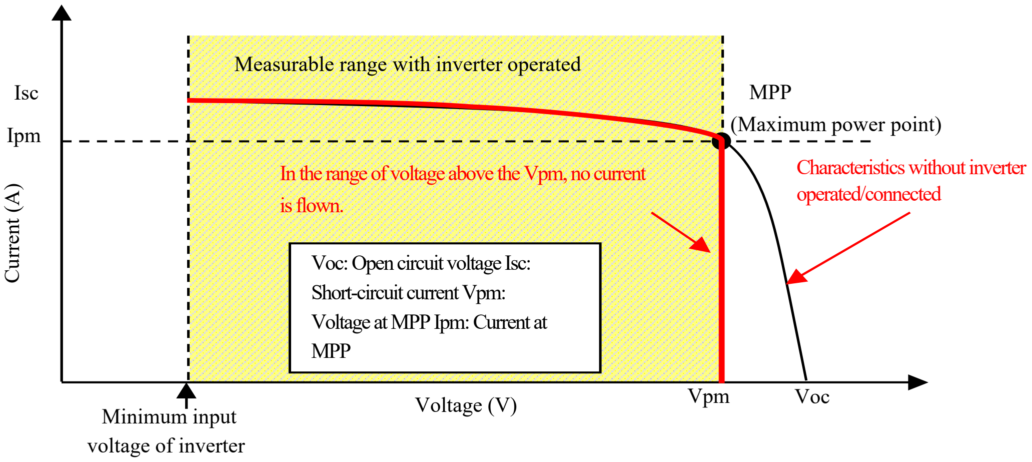
Under the operation of inverter, the PV modules output power at MPP (maximum power point).

I-V characteristics from Voc to Vpm is not measurable under this condition because all the current flows into the inverter between these points.

Additionally, in order not to stop the operation of inverter because of the voltage drop during the measurement, the minimum input voltage shall be set, and the range below the set voltage cannot be measured by String Tracer.

Therefore, in the ranges from MPP to Voc and the set minimum input voltage or below, the fault cannot be determined. (Refer the figure below.)

* Depending on timing of measurement, Vpm of each string may be different, but sinceVpm varies from time to time, it may not be a fault.



7.4 I-V curve measurement (Simultaneous mode) 【Inverter: stop】

Purpose

Measure the I-V curves of up to 2 strings simultaneously, and display the results on the same graph. By comparing the I-V curves in the graph, the condition of strings can be checked relatively.

CAUTION I-V curves shall be measured after conducting the string check. There is a possibility to cause problems in the equipment if the measurement is conducted with an incorrect connection.

【Preparation】

(1) Connect the clamps and I-V test probes.

(2) Connect the test leads to the connectors located on the side of String Tracer. (Connect the necessary leads depending on the number of strings to measure.)

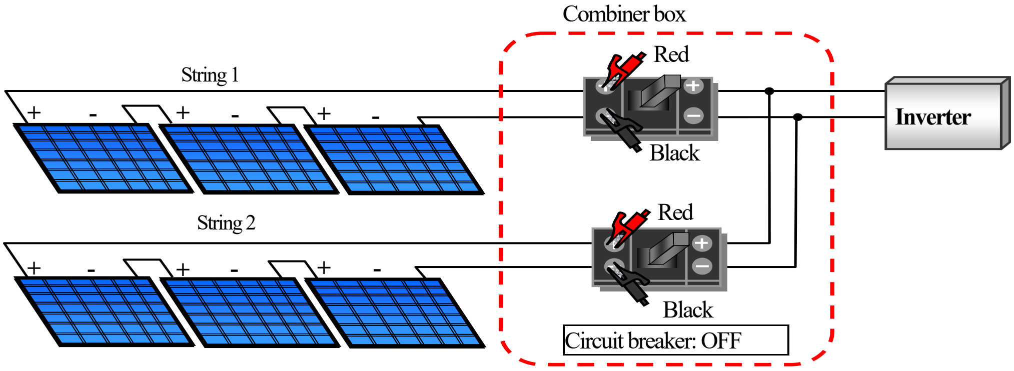
* Make sure to always hold the connecter when inserting the connecter into or removing it from the string tracer.

【Measurement】

(1) Open the string circuit breakers connected to the strings to be measured.
Remove the fuse from the combiner box when the string is protected by a fuse.

(2) Clamp the leads to the CB terminals. (The figure below shows the case of 2-string measurement.)

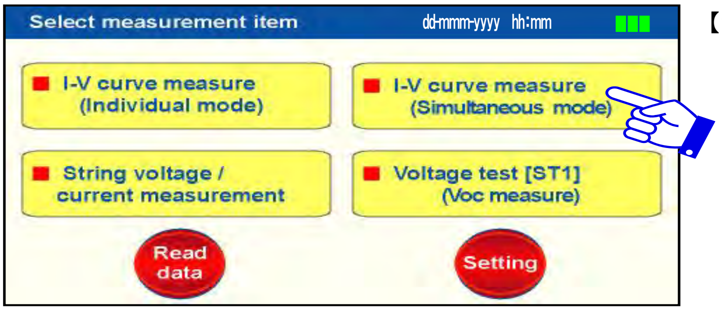
(3) Make sure to firmly push the probe against the terminal. Poor contact may cause disturbance in the measured waveform or damage to the equipment.



* The following procedure starts from turning on the power. If other measurements are done prior to this measurement, select "Return" button and display the necessary screen.

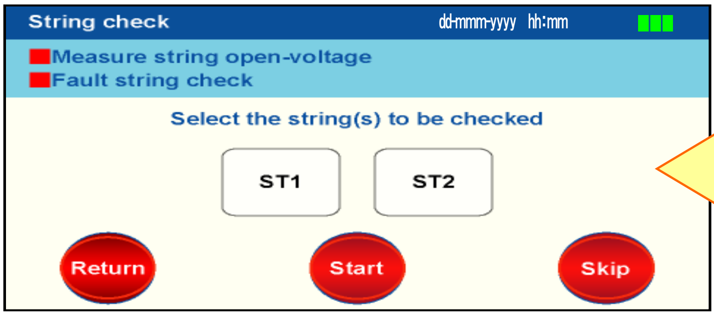
(3) Press and hold the power button for more than 2 seconds to turn on the power.

(4) Measurement items are displayed on the screen as【Screen 12】, and select "I-V measurement (Simultaneous mode)."



【Screen 12】

(5) String check screen【Screen 13】is displayed. Select the string number to measure so that the color of the button changes from white to yellow. (In order to cancel the selection, press the same button again.)



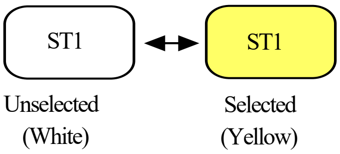
String check dd-mmm-yyyy hh:mm

🟥Measure string open-voltage
🟥Fault string check

Select the string(s) to be checked

【Screen 13】

Press the string number to measure.



* If “Skip” is selected, string check is skipped, so move to the next screen to select the measuring item. Purpose of

string check

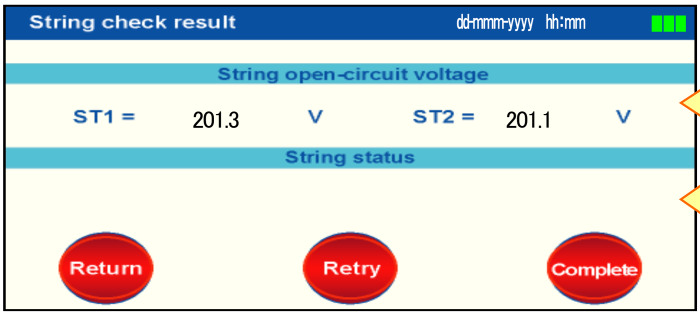
Measure the open circuit voltage (Voc) to check the effectiveness of relative comparison of each I-V curve. Additionally, connection failure and open circuit (measured voltage as 0V) can be checked.

Note

- Voltage difference (Voc per module × the difference in the number of modules) appears if the number of modules in each string varies. In such a case, relative comparison among different strings is not efficient.
- Even though Voc are approximately the same, if the installation direction of the modules is different by strings, I-V curves would be different depending on the suns position towards the module surface. Check the module direction/angle with respect to the sun when determining the condition (good or bad) of the module.

(6) Press “Start” button.

The equipment starts the measurement on the selected string. Results are displayed as【Screen 14】. (Example is the measurement of string 1 and 2.)



String check result dd-mmm-yyyy hh:mm

String open-circuit voltage

ST1 = 201.3 V ST2 = 201.1 V

String status

【Screen 14】

Measured values are shown here.

In case of error, messages are shown here.

【Result】

Confirm no error messages are shown on the screen.
If a message “Proceed to measurement.” is shown, select “complete” and go to the next step. If any error messages are shown, follow the instruction.

Error message

- Voc is lower than the set value for the criterion in the equipment.
  Check the connection of test probes.
  If the connection of test probes is OK, wiring between modules has failure/open.

- Maximum value of Voc difference among the strings is larger than the set value. **Voltage difference of the strings is larger than the set value.**
  Confirm each string has the same number of modules.

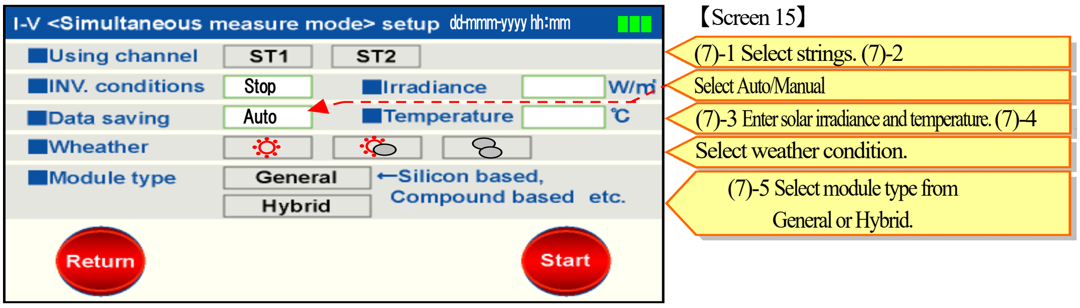
【String failure criteria initial set value】

The initial set values for string failure criteria of string check are:
- Voc dispersion value: indicating as fault when the difference is more than 10V
- Module wiring failure: indicating as fault when the difference is more than 10V

If the values need to be changed from the initial settings, refer to “8.3 String failure criteria.”

(7) Set each item in【Screen 15】.

【Screen 15】



(7)-1 Select strings. (7)-2 Select Auto/Manual

(7)-3 Enter solar irradiance and temperature. (7)-4 Select weather condition.

(7)-5 Select module type from General or Hybrid.

(7)-1 Select the strings to be measured.

Previously measured strings are stored in the equipment; make sure the right strings are selected. If no strings are selected and the "Start" button is pressed, a message "Strings are not selected. Select the strings." will be displayed on the screen.

String button turns yellow when selected.

(7)-2 Select the way of saving data.

The default setting is "Manual"

Or previous selection is kept.

When "Automatic" is selected, the data is saved automatically after measurement of waveform and returns to【Screen 15】

(The waveform is not displayed. To confirm the waveform, see "7.7 Measured data readout".)

In case of "Manual", the measured data will be saved by pushing "Save Data" button after measurement.

(7)-3 Enter solar irradiance and temperature. (If the selection of solar irradiance and temperature input is "automatic", such values cannot be entered manually.)

This is a reference record of weather conditions at the time of measurement; therefore, this is not a mandatory item.

However, STC conversion in the PC software requires such data.

* If the optional pyranometer and thermometer are used and "auto saving" is selected in the setting, the measured data by pyranometer and thermometer are automatically saved.

* When using pyranometer, leave it under the sun for more than 30 seconds until the start of measurement. (Response time of pyranometer: within 30 seconds)

* Thermometer shall be left under the sun until the measuring temperature gets stable. (Wait until the temperature of meter installation bracket and the modules are approximately the same.)

(7)-4 Select the weather condition.

Weather selection is not mandatory, but this information can be saved and checked by PC software for reference.

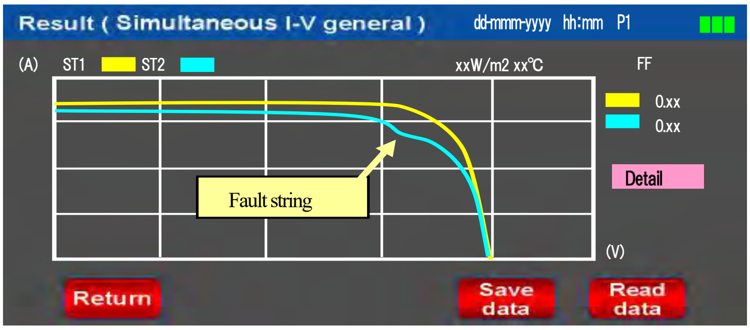
(7)-5 Select module type.

Select the module type between General and Hybrid according to the type of a module to be measured. See P14 (9) for details on this selection.

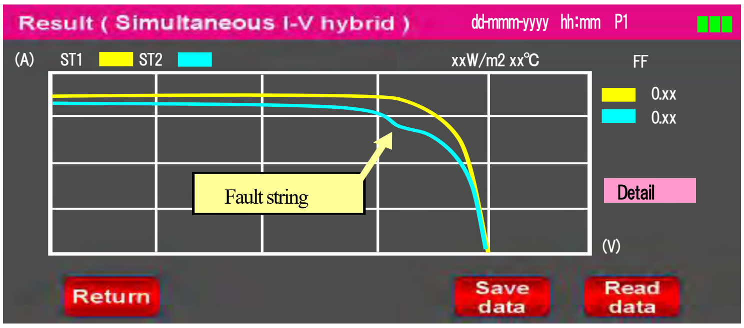
(8) Press “Start” button.

The equipment starts the measurement of the selected strings.【Check Results】

Measured results are automatically displayed on a graph.【Screen 16】&【Screen17】Color at the top of the screen depends on the module type. (General: blue and Hybrid: pink)



【Screen 16】



【Screen 17】

In the example above, only one string shows the different/irregular curve; therefore, the string can be determined to have some kind of failure.

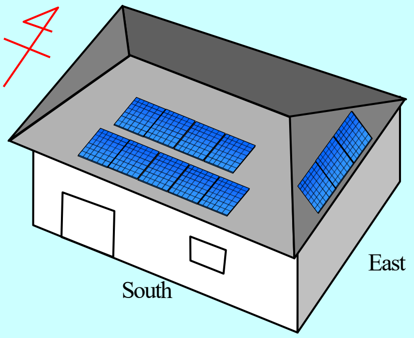
【Saving Results】

After measurement, save the results by selecting “Save data”. Saved data can be checked by selecting “Read data”. Refer to “7.7 Measured data readout.”

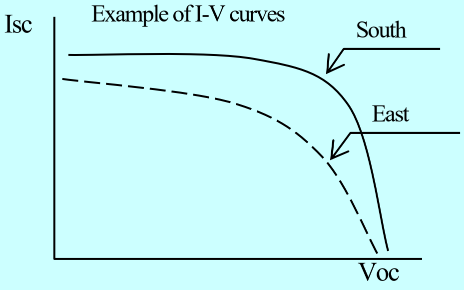
Note

Even though the Voc is approximately the same, if modules are installed towards the direction different from the strings, measured I-V characteristics will vary depending on the position of the sun. (Short-circuit current (Isc) is different.)

Prior to the measurement, check the direction of modules, and determine the module conditions by considering the I-V curve measurement state.



Example in the Northern hemisphere:
String 1 to 3 are installed on the south-facing roof, but only string 4 is installed on the east-facing roof.
In general, output of strings installed toward east or west is 20 to 30% lower than that of toward south.



7.5 String voltage/current measurement 【Inverter: under operation】

Use the optional clamp CT sensors for current measurement.
Continuous measurements require AC adapter.

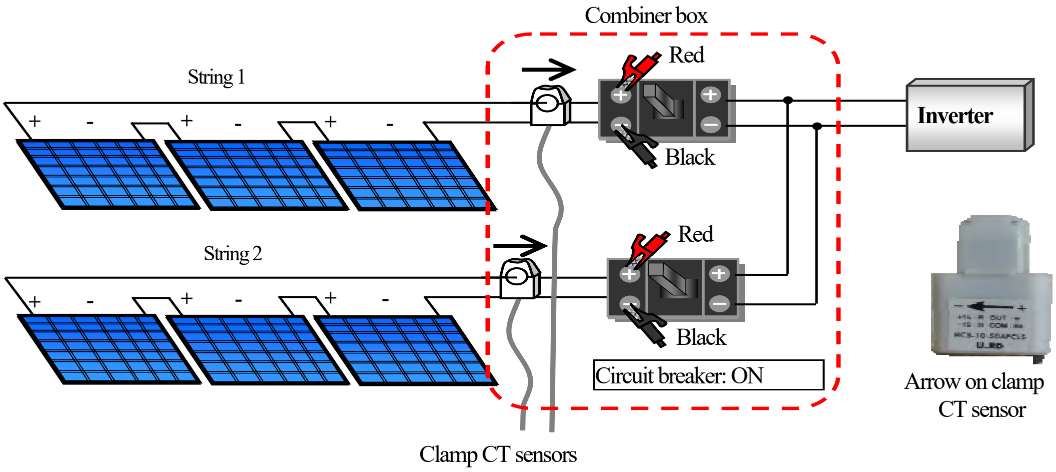
Purpose

Measure the voltage and current with inverter operated. (Under normal generating condition) Continuous monitoring of voltage and current enables to check the change in power generation throughout the day. Checking the specific time at which power output is lower on different days may help determine the effect of shade on the power output.
Current and voltage are affected by the solar irradiance and module temperature respectively.

【Connection】

(1) Connect the test leads and clamp CT sensors to each channel of String Tracer depending on the number of strings and voltage/current to be measured.
  * Make sure to always hold the connecter when inserting and removing.
  * Make sure of the insertion direction of clamp CT sensors.
(2) Turn on the string circuit breakers of the strings to be measured.
(3) Connect the clamps to the primary (module) side of breaker terminals. (The figure below indicates an example of 2-string measurement.)
  * Make sure to firmly push the probe against the terminal. Poor contact may cause disturbance in the measured waveform or damage to the equipment.
(4) <u>Make sure to adjust the sensor before CT sensors are clamped on the cables.</u>
  Refer to【Screen 21】for the adjustment procedure.
  - After the adjustment of sensor, clamp the sensor on positive-pole cable of each module side string. When clamping, the arrow indicated on the CT sensor shall point to the inverter. Make sure to close and lock the CT sensor. (The figure below indicates an example of 2-string measurement.)

  * If CT is clamped on the negative pole, arrows shall be towards the other direction.



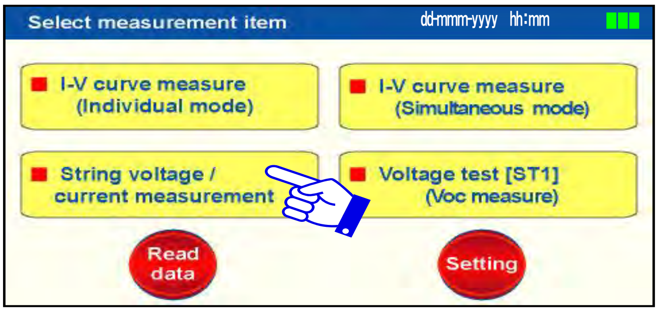
【Measurement】

The following procedure starts from turning on the power. If other measurements are done prior to this procedure, select "Return" button and display the necessary screen.

Use the enclosed AC adapter for power supply when conducting continuous measurement. Batteries cannot be used as a power supply. (When the equipment is powered by the battery, the measurement may not be performed properly due to the voltage drop of the battery.)

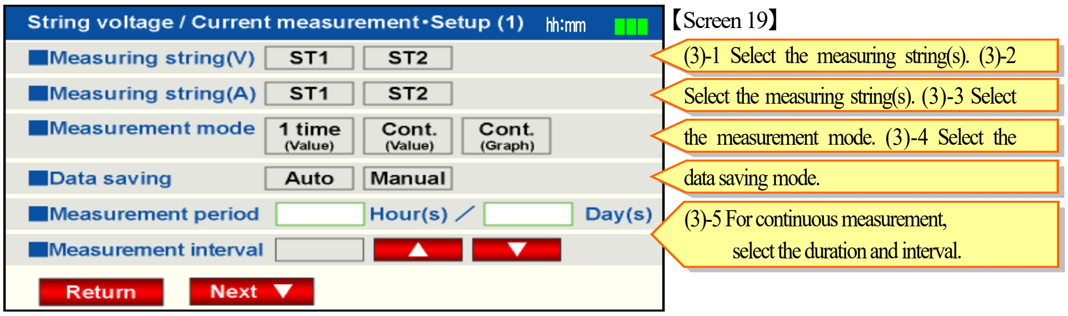
(1) Press and hold the power button of String Tracer for more than 2 seconds to turn on.

(2) Select "String voltage/current measurement" when the measurement menu appears on the screen【Screen 18】.



【Screen 18】

(3) String voltage/current measurement・Setup (1) screen【Screen 19】is displayed, and each item shall be set.

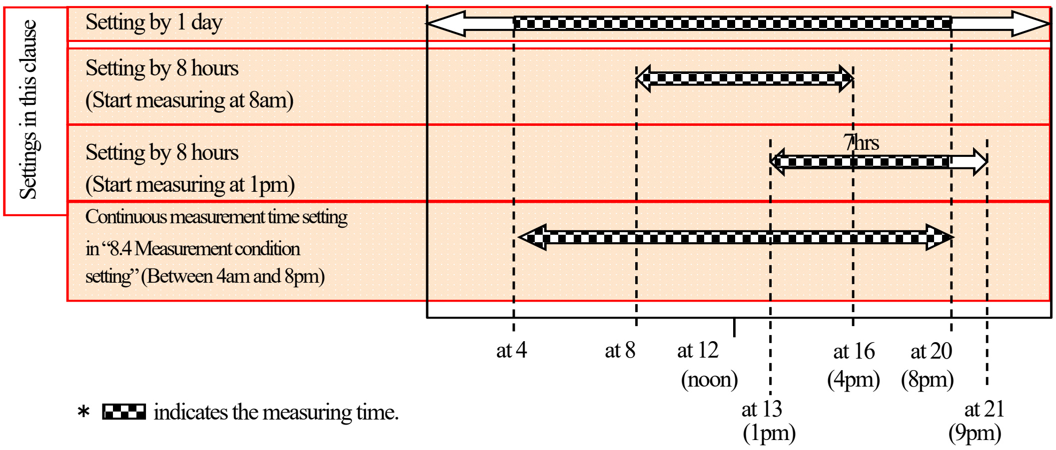


【Screen 19】

(3)-1 Select the measuring string(s). (3)-2 Select the measuring string(s). (3)-3 Select the measurement mode. (3)-4 Select the data saving mode.

(3)-5 For continuous measurement, select the duration and interval.

- The comparison of measurement time of continuous measurement mentioned in "8.4 Measurement condition setting" and the measurement time mentioned in this clause are indicated in the table below. If the measurement time is set as hourly basis as mentioned in this clause, the measurement time begins when the "Start" button is pressed, which may change the total duration of measuring time.



(3)-1 Select the string numbers to measure the voltage, and confirm that the button color changes from white to yellow.

(3)-2 Select the string numbers to measure the current, and confirm that the button color changes from white to yellow.

(3)-3 Select the measurement mode, and confirm that the button color changes from white to yellow. Each measurement mode is different in the following points.

- Selecting "1 time (Value)":
  Measured results are displayed in numbers.
- Selecting "Cont. (Value)":
  Measured results are displayed in numbers in order.
  (In every measurement, the results are displayed sequentially.)
- Selecting "Cont. (Graph)":
  Measured results are displayed in graph.

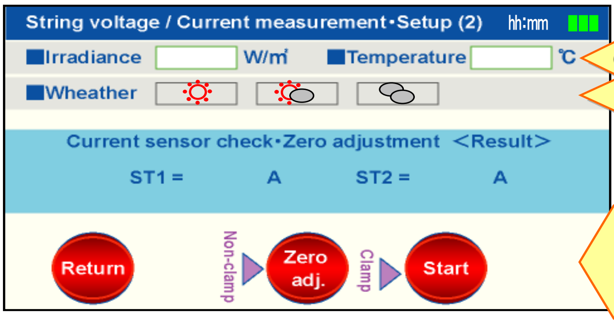
* In measurement mode selection, regardless of selecting either "Cont. (Value)" or "Cont. (Graph)," the content of the data stored in the SD card is the same.

(3)-4 Select the mode of data saving.

(3)-5 If measurement mode is set either “Cont. (Value)” or “Cont. (Graph),” enter the duration and interval of measurement.

- The duration can be set from 1 to 7 days. If the no. of days is set to 0(zero), the duration can be set by time. Time can be selected from 1 to 16 on an hourly basis.
- The interval changes each time the arrow buttons are pressed “△” or “▽.”
  <u>If the duration is 1 to 16hours,</u> (the unit: sec and min)
  5sec→10sec→30sec→1min→5min→10min→30min→60min
  <u>If the duration is 1 to 7days</u>, (the unit: min)
  1min→5min→10min→30min→60min

(4) If the setting is completed in【Screen 19】, press “Next” button to display the String voltage/ current measurement - Setup (2)【Screen 20】, select and enter the following items.


String voltage / Current measurement・Setup (2) hh:mm

■Irradiance W/㎡ ■Temperature ℃

■Wheather

Current sensor check・Zero adjustment <Result>

ST1 = A ST2 = A

【Screen 20】

(4)-1 Enter the solar irradiance and temperature.

(4)-2 Select the weather condition.

(4)-3 Prior to the current measurement, conduct the zero adjustment of clamp CT sensors.

(4)-1 Enter the solar irradiance and temperature. If the setting in “8.4 Measurement condition setting” is “Auto” (automatic), these items cannot be manually entered.
This is only a reference record of weather conditions at the time of measurement and not mandatory to be selected.

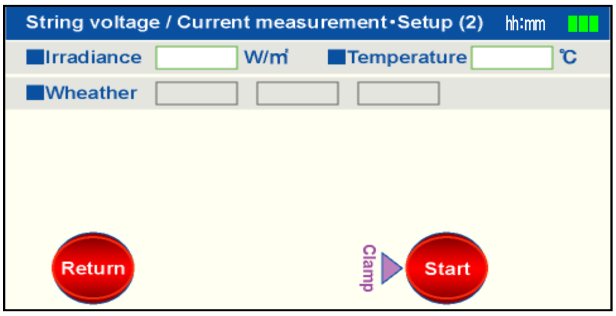
* In case of using pyranometer and thermometer (optional), measured data by these sensors are automatically saved by selecting “Auto” in the measurement setting.

* When using pyranometer, leave it under the sun for more than 30 seconds until the start of measurement. (Response time of pyranometer: within 30 seconds)

* Thermometer shall be left under the sun until the measuring temperature gets stable.(Wait until the temperature of meter installation bracket and the modules are approximately the same.)

(4)-2 Select the weather condition.
This is not mandatory, but for a reference of weather at the time of measurement. Weather condition can be checked later in the PC software.

(4)-3 Clamp CT sensor adjustment is necessary only when measuring the current.
Press the “Zero adj.” button <u>without clamping the CT sensors on the cables</u>. When adjustment is completed, standby screen【Screen 21】is displayed. CT adjustment is effective until the power of String Tracer is tuned off.


String voltage / Current measurement・Setup (2) hh:mm

■Irradiance W/㎡ ■Temperature ℃

■Wheather

【Screen 21】

(5) After clamping the CT sensors to the cables, press “Start” button. The measurement starts.

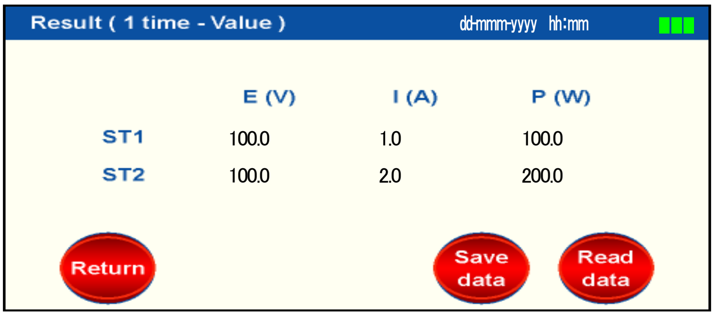
* When the start button is pressed, the measurement time begins.

Note when measurement mode is set "Continuous".

- If the interval is set 1min or more, the power turns off until the next measurement in order to save the power consumption. The screen display also turns off, but it is not a malfunction. When it gets to the time for measurement, equipment turns on the power automatically and starts measurement.
  * In case of the continuous measurement to be stopped: when the screen display is on, select "Exit" button; when the screen display is off, press and hold the power button for 2sec or more.

(6) Measured results are displayed on the screen depending on the measurement modes as indicated below.
 - If the data saving is set as automatic, a message "Measured data has been saved in SD card." appears before the measured results are shown on the screen. If you press "OK," the results are displayed.

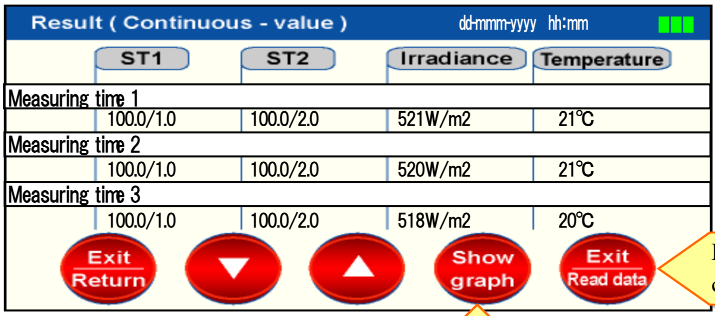
Display when 1 time measurement is selected



	E (V)	I (A)	P (W)
ST1	100.0	1.0	100.0
ST2	100.0	2.0	200.0

【Screen 22】

Display when continuous (value) measurement is selected



	ST1	ST2	Irradiance	Temperature
Measuring time 1				
	100.0/1.0	100.0/2.0	521W/m2	21℃
Measuring time 2				
	100.0/1.0	100.0/2.0	520W/m2	21℃
Measuring time 3				
	100.0/1.0	100.0/2.0	518W/m2	20℃

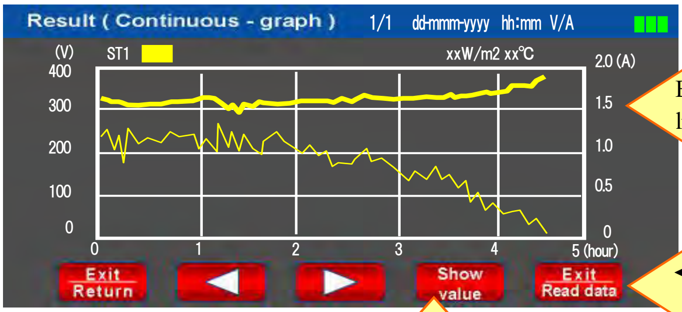
【Screen 23】

Pressing ▲▼ buttons changes the display.

After completed measurement, graph can be displayed.

Display when Continuous (graph) measurement is selected

The example below shows the current decreases towards the sunset and the voltage increases by lowering the temperature and the current.



【Screen 24】

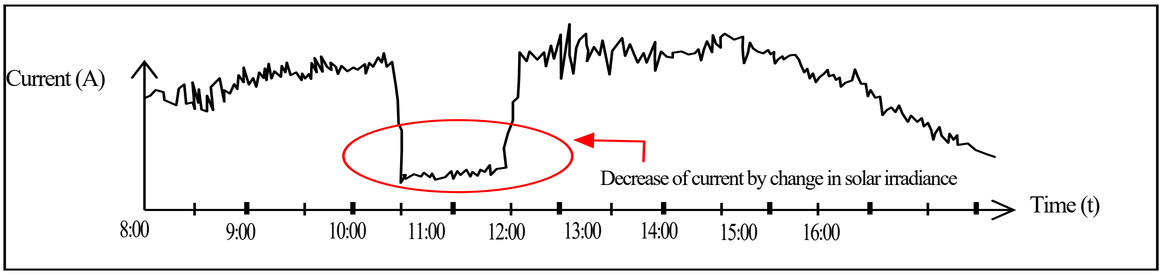
Bold line indicates voltage, and thin line indicated current.

◀ ▶move to the previous and next measuring hour.

After measurement is completed, graph can be displayed.

- Fault determination by current (Continuous - graph display mode)

  If the current is measured for several days and shows the decrease during the same time everyday, shading by such as trees or overhead cables may be the cause of its decrease.



【Saving data and completing the measurement】

- The followings explanation is for the case where the data saving option is set as manual.

(1) If the measuring mode is set “1 time”, select “Save data” button on【Screen 22】. After saving the data, the display automatically returns to【Screen 22】.

(2) If the measuring mode is set “Cont. (Value)”【Screen 23】 or “Cont. (Graph)”【Screen 24】, select ”Exit/Return” or “Exit/Read data” button. A confirmation message that the data was saved will appear.

7.6 Voltage test [ST1] (Measurement of open circuit voltage)

Purpose

Voltage test mode is for measuring open circuit voltage (Voc) like a circuit tester.
This function is useful when Voc needs to be measured before the I-V curve measurement.

【Preparation】

(1) Connect I-V probes (either clamp type or needle type) to I-V test leads.

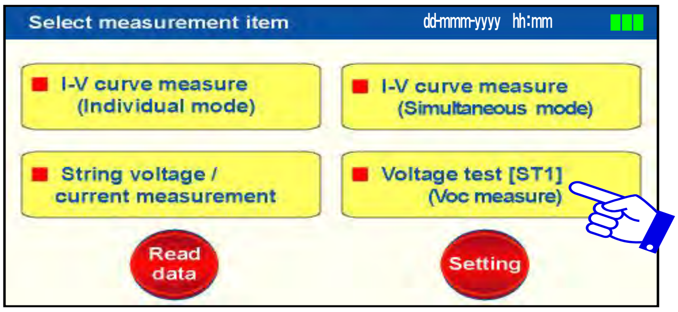
(2) Connect the test leads to the connecter “String-1” channel on the side of String Tracer.
  - * Only the Sting-1 channel can be used for the voltage test function.
  - * Make sure to always hold the connecter when inserting the connecter into or removing it from the string tracer.

【Measurement】

(1) Open the string circuit breakers. (Voltage can also be checked with the breakers on.)

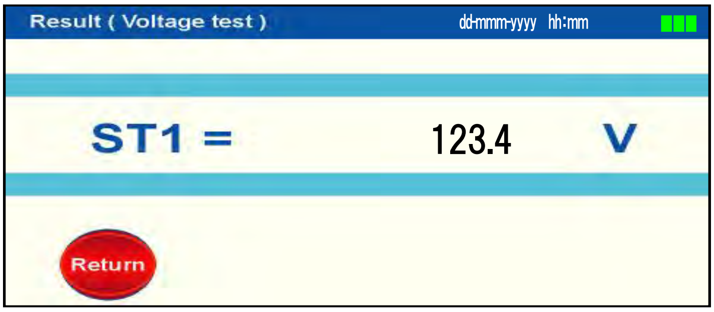
(2) Turn on the power of String Tracer by pressing and holding the power button for 2 seconds or more.

(3) Measurement item selection screen【Screen 25】is automatically displayed, and select “Voltage test [ST1] (Voc measure) .”



【Screen 25】

(4) If I-V probes are brought into contact with the string circuit breaker terminals of the module side, the measured value is displayed on【Screen 26】.



【Screen 26】

7.7 Measured data readout

Purpose

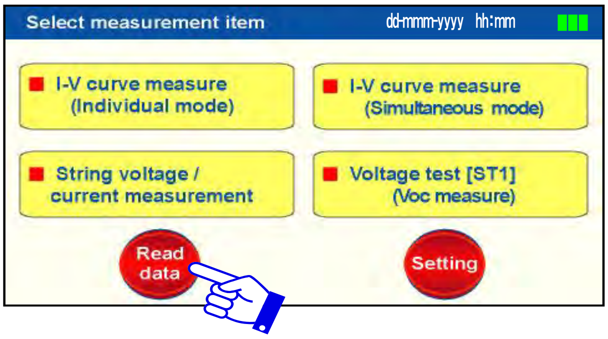
In order to confirm the measured data, or to determine the fault, data can be readout.

【Procedure】

The following procedure starts from turning on the power. If other measurements are done prior to this procedure, select "Return" button and display the necessary screen.

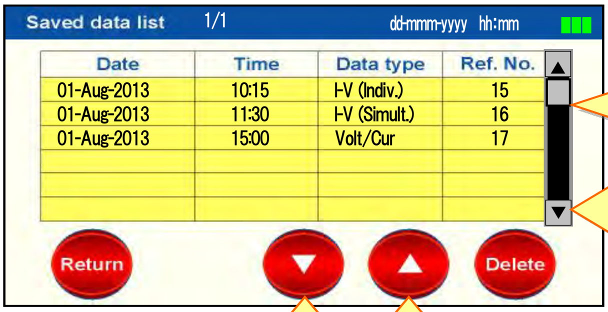
(1) Press and hold the power button of String Tracer for 2 seconds or more to turn on the power.

(2) Measurement item selection screen【Screen 27】is automatically displayed, and select "Read data" button.



【Screen 27】

(3) Saved data list screen【Screen 28】is displayed.



Date	Time	Data type	Ref. No.
01-Aug-2013	10:15	I-V (Indiv.)	15
01-Aug-2013	11:30	I-V (Simult.)	16
01-Aug-2013	15:00	Volt/Cur	17

【Screen 28】

Display as the measured date.

Press ▲ or ▼ to move to the first or last page.

Press ▽ or △ button to move to each page.
By holding the button, allows continuous selection to the following pages.

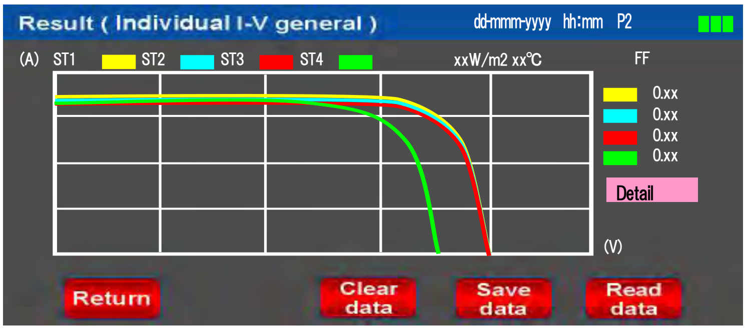
(3)-1 Saved data are displayed in the order of date.

(3)-2 Press "▽" or "△" button to move to another page (with 6 lines).
The data are displayed according to the measured date; for example, if there are eight measured data on the same day, the last two data will be displayed on the next page. Hold the button "▽" or "△" to move to the following pages.

* Numbers of the data list

- Each measured data has a series number from 1 to 99 for data management.
- These serial numbers are useful to manage the data in the equipment. For example, the serial numbers from 1 to 10 are the data at LOCATION I, from 11 to 20 at LOCATION II, etc.
- If the serial number reaches No. 99, the next data will be saved as No.1. When the number returns to No.1, the new data will have the same number as the data which has been saved previously.
- If any saved data are deleted, the deleted data number will be absent.
- If the data number needs to start from No.1 before it reaches No.99, on the setting screen, select the button "Ref. No. in the data list clear." (Refer the clause 8.5 for details.)

(3)-3 If a specific result is selected in【Screen 28】, numerical data or graph is displayed depending on the data type as shown in【Screen 29】.



【Screen 29】

* Once the data are saved, neither "Clear data" nor "Save data" button can function.

- If any other data needs to be readout, select "Return" or "Read data" button, and move to the saved data screen.

Measured data in PC

Measured data can be downloaded to your personal computer from SD card for data management.

Measured data are saved as the following file.

SD[saved drive]:¥LIST¥[measured date]¥[measured data].csv

Each data is saved in 8 alphanumeric characters.

hhmmDDNN.csv (Name of file)
hh: hour of measurement (between 00 - 23)
mm: minute of measurement (between 00 - 60)
DD: Data type*1
NN: Serial number (between 01 - 99)

*1 VV: Voltage measurement
AA: Current measurement
VA: Voltage & current measurement,
P1: Simultaneous I-V mode
P2: Individual I-V mode

7.8 STC Conversion

Purpose

When checking the aging and comparing the absolute values of PV modules, STC conversion shall be necessary. String Tracer carries out the value conversion by the calculating formula according to "IEC 61853-1: Irradiance and Temperature Performance Measurements and Power Rating".

※ The standard recommend you that the value used for STC conversion is measured when irradiance is more than 700 W/m^2.

※ **For STC conversion, the parameters need to be registered prior to the measurement. The parameters for STC conversion are recorded on each measured data; therefore, confirm that a selected parameters are correct at every time the measurement is carried out. For details, refer the clause "8.6 STC conversion parameter setting."**

※ **String Tracer converts the measured data, such as Open-circuit voltage: Voc, Short-circuit current: Isc, Maximum power: Pmax, and FF values, to STC converted data. If the waveform display is necessary, install the enclosed "Data Management Software to your computer and conduct the STC conversion.**

※ The data measured by models prior to this SPST-A2A are not convertible on this String Tracer.

※ For STC conversion, the parameters, such as α value, β value, Rs, and K, are necessary. Refer to the specification issued by the module manufacturer or request to the module manufacturer.

[Procedure of STC conversion]

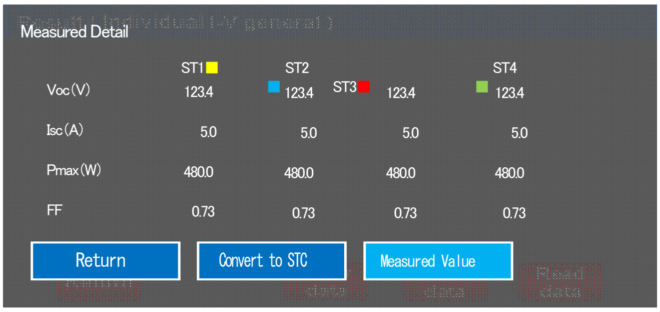
STC converted values can be displayed on the following screens.

- "Details of measured data" screen of the saved data
- "Details of measured data" screen of the measured data

The following procedure indicates the STC conversion conducted on the "Details of measured data" screen of the saved data.

(1) Refer "7.7 Measured data readout," and display the results on【Screen 29】.

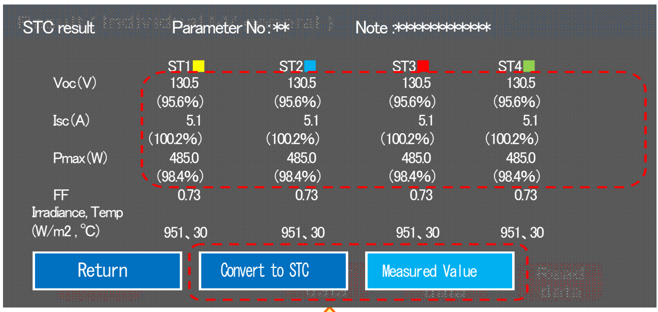
(2) Push "Detail" button to indicate Data of measured values in detail【Screen 30】


Measured Detail

	ST1 🟨	ST2 🟦	ST3 🟥	ST4 🟩
Voc (V)	123.4	123.4	123.4	123.4
Isc (A)	5.0	5.0	5.0	5.0
Pmax (W)	480.0	480.0	480.0	480.0
FF	0.73	0.73	0.73	0.73

【Screen 30】

(3) Display the screen 【Screen 31】 STC converted results by touching the "STC conversion" button in the bottom of 【Screen 30】.


STC result Parameter No : ** Note :************

	ST1 🟨	ST2 🟦	ST3 🟥	ST4 🟩
Voc (V)	130.5 (95.6%)	130.5 (95.6%)	130.5 (95.6%)	130.5 (95.6%)
Isc (A)	5.1 (100.2%)	5.1 (100.2%)	5.1 (100.2%)	5.1 (100.2%)
Pmax (W)	485.0 (98.4%)	485.0 (98.4%)	485.0 (98.4%)	485.0 (98.4%)
FF	0.73	0.73	0.73	0.73
Irradiance, Temp (W/m2 , ℃)	951、30	951、30	951、30	951、30

【Screen 31】

The upper level is the STC converted values of the measured data.
The values in parentheses show the ratio of the STC conversion to the module ratings. In case the ratio is more than 100%, the output exceeds the ratings.

Pushing either buttons displays the selected data. The selected button is displayed in the lighter color.

※ When conducting STC conversion, if there is no module parameters, the numbers are displayed as zero or * (asterisk).

7.9 Delete measured data

Purpose

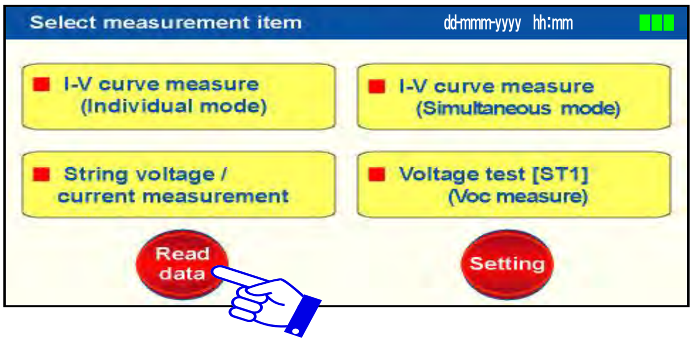
Delete the unnecessary measured data.

【Procedure】

The following procedure starts from turning on the power. If other measurements are done prior to this procedure, select "Return" button and display the necessary screen.

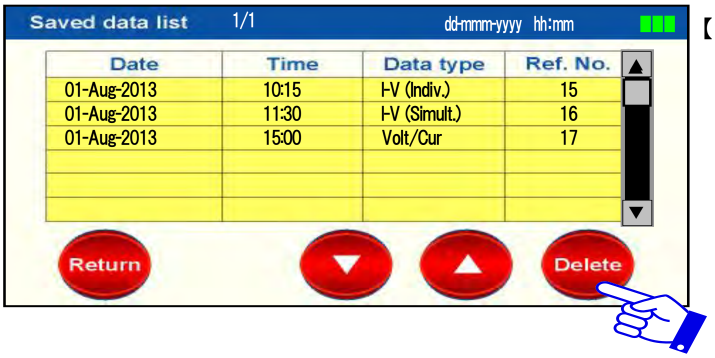
(1) Press and hold the power button of String Tracer for 2 seconds or more to turn on the power.

(2) Measurement item selection screen【Screen 32】is automatically displayed, and select "Read data" button.



【Screen 32】

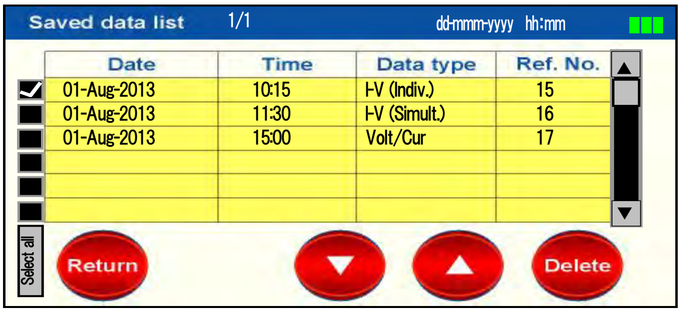
(3) When saved data list screen【Screen 33】is displayed, press "Delete" button.



Date	Time	Data type	Ref. No.
01-Aug-2013	10:15	I-V (Indiv.)	15
01-Aug-2013	11:30	I-V (Simult.)	16
01-Aug-2013	15:00	Volt/Cur	17

【Screen 33】

(4) Sele and place a checkmark in the box at the left side of the data to be deleted, and press "Delete" button. Only the checked data will be deleted.
If all the data on the screen needs to be deleted, press "Select all" button indicated on【Screen 34】. All the data displayed on the screen will be deleted.



	Date	Time	Data type	Ref. No.
☑	01-Aug-2013	10:15	I-V (Indiv.)	15
☐	01-Aug-2013	11:30	I-V (Simult.)	16
☐	01-Aug-2013	15:00	Volt/Cur	17
☐				
☐				
☐				

【Screen 34】

Check boxes will be displayed after pressing "Delete" button once.
After selecting and checking the data to be deleted, press "Delete" button again to delete.

By pressing "Select all" button, all data displayed on the screen will be checked.

8. Settings

8.1 Date setting

Purpose

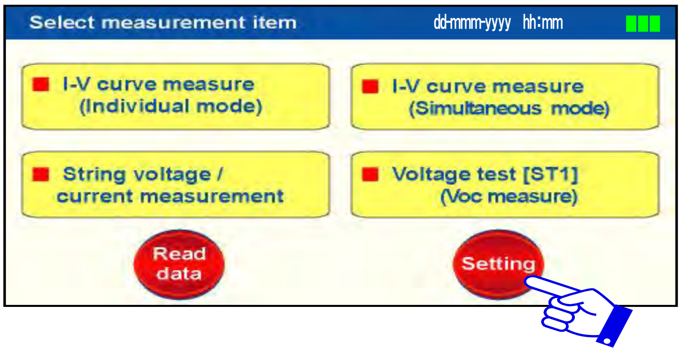
Set or change the current date and time.

【Procedure】

The following procedure starts from turning on the power. If other measurements are done prior to this procedure, select “Return” button and display the necessary screen.

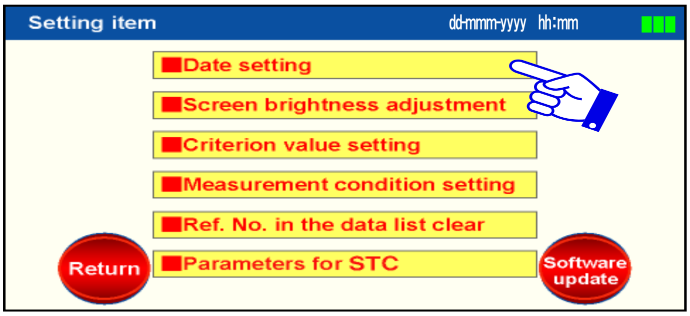
(1) Press and hold the power button of String Tracer for 2 seconds or more to turn on the power.

(2) Measurement item selection screen【Screen 35】is automatically displayed, and select “Setting” button.



【Screen 35】

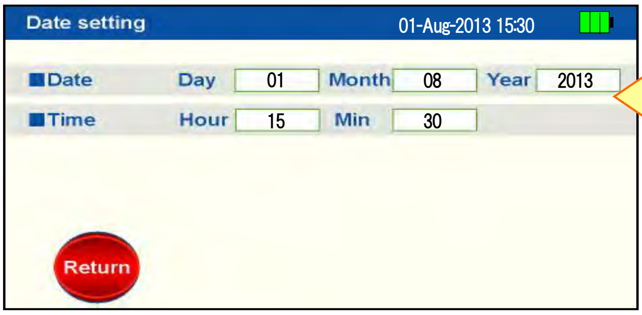
(3) After【Screen 36】is displayed, select “Date setting” button.



【Screen 36】

(4) 4) Aft 【Screen 37】is displayed, input the numbers, and press “Enter” button.

* At each settin of day, month, year, hour, and minute, when “Enter” button is pressed, seconds will begin from 0(zero).



01-Aug-2013 15:30

Date Day 01 Month 08 Year 2013

Time Hour 15 Min 30

【Screen 37】

Press the screen and set the date and hour.

Date and time display

If an incorrect date and time are displayed on the upper right screen every time the equipment is turned on, the backup battery for date setting may be burned-out or dead.

In such a case, contact our distributor for battery replacement.

8.2 Screen brightness adjustment

Purpose

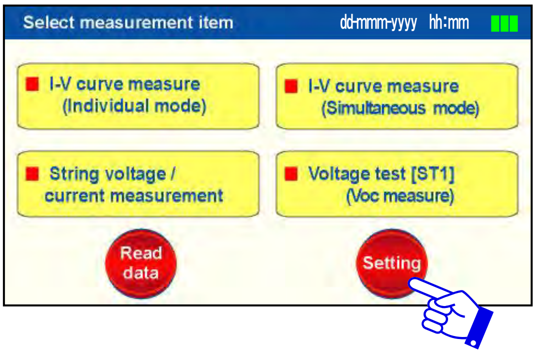
Adjust the brightness of LCD screen.

【Procedure】

The following procedure starts from turning on the power. If other measurement are done prior to this procedure, select “Return” button and display the necessary screen.

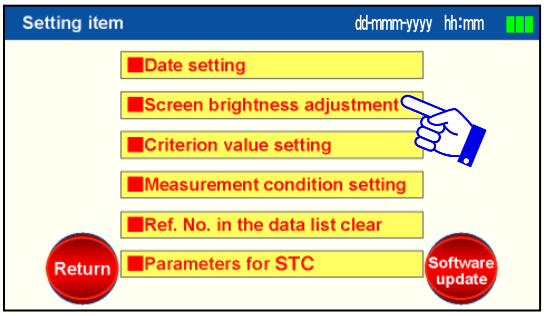
(1) Press and hold the power button of String Tracer for 2 seconds or more to turn on the power.

(2) Measurement item selection screen【Screen 38】is automatically displayed, and select “Setting” button.



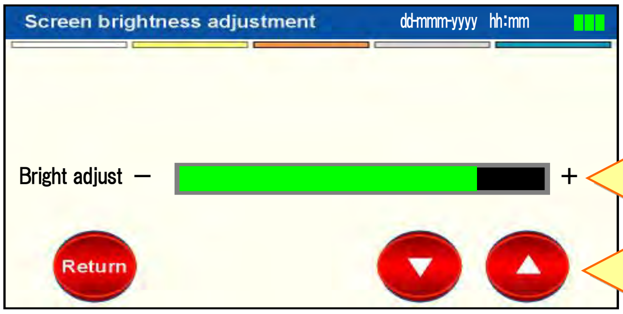
【Screen 38】

(3) After【Screen 39】is displayed, select “Screen brightness adjustment” button.



【Screen 39】

(4) Wh【Screen 40】is displayed, adjust the screen brightness by pressing “△” or “▽” button. Brightness can be adjusted in 10 levels.



【Screen 40】

Confirm with the color bar.

Adjust with ▽ and △ buttons.

* The battery life mentioned in clause “5. Specifications” is based on the setting of the screen brightness at the highest level.

8.3 Criteria value setting

Purpose

Set the standard criteria values for the string check.
Unless the criteria are changed, the initial setting values are applied for the determination.
The initial setting is only for reference. When you want to set the criteria by yourself, reconfigure according to own criteria.

【Initial settings of string check criteria】

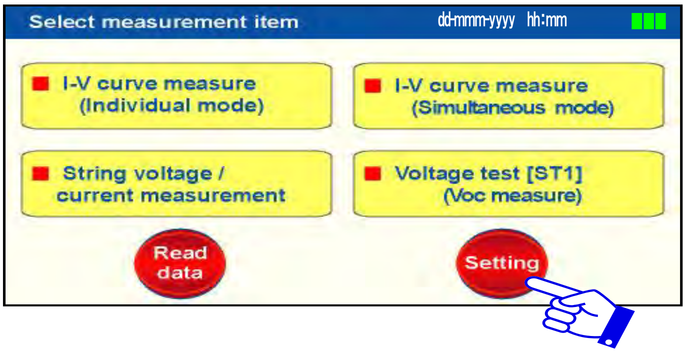
- Open circuit voltage (Voc) dispersion setting: “Fault” when 10V or more
- Module connection: “Disconnection” when 10V or less
- String failure: “Fault” when the difference between strings is 30% or more

【Procedure】

The following procedure starts from turning on the power. If other measurements are done prior to this procedure, select “Return” button and display the necessary screen.

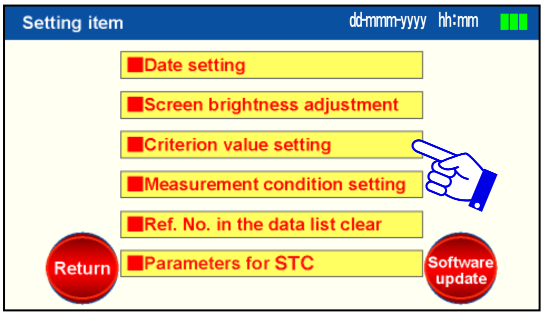
(1) Press and hold the power button of String Tracer for 2 seconds or more to turn on the power.

(2) Measurement item selection screen【Screen 41】is automatically displayed, and select “Setting” button.



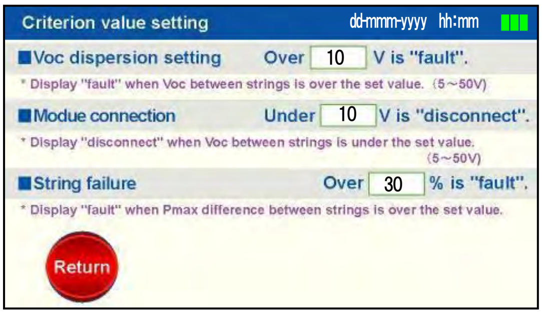
【Screen 41】

(3) Wh 【Screen 42】is displayed, select “Criterion value setting” button.



【Screen 42】

(4) Wh 【Screen 43】is displayed, select the item and enter the value.



Criterion value setting dd-mmm-yyyy hh:mm

■Voc dispersion setting Over 10 V is "fault".
* Display "fault" when Voc between strings is over the set value. (5～50V)

■Modue connection Under 10 V is "disconnect".
* Display "disconnect" when Voc between strings is under the set value. (5～50V)

■String failure Over 30 % is "fault".
* Display "fault" when Pmax difference between strings is over the set value.

【Screen 43】

- Open circuit voltage (Voc) dispersion setting

This setting is for the measurement of Voc when conducting the string check, which is related to clause "7.4 I-V curve measurement (Simultaneous mode)."

When Voc is measured, if the difference between the highest and lowest string Voc is above the set value, an error message appears on the screen.

Setting range is between 5Vdc and 50Vdc.

<Error message>

Difference between the highest and lowest string Voc is above the set value.
Check the number of modules in series in each string.

- Module connection

This setting is for the measurement of Voc when conducting the string check, which is related to clause "7.4 I-V curve measurement (Simultaneous mode)."

When Voc is measured, if the Voc is below the set value, an error message appears on the screen.

Setting range is between 5Vdc and 50Vdc.

<Error message>

Check whether the test probes are correctly connected.
If connection of test probe is OK, wiring between modules has disconnection.

- String failure

When the Pmax difference between strings is over the set value, an error message appears on the screen, which is mentioned in clause "7.4 I-V curve measurement (Simultaneous mode)."

* String failure judgment can be conducted when I-V curves are measured in simultaneous mode. For individual mode, changes in solar irradiance at the time of I-V curve measurement may affect the results. Therefore, string failure judgment cannot be done with individual I-V measurement.

<Error message>

Pmax difference between modules is above the set value. Check the conditions of modules, such as shading, the number of modules per string, etc.

8.4 Measurement condition setting

Purpose

- Set the measurement start time and finish time of continuous measurement mentioned in "7.5 String voltage/current measurement."

- Set the measuring voltage under the system interconnected in order not to stop the operation of inverter, which is mentioned in "7.3 I-V curve measurement (Individual mode)."

- Set the ata saving option to either automatic or manual when the optional pyranometer and thermometer are connected to the String Tracer.

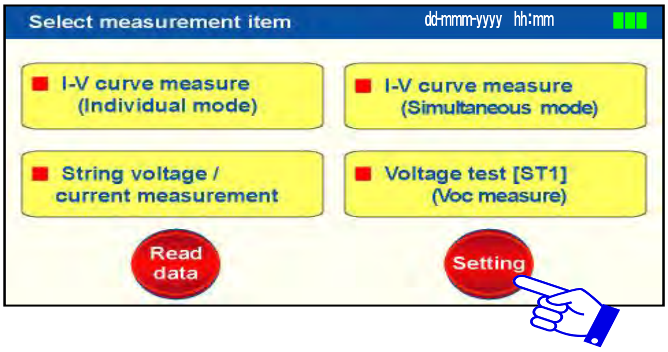
【Initial settings of measurement conditions】
- Measuring time for continuous measurement: 4am to 8pm
- Minimum input voltage of inverter: 100V
- Solar irradiance and temperature saving: Automatic

【Setting change】

The following procedure starts from turning on the power. If other measurements are done prior to this procedure, select "Return" button and display the necessary screen.

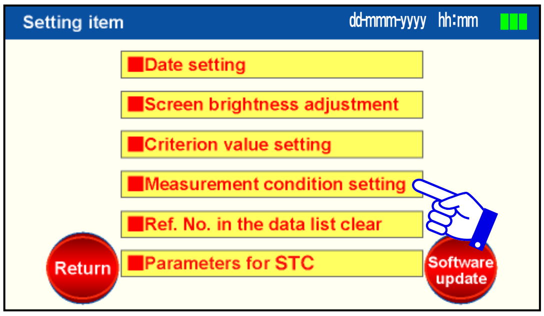
(1) Press and hold the power button of String Tracer for 2 seconds or more to turn on the power.

(2) Measurement item selection screen【Screen 44】is automatically displayed, and select "Setting" button.



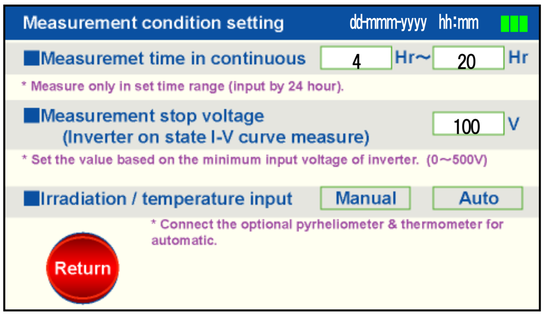
【Screen 44】

(3) When【Screen 45】is displayed, select "Measurement condition setting" button.



【Screen 45】

(4) When【Screen 46】is displayed, select the item and enter the values.



Measuremet time in continuous 4 Hr~ 20 Hr

* Measure only in set time range (input by 24 hour).

Measurement stop voltage (Inverter on state I-V curve measure) 100 V

* Set the value based on the minimum input voltage of inverter. (0~500V)

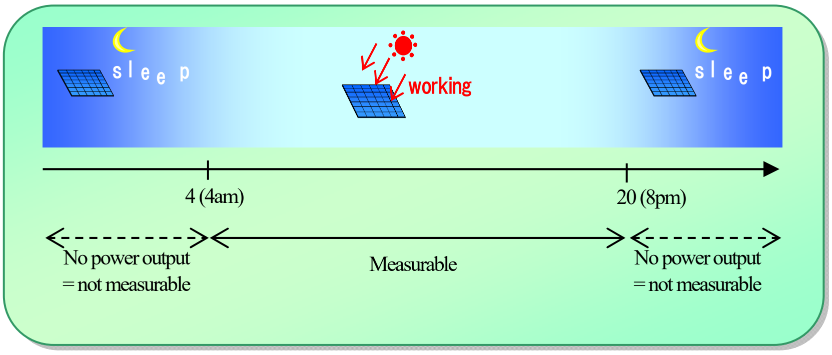
Irradiation / temperature input Manual Auto

* Connect the optional pyrheliometer & thermometer for automatic.

【Screen 46】

- Measuring time of continuous measurement

Set the measuring time in order not to measure the "7.5 String voltage/current measurement" when no power is generated during the night. The measurable time is between 4 (4am) and 20 (8pm).



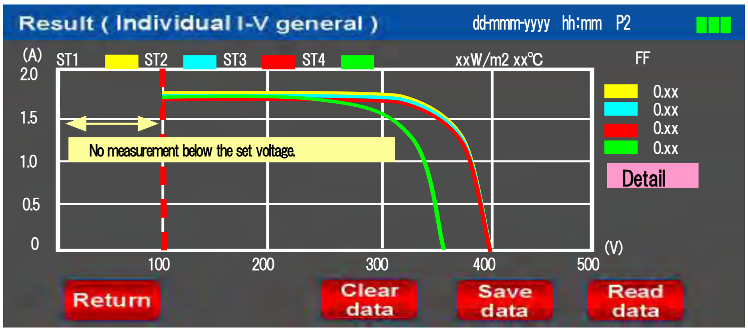
- Minimum input voltage of inverter under the system interconnected

Set the measuring voltage at the minimum input voltage of inverter or above. The minimum input voltage can be referred to the manufacturer of the inverter.

If the voltage falls below the set value, the String Tracer stops measuring the string. In such a case, the remaining data shall be saved as the same value as the measurement stops.

Example: If the measurement stops at the 70th point out of 100 measuring points, the result of the remaining 30 points are saved as the same value as the point at which the measurement has stopped.

Display example when the measurement stops【Screen 47】

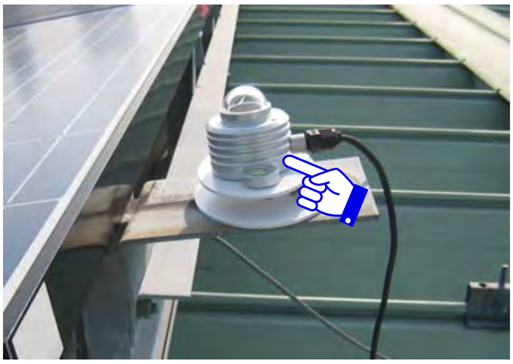


No measurement below the set voltage.

【Screen 47】

- Pyranometer and thermometer

If the data saving option is set to manual, the measured data shall be entered by the operator at the time of measurement.
If the data saving option is set to automatic, a pop-up screen will be displayed for entering the pyranometer sensitivity factor. The sensitivity factor differs to each sensor purchased by the user. Enter the value indicated on the sensor at the time of purchase. (Standard value is 7.00µV.)



8.5 Clearing Sequential number

Purpose

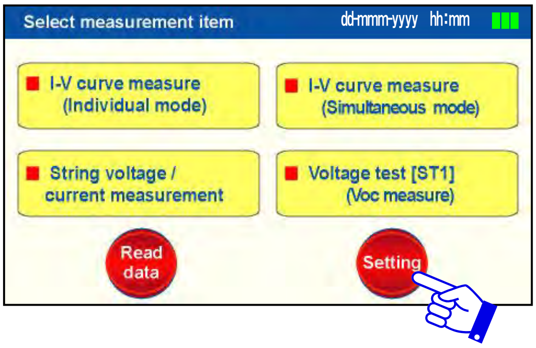
Clear the serial number of the data list.
This serial number is assigned to the measured data from No.1 to 99 in order. In case of reassigning serial number from No.1, this function can be used.

【Procedure】

The following procedure starts from turning on the power. If other measurements are done prior to this procedure, select "Return" button and display the necessary screen.

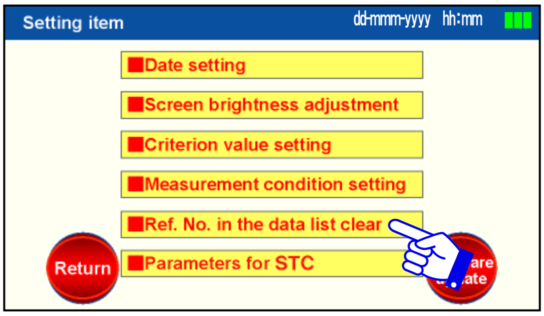
(1) Press and hold the power button of String Tracer for 2 seconds or more to turn on the power.

(2) Measurement item selection screen【Screen 48】is automatically displayed, and select "Setting" button.



【Screen 48】

(3) Wh 【Screen 49】is displayed, select "Ref. No. in the data list clear" button.
When a message "Clear the CSV file numbers. OK?" is displayed, select "Yes", and the next serial number starts from No. 1.



【Screen 49】

8.6 STC Conversion parameter setting

Purpose

When checking the aging and comparing the absolute values of PV modules, STC conversion shall be necessary. String Tracer carries out the value conversion by the calculating formula according to "IEC 61853-1: Irradiance and Temperature Performance Measurements and Power Rating".

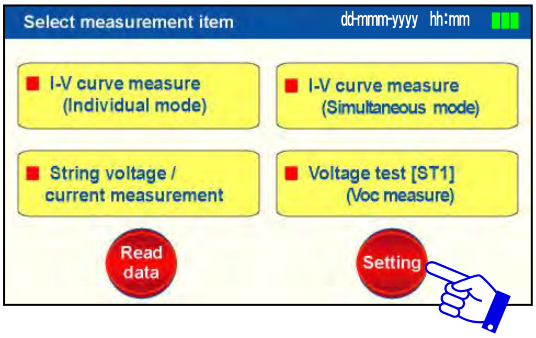
※ For STC conversion, the parameters, such as α value, β value, Rs, and K, are necessary. Refer to the specification issued by the module manufacturer or request to the module manufacturer.

[How to register the parameters used for STC conversion]

Module parameters shall be registered in String Tracer itself for STC conversion. Register the necessary parameters as follows.

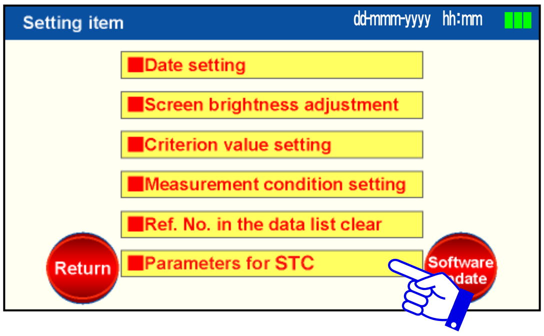
(1) Press and hold the power button of String Tracer for 2 seconds or more to turn on the power.

(2) Measurement item selection screen【Screen 50】is automatically displayed, and select "Setting" button.



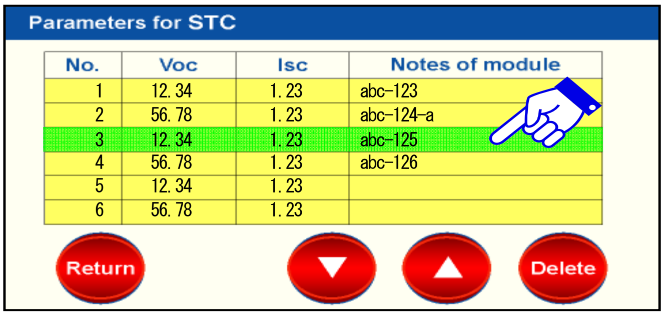
【Screen 50】

(3) When【Screen 51】is displayed, touch "Parameters for STC" button.



【Screen 51】

(4) When STC conversion screen【Screen 52】is displayed, select a column of the parameter to be changed. The background color of column shall be green when selected. The picture below shows an example that No. 3 is selected.



Parameters for STC

No.	Voc	Isc	Notes of module
1	12. 34	1. 23	abc-123
2	56. 78	1. 23	abc-124-a
3	12. 34	1. 23	abc-125
4	56. 78	1. 23	abc-126
5	12. 34	1. 23	
6	56. 78	1. 23	

【Screen 52】

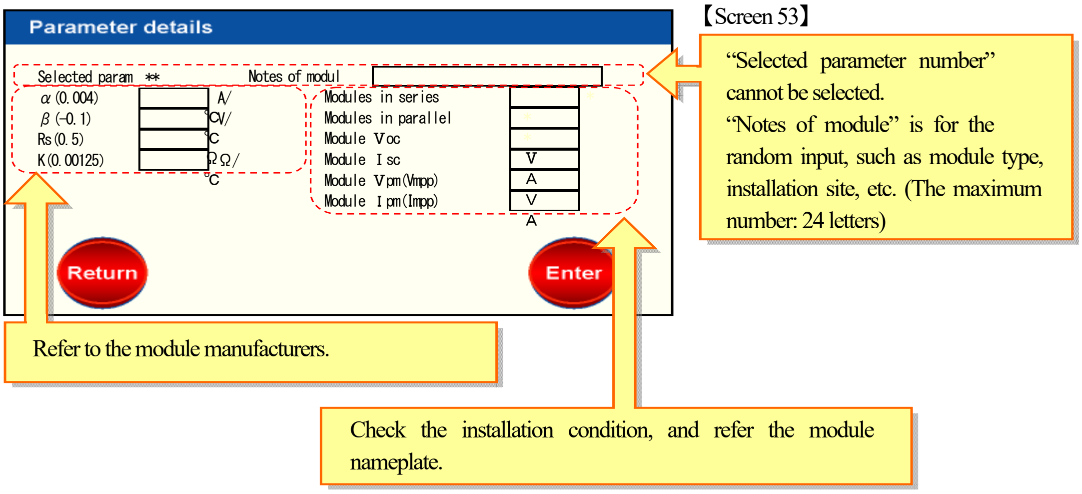
(5) The detailed parameters are displayed in the screen. If there is no need to change in numbers or the previous screen needs to be displayed, touch "Setting effective" button. If the numbers in parameters need to be changed, touch "Correct."

※ The number of parameters to be registered is up to 60.

※ STC conversion shall be conducted per string. Even though the module is same model/type from the same manufacturer, if the number of module in series/parallel is different, the parameters shall be registered in another group. .

(6) On the screen of "Parameter details"【Screen 53】, the parameters of the specific module shall be input

※ If the module parameters cannot be obtained, use the numbers shown in the parentheses as the referential numbers.



Selected param **
Notes of modul
α (0.004) A/°C
β (-0.1) V/°C
Rs (0.5) Ω
K (0.00125) Ω/°C
Modules in series
Modules in parallel
Module Voc V
Module Isc A
Module Vpm(Vmpp) V
Module Ipm(Impp) A

【Screen 53】

"Selected parameter number" cannot be selected. "Notes of module" is for the random input, such as module type, installation site, etc. (The maximum number: 24 letters)

Refer to the module manufacturers.

Check the installation condition, and refer the module nameplate.

(7) After input the parameter, touch "Enter" button. The background color is changed to green in the column whose parameter is changed when【Screen 52】is displayed.

8.7 Software update

Purpose

Update the software to improve the performance and function of the equipment.
Information about the data update is notified to the user by the manufacturer as necessary. Operation procedure and method for transferring data to SD card for update shall be notified to the user individually by the manufacturer.

Cautions

Be aware of the following matters.
If the software update fails, String Tracer will not function. In such a case, the equipment should be send back to the manufacturer.

- Do not remove SD card while updating the software.
- If the power is turned off while updating the software, the update will fail.

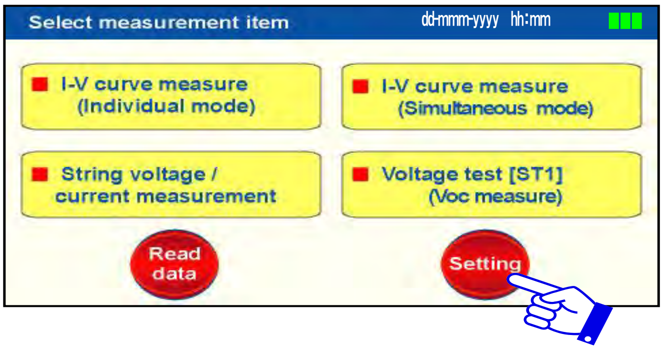
In case of blackout and low battery level, insert the batteries and supply power with AC adapter while updating the software.

【Procedure of software update】

The following procedure starts from turning on the power. If other measurements are done prior to this procedure, select "Return" button and display the necessary screen.

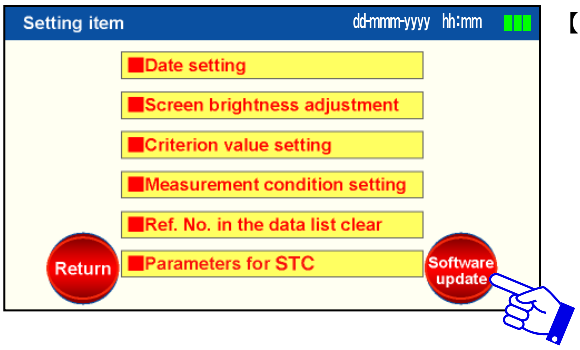
(1) Press and hold the power button of String Tracer for 2 seconds or more to turn on the power.

(2) Measurement item selection screen【Screen 54】is automatically displayed, and select "Setting" button.



【Screen 54】

(3) When【Screen 55】is displayed, select "Software update" button.



【Screen 55】

(4) Pop-up message "Updating the software. OK?" is displayed, select "Yes". The software will be updated.

If there is no efficient software in the SD card, software update will not be conducted.

9. Usage of option

(5) **Clamp CT sensor (SPST-A-F1Y1)**
Clamp CT sensor is used for "7.5 String voltage/current measurement." Procedure

Refer to clause 7.5 on page 31 on how to use the clamp CT sensors.

⚠ CAUTION

Never bend, twist, or pull the cable or connector extremely. Never place heavy objects on it. The sensor may be damaged and become out of order.

(2) Pyranometer and thermometer (SPST-A-F2Y1)
Pyranometer and thermometer are used for the I-V curve measurement (individual or simultaneous mode).

Procedure

(1) Insert the end of sensor cable to the miniDIN connector located on the side of String Tracer.
(2) Place the pyranometer parallel to the module surface. When placing the meter, do not cast a shadow on the module surface.
(3) Attach the thermometer on the rear surface of the module located around the center of the string.
(4) After confirming that the observed values are stable, conduct the measurement according to the instruction mentioned in "7.3 I-V curve measurement (Individual mode)" or "7.4 I-V curve measurement (Simultaneous mode)."

⚠ CAUTION

Never bend, twist, or pull the cable or connector extremely. Never place heavy objects on it. The sensor may be damaged and become out of order.

(3) Magnetic test probe (SPST-A-F4)
Magnetic test probe is used for simultaneous I-V curve measurement (measurement of 2 strings at the same time) and voltage measurement
* It can't be connected to screws made from stainless or brass.

Procedure

Touch the leads to the CB terminals.

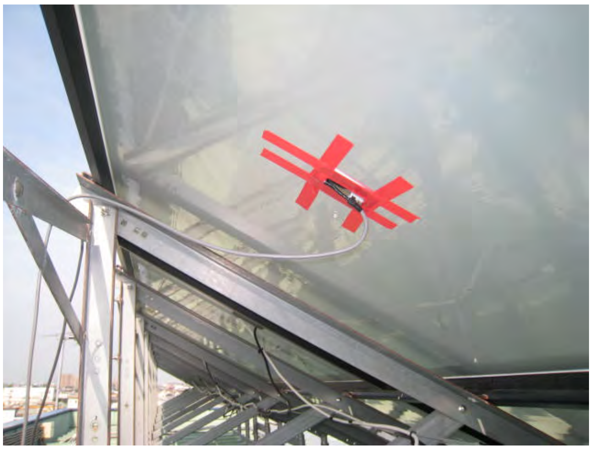
* Make sure to firmly push the leads against terminal. Poor contact may cause disturbance in the measured waveform or damage to the equipment.

Its procedure of measurement is the same as for the clamp probe.

Example

Pyranometer

Thermometer



CAUTION

Be aware of the following matters when using the optional equipment.

- In case that the amount of solar irradiance changes, pyranometer needs time to follow the change of irradiance. Wait for about 30 seconds before measurement if the solar irradiance changes significantly.
- It takes time to obtain a stable value after mounting the thermometer. Wait until the temperature is stable.
- If the thermometer is cooled by wind, etc., the correct module temperature cannot be measured. In such a case, cover the meter with cloth, etc. to prevent the influence of wind.
- When mounting the thermometer, it must be attached to the back sheet on the rear side of the module. The back sheet of the module breaks easily, so be careful when attaching and removing the thermometer.
- Even though the pyranometer and thermometer is connected to String Tracer, if the values are not displayed on the screen, the setting of the String Tracer may not be correct. According to “8.4 Measurement condition setting,” change the data input setting of pyranometer and thermometer to automatic.
- When mounting the pyranometer, avoid casting a shadow to the module with the pyranometer itself in order to obtain the correct waveform.
- Make sure of its insertion direction. Wrong direction may damage the equipment.
- Make sure to always hold the connecter when inserting the connecter into or removing it from the string tracer, and do not pull the cable.

10. FAQ

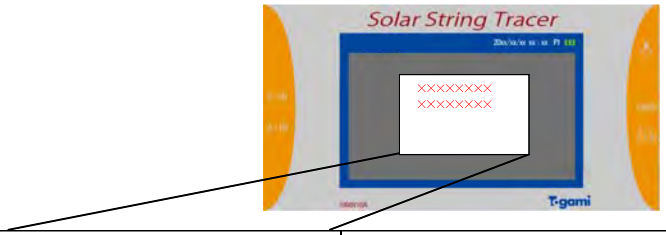
See the table below before requesting repair of String Tracer.

Contact our office or our customer service if the table below can't solve your problem. You can also contact to us from our web site, http://www.togami-elec.co.jp.

Phenomenon	Subject to be confirmed	Ref.
Power can`t be turned on.	・Did you insert the batteries into the equipment?	-
	・Is the direction of the battery (+/-) correct? (Did you insert the batteries appropriately?)	
	・Did you push and hold the power button for 2 seconds or more?	
Cannot Measure	・Is the polarity of the connector correct?	P11 No.2
	・Did you contact the needle to the terminal for 1 second or more? (in case of individual measurement)	P21 (6)
	・Did you have an interval for 2 seconds or more between measurements?	P21 (6)
	・Is the lead inserted all the way in?	-
"The measured value exceeds the rating" is indicated on the display.	・Did you select the correct measurement mode according to the type of your module, "General" or "Hybrid"?	P14 (9)
	・Are the rated voltage and current of your module within the ratings of String Tracer?	P8 5.2 Rating
	・Is the breaker (or fuse) of your combiner box opened?	-
Software can't be installed into PC.	・Did you already read the installation procedure saved on the attached SD card?	-
"There is no data list folder in SD card" is indicated.	・Is there any files other than measured data file in the "LIST" folder of the SD card? ・Did you rename folder or file?	

11. Error messages and alarm

The chart below explains the meaning of error messages and alarms during measurement and their countermeasures. If the error message is displayed even after following the countermeasures explained below, contact to us.



Message	Detail
Measuring is stopped because the measured value exceeds the rating. (Voc)	・ This message is indicated when the measured value of voltage exceeds its range. (see “5.2 Ratings” on page 8) ➢**Confirm whether the voltage of string to be measured does not exceed the rated voltage of this product.**
Measuring is stopped because the measured value exceeds the rating. Wait for xx seconds to radiate heat. (Isc X) X of (Isc X) is 1 or 2	・ This message is indicated when the measured value of current exceeds its range. (see “5.2 Ratings” on page 8) ➢**Confirm whether the current of string to be measured does not exceed the rated current of this product.** ➢**If that current does not exceed the rating, the solar irradiance to the module is more than expected due to sunlight reflection. Confirm the ambient environment and measure again after the amount of irradiance decreases.** ➢**If the current does not exceed the rating, the modules to be measured can be a high performance module, such as Heterojunction and back contact type. Measure again after changing the module type from General to Hybrid mode.** ➢**Current may be flowing from multiple modules into a module, because the circuit between the modules is not separated. Confirm whether it is separated by means of opening a circuit breaker or fuse etc.**
Measuring is stopped because the measured value exceeds the rating. Wait for xx seconds to radiate heat. (Pmax)	・ This message is indicated when the measured value of power exceeds its range. (see “5.2 Ratings” on page 8. ➢**Confirm whether the rating of the measured string is 8,000W or less.**
Measured value is around the rating. Wait for xx seconds to radiate heat.	・ This message is indicated when string tracer is in standby mode due to heat radiation. This radiation can cause when the measured value of the string is around the rating of this product. ➢**Wait until heat radiation will be completed, i.e. until the countdown reaches 0.**
Difference in maximum power output between each string is over the range. Check the modules.	・ This message is indicated when difference in maximum power output between each string to be measured is over the set range. ➢**Check the modules.** ※ See P50 “8.3 Criteria voltage setting” to change the criteria.

[NOTE]

The messages above can be indicated by a distorted waveform in the voltage measurement around the open circuit point when arc is caused by a poor contact between the needle probe and the terminal to be measured or by a long cable connected to a string.

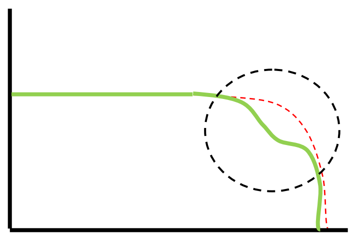
Pay attention to the condition of connection and contact between the probe and terminal before measurement.

12. Typical example of errors

Followings show the characteristics of the IV curve in case of abnormality in modules or strings.

※ It does not guarantee that similar characteristics can be found even with similar errors.

12-1. Declination around Pmax



■ Factor

➢Declination and/or stop of power output, but not enough to become a cluster failure, on some cells can be suspected.
Find the factors preventing the modules from power output to eliminate them.

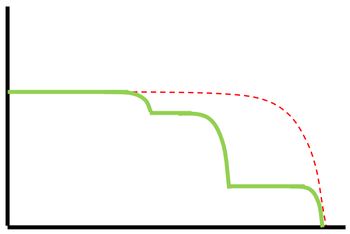
■ Expected reasons

・Shading in few cells due to small shadows.

・Small stain on a cell due to bird or animal damage, such as their excrement

・Shading due to some glass breakage of cells.

12-2. Stepwise declination



■ Factor

➢Declination of power output, but not enough to become a cluster failure, such as 12-1 on multiple clusters and/or modules can be suspected.

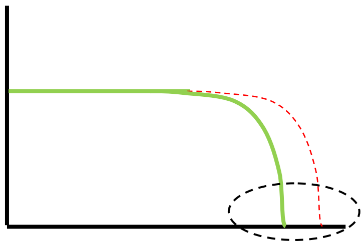
■ Expected reasons

・Shading in multiple clusters due to large shadows.

・Pollution due to accumulation of dust.

・Shading due to some glass breakage of cells.

12-3. Declination of Voc



■ Factor

➢Suspension of power output on clusters and/or panels are suspected.

➢Composition between strings can be different.

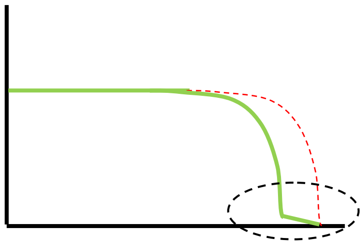
■ Expected reason

・Shading in clusters and/or modules due to large shadows.

・Pollution due to wide accumulation of dust.

・The number of modules per string is different between the modules.

12-4. Changing from IV curve to line (Change of Voc is very little.)



■ Factor

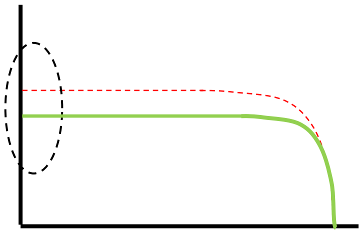
➢Declination of power output, but not enough to become a module failure, on single or a few modules can be suspected.

■ Expected reason

・Shading in modules due to large shadows.

・Pollution due to accumulation of dust.

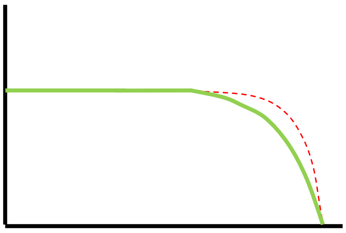
12-5. Declination of Isc



- ■ Factor
  - ➢Declination of power output on an entire string, i.e. shadow or light reduction on a whole string, can be suspected.
  - ➢Composition between strings can be different.

- ■ Expected reason
  - ・Irradiance during measurement itself may have been changed due to cloudy weather.
  - ・Shading in the whole module due to contamination of dust.
  - ・Difference in the number of the strings connected in parallel.

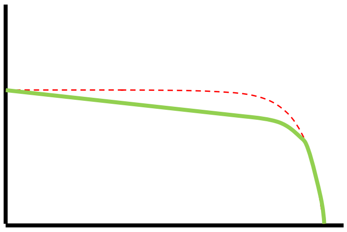
12-6. Gentle slope between Voc and Pmax



- ■ Factor
  - ➢Increased series resistance inside the string can be suspected.

- ■ Expected reason
  - ・Loose connectors, poor contact, etc.
  - ・Deterioration of modules.

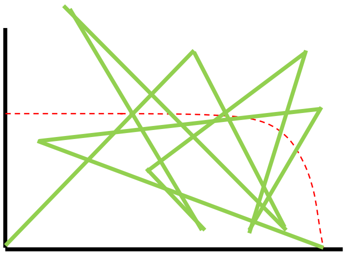
12-7. Gentle slope between Voc and Pmax



- ■ Factor
  - ➢Decreased parallel resistance inside the string can be suspected.

- ■ Expected reason
  - ・Deterioration of bypass diode.

12-8. Impossible to acquire waveform (Particularly turbulent waveform)



- ■ Factor
  - ➢Arc during measurement prevents it from completing under normal sequence.

- ■ Expected reason
  - ・Contact failure of the probe.
  - ・Increased resistance due to corrosion on probe and/or breaker terminals.

※ Stop the measurement once this type of waveform is indicated on the display.
If you continue measuring in spite of this condition, this equipment can be damaged.

12-9. Impossible to acquire waveform

- ■ Factor
  - ➢Improper voltage application to the measurement probe is suspected.

- ■ Expected reason
  - ・Wiring of strings is disconnected.
  - ・Voltage is inversely applied to anode and cathode because of wrong wiring or/and contact failure of the probe/
  - ・A fuse inside the device has blown.

13. Calibration

Regular calibration shall be necessary to keep the quality and accuracy of String Tracer. Frequency of calibration is based on customer's company regulation; however, calibration at least once every 2 years is recommended.

* String Tracer is designed especially for the I-V curve measurement of photovoltaic module. <u>Calibration at the manufacturer's facility is recommended to prevent damage to the circuits, as the calibration needs to be carried out with the devices having similar I-V characteristics to photovoltaic module.</u>
Never use a constant current/voltage source for calibration.

14. Warranty period

The warranty period of the product shall be one year from the date of delivery.

15. Warranty coverage

The manufacturer will repair or replace the product free of charge, provided that such failure is determined to be due to defects in materials or workmanship under normal operation within the warranty period.

However, warranty coverage does not apply when:

(1) the failure is caused by user's negligence, misuse or involved in accident or natural disasters;

(2) the failure is caused by modification and service by anyone other than the manufacturer or an authorized personnel.

This limited warranty covers only the supplied product itself, and the manufacturer has the right to refuse to compensate for any consequential damage caused by the supplied product.

16. Contact

If you have any technical inquiries on our products, please contact us at the following address or numbers.

TOGAMI ELECTRIC MFG. CO., LTD.

GLOBAL DEPARTMENT

Mailing address	1-1 Ohtakara-Kitamachi, Saga 840-0802, Japan
TEL	+81-952-25
FAX	+81-952-25
E-mail	global.info@ mi-elec.co.jp

INSTRUCTION MANUAL

Togami *Cell Line Checker*

Model: SPLC-A-Y1

- This instruction manual describes the operation and maintenance for the correct and safe use of Cell Line Checker.
  Thoroughly read and understand the information contained in this instruction manual before operating Cell Line Checker.
- After reading, keep this instruction manual for future reference.

Togami Electric Mfg.Co.,Ltd.

Instruction Manual
No.00989b

Contents

1. Safety precautions

- In order to prevent accident and injury, the following points should always be observed. Please be proficient in the knowledge of product, safety information, and precautions before operating Cell Line Checker. After reading, please keep this instruction manual at hand and refer to it when necessary.
- Safety precaution levels are classified as "DANGER" and "CAUTION".

⚠ DANGER : If operation is incorrect, a dangerous situation may occur, resulting in death or serious injury.

⚠ CAUTION : If operation is incorrect, a dangerous situation may occur, resulting in moderate impairment or minor injury or physical damage to the equipment.

⚠ DANGER

- To avoid electric shock, always wear rubber insulated gloves and electrical safety shoes when operating the equipments and performing detection.
- To avoid electric shock, damage, and fire, never use this equipment with the PV module having the higher output ratings than the ratings of this product.
- To avoid electric shock, damage, heat, and fire, never disassemble or modify the equipment.
- To avoid electric shock and damage, never use this equipment in or around water.
- To avoid electric shock, never connect the cables or equipments to this equipment other than the ones provided from the manufacturer.
- To avoid electric shock, never use the optional Rod Sensor if thunder is predicted.

⚠ CAUTION

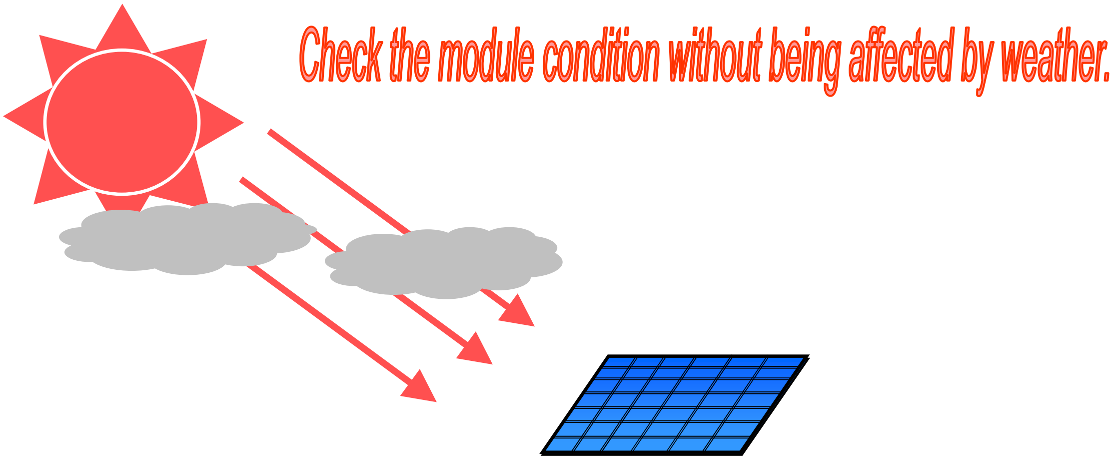
- To avoid damage, ensure to connect the lead wires to the terminal block, etc.
- To avoid damage, remove the batteries and store the equipment if it is not used over a long period of time.
- To avoid damage, disconnect the string from inverter while conducting the fault detection.
- To avoid damage, never leave the equipment in the car or anywhere becoming hot during summer.
- To avoid electric shock and damage, check whether there is no damage to the case or it does not show abnormal function prior to use if the equipment is dropped. There is a possibility of internal damage.
- To avoid electric shock, equipment should be operated only by the qualified personnel, e.g., licensed electrical worker or electrician.

2. Product overview

Cell Line Checker is designed for the wiring check at installation inspection and for module configuration check and the electrical fault detection at routine maintenance in the photovoltaic (PV) power generation system.

- PV module configuration (module layout of each string)
- Detection of PV module having low or no power output
  - Locating the wiring fault between modules
  - Locating the bad connector between modules
  - Detecting the module with the fault bypass diode
  - Detecting the module with the fault cluster
  - Locating the failure of interconnector
  - Locating the failure of busbar

Cell Line Checker consists of a transmitter, a receiver, and an optional rod sensor to detect the electrical failure of PV modules.



Check the module condition without being affected by weather.

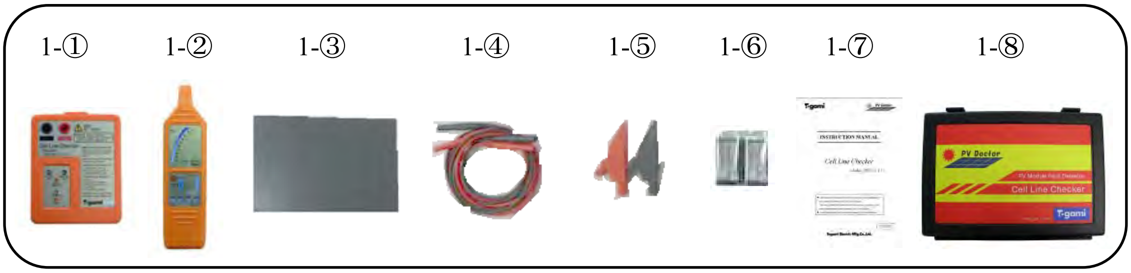
3. Features

- Efficient maintenance work: Employed signal detection method is less affected by shade; therefore, Cell Line Checker can be used in the cloudy day.
- Protective maintenance: Failures of interconnector and bypass diode can be detected for the protective maintenance purpose.
- Efficient work: Optional rod sensor enables to check the modules mounted in the inaccessible location.

4. Product components

Upon delivery, unpack and inspect the components and for any damage. If any damage or lack of component is discovered, please contact the manufacturer.

Components are indicated in the table below.



No.	Item	Type	Description	Quantity
1	Standard set	SPLC-A-Y1	-	-
1-①	Transmitter	SPLC-A-TY1	Signal generator Generate two types of signal: magnetic field and electric field. Connect 1-④test leads for transmitting the signal.	1
1-②	Receiver	SPLC-A-RY1	Signal receiver Detect the signal on the surface of PV modules. Display the signal level.	1
1-③	Rubber sheet	-	Sunlight shielding Place these shielding rubber sheets on cells while detecting bypass diode failure.	2
1-④	Test lead	-	Connect to the 1-①transmitter and 1-⑤ connection clip at each end. Use these leads when applying the signal generated by 1-① transmitter to the string. *1set: red and black, each 1.5m	1 set
1-⑤	Connection clip	-	Connect to the 1-④test leads. Use when connecting the transmitter to the breaker or string output terminal in the combiner box. *1set: red and black	1 set
1-⑥	9V battery	-	Batteries for transmitter and receiver	2
1-⑦	Instruction manual	-	Precautions and instruction shall be mentioned.	1
1-⑧	Carrying case	-	Case for 1-① to 1-⑦ above	1
Options				
2-①	Rod sensor	SPLC-A-F1Y1	Extendable sensor used with receiver Use this sensor when detecting the modules mounted in the inaccessible location.	-

5. Specifications

5.1 Condition of use

Item	Condition of use
Environment	Avoid using in the rain
Temperature rang	-10°C to 50°C
Humidity range	Relative humidity: 80% or less (No condensation)
Storage temperature range	-20°C to 60°C

5.2 Ratings of transmitter

Item	Description
Rated power voltage	DC9.0V: Operation range DC6.5V to DC9.0V Using one 9V battery Either manganese or alkaline
Applicable voltage range	0V to DC1000.0V
Detection method	- Current consumption with magnetic field mode - Signal input with electric field mode
Signal frequency	5kHz
Operation display	Green or blue LED (ON or flash)
Dimensions (mm)	153(H)×120(W)×50(D)
Weight (g)	Approx. 290 (including a battery)
Other functions	Auto power off ・Mg. field mode: A condition of input voltage less than 10V and no operation continues 10 minutes. ・Elec. field mode: After non-operation for 2 hours

5.3 Ratings of receiver

Item	Description
Rated power voltage	DC9.0V : Operation range DC6.5V to DC9.0V Using one 9V battery Either manganese or alkaline
Receiver sensitivity selector	Select from 5 levels. Each level has 5 level adjust from -20% to +20%.
Receiver display	Receiving level display: Flashing 10 green LEDs Alarm sound synchronized with LED flash
Built-in sensor	Coil sensor: 1 Electrode sensor: 1
Dimensions (mm)	235(H)×60(W)×30(D)
Weight (g)	Approx. 160 (including a battery)
Other functions	Auto power off and silent mode Power off after 10 minutes of no signal input and no operation

5.4 Ratings of option

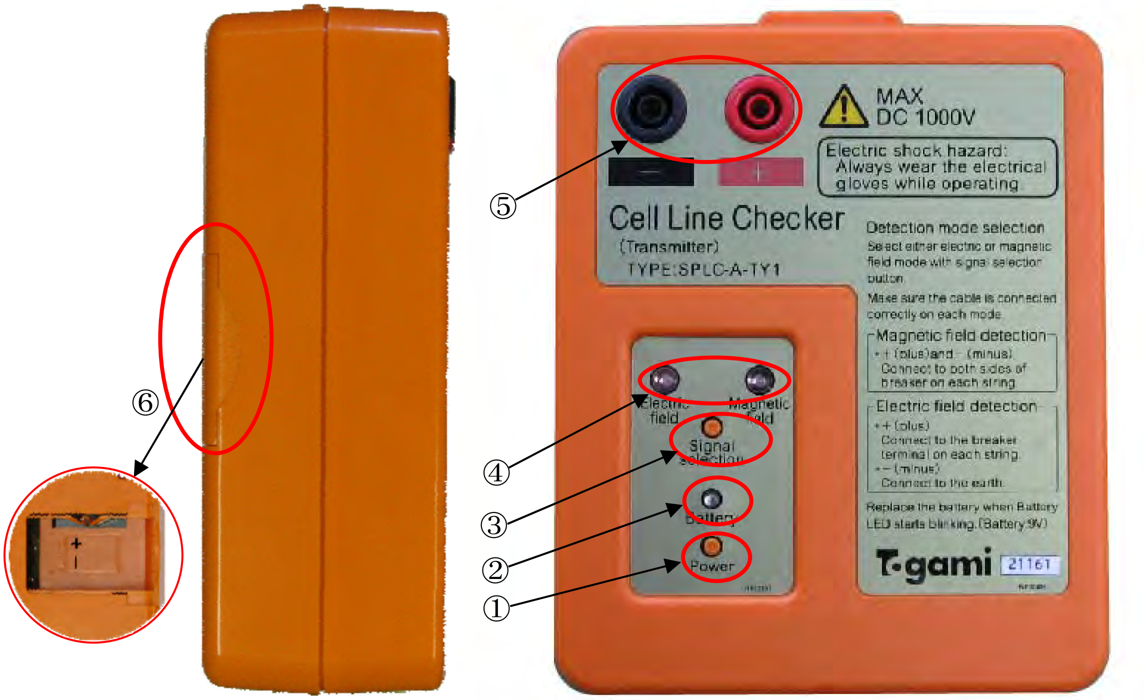
■ Rod sensor (Type: SPLC-A-F1Y1)

Item	Description
Built-in sensor	Coil sensor×2 (horizontal and vertical)
Rod length when detecting	Max. 2m (0.92m when storing)
Dimensions when storing (mm)	920(H)×70(W)×60(D)
Weight (g)	Approx. 850 (excluding receiver)
Other functions	Angle adjustable sensor head (The angle keeps the surface of module parallel to the sensor box by only placing the sensor box over the module. This mechanism prevents the variations in the response level which may occur if sensor box and module cannot maintain a certain space during the detection.)
Accessory	Storage bag and shoulder belt

【Rod Sensor】

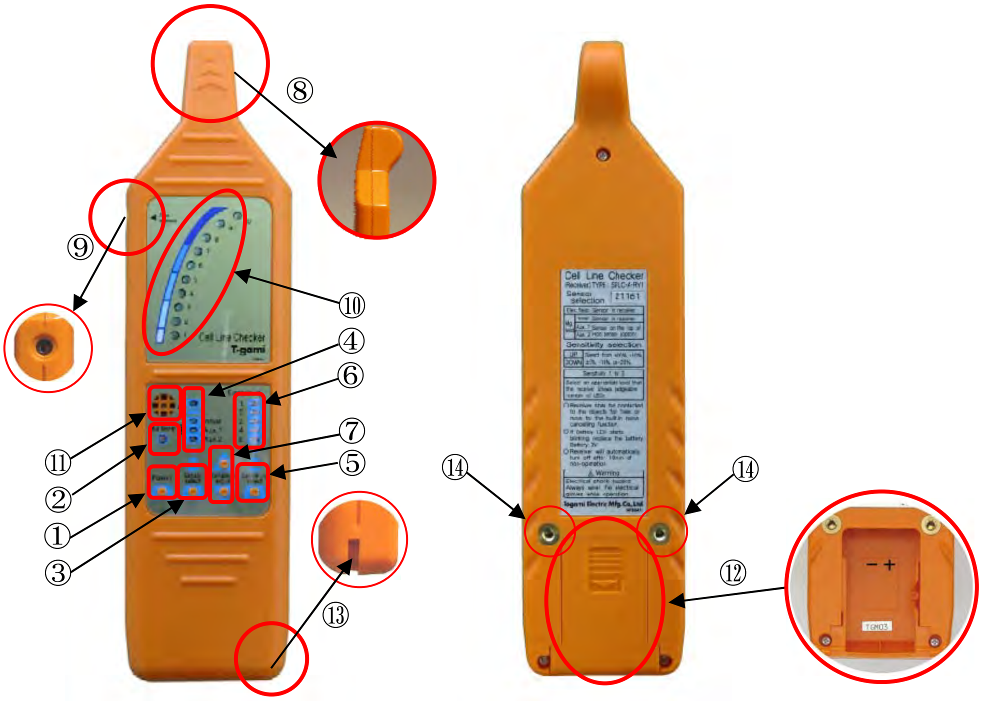
6. Part names and functions

6.1 Transmitter



No.	Name	Function
①	Power button	To turn ON and OFF the power Pushing and holding the button for 0.5sec or more to turn ON or OFF.
②	Battery LED	ON: Power ON BLINK: Low battery level OFF: Power OFF or no battery left
③	Mode selector	Mode changes in the sequence of “Electric”→“Magnetic”→ “Electric” at every push of the button. Select the mode depending on the purpose of detection. Initial setting: Magnetic field mode
④	Mode LED (Magnetic/Electric)	Display the selected mode; Blue: Magnetic field, Green: Electric field. Flash 3times in 1sec along to the signal. LED keeps ON with the condition below (in case of error): ･Magnetic: If input voltage from ⑤ is DC1040V or more, signal is unable to output. (Blue and Green LED keep ON.) ･Electric: If input voltage from ⑤ is 50V or more (between plus(+) terminal and earth), signal is unable to output. (Green LED keeps ON.)
⑤	Lead connector	Connector for the leads (accessory) which are red and black. Connect red lead to “plus (+)” terminal and black to “minus (-)” terminal. Make sure to insert the leads all the way.
⑥	Battery	Insert a 9V battery. Make sure the battery polarity is correct.

6.2 Receiver

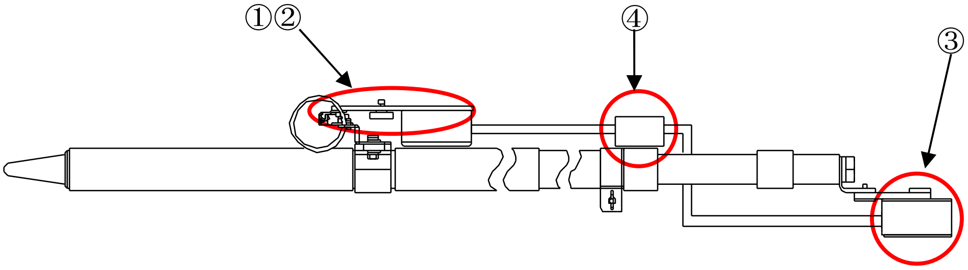


No.	Name	Function
①	Power button	To turn ON and OFF the power Pushing and holding the button for 0.5sec or more to turn ON or OFF.
②	Battery LED	ON: Power ON BLINK: Low Battery level OFF: Power OFF or no battery left
③	Sensor selector	Sensor changes in the sequence of “Aux.1”→”Aux.2”→”Elec.”→”Inner” →”Aux.1” at every push of the button. Select an appropriate sensor depending on the detection. Initial setting: “Inner”
④	Sensor LED	LED of the selected sensor shall be on.
⑤	Sensitivity selector	Sensitivity changes in the sequence of “2”→”3”→“4”→”5” →“1”→“2” at every push of the button. The bigger number has high sensitivity and can detect the weaker signal. Initial setting: “1”
⑥	Sensitivity LED	LED of the selected sensitivity shall be on.

No	Name	Function
⑦	Sensitivity adjustor	After sensitivity setting from 1 to 5, if the sensitivity needs to be adjusted much finer, use this function. △(up button) is for increasing the detection sensitivity, and ▽(down button) for decreasing. Each sensitivity level can be adjusted from the range between -20% and +20% in case of over/under setting. The adjusted level can be checked and displayed with ⑩Detection level LED. Number of LEDs and adjusting level are indicated in the table below. Initial setting: "±0%" Number of LEDs: 1 / 3 / 5 / 7 / 10 Adjusting level: -20% / -10% / ±0% / +10% / +20%
⑧	Inner sensor	2 types of sensors are equipped for 2 different detection modes: Electric field and Magnetic field.
⑨	Auxiliary sensor connector	Connector for optional auxiliary rod sensor. * Sensor should be selected by receiver with the rod sensor connected.
⑩	Detection level LED	LEDs flash while detecting the signal and when adjusting the sensitivity.
⑪	Alarm	Alarm sounds when the power turns ON and OFF, receiver detects the signal, and the auto-power off functions.
⑫	Battery	Insert a 9V battery. Make sure the battery polarity is correct.
⑬	Strap hole	Attach a strap for prevention of dropping the equipment.
⑭	Rod sensor nut	Embedded nuts to fix the receiver on the optional rod sensor. Fix with the knurled screws on rod sensor.

6.3 Option

■ Rod sensor



No.	Name	Function
①	Receiver board	Board to hold the receiver on the rod sensor Fix receiver with the knurled screws. (No tools needed)
②	Auxiliary sensor cable	Cable to connect receiver and rod sensor Insert to the【Auxiliary sensor connector】of receiver.
③	Sensor box	Magnetic field detection sensor Two sensors are equipped in the horizontal and vertical angles for detecting the signals on the surface of modules. Sensors will be selected depending on the direction of module installation. * Sensor for the electric field detection is not equipped. * Sensor shall be selected by receiver.
④	Retractable cable	Cable to transmit the signal detected in the sensor box to the receiver Cable length is adjustable depending on the rod length, and cable can be fixed with the hook-and-loop fastener. * When extending the cable, both ends of retractable cable shall be held and pulled. If only one end is extended, the cable may be entangled.

7. Usage

⚠ CAUTION Read thoroughly before use the equipment.

7.1 Precautions

(1) Power ON/OFF

Press and hold the power button 0.5sec or more when turning on or off the power.

(2) Cable connection

- Always wear the insulated protectors when connecting the clips to the terminals located in the combiner box to prevent the electric shock.
- Make sure to insert the test leads all the way when connecting the leads to transmitter and connection clips. If the connection is loose, there is a risk of electric shock.

(3) Operating precautions

- Auto power-off function is equipped to prevent unnecessary power consumption.
  Refer to 7.7 (1) on page 36 in this manual for the details of this function.
- When using the optional rod sensor, make sure there is no electrical wires, etc. around the work site to prevent the electric shock.
- If a string has multiple parallel circuits with compound semiconductor modules, the fault may not be able to locate accurately because, in some cases, the signal would be split to the parallel circuits other than detecting.

(4) Handling precautions

- If the equipment is dropped, check for any damages to the case and any abnormal functions prior to use.
- If Battery LED starts blinking, replace the battery soon because the battery level is low.

(5) Maximum continuous operation time

Referential operation time of using 9V alkaline and manganese batteries:

Alkaline battery

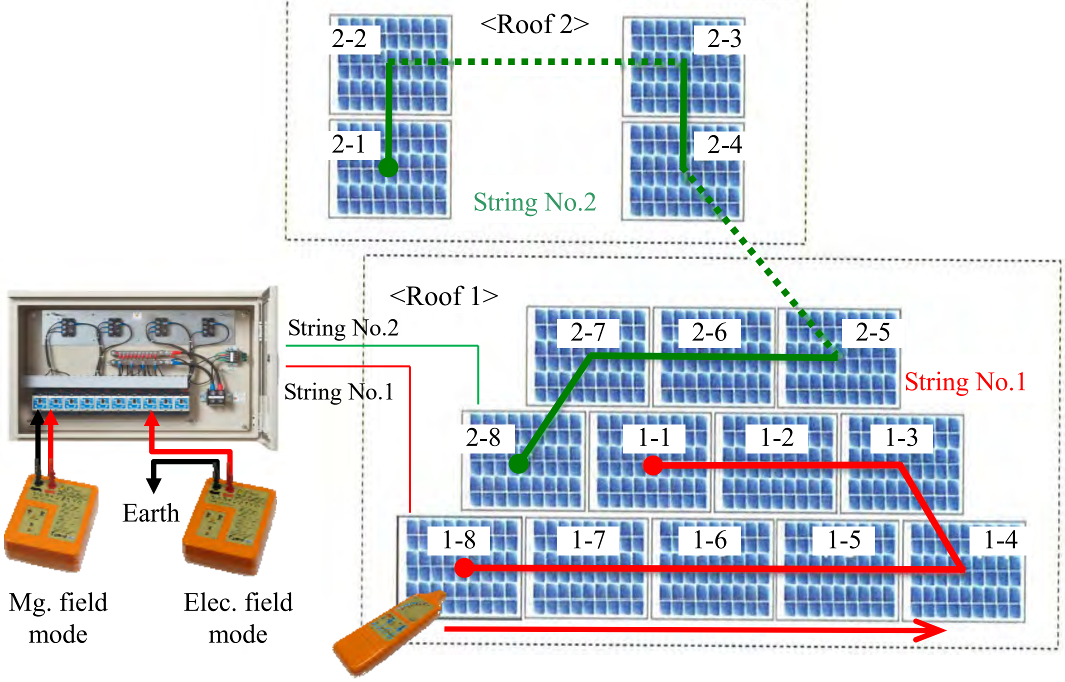
- Transmitter: 120 hours or more (Magnetic field mode)
- Receiver: approx. 12 hours

Manganese battery

- Transmitter: approx. 100 hours (Magnetic field mode)
- Receiver: approx. 4 hours

* To prevent the damage by battery leakage, remove the battery when the equipment is not used for a long period of time.

7.2 Basic usage

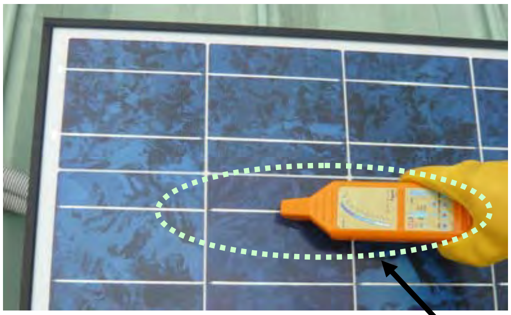


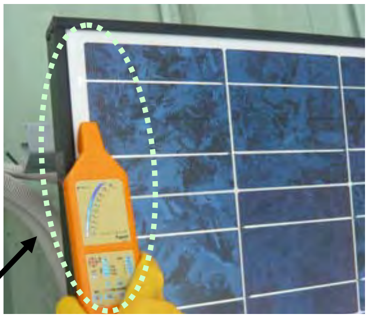
1) Turn off the string breaker. Connect the test leads of transmitter to the breaker terminals of module side, and then apply the signal. 【Table 1】

Mode	Connection Transmitter ⇒ Receiver
Mg. field	Test lead [RED] ⇒ Plus terminal of breaker primary side (module side)
	Test lead [BLACK] ⇒ Minus terminal of breaker primary side (module side)
Elec. field	Test lead [RED] ⇒ Minus terminal of breaker primary side (module side)
	Test lead [BLACK] ⇒ Earthing terminal

* Refer to 7.3 (2) on page 14 for the details of selecting either magnetic field or electric field mode.

2) Contact the sensor part of receiver to the module interconnector, busbar, etc. By checking the change in the number of LEDs flashing, locate the fault.


<Interconnector detection>


<Busbar detection>

Note: Magnetic field sensor on the top of receiver has directionality.
Make sure to place and move the receiver parallel to the wiring direction.

7.3 Functions for each fault case

(1) Fault case vs. functions 【Table 2】

Phenomenon	Details of fault	Fault case	Detection function
Reduced power output	**No string output** * Series circuit in the module or between modules has failure.	1) Bad connection of the module connector or failure of wiring between modules 2) Failure of bypass diode in a module AND busbar failure, interconnector failure, or PV cell damage	・Detecting the damaged PV module ・Locating the wiring failure between modules ・Locating the module connector having continuity damage
	Lowering string output * Series circuit in a module has failure.	1) Busbar failure in a module 2) Interconnector failure (All interconnectors have failure.) 3) PV cell damage	・Detecting the damaged PV module ・Detecting the damaged cluster in a damaged PV module ・Detecting the damaged PV cell in a damaged PV module ・Detecting the bypass diode failure in a cluster
	Lowering string output * A part of series circuit in a module is damaged.	1) Interconnector failure (At least one interconnector is normal.) 2) PV cell damage	

According to the next clause 7.3 (2) “Selection of magnetic field or electric field detection,” select the appropriate detection mode depending on the failure case.

(2) Selection of magnetic field or electric field detection

First, it is necessary to select an appropriate detection mode depending on the PV module type (circuit configuration) and fault case.

The tables below indicate the recommended selection of either "Magnetic field detection by current consumption method" or "Electric field detection by signal input method" depending on the purpose.

PV module strings are all connected in series circuit.
(Mainly crystalline silicon: c-Si (monocrystalline and polycrystalline) modules) 【Table 3】

Purpose of detection	Magnetic field	Electric field
String configuration (Module layout)	✓ (Refer to 7.4.1)	✓ (Refer to 7.5.1)
Failure and bad connection of wirings or connectors between modules	-	✓ (Refer to 7.5.2)
Failure in busbars	✓ (Refer to 7.4.2)	-
Failure in interconnector	✓ (Refer to 7.4.3)	-
Failure in bypass diode	(Refer to 7.4.4)	-

PV module strings are connected in series-parallel combination circuit.
(Mainly compound semiconductor (CIS and CIGS) modules) 【Table 4】

Purpose of detection	Magnetic field	Electric field
String configuration (Module layout)	✓(maybe) *1 (Refer to 7.4.1)	✓ (Refer to 7.5.1)
Failure and bad connection of wirings or connectors between modules	-	✓ *2 (Refer to 7.5.3)
Failure in busbars	✓ *1 (Refer to 7.4.2)	-
Failure in bypass diode	✓ *1 (Refer to 7.4.4)	-

*1. If any blocking diodes are installed in the parallel circuits in a string, the circuit which has the highest Voc would only show response, and other circuits would not show response. Disconnect the plus(+) output connectors of the circuit other than the one detecting. (Please be noted that the blocking diodes may be installed in the cable enclosure.)

*2 Disconnect all plus(+) output connectors of each parallel circuit when conducting the detection.

7.4 Detection with magnetic field mode

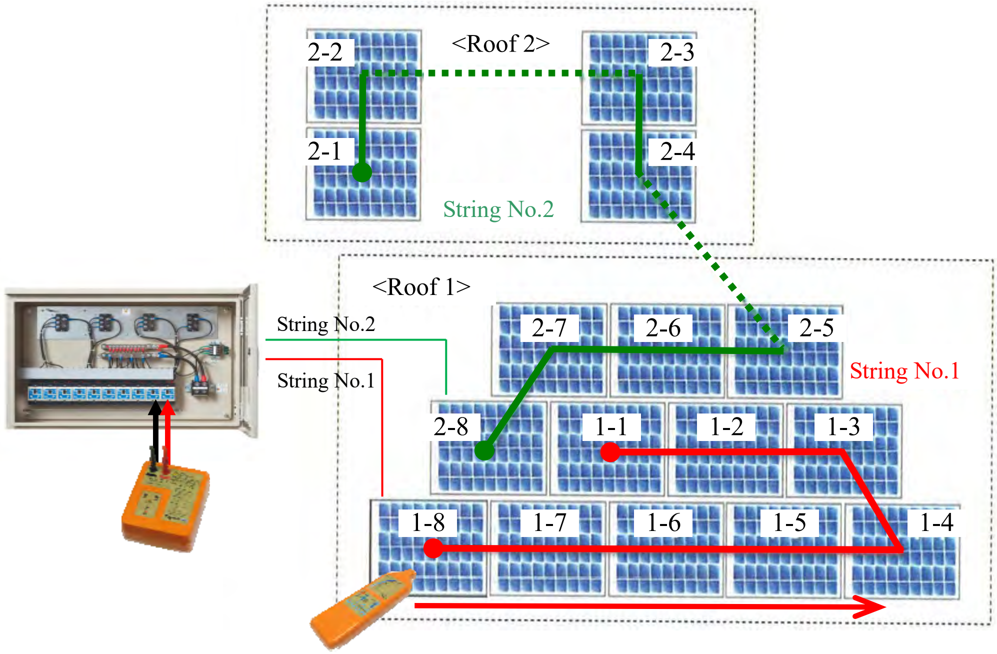
7.4.1 Module configuration (string layout check) [c-Si and compound semiconductor modules]

If a PV system with multiple strings is installed on the multiple roof tops, use this function to confirm the module configuration.

* If wiring between modules is disconnected, magnetic field mode cannot be used. Locate the fault point by the procedure indicated in 7.5.2 "Detection of failure and bad connection between modules" on page 29, and after repair/replacement, conduct the configuration check.

The diagram below shows an example of module layout check in a two-string system.

NOTE If modules are connected in series-parallel combination circuit, refer to 7.5 "Detection with electric field mode" on page 27.

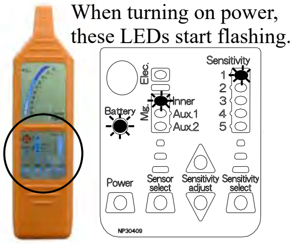


【Connection】

1. Turn off the string breaker to be detected in the combiner box.
2. Connect transmitter with test leads and clips to the primary side (module side) of the breaker turned off in the previous step. If there is a terminal block between breakers and PV modules, transmitter can be connected to the terminal block.
3. Push and hold the power button for 0.5sec or more to turn on the transmitter. At the same time, transmitter starts generating the magnetic field signal. Blue LED on "Magnetic field" of mode LED starts flashing.

【Detection】

1. Push and hold the power button for 0.5sec or more to turn on the receiver.
2. As turning on the receiver, "Battery," "Mg.-Inner," and "Sensitivity 1" LEDs are turned on as shown on the right.


When turning on power, these LEDs start flashing.

3. Depending on the types of module or circuit configuration, select an appropriate sensitivity. Refer to the tables 5 and 6 for the sensitivity settings.
4. Cont act the top of receiver to the test lead, either red or black, to check whether the detecting signal is applied to the line near the transmitter.
5. After checking on the test lead, contact the top of receiver to the interconnectors or busbars on the surface of modules to check whether the signal is applied to the string.

* Refer to 7.7(3) on page 36 for the detection with Rod sensor.

<Interconnector detection for c-Si modules>

* In case of back-contact modules whose interconnectors cannot be seen from the front surface, receiver will show the highest response above the interconnectors. Find the highest response level in a cell, and check whether the signal is applied at the highest point.

<Busbar detection for compound semiconductor modules>

* Depending on the module type, receiver shows different level of response at different location in a module. Find the highest response level along the busbar, and check whether the signal is applied at the highest point.

【Judgment】

If receiver shows the response by flashing LEDs with synchronized alarm in a module, the module shall be a part of the string. If the LEDs are all off, the module shall be a part of other strings.

NOTE

- Sensitivity should be changed depending on the module type and the number of modules connected in parallel. The tables below indicate the recommended settings when conducting the string configuration check. Moreover, adjust the sensitivity if necessary.

【c-Si modules (monocrystalline and polycrystalline)】 【Table 5】

Number of interconnectors	2	3	4	Back contact
Sensor selector	Receiver detection: Magnetic field mode [Inner] Rod sensor detection: Magnetic field mode [Aux.1] or Magnetic field mode [Aux. 2]			
Sensitivity selector	Sens. 2	Sens. 3	Sens. 4	Sens. 3

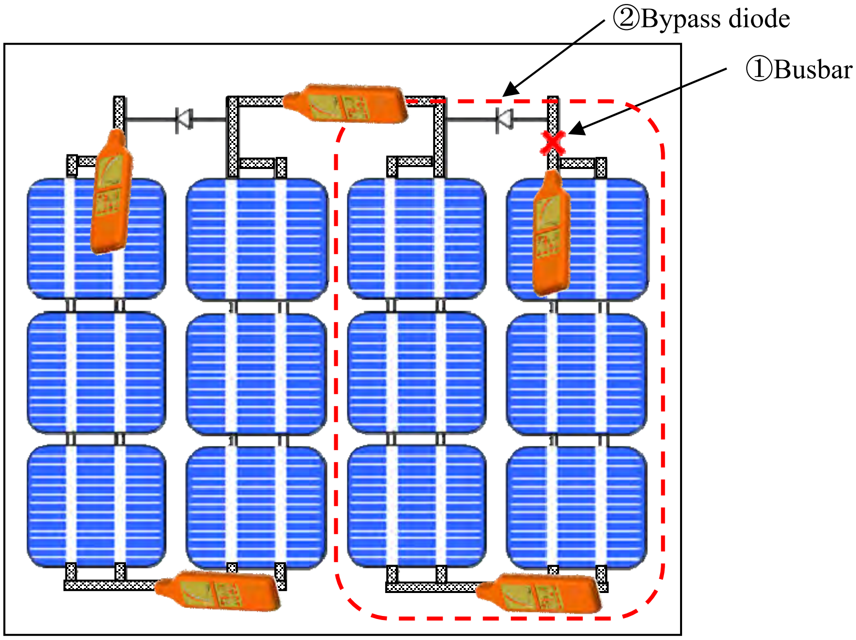
【Compound semiconductor modules (CIS and CIGS)】 【Table 6】

Number of module in parallel	2	3	4 - 10	11 or more
Sensor selector	Receiver detection: Magnetic field mode [Inner] Rod sensor detection: Magnetic field mode [Aux.1] or Magnetic field mode [Aux. 2]			
Sensitivity selector	Sens. 2	Sens. 3	Sens. 4	Sens. 5

7.4.2 Detection of busbar failure (c-Si and compound semiconductor modules)

Electric power generated in the PV modules is transmitted to combiner box and inverter through busbars in each module. If any busbar has failure, the part called cluster which contains the fault busbar is unable to generate the power, which, as a result, leads to lowering the total power output.

The diagram below shows an example of busbar failure. The shaded parts indicate the busbars. If ①busbar has failure, ②bypass diode functions. As a result, the right half of the module is unable to generate power, which leads to lowering the total system output.



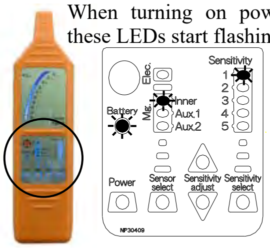
▨ : busbars

【Connection】

1. Turn off the string breaker to be detected in the combiner box.
2. Connect transmitter with test leads and clips to the primary side (module side) of the breaker turned off in the previous step. If there is a terminal block between breakers and PV modules, transmitter can be connected to the terminal block.
3. Push and hold the power button for 0.5sec or more to turn on the transmitter. At the same time, transmitter starts generating the magnetic field signal. Blue LED on "Magnetic field" of mode LED starts flashing.

【Detection】

1. Push and hold the power button for 0.5sec or more to turn on the receiver.


When turning on power, these LEDs start flashing.

2. As turning on the receiver, “Battery,” “Mg.-Inner,” and “Sensitivity 1” LEDs are turned on as shown on the right.
3. Depending on the types of module, select an appropriate sensitivity. Refer to the tables 7 and 8 for the sensitivity settings.
4. Contact the top of receiver to the test lead, either red or black, to check whether the detection signal is applied to the line near the transmitter.
5. After checking on the test lead, contact the top of receiver to the busbars on the surface of modules to check whether the signal is applied.

   * Refer to 7.7(3) on page 36 for the detection with Rod sensor.


<Busbar detection for c-Si module>

* Busbars of back-contact module may not be seen from the surface. However, check whether the signal is applied by contacting the top of receiver to the busbars as shown in the picture above.


<Busbar detection for compound semiconductor modules>

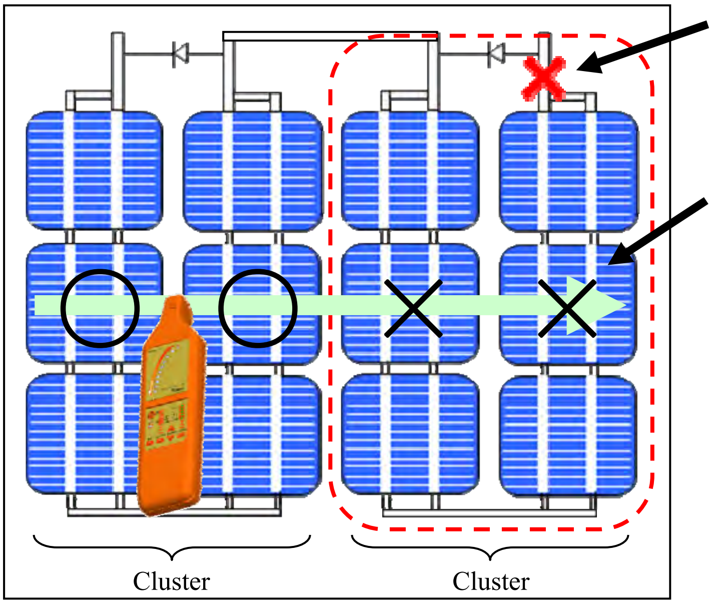
* Depending on the module type, receiver shows different level of response at different location in a module. Find the highest response level along the busbar, and check whether the signal is applied at the highest point.

【Judgment】

If receiver shows the response by flashing LEDs with synchronized alarm in a module, the module should be the normal (good) module. If the LEDs are all off, the module should be the one having failure.

<u>Rough detection</u> (c-Si module only)

Cluster failure of c-Si modules can be detected with a simple detection. As indicated in the diagram below, move the receiver on a module surface from left to right as crossing the different clusters, and check whether the receiver shows response or not.



Busbar failure

Receiver cannot detect signal in this cluster. Therefore, failure somewhere in this cluster can be confirmed.

NOTE

- Sensitivity should be changed depending on the module type and number of modules connected in parallel. The tables below indicate the recommended settings when conducting busbar failure detection. Moreover, adjust the sensitivity if necessary.

【c-Si modules (monocrystalline and polycrystalline)】 【Table 7】

Number of interconnectors	2	3	4	Back contact
Sensor selector	Receiver detection: Magnetic field mode [Inner] Rod sensor detection: Magnetic field mode [Aux.1] or Magnetic field mode [Aux. 2]			
Sensitivity selector	Sens. 1	Sens. 1	Sens. 1	Sens. 3

【Compound semiconductor modules (CIS and CIGS)】 【Table 8】

Number of module in parallel	2	3	4 - 10	11 or more
Sensor selector	Receiver detection: Magnetic field mode [Inner] Rod sensor detection: Magnetic field mode [Aux.1] or Magnetic field mode [Aux. 2]			
Sensitivity selector	Sens. 2	Sens. 3	Sens. 4	Sens. 5

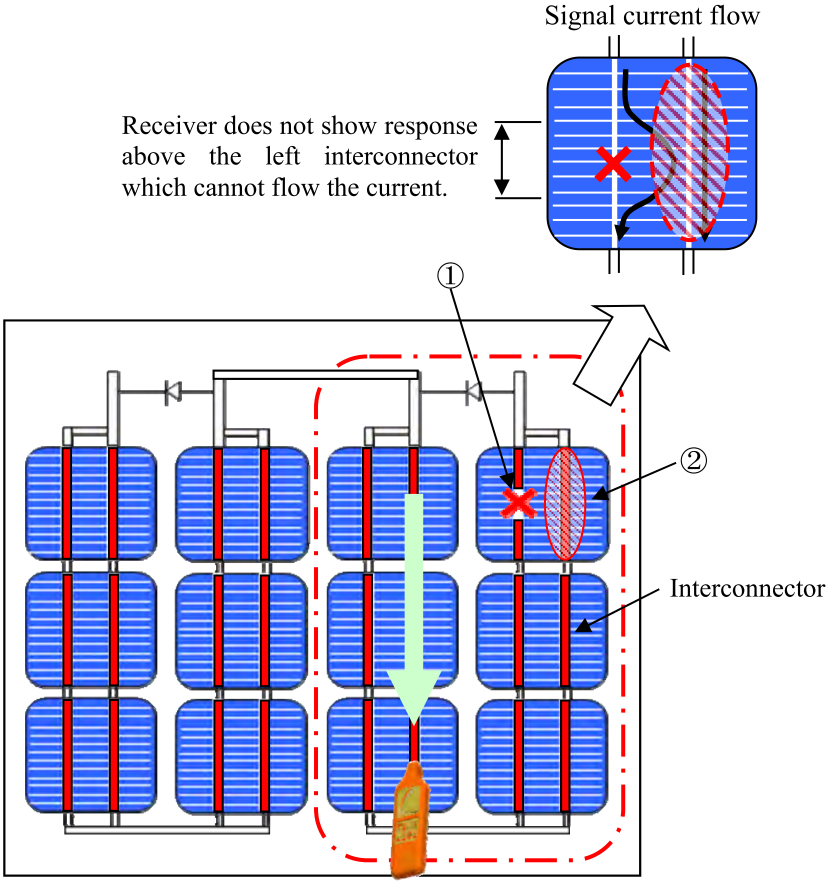
* Depending on the module installation, if the sensitivity is too high, the surrounding modules and/or wirings behind the module may affect the result.

7.4.3 Detection of interconnector failure (c-Si modules except back-contact modules)

Wiring strips, usually 2 to 4, connecting each cell in a PV module are called interconnectors. If an interconnector has failure but at least one of the other interconnectors works fine, it will not necessarily lead to lowering the string output. However, it will possibly lead to a heat generating phenomenon by the concentrated current flow to the normal interconnector, which is called the **Hot Spot**. Hot spot will cause the module degradation eventually.

The diagram below shows an example of interconnector failure. If an interconnector has failure (indicated as ① in the diagram), generated signal current will flow to the other interconnector in the same cell (indicated as ②), and around the area ② will generate heat because of the concentrated current flow. If, even worse, both interconnectors ① and ② have failures, current cannot be flown into right half of the module, and the condition is as same as the busbar failure mentioned in 7.4.2. (The right cluster is unable to generate power.)

In order to detect the interconnector failure of such case, trace every interconnector one by one as the diagram below, and check the change in the number of LEDs flashing.



【Connection】

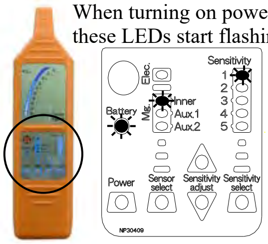
1. Turn off the string breaker to be detected in the combiner box
2. Connect transmitter with test leads and clips to the primary side (module side) of the breaker turned off in the previous step. If there is a terminal block between breakers and PV modules, transmitter can be connected to the terminal block.
3. Push and hold the power button for 0.5sec or more to turn on the transmitter. At the same time, transmitter starts generating the magnetic field signal. Blue LED on “Magnetic field” of mode LED starts flashing.

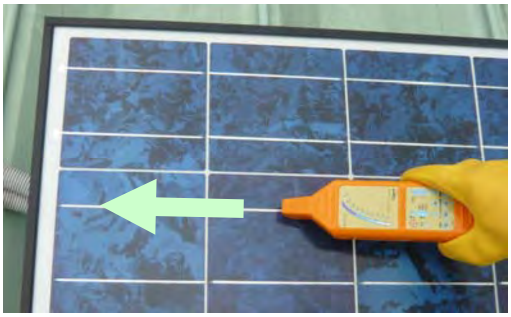
【Detection】

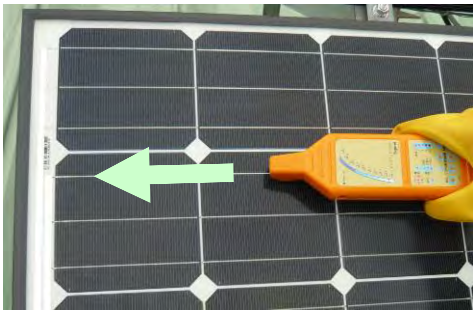
1. Push and hold the power button for 0.5sec or more to turn on the receiver.
2. As turning on the receiver, “Battery,” “Mg.-Inner,” and “Sensitivity 1” LEDs are turned on as shown on the right.
3. Depending on the types of module, select an appropriate sensitivity. Refer to the table 9 for the sensitivity settings.
4. Contact the top of receiver to the test lead, either red or black, to check whether the detection signal is applied to the line near the transmitter.

   After checking the signal on the test lead, top of the receiver shall be moved along the interconnectors on the surface of module, and the number of flashing LED shall be checked.

   * Refer to 7.7 (3) on page 36 for the detection with Rod sensor.


When turning on power, these LEDs start flashing.


<Interconnector of c-Si modules>
Two-interconnector type

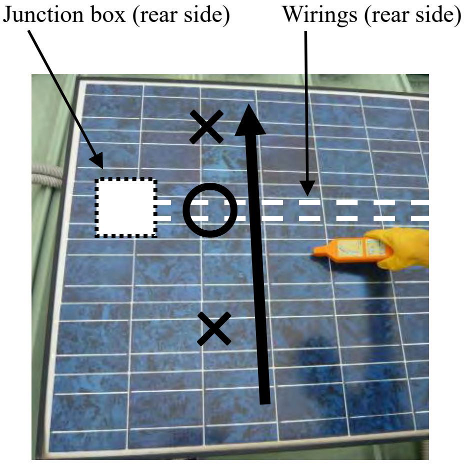

<Interconnector detection of c-Si modules>
Three-interconnector type

【Judgment】

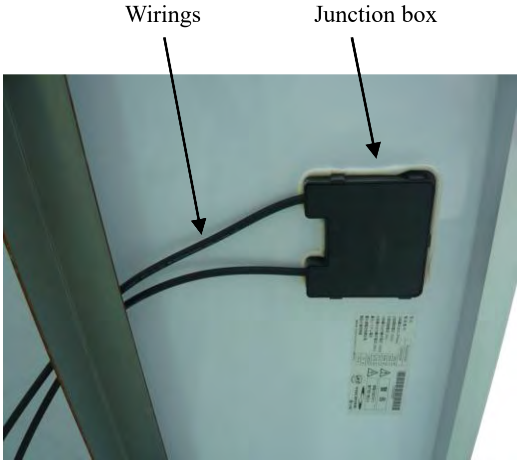
Interconnector may have failure at where the number of LEDs becomes 0(zero) or decreased.

NOTE

- Receiver may show higher level of response around the junction box equipped on the back of module.
- If the sensitivity is set too high, receiver may detect the unnecessary signal flown in the back wirings and junction box as the signal flown in the module interconnectors/busbars, which may affect the detection result.
- Location of the junction box is different from module to module; therefore, check where it locates prior to the detection.



<Detection from the surface of module)



<Wiring on rear side of module>

- Sensitivity setting shall be changed depending on the module type or the number of modules connected in parallel. The table below shows the recommended settings when conducting interconnector failure detection.

【c-Si modules (monocrystalline and polycrystalline)】 【Table 9】

Number of interconnectors	2	3	4
Sensor selector	Receiver detection: Magnetic field mode [Inner] Rod sensor detection: Magnetic field mode [Aux.1] or Magnetic field mode [Aux. 2]		
Sensitivity selector	Sens. 2	Sens. 3	Sens. 4

* For detection of interconnector failure, conduct the detection with finer sensitivity setting to see the change in number of LEDs in details. Adjusting the sensitivity to keep the number of LEDs around 5 to 7 is recommended while detection.

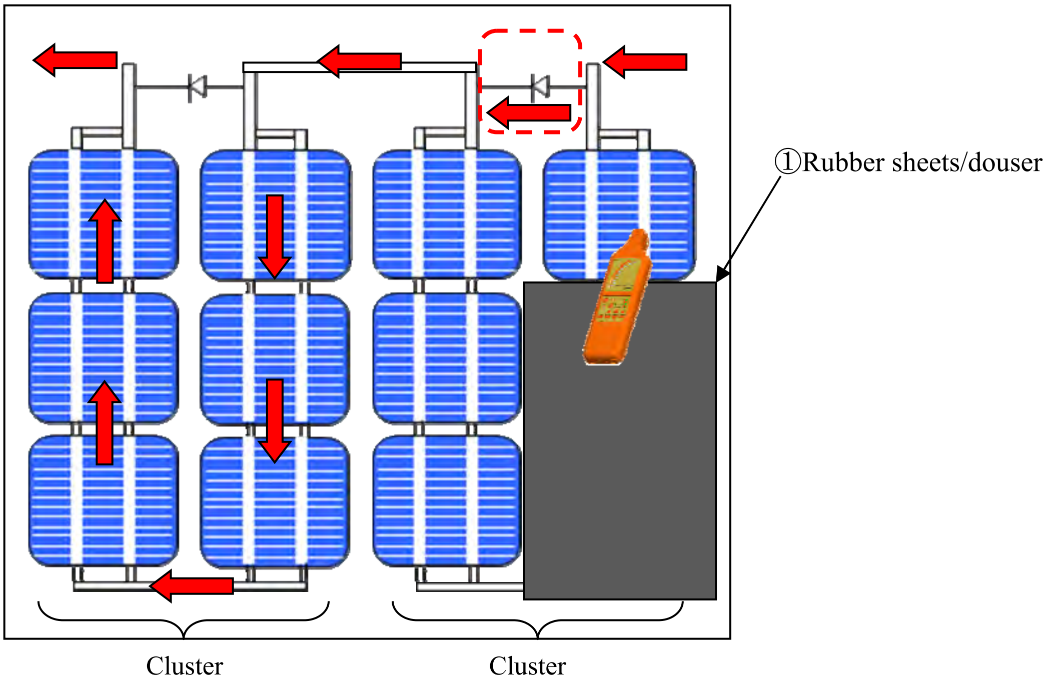
7.4.4. Detection of bypass diode failure (c-Si and compound semiconductor modules)

If, for example, any part of PV module is shaded and series connected cluster having the shaded cells cannot generate power, it will lead to lowering the total system output. In order to minimize the effect of shading, most photovoltaic modules have bypass diodes.

The diagram below shows the flow of the signal current as arrows in case an artificial shading condition is applied by using the ①light-blocking rubber sheets.

If the bypass diode normally functions, the current from the series-connected previous module would flow through the diode to the left cluster because electricity is generated in and flow to all cells in left cluster but not to the cells in right cluster.

If the bypass diode has failure, the current would not flow to the part enclosed by a dotted line in the diagram but would flow to the cells which are shaded with the light-blocking rubber sheets. In such a case, receiver shows response above the rubber sheets, which means the bypass diode in the module has failure.



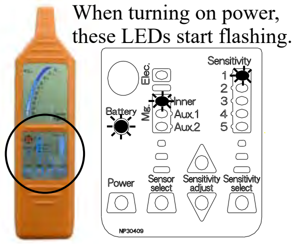
Internal cell construction varies between c-Si and compound semiconductor modules. Compound semiconductor module may need to block the sunlight on the whole surface to conduct the bypass diode failure detection. Moreover, if the modules are connected in series-parallel combination circuit, disconnect the connection of parallel circuits, and then conduct the detection. Refer to **NOTE** on page 25 for details.

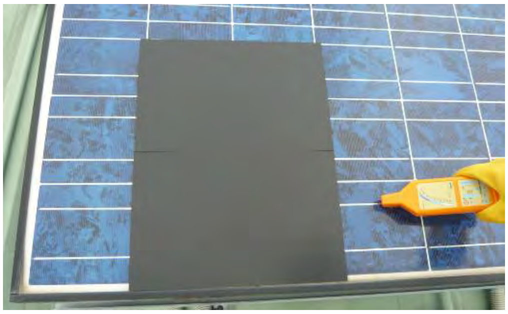
【Connection】

1. Turn off the string breaker to be detected in the combiner box.
2. Connect transmitter with test leads and clips to the primary side (module side) of the breaker turned off in the previous step. If there is a terminal block between breakers and PV modules, transmitter can be connected to the terminal block.
3. Push and hold the power button for 0.5sec or more to turn on the transmitter. At the same time, transmitter starts generating the magnetic field signal. Blue LED on “Magnetic field” of mode LED starts flashing.

【Detection】

1. Cover over the multiple cells of the module with the light-blocking rubber sheets.
2. Push and hold the power button for 0.5sec or more to turn on the receiver.
3. As turning on the receiver, “Battery,” “Mg.-Inner,” and “Sensitivity 1” LEDs are turned on as shown on the right.
4. Depending on the types of module or circuit configuration, select an appropriate sensitivity. Refer to the tables 10 and 11 for the sensitivity settings.
5. Contact the top of receiver to the test lead, either red or black, to check whether the detecting signal is applied to the line near the transmitter.
   After checking on the test lead, contact the top of receiver to the interconnectors or busbars on the surface of modules whose cells are covered with the light-blocking rubber sheets to check whether the signal flows.
   * Refer to 7.7(3) on page 36 for the detection with Rod sensor.

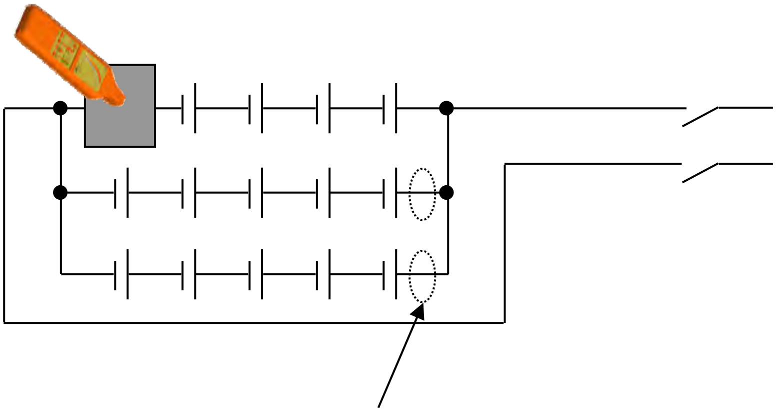

When turning on power, these LEDs start flashing.


<Bypass diode failure detection for c-Si>
Interconnector detection


<Bypass diode failure detection for c-Si>
Busbar detection

NOTE

- Cover at least 2 cells completely with the light-blocking rubber sheets. If any part of those cells is not completely covered, the bypass diode does not fully function, and receiver cannot conduct the proper detection. For compound semiconductor module detection, whole module surface should be covered to block the sunlight completely.
- If compound semiconductor modules are connected in series-parallel combination circuit as the diagram below, disconnect all plus(+) output connectors other than detecting to prevent shunting the signal.



Disconnect all output connectors other than detecting.

- If there is a space between module back and mounting surface, the reflected light enters into the module from the back surface. Even if the cells on the front surface are covered, ideal detection result may not be obtained. In such cases, first, lower the receiver sensitivity setting in order not to exceed the number of flashing LEDs more than 10, and second, compare the number of flashing LEDs before and after blocking the sunlight with rubber sheets. If the number of flashing LEDs does not change, the bypass diode has failure.

【Judgment】

If receiver shows response above the light-blocking rubber sheets, the bypass diode of the cluster has failure. If bypass diode normally functions, the signal flows through the bypass diode, and receiver would not show response on the covered cells.

- Sensitivity setting shall be changed depending on the module type or the number of modules connected in parallel. The tables below indicate the recommended settings when detecting the bypass diode failure.

【c-Si modules (monocrystalline and polycrystalline)】 【Table 10】

Number of interconnectors	2	3	4	Back contact
Sensor selector	Receiver detection: Magnetic field mode [Inner] Rod sensor detection: Magnetic field mode [Aux.1] or Magnetic field mode [Aux. 2]			
Sensitivity selector	Sens. 2	Sens. 3	Sens. 4	Sens. 3

【Compound semiconductor modules (CIS and CIGS)】 【Table 11】

Sensor selector	Receiver detection: Magnetic field mode [Inner] Rod sensor detection: Magnetic field mode [Aux.1] or Magnetic field mode [Aux. 2]
Sensitivity selector	Sens. 3

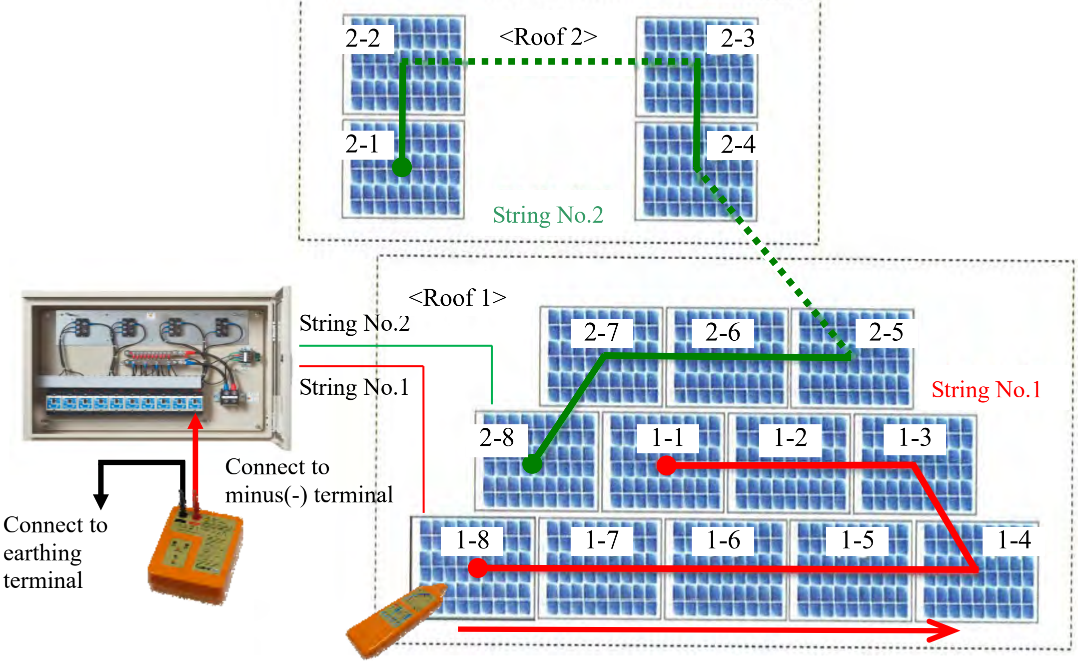
7.5 Detection with electric field mode

7.5.1 Module configuration [c-Si and compound semiconductor modules]

As well as the magnetic field mode detection mentioned in 7.4.1, module layout check can be conducted with electric field mode.

If any connectors/wires between modules are not connected properly, magnetic field mode cannot be used for string module layout check. Therefore, conduct the check with electric field mode.

* If connector/wire between modules is disconnected, receiver does not show any response after the disconnected point.

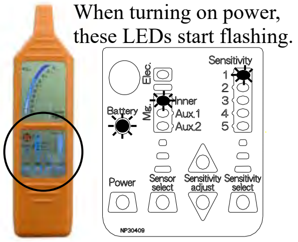


【Connection】

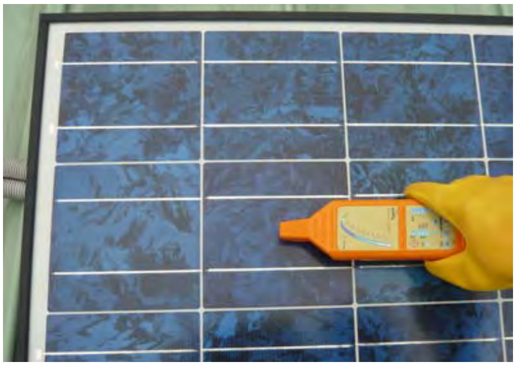
1. Turn off the string breaker to be detected in the combiner box.
2. Connect transmitter with red test lead and clip to the minus(-) terminal of primary side (module side) of the breaker turned off in the previous step and black test lead and clip to the earthing terminal. If there is a terminal block between breakers and PV modules, transmitter can also be connected to the terminal block.
3. Push and hold the power button for 0.5sec or more to turn on the transmitter.
4. At the same time, transmitter generates the magnetic field signal, so change the detection mode to the electric field mode with mode selector. Green LED on "Electric field" of mode LED starts flashing.

【Detection】

1. Push and hold the power button for 0.5sec or more to turn on the receiver.
2. As turning on the receiver, "Battery," "Mg.-Inner," and "Sensitivity 1" LEDs are turned on as shown on the right.


When turning on power, these LEDs start flashing.

3. Set the mode “Elec.” with sensor selector and the sensitivity “5” with sensitivity selector on the receiver respectively.
4. At the primary side of breaker that the red clip is connected, check whether the signal is applied to the line by contacting the receiver top on the lead. (Please be noted that no signal would be detected on the black clip.) After checking at the clip, contact the top of receiver on the surface of modules to check whether the signal is applied.



<Module surface detection for c-Si modules>

<Module surface detection for compound semiconductor modules>

【Judgment】

If receiver shows the response by flashing LEDs with synchronized alarm in a module, the module shall be a part of the string. If the LEDs are all off, the module shall be a part of other strings.

NOTE

- Hold the receiver in the hand while detection. Otherwise, receiver sensitivity may weaken.
- Regardless of any condition at the site, set the sensitivity “5” when conducting module configuration check with electric field mode.

【Any module types】 【Table 12】

Sensor selector	Receiver detection: Electric field mode
Sensitivity selector	Sens. 5

* Electric field mode cannot be conducted with Rod sensor.

* Since the sensitivity shall be set “5” which is the highest setting, the number of flashing LEDs may change depending on the module types and condition of connection. In order not to exceed the number of flashing LED more than 10 (keep the LEDs between 5 and 10), maintain the certain space between module surface and receiver while detecting.

7.5.2 Detection of failure and bad connection between modules

(In case of all modules in a string are connected in series.)

Series connected c-Si modules stop generating power when connectors/wirings between modules have failure. In such a case, the string voltage would be 0V. Therefore, quick repair or maintenance work is needed to prevent lowering the total power output of the whole system.

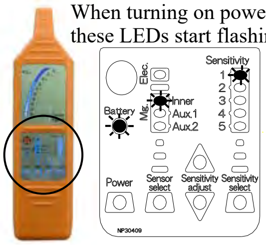
【Connection】

1. Turn off the string breaker to be detected in the combiner box.
2. Connect transmitter with red test lead and clip to the minus(-) terminal of breaker primary side (module side) which has been turned off in the previous step and black test lead and clip to the earthing terminal. If there is a terminal block between breakers and PV modules, transmitter can be connected to the terminal block.
3. Push and hold the power button for 0.5sec or more to turn on the transmitter.
4. At the same time, transmitter generates the magnetic field signal, so change the detection mode to the electric field mode with mode selector. Green LED on “Electric field” of mode LED starts flashing.

【Detection】

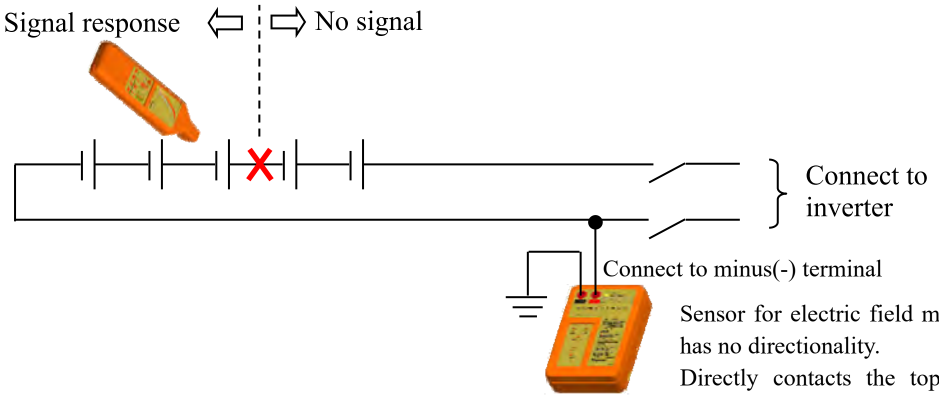
1. Push and hold the power button for 0.5sec or more to turn on the receiver.
2. As turning on the receiver, “Battery,” “Mg.-Inner,” and “Sensitivity 1” LEDs are turned on as shown on the right.
3. Set the mode “Elec.” with sensor selector and the sensitivity “5” with sensitivity selector on receiver.
4. At the primary side of breaker that the red clip is connected, check whether the signal is applied to the line by contacting the receiver top on the lead which is connected to the detecting module. (Please be noted that no signal would be detected on the black clip.)

   After checking at the clip, contact the top of receiver on the module surface to check whether the signal has been applied. (Start the detection with receiver from the module located in the minus(-) terminal of the string.)

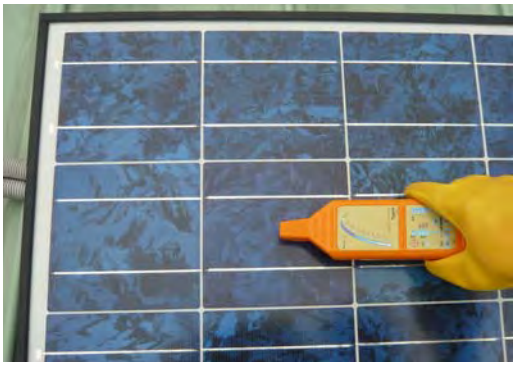

When turning on power, these LEDs start flashing.

【Judgment】

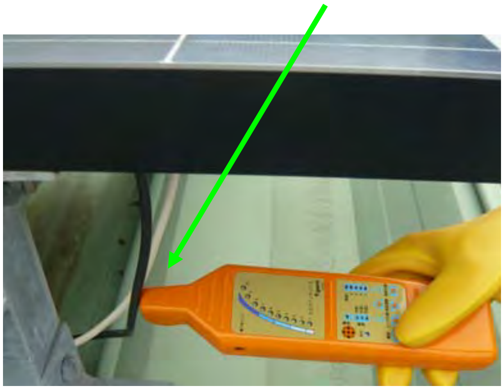
There should be no failure or bad connection if receiver shows response with flashing LEDs and synchronized alarm sound. If LEDs are off on a module, connector/wiring between the module and the one installed on minus(-) terminal side may have failure.



Sensor for electric field mode has no directionality.
Directly contacts the top of receiver on the wire.



<Module surface detection>



< Wire detection>

NOTE

- Hold the receiver in the hand while detection. Otherwise, receiver sensitivity may weaken.
- Regardless of any condition, set the sensitivity “5” when using the electric field mode.

【Table 13】

Sensor selector	Receiver detection: Electric field mode
Sensitivity selector	Sens. 5

* Electric field mode detection cannot be conducted with Rod sensor.

* Since the sensitivity shall be set “5” which is the highest setting, the number of flashing LEDs will be different on the module surface and wirings. In order not to exceed the number of flashing LED more than 10 (keep the LEDs between 5 and 10), maintain the certain space between module surface and receiver while detecting.

7.5.3 Detection of failure and bad connection between modules

(In case of all modules in a string are connected in series-parallel combination circuit.)

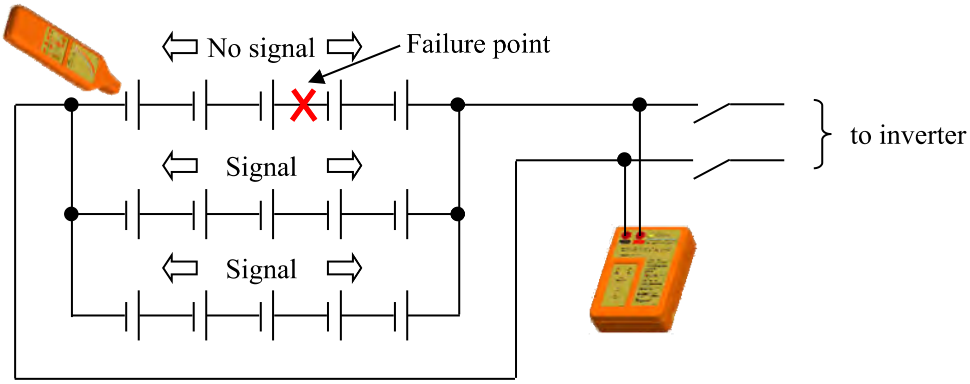
(1) Detection overview

In general, strings of compound semiconductor modules are connected in series-parallel combination circuit. Therefore, first, plus(+) connectors of parallel circuits have to be disconnected in order to prevent the electric field signal from flowing into the parallel circuits.

There are two detecting methods; Method 1: Combination of magnetic field and electric field mode detection, Method 2: Electric field mode detection as mentioned in the REFERENCE on page 34.

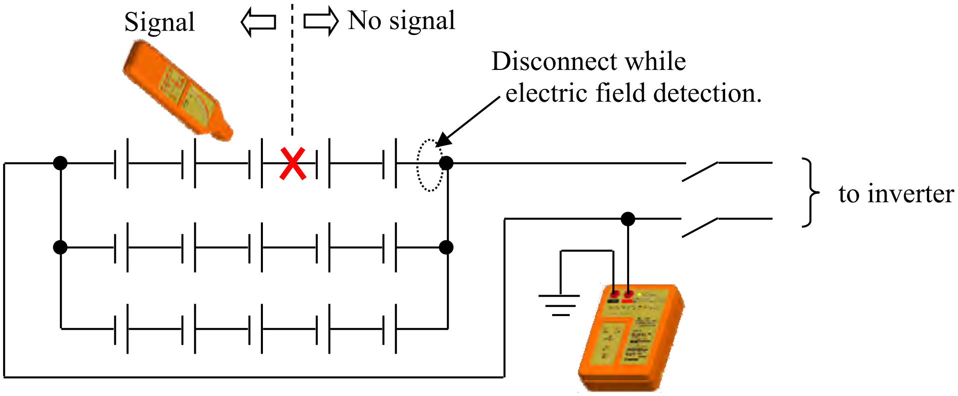
【Method 1: Combination of magnetic field mode and electric field mode】

① Check which parallel circuit has failure with magnetic field mode.



② Locate the fault wiring/connector between modules with electric field mode.

Disconnect plus(+) output connector of the detecting circuit in order to prevent the loop connection to other parallel connected circuits.



(2) Detection details

① Detection of fault parallel circuit with magnetic field mode

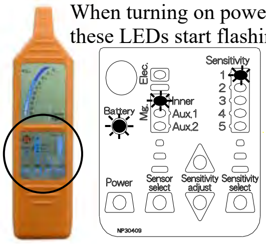
【Connection】

1. Turn off the string breaker to be detected in the combiner box.
2. Connect transmitter with test leads and clips to the primary side (module side) of the breaker turned off in the previous step. If there is a terminal block between breakers and PV modules, transmitter can also be connected to the terminal block.
3. Push and hold the power button for 0.5sec or more to turn on the transmitter. At the same time, transmitter starts generating the magnetic field signal. Blue LED on "Magnetic field" of mode LED starts flashing.

【Detection】

1. Push and hold the power button for 0.5sec or more to turn on the receiver.
2. As turning on the receiver, "Battery," "Mg.-Inner," and "Sensitivity 1" LEDs are turned on as shown on the right.
3. Depending on the types of module or circuit configuration, select an appropriate sensitivity. Refer to the table 14 on page 34 for the sensitivity settings.
4. Contact the top of receiver to the test lead, either red or black, to check whether the detecting signal is applied to the line near the transmitter.

   After checking on the lead, contact the top of receiver to the busbars on the surface of modules whether the signal is applied.


When turning on power, these LEDs start flashing.


<Busbar detection for compound semiconductor module>

* Depending on the module type, receiver shows different level of response at different location. Find the highest response level along the busbar, and check whether the signal is applied.

【Judgment】

If receiver shows the response by flashing LEDs with synchronized alarm sound, the connection has no failure. If the LEDs are off, circuits in the module may have failure.

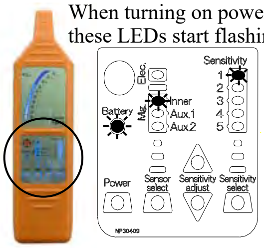
② Locating the failure with electric field mode

【Connection】

1. Turn off the string breaker to be detected in the combiner box
2. Connect transmitter with red test lead and clip to the minus(-)terminal of breaker primary side (module side) which has been turned off in the previous step and black test lead and clip to the earthing terminal.
3. Push and hold the power button for 0.5sec or more to turn on the transmitter.
4. At the same time, transmitter generates the magnetic field signal, so change the detection mode to the electric field mode with mode selector. Green LED on "Electric field" of mode LED starts flashing.

【Detection】

1. Disconnect the plus(+) output connector of parallel circuit which has not shown any response in ①Detection of fault parallel circuit with magnetic field mode.
2. Push and hold the power button for 0.5sec or more to turn on the receiver.


When turning on power, these LEDs start flashing.

3. As turning on the receiver, "Battery," "Mg.-Inner," and "Sensitivity 1" LEDs are turned on as shown on the right.
4. Set the mode "Elec." with sensor selector and the sensitivity "5" with sensitivity selector on receiver.
5. At the primary side of breaker that the red clip is connected, check whether the signal is applied to the line by contacting the receiver top on the clip which is connected to the detecting module. (Please be noted that no signal would be detected on the black clip.)

   After checking at the clip, contact the top of receiver on the surface of modules to check whether the signal is applied. (Start the detection with receiver from the module located in the minus(-) terminal of the string.)


<Surface detection for compound semiconductor module>


<Wiring detection between modules>

【Judgment】

There should be no failure or bad connection if receiver shows response with flashing LEDs and synchronized alarm sound. If LEDs are off in a module, connector/wiring between the module and the next one may have failure.

NOTE

- Sensitivity setting should be changed depending on the module type or the number of modules connected in parallel. The tables below show the recommended settings when detecting the failure and bad connection between modules.

①Detecting fault parallel circuit with magnetic field mode 【Table 14】

Number of module in parallel	2	3	4 to 10	11 or more
Sensor selector	Receiver detection: Magnetic field mode [Inner]			
Sensitivity selector	Sens. 2	Sens. 3	Sens. 4	Sens. 5

②Locating failure with electric field mode 【Table 15】

Sensor selector	Receiver detection: Electric field mode
Sensitivity selector	Sens. 5

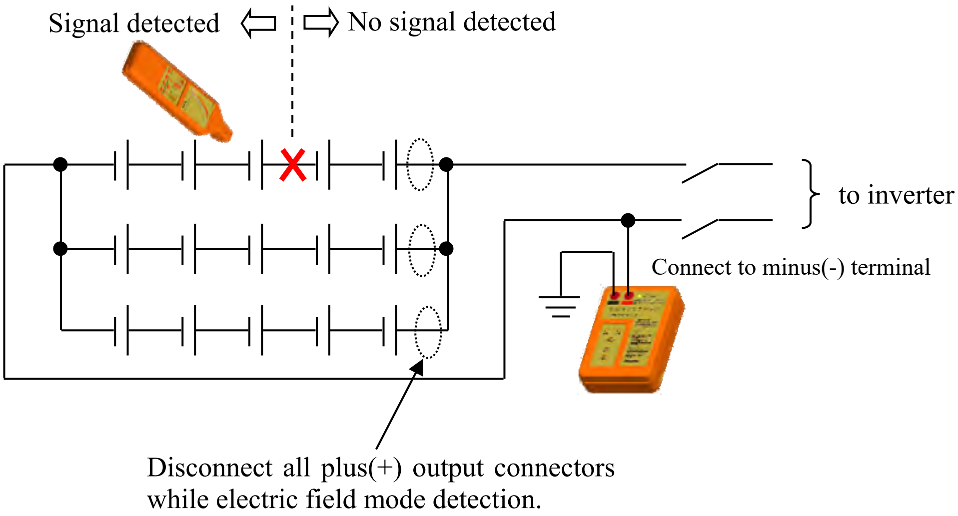
* Electric field mode detection cannot be conducted with Rod sensor.

* Since the sensitivity shall be set “5” which is the highest setting, the number of flashing LEDs may be different on the module surface and wirings. In order not to exceed the number of flashing LED more than 10 (keep the LEDs between 5 to 10), maintain the certain space between module surface and receiver while detecting.

REFERENCE

【Method 2: Electric field mode】

If all plus(+) connectors of parallel circuits are disconnected, fault location can be conducted with electric field mode.



7.6 Sensitivity setting selection

Sensitivity setting with magnetic field detection mode

【In case all modules are connected in series】

(In most cases, modules are c-Si (monocrystalline and polycrystalline).) 【Table 16】

Number of interconnectors	2	3	4	Back contact
Module configuration check	Sens. 2	Sens. 3	Sens. 4	Sens. 3
Detection of failure and bad connection of wirings/connectors between modules	-	-	-	-
Detection of busbar failure	Sens. 1	Sens. 1	Sens. 1	Sens. 3
Detection of interconnector failure	Sens. 2	Sens. 3	Sens. 4	-
Detection of bypass diode failure (interconnector detection)	Sens. 2	Sens. 3	Sens. 4	Sens. 3

【In case all modules are connected in series-parallel combination circuit】

(In most cases, modules are compound semiconductor (CIS and CIGS).) 【Table 17】

Number of parallel connected modules	2	3	4 to 10	11 or more
Module configuration check	Sens. 2	Sens. 3	Sens. 4	Sens. 5
Detection of busbar failure	Sens. 2	Sens. 3	Sens. 4	Sens. 5
Detection of bypass diode failure (busbar detection)	Sens. 2	Sens. 3	Sens. 4	Sens. 5

* Sensitivity settings mentioned above shall be deemed as only a reference and suggestion. It may be necessary to change and adjust the sensitivity depending on the module type and level of degradation. 5 to 9 LEDs flashing are the ideal number to conduct the detection.

* If the sensitivity is too high, surrounding modules and wirings on the back surface may affect the detection result.

Sensitivity setting with electric field detection mode

【Any module types】 【Table 18】

Module configuration check	Sens. 5
Detection of failure and bad connection of wirings/connectors between modules	Sens. 5

7.7 Other featured functions

(1) Auto-power off

Receiver: If the receiver is not operated for 10 minutes, power turns off automatically.

Transmitter: With electric field mode, if the transmitter is not operated for 2 hours, power turns off automatically.

With magnetic field mode, if input voltage continues less than 10V and transmitter is not operated for 10 minutes, power turns off automatically.

(2) Silent function

Alarm sound can be set for silent operation when the equipment is used around the residential area or where the alarm sound should be turned off.

How to set silent function: Turn on the receiver with pushing and holding the “Sensor Selector” button and “Sensitivity Selector” button.

How to reset: Turn off the power and turn on as normal.

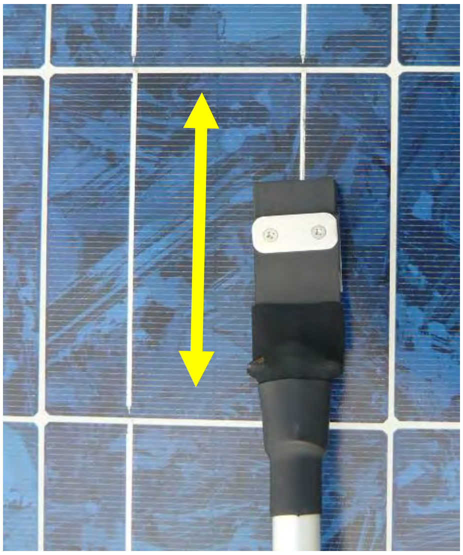
(3) Rod sensor (optional)

Rod sensor is a sensor mounted on an extension rod for conducting the failure detection of modules installed where the worker cannot reach and directly conduct the detection with receiver. It is made from aluminum and lightweight. No tools necessary to extend and shrink the rod. Receiver can be mounted and un-mounted without any tools.

While using the rod sensor, set the mode and sensor of receiver as “Mg.” and “Aux. 1” for vertical move or “Mg.” and “Aux. 2” for horizontal move.

Other settings, such as receiver connection and receiver sensitivity, shall be as same as the detection with receiver itself.

<Rod sensor detection>

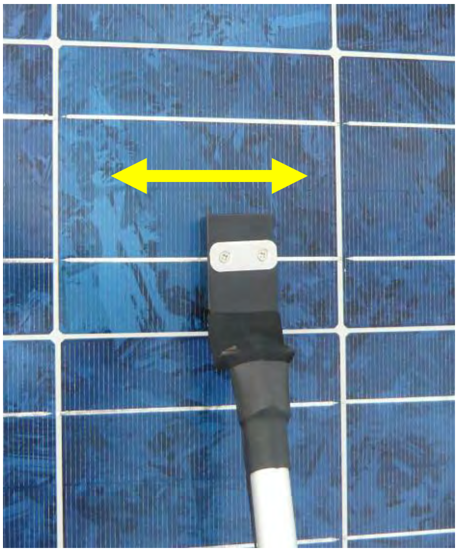


<Vertical movement>
Receiver sensor selection: Mg. field [Aux. 1]

Note: Vertical sensor is equipped on the center of vertical axis in the sensor box.
During the detection, center of sensor box shall move along the interconnectors.

* In case of back-contact modules whose interconnectors cannot be seen from the front surface, receiver will show the highest response above the interconnectors. Find the highest response level in a cell, and check whether the signal is applied at the highest point.

<Receiver mounting>



<Horizontal movement>
Receiver sensor selection: Mg. field [Aux. 2]

Note: Horizontal sensor is equipped around the metal fitting in the sensor box.
During the detection, metal fitting of sensor box shall move along the interconnectors.

* In case of busbar detection of compound semiconductor modules, depending on the module type, receiver shows different level of response at different location. Find the highest response level along the busbar, and check whether the signal is applied.

<Receiver mounting (rear side)>
Fix the receiver with the knurled screws and connect the Aux. sensor cable.

8. Warranty period

The warranty period of the product shall be one year after the date of delivery.

9. Warranty coverage

The manufacturer will repair or replace the product free of charge, provided that such failure is determined to be due to defects in materials or workmanship under normal operation within the warranty period.

However, warranty coverage does not apply when:

(1) the failure is caused by user's negligence and force majeure, and

(2) the failure is caused by the modification and service by anyone other than the manufacturer or an authorized personnel.

This limited warranty cover only the supplied product itself, and the manufacturer has right to refuse to compensate for the consequential damages that have occurred by the supplied product.

10. Contact

If you have any technical inquiries on our products, please contact us at the following address or numbers.

TOGAMI ELECTRIC MFG. CO., LTD.
GLOBAL DEPARTMENT

Address	1-1 Ohtakara-Kitamachi, Saga 840-0802, Japan
TEL	+81-952-25-4131
FAX	+81-952-25-9767
E-mail	global.info@togami-elec.co.jp

Togami Electric Mfg.Co.,Ltd.

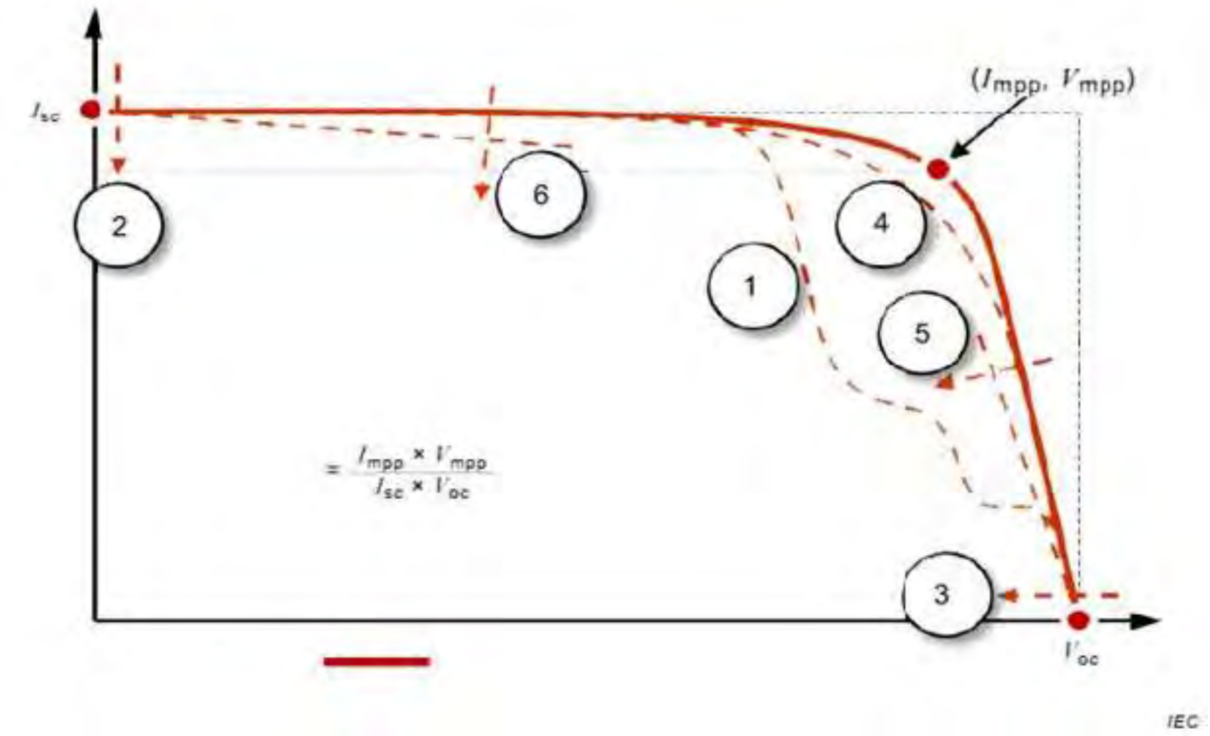
GLOBAL DEPARTMENT

Mailing address 1-1 Ohtakara-Kitamachi, Saga 840-0802, Japan
TEL +81-952-25-4131
FAX +81-952-25-9767
E-mail global.info@togami-elec.co.jp

(Attachment) Interpretation of the I-V curve shape

The I-V curve of a normal solar cell has a smooth shape and can be divided into the following three elements.

- Part starting from *I*SC and gradually declining with increasing voltage
- Part where the current value sharply declines and voltage reaches *V*OC as voltage increases
- Curved portion (shoulder portion) connecting the above two elements



The numbers from NOTE ① to ⑥ indicate variations of the curve shape described below.

Figure 2.14 I-V curve shape

There may be some differences in the I-V curves measured and I-V curves assumed from electrical specifications due to uncertainty of solar irradiance measurement, partial shading, or soiling of the light receiving surface. Such differences also include cases where the parameter settings of the measuring instrument or measuring method is incorrect.

Variation ① - Step or deformation in the curve

An abnormal step or deformation of the I-V curve indicates a possibility that a malfunction has occurred in the test solar cell module.

The following is a conceivable cause.

- A partial shadow is cast on the solar cell array or the solar cell module.
- The light receiving surface of the solar cell array or the solar cell module is partially soiled.
- The solar cell module is damaged.
- The bypass diode is faulty.

Note: Even when one cell in the solar cell module is partially shaded, current may flow in the bypass diode and deformation may appear in the I-V curve.

Variation ② - Low current

If there is a difference between the expected current value and the measured current value, there is a possibility that some malfunction has occurred. Some examples are shown below.

a) Cause on the solar cell array side
- Extensive soiling of the light-receiving surface
- Ribbon-shaped shadow
- Dam-shaped dust accumulation
- Degradation of solar cell module
- Cracking, clouding, and discoloration of modules

Note: The influence of the ribbon-shaped shadow or the dam-shaped dust accumulation differs depending on the solar battery cell connection pattern in the solar cell module, the mounting direction (vertical placement, horizontal placement) of the solar cell module, etc.

b) Parameter settings of the measuring instrument
- Solar cell module data was not entered correctly.
- Number of serial and parallel strings was not correctly entered.

c) Accuracy of irradiance measurement
- Improper calibration or failure of the sensor
- The sensor is not mounted on the same side as the solar cell array.
- Irradiance change during I-V curve measurement.
- It is affected by reflected light from the ground surface or surrounding structures.
- Irradiance is too low, or sun altitude is too low.

Note: For measurement abnormalities, the measurement value may be both low and high.

Variation ③ - Voltage drop

The following are conceivable causes of voltage drop.

a) Cause on the solar cell array side
- Bypass diode failure.
- Defective internal connection of solar cell module or solar cell array.
- The number of solar cell modules in the strings is different.
- PID (Potential Induced Degradation) has occurred.
- Shading of solar cells, solar cell modules, and entire solar cell string.

b) Problems with instrument parameter settings
- Solar cell module data was not entered correctly.
- The number of strings was not entered correctly.

c) Measurement causes
- The temperature of the solar cell and solar cell module cannot be measured correctly.

The temperature of the solar cell and the solar cell module is generally measured at a representative point near the central portion, but in some cases, it cannot be measured adequately due to the installation conditions or the influence of the wind, etc. In addition, measuring the temperature of the solar cell and the solar cell module requires knowledge or experience in selecting the mounting method or location of the sensor.

Variation ④ - The shoulder part of the curve becomes gradual

The shoulder part of the I-V curve may indicate deterioration (decrease of FF). In addition, when the slope of the linear portion before and after the shoulder part is changing, the curve of the shoulder part may appear to be gentle.

Variation ⑤ - The slope of the sloping part becomes gradual

The slope at the right side of the I-V curve between the maximum output point (*V*mpp) and *V*OC is affected by the series resistance of the test circuit. When the series resistance is high, the slope of this portion is relatively gradual.

The following phenomenon are conceivable as a cause of the series resistance becoming large.

- Damaged or disconnected solar cell wiring (or insufficient cable size)
- Defective internal connection of solar cell module or solar cell array.
- Increase in series resistance value of the solar cell module itself

When the cable of the solar cell array is drawn over a long distance, it causes the series resistance to rise and affects the shape of the shoulder portion. When this type of error is seen on the I-V curve, it is necessary to pay attention to the quality of the wiring or internal connection between the solar cell modules. In addition, this type of error may indicate a fault in the wiring of the solar array circuit, its resulting damage, or corrosion.

The increase in the series resistance of the solar cell module may increase the internal resistance of the solar cell and increase the resistance value in the junction box due to deterioration and/or corrosion or manufacturing error.

An infrared thermography test is an effective tool to identify this type of high resistance fault.

Variation ⑥ - Changes in the slope of the upper gradual sloping part

Changes in the gradual slope at the top of the I-V curve can be attributed to the following reasons.

- Increase in leakage current in the solar cell
- Mismatch of solar cell module *I*SC
- Partial shading or soiling (such as dam-shaped dust accumulation)

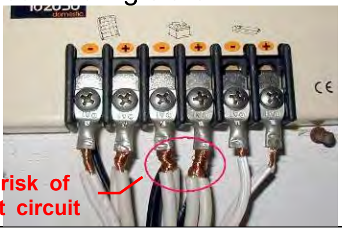
A leakage current of a solar cell is usually caused by a local defect of the solar cell itself or the connection between solar cells. The leakage current may lead to local heat generation, and this phenomenon called hot spot can also be identified with an infrared thermography test.

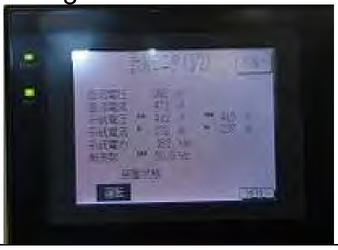
The *I*SC of the solar cell modules constituting the string have a certain degree of variation when manufactured, but when such variations are randomly distributed, it is difficult to make it appear as an abnormality in the I-V curve.

Significant shading causes a step or partial deformation in the I-V curve, but when a small portion of the solar cell modules in the string is shaded or when a shade with a complex shape is cast on them, it may not appear as an abnormality in the I-V curve.

(Attachment)

Table 2-5: Recommended checkpoints during patrol

Equip	Component	Checkpoint	Aging ctrl.	Component	Checkpoint	Aging ctrl.
PV array	Module	Damage, stain on surface, noise, bad odor, and mounting state 		External wiring	Damage and connecting state 	
	External wiring along rack	Rust, corrosion, break, damage to assembly, and connecting state 		Earth wire	Damage and connecting state 	
	Foundation	Damage and tilt 		Ground	Tall plants	
Junction box	Housing	Rust, corrosion, break, and, mounting state 		Wiring	Damage, connecting state, bad odor, and burning mark 	
PCS	Housing	Rust, corrosion, break, and, mounting state 		Wiring	Corrosion, damage, and connecting state 	
	Conditions	Noise and bad odor		Protection relays	Check on operating state	

Equip	Component	Checkpoint	Aging ctrl.	Component	Checkpoint	Aging ctrl.
	Room temperature (present and peak values)	Check on specified range	Yes	Room humidity (present value)	Check on specified range	
	DC voltage (V)	Within total open-circuit voltage of modules 	Yes	Total generated energy (kWh)	Check on monitor	Yes
Distribution board (power receiving panel)	Conditions	Noise, bad odor, vibration, and break 		Output power (kW)	Below total capacity of PV modules. Irradiation data is used to evaluate power generation if available. 	Yes
Output board	AC voltage (V)	About design value	Yes	AC voltage (A)		Yes
	Total energy supplied to grid (kWh)	Check on watt-hour meter for selling to the power company 	Yes	In-house energy consumption (kWh)		Yes
Transformer and switch board for grid	Conditions	Noise, bad odor, vibration, break, and oil leak 		Oil temperature (present value)	Check on specified range	Yes
	Oil level (present value)	Check on specified range		Conditions	Noise, bad odor, vibration, and break	
	Open/close counter	Check on specified range	Yes			

Equip	Component	Checkpoint	Aging ctrl.	Component	Checkpoint	Aging ctrl.
Yard of PV arrays	Irradiation (kW/m^2)	Check on cleaning condition 	Yes	Temperature (present, peak, and bottom values)	Check on cleaning condition 	Yes
	Humidity (present value)		Yes			
Security equipment	Outer fence	Installation condition, breakage or damage				
Circumstance	Possible shadow by structure	Growth of trees and newly constructed buildings		Dust generation	Ground and construction work around site	

(Source: Shikoku Electric Power Company, Inc.)

(Attachments)

Owned measuring instruments, spare parts and tools

Date: ______________

List of measuring instruments for PV O&M

Instrument name	quantity	Purpose	Manufactured Date
1. Digital multi meter	1	General measurement to know circuit condition	
2. Voltage detector	1		
3. Terminal boards & wire clips	1 set	To make up circuits for inspections	
4. Insulation Resistance Tester (Megger)	1	Measurement to verify insulation condition of the circuit from PV panels to the switching board	
5. I-V Curve tracer	1	Verification of the condition of strings	
6. Line tracer	1	Verification of the condition of panels	
7. Infrared camera	1	Verification of the condition of panels	
8. Battery Tester	1	Detection of bad battery cells	
9.			
10.			

Date: ______________

List of needed spare parts for O&M of solar PV facilities

Spare Part Name	Use	Quantity	Manufactured Date
1. PV modules			
2. DC Circuit Breakers for the termination of PV circuit			
3. Fuse for PCS			
4. Condensers, touch panels, batteries of touch panels, fans for PCS			
5. Circuit boards for PCS			
6. PCS (Whole equipment)			
7.			
8.			
9.			
10.			

Date: ______________

List of tools needed for renewable energy O&M

Items	quantity		Specifications	Manufactured Date
1. Screwdriver (+ and -)	2	set	Screwdriver (+ and -)	
2. Terminals board & wire clips	1	set	Terminals board & wire clips	
3. Cutting nipper	2		Cutting nipper	
4. Cutting Plier	2		Cutting Plier	
5. Hammer	2		Hammer	
6. Card tester	2		Card tester	
7. Socket wrench	1	set	Socket wrench	
8. Paint	2	can	Paint	
9. Anti-corrosive paint	2	can	Anti-corrosive paint	
10. Tool cabinet with door	1	unit	Tool cabinet with door	
11.				
12.				
13.				
14.				
15.				

PEC Fund PV Performance Ratio

Date Item	2020												Annual Average
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Rated Capacity of PV system(kW)	200	200	200	200	200	200	200	200	200	200	200	200	
Monthly Total Power Generation by PV system (kWh)	2825	13833	22338	13432	3287	0	0	1654	0	0	0	0	4780.75
Monthly Average Solar Radiation (kWh/m2/day)	3.9	3.9	4.9	3.6	5.4	0	0	3.5	0	0	0	0	2.1
Number of days per month	5	26	31	24	4			7					
Theoretical maximum energy yield(kWh/month)	3,900	20,280	30,380	17,280	4,320	0	0	4,900	0	0	0	0	
Performance Ratio(%)	**72.4**	**68.2**	**73.5**	**77.7**	**76**	**#DIV/0!**	**#DIV/0!**	**33.7**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**66.92**

Date Item	2021												Annual Average
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Rated Capacity of PV system(kW)	200	200	200	200	200	200	200	200	200	200	200	200	
Monthly Total Power Generation by PV system (kWh)	0	0	0	21287	15091	20047	20444	15189	21145	21797	13219	12397	13384.66667
Monthly Average Solar Radiation (kWh/m2/day)	0	0	0	4.560675	3.049576	4.206089	4.075959	4.230562	4.558666	4.93866	3.691585	3.997797	4.145507667
Number of days per month	31	28	31	30	31	30	31	31	30	31	30	31	
Theoretical maximum energy yield(kWh/month)	0	0	0	27,364	18,907	25,237	25,271	26,229	27,352	30,620	22,150	24,786	
Performance Ratio(%)	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**77.7**	**79.8**	**79.4**	**80.8**	**57.9**	**77.3**	**71.1**	**59.6**	**50**	**#DIV/0!**

Date Item	2022												Annual Average
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Rated Capacity of PV system(kW)	200	200	200	200	200	200	200	200	200	200	200	200	
Monthly Total Power Generation by PV system (kWh)	17551	16020	15928	16717	18366	13123	14836	19710	18290	17328	17032	8458	16113.25
Monthly Average Solar Radiation (kWh/m2/day)	4.0629	3.958563	3.509197	3.532313	3.977221	4.509525	3.268736	4.718622	4.73838	4.43784	4.455989	3.941675	4.092580236
Number of days per month	31	28	31	30	31	30	31	31	30	31	30	15	
Theoretical maximum energy yield(kWh/month)	25,190	22,168	21,757	21,194	24,659	27,057	20,266	29,255	28,430	27,515	26,736	11,825	
Performance Ratio(%)	**69.6**	**72.2**	**73.2**	**78.8**	**74.4**	**48.5**	**73.2**	**67.3**	**64.3**	**62.9**	**63.7**	**71.5**	**68.3**

Date Item	2023												Annual Average
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	
Rated Capacity of PV system(kW)	200	200	200	200	200	200	200	200	200	200	200	200	
Monthly Total Power Generation by PV system (kWh)	16182	14482	16202	15466	13670								15200.4
Monthly Average Solar Radiation (kWh/m2/day)	3.960471	4.536541	5.018624	3.992912	4.186321								4.33897363
Number of days per month	31	28	31	30	31	30	31	31	30	31	30	15	
Theoretical maximum energy yield(kWh/month)	25,190	22,168	21,757	21,194	24,659	27,057	20,266	29,255	28,430	27,515	26,736	11,825	
Performance Ratio(%)	**64.2**	**65.3**	**74.4**	**72.9**	**55.4**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**27.68333333**

(Remarks) 1. Input yellow cells.

2. Usual Performacne Ratio is between 70 and 85%.

3. 2016 Baseline Perfomance Ratio =66%

Inverters were out
of order from May 3

[Annual Work Schedule]

PV System Maintenance

Country name: Kosrae, FSM

							January																									February									March																			
NO	Site name	PV capacity		No. of inspectors	Inspector name		1	～	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	1	～	18	19	20	21	22	～	29	1	2	3	4	5	～	14	15	16	17	18	19	20	21	22	23	24	25	～	31
1	PEC PV	200KW	Plan	2	Robert, Gerry					■	■	■	■	■																																														
			Conducted	2	Robert, Gifford												🟥	🟥	🟥	🟥	🟥																										■	■	■	■	■	■								
2			Plan																																							🟥	🟥	🟥			🟥	🟥	🟥	🟥										
			Conducted																																																								
3	EU PV	100 KW	Plan	2	Robert, Gerry																			■	■	■	■																												■	■	■	■			
			Conducted	2	Robert, Ronnie																																																						
4			Plan																																																								
			Conducted																																																								
5			Plan																																																								
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19			Plan																																																									
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20			Plan																																																									
			Conducted																																																								

Remarks

Plan ■

Conducted 🟥

* Estimated No. of inspectors		* Estimated inspection period
• Up to 100 kW	1-2 inspectors	1-2 days
• 100-500 kW	2-3 inspectors	2-3 days
• 500 kW-1 MW	3-4 inspectors	4-6 days

Chapter 3. KUA(Kosrae) REO&M

Future Maintenance Work Plan (RE O&M)

1. Objective.

The purpose of this plan is to establish the schedule and estimate the approximate budget required for the operation and maintenance of the solar PV installations managed by the KOSRAE Utilities Authority (KUA). The plan is based on the scale of the current and planned future installations, and KUA's use of this plan will be an important guide in maintaining a reliable and affordable supply of power from renewable energy and contributing to the reduction of CO2 emissions from conventional DGs power generation facilities.

2. Preparatory process for inspection and maintenance plan of PV facilities (RE)

The following flow chart shows the process for performing inspections and maintenance on the facilities currently managed by KUA.

1. Prepare a periodic inspection and maintenance schedule for each PV solar installation, including the execution cycle and the required time and manpower.
   Basic conditions for each PV facility:
   - At least one periodic inspection per year.
   - At least one periodic maintenance per year including inspection.
   (See attachment 1. Inspection and Maintenance Schedule)

↓

2. Perform verification of spare parts and measuring instruments that need to be ordered for periodical inspection and maintenance works.
   (See attachment 2.)

↓

3. Calculate the budget required for periodical inspections and maintenance, including manpower cost, spare parts and necessary measuring instruments, equipment costs. Also, carry out the necessary procedures in the company to secure the budget.
   (See attachment 2.)

↓

4. Preparation for execution of periodical inspections and maintenance. Preparation includes secure manpower for the works, purchasing of the necessary material (spare parts, instruments, etc.) and consumables.

↓

5. Execution of periodical inspections and maintenance according to the O&M manual.

3. Conditions for planning and budgeting calculations.

The following conditions have been considered in the preparation of this plan.

No.	Conditions
1.	The plan covers only grid connected PV installations of pre-planned maintenance and inspections. (Including removal of obstruction to the sunshine, PCS and solar panels replacement, etc.)
2.	The plan excludes urgent, emergency improvement works, and unforeseen damage restoration works (Costing should be done on a case-by-case basis).
3.	The necessary budget for O&M of PV solar facilities was calculated based on Japan values as reference, so it is necessary recalculate the budget according to local values, actual results, and future forecasts.
4.	In the budgeting below assumptions are considered. ➢ PCS life span is 15 years. It is necessary to save a certain amount of money annually for the replacement of all PCS in 15 years. ➢ Internal parts of the PCS will need to be replaced during its lifetime, such as the cooling fan (5 years), digital panels and boards (10 years), but as these replacements depend on the installation environment, they are not considered in this budgeting.

3.1 List of RE facilities

The table below shows the facilities under management as of June 2023 and those planned for future establishment.

No.	PV Site name	Capacity(kW)	Commissioning
1	PEC Fund PV (Tofol Power Plant premises)	200	2015
2	EU PV (Parking area of Kosrae state government offices)	100	2015
Future Plan			
3	Solar PV (ADB)	1150	undecided

3.2 Type of periodical inspection and maintenance

(1) The periodic inspection is planned to be performed once a year at each PV site.

Visual inspections and measurement (open circuit voltage measurement, I-V curve measurement, insulation resistance measurement and checking for disconnection points using a cell line checker) are assumed to be carried out between the PV module and the PCS.

(2) Periodical maintenance is planned to be performed once a year at each PV Site. The set contents are:

- ➢ Removal of obstruction to the sunshine (panel cleaning, grass cutting, etc.).

- Cable and module replacement (assumed to be about 0.1% of the installed capacity of each facility/year).
- PCS replacement (assumed to be carried out after 15 years).
- Inspections are also conducted at the end of the periodical maintenance.

The following is the Schedule plan for regular inspections and regular maintenance.

PV Inspection and Maintenance schedule (Kosrae)

No.	PV Site name	capacity	Year of Installation	No. of inspectors and days	Plan	1											2											3											4											5											6										
						2023											2024											2025											2026											2027											2028										
1	PEC PV	200 kW	2015	2person×2days	inspection	🟧											🟧											🟧											🟧											🟧											🟧										
				2person×2days	maintenance	★						🟩					★						🟩					★						🟩					★						🟩					★						🟩					★						🟩				
2	EU PV	100kW	2015	2person×2days	inspection		🟧												🟧												🟧												🟧												🟧												🟧									
				2person×2days	maintenance		★						🟩						★						🟩						★						🟩						★						🟩						★						🟩						★						🟩			
3	Solar PV (ADB)	1150kW	undecided	3person×5days	inspection																																																																								
				3person×5days	maintenance																																																																								
4																																																																													
5																																																																													
6																																																																													
7																																																																													
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10																																																																													

🟧 : Regular measurement inspection (assuming implementation of visual inspection and measurement inspection)

🟩 : Regular maintenance (panel replacement, obstruction removal (panel cleaning, weed treatment, etc.)
+ Regular measurement inspections (visual and measurement inspections are assumed to be performed)

★ : Order spare parts for maintenance

(See Attachment)

4. Estimated periodical inspection and maintenance costs

Periodic inspection and maintenance costs are estimated for the next five years. The costs include labor cost, spare parts and purchase of measuring equipment cost.

(1) Labor costs (periodical inspections, maintenance)

For periodical inspections and maintenance, the following conditions shall be considered.

a) Visual inspections are not included in the cost as it is carried out during the daily work of operation and maintenance staff.

b) Inspections during emergencies and emergencies are not included.
(Inspections, restoration methods and costs need to be considered in another budget).

c) The manpower (number) and duration (days) for each periodical inspection should be set according to the scale of each facility, referring to the following.

Up to 100 kW	1-2 inspectors × 1-2 days
100～500kW	2-3 inspectors × 2-3 days
500 kW-1 MW	3-4 inspectors × 4-6 days

d) The same manpower (number) is used for periodical maintenance as for periodical inspections. During maintenance, inspections are also carried out.

(2) Spare parts and measuring instruments purchase costs

Panels (spare parts), PCS and measuring instruments in the periodical maintenance of photovoltaic installations are expected to be expensive on their own. They should be spread and accumulated in the annual budget to cover maintenance replacements.

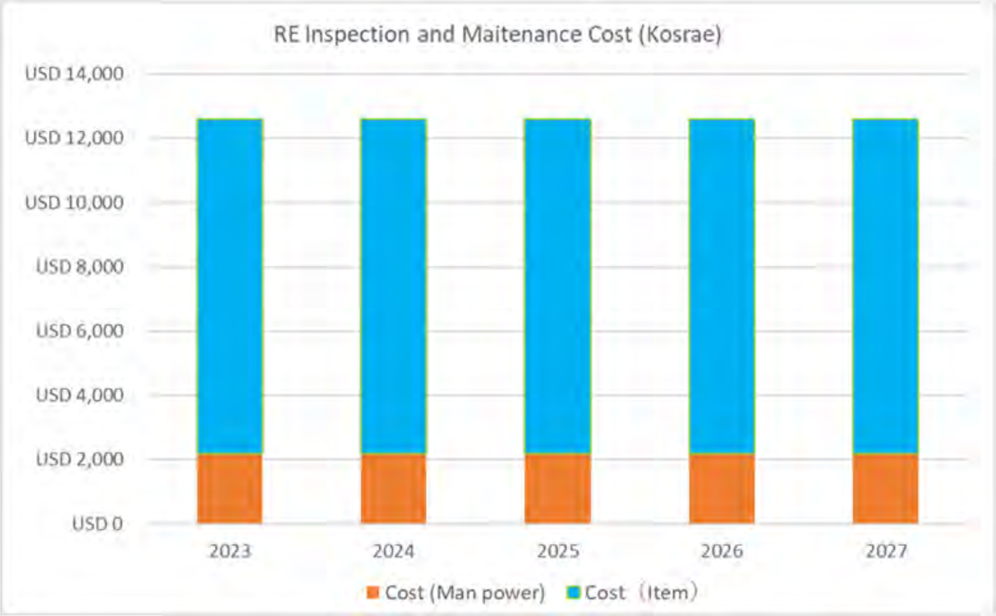
Item		Annual budgeted amount※1	Quantity and budget approach
Tools			General purpose tools shall be stored at the beginning of the operation. Excluded from the budget
Spare parts	PCS Power Conditioning System	8,128 USD	Assuming that the PCS will be replaced in about 15 years (*1), an average amount is considered as an annual budget so that the purchase price can be funded over 15 years.
	Solar panels	428 USD	Consider a budget that allows for a reserve panel of about 0.1% (*1) of the capacity of each installation each year.
Measuring instruments	(1) String tracer (2) Cell line checkers (3) Insulation resistance testers (4) Digital multi-meters (5) IR cameras	(1)927 USD (2)285 USD (3)57 USD (4)29 USD (5)570 USD (1,868 USD)	At present, one of each measuring instrument is provided. To avoid the risk of breakdowns, an average amount is set aside in the annual budget to enable renewal every five years (*1).

*1: Each figure will be revised based on operational results to improve accuracy.

*2: Costs are based on procurement costs in Japan and take into account the USD/JPY rate.
(140.25 JPY/USD 5/June/2023)
Transport costs are not included.

(3) Maintenance Cost Chart

Below are the results of the inspection and maintenance cost (budget) calculations.



Year	Cost（Man power）	Cost（Item）	Cost（Total）
2023	USD 2,168	USD 10,424	USD 12,592
2024	USD 2,168	USD 10,424	USD 12,592
2025	USD 2,168	USD 10,424	USD 12,592
2026	USD 2,168	USD 10,424	USD 12,592
2027	USD 2,168	USD 10,424	USD 12,592

Rate :JPY 140.25/USD (2023/6/5)

Chart-1 Inspection and Maintenance Cost

5. Attachment

1 PV Inspection and Maintenance schedule (Kosrae) (2023-2028)

2 Inspection and Maintenance Cost Calculation Chart (Excel Data)

End

Attachment 3-1
June , 2023
JICA Expert Teaam

PV Inspection and Maintenance schedule (Kosrae)

No.	PV Site name	capacity	Year of Installation	No. of inspectors and days	Plan	1												2												3												4												5												6											
						2023												2024												2025												2026												2027												2028											
1	PEC PV	200 kW	2015	2staff×2days	inspection	🟧												🟧												🟧												🟧												🟧												🟧											
				2staff×2days	maintenance	★						🟩						★						🟩						★						🟩						★						🟩						★						🟩						★						🟩					
2	EU PV	100kW	2015	2staff×2days	inspection		🟧												🟧												🟧												🟧												🟧												🟧										
				2staff×2days	maintenance		★						🟩						★						🟩						★						🟩						★						🟩						★						🟩						★						🟩				
3	Solar PV (ADB)	1150kW	undecided	3staff×5days	inspection																																																																			
				3staff×5days	maintenance																																																																				
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🟧：Regular measurement inspection (assuming implementation of visual inspection and measurement inspection)

🟩：Regular maintenance (panel replacement, obstruction removal (panel cleaning, weed treatment, etc.)
＋ Regular measurement inspections (visual and measurement inspections are assumed to be performed)

★：Order spare parts for maintenance

1.For regular inspections and regular maintenance, the following conditions shall be set

a) Visual inspections are not included in the budget as they are carried out during the daily work of staff.

b) Inspections during emergencies and emergencies are not included.
(Separate inspections, restoration methods and costs need to be considered).

c) The manpower (number) and duration (days) for each regular inspection should be set according to the scale of each facility, referring to the following.

Up to 100 kW：1-2 inspectors × 1-2days
100～500kW：2-3 inspectors × 2-3 days
500 kW-1 MW：3-4 inspectors × 4-6 days

d) The same manpower (number) is used for regular maintenance as for regular inspections. During maintenance, inspections are also carried out.

Attachment 3-2

Inspection and Maintenance Cost Calculation Chart (Excel Data)

1. Calculation of labor costs for regular inspections and regular maintenance (2023-2027)

(1)2023 2,168 [USD/year]

Labor costs related to regular inspections (planned once per year)

No.	PV Site name	capacity (kW)	Number of inspectors (per inspection)			Number of annual inspections	Cost/person (USD)	Cost/inspection (USD)
			inspectors	days	needs man power			
1	PEC Fund PV	200	2	2	4	1	135.47	542
2	EU PV	100	2	2	4	1	135.47	542
3	Solar PV (ADB)	1150	3	5	15	1	135.47	2,032
Cost of regular inspections [USD/year]								1,084

Labor costs for regular maintenance and regular inspections (planned once a year)

No.	PV Site name	capacity (kW)	Number of inspectors (per maintenance)			Number of annual maintenance	Cost/person (USD)	Cost/maintenance (USD)
			inspectors	days	needs man power			
1	PEC Fund PV	200	2	2	4	1	135.47	542
2	EU PV	100	2	2	4	1	135.47	542
3	Solar PV (ADB)	1150	3	5	15	1	135.47	2,032
Cost of regular maintenance [USD/year]								1,084

(2)2024 2,168 [USD/year]

Labor costs related to regular inspections (planned once per year)

No.	PV Site name	capacity (kW)	Number of inspectors (per inspection)			Number of annual inspections	Cost/person (USD)	Cost/inspection (USD)
			inspectors	days	needs man power			
1	PEC Fund PV	200	2	2	4	1	135.47	542
2	EU PV	100	2	2	4	1	135.47	542
3	Solar PV (ADB)	1150	3	5	15	1	135.47	2,032
Cost of regular inspections [USD/year]								1,084

Labor costs for regular maintenance and regular inspections (planned once a year)

No.	PV Site name	capacity (kW)	Number of inspectors (per maintenance)			Number of annual maintenance	Cost/person (USD)	Cost/maintenance (USD)
			inspectors	days	needs man power			
1	PEC Fund PV	200	2	2	4	1	135.47	542
2	EU PV	100	2	2	4	1	135.47	542
3	Solar PV (ADB)	1150	3	5	15	1	135.47	2,032
Cost of regular maintenance [USD/year]								1,084

(3)2025 2,168 [USD/year]

Labor costs related to regular inspections (planned once per year)

No.	PV Site name	capacity (kW)	Number of inspectors (per inspection)			Number of annual inspections	Cost/person (USD)	Cost/inspection (USD)
			inspectors	days	needs man power			
1	PEC Fund PV	200	2	2	4	1	135.47	542
2	EU PV	100	2	2	4	1	135.47	542
3	Solar PV (ADB)	1150	3	5	15	1	135.47	2,032
Cost of regular inspections [USD/year]								1,084

Labor costs for regular maintenance and regular inspections (planned once a year)

No.	PV Site name	capacity (kW)	Number of inspectors (per maintenance)			Number of annual maintenance	Cost/person (USD)	Cost/maintenance (USD)
			inspectors	days	needs man power			
1	PEC Fund PV	200	2	2	4	1	135.47	542
2	EU PV	100	2	2	4	1	135.47	542
3	Solar PV (ADB)	1150	3	5	15	1	135.47	2,032
Cost of regular maintenance [USD/year]								1,084

(4)2026 2,168 [USD/year]

Labor costs related to regular inspections (planned once per year)

			Number of inspectors (per inspection)					
No.	PV Site name	capacity (kW)	inspectors	days	needs man power	Number of annual inspections	Cost/person (USD)	Cost/inspection (USD)
1	PEC Fund PV	200	2	2	4	1	135.47	542
2	EU PV	100	2	2	4	1	135.47	542
3	Solar PV (ADB)	1150	3	5	15	1	135.47	2,032
							Cost of regular inspections [USD/year]	1,084

Labor costs for regular maintenance and regular inspections (planned once a year)

			Number of inspectors (per maintenance)					
No.	PV Site name	capacity (kW)	inspectors	days	needs man power	Number of annual maintenance	Cost/person (USD)	Cost/maintenance (USD)
1	PEC Fund PV	200	2	2	4	1	135.47	542
2	EU PV	100	2	2	4	1	135.47	542
3	Solar PV (ADB)	1150	3	5	15	1	135.47	2,032
							Cost of regular maintenance [USD/year]	1,084

(5)2027 2,168 [USD/year]

Labor costs related to regular inspections (planned once per year)

			Number of inspectors (per inspection)					
No.	PV Site name	capacity (kW)	inspectors	days	needs man power	Number of annual inspections	Cost/person (USD)	Cost/inspection (USD)
1	PEC Fund PV	200	2	2	4	1	135.47	542
2	EU PV	100	2	2	4	1	135.47	542
3	Solar PV (ADB)	1150	3	5	15	1	135.47	2,032
							Cost of regular inspections [USD/year]	1,084

Labor costs for regular maintenance and regular inspections (planned once a year)

			Number of inspectors (per maintenance)					
No.	PV Site name	capacity (kW)	inspectors	days	needs man power	Number of annual maintenance	Cost/person (USD)	Cost/maintenance (USD)
1	PEC Fund PV	200	2	2	4	1	135.47	542
2	EU PV	100	2	2	4	1	135.47	542
3	Solar PV (ADB)	1150	3	5	15	1	135.47	2,032
							Cost of regular maintenance [USD/year]	1,084

Inspection and Maintenance Cost Calculation Chart

Attachment 3-2

2.Spare Parts , calculation of costs for measuring instruments (2023-2027)

(1)2023 - 2028 10,424 [USD/year]

1.P C S

Replacement shall occur periodically over the operational period of 10-15 years. The costs shall be funded equally over 15 years.

No.	PV Site name	capacity (kW)	Year of Installation	Unit capacity (kW)	Number of units	Unit cost (USD)	Cost (USD)	durable year (prediction)	Yearly Accumulation (USD/year)
1	PEC Fund PV	200	2015	10	20	4,064	81,280	15	5,419
2	EU PV	100	2015	10	10	4,064	40,640	15	2,709
3	Solar PV (ADB)	1150	undecided	10	115	4,064	467,360	15	31,157
								PCS Total annual reserve(USD)	8,128

2. reserve panels

Reserve annually, assuming that about 0.1% of the facility capacity is replaced by panels per year.

No.	PV Site name	capacity (kW)	Year of Installation	Expected annual replacement capacity [W]	Number of panels	Unit cost (USD)	Cost (USD)
1	PEC Fund PV	200	2015	200	1	214	214
2	EU PV	100	2015	100	1	214	214
3	Solar PV (ADB)	1150	undecided	1,150	3	214	642
				Reserve panel Total annual reserve(USD)	428		
(1)Around 0.1% of the capacity (at least one panel) shall be prepared. (2)The budget shall be calculated as 410 W/panel for industrial use.							

3. measuring instruments.

Shared by all facilities. The useful life is set at around five years and accumulated annually.

No.	Measuring instrument items	Unit cost (USD)	durable year (prediction)	Number of measuring instruments	Yearly Accumulation (USD/year)
1	String tracer	4,635	5	1	927
2	Cell line checkers	1,426	5	1	285
3	Insulation resistance testers	285	5	1	57
3	Digital multi-meters	143	5	1	29
4	IR cameras	2,852	5	1	570
				Measuring instruments Total annual reserve(USD)	1,868

Inspection and Maintenance Cost Calculation Chart

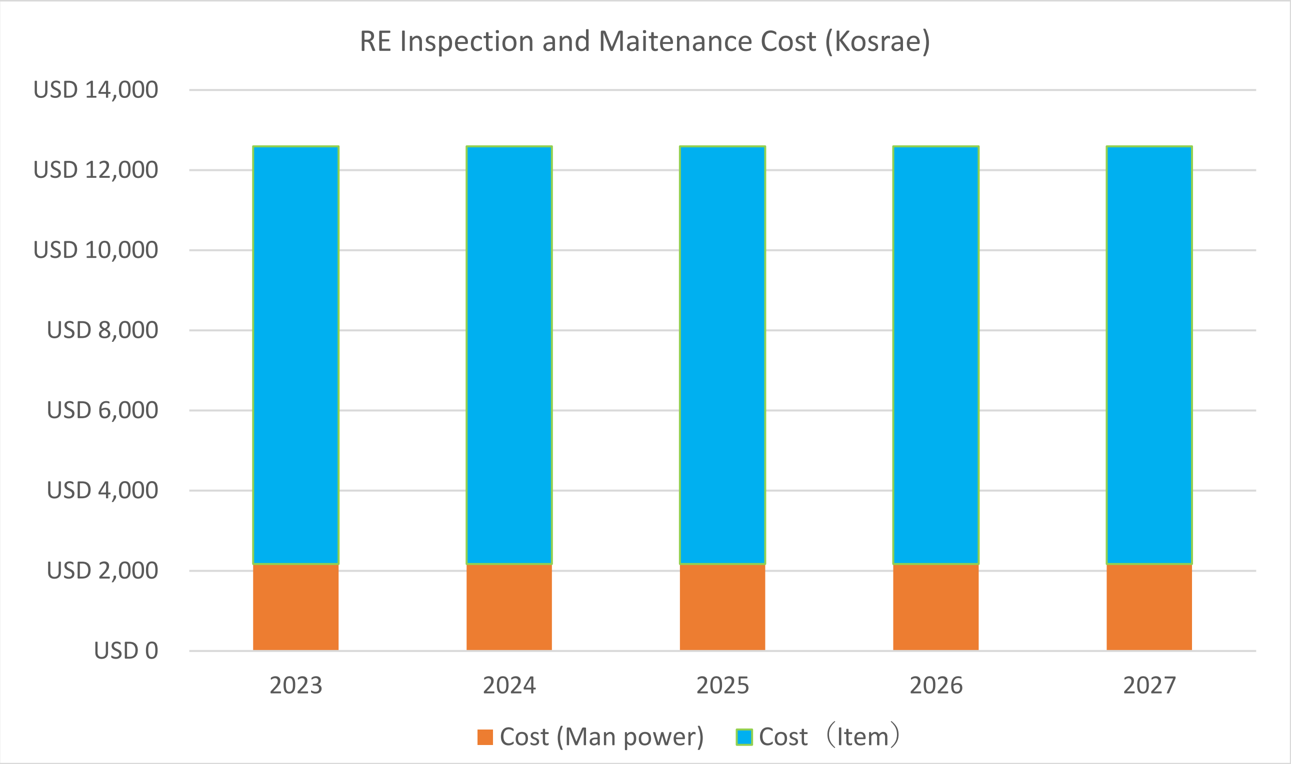
Attachment 3-2

Cost(USD)

Year	Cost (Man power)	Cost（Item）	Cost（Total）
2023	USD 2,168	USD 10,424	USD 12,592
2024	USD 2,168	USD 10,424	USD 12,592
2025	USD 2,168	USD 10,424	USD 12,592
2026	USD 2,168	USD 10,424	USD 12,592
2027	USD 2,168	USD 10,424	USD 12,592

2023/6/5 Rate : JPY 140.25 /USD

JPY 92.34 /AUD



11.2.2　PV施設測定記録シート

<u>(Form) Array Measurement Records</u>

(place)

Date	XX/XX/XX	Humidity	%	**Measuring Instrument**	Digital multimeter Kyoritsu KEW 1021R	String Tracer Togami SPST-A2A-Y1	Meggar Kyoritsu KEW 3021	**Measurer**		**Person in charge**	Approval	Confirmation	Confirmation
Weather	Sunny	Solar radiation											
Temperature	℃												

Junction Box Number	Combiner Box Number	Circuit/ Breaker No.	Measurement time	Number of panels	Open circuit voltage (1 panel)	Theoretical Voc (string)	Circuit Voc (1 String) Difference no larger than voltage of one panel	P-side 0.2 MΩ or more at DC 500V	N-side 0.2 MΩ or more at DC 500V	I-V measurement Presence of abnormal string	NFB		Comprehensive judgment	Remarks
											Start	Finish		
	1	1												
		2												
		3												
		4												
	2	1												
		2												
		3												
		4												
	3	1												
		2												
		3												
		4												
	4	1												
		2												
		3												
		4												

11.2.3　パフォーマンスレシオ計測記録シート

(Form) PEC Fund PV Performance Ratio

Date	**2020**												**Annual Average**
Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Rated Capacity of PV system(kW)	200	200	200	200	200	200	200	200	200	200	200	200	
Monthly Total Power Generation by PV system (kWh)													
Monthly Average Solar Radiation (kWh/m2/day)													
Number of days per month	31	29	31	30	31	30	31	31	30	31	30	31	
Theoretical maximum energy yield(kWh/month)	0	0	0	0	0	0	0	0	0	0	0	0	
Performance Ratio(%)													

Date	**2021**												**Annual Average**
Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Rated Capacity of PV system(kW)	200	200	200	200	200	200	200	200	200	200	200	200	
Monthly Total Power Generation by PV system (kWh)													
Monthly Average Solar Radiation (kWh/m2/day)													
Number of days per month	31	28	31	30	31	30	31	31	30	31	30	31	
Theoretical maximum energy yield(kWh/month)	0	0	0	0	0	0	0	0	0	0	0	0	
Performance Ratio(%)													

Date	**2022**												**Annual Average**
Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Rated Capacity of PV system(kW)	200	200	200	200	200	200	200	200	200	200	200	200	
Monthly Total Power Generation by PV system (kWh)													
Monthly Average Solar Radiation (kWh/m2/day)													
Number of days per month	31	28	31	30	31	30	31	31	30	31	30	31	
Theoretical maximum energy yield(kWh/month)	0	0	0	0	0	0	0	0	0	0	0	0	
Performance Ratio(%)													

(Remarks) 1. Input yellow cells.
2. Usual Performacne Ratio is between 70 and 85%.
3. Baseline Perfomance Ratio =66%

(Form) EU Fund PV Performance Ratio

Date	2020												Annual Average
Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Rated Capacity of PV system(kW)	100	100	100	100	100	100	100	100	100	100	100	100	
Monthly Total Power Generation by PV system (kWh)													
Monthly Average Solar Radiation (kWh/m2/day)													
Number of days per month	31	29	31	30	31	30	31	31	30	31	30	31	
Theoretical maximum energy yield(kWh/month)	0	0	0	0	0	0	0	0	0	0	0	0	
Performance Ratio(%)													

Date	2021												Annual Average
Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Rated Capacity of PV system(kW)	100	100	100	100	100	100	100	100	100	100	100	100	
Monthly Total Power Generation by PV system (kWh)													
Monthly Average Solar Radiation (kWh/m2/day)													
Number of days per month	31	28	31	30	31	30	31	31	30	31	30	31	
Theoretical maximum energy yield(kWh/month)	0	0	0	0	0	0	0	0	0	0	0	0	
Performance Ratio(%)													

Date	2022												Annual Average
Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Rated Capacity of PV system(kW)	100	100	100	100	100	100	100	100	100	100	100	100	
Monthly Total Power Generation by PV system (kWh)													
Monthly Average Solar Radiation (kWh/m2/day)													
Number of days per month	31	28	31	30	31	30	31	31	30	31	30	31	
Theoretical maximum energy yield(kWh/month)	0	0	0	0	0	0	0	0	0	0	0	0	
Performance Ratio(%)													

(Remarks) 1. Input yellow cells.
2. Usual Performacne Ratio is between 70 and 85%.
3. Baseline Perfomance Ratio =56%

11.2.4　測定器リスト
スペアパーツリスト
工具リスト

（List form）Owned measuring instruments

Date: ______________

List of measuring instruments for PV O&M

Instrument name	quantity	Purpose	Manufactured Date
(Sample description) 1. Digital multi meter	1	General measurement to know circuit condition	
(Sample description) 2. Cell Line Checker	1	Verification of the condition of panels	
(Sample description) 3. I-V Curve Strings tracer	1	Verification of the condition of strings	
(Sample description) 4. Insulation Resistance Tester (Megger)	1	Measurement to verify insulation condition of the circuit from PV panels to the switching board	
(Sample description) 5. IR camera	1	Verification of the condition of panels	
6.			
7.			
8.			
9.			
10.			
11.			
12.			

（List form）Owned Spare parts

Date: ______________

List of needed spare parts for O&M of solar PV facilities

Spare Part Name	Use	Quantity	Manufactured Date
(Sample description) 1. PV modules	Failure		
(Sample description) 2. Fuse for PCS	Abnormal event		
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			
11.			
12.			

（List form）Owned tools

Date: ______________

List of tools needed for renewable energy O&M

Items	quantity		Specifications	Manufactured Date
(Sample description) 1. Screwdriver (+ and -)	2	set	Screwdriver (+ and -)	
(Sample description) 2. Terminals board & wire clips	1	set	Terminals board & wire clips	
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				
11.				
12.				

11.3　再エネマニュアル（ドラフト）

→Annex F:対象国 共通資料
「3.再エネマニュアル（ドラフト）」
参照

11.3.1　メンテナンススケジュールと点検報告

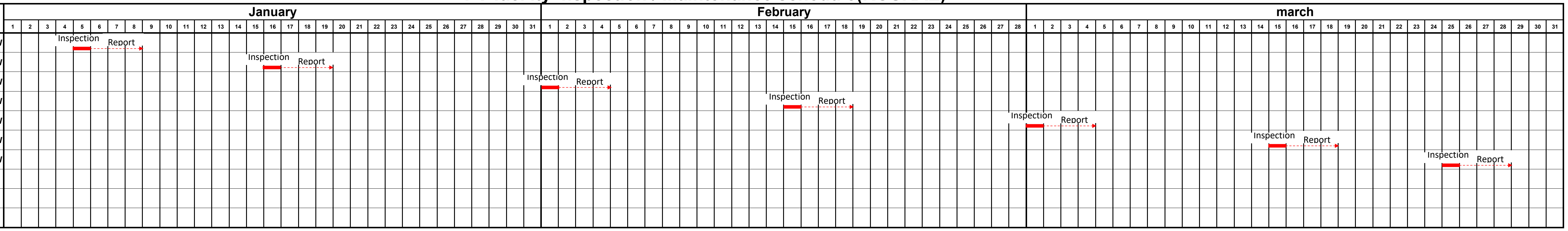
1． KOSRAE　PV Facilities List

№	Facility name	Output (kW)	Picture	Comments
1	Parking area of Kosrae state government offices	100		2005 / EU
2	Parking area of Kosrae state government offices	9.4		2008 / EU
3	Tofol Power Station premises	200		2015 / PEC
4	KUA car park roof	4.8		2008 / EU
5	Hospital	15.7		2008 / EU

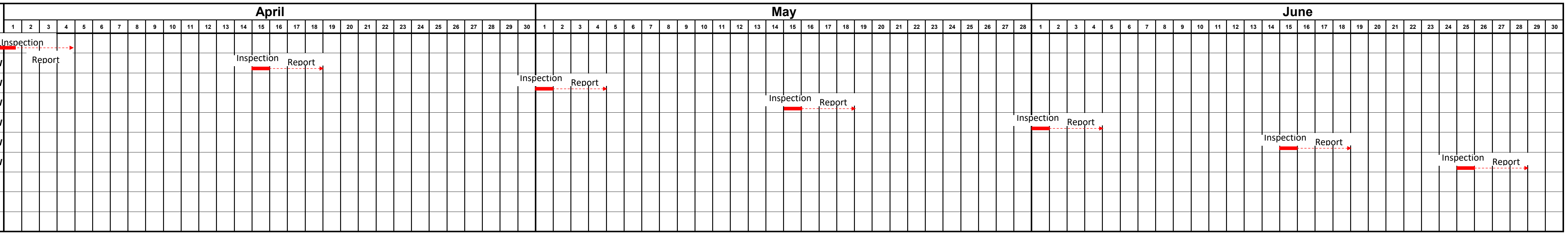
6	State government assembly building	9.0		2008 / EU
7	Roof of entrance to Kosrae International Airport	6.5		2008 / EU

PV facility Inspection / Maintenance schedule(KOSRAE)

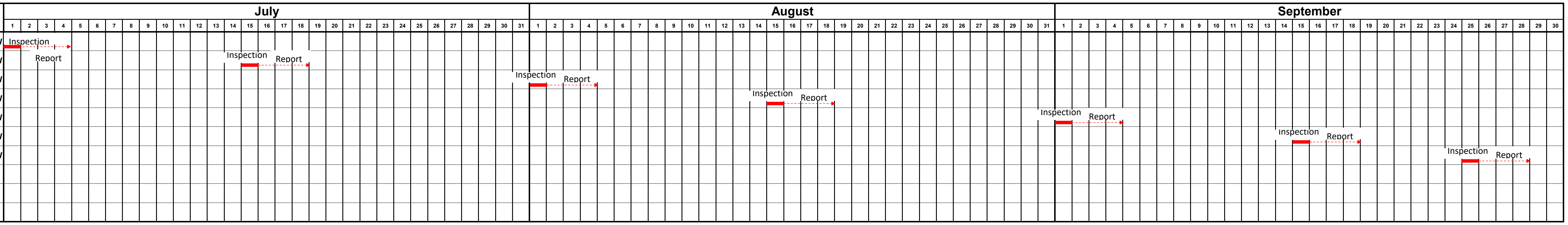
No.	PV Facility name	
1	Parking area of Kosrae state	100kW
2	Tuvalu Media Corporation	9.4kW
3	TEC power plant	200kW
4	Hospital	4.8kW
5	Marine warehouse	15.7kW
6	Water plant	9kW
7	Roof of entrance to Kosrae International Airport	6.5kW
8		
9		
10		



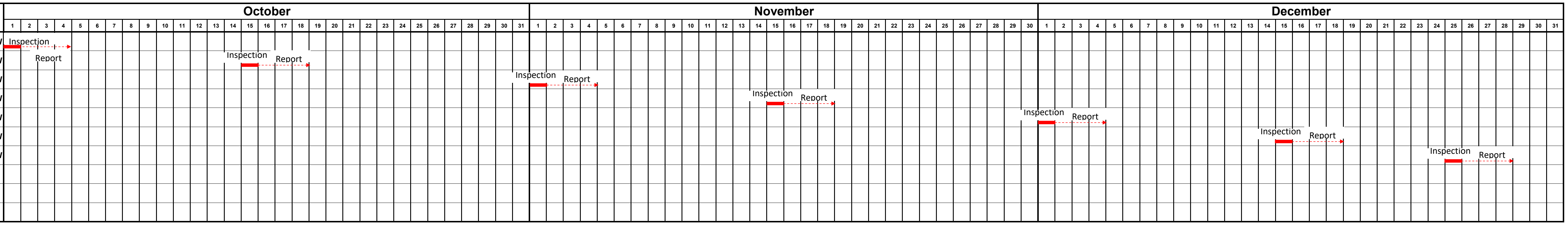
No.	PV Facility name	
1	Parking area of Kosrae state	100kW
2	Kosrae state government offices	9.4kW
3	Tofol Power Station premises	200kW
4	KUA car park roof	4.8kW
5	Hospital	15.7kW
6	State government assembly building	9kW
7	Roof of entrance to Kosrae International Airport	6.5kW
8		
9		
10		



No.	PV Facility name	
1	Parking area of Kosrae state	100kW
2	Kosrae state government offices	9.4kW
3	Tofol Power Station premises	200kW
4	KUA car park roof	4.8kW
5	Hospital	15.7kW
6	State government assembly building	9kW
7	Roof of entrance to Kosrae International Airport	6.5kW
8		
9		
10		



No.	PV Facility name	
1	Parking area of Kosrae state	100kW
2	Kosrae state government offices	9.4kW
3	Tofol Power Station premises	200kW
4	KUA car park roof	4.8kW
5	Hospital	15.7kW
6	State government assembly building	9kW
7	Roof of entrance to Kosrae International Airport	6.5kW
8		
9		
10		



12. 対応記録

12.1　DG分野対応記録カルテ

コスラエ発電設備カルテ

対応履歴

No.	日時	項目	内容	対応事項	備考	添付資料	
						有	無
1	2020/8/24	第3回リモートトレーニング実施のお知らせ	第3回リモートトレーニングを下記の日時で実施する旨を連絡。 日時：2020年8月25日(火)13:00～16:00	8/25にグレッグ氏よりOKの返事有 カレストン氏は入院のためトレーニングへ参加出来ない旨を受信			
2	2020/8/26	第3回リモートトレーニング後のリマインド	下記の項目のリマインドを実施 ①OneDriveへのアクセス ②O&Mマニュアル第1章、第2章の改訂担当者の任命 ③O&Mマニュアル第1章、第2章の改訂 ④発電所運用データの送付 ⑤SFCデータの送付 ⑥Improvement Planの更新(改善後の写真)	8/27にグレック氏より対応する旨返信あり			
3	2020/9/16	データ提供の依頼	下記の項目のデータ提供の依頼（渡辺） ①O&Mマニュアル第1章、第2章の改訂 ②発電所運用データ ③SFCデータ ④Improvement Planの進捗 ⑤WB供与のCaterpillarエンジンの仕様と型式	特に無し			
4	2020/9/27	MGクラス会議日程変更施のリマインド	MGクラスの会議開催（10/1）のリマインド	特に無し			
5	2020/9/29	MGクラス会議のリマインド	Fred氏へMGクラス会議のリマインドを実施	9/29にFred氏より参加OKの返信あり			
6	2020/9/30	MGクラス会議のリマインド	MGクラスの会議開催（10/1）のリマインド	特に無し			
7	2020/10/9	第4回リモートトレーニングの開催のお知らせ	第4回リモートトレーニングの開催のお知らせを実施した。(2020/10/20)	特に無し			
8	2020/10/17	データ提供の依頼	下記の項目のデータ提供の依頼（渡辺） ①O&Mマニュアル第1章、第2章の改訂 ②発電所運用データ ③SFCデータ ④Improvement Planの進捗 ⑤WB供与のCaterpillarエンジンの仕様と型式	特に無し			
9	2020/10/19	第4回リモートトレーニングのリマインド	第4回リモートトレーニングのリマインドを実施。 Zoomリンク及びテキストを送付。	特に無し			
10	2020/10/21	データ提供の依頼	下記の項目のデータ提供の依頼（渡辺） ①O&Mマニュアル第1章、第2章の改訂 ②発電所運用データ ③SFCデータ ④Improvement Planの進捗 ⑤OHスケジュール ⑥WB供与のCaterpillarエンジンの仕様と型式	特に無し			
11	2020/10/21	今後のトレーニング及び会議のスケジュール	今後のトレーニング及び会議のスケジュールを送付した。	10/21にFred氏よりOKの返信あり			
12	2023/11/2	今後のトレーニング及び会議のスケジュール	今後のトレーニング及び会議のスケジュールを送付した。	11/2にFred氏よりOKの返信あり			
13	2020/11/25	データ提供の依頼のリマインド	下記の項目のデータ提供の依頼（渡辺） ①O&Mマニュアル第1章、第2章の改訂 ②発電所運用データ ③SFCデータ ④Improvement Planの進捗 ⑤OHスケジュール ⑥WB供与のCaterpillarエンジンの仕様と型式	特に無し			
14	2020/12/14	データ提供の依頼のリマインド	下記の項目のデータ提供の依頼（渡辺） ①O&Mマニュアル第1章、第3章の改訂 ②発電所運用データ ③SFCデータ ④Improvement Planの進捗 ⑤OHスケジュール ⑥WB供与のCaterpillarエンジンの仕様と型式	特に無し			
15	2020/12/22	燃料流量計の設置についての確認	燃料流量計の設置状況の報告を依頼。 2機は8号機に設置済みだが、その他の流量計設置の予定は？	特に無し			
16	2020/12/24	来年のトレーニング及び会議のスケジュール	来年のトレーニング及び会議のスケジュールを送付した。	特に無し			
17	2020/12/28	第5回リモートトレーニング実施のリマインド	第5回リモートトレーニングの開催のお知らせを実施した。(2021/1/26)	12/28にGreg氏よりOKの返信あり			
18	2020/12/29	来年のリモートトレーニングへの参加依頼のレターを送付。	来年のリモートトレーニングへの参加依頼のレターを送付。	特に無し			
19	2021/1/5	燃料流量計の設置についての確認のリマインド	燃料流量計の設置状況の報告を依頼。 2機は8号機に設置済みだが、その他の流量計設置の予定は？	特に無し			
20	2021/1/5	１月期のデータ提供の依頼のリマインド	下記の項目のデータ提供の依頼（渡辺） ①O&Mマニュアル第1章、第3章の改訂 ②発電所運用データ ③SFCデータ ④Improvement Planの進捗 ⑤OHスケジュール ⑥WB供与のCaterpillarエンジンの仕様と型式	特に無し			
21	2021/1/20	第5回リモートトレーニング実施のリマインド	第5回リモートトレーニングの開催のお知らせを実施した。(2021/1/26)	1/20にGreg氏よりOKの返信あり			
22	2021/1/25	第5回リモートトレーニング実施のリマインド	第5回リモートトレーニングの開催のお知らせを実施した。(2021/1/26)	特に無し			
23	2021/1/25	MGクラス会議開催の連絡	MGクラス会議開催の連絡(2021/3/26)	1/25にGreg氏よりOKの返信あり			
24	2021/1/27	燃料流量計の設置についての確認のリマインド	燃料流量計の設置状況の報告を依頼。 ・6号機にはまだ未設置 ・WBのDGに流量計を設置したのか？	特に無し			
25	2021/1/27	第5回リモートトレーニング後のリマインド	下記の項目のリマインドを実施 ①O&Mマニュアル第1章、第2章、第5章の改訂 ②発電所運用データの送付 ③SFCデータの送付 ④燃料流量計の設置について ⑤OHスケジュール ⑥リモートトレーニングへの要望	特に無し			
26	2021/2/3	燃料流量計の設置についての確認のリマインド	燃料流量計の設置状況の報告を依頼。 ・6号機にはまだ未設置 ・WBのDGに流量計を設置したのか？	特に無し			
27	2021/3/9	燃料流量計の設置についての確認のリマインド	燃料流量計の設置状況の報告を依頼。 ・8号機には設置？ ・6号機設置には継手が必要？ ・WBのDGに流量計を設置したい？	特に無し			
28	2021/3/10	燃料消費率データ提供のリマインド	9号機、10号機のSFCデータ提供のリマインド	特に無し			
29	2021/3/12	DGとREのO&Mマニュアル改訂スケジュールの送付	DGとREのO&Mマニュアル改訂スケジュールの送付し、スケジュールを遵守する様要請 下記の項目のリマインドを実施 ①発電所運用データ ②SFCデータ ③Improvement Planの進捗 ④OHスケジュール ⑤WB供与のCaterpillarエンジンの仕様と型式	特に無し			

30	2021/3/12	燃料消費率データ提供のリマインド	9号機、10号機のSFCデータ提供のリマインド 測定シートを送付。	特に無し			
31	2021/3/16	OneDriveへのアクセスについて	Robert氏よりOneDriveへアクセスが出来ないため、再度リンクとパスコードの教示依頼	3/16に渡辺よりOneDriveのlinkとパスコードを送付。			
32	2021/3/18	DGとREのO&Mマニュアル改訂スケジュールの変更	DGとREのO&Mマニュアル改訂スケジュールの変更を連絡	特に無し			
33	2021/3/29	DG O&Mマニュアル改訂について	Robert氏より第1章の改訂を行ったが、アドバイスをもらいたい。	3/29に掛福より下記をアドバイスした。 ・第1章：KUAの条件、機器の写真を更新 ・第2章：各系統図をKUAのものに更新 ・第3章：KUAに無い機器は削除 ・第4章、5章：別途アドバイスする。			
34	2021/4/21	第6回DG遠隔トレーニング開催の連絡	第6回DG遠隔トレーニング、DGマニュアル改訂トレーニング開催の連絡	特に無し			
35	2021/5/6	第6回DG遠隔トレーニングのリマインド	第6回DG遠隔トレーニング、DGマニュアル改訂トレーニング開催のリマインド	特に無し			
36	2021/5/20	第6回DG遠隔トレーニングのリマインド	第6回DG遠隔トレーニング、DGマニュアル改訂トレーニング開催のリマインド	特に無し			
37	2021/5/21	第1回DGマニュアル改訂トレーニング開催のリマインド	第1回DGマニュアル改訂トレーニング(5/21)開催のリマインド	特に無し			
38	2021/5/21	第1回DGマニュアル改訂トレーニング後のリマインド	下記の項目のリマインドを実施 ①燃料流量計の写真 ②SFCデータの送付	特に無し			
39	2021/5/24	第6回DG遠隔トレーニング開催のリマインド	第6回DG遠隔トレーニング(5/25)開催のリマインド	特に無し			
40	2021/5/25	第6回DG遠隔トレーニング理解度テスト	第6回DG遠隔トレーニングの理解度テストの実施	特に無し			
41	2021/5/27	燃料流量計設置のリマインド	燃料流量計設置写真の提出の依頼	特に無し			
42	2021/5/31	第6回DG遠隔トレーニング理解度テストリマインド	第6回DG遠隔トレーニングの理解度テストの提出	特に無し			
43	2021/6/11	第6回DG遠隔トレーニング理解度テストリマインド	第6回DG遠隔トレーニングの理解度テストの提出 (Ronald氏、Careston氏未提出)	特に無し			
44	2021/6/22	第2回DG O&Mマニュアル改訂トレーニング開催の連絡	第1回DG O&Mマニュアル改訂トレーニング開催(7/15)の連絡	特に無し			
45	2021/6/24	マネージャー評価シートとサマリーテストの実施	マネージャー評価シートとサマリーテストの実施(各カウンターパート)	特に無し			
46	2021/7/1	第2回DG O&Mマニュアル改訂トレーニングのリマインド	第2回DG O&Mマニュアル改訂トレーニング(7/15)のリマインド	特に無し			
47	2021/7/2	DG O&Mマニュアル改訂について	下記のリマインド ①マニュアルはダイハツベースに作成しているためコスラエでは大きな変更はない。第5章から改訂を実施 ②OH用の一般・特殊ツールは受領したか？ ③電気検査用の測定も受領したか？ ④機械、電気のスペアパーツリストの提出	7/30にRobert氏よりスペアパーツリストを入手した。			
48	2021/7/10	DG燃料漏れの発生	6/2日燃料リークがあり、バケツに漏れた燃料を集めてからメインの貯蔵タンクに戻している。燃料ポンプや燃料噴射から漏れた燃料はリークスラッジタンクに排出されます。綺麗な燃料なのでリターンラインに戻るべきだと思われる。燃料回収のため配管切断しホースを接続しました。6/26から7/8まで燃料22缶合計1,210ガロン（約4,580リットル/13日で1日あたり352リットル）を回収しました。この状況について何かコメントがあれば教示願う。	7/14に回答 漏油タンクには、燃料高圧接手と燃料噴射弁の漏油が溜められます。 燃料噴射ポンプと燃料噴射弁を調べてみないとわからないが、今回のように1日あたり300L近く漏油しているのであれば目視で確認できると思いますので、燃料ラインやヘッド廻りを注視してパトロールお願いします。 また、リターンタンクに燃料を戻しているため漏油タンクに燃料以外(潤滑油や水)が混入しないように確認してください。			
49	2021/7/14	第2回DG O&Mマニュアル改訂トレーニングのリマインド	第2回DG O&Mマニュアル改訂トレーニング(7/15)のリマインド Zoomリンクの送付	特に無し			
50	2021/7/28	第2回DG O&Mマニュアル改訂トレーニング後のリマインド	下記のリマインドを実施した。 ①議事録の送付	特に無し			
51	2021/7/30	OH費用についての問い合わせ	TOP OHにメンテナンスチームを派遣する費用の概算を問い合わせ	8/4に掛福より返信 ・TopOH21日間を想定し、費用は57,700USD ・メンバーは監督と機械担当、電気担当の3人で構成。 ・渡航可能になればJICAチームで対応可能			
52	2021/8/2	DGとREのO&Mマニュアル改訂スケジュールの変更	DGとREのO&Mマニュアル改訂スケジュールの変更を連絡	特に無し			
53	2021/8/13	8月期データ提供の依頼のリマインド	下記の項目のデータ提供の依頼（渡辺） ①SFCデータ	特に無し			
54	2021/8/13	MGクラス会議とJICC会議開催の連絡	MGクラス会議(9/24)とJCC会議(10/25)開催の連絡	特に無し			
55	2021/8/18	第7回DGトレーニング開催の連絡	第7回DGトレーニング開催(9/7)の連絡	特に無し			
56	2021/9/3	第7回DGトレーニング開催のリマインド	第7回DGトレーニング開催(9/7)のリマインド	特に無し			
57	2021/9/7	第7回DGトレーニング開催のリマインド	第7回DGトレーニング開催(9/7)のリマインド 参加が不可能なら9/8マーシャルと合同で開催	特に無し			
58	2021/9/8	第7回DGトレーニング開催のリマインド	第7回DGトレーニング開催(9/7)のリマインド 参加が不可能なら9/30ヤップ合同で開催	特に無し			
59	2021/9/21	第2回地域研修開催(オンライン)の連絡	第2回地域研修開催(オンライン)の連絡と下記資料の送付 ・第2回地域研修招待状 ・推薦状 ・キャパシティアセスメント	特に無し			
60	2021/9/22	MGクラス会議開催のリマインド	MGクラス会議(9/24)と開催のリマインド Zoomリンクと資料の送付	特に無し			
61	2021/9/24	過去のトレーニング教材について	過去のトレーニングビデオや教材を送付して欲しい。(Robert氏)	9/24に掛福より返信 各遠隔トレーニングの資料は、OneDriveへアップしている。アドレスとパスワードを教示。			
62	2021/9/24	OHスケジュールのリマインド	OHスケジュールのリマインドを実施	10/18にGerry氏よりOHは2022年の中旬に実施予定との連絡あり			
63	2021/9/28	第7回DGトレーニング開催のリマインド	第7回DGトレーニング開催(9/30)のリマインド ヤップと合同で開催 Zoomリンクの送付	特に無し			
64	2021/9/30	第7回DGトレーニング理解度テストの実施	第7回DGトレーニング理解度テストの実施した。 メールにて送付	特に無し			
65	2021/10/4	10月期データ提供依頼のリマインド	下記の項目のデータ提供の依頼（渡辺） ①O&Mマニュアルの改訂 ②SFCデータ ③OHスケジュール ④第7回遠隔トレーニング理解度テスト ⑤サマリーテスト、マネージャー評価 ⑥第2回地域研修ノミネート資料	特に無し			
66	2021/10/6	MGクラス会議日程変更の連絡	MGクラス会議の日程の変更9/24→10/14or10/18	10/7にFred氏より10/18開催希望の返信あり			

67	2021/10/11	10月期データ提供依頼の再リマインド	下記の項目のデータ提供の依頼（渡辺） ①O&Mマニュアルの改訂 ②SFCデータ ③OHスケジュール ④第7回遠隔トレーニング理解度テスト ⑤サマリーテスト、マネージャー評価 ⑥第2回地域研修ノミネート資料	特に無し			
68	2021/10/14	第2回地域研修開催(オンライン)の連絡	第2回地域研修開催(オンライン)の連絡と下記資料の送付 ・第2回地域研修招待状 ・推薦状 ・キャパシティアセスメント	特に無し			
69	2021/10/14	MGクラス会議開催のリマインド	MGクラス会議(10/18)と開催のリマインド Zoomリンクと資料の送付	特に無し			
70	2021/10/19	MGクラス会議議事録の送付	MGクラス会議(10/18)議事録の送付	10/7にFred氏よりOKの返信あり			
71	2021/10/21	JCC会議開催のリマインド	JCC会議開催(10/26)のリマインド Zoomリンクの送付	特に無し			
72	2021/10/26	第2回地域研修開催(オンライン)の連絡	第2回地域研修開催(オンライン)の連絡と下記資料の送付 ・第2回地域研修招待状 ・推薦状 ・キャパシティアセスメント	特に無し			
73	2021/10/28	燃料流量計について	燃料流量計について連絡があった。(Robert氏) ・WBのユニットに燃料流量計を設置した。 ・#6以外のユニットに流量計を設置しあ。 ・ダイハツの#9ユニットに燃料流量計を設置した。	10/28に掛福より下記のリマインドをした。 ①ユニット#8の両方の流量計を交換したか?(流量計2台、または1台のみ) 2. #8流量計のどの部分に障害があるかを示すことができますか。(流量計のカタログを添付) 3. 流量計は、設置直後、または数日または数か月の作業後に動作を停止します。 4. 設置は正しかったですか?(流れ方向) 5. ダイハツユニット#9燃料流量計用の流量計を探しているとは、流量計が設置されていないために交換することを意味するのか。			
74				10/29にRobert氏より下記の回答を貰った。 ①ユニット#8の両方の流量計を交換したか?(流量計2台、または1台のみ) →両方の燃料メーターが同じ数の読み取りになるように交換しました。 2. #8流量計のどの部分に障害があるかを示すことができますか。(流量計のカタログを添付) →7Aシャフトの内部とその下部の部品が摩耗しており、摩耗した部品が他の部品にも影響を与えるように思われる。 3. 流量計は、設置直後、または数日または数か月の作業後に動作を停止します。 →流量計は、数ヶ月間インストール後に動作を停止した。 4. 設置は正しかったですか?(流れ方向) →流量計の矢印の方向に取り付けた。 5. ダイハツユニット#9燃料流量計用の流量計を探しているとは、流量計が設置されていないために交換することを意味するのか。 →ユニット#8からインストールして動作確認をする。 ユニット#9ダイハツ純正の流量計は、ダイヤルの針先は回転しているが、何リットル流れたのか表示しない。			
75	2021/11/10	第2回地域研修開催(オンライン)のリマインド	第2回地域研修開催(オンライン)のリマインドを実施 ・日程、時間 ・Zoomリンクの送付	特に無し			
76	2021/11/15 ～ 2021/11/24	第2回地域研修開催(オンライン)DG分野	第2回地域研修開催(オンライン) DG：11/15～11/24 RE：11/29～12/04	特に無し			
77	2021/11/15 ～ 2021/11/24	第2回地域研修開催(オンライン)トレーナー評価シートの送付	第2回地域研修開催(オンライン) DG：11/15～11/24 研修終了後に各トレーナー評価シートを送付、回収した。	特に無し			
82	2022/2/15	2月期渡辺氏のリマインド	下記の項目のリマインド ①Manual改訂 ②SFCデータ ③Improvement planの進捗	特に無し			
83	2022/3/22	3月期渡辺氏のリマインド	下記の項目のリマインド ①Manual改訂 ②SFCデータ ③Improvement planの進捗 ④OHスケジュール	特に無し			
84	2022/3/31	3月期渡辺氏の再リマインド	下記の項目のリマインド ①Manual改訂 ②SFCデータ ③Improvement planの進捗 ④OHスケジュール	特に無し			
85	2022/4/4	渡辺氏のリマインド	燃料流量計の設置状況のリマインド	特に無し			
86	2022/4/21	4月期渡辺氏の再リマインド	下記の項目のリマインド ①Manual改訂 ②SFCデータ ③Improvement planの進捗 ④OHスケジュール	特に無し			
87	2022/5/11	5月期渡辺氏のリマインド	燃料流量計の設置状況、OHについて	ダイハツ製2機のOHを9月に予定。（詳細は不明）			
88	2022/5/20	5月期渡辺氏の再リマインド	下記の項目のリマインド ①Manual改訂 ②SFCデータ ③Improvement planの進捗 ④OHスケジュール ⑤第8回遠隔トレーニング開催のリマインド	特に無し			
89	2022/5/31	第8回DG遠隔トレーニング	下記の項目のリマインド ①O&Mマニュアル改訂 ②燃料消費率データ ③Improvement planの進捗確認 ④トラブルシューティング	・O&Mマニュアルのドラフト版を毎月提出 ・燃料消費率データの共有 ・燃料流量計の故障個所情報の共有			
90	2022/6/2	6月期渡辺氏のリマインド	Manual改訂,SFCのリマインド	特に無し			
91	2022/6/16	6月期渡辺氏の再リマインド	Manual,SFC(ベースライン),Improvement plan,OHの日程,燃料流量計故障の原因調査及び写真のリマインド	特に無し			
92	2022/6/17	OH日程の確認（掛福）	下記の情報の要請 ・OHのスケジュール ・コスラエの国境開放の情報	特に無し			
93	2022/6/28	6月期渡辺氏の再リマインド	Manual改訂のリマインド	特に無し			
94	2022/7/6	7月期渡辺氏のリマインド	下記のリマインド ①O&Mマニュアル改訂 ②燃料消費率データ ③Improvement planの進捗確認 ④燃料流量計の原因究明と再発防止 ⑤OHスケジュール ⑥Capacity assessmentの提出Tedrick氏	特に無し			
95	2022/7/12	7月期渡辺氏のリマインド	下記のリマインド ①燃料消費率データ ②燃料流量計の原因究明と再発防止 ③OHスケジュール	特に無し			

96	2022/7/22	Robert氏からのメール	コスラエでは発電所のスタッフがコロナに罹患して対応が遅くなったこととのこと。 マニュアルはDGがダイハツ製のため変更する必要はない。	掛福より、マニュアルはコスラエでフィードバックして改訂するように指示。			
97	2022/7/26	7月期渡辺氏の再リマインド	下記のリマインド ①O&Mマニュアル改訂 ②燃料消費率データ ③Improvement planの進捗確認 ④燃料流量計の原因究明と再発防止 ⑤OHスケジュール ⑥OneDriveへのアクセスの確認 ⑦8月遠隔トレーニング	特に無し			
98	2022/8/12	8月期渡辺氏のリマインド	下記のリマインド ①O&Mマニュアル改訂 ②燃料消費率データ ③燃料流量計設置写真(8,9,11号)燃料流量計の原因究明と再発防止 ④Improvement planの進捗確認 ⑤OHスケジュール ⑥OneDriveへのアクセスの確認 ⑦Tedrick氏のキャパシティーアセスメント	特に無し			
99	2022/8/24	8月期渡辺氏の再リマインド	下記のリマインド ①O&Mマニュアル改訂 ②燃料消費率データ ③燃料流量計設置写真(8,9,11号)燃料流量計の原因究明と再発防止 ④Improvement planの進捗確認 ⑤OHスケジュール ⑥OneDriveへのアクセスの確認 ⑦Tedrick氏のキャパシティーアセスメント	特に無し			
100	2022/8/29	8月期渡辺氏の再リマインド	第9回遠隔トレーニングと下記のリマインド ①O&Mマニュアル改訂 ②燃料消費率データ ③燃料流量計設置写真(8,9,11号)燃料流量計の原因究明と再発防止 ④Improvement planの進捗確認 ⑤OHスケジュール ⑥OneDriveへのアクセスの確認 ⑦Tedrick氏のキャパシティーアセスメント	8/29 Facebookにて、Robert氏より連絡あり Robert氏のケガによるトレーニング日程変更を要望	8/9に日程変更（調整中）		
101	2022/9/6	9月期渡辺氏のリマインド	第9回遠隔トレーニングと下記のリマインド ①O&Mマニュアル改訂 ②燃料消費率データ ③燃料流量計設置写真(8,9,11号)燃料流量計の原因究明と再発防止 ④Improvement planの進捗確認 ⑤OHスケジュール ⑥OneDriveへのアクセスの確認 ⑦Tedrick氏のキャパシティーアセスメント	特に無し			
102	2022/9/12	9月期渡辺氏の再リマインド	第9回遠隔トレーニングのリマインド	特に無し			
103	2022/9/13	第9回DG遠隔トレーニング	①O&Mマニュアル改訂 ②燃料消費率データ ③Improvement planの進捗確認 ④OH・メンテナンススケジュールの管理 ④トラブルシューティング	・O&Mマニュアルの改訂を指示 ・Improvement planで作業完了分の写真の共有 ・メンテナンススケジュールシートを共有			
104	2022/10/7	10月期渡辺氏のリマインド	下記のリマインド ①O&Mマニュアル改訂 ②燃料消費率データ ③燃料流量計設置写真(8,9,11号)の送付 ④Improvement planの進捗確認 ⑤OHスケジュール ⑥Tedrick氏のキャパシティーアセスメント	特に無し			
105	2022/11/8	DGマニュアルフォローアップトレーニングの日程調整	下記のリマインド ①O&Mマニュアル改訂進捗及びトレーニング日程調整 ②燃料消費率データ ③Improvement planの進捗確認 ④OHスケジュール	特に無し			
106	2022/11/15	DGマニュアルフォローアップトレーニングの日程調整	O&Mマニュアルトレーニング日程リマインド	特に無し			
107	2022/11/30	DGマニュアルフォローアップトレーニングの日程調整	下記のリマインド ①O&Mマニュアル改訂進捗及びトレーニング日程調整 ②燃料消費率データ ③Improvement planの進捗確認 ④OHスケジュール ⑤Capacity assessment Tedrickの要求 ⑥燃料流量計の状況	特に無し			
108	2022/12/21	12月期渡辺氏リマインド	下記のリマインド ①O&Mマニュアル改訂進捗 ②燃料消費率データ ③Improvement planの進捗確認	特に無し			
109	2023/2/28	2月期渡辺氏のリマインド	下記のリマインド ①燃料消費率データ	特に無			
110	2023/4/18	4月期渡辺氏のリマインド	下記のリマインド ①燃料消費率データ ②OH日程	4/18 Fred氏よりOHは2023年7月の第1週を予定していると連絡あり。			
111	2023/5/10	5月期渡辺氏のリマインド	下記のリマインド ①燃料消費率データ	特に無し			
112	2023/6/2	6月期掛福からのリマインド	下記のリマインド ①燃料消費率データ ②PVのパフォーマンスレシオ	特に無し			
113	2023/6/26	6月期渡辺氏のリマインド	下記のリマインド ①燃料消費率データ ②Improvement planの進捗状況	特に無し			
114	2023/7/11	渡辺氏からのリマインド	DGO&Mマニュアルの表紙にGM Fred氏のサインを依頼	特に無し			
115	2023/7/12	7月期渡辺氏のリマインド	燃料消費率データのリマインド(OH前後)				
116	2023/7/31	渡辺氏からの依頼	下記のマニュアルへFred氏のサインを依頼 ①DG O&Mマニュアル表紙 ②RE O&Mマニュアル表紙 ③DG メンテナンスマニュアル表紙				
117	2023/8/2	渡辺氏からの依頼	下記のデータの送付をFred氏へ依頼 2016年～2022年までの ①年間のDG燃料消費量 [kL/ Gal] ②年間のDG発電電力量 [kWh] ③年間のPV発電量 [kWh]	8/3 Fred氏より依頼したデータ収受した。			

12.2　再エネ分野対応記録カルテ

コスラエPV設備カルテ（PEC Fund PV）

基本情報			
設備名称	PEC Fund PV	外観写真	 
導入年	2015年		
容量(kW)	200kW		
ドナー名			
管理者	KUA		

パフォーマンスレシオ(ベースライン:66%)													
2020年	1月	2月	3月	4月	5月	6月	7月	8月	9月	10月	11月	12月	平均
	72.4	68.2	73.5	77.7	76	－	－	33.7	－	－	－	－	66.92
2021年	1月	2月	3月	4月	5月	6月	7月	8月	9月	10月	11月	12月	平均
	－	－	－	77.7	79.8	79.4	80.8	57.9	77.3	71.1	59.6	50	70.4
2022年	1月	2月	3月	4月	5月	6月	7月	8月	9月	10月	11月	12月	平均
	69.6	72.2	73.2	78.8	74.4	48.5	73.2	67.3	64.3	62.9	63.7	71.5	68.3
2023年	1月	2月	3月	4月	5月	6月	7月	8月	9月	10月	11月	12月	平均
	64.2	65.3	74.4	72.9	55.4	－	－	－	－	－	－	－	66.44

メモ

パフォーマンスレシオ　ベース値
1. Usual Performacne Ratio is between 70 and 85%.
2. Baseline Perfomance Ratio =66%

※コスラエの各PV設備共通の対応事項も本設備の対応履歴に含めて記録する。

コスラエPV設備カルテ（PEC Fund PV）

対応履歴				
No.	日時	内容	対応事項	備考
1	2020/8/5	・パフォーマンスレシオについて、Excel様式の表“5_Perfomance_Ratio_Calculation_Sheet_Kosrae”を提供し、ファイルの黄色い部分(毎月のPV発電量と平均日射量)をKUAで入力するよう依頼した。	日射量実測値がわからない場合は、NASA等の信頼性が高いスタンダードデータを代用するようアドバイスした。	第2回国内遠隔トレーニング
2	2020/8/5	PV点検についての確認 ①頻度 ②点検記録作成、保管 ③昨年現地トレーニングで共同作成した記録表の活用および最新記録の共有依頼	Robert氏から以下の回答を得た。 ①基本的には2ヵ月に1回の実施しているが、最近はGerry氏がコロナの影響でグアムから帰ってこれないため、定期点検が実施できていないようである。。 ②作成している ③活用しているので共有するとのこと	第2回国内遠隔トレーニング
3	2020/9/24	PR値についての確認 ・コスラエでPVの出力が落ちている。DGの下限値出力制限のためか。	以下の回答を得た。 推測のとおりDGの下限値出力制限のため、PVの出力が落ちているとのこと（Robert氏回答） 負荷が低い時間帯で、再エネだけで電力を賄うことができるかについて、再エネのみで需要を賄うための再エネの設備容量が足りていないとの回答であった。(Gerardo氏回答)	第3回国内遠隔トレーニング
4	2020/11/10	PR値の計測データ（2020年10月まで）を更新して提示するよう依頼した。	Robert氏から対応するとの回答を得た。	第4回国内遠隔トレーニング

コスラエPV設備カルテ（PEC Fund PV）

対応履歴				
No.	日時	内容	対応事項	備考
5	2020/11/10	施設運用について確認した。 ①PV設備の点検頻度 ②点検は同じ職員が実施しているか。また、点検の為のチームがあるか。 ③10名程度の要員配置が理想と紹介したが、点検チームを編成することは可能か。（JICA専門家チームの例では兼務させ7名のチーム編成で対応）	①2ヶ月に1回点検、目視はほぼ毎日。洗浄は4半期ごとに実施している。(Gerardo) ②KUAでは、4名が点検担当している。現在コロナの影響で2名で点検を実施している。洗浄作業などは電線作業員に手伝ってもらうことがある。監督者（Robert氏）以外の担当者について、役割分担が決まっていないとのこと。(Gerardo) ③KUAで現状以上の人員増は難しい。将来的に1MWのPV導入を目指しているため、設備の拡大に伴い人員増は必要と考えている。その際にJICA専門家チームの兼務での体制は参考になる。一方で人件費が課題と考える。(Gerardo) 担当者にそれぞれ役割を与えることが体制づくりによいことをコメントした。	第4回国内遠隔トレーニング
6	2021/2/16	PR値の計測データ（2021年1月まで）を更新して提示するよう依頼した。	Robert氏から対応するとの回答を得た。	第5回国内遠隔トレーニング
7	2021/2/16	以下についてKUAからへ確認した。 ①PVの点検頻度？ ②PVの点検メンバーは専任されたメンバーか ③長期運用のために予算は確保されていますか？ ④他ドナーからの支援はどのような計画があるか	Gerardo氏から以下の回答、情報を得た。 ①2カ月に1回（目視ではほぼ毎日、また定期的にパネルの洗浄も行っている） ②4名は配属しているが現在は2名のコロナの影響で帰国できていないとの事だった。 ③予算はあるが配電計画と一緒にされている。人件費と消耗品が基本的な項目である。 ④ADB支援で1MWの太陽光を導入予定。 今後のPV設備の拡大に伴い、メンテナンスの体制を整える必要であることをアドバイスした。	第5回国内遠隔トレーニング
8	2021/3/23	Gerry氏から情報提供 ①2020年1月～2020年8月までのパフォーマンスレシオのデータ		メール情報

コスラエPV設備カルテ（PEC Fund PV）

対応履歴				
No.	日時	内容	対応事項	備考
9	2021/3/25	Gerry氏から情報提供 ①～2022年2月までのパフォーマンスレシオのデータ		メール情報
10	2021/6/8	PR値の計測データを更新して提示するよう依頼した。 ※インターネットが不安定なため、データが中途半端になっている。（正確なPR値ではない）との説明があった。データを記録するメモリー容量が4～5カ月分しかないのでデータ収集が半端になっているとの情報も得た。	・2020年5月までのPRデータの共有を確認。各月の日数に誤入力であり、正しく入力し、ベース値66%（2016年）との比較確認したいことをコメントした。 ・日射量の実測値とNASAのデータと比較し、乖離がある場合はNASA提供のデータの活用をアドバイス。 ・パフォーマンスレシオの値が低い場合には、想定される原因をPR値シートに記載し、次に解決に向けた検討などにつなげていきたいことをコメントした。 　※Robertからの聞き取りで、PR値に影響が考えられる原因の一つで通信回線が悪いため、ロガーのデータを正しく入手できないことがあるとのこと 　通信回線での遠隔確認ではなく現場でデータを入手することは可能だが、ロガー内のメモリ容量がいっぱいになると、過去のデータが自動的に削除される。(4～5ヶ月くらいの期間のデータが記録可能) 　まずは自動削除前にデータを取り出す対応が必要がある。この対応についてマニュアル改訂の際に記載して実践して欲しいことをコメントした。（引き続き改善削除防止について改善が必要）	第6回国内遠隔トレーニング
11	2021/6/8	・PVシステムの点検は実施しているか。	Robert氏から、時々実施しているとのこと。 ただし、KUAとJICA専門家チームで共同作成した点検シートを活用していないようである。 　フォーマットを再送し、今後の点検に活用して頂き、結果データの共有をお願いした	第6回国内遠隔トレーニング

コスラエPV設備カルテ（PEC Fund PV）

対応履歴				
No.	日時	内容	対応事項	備考
12	2021/6/8	PV設備点検について年間スケジュールを様式に沿って計画し、共有をお願いした。	対象設備毎に、点検担当者、点検スケジュールの計画を入力して計画、実績表を共有するよう依頼 ・PECはRobert氏とRonnie氏の2名、EUはGerard氏とRonnie氏が担当。 ・直近2021年7月の点検日程を計画 （PEC、EUともに7月5日～6日で設定した。Robert） ・今後PV設備が増えた際、点検計画表に追加を依頼した。 その際、現在の点検担当者で点検管理が厳しくなってきた場合は、担当者の追加検討の資料で役立つと考える。 ・実施後に結果欄に実績を記入。計画と実施がずれた場合、その原因を特定し、その後の計画策定の際、留意すること。	第6回国内遠隔トレーニング
13	2021/6/8	メンテナンス実施体制について ・表形式で明確にして情報共有するよう依頼来した。	・スケジュール、役割、人員を表に整理することで、チームメンバーが共通の認識をもち、効率の良い業務が可能となる。体制表を作成し活用してほしいことを説明した。 ・役職と役割分担を決める必要がある。チーム内で相談の上、6月中に表に記載してほしい。担当者が重複しても構わない。	第6回国内遠隔トレーニング
14	2021/9/20	Gerry氏から情報提供 ①再エネマニュアル第1章（統合計画)のために収集された情報の共有		メール情報
15	2021/9/21	PR値の計測データを更新して提示するよう依頼した。 PECは2020年8月、EUは同12月までのデータは共有済。 最新のデータ共有をお願いした。	Gerry氏からの聞き取りでは、PECのシステムはデータロガーが故障していて正常に記録できていない。遡ってできる限り入力するがデータが無い箇所については対応できない可能性もあるとのこと。 PECのデータのメモリ保存容量の問題については、今後はメモリが足りなくなる前に定期的にデータ回収するように対応する。(Gerry) メモリが足りなくなる前にデータ回収する件については、必要に応じてマニュアルの手順で共有化したほうが良いと思うので検討をお願いした。	第7回国内遠隔トレーニング

コスラエPV設備カルテ（PEC Fund PV）

対応履歴				
No.	日時	内容	対応事項	備考
16	2021/9/21	Gerry氏から情報提供 ①点検体制表		
17	2021/9/22	Gerry氏から情報提供 ①点検計画表　改訂		
18	2022/4/1	Gerry氏から情報提供 ①～2022年3月までのパフォーマンスレシオのデータ ②再エネマニュアル第1章（統合計画）のために収集された情報の共有		メール情報
19	2022/4/1	PR値、点検計画、点検結果の情報を定期的に共有するよう依頼した。 また、PR値測定できていない月(2021年1月～3月)があり、遡って記録してほしいが、測定データが引き出せない理由があるか確認した。	Gerardo氏から対応するとの回答を得た。 PR値測定できていない月について、データロガーに不具合があり記録できていないか、或は長期間データをダウンロードしていないことから消去されている可能性が考えられるが、現時点では原因は不明とのこと	第3回再エネマニュアル改訂トレーニング
20	2022/5/13	Gerry氏へ情報提供 ①マニュアル改訂版（第1章統合計画、第2章再エネO&M)へJICA専門家チームのコメントを発信		メール情報
21	2022/5/16	Gerry氏から情報提供 ①マニュアル改訂版（第1章統合計画、第2章再エネO&M ②～2022年4月までのパフォーマンスレシオのデータ ③点検計画表改訂版 ④再エネマニュアル第1章（統合計画）のために収集された情報の共有	①JICA専門家チームコメントを踏まえた改訂版	メール情報

コスラエPV設備カルテ（PEC Fund PV）

対応履歴				
No.	日時	内容	対応事項	備考
22	2022/5/16	点検計画データ (4.1_Inspection_plan_schedule_(form)_PV_System_Maintenance)について (1)2022年2月は点検実施になっているが、計測機器を用いた点検は実施したか、その際、誰が実施したのか。 (2)2022年4月は点検実施計画があるが、計測器を用いた点検は実施したか(渡辺)	(1)計測器は使用していない。ロバート氏および配電部スタッフ数名が対応したと思われる。(Gerardo) 2022年2月は点検シートの活用が確認できなかったので、次回PEC-PV施設の点検の際はこの記録シートおよび供与した測定機器を活用し、情報共有するよう依頼した。 (2)4月、5月は雨が多く実施していない。次回は6月に実施する見込みとのことである。(Gerardo) 点検計画の修正を依頼した。 ・国名の修正 ・点検者の名前を記載。 ・PEC PV：点検を行っていないのであれば、実施記載を削除	第4回再エネマニュアル改訂トレーニング
23	2022/7/5	Gerry氏から情報提供 ①～2022年6月までのパフォーマンスレシオのデータ		メール情報
24	2022/7/6	Gerry氏から情報提供 ①点検計画表改訂版		メール情報
25	2022/7/7	PR値計測値についての確認、アドバイスを行った。	・2022年5月と6月分を記録したパフォーマンスレシオシートは渡辺氏経由で共有したとのこと。 データが確認ができなかったため、直近過去に共有頂いたシートでアドバイスした。 ・2021年の日射量値を月ごとで比較すると、非常に変動幅が大きい。再度日射量値の確認をお願いした。 Gerardo氏からの聞き取りでは、毎月の日射量値はデータロガー入手。毎日のデータがロガーにあるので、それを集めて手動で計算している。 NASAが公開している日射量データがあるので、それを活用することもできる。JICA専門家チームが、NASAデータと実データを比較して、ほぼ違いは無く信ぴょう性は高いと考える。コスラエの月ごとの日射量平均値(2000年から2019年までの平均値)を共有する。 再度、PR値を計算する。(Gerardo)	第8回再エネトレーニング及びフォローアップセッション

コスラエPV設備カルテ（PEC Fund PV）

対応履歴				
No.	日時	内容	対応事項	備考
26	2022/9/7	Gerry氏から情報提供 ①マニュアル改訂版（第1章統合計画、第2章再エネO&M ②～2022年8月までのパフォーマンスレシオのデータ ③点検計画表改訂版		メール情報
27	2022/9/12	PECのPR値について、直近3ヶ月(2022年6月～8月)はPR値が急に低下しており、何か気づいている点がないか確認した。	Gerardo氏からは、この時期は雨が多かったのでそれが影響しているのではないかと考えるとのこと。 以下についてアドバイスした。 PR値は天候に左右されないと思われること。 雨が多い月と思われていても、日射量の数値が極端に高い値であり、何等か他の原因も考えられること。 発電量も減っているように見えるため、まずは発電量と日射量の計測値が正しく入力されているか確認するようアドバイスした。 それでも原因がわからない場合は、次のステップとして設備点検を実施してください。ストリングトレーサーで各ストリングのI-Vカーブを確認し設備に異常が無いか確認するようアドバイスした。 また、雨の日に絶縁抵抗値を測定してみるのも有効で、雨の日にインバータトリップしている可能性について確認できることを説明した。 さらに、9月のPR値も継続して測定しチェックするよう依頼した。	第5回再エネマニュアル改訂トレーニング
28	2022/9/12	点検計画データ （4.1_Inspection_plan_schedule_(form)_PV_System_Maintenance_Kosrae(FSM)_2022) について、 (1)各施設の点検計画と実績の線が適切に記載されていないので、訂正して再提出を依頼した。（特に2022年7月、8月、9月のチェックを依頼） また、実績ありで記載している期間について。点検記録の共有をお願いした。		第5回再エネマニュアル改訂トレーニング

コスラエPV設備カルテ（PEC Fund PV）

対応履歴				
No.	日時	内容	対応事項	備考
29	2022/9/20	Gerry氏へ情報提供 ①マニュアル改訂版（第1章統合計画、第2章再エネO&M)へJICA専門家チームのコメントを発信		メール情報
30	2022/11/28	Gerry氏から情報提供 ①～2022年10月までのパフォーマンスレシオのデータ	（翌日29日に改訂版の情報共有があり、再確認した。）	メール情報
31	2022/11/30	Gerry氏から情報提供 ①マニュアル改訂版（第1章統合計画、第2章再エネO&M ②点検計画表改訂版		メール情報
32	2023/3/22	Gerry氏から情報提供 ①～2023年1月までのパフォーマンスレシオのデータ		第14回現地渡航
33	2023/3/27	Gerry氏から情報提供 ①マニュアル改訂共同作業にて現地最終化 第1章、第2章	今後、JICA専門家チームで必要な修正を追加して最終化版とする。	第14回現地渡航
34	2023/6/13	Gerry氏から情報提供 ①～2023年5月までのパフォーマンスレシオのデータ		メール情報

コスラエPV設備カルテ（EU PV）

基本情報

設備名称	EU PV	外観写真	 
導入年	2015年		
容量(kW)	100kW		
ドナー名			
管理者	KUA		

パフォーマンスレシオ(ベースライン:56%)

2020年	1月	2月	3月	4月	5月	6月	7月	8月	9月	10月	11月	12月	平均
	53.4	54	60.6	56.1	54.7	57.2	59.1	59.8	59.8	58.4	56.2	50.7	56.67
2021年	1月	2月	3月	4月	5月	6月	7月	8月	9月	10月	11月	12月	平均
	–	–	–	56.8	53.7	52.7	51.1	59.3	55.4	54.8	57.3	23.9	51.67
2022年	1月	2月	3月	4月	5月	6月	7月	8月	9月	10月	11月	12月	平均
	55.6	53.6	55.4	–	53.5	55.5	52.8	54.5	59.1	58.2	61.4	58.5	56.19
2023年	1月	2月	3月	4月	5月	6月	7月	8月	9月	10月	11月	12月	平均
	61.2	–	44.4	58.9	58.3	–	–	–	–	–	–	–	55.7

メモ

パフォーマンスレシオ　ベース値
1. Usual Performacne Ratio is between 70 and 85%.
2. Baseline Perfomance Ratio =56%

※コスラエの各PV設備共通の対応事項は、「PEC Fund PV」の対応履歴に記録する。

コスラエPV設備カルテ（EU PV）

対応履歴				
No.	EU PV	内容	対応事項	備考
1	2020/8/5	・パフォーマンスレシオについて、Excel様式の表“5_Perfomance_Ratio_Calculation_Sheet_Kosrae”を提供し、ファイルの黄色い部分(毎月のPV発電量と平均日射量)をKUAで入力するよう依頼した。	日射量実測値がわからない場合は、NASA等の信頼性が高いスタンダードデータを代用するようアドバイスした。	第2回国内遠隔トレーニング
2	2020/8/5	PV点検についての確認 ・頻度 ・点検記録作成、保管 ・昨年現地トレーニングで共同作成した記録表の活用および最新記録の共有依頼	・基本的には2ヵ月に1回の実施しているが、最近はGerry氏がコロナの影響でグアムから帰ってこれないため、定期点検が実施できていない。 ・作成している ・活用している。（共有する）	第2回国内遠隔トレーニング
3	2020/11/10	PR値の計測データ（2020年10月まで）を更新して提示するよう依頼した。	Robert氏から対応するとの回答を得た。	第4回国内遠隔トレーニング
4	2020/11/10	施設運用について確認した。 ・PV設備の点検頻度 ・点検は同じ職員が実施しているか。また、点検の為のチームがあるか。 ・10名程度の要員配置が理想と紹介したが、点検チームを編成することは可能か。（JICA専門家チームの例では兼務させ7名のチーム編成で対応）	・2ヶ月に1回点検、目視はほぼ毎日。洗浄は4半期ごとに実施している。(Gerardo) ・KUAでは、4名が点検担当している。現在コロナの影響で2名で点検を実施している。洗浄作業などは電線作業員に手伝ってもらうことがある。監督者（Robert氏）以外の担当者について、役割分担が決まっていないとのこと。(Gerardo) ・KUAで現状以上の人員増は難しい。将来的に1MWのPV導入を目指しているため、設備の拡大に伴い人員増は必要と考えている。その際にJICA専門家チームの兼務での体制は参考になる。一方で人件費が課題と考える。(Gerardo) 担当者にそれぞれ役割を与えることが体制づくりによい　ことをコメントした。	第4回国内遠隔トレーニング
5	2021/2/16	PR値の計測データ（2021年1月まで）を更新して提示するよう依頼した。	Robert氏から対応するとの回答を得た。	第5回国内遠隔トレーニング

コスラエPV設備カルテ（EU PV）

対応履歴				
No.	EU PV	内容	対応事項	備考
6	2021/2/16	以下についてKUAからへ確認した。 ①PVの点検頻度？ ②PVの点検メンバーは専任されたメンバーか ③長期運用のために予算は確保されていますか？ ④他ドナーからの支援はどのような計画があるか	Gerardo氏から以下の回答、情報を得た。 ①2カ月に1回（目視ではほぼ毎日、また定期的にパネルの洗浄も行っている） ②4名は配属しているが現在は2名のコロナの影響で帰国できていないとの事だった。 ③予算はあるが配電計画と一緒にされている。人件費と消耗品が基本的な項目である。 ④ADB支援で1MWの太陽光を導入予定。 今後のPV設備の拡大に伴い、メンテナンスの体制を整える必要であることをアドバイスした。	第5回国内遠隔トレーニング
7	2021/6/8	PR値の計測データを更新して提示するよう依頼した。	・2020年5月までのPRデータの共有を確認。各月の日数に誤入力であり、正しく入力し、ベース値66%（2016年）との比較確認したいことをコメントした。 ・日射量の実測値とNASAのデータと比較し、乖離がある場合はNASA提供のデータの活用をアドバイス。 ・パフォーマンスレシオの値が低い場合には、想定される原因をPR値シートに記載し、次に解決に向けた検討などにつなげていきたいことをコメントした。	第6回国内遠隔トレーニング
8	2021/6/8	・PVシステムの点検の実施について確認した。	Robert氏から、時々実施しているとのこと。 ただし、KUAとJICA専門家チームで共同作成した点検シートを活用していないようである。 　フォーマットを再送し、今後の点検に活用して頂き、結果データの共有をお願いした	第6回国内遠隔トレーニング

コスラエPV設備カルテ（EU PV）

対応履歴				
No.	EU PV	内容	対応事項	備考
9	2021/6/8	PV設備点検について年間スケジュールを様式に沿って計画し、共有をお願いした。	対象設備毎に、点検担当者、点検スケジュールの計画を入力して計画、実績表を共有するよう依頼 ・PECはRobert氏とRonnie氏の2名、EUはGerard氏とRonnie氏が担当。 ・直近2021年7月の点検日程を計画 （PEC、EUともに7月5日～6日で設定した。Robert） ・今後PV設備が増えた際、点検計画表に追加を依頼した。 その際、現在の点検担当者で点検管理が厳しくなってきた場合は、担当者の追加検討の資料で役立つと考える。 ・実施後に結果欄に実績を記入。計画と実施がずれた場合、その原因を特定し、その後の計画策定の際、留意すること。	第6回国内遠隔トレーニング
10	2021/6/8	メンテンナンス実施体制について ・表形式で明確にして情報共有するよう依頼来した。	・スケジュール、役割、人員を表に整理することで、チームメンバーが共通の認識をもち、効率の良い業務が可能となる。体制表を作成し活用してほしいことを説明した。 ・役職と役割分担を決める必要がある。チーム内で相談の上、6月中に表に記載してほしい。担当者が重複しても構わない。	第6回国内遠隔トレーニング
11	2021/9/21	PR値の計測データを更新して提示するよう依頼した。 PECは2020年8月、EUは同12月までのデータは共有済。 最新のデータ共有をお願いした。	EUについてはデータが正常に記録できていると思われる。過去のPRデータを確認するとのこと（コスラエ） ※Gerry氏からの聞き取りでは、PECのシステムはデータロガーが故障していて正常に記録できていない。遡ってできる限り入力するがデータが無い箇所については対応できない可能性もあるとのこと。	第7回再エネトレーニング及びフォローアップセッション
12	2022/4/1	PR値、点検計画、点検結果の情報を定期的に共有するよう依頼した。 また、PR値測定できていない月(2021年1月～3月)があり、遡って記録してほしいが、測定データが引き出せない理由があるか確認した。	Gerardo氏から対応するとの回答を得た。 PR値測定できていない月について、データロガーに不具合があり記録できていないか、或は長期間データをダウンロードしていないことから消去されている可能性が考えられるが、現時点では原因は不明とのこと	第3回再エネマニュアル改訂トレーニング

コスラエPV設備カルテ（EU PV）

対応履歴				
No.	EU PV	内容	対応事項	備考
13	2022/5/16	点検計画データ (4.1_Inspection_plan_schedule_(form)_PV_System_Maintenance)について (1)2022年2月は点検実施になっているが、計測機器を用いた点検は実施したか、その際、誰が実施したのか。 (2)2022年4月は点検実施計画があるが、計測器を用いた点検は実施したか(渡辺)	(1)計測器は使用していない。ロバート氏および配電部スタッフ数名が対応したと思われる。(Gerardo) 次回点検の際はこの記録シートおよび供与した測定機器を活用し、情報共有するよう依頼した。 (2)4月、5月は雨が多く実施していない。次回は6月に実施する見込みとのことである。(Gerardo) 点検計画の修正を依頼した。 ・国名の修正 ・点検者の名前を記載。 ・EU PVの計画に実施予定者を記入すること。	第4回再エネマニュアル改訂トレーニング
14	2022/7/7	・PR値について	・EU PVについては、2016年のベースライン値(56%)に対して、2022年4月までほぼ同じくらいの値で推移している。	第8回再エネトレーニング及びフォローアップセッション
15	2022/7/8	点検計画データ （4.1_Inspection_plan_schedule_(form)_PV_System_Maintenance_Kosrae(FSM)_2022) について、 (1)各施設の点検計画と実績の線が適切に記載されていないので、訂正して再提出を依頼した。（特に2022年7月、8月、9月のチェックを依頼） また、実績ありで記載している期間について。点検記録の共有をお願いした。		第5回再エネマニュアル改訂トレーニング