SOCIALIST REPUBLIC OF VIETNAM
Ministry of Industry and Trade (MOIT)

Guideline for Technical Regulation Volume 4

Operation and Maintenance of Power Plants and Grid

Final Draft

June 2013

Japan International Cooperation Agency

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IL
CR(2)
13-094

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Abbreviation

Abbreviation	Description
AC	Alternating current
AH	Air Heater
ANSI	American National Standards Institute
APC	Automatic Plant Control
APFR	Automatic Power Factor Regulator
AQR	Automatic Reactive power Regulator
ASME	American Society of Mechanical Engineers
AVR	Automatic Voltage Regulator
BFB	Bubbling Fluidized Bed
BFP	Boiler Feed Water Pump
BFPT	Boiler Feed Water Pump Turbine Drive
BTG	Boiler-Turbine-Generator
C/C	Control Center
CB	Circuit breaker
CFB	Circulating Fluidized Bed
CO2	Carbon dioxide gas
COD	Chemical Oxygen Demand
CRT	Cathode Ray Tube
CT	Current transformer
CV	Control Valve
CV cable	Cross-linked polyethylene insulated vinyl sheath cable
DC	Direct Current
DCHVTE	DC high voltage testing equipment
De-NOx	Denitrogenation -Nitrogen Oxide
De-SOx	Desulfurization-Sulfur Oxide
DS	Disconnecting switch
EHC	Electric Hydraulic Control System
FDF	Forced Draft Fan
GL	Green Lamp
GRF	Gas Recirculation Fan
ICV	Intercept Valve
IDF	Induced Draft Fan
IEC	International Electrotechnical Commission

Abbreviation	Description
IEEE	Institute of Electrical and Electronics Engineers
IPB	Isled / Insulated phase bus
IRM	Insulation Resistance measurement
ISO	International Organization for Standardization
JIS	Japanese Industrial Standards
kV	kilo volt
kVA	kilo volt ampere
kW	kilo watt
LB	Lower bracket
LNG	Liquefied Natural Gas
M/C	Metal Clad Switchgear
MARD	Ministry of Agriculture and Rural Development
M-BFP	Motor drive - Boiler Feed Water Pump
MCR	Maximum Continuous Rating
MFT	Main (Master) Fuel Trip
MHC	Mechanical Hydraulic Control
MOIT	Ministry of Industry and Trade
MSV	Main Stop Valve
MΩ	mega ohm
NFPA	National Fire Protection Association
NGR	Neutral grounding resistor
NGT	Neutral grounding transformer
OCL	Over-current limiter
OEL	Over-excitation limiter
OF cable	Oil field cable
P/C	Power Center
PAC	Provisional Acceptance Certificate
PAF	Primary Air Fan
PB	Push Button
PDCA	Plan Do Check Act
PI	Polarization Index
PM	Planning maintenance
PPE	Power plant equipment
PSS	Power system stabilizer
PT	Penetrant Test

Abbreviation	Description
PT (PD)	Potential Transformer (Potential Device)
RAM	Random Access Memory
RL	Red Lamp
rms	Root-mean square
RSV	Re-heat Stop Valve
SC	Super Critical
SFC	Static Frequency Converter
Tan δ	Dielectric loss angle
TCVN	Tieu Chuan Viet Nam
THC	Turbine head cover
TM	Temporary maintenance
UB	Upper bracket
UEL	Under-excitation limiter
USC	Ultra Super Critical
UT	Ultrasonic Test
V/F	Voltage / Frequency
VT	Voltage transformer
WL	White Lamp
XLPE	Cross-linked polyethylene

Part 1
General

Article 1. Purpose

As stipulated in the Technical Regulation.

Article 2. Scope of application

As stipulated in the Technical Regulation.

Article 3. Definitions

As stipulated in the Technical Regulation.

Article 4. Formulation of inspection

As stipulated in the Technical Regulation.

Part 2
Transmission & Distribution Line and Substations

Chapter 1 General Provisions

Article 5. Definitions

The definition of inspection shall be in accordance with the definition of Chapter 1 in Part 2 in Technical Regulation Vol.5.

Chapter 2 Organizations and Management of Operation and Maintenance

Article 6. Organizations

The organization related to overhead transmission lines, underground transmission lines and substations shall satisfy the requirement of Chapter 1 in Part 2 in Technical Regulation Vol.4.

Article 7. Documentation

The documents related to overhead transmission lines, underground transmission lines and substation shall satisfy the requirement of Chapter 1 in Part 6 in Technical Regulation Vol.4.

Chapter 3 Inspection

Article 8. General provisions

The owner shall carry out the acceptance inspection that confirms expected quantity and quality of materials.

The owner shall carry out the visual inspection at the time of acceptance inspection, if necessary.

Article 9. The detail of inspection (Inspection content)

The detail acceptance inspection shall be carried out to confirm materials purchased according to the procurement specifications.

This inspection shall include the above mentioned inspection in Article 8 and the inspection to confirm materials to ensure specifications required by the procurement specifications and factory test reports.

Chapter 4 In-Progress Inspection

Section 1 General

Article 10. General provisions

In-progress inspection for facilities of overhead transmission lines, underground transmission lines and substations shall be carried out according to Chapter 4 in Part 2 in Technical Regulation Vol.5 and this Guideline.

Section 2 Overhead Transmission Line

Article 11. Earth resistances of poles, rafters, brackets and earthing system

Grounding resistance of the pole or the steel tower shall satisfy inspection items as shown in the following Table 11.

Grounding resistance of the pole or the steel tower shall be measured according to following procedures by a grounding resistance meter.

- Grounding resistance of the pole shall be measured after erection of poles and burying the grounding conductor.
- Grounding resistance of the steel tower shall be measured the combined grounding resistance of which four legs of a steel tower combined by measurement conductors of a grounding resistance meter after backfill of the foundation.

Table 11 Inspection of grounding resistance

Item	Method	Acceptance criteria
Value of grounding resistance	Measurement	- The value of grounding resistance shall be less or equal to the value shown in chapter 6 in Technical Regulation Vol.1.
Conditions of buried grounding conductor	Visual inspection	- Kind, nominal cross sectional area and buried situation of the grounding conductor and the condition of the terminal part shall be in accordance with the specification.

Article 12. Overhead wire inspection

Conductors, overhead grounding conductors, clamps (metal parts for holding a conductor or a overhead grounding conductor) and accessories (spacer between conductors, or damper for preventing vibration of a conductor or a overhead grounding conductor, etc.) shall satisfy inspection items in the following tables.

Table 12-1 Inspection of conductor and overhead grounding conductor

Items	Method	Acceptance criteria
Conditions	Visual inspection	- Kind, nominal cross sectional area and number of conductors and overhead grounding conductors shall be in accordance with the specification. - The strand of conductors and overhead grounding conductors shall not be damaged or loosened.
Sag	Measurement	- The sag of the conductors and the overhead grounding conductors shall be from -10 cm to +10 cm of the value in the specification. - The difference of sag between conductors of multiple conductors in one phase shall be less or equal to the external diameter of the conductor.

Table 12-2 Inspection of clamp and accessory

Items	Method	Acceptance criteria
Conditions of fixed clamp and accessory	Visual inspection	- Kind and number of clamps and accessories shall be in accordance with the specification. - The fixed position and condition of clamps and the accessories shall be in accordance with the specification. - The torque value of bolts of the clamp and the accessory shall be the value shown the construction specification.

Article 13. Wire connection inspection

Connections of conductors and overhead grounding conductors shall satisfy inspection items in the following table.

Table 13 Inspection of connection of conductor and overhead grounding conductor

Items	Method	Acceptance criteria
Dimension	Measurement	- The dimension of two opposite sides of the pressured sleeve shall be in accordance with the dimension of the pressure gauge. - The extended length of the pressured sleeve shall be from +10 % to +20 % of the length before pressured.
Conditions	Visual inspection	- The pressured sleeve shall not be damaged or cracked. - The fixed position of the pressured sleeve shall be in accordance with the specification. - In case of steel core aluminium conductor steel reinforced, the center point of the sleeve shall be at the center point of the connection.

Article 14. Optical Ground Wire (OPGW) inspection

Optical fiber compound grounding conductor (hereafter, OPGW) shall satisfy inspection items in the following table.

In Addition, all clamps and all accessories of the OPGW shall be complied with inspection items in Article 12.

Table 14 Inspection of OPGW

Items	Method	Acceptance criteria
Conditions	Visual inspection	- Kind, nominal cross sectional area and number of OPGWs shall be in accordance with the specification. - The strand of the OPGW shall not be damaged or loosened. - The bending diameter of the OPGW shall be more than the specification. - The number of change in twist of the OPGW shall be less or equal to five turns per 100 m.
Sag	Measurement	- The sag of the OPGWs shall be from -10 cm to +10 cm of the value in the specification.
Transmission loss of optical fiber	Measurement	- The transmission loss of optical fiber is in accordance with the specification approximately.

Article 15. Insulation clearance inspection

Insulation clearance from a conductor to the body or arm of the pole or the steel tower, and between conductors shall satisfy inspection items in the following table.

Table 15 Inspection of insulation clearance

Items	Method	Acceptance criteria
Insulation clearance	Measurement	- The value of insulation clearance from a conductor to the body or arm of the pole or the steel tower, and between conductors shall be more than the value shown in Chapter3-3 in Technical Regulation Vol.1 .

Article 16. Insulator inspection

Insulators shall satisfy inspection items in the following table.

Table 16 Inspection of Insulator

Items	Method	Acceptance criteria
Conditions of fixed insulator	Visual inspection	- Kind (manufacturer's number), number in one string, type of fixed conductors (suspended type or string type) shall be in accordance with the specification. - The assembled condition of the insulator and linked parts shall be in accordance with the specification. - The insulator and linked parts shall not be damaged, loosened, polluted or corroded. - Permissible level of the defect in visual shall be in accordance with Part 1 in "IEC 60381-1(1993) Insulators for overhead lines with a nominal voltage above 1000 V". - Split pin to prevent from dropping connection parts of insulator shall open more than 45 degrees. - Suspended insulator string shall not incline to the direction of the conductor or be pulled up by the conductor.

Article 17. Span lengths, horizontal angles and minimum heights above ground

Span length, horizontal angle and minimum height of the lowest conductor above ground shall satisfy inspection items in the following table.

In addition, results of each measurement shall be recorded.

Table 17 Inspection of span length, horizontal angle and minimum height above ground

Item	Method	Acceptance criteria
Span length	Measurement	Span length between center points of poles or steel towers shall be from -1 m to +1 m of the length of the specification.
Horizontal angle	Measurement	Horizontal angle of overhead power line at center point of the pole or the steel tower shall be from -0.5 to +0.5 degrees of the value of the specification.
Minimum height of the lowest conductor above ground	Measurement	The height of the lowest conductor above ground at the point where vertical offset distance from the conductor to the ground is the closest on the side view diagram shall be in accordance with the specification. However, the difference of the sag due to the difference of air temperature between design and measurement shall be corrected for the measurement of the minimum height.

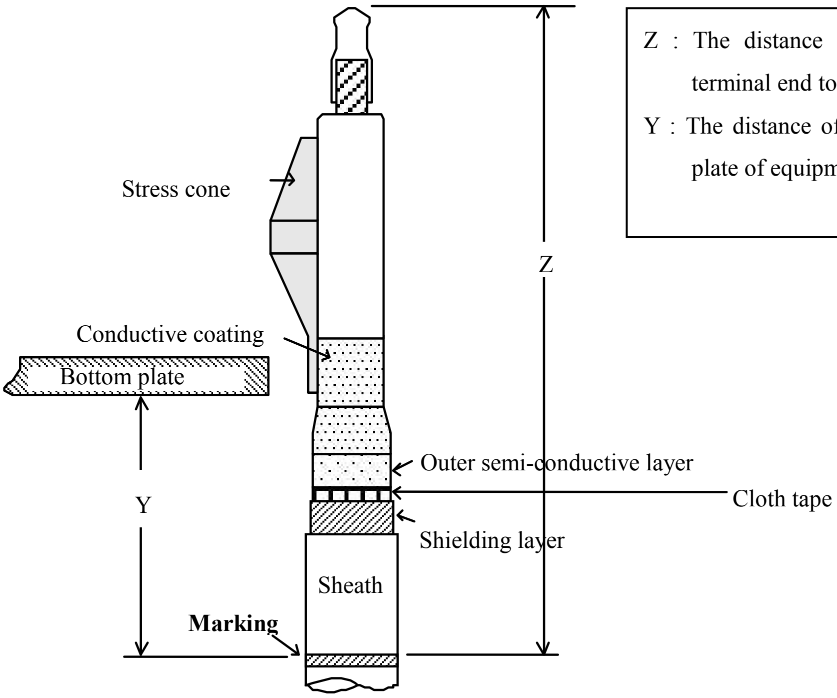
Section 3 Underground Transmission Line

Article 18. Inspection of cable joint boxes

The connection box and terminal box of the cable line shall satisfy inspection items in the following table.

Table 18 Inspection of connection box and terminal box

Items	Method	Acceptance criteria
Insulation resistance	Measurement	- Insulation resistance between each core of the cable and the ground shall be confirmed by megger. In addition, insulation resistance between cores of multiple cores cable (except cables with shielding layer) which each core is insulated mutually shall be confirmed. - The value measured at one minute after the measurement was started shall basically be adopted. In case that the value is not stable, it should be measured after the value becomes stable. - Use 2,500V megger for testing. - Air temperature and humidity at the measurement shall be recorded.
Connection box Terminal box	Document	- The dimensions and the construction methods of connection box and terminal box confirmed by quality and construction records shall be in accordance with the specification. In addition, all dimensions (the length of removing protective covering outer sheath, the length of exposed shielding layer and the length of penciling of insulation material, etc.) of connection box and terminal box shall be within permissible values.
Straightness of cable	Document	- Straightness of cable straightened by heat shall be in accordance with the specification.
Insertion of terminal box of slip-on type (Only EB-GS and EB-OS)	Measurement	- The cable shall be marked before it is inserted into the transformer equipment. The distance from the bottom plate of equipment to marking on the cable shall be in accordance with the specification after the insertion. (Refer to Figure ure 18) - Inserted cable shall be checked to ensure the appropriate insertion by hearing and touching by the construction worker in the event of the insertion.



Z : The distance of marking is from the cable terminal end to the marking point.
Y : The distance of measuring is from the bottom plate of equipment to the marking point.

Figure 18 (Reference drawing) Insertion of terminal box of slip-on type

Article 19. Phase check

Phases of the cable shall satisfy inspection items in the following table.

Table 19 Inspection of phase of cable

Items	Method	Acceptance criteria
Phase	Measurement	- The same phase of both ends of the cable shall satisfy following conditions. (1) When one end of the cable is attached the grounding, the value of insulation resistance between the phase and the ground which measured at opposite end is 0 Ω. (2) When one end of the cable is removed from the grounding, the value of insulation resistance between the phase and the ground which measured at opposite end increases. (more than 0 Ω)

Article 20. Earth connection

Grounding conductors of the cable and metallic parts shall satisfy inspection items in the following table.

Table 20 Inspection of grounding conductor of cable and metallic parts

Items	Method	Acceptance criteria
Value of grounding resistance	Measurement	- The value of grounding resistance shall be less or equal to the value shown in chapter 6 in Technical Regulation Vol.1.
Conditions	Visual inspection	- Kind, nominal cross sectional area and buried situation of the grounding conductor and the condition of the terminal part of the grounding conductor shall be in accordance with the specification.

Article 21. Conditions of cable supporters

Cable supporters (cable rack, etc.) shall satisfy inspection items in the following table.

Table 21 Inspection of cable supporter

Items	Method	Acceptance criteria
Conditions	Visual inspection	- Number and fixed position of cable supporters shall be in accordance with the specification. - Cable supporters shall not be damaged or corroded, and bolts of the supporters shall not be loose.

Article 22. Cable installation

The cable at the laying work shall satisfy inspection items in the following table.

Table 22-1 Inspection of cable

Items	Method	Acceptance criteria
Conditions	Visual inspection	- Kind, nominal cross sectional area and number of cables shall be in accordance with the specification. - The cable shall not be damaged.
Tension of cable laying	Measurement	- Tension of cable laying shall be less or equal to the permissible tension of cable laying. - Permissible tension ＝ 68.6×N×A (N) N : Number of cores of cable A : Cross sectional area of cable (mm^2)
Cable lateral pressure	Document	- The value of cable lateral pressure calculated by the tension of cable laying shall be less or equal to the value of permissible cable lateral pressure. - Permissible cable lateral pressure is shown in Table 22-2.
Bending radius	Measurement	- Bending radius of cable shall be more than the permissible bending radius shown in Table 22-3. However, bending radius at the construction work shall be 1.5 times more than the permissible bending radius.

Table 22-2 Permissible cable lateral pressure

Kind of cable			Permissible cable lateral pressure (N/m)
Oil-filled cable	Aluminium sheath	Single core	2,940
		Triple cores	2,940
XLPE cable	No metallic sheath	Single core	2,940
		Triple cores	2,450
	Aluminium sheath	Single core	2,940
	Stainless sheath	Single core	2,940

Table 22-3 Permissible bending radius

Kind of cable			Permissible bending radius (m)	Permissible bending radius at construction work (m)
Oil-filled cable	Aluminium sheath	Single core	15×(Cable diameter)	22.5×(Cable diameter)
		Triple cores	12×(Average twisted diameter)	18×(Average twisted diameter)
XLPE cable	No metallic sheath	Single core	10×(Cable diameter)	15×(Cable diameter)
		Triple cores	8×(Average twisted diameter)	12×(Average twisted diameter)
	Aluminium sheath	Single core	15×(Cable diameter)	22.5×(Cable diameter)
	Stainless sheath	Single core	17.5×(Cable diameter)	26.3×(Cable diameter)

Remark : If the cable specification exceeds the above value, the specification shall be applied.

Article 23. Insulation resistance of cable jacket

Insulation resistance of protective covering outer sheath shall satisfy inspection items in the following table.

The inspection time shall be after laying the cable and before shielding layer is attached to the grounding conductor.

Table 23-1 Inspection of insulation resistance of protective covering outer sheath

Items	Method	Acceptance criteria
Insulation resistance of protective covering outer sheath	Measurement	- The value of insulation resistance of protective covering outer sheath (between shielding layer and the ground) shall be more than the value of permissible insulation resistance shown in Table 23-2. - The value measured at one minute after the measurement was started shall basically be adopted. In case that the value is not stable, it should be measured after the value becomes stable. - - Use 1,000V or 2,500V megger for testing.

Table 23-2 Permissible insulation resistance of protective covering outer sheath

Kind of cable	Permissible insulation resistance of protective covering outer sheath (Ω-km)
XLPE cable	10×10^6
Oil-filled cable	10×10^6

Article 24. Cable snaking

Snaking installation of the cable shall satisfy inspection items in the following table.

Table 24 Inspection of snaking installation

Items	Method	Acceptance criteria
Conditions of snaking installation	Measurement	- Length and width of snaking installation shall be in accordance with the specification.
	Visual inspection	- Number and position of the fixed parts for snaking installation shall be in accordance with the specification. - The fixed parts for snaking installation shall not be damaged or corroded, and bolts shall not be loosened.

Article 25. Grounding points

Grounding conductor of the connection box and the terminal box shall satisfy inspection items in the following table.

Table 25 Inspection of grounding conductor of connection box and terminal box

Items	Method	Acceptance criteria
Grounding method	Visual inspection	- Grounding methods (cross-bonding method, etc.) of connection boxes and terminal boxes shall be in accordance with the specification.
Value of grounding resistance	Measurement	- The value of grounding resistance shall be less or equal to the value shown in chapter 6 in Technical Regulation Vol.1.
Conditions	Visual inspection	- Kind, nominal cross sectional area and buried situation of the grounding conductor and the condition of the terminal part of the grounding conductor shall be in accordance with the specification.

Article 26. Clearance from other cables, pipes, etc

Offset distance from the cable to other lines and pipe lines shall satisfy inspection items in the following table.

Table 26 Inspection of offset distance from the cable to other lines and pipe lines

Items	Method	Acceptance criteria
Offset distance	Measurement	- The offset distance from the cable to other lines and pipe lines shall be more or equal to the distance shown in Chapter 3-2 in Technical Regulation Vol.1.
Conditions	Visual inspection	- Number and position of the protective measure for the cable, other lines and pipe lines shall be in accordance with the specification.

Article 26-a1. DC high voltage test and measurement of leakage current

DC voltage test shall be implemented as follows.

(1) DC voltage test for the rated voltage from 1kV to 30kV (IEC 60502-1)
- Test voltage is shown in the Table 26-a1-1
- Duration of test is 15 minutes.

Table 26-a1-1 DC voltage test for cables rated voltage from 1kV up to 30kV

(IEC60502-1)

Rated voltage U_0 / U (U_m) (kV)	Test voltage 4 U_0 (kV) (phase-to-ground)
0.6 / 1 (1.2)	2.4
1.8 / 3 (3.6)	7.2
3.6 / 6 (7.2)	14.4
6 / 10 (12)	24
8.7 / 15 (17.5)	34.8
12 / 20 (24)	48
18 / 30 (36)	72

NOTE

- U_0 is the rated power frequency voltage between conductor and earth or metallic screen for which the cable is designed.
- U is the rated power frequency voltage between conductors for which the cable is designed.
- U_m is the maximum voltage of the "highest system voltage" for which the equipment may be used.
- For cables rated voltage from 1kV up to 30kV, if it is possible to implement AC voltage test, it shall be implemented by applying rated power frequency voltage U for 5 minutes instead of DC voltage test.

(2) DC voltage test for the rated voltage more than 30kV (IEEE 400.1, IEC60840, IEC62067)

1) DC voltage test of the conductor (IEEE 400.1)
   - Test voltage is shown in the Table 26-a1-2
   - Duration of test is 15 minutes.

Table 26-a1-2 DC voltage test for cables rated voltage more than 30kV

(IEEE 400.1)

System voltage (kV) (phase-to-phase)	BIL (kV)	Test voltage (DC, kV) (phase-to-ground)
69	350	175
115	450	225
138	650	325
230	1,050	525

NOTE: If it is possible to implement AC voltage test, one of the following test procedures shall be chosen instead of above DC voltage test

1) -Test voltage is shown Table 26-a1-3. (frequency is between 20Hz and 300Hz)
   - Duration of test is 1 hour.
2) Alternatively, voltage of Uo may be applied for 24hours.

Table 26-a1-3 AC voltage test for cables rated voltage more than 30kV

(IEC60840, 62067)

Rated voltage U (kV)	Test voltage (kV r.m.s) (phase-to-ground)
110	128
220	180
500	320

2) DC voltage test of the oversheath
   - Test voltage: DC voltage of 4 kV per millimeter of specified thickness of extruded oversheath shall be applied with a maximum of 10 kV DC between the underlying metallic layers and the outer electrode.
   - Duration of test is 1 minute.

Section 4 Substation Equipment

Article 27. The inspection item for transformers

1. Visual Inspection

It shall be checked whether the transformer has abnormalities such as oil leakage, crack, breakage, damage, looseness at screwed parts, etc. or not.

It shall be checked whether the installation of components such as pipes, bushing, tank, valve, auxiliary systems, etc. have abnormalities or not.

Silica gel, which is used to eliminate the moisture of oil-filled transformers, shall be checked of its color. If it was discolored in pink, silica gel shall be replaced.

2. Measurement of Insulation Performance

Insulation-resistance tests are made to determine the insulation resistance from individual windings to ground or between individual windings.

It is subject to wide variation with design, temperature, dryness, and cleanliness of the parts. When the insulation resistance falls below prescribed values, it can, in most cases, if it is of good design and has no defect, be brought up to the prescribed value by cleaning and drying the apparatus.

The significance of values of insulation-resistance tests generally requires some interpretation, depending on the design, dryness, and cleanliness of the insulation involved. If a user decides to make insulation-resistance tests, it is recommended that insulation-resistance values be measured periodically (during maintenance shutdown) and that these periodic values be plotted. Substantial variation in the plotted values of insulation resistance should be investigated for cause.

The inspection method and criteria are as below.

(1)-1 Measurement of Insulation resistance of windings: R_{60} (for oil-immersed type)

This measurement shall comply with the following conditions by using a 2,500V megger.

1) Insulation resistance for transformers lower than 150 kV shall be measured at 10 ^{o}C and higher, and one for transformers higher than 220 kV shall be measured at higher than 30 ^{o}C.

2) Insulation resistance for transformers 110kV and higher than 80,000 kVA or one for transformers higher than 220kV shall be measured at temperature not exceeding plus/minus 5 ^{o}C in comparison with temperature when manufacturer measured the insulation resistance. For transformers lower than 150kV and 80,000kVA, this difference of temperature shall not exceed plus/minus 10 ^{o}C.
Nevertheless, in the case that the temperature in the field is different from the one in the factory, the measurement result of the insulation resistance shall be compensated by using the coefficient K_1 in Table 27-1.

Table 27-1 Coefficient K_1

Difference of temperature [^{o}C]	**1**	**2**	**3**	**4**	**5**	**10**	**15**	**20**	**25**	**30**
Coefficient K_1	1.04	1.08	1.13	1.17	1.22	1.50	1.84	2.25	2.75	3.40

If difference of temperature is not included in Table 27-1, coefficient corresponding to it shall be calculated by multiplication of each coefficient.
Ex.) Difference of temperature 9 ^{o}C is not included in Table 27-1;

$K_9 = K_5\, K_4 = 1.22 * 1.17 = 1.42$

3) The temperature of windings for transformers lower than 35kV is considered to be equal with the top layer of oil. On the other hand, the one for transformers higher than 35kV is considered to be equal with the temperature of phase B of primary windings calculated by the following formula.

$t_x = R_x/R_0\,(235+t_0)-235$

R_0: the winding resistance measured at temperature t_0 in the factory

$R_{x:}$ the winding resistance measured at temperature t_x

4) The measurement for the transformers higher than 110kV shall be carried out for 120 seconds after grounding the windings. If the measurement is repeated, it should be carried out for more than 300 seconds after grounding the windings again.
If there is no data of inspection done by manufacturers at factories, it is possible to refer to the permissible minimum values in Table 27-2.

Table 27-2 Standards of the insulation resistance [MΩ]

Voltage level for primary windings	Windings temperature [^{o}C]						
	10	**20**	**30**	**40**	**50**	**60**	**70**
Lower than 35kV and lower than 10,000kVA	450	300	200	130	90	60	40
Higher than 35kV and higher than 10,000kVA or higher than 110kV independent of capacity	900	600	400	260	180	120	80

In the case that transformer is not fully filled with oil, measurement of winding resistance can be carried out if oil level is 150 to 200 mm from the top of transformer, and the main insulating parts are fully in the oil.

(1) - 2 Measurement of Insulation resistance of windings for Dry-type transformers

This measurement shall comply with the manufacturer's instruction. If there is no data of inspection done by manufacturers at factories, insulation resistance shall be more than 100 MΩ.

(Japanese standard for reference).

(2) Measurement of Insulation resistance for control circuits (for oil-immersed and dry type)

Insulation resistance between control circuits and the ground shall be measured by a 500V or 1,000V megger to confirm that it is more than 2 MΩ.

(3) Measurement of dielectric loss for windings (for oil-immersed type)

Measurement of dielectric loss angle (tan δ) shall be applied to the transformer of voltage 110kV and over and the transformer of voltage 35 kV and over with capacity 10,000 kVA and higher. This measurement shall comply with 1), 2) and 3) in Section (1). As like R_{60}, tan δ measured in the field shall be compared with the data of factory inspection or latest inspection. However, it is possible to refer to the permissible maximum value of tan δ% in Table 27-3, if there is not such data.

Table 27-3 Standards of tan *δ* for windings of transformers

(%)

Voltage level of primary windings	Windings temperature [^{o}C]						
	10	**20**	**30**	**40**	**50**	**60**	**70**
Lower than 35kV and lower than 10,000kVA	1.2	1.5	2.0	2.6	3.4	4.5	6.0
Higher than 35kV and higher than 10,000kVA or higher than 110kV independent capacity	0.8	1.0	1.3	1.7	2.3	3.0	4.0

In the case that the temperature in the field is different from the one in the factory, the measurement result shall be compensated by using the coefficient K_2 in Table 27-4.

Table 27-4 Coefficient K_2

Difference of temperature [°C]	**1**	**2**	**3**	**4**	**5**	**10**	**15**	**16**
Coefficient K2	1.05	1.10	1.15	1.20	1.25	1.55	1.95	2.4

If difference of temperature is not included in above table, coefficient corresponding to it shall be calculated by multiplication of each coefficient as well as R_{60} in Part 1) Section (1). Since this measurement is influenced by insulating oil, it is necessary to exclude the influence in order to evaluate the result correctly.

$\tan \delta_{Tr} = \tan \delta_{Me} - K_3 (\tan \delta_{Oil2} - \tan \delta_{Oil1})$

$\tan \delta_{Tr}$: Actual value of tan δ for windings of transformer

$\tan \delta_{Me}$: Measured value of tan δ for windings in the field

$\tan \delta_{Oil1}$: tan δ of oil in the transformer measured in the factory which is modified to the measurement temperature.

$\tan \delta_{Oil2}$: tan δ of oil in the transformer measured in the field which is modified to the measurement temperature.

K_3 : Conversion coefficient depending on structure of transformer with its value of nearly equal to the coefficient in Table 27-5.

Tan δ for oil is modified by using coefficeint K_3 according to the differece of temperature.

Table 27-5 Coefficient K_3

Difference of temperature [°C]	**1**	**2**	**3**	**4**	**5**	**10**	**15**	**20**	**30**
Coefficient K_3	1.03	1.06	1.09	1.12	1.15	1.31	1.51	2.0	2.3

If tan δ measured in the field is lower than 1%, it is considered as it satisfies the standards regardless of the result of the factory inspection.

(4) Measurement of dielectric loss for bushing

Dielectric loss angle (tan δ) for bushing shall be measured between the bushing head terminal and the bracket, to confirm that the measured value is within the manufacturers' standards.

3. Measurement of Transformation Ratio (for oil-immersed and dry type)

Transformation ratio shall be checked for each tap to confirm that the difference between measured value and the manufacturers' standards is less than 0.5%. The transformation ratio (n) shall be calculated as below by measuring secondary voltage (V2) when primary voltage (V1=100-200V; AC) is applied.

$$n = V_1/V_2$$

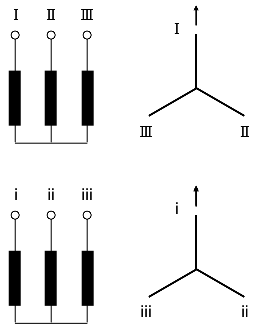
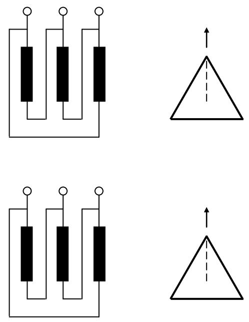
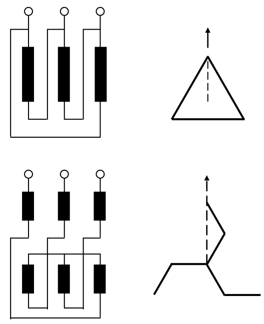
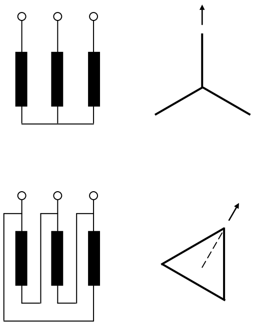
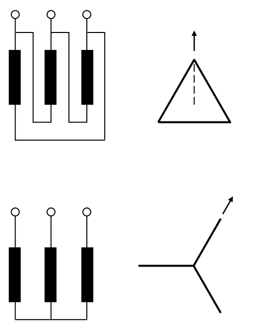
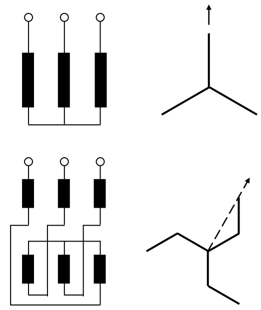
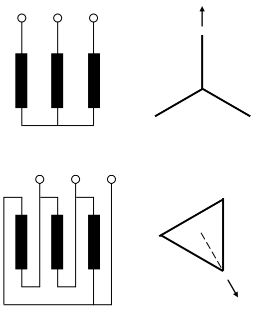
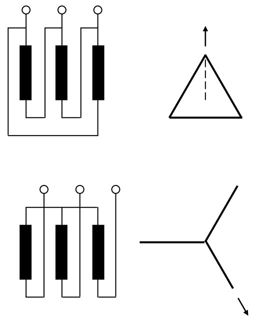
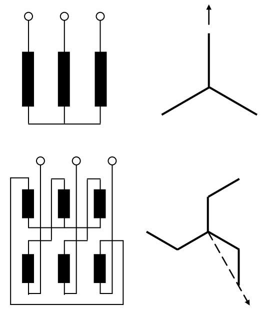
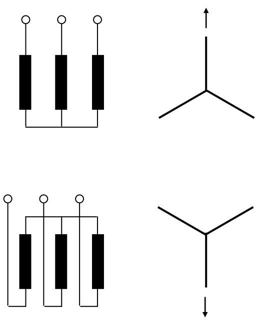
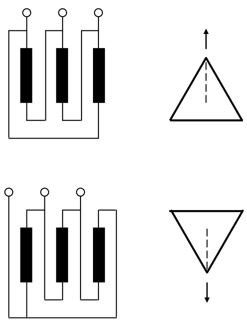
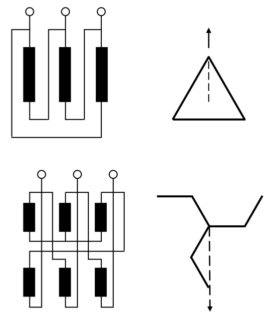
4. Vector group Test (for oil-immersed and dry type)

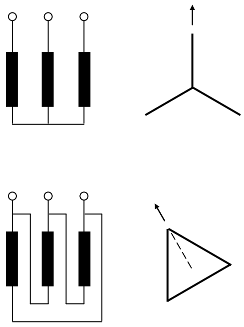
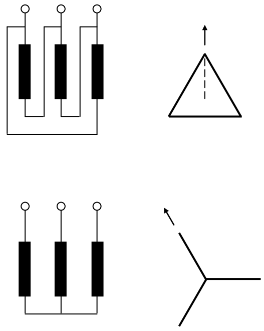
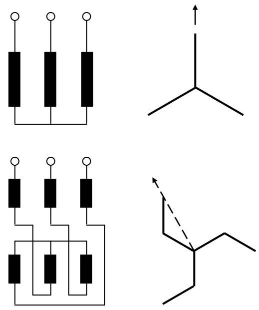
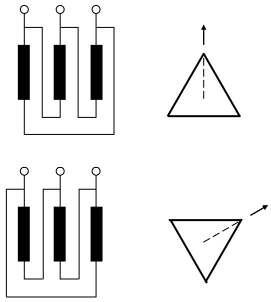
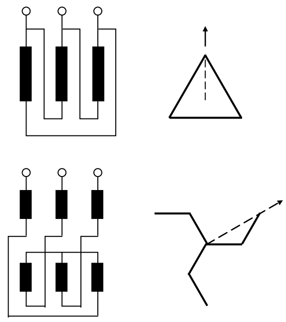
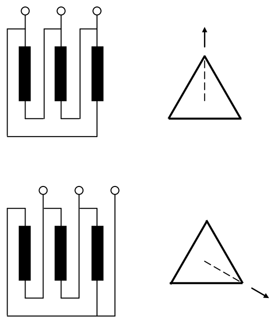
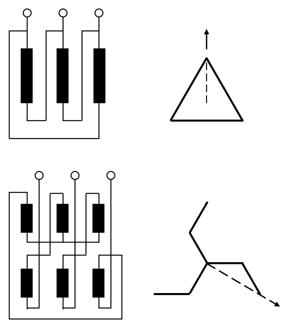
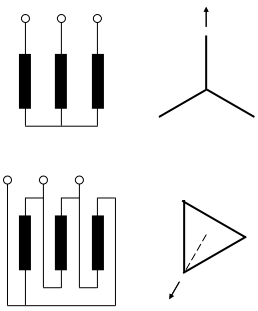
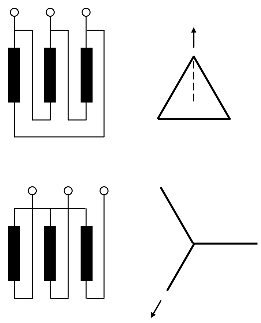
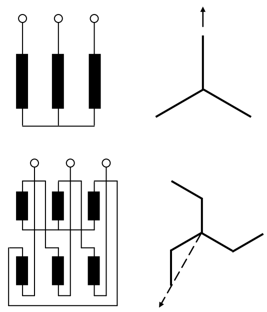
Polarity, wire connection and phase sequence of transformers shall be checked. For single-phase transformers, all windings shall be checked for polarity.

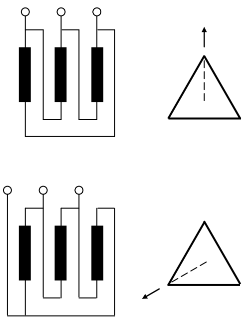
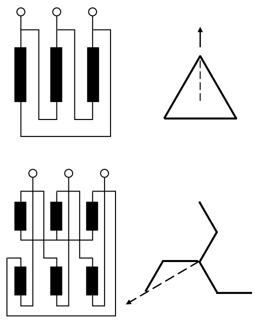
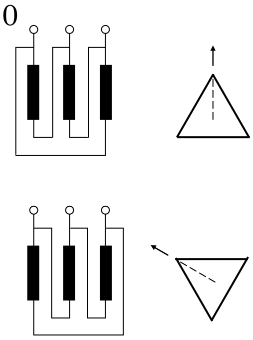
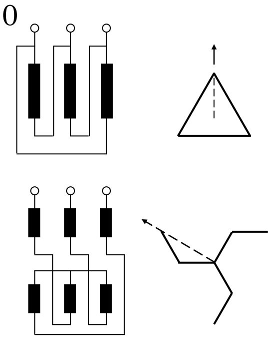
For three-phase transformers, all windings shall be checked for wire connection and phase sequence to confirm that there is no difference from the manufacturers' specifications. The criteria of wire connection and phase sequence of three-phase transformers are in Table 27-6.

Table 27-6 Wire connection and phase sequence of three-phase transformers

(IEC60076-1)

No.*	Wire connection and phase sequence (Vector group symbols)		
0	Yy0 	Dd0 	Dz0 
1	Yd1 	Dy1 	Yz1 
5	Yd5 	Dy5 	Yz5 
6	Yy6 	Dd6 	Dz6 

No.*	Wire connection and phase sequence (Vector group symbols)		
11	Yd11 	Dy11 	Yz11 
2		Dd2 	Dz2 
4		Dd4 	Dz4 
7	Yd7 	Dy7 	Yz7 

No.*	Wire connection and phase sequence (Vector group symbols)		
8		Dd8 	Dz8 
10		Dd10 	Dz10 

*No. Phase shift number of hour;

The number represents the position of the hour hand of a clock as assuming the minute hand is at the position of zero minute. The voltage vector of lower winding is compared to the hour hand, and the voltage vector of higher winding is compared to the minute hand.

5. Measurement of Winding Resistance (for oil-immersed and dry type)

(1) Oil-immersed type

Winding resistance of transformers shall be measured for each tap by using direct current. The difference between the measured value and the manufacturers' standards shall be less than 2%.

As the measured value will change according to the temperature, it shall be modified as below.

$$R_{75}=R_t\times\frac{235*+75}{235*+t}$$

R_{75} : winding resistance at 75 ^{o}C

R_t : winding resistance at t ^{o}C

t : temperature when measurement was carried out

* = 235 for copper or 225 for aluminum.

The measurement shall be carried out as promptly as possible to avoid rise in temperature of windings.

(2) Dry type

Winding resistance of transformers shall be measured for each tap by using direct current. The difference between the measured value and the manufacturers' standards shall be within manufacturers' criteria.

Cold-winding resistance measurements are normally converted to a standard reference temperature equal to rated average winding temperature rise plus 20 °C. In addition, it may be necessary to convert the resistance measurements to the temperature at which the impedance-loss measurements were made. The conversions are accomplished by the following formula.

$$Rs = Rm \{(Ts + Tk) / (Tm + Tk)\}$$

where

Rs is resistance at desired temperature Ts

Rm is measured resistance

Ts is desired reference temperature

Tk is 234.5 °C for copper and 225 °C for aluminum

Tm is the temperature at which resistance was measured

NOTE:

The value of Tk is 225 °C for pure Electrical Conductor Grade (EC) aluminum. Tk may be as high as 240 °C for alloyed aluminum.

6. Measurement of No-load current and loss (for oil-immersed and dry type)

No-load current and loss shall be measured to confirm that there is no difference between measured value and the manufacturers' standards.

The measurement shall be carried out on one winding with no wire connection by applying the rated voltage with the rated frequency to another winding.

If the implementation of the test by applying rated voltage is difficult, it is possible to apply lower voltage to check the balance of no-load current and loss between three phases.

If it is necessary, this test shall be implemented in consultation with manufacturer.

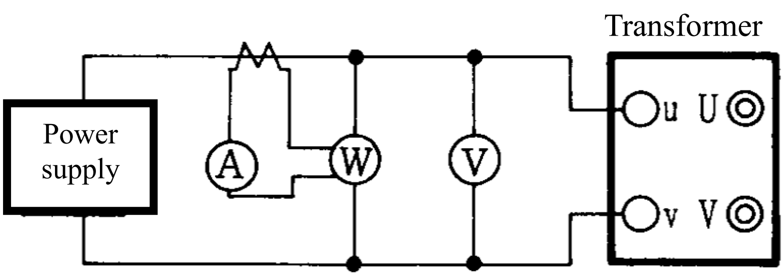


Figure 27 Testing circuit

7. Insulation Oil Test (for oil-immersed type)

(1) Test of new oil received from supplier

When insulation oil is received from supplier, the performance of oil shall be checked that it meets the standards shown in Table 27-7.

Table 27-7 Quality standards of new oil received from supplier

No.	Items	Standards
1	Breakdown voltage (kV/2.5mm) Not less than: - Before filtering - After filtering	 30 70
2	Dielectric loss angle (%) Not more than - at 25°C - at 90°C	 0.05 0.50
3	Acidity (mgKOH/1g oil) Not more than	 0.02
4	Water content (volume ppm) Not more than - In tank - In drum	 30 40
5	Stability oxygenation resistance + Method A: - Residue volume (%) Not more than - Acidity after oxygenation (mg KOH /1g of oil) Not more than + Method B: Time (minute) Not less than	 0.01 0.10 195
6	Dynamic viscosity (m^2/s) Not more than - at 40°C - at 50°C	 12.0 9.0
7	Density Not more than - at 15°C - at 20°C	 0.91 0.90
8	Color-ASTM Scale Not more than	0.5
9	Flash temperature (°C) Not more than - Closed - Open	 135 145
10	Sulfur corrosion	Not
11	Content of PCB[1] (ppm)	5
12[*]	Content of 2-furfural (ppm) Not more than	 0.1

No.	Items	Standards
13(*)	Surface tension at 25^{o}C (mN/m) Not less than	 40
14(*)	Content of anti-oxygenation (2) (%) - Not less than - Not more than	 0.2 0.4

Note:

(1) The limits of initial content of PCB in insulation oil in accordance with the law for environmental protection at the time of application.

(2) The standards are not mandatory for transformers sealed or protected by a plastic film.

(*) The test is not mandatory.

(2) Test of oil before installation

1) For acceptance test of new transformer, insulation oil shall be checked that it meets the standards shown in Table 27-8 before filling.

2) For transformers with voltage 110kV or more, insulation oil shall be filled after checking that the sample oil immersed in the transformer meets the following criteria; Breakdown voltage is not less than 50kV (for 110-500 kV transformer), and water content is not more than 25ppm (for 100-220kV transformer), 20ppm (for 500kV transformer).

3) For transformers with voltage 110kV or more, insulation oil shall be checked that it meets the standards shown in Table 27-8 before filling in transformer.

4) When insulation oil is filled in transformer and transported to the installation location, the insulation oil shall be checked that it meets the standards shown in item 1, 2 and 4 of Table 27-8 if the last oil test is more than 3 months ago. For transformer protected by a plastic film with voltage 110kV or more, insulation oil shall be checked that it meets the standards shown in item 7 of Table 27-8.

(3) Test of oil for transformers in preservation process

1) For transformers in preservation process (standby state or storage).

2) For transformers with voltage 35 kV or less shall be checked item 1 in Table 27-8 at least once a year.

3) For transformers with voltage 110kV or more shall be checked item 1-4 in Table 27-8 at least 3 months.

(4) Test of new oil in new transformers before energizing

New oil in new transformers before energizing shall be checked that it meets the standards of the standards shown in Table 27-8

Table 27-8 Insulation oil quality standards during installation and before energizing

No.	Items	Nominal Voltage (kV)				
		≤15	15-35	110	220	500
1	Breakdown voltage (kV/2.5mm) Not less than	30	35	60	60	70
2	Dielectric loss angle at 90°C (%) Not more than	-	-	1.5	1.0	1.0
3	Acidity (mgKOH/1g oil) Not more than	0.02	0.02	0.02	0.02	0.02
4	Water content (volume ppm) Not more than	-	-	20[1] 10[2]	10	10
5	Color - ASTM Scale Not more than	1.0	1.0	1.0	1.0	0.5
		Transparent, bright, no water and impurities				
6	Content of impurities[3] ISO 4406-1991	No (Visual observation)			-/15/12	-/13/10
7	Total dissolved gas[3] (volume %) Not more than	-	-	1	1	0.5
8[*]	Content of 2-furfural (ppm) Not more than	-		0.1		
9[*]	Surface tension at 25 °C (mN/m) Not less than	35	35	35	38	38
10	Antioxidant stability + Method A: - Sludge volume (%) Not higher than - Acidity after oxidation (mgKOH/g) Not higher than + Method B: - Time (minute) Not less than	-		 0.01 0.10 195		
11	Dynamic viscosity (m^2/s) Not more than - at 40 °C - at 50 °C	 12 9				
12	Density (g/cm^3) Not more than - at 15°C - at 20°C	 0.91 0.90				
13	Flash temperature (°C) Not more than - Closed - Open	 135 145				
14	Sulfur corrosion	No				
15	Content of PCB (ppm) [4]	5				

Note:

The sign "-" in the table is not specified.

(1) For 110 kV transformer which is not protected by a plastic film.

(2) For 110 kV transformer which is protected by a plastic film.

(3) For 110 kV transformer which is protected by a plastic film.

(4) The limits of initial content of PCB in insulation oil in accordance with the law for environmental protection at the time of application.

(*) Test is not mandatory.

8. On-Line Tap Changer Inspection (for oil-immersed and dry type)

(1) Switching operation test

It shall be checked that On-Line Tap Changer (OLTC) can be switched both manually and by electric drive without any abnormality.

1) Operation test

Switching operation for each tap shall be checked without voltage application. It shall be checked that there is no change on OLTC both before and after operation. The time for tap change shall be measured to confirm that the measured value is within the manufacturers' standards. It shall be checked that there is no abnormality on tap number indication.

2) Alarm test

Activation of tap-jam alarm shall be checked by turning off OLTC, while OLTC is operated.

(2) Measurement of current of electric motors

Current of electric motors shall be measured to confirm that OLTC switches smoothly without any abnormality on electric drive mechanism. The current shall be within the manufacturers' standards.

(3) Oil test in OLTC

For transformers with OLTC compartment, insulation oil used in OLTC shall be checked that it meets the standards in manufacturer's instructions as required for insulation oil of the transformer. If there are no manufacturer's instructions, the quality of oil shall meet the standards shown in Table 27-9.

Table 27-9 Quality standards of oil in OLTC compartment before energizing

<table>
<tr><th rowspan="3">No.</th><th rowspan="3">Items</th><th colspan="4">Limit values</th></tr>
<tr><th rowspan="2">For OLTC connected to the neutral point</th><th colspan="3">For OLTC connected the beginning or middle of the coil
Nominal voltage (kV)</th></tr>
<tr><th>≤ 35</th><th>110-220</th><th>500</th></tr>
<tr><td>1</td><td>Breakdown voltage (kV/2.5mm)
Not less than</td><td>40</td><td>35</td><td>50</td><td>60</td></tr>
<tr><td>2</td><td>Water content (volume ppm)
Not more than</td><td>30</td><td>-</td><td>25</td><td>20</td></tr>
</table>

9. Bushing CT Inspection (for oil-immersed and dry type)

It shall be carried out according to the inspection items specified separately in Article 29.

10. Cooling System and auxiliary system Inspection (for oil-immersed and dry type)

(1) Cooling system

Cooling systems of transformer shall be inspected to confirm that pumps and fans operate without any abnormality. Phase rotations shall be checked if it meets the manufacturers' specifications. Current of the cooling systems shall be measured if it meets the manufacturers' specifications.

(2) Auxiliary system

- The operation of hot line oil filter shall be checked that there is no abnormality.
- It shall be checked that alarms are activated appropriately by operating mechanical relays such as sudden oil pressure relay and hydraulic relay artificially.
- It shall be checked that the indication of thermometer is within the manufacturers' standards.

11. Withstand Voltage Test (for oil-immersed and dry type)

Withstand voltage test shall be carried out after installation on site if it is necessary.

The methods of withstand voltage test are as follows:

(1) Test method of IEC or Vietnamese standard (regulated for equipment individually)

(2) Test method of Japanese standard (regulated for all equipment comprehensively)

The test shall be carried out according to test method of IEC etc. preferentially, and be carried out according to test method of Japanese standard alternatively if it is difficult to apply the former method. If it is uncertain about test method, test shall be carried out in consultation with manufacturer.

(1) Test method of Vietnamese standard (regulated in Vietnamese standard "QUY TRÌNH THÍ NGHIỆM MÁY BIẾN ÁP LỰC PHẦN I: MÁY BIẾN ÁP")

Withstand voltage test should be carried out to check the ability for temporary overvoltage of windings, cores and other insulated parts of transformers.

The test voltage is specified in Table 27-8 and 27-9, Column 3. The duration of withstand voltage test is 1 minute. The detailed test program shall be referred to Vietnamese standard "QUY TRÌNH THÍ NGHIỆM MÁY BIẾN ÁP LỰC PHẦN I: MÁY BIẾN ÁP".

For transformers which have already been in service and have been refurbished or serviced, withstand voltage tests shall be repeated at test levels of 80% of the original value (Table 27-10 and 27-11, column 3).

Table 27-10 Withstand voltage for transformer windings Um ≤ 170kV

Maximum voltage on equipment U_m (kV rms)	**Withstand basic impulse lightening (BIL) (kV peak)**	**Short-duration power frequency withstand voltage* (kV rms)**
	40	
7.2		20
	60	
12		28
	75	
17.5		38
	95	
24		50
	125	
36	145	
		70
	170	
52	250	95
60	280	115
72.5	325	140
100	380	150
123	450	185
145	550	230
170	650	275
	750	325

*Note : for transformers which have already been in service and have been refurbished or serviced, test voltage is 80% of column 3.

Table 27-11 Withstand voltage for transformer windings Um > 170kV

Maximum voltage on equipment U_m (kV rms)	**Withstand basic impulse lightening (BIL) (kV peak)**	**Short-duration power frequency withstand voltage * (kV rms)**
245	650, 750	325
245	750, 850	360
245	850, 950	395
245	950, 1050	460
550	1175, 1300	510
550	1300, 1425	570
550	1425, 1550	630
550	1550, 1675	680
550	1675, 1800	710

*Note : for transformers which have already been in service and have been refurbished or serviced, test voltage is 80% of column 3.

(2) (Reference) Test method of Japanese standard

The test voltage is shown in Table 27-12 and applying time is for 10 minutes.

Table 27-12 Test voltage for withstand voltage test

Nominal Voltage of system (Un) [kV]	Highest voltage for equipment (Um) [kV]	Test voltage [kV]	Derivation	Neutral grounding system
6	7.2	10.8	1.5 times of Um	All type
10	12	15.0	1.25 times of Um	All type
15	17.5	21.9	1.25 times of Um	All type
22	24	30.0	1.25 times of Um	All type
35	38.5	48.1	1.25 times of Um	All type
110	123	135.3	1.1 times of Um	Resistance grounded system
		88.6	0.72 times of Um	Solidly grounded system(The following cases are excluded.apply to switching station, etc.)
		78.7	0.64 times of Um	Solidly grounded system(apply to a power station, substation, and the like to which the neutral line is solidly grounded.)
220	245	176.4	0.72 times of Um	Solidly grounded system(The following cases are excluded.apply to switching station, etc.)
		156.8	0.64 times of Um	Solidly grounded system(apply to a power station, substation, and the like to which the neutral line is solidly grounded.)
500	550	396.0	0.72 times of Um	Solidly grounded system(The following cases are excluded.apply to switching station, etc.)
		352.0	0.64 times of Um	Solidly grounded system(apply to a power station, substation, and the like to which the neutral line is solidly grounded.)

Test voltage of withstand voltage test is defined as the highest voltage multiplied by a margin.
At lower voltage levels, the margin is set to 1.5 since surge voltage etc. affect considerably. However, as the voltage level becomes higher, the effect becomes less, the margin is set to smaller value.
At solidly grounded neutral system, smaller test voltage can be used since voltage rise of the sound phases at the time of single line-to-ground fault is smaller than that of ungrounded neutral system and resistance neutral system.

Article 28. The inspection item for Potential Transformers (PT)

1. Visual Inspection

It shall be checked whether the PT has abnormalities such as oil leakage, crack, breakage, damage, looseness at screwed parts, etc. or not.

2. Measurement of Insulation Performances

(1) Insulation resistance for windings

Insulation resistance between a winding and the ground, and between windings shall be measured by a 2,500V megger. Standards of the insulation resistance by types are in Table 28-1.

1) Winding type

Table 28-1 Standards of Insulation resistance for winding type PT (MΩ)

Oil temperature / Nominal Voltage (kV)	20°C	30°C	40°C	50°C	60°C
110 and over	1,200	600	300	150	75
22 - 35	1,000	500	250	125	65
10 - 15	800	400	200	100	50
Lower than 10	400	200	100	50	25

2) Condenser-type and dry mold-type

Insulation resistance of primary windings shall be 100 MΩ and more.

3) SF6 gas insulation-type

Insulation resistance of primary windings shall be more than manufacturers' standards.

(2) Insulation resistance for control circuits

Insulation resistance between control circuits and the ground shall be measured by a 500V or 1,000V megger to confirm that it is more than 2 MΩ.

(3) Measurement of dielectric loss

The dielectric loss angle (tanδ) and capacitance for coupling condenser of bushing shall be measured to confirm that the measured value is within the manufacturers' standards. This measurement is relevant to CVT of voltage 110 kV and over.

3. Measurement of Transformation Ratio

Transformation ratio shall be measured for each secondary output of PT. The measurement shall be performed with the PT being connected to control boards. With the primary circuit of PT being energized, the voltage of secondary circuit shall be measured at the test terminal on control board in order to confirm comprehensively that the transformation ratio and the wire connection are adequate.

The measured value shall be checked if it meets the criteria as below in accordance with the accuracy classes of PT.

Table 28-2 Limits of voltage error and phase displacement for measuring PT

(IEC60044-2)

Accuracy class	Voltage (ratio) error %	Phase displacement (Minutes)
0.1	From -0.1 to +0.1	From -5 to +5
0.2	From -0.2 to +0.2	From -10 to +10
0.5	From -0.5 to +0.5	From -20 to +20
1.0	From -1.0 to +1.0	From -40 to +40
3.0	From -3.0 to +3.0	Not specified

Table 28-3 Limits of voltage error and phase displacement for protective PT

(IEC60044-2)

Accuracy class	Voltage (ratio) error %	Phase displacement (Minutes)
3P	From -3.0 to +3.0	From -120 to +120
6P	From -6.0 to +6.0	From -240 to +240

4. Polarity Test

Polarity of PT shall be checked. The primary circuit of PT shall be connected to a tester, and the polarity of the secondary circuit shall be checked if it meets the manufacturers' specifications.

5. Measurement of Winding Resistance

It shall be carried out according to the inspection items specified separately in Article 27.

6. Measurement of No-load current and loss

It shall be carried out according to the inspection items specified separately in Article 27.

7. Insulation oil test before energizing

New insulation oil for sealed or open type shall be checked that it meets the standards shown in Table 28-4 before filling.

Table 28-4 Quality standards of new insulation oil for PT before energizing

No.	Items	Nominal Voltage (kV)				
		≤15	**22, 35**	**110**	**220**	**500**
1	Breakdown voltage (kV/2.5mm) Not less than	30	35	60	60	70
2	Dielectric loss angle at 90°C (%) Not more than	-	-	1.5	1.0	1.0
3	Acidity (mgKOH/1g oil) Not more than	0.02	0.02	0.02	0.02	0.02
4	Color - ASTM Scale Not more than	1.0	1.0	1.0	1.0	0.5
		Transparent, bright, no water and impurities				
5	Water content (volume ppm) Not more than	-	-	10	10	10
6	Total dissolved gas (volume %) Not more than	-	-	1		

Note:
- Item 5 and 6 are mandatory for measuring transformers with voltage 110 kV or more.
- The sign "-" in the table is not specified.

8. Withstand Voltage Test

Withstand voltage test shall be carried out after installation on site if it is necessary.
The methods of withstand voltage test are as follows:

(1) Test method of IEC or Vietnamese standard (regulated for equipment individually)

(2) Test method of Japanese standard (regulated for all equipment comprehensively)
The test shall be carried out according to test method of IEC etc. preferentially, and be carried out according to test method of Japanese standard alternatively if it is difficult to apply the former method. If it is uncertain about test method, test shall be carried out in consultation with manufacturer.

(1) Test method of IEC (power frequency test for instrument transformer regulated in IEC60044-2)

1) The test voltage is specified in Table 28-5, Column 4. The duration of withstand voltage test is 1 minute.
The detailed test program shall be decided between manufacturer and user.

Table 28-5 On site test voltages

Nominal voltage of system U_n kV (r.m.s.)	Highest voltage for equipment U_r kV (r.m.s.)	Rated lightning impulse withstand voltage (BIL) kV (peak)	On-site short-duration power-frequency withstand voltage U_{ds} kV (r.m.s.)	Rated short-duration power-frequency withstand voltage U_d kV (r.m.s.)
[1]	[2]	[3]	[4]	[5]
6	7.2	40 60	16	20
10	12	60 75 95	22.4	28
15	17.5	75 95	30.4	38
22	24	95 125 145	40	50
35	38.5	155 180 195	60	75
	40.5	190	64	80
110	123	450 550	148 184	185 230
220	245	850 950 1050	288 316 368	360 395 460
500	550	1175 1300 1425 1550	408 456 488 544	510 570 610 680

Note :
- The on-site test voltages have been calculated as follows:
  U_{ds} (on-site test value) = $U_d \times 0.8$ (column [4])
- The above test voltage is applied for only uniformly insulated high-voltage windings.
- Frequency is from 45 to 65Hz

2) For the earthed PT, the test shall excite the secondary winding. The test voltage and duration of the test are as follows.
   - Test Voltage = 1.3 * 110V/$\sqrt{3}$ (Frequency is from 45 to 65Hz)
   - Duration: 5 minutes

(2) (Reference) Test method of Japanese standard
The details are specified in item 11 of article27.

Article 29. The inspection item for Current Transformers (CT)

1. Visual Inspection

It shall be checked whether the CT has abnormalities such as oil leakage, crack, breakage, damage, looseness at screwed parts, etc. or not.

2. Measurement of Insulation Performance

(1) Insulation resistance of primary windings

Insulation resistance between a winding and the ground, and between windings shall be measured by a 2,500V megger. Standards of the insulation resistance by types are in Table 29-1.

1) Porcelain-type

Table 29-1 Standards of insulation resistance for porcelain type CT

(MΩ)

Oil temperature / Nominal Voltage (kV)	20°C	30°C	40°C	50°C	60°C
110 and over	1,200	600	300	150	75
22 - 35	1,000	500	250	125	65
10 - 15	800	400	200	100	50
Lower than 10	400	200	100	50	25

2) Bushing -type

Not necessary to measure insulation resistance of windings.

(2) Insulation resistance of secondary circuits and control circuits

Insulation resistance of secondary circuits and control circuits shall be measured by a 500V or 1,000V megger to confirm that they are more than 2 MΩ.

(3) Measurement of dielectric loss

Only oiled CT (with oil paper insulation) is relevant. The dielectric loss angle (tan δ) should be measured for the CT of nominal Voltage 110 kV or over. The measured value of tan δ at temperature +20 °C should not exceed the values stipulated separately in Table 29-2.

Table 29-2 Standards of tan δ for CT

Test Object	Dielectric loss value tanδ% at nominal voltage (kV)		
	35	110	220-500
Oiled CT (with oil paper insulation)	2.5	2	1.5

3. Measurement of Winding Resistance

It shall be carried out according to the inspection items specified separately in Article 27.

4. Measurement of Transformation Ratio

Transformation ratio shall be measured for each output of CT. The measurement shall be performed with the CT being connected to control boards. With the primary circuit of CT being applied test current, the current on control board shall be measured in order to comprehensively confirm that the transformation ratio and the wire connection are adequate.

The measured value shall be checked if it meets the criteria as below in accordance with the accuracy classes of CT.

Table 29-3 Limits of current error and phase displacement for measuring CT

(Classes from 0.1 to 1.0) (IEC60044-1)

Accuracy class	Percentage current (ratio) error at percentage of rated current shown below (From -* to +*)				Phase displacement at percentage of rated current shown below (Minutes) (From -* to +*)			
	Primary current%				Primary current%			
	5	20	100	120	5	20	100	120
0.1	0.4	0.2	0.1	0.1	15	8	5	5
0.2	0.75	0.35	0.2	0.2	30	15	10	10
0.5	1.5	0.75	0.5	0.5	90	45	30	30
1.0	3.0	1.5	1.0	1.0	180	90	60	60

* Range of standards

Ex.) The range of standard for a CT of accuracy class 0.1 applying 5% of primary current is from -0.4% to +0.4%.

Table 29-4 Limits of current error and phase displacement for measuring CT for special application

(IEC60044-1)

Accuracy class	Percentage current(ratio) error at percentage of rated current shown below (From -* to +*)					Phase displacement at percentage of rated current shown below (Minutes) (From -* to +*)				
	Primary current%					Primary current%				
	1	5	20	100	120	1	5	20	100	120
0.2S	0.75	0.35	0.2	0.2	0.2	30	15	10	10	10
0.5S	1.5	0.75	0.5	0.5	0.5	90	45	30	30	30

Table 29-5 Limits of error for protective CT

(IEC60044-1)

Accuracy class	Current error at rated primary current %	Phase displacement at rated primary current (Minutes)	Composite error at rated accuracy limit primary current %
5P	From -1 to +1	From -60 to +60	5
10P	From -3 to +3	-	10

“P” indicates protection.

Table 29-6 imits of error for PR protective CT

(IEC60044-1)

Accuracy class	Current error at rated primary current %	Phase displacement at rated primary current (Minutes)	Composite error at rated accuracy limit primary current %
5PR	From -1 to +1	From -60 to +60	5
10PR	From -3 to +3	-	10

"PR" indicates protection low remanence.

5. Polarity Test

Polarity of CT shall be checked. The primary circuit of CT shall be connected to a tester, and the polarity of the secondary circuit shall be checked if it meets the manufacturers’ specifications.

6. Measurement of Excitation Characteristics

Excitation Characteristics shall be measured to check the change of the characteristics caused by any core movement or gap. Only those CT that have split-type cores are relevant.

The measurement result shall be compared with factory inspection records to confirm that there is no difference.

The saturation point* (knee point) shall be checked in measurement. In case of measurement, the voltage applying to secondary circuit shall be with the rated frequency, and the other terminals shall be opened.

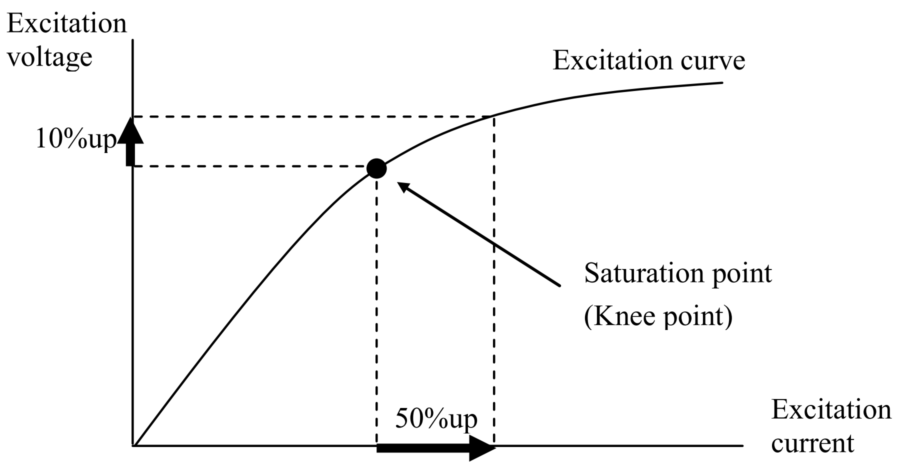


Figure 29 The image of Excitation Characteristics

*Saturation point
As it is shown in Figure 30, excitation current is proportionally risen with excitation voltage, but it is increased substantially at a certain point. The saturation point is the lowest point where the measuring current increases 50% as a result of increasing the applying voltage 10%.

7. Insulation oil test before energizing
The details are specified in item 7 of artilcle28.

8. Withstand Voltage Test
Withstand voltage test shall be carried out after installation on site if it is necessary.

The methods of withstand voltage test are as follows:

(1) Test method of IEC or Vietnamese standard (regulated for equipment individually)
(2) Test method of Japanese standard (regulated for all equipment comprehensively)
The test shall be carried out according to test method of IEC etc. preferentially, and be carried out according to test method of Japanese standard alternatively if it is difficult to apply the former method. If it is uncertain about test method, test shall be carried out in consultation with manufacturer.
   (1) Test method of IEC (power frequency test for current transformer regulated in IEC60044-1)
   The details are specified in item 8 of article28.
   (2) (Reference) Test method of Japanese standard
   The details are specified in item 11 of article27.

Article 30. The inspection item for Gas Circuit Breaker (GCB)

1. Visual Inspection
It shall be checked whether GCB has abnormalities such as gas leakage, crack, breakage, damage, looseness at screwed parts, etc. or not.

Gas leakage test shall be carried out to confirm that the leakage is not detected by a gas leak detector. The criterion of gas leakage to the atmosphere is less than 1% per year. There are two test methods; they are accumulation method and trace method. The former is the standard method, the latter is used only for the part that the accumulation method can not be carried out easily.

(1) Accumulation method
Surround binding parts of a tank and whole circumference of gas fitting with polyethylene sheets, the accumulated leakage gas in the sheets shall be detected with a gas leak detector after the appropriate time elapsed.

(2) Trace method
The existence of gas leakage is checked by bringing a gas leak detector close to connection parts of a tank and gas piping directly.

Figure 30 Accumulation method

2. Measurement of Insulation Resistance

(1) Insulation resistance of main circuits

Insulation resistance shall be measured by a 2,500V megger in the following case. Standards of the insulation resistance are in Table 30-1.

- Between main circuits and the ground at the time of ON
- Between poles of main circuits at the time of OFF

(2) Insulation resistance of control circuits

Insulation resistance of control circuits (including motors for motor spring operation) shall be measured by a 500V or 1,000V megger. Standards of the insulation resistance are in Table 30-1.

Table 30-1 Standards of insulation resistance for GCB

Test object	Nominal voltage (kV)	Standards (MΩ)
Main circuit	110 and over	1,000 and more
	35 and less	500 and more
Control circuit		2 and more

NOTE

- The equipment which has been charged once shall be discharged before measurement sufficiently.
- In case of measurement of one phase, other 2 phases shall be grounded.
- In case of measurement, stringings shall be disconnected from main circuits as far as possible. The surface of insulators shall be cleaned and dried sufficiently.
- Measured value shall be recorded after 1 minute of applying the test voltage, and temperature, weather, etc. shall be recorded.

3. Measurement of Contact Resistance for Direct Current

Contact resistance of primary circuits shall be measured and checked if it meets the manufacturers' standards.

Contact resistance can be calculated by dividing the measured voltage between terminals by applied current. Direct current more than 50A shall be applied for measurement.

4. Gas Density alarm or Gas Pressure alarm Test

(1) SF6 gas pressure that detectors are activated for alarm and lock of operation of GCB

It shall be checked that alarm and lock of operation of GCB are activated by lowering the gas pressure by valve operation. SF6 gas pressure at which detectors are activated for alarm and lock of operation of GCB shall be checked that it meets manufacturers' standards.

(2) SF6 gas pressure that alarm and lock of operation of GCB are reset

It shall be checked that alarm and lock of operation of GCB are reset by heightening the gas pressure by valve operation. SF6 gas pressure at which alarm and lock of operation of GCB are reset shall be checked that it meets manufacturers' standards.

Measured value shall be modified according to the difference between temperature when measurement was carried out and one in manufacturers' standards by using the formula as below.

$$P_{20}=P_t \times \frac{273.15+20}{273.15+t}$$

P_{20} : gas pressure at 20 ^{o}C

P_t : gas pressure at t ^{o}C

t : temperature when measurement was carried out

5. Opening and Closing Operations Test

(1) Manual opening and closing operations test

It shall be checked that there is no abnormality in GCB by opening and closing it 3 times by manual handle or press button in the field.

(2) Opening and closing operations test by remote control

It shall be checked that there is no abnormality in GCB by opening and closing it 3 times at the rated voltage (pressure) by remote control.

(3) Continuous opening and closing operations test

It shall be checked that there is no abnormality in GCB by opening and closing it 20 times continuously at the rated voltage (pressure).

(4) Trip free mechanism test

A GCB that has no trip-free mechanism is irrelevant. The test procedure is as below.

- It shall be confirmed that GCB is opened immediately and not closed again during closing operation if tripping command is inputted.
- After that, it shall be confirmed that GCB can be closed again if closing command is canceled once, then closing command is inputted again. (Anti-pomping test)

6. Measurement of Opening and Closing Characteristics

(1) Contact opening time and closing time

Contact opening time and closing time shall be measured and checked if they are within the manufacturers' standards.

(2) Minimum operational voltage (pressure)

In the state which voltage is not applied to the primary circuit, either the voltage of electromagnetic coil or the pressure of compressed air (oil) shall be maintained at the rated value, and the minimum voltage or pressure shall be measured by changing the other parameter (pressure or voltage). At this time, the opening-and-closing speed characteristic of GCB does not meet the manufacturers' specifications.

The value of minimum operating voltage (pressure) is shown in Table 30-2.

Table 30-2 Minimum operating voltage (pressure)

(IEC62271-100)

Items	Standards
Minimum closing voltage	85% of the rated voltage
Minimum opening voltage	85% of the rated voltage if AC 70% of the rated voltage if DC
Minimum closing pressure (For pneumatic or oil pressure drive)	85% of the rated pressure
Minimum opening pressure (For pneumatic or oil pressure drive)	85% of the rated pressure

(3) Operating sequence

It shall be confirmed that the operating sequence of GCB meets the standards as below.

Table 30-3 Operating sequence for GCB

(IEC62271-100)

Operating sequence	Note
O - 3min - CO - 3min - CO	For CB not intended for rapid auto-reclosing
O - 0.3s - CO - 3min* - CO	For CB intended for rapid auto-reclosing
CO - 15s - CO	For CB not intended for rapid auto-reclosing

* instead of 3min, other values 15s and 1min are also used for CB intended for rapid auto-reclosing.

O represents an opening operation

CO represents a closing operation followed immediately (that is, without any intentional delay) by an opening operation

(4) Three phase imbalance

Three phase imbalance of opening and closing time shall be measured and checked if it meets the standards as below.

Table 30-4 Standards of three phase imbalance

(IEC62271-100)

Operation	Standards
Open	3.3ms and less
Close	5ms and less

(Reference from IEC62271-100)

- If one pole consists of more than one interrupter unit connected in series, the maximum difference between the instants of contacts touching within these series connected interrupter units shall not exceed a sixth of a cycle of rated frequency.
- Where closing resistors are used, the maximum difference between the instants of contacts touching during closing in the individual closing resistors shall not exceed half a cycle of rated frequency.
- If on one pole more than one individual closing resistor is used, each assigned to one of the interrupter units which are connected in series, the maximum difference between the instants of contacts touching within these series connected closing resistors shall not exceed a third of a cycle of rated frequency.
- If one pole consists of more than one interrupter unit connected in series, the maximum difference between the instants of contact separation within these series connected interrupter units shall not exceed an eighth of a cycle of rated frequency.

7. Associated Tank Capacity

Only those GCB that have pneumatic or oil pressure drive are relevant. It shall be confirmed that GCB can be opened and closed consecutively (more than twice for those GCB that have duties to re-close) when the associated tank is not connected to driving sources (pressurized air or power source).

8. Interlocking System Test

(1) Locking by oil pressure drive

Only those GCB that have oil pressure drive are relevant. It shall be confirmed that GCB cannot be opened or closed when oil pressure is lower than the regulation level.

(2) Locking by pneumatic drive

Only those GCB that have pneumatic drive are relevant. It shall be confirmed that GCB cannot be opened or closed when air pressure is lower than the regulation level.

9. Operation Test of Safety Valve

Only those GCB that have pneumatic or oil pressure drive are relevant. It shall be confirmed the safety valve operates when the air or oil pressure rises to the tank maximum allowable pressure.

10. Bushing CT Inspection

It shall be carried out according to the inspection items specified separately in Article 29 if it is necessary.

11. Check of SF6 gas quality

The purity and water content in SF6 gas enclosed in equipment shall be checked as directed by manufacturer. Maximum allowable moisture to ensure no dew condensation is converted to dew point not more than -5°C. (Converted to rated pressure of equipment at 20 °C) (refer to IEC62271-1: 2011)

If there are no standards of SF6 gas in manufacturer’s instructions, it shall meet the standards shown in table 30-5.

Table 30-5 Standards of SF6 gas quality before energizing

(GB / T 8905-1996)

Items		**Standards**
Gas purity		97 vol. %and more
Water content	Equipment with current interruption	150ppm or less
	Equipment without current interruption	500ppm or less

Note: Inspection of water content shall be carried out after 24 hours after filling gas.

12. Withstand Voltage Test

Withstand voltage test shall be carried out after installation on site if it is necessary.

The methods of withstand voltage test are as follows:

(1) Test method of IEC or Vietnamese standard (regulated for equipment individually)

(2) Test method of Japanese standard (regulated for all equipment comprehensively)
The test shall be carried out according to test method of IEC etc. preferentially, and be carried out according to test method of Japanese standard alternatively if it is difficult to apply the former method. If it is uncertain about test method, test shall be carried out in consultation with manufacturer.

(1) Test method of IEC (power frequency test for current transformer regulated in IEC60694)
The test voltage is specified in Table 30-6, Column 4. The duration of withstand voltage test is 1 minute.
The detailed test program shall be decided between manufacturer and user.

Table 30-6 On site test voltages

Nominal voltage of system U_n kV (r.m.s.)	Highest voltage for equipment U_r kV (r.m.s.)	Rated lightning impulse withstand voltage (BIL) kV (peak)	On-site short-duration power-frequency withstand voltage U_{ds} kV (r.m.s.)	Rated short-duration power-frequency withstand voltage U_d kV (r.m.s.)
[1]	[2]	[3]	[4]	[5]
6	7.2	40 60	16	20
10	12	60 75 95	22.4	28
15	17.5	75 95	30.4	38
22	24	95 125 145	40	50
35	38.5	155 180 195	60	75
	40.5	190	64	80
110	123	45 550	148 184	185 230
220	245	850 950 1050	288 316 368	360 395 460
500	550	1425 1550 1800	496 496 568	620 620 710

Note : - The on-site test voltages have been calculated as follows:
U_{ds} (on-site test value) = $U_d \times 0.8$ (column [4])
- Frequency is from 45 to 65Hz

(2) (Reference) Test method of Japanese standard
The details are specified in item 11 of article27.

Article 31. The inspection item for Gas Insulated Switchgear (GIS)

1. Visual Inspection

It shall be checked whether GIS has abnormalities such as gas leakage, crack, breakage, damage, looseness at screwed parts, etc. or not.

2. Measurement of Insulation Resistance

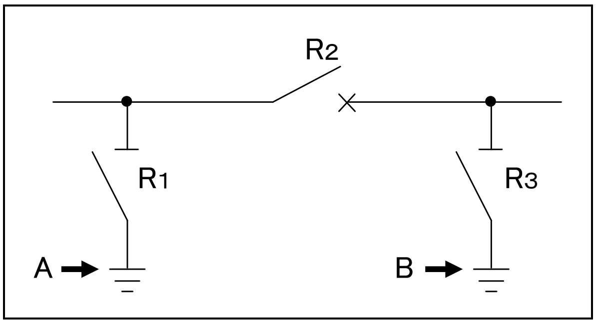
It shall be carried out according to the inspection items specified separately in Article 30.

3. Measurement of Contact Resistance for Direct Current

Contact resistance for primary circuits shall be measured and checked if it meets the manufacturers' specifications. In principle, the measurement shall be performed for each contact. However, a measurement for all contacts in block may be performed if the measurements for individual contacts are impossible due to the structure of GIS.

In this case, the standard of measuring value shall be figured out from the summation of contact resistance values which are within the measuring part.

Direct current more than 100A shall be applied for measurement.



Standard of contact resistance : Rx = R1+R2+R3

R*i* : Contact resistance of circuit breaker or disconnector of No.*i*

Measuring part : A - B

Figure 31-1 Standard of contact resistance

4. Gas Density Detectors Test

It shall be carried out according to the inspection items specified separately in Article 30.

5. SF6 Tightness Test and Gas quality Check

(1) SF6 tightness test

It shall be carried out according to the inspection items specified separately in Item 1of Article 30.

(2) Check of SF6 gas quality

It shall be carried out according to the inspection items specified separately in Item 11 of Article 30.

6. Opening and Closing Operations Test in Disconnector

It shall be carried out according to the inspection items specified separately in Article 34.

7. Arresters Inspection

It shall be carried out according to the inspection items specified separately in Article 38.

8. PT Inspection

It shall be carried out according to the inspection items specified separately in Article 28.

9. CT Inspection

It shall be carried out according to the inspection items specified separately in Article 29 if it is necessary.

10. Sequence and Interlock Tests

A breaker of line, a breaker of busbar connection and a disconnecting switch shall satisfy the interlock conditions of breaker and disconnecting switch, and they are shown in the following figure and table.

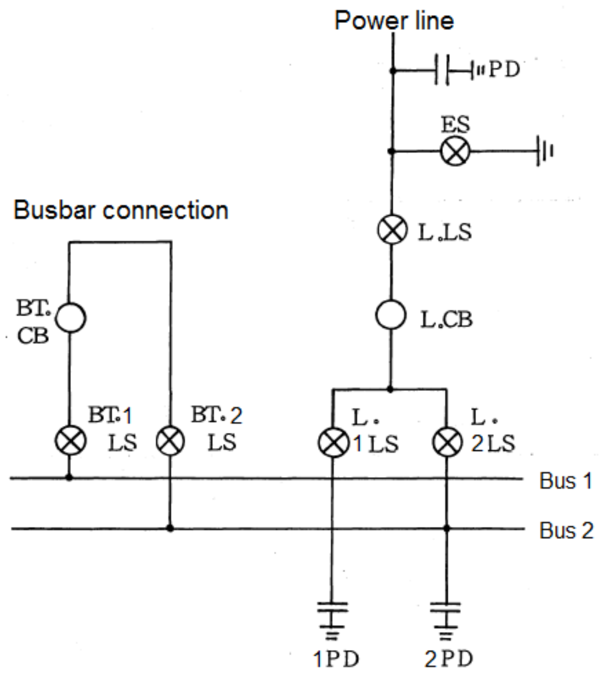


Figure 31-2 Example of single-line diagram for substation

Table 31-1 Interlock conditions

Operation	Conditions
L.LS ON or OFF	L.CB (OFF) + ES (OFF)
ES ON or OFF	L.LS (OFF) + With NO Line Voltage
L.1LS ON or OFF	L.CB (OFF) + L.2LS (OFF) BT.1LS (ON) + BT.2LS (ON) + BT.CB(ON) + L.2LS (ON)
L.2LS ON or OFF	L.CB (OFF) + L.1LS (OFF) BT.1LS (ON) + BT.2LS (ON) + BT.CB(ON) + L.1LS (ON)
BT.1LS ON or OFF	BT.CB (OFF)
BT.2LS ON or OFF	BT.CB (OFF)

11. Phase Check

Phase check shall be carried out for each outlet of GIS to confirm that the primary circuit connection conforms to the manufacturers' specifications and phase arrangement of grid link.

12. Withstand Voltage Test

Withstand voltage test shall be carried out after installation on site if it is necessary.

The methods of withstand voltage test are as follows:

(1) Test method of IEC or Vietnamese standard (regulated for equipment individually)

(2) Test method of Japanese standard (regulated for all equipment comprehensively)
The test shall be carried out according to test method of IEC etc. preferentially, and be carried out according to test method of Japanese standard alternatively if it is difficult to apply the former method. If it is uncertain about test method, test shall be carried out in consultation with manufacturer.

(1) Test method of IEC (Withstand voltage test on site for GIS regulated in IEC 62271-203)

1) Purpose

Since it is especially important for GIS, the dielectric integrity shall be checked in order to eliminate fortuitous causes (wrong fastening, damage during handling, transportation, storage and installation, presence of foreign bodies, etc.) which might in the future give rise to an internal fault.

Normally the withstand voltage test shall be made after the GIS has been fully installed and gas-filled at the rated filling density preferably at the end of all site tests, when newly installed.
A detailed test program for the withstand voltage tests on site shall be agreed between manufacturer and user.

2) Test procedures

(a) Preparation before test

The GIS shall be installed completely and gas-filled at its rated filling density.

Some parts may be disconnected for the test, either because of their high charging current or because of their effect on voltage limitation, such as

- High voltage cables and overhead lines;
- Power transformers and, occasionally, voltage transformers;
- Surge arresters and protective spark gaps.

(b) Detailed above matters shall be decided between manufacturer and user.
Test procedures

One of the following test procedures shall be chosen to check that no abnormality exists in GIS.

Procedure A (recommended for nominal voltage 110kV and below)
Power-frequency voltage test for the duration of 1 minute at the value U_{ds} specified in Table 31-3, Column 3.

Procedure B (recommended for nominal voltage 220kV and above)

- Power-frequency voltage test for the duration of 1 minute at the value U_{ds} specified in Table 31-3, Column 3;

- And partial discharge (PD) measurements according to Table 31-3, however with $U_{pre\text{-}stress} = U_{ds}$ of Table 31-3 Column 3.

Procedure C (recommended for nominal voltage 220kV and above, alternative to procedure B)

- Power-frequency voltage test for the duration of 1 minute at the value Uds specified in Table 31-3, Column 3;
- And lightning impulse tests with three impulses of each polarity and with the value Ups specified in Table 31-3, Column 4.

Table 31-2 Test voltage for measuring PD intensity

	System with solidly earthed neutral		**System without solidly earthed neutral**	
	Pre-stress voltage $U_{pre\text{-}stress}$ **(1 minute)**	**Test voltage for PD measurement** $U_{pd\text{-}test}$ **(>1 minute)**	**Pre-stress voltage** $U_{pre\text{-}stress}$ **(1 minute)**	**Test voltage for PD measurement** $U_{pd\text{-}test}$ **(>1 minute)**
Single-phase enclosures design (phase-to-earth voltage)	$U_{pre\text{-}stress} = U_{ds}$	$U_{pd\text{-}test} = 1.2U_r / \sqrt{3}$	$U_{pre\text{-}stress} = U_{ds}$	$U_{pd\text{-}test} = 1.2U_r$
Three-phase enclosures design	$U_{pre\text{-}stress} = U_{ds}$	$U_{pd\text{-}test,\ ph\text{-}ea} = 1.2U_r /\sqrt{3}$ $U_{pd\text{-}test,\ ph\text{-}ph} = 1.2U_r$	$U_{pre\text{-}stress} = U_{ds}$	$U_{pd\text{-}test,\ ph\text{-}ea} = 1.2U_r$

U_r: Rated highest voltage for equipment as per Table 31-3.
U_{ds}: Power-frequency withstand test voltage as per Table 31-3.
$U_{pre\text{-}stress}$: Pre-stress voltage.
$U_{pd\text{-}test}$: Test voltage for PD measurement.
$U_{pd\text{-}test,\ ph\text{-}ea}$: Test voltage for PD measurement, phase-to-earth.
$U_{pd\text{-}test,\ ph\text{-}ph}$: Test voltage for PD measurement, phase-to-phase.

3) Partial discharge test procedure
The applied power-frequency voltage is raised to a pre-stress value ($U_{pre\text{-}stress}$) which is identical to the power-frequency withstand voltage test and maintained at that value for 1 minute. Partial discharges occurring during this period shall be disregarded. Then, the voltage is decreased to a specific value ($U_{pd\text{-}test}$) defined in Table 31-3 depending on the configuration of equipment and system neutral for partial discharge measurement.

In addition, all components shall be tested in accordance with their relevant standards.

4) Maximum permissible partial discharge intensity
The maximum permissible partial discharge level shall not exceed 5pC of the test voltage specified in Table 31-3.

The values stated above applies to individual components as well as to the sub-assemblies in which they are contained. However, some equipment, such as voltage transformers isolated with liquid, immersed or solid, have an acceptable level of partial discharge in accordance with their relevant standard more than 5pC. Any sub-assembly containing components with a permitted partial discharge intensity more than 5pC shall be considered acceptable if the discharge level does not exceed 10pC. Components for which higher levels are accepted shall be tested individually and are not integrated to the sub-assembly during test.

Table 31-3 On site test voltages

Nominal voltage of system U_n **kV (r.m.s.)**	**Highest voltage for equipment** U_r **kV (r.m.s.)**	**On-site short-duration power-frequency withstand voltage** U_{ds} **kV (r.m.s.)**	**On-site lightning impulse withstand voltage 1.2/50µs** U_{ps} **kV (peak value)**	**Rated lightning impulse withstand voltage 1.2/50µs** U_p **kV (peak value)**
[1]	**[2]**	**[3]**	**[4]**	**[5]**
110	123	165 200	360 440	450 550
220	245	310 345 380	680 760 840	850 950 1,050
500	550	560	940	1,240
Note : - The on-site test voltages have been calculated as follows: U_{ds} (on-site test value) = $U_p \times 0.45 \times 0.8$ (column [3]) U_{ps} (on-site test value) = $U_p \times 0.8$ (column [4]) - All values have been rounded up to the next higher modus 5 kV. - Frequency is from 10 to 300Hz				

(2) (Reference) Test method of Japanese standard

The details are specified in item 11 of article 27.

Article 32. The inspection item for Vacuum Circuit Breaker (VCB)

1. Visual Inspection

It shall be checked whether VCB has abnormalities such as gas leakage, crack, breakage, damage, looseness at screwed parts, etc. or not.

2. Measurement of Insulation Resistance

It shall be carried out according to the inspection items specified separately in Article 30.

3. Measurement of Contact Resistance for Direct Current

It shall be carried out according to the inspection items specified separately in Article 30.

4. Opening and Closing Operations Test

It shall be carried out according to the inspection items specified separately in Article 30.

5. Measurement of Opening and Closing Characteristics

It shall be carried out according to the inspection items specified separately in Article 30.

6. Associated Tank Capacity
It shall be carried out according to the inspection items specified separately in Article 30.

7. Interlocking System Test
It shall be carried out according to the inspection items specified separately in Article 30.

8. Operation Test of Safety Valve
It shall be carried out according to the inspection items specified separately in Article 30.

9. Bushing CT Inspection
It shall be carried out according to the inspection items specified separately in Article 29 if it is necessary.

10. Withstand Voltage Test
Withstand voltage test shall be carried out after installation on site if it is necessary.

The methods of withstand voltage test are as follows:

(1) Test method of IEC or Vietnamese standard (regulated for equipment individually)
(2) Test method of Japanese standard (regulated for all equipment comprehensively)
The test shall be carried out according to test method of IEC etc. preferentially, and be carried out according to test method of Japanese standard alternatively if it is difficult to apply the former method. If it is uncertain about test method, test shall be carried out in consultation with manufacturer.

(1) Test method of IEC (power frequency test for current tansformer regulated in IEC60694)
The details are specified in item 11 of article30.

(2) (Reference) Test method of Japanese standard
The details are specified in item 11 of article27.

Article 33. The inspection item for Oil Circuit Breaker (OCB)

1. Visual Inspection
It shall be checked whether OCB has abnormalities such as oil leakage, crack, breakage, damage, looseness at screwed parts, etc. or not.

2. Measurement of Insulation Resistance
It shall be carried out according to the inspection items specified separately in Article 30.

3. Measurement of Contact Resistance for Direct Current
It shall be carried out according to the inspection items specified separately in Article 30.

4. Opening and Closing Operations Test
It shall be carried out according to the inspection items specified separately in Article 30.

5. Measurement of Opening and Closing Characteristics
It shall be carried out according to the inspection items specified separately in Article 30.

6. Insulation Oil Test
Insulation performance of OCB oil shall be checked to confirm that the performance complies with the standards shown in Table 33

Table 33 Main characteristics of OCB oil for new OCB after filling

(IEC60422)

Property	Nominal voltage	Standards
Breakdown voltage (kV/2.5mm)	More than 72.5kV	More than 40
	72.5kV and less	More than 30

7. Associated Tank Capacity
It shall be carried out according to the inspection items specified separately in Article 30.

8. Interlocking System Test
It shall be carried out according to the inspection items specified separately in Article 30.

9. Operation Test of Safety Valve
It shall be carried out according to the inspection items specified separately in Article 30.

10. Bushing CT Inspection
It shall be carried out according to the inspection items specified separately in Article 29 if it is necessary.

11. Withstand Voltage Test
Withstand voltage test shall be carried out after installation on site if it is necessary.

The methods of withstand voltage test are as follows:

(1) Test method of IEC or Vietnamese standard (regulated for equipment individually)
(2) Test method of Japanese standard (regulated for all equipment comprehensively)
The test shall be carried out according to test method of IEC etc. preferentially, and be carried out according to test method of Japanese standard alternatively if it is difficult to apply the former method. If it is uncertain about test method, test shall be carried out in consultation with manufacturer.

(1) Test method of IEC (power frequency test for current transformers regulated in IEC60694)
The details are specified in item 11 of article30.
(2) (Reference) Test method of Japanese standard
The details are specified in item 11 of article27.

Article 34. The inspection item for disconnector

1. Visual Inspection
It shall be checked whether disconnector has abnormalities such as crack, breakage, damage, looseness at screwed parts, etc. or not.

2. Measurement of Insulation Resistance

It shall be carried out according to the inspection items specified separately in Article 30.

3. Measurement of Contact Resistance for Direct Current

It shall be carried out according to the inspection items specified separately in Article 30.

4. Opening and Closing Operations Test

(1) Manual opening and closing operations test

It shall be checked that there is no abnormality in disconnector by opening and closing it three times by manual handle or press button in the field.

(2) Opening and closing operations test by remote control

It shall be checked that there is no abnormality in disconnector by opening and closing it three times at the rated voltage (pressure) by remote control.

5. Interlock Tests

It shall be carried out according to the inspection items specified separately in Article 31.

6. Withstand Voltage Test

Withstand voltage test shall be carried out after installation on site if it is necessary.

The methods of withstand voltage test are as follows:

(1) Test method of IEC or Vietnamese standard (regulated for equipment individually)

(2) Test method of Japanese standard (regulated for all equipment comprehensively)

The test shall be carried out according to test method of IEC etc. preferentially, and be carried out according to test method of Japanese standard alternatively if it is difficult to apply the former method. If it is uncertain about test method, test shall be carried out in consultation with manufacturer.

(1) Test method of IEC (power frequency test for current transformer regulated in IEC60694)

The details are specified in item 11 of article30.

(2) (Reference) Test method of Japanese standard

The details are specified in item 11 of article27.

Article 35. The inspection item for air compressor

1. Visual Inspection

It shall be checked whether the air compressor has abnormalities such as air leakage, crack, breakage, damage, looseness at screwed parts, etc. or not.

2. Safety Valve Test

It shall be confirmed the safety valve operates before the air or oil pressure rises to the maximum allowable pressure of a tank. Operating pressure and reset pressure shall be measured to confirm that the measured value is within the manufacturers' standards.

3. Automatic Start and Stop Test

It shall be confirmed that the compressor shall automatically start at the starting pressure and stop at the stopping pressure. Starting and stopping pressure shall be measured to confirm that the measured value is within the manufacturers' standards.

4. Air Pressure alarm Test

(1) Air pressure that detectors are activated for high and low pressure alarm

It shall be checked that detectors are activated for high and low pressure alarm by changing the pressure. The activation pressure shall be within the manufacturers' standards and meet the relation of pressure as below.

Operation lock pressure < Low alarm pressure < High alarm pressure < Safety valve operating pressure

(2) Air pressure that alarms are reset

It shall be checked that high and low alarms are reset by changing the pressure. The reset pressure shall be within the manufacturers' standards.

Article 36. The inspection item for compact switch gear cubicle

1. Visual Inspection

It shall be checked whether the compact switch gear cubicle has abnormalities such as crack, breakage, damage, looseness at screwed parts, etc. or not.

2. Measurement of Insulation Resistance

It shall be carried out according to the inspection items specified separately in Article 30.

3. Sequence and Interlock Tests

(1) Sequence test of distribution cubicle control boards

Sequence test shall be carried out to confirm that the control circuits conform to the design diagram.

(2) Interlock test of distribution cubicle control boards

Interlock test shall be carried out to confirm that both electrical and mechanical interlocks conform to the procurement specifications.

4. Phase check

Phase check shall be carried out to confirm that the phase arrangement of equipment and primary circuit connection conform to the design diagram.

The test procedure is as below.

- -All of the grounding points of equipment shall be disconnected.
- -Only testing phase shall be grounded and the other 2 phases shall be ungrounded.
- -It shall be confirmed that the insulation resistance between the testing phase and the ground is 0, and those of other 2 phases are not 0.
- -All 3 phases shall be checked in these ways.

5. Withstand Voltage Test
Withstand voltage test shall be carried out after installation on site if it is necessary.

The methods of withstand voltage test are as follows:

(1) Test method of IEC or Vietnamese standard (regulated for equipment individually)

(2) Test method of Japanese standard (regulated for all equipment comprehensively)

The test shall be carried out according to test method of IEC etc. preferentially, and be carried out according to test method of Japanese standard alternatively if it is difficult to apply the former method. If it is uncertain about test method, test shall be carried out in consultation with manufacturer.

(1) Test method of IEC etc. (Withstand voltage test on site for cubicle regulated in IEC62271-200)
After erection, cubicle should be tested to check correct operation.

The test voltage is specified in Table 36, Column 3. The duration of withstand voltage test is 1 minute.

The detailed test program shall be decided between manufacturer and user.

Table 36 On site test voltages

Nominal voltage of system U_n **kV (r.m.s.)**	**Highest voltage for equipment** U_r **kV (r.m.s.)**	**On-site short-duration power-frequency withstand voltage** U_{ds} **kV (r.m.s.)**	**Rated short-duration power-frequency withstand voltage** U_d **kV (r.m.s.)**
[1]	**[2]**	**[3]**	**[4]**
6	7.2	16	20
10	12	22.4	28
15	17.5	30.4	38
22	24	40	50
35	38.5 40.5	60 64	75 80
Note : The on-site test voltages have been calculated as follows: - U_{ds} (on-site test value) = $U_d \times 0.8$ (column [3]) - Frequency is from 45 to 65Hz			

(2) (Reference) Test method of Japanese standard
The details are specified in item 11 of article 27.

Article 37. The inspection item for power capacitor

1. Visual Inspection
It shall be checked whether the power capacitor has abnormalities such as oil leakage, crack, breakage, damage, looseness at screwed parts, etc. or not.

2. Measurement of Insulation Performance

(1) Insulation resistance of main circuits

Insulation resistance between main circuits and the ground shall be measured by a 2,500V megger. Standards of the insulation resistance are in Table 37-1.

(2) Insulation resistance of control circuits

Insulation resistance of control circuits shall be measured by a 500V or 1,000V megger. Standards of the insulation resistance are in Table 37-1.

Table 37-1 Standards of insulation resistance for power capacitor

Test object	**Standards (MΩ)**
Main circuit	1,000 and more
Control circuit	2 and more

(3) Measurement of dielectric loss

Dielectric loss angle (tan δ) shall be measured to confirm that the measured value is within the manufacturers' standards by applying the rated voltage. The measured value shall be modified to one at standard temperature to evaluate correctly.

If the implementation of the test by applying rated voltage is difficult, it is possible to change the test conditions in consultation with the manufacturer.

3. Condenser capacity measurement

Condenser capacity shall be measured to confirm that the measured value is within the manufacturers' standards.

4. Sequence Tests

Sequence test shall be carried out to confirm that the control circuits (such as alarm circuits) conform to the design diagram.

5. Withstand Voltage Test

Withstand voltage test shall be carried out after installation on site if it is necessary.

The methods of withstand voltage test are as follows:

(1) Test method of IEC or Vietnamese standard (regulated for equipment individually)

(2) Test method of Japanese standard (regulated for all equipment comprehensively)

The test shall be carried out according to test method of IEC etc. preferentially, and be carried out according to test method of Japanese standard alternatively if it is difficult to apply the former method. If it is uncertain about test method, test shall be carried out in consultation with manufacturer.

(1) Test method of IEC

1) One of the following test procedures shall be chosen for live-tank type

(a) AC voltage test between terminals and container regulated in IEC60871-1

The conditions of applying test voltage shall refer to IEC 60060-1. The test shall be implemented as follows.

- Test voltage: The voltage (Ut) calculated according to the following equation shall be applied

$$U_t = 2.5 \times U_n \times n$$

where

U_t is the power-frequency test voltage

U_n is the rated voltage of the capacitor

n is the number of units in series relative to the electrical potential to which the containers are connected.

- Duration of test is 10 seconds.

(b) DC voltage test between terminals regulated in IEC60871-1

The test shall be implemented as follows.

- Test voltage: The voltage (Ut) calculated according to the following equation shall be applied

$$U_t = 4.0 \times U_n \times n \times 0.75$$

where

U_t is the power-frequency test voltage

U_n is the rated voltage of the capacitor

n is the number of units in series relative to the electrical potential to which the containers are connected.

- Duration of test is 10 seconds.

2) One of the following test procedures shall be chosen for dead-tank type

(a) AC voltage test (capacitors in single phase system) regulated in IEC60871-1

The conditions of applying test voltage shall refer to IEC 60060-1. The test voltage is specified in Table 37-2, Column 2. The duration of withstand voltage test is 10 seconds

Table 37-2 On site test voltages

Highest voltage for equipment U_r kV (r.m.s.)	On-site short-duration power-frequency withstand voltage U_{ds} kV (r.m.s.)	Rated short-duration power-frequency withstand voltage U_d kV (r.m.s.)
[1]	[2]	[3]
1.2	4.5	6
2.4	6	8
3.6	7.5	10
7.2	15.0	20
12	21	28
17.5	28.5	38
24	37.5	50
36	52.5	70

Note :
- The on-site test voltages have been calculated as follows:
  U_{ds} (on-site test value) = $U_d \times 0.75$ (column [2])
- Frequency is from 45 to 65Hz

(b) DC voltage test between terminals regulated in IEC60871-1
The details are specified in item (1)-1)-(b) of this item.

(2) (Reference) Test method of Japanese standard
The details are specified in item 11 of article 27.

Article 38. The inspection item for surge arrester

1. Visual Inspection

It shall be checked whether the surge arrester has abnormalities such as crack, breakage, damage, looseness at screwed parts, etc. or not.

2. Measurement of Insulation Resistance

Insulation resistance between pole and ground shall be measured by a 2,500V megger. Standards of the insulation resistance are according to manufacturer.

3. Measurement of leakage current

Measurement of leakage current is an effective inspection method to detect moisture absorption or performance deterioration of inner component of a surge arrester. Leakage current shall be measured by applying the rated voltage with the rated frequency to each phase. It shall be confirmed that the measured value is within manufacturers' specifications. In case of measurement, the surface of surge arrester (insulator) shall be cleaned sufficiently.

Article 39. The inspection item for battery system

1. Visual Inspection

It shall be checked whether the battery system has abnormalities such as electrolyte leakage, crack, breakage, damage, looseness at screwed parts, etc. or not.

2. Measurement of Voltage

The voltage for each cell shall be measured to confirm that the measured value is within the manufacturers' standards. The sample standards of cell voltage such as nominal voltage, floating charge voltage and equalizing charge voltage are shown in Table 39-1.

Table 39-1 Sample standards of cell voltage

(V/cell)

Category	Electrode type	Nominal voltage	Floating charge voltage	Equalizing charge voltage
Alkaline battery	Pocket	1.20	1.40 - 1.44	1.55 - 1.65
	Sintered	1.20	1.35	1.50
Lead acid battery	Pasted (Flat)	2.00	2.15 - 2.23	2.30
	Tubular (Clad)	2.00	2.15	2.30

The test procedure and standards of cell voltage shall comply with the manufactures' specifications.

3. Equalizing charge test

Equalizing charging test shall be carried out to correct unbalanced voltage and liquid density and homogenize the upper and lower layer of electrolytes. The test procedure shall comply with the manufacturers' specifications. After equalizing charge test, the voltage for each cell shall be measured to confirm that the measured value is within the manufacturers' standards.

4. Measurement of specific gravity

Only the electrolyte of lead acid battery is relevant. The specific gravity of electrolyte for each cell shall be measured to confirm that the measured value is within the manufacturers' standards. The sample standards of specific gravity of electrolyte are shown in Table 39-2.

Table 39-2 Sample standards of specific gravity of electrolyte

Category	Electrode type	Specific gravity (At full charged, 20 ^{o}C)
Lead acid battery	Pasted (Flat)	1.24
	Tubular (Clad)	1.215

The test procedure and standards of specific gravity of electrolyte shall comply with the manufactures' specifications.

As the measured value will change according to the temperature, it shall be modified as below.

$S_{20} = S_t + 0.0007\ (t - 20)$

S_{20} : specific gravity of electrolyte at 20 °C

S_t : specific gravity of electrolyte at t °C

t : temperature when measurement was carried out

Article 40. The inspection item for protective relays and control equipment

1. Unit Test

Performance and characteristic tests cited below shall be carried out for each meter and relay to confirm that the measured value is within the manufacturers' standards. The operating value shall be set for relays. In principal, these unit tests shall be carried out with relay circuits for open and close command signals as well as CT and PT circuits being completely separated.

(1) Meter calibration

Meter calibration error of indicator shall be measured to confirm that the measured value is within the criterion which is made from the summation of the rated error range of indicator and the one of test equipment.

(2) Measurement of relay operate value

Relay operate value shall be measured.

(3) Measurement of voltage and current characteristic

Operating voltage or current of relay shall be measured at setting conditions defined by manufacturers etc.

(4) Measurement of phase characteristic

Operating phase of relay shall be measured at setting conditions defined by manufacturers etc.

(5) Measurement of operating time

Operating time of relay shall be measured by changing relay input such as voltage, current and phase from steady to fault suddenly.

2. DC Circuit Test

(1) DC sequence test

By operating the auxiliary relays with applying the voltage to DC circuits, it shall be checked that the control circuits meet the design diagram.

(2) Measurement of Insulation resistance

Insulation resistance of control circuits shall be measured by a 500V megger. Standards of the insulation resistance are in Table 40.

Table 40 Standards of insulation resistance for protective relays and control equipment

Test object	Standards (MΩ)
Control circuit	2 and more

(3) Load measurement

Electric power consumption shall be calculated from measured current by applying the rated control voltage. It shall be confirmed that the calculated value is within the manufacturers' standards.

3. AC Circuit Test

(1) Secondary circuit test

1) Measurement of Insulation resistance
It shall be carried out according to the inspection items specified separately in 2.(2) of this article.

2) Load measurement
Electric power consumption shall be calculated from measured current or voltage by applying the rated voltage or current to PT or CT circuits. It shall be confirmed that the calculated value is within the manufacturers' standards.

(2) AC circuit test (Simulation test)

1) Fault simulation test
Operation characteristics of relay shall be checked by changing relay input from steady to fault suddenly. In case of test, relay operation including automatic reclosing shall be checked by simulating short circuits or ground faults at setting points. Operating time of relay shall also be measured by changing relay input from steady to fault suddenly. In case of measurement, the time until tripping command and automatic reclosing command sent out after changing relay input shall be measured. In addition, indications on relevant equipment shall be checked.

2) Operational simulation test
Operation of automatic operating equipment shall be checked.

4. Counter Test

AC Circuit Test (simulation) shall be carried out for equipment and transmission channels which are installed in two or more electric-supply stations and exchange information with one another. In case of test, the comprehensive operations combined with related equipment shall be checked by applying the imitation input at each electric-supply station. The test contents and the check items are specified separately in 3.(2) of this article.

5. Comprehensive Test

It shall be carried out in actual operation conditions in which the switchboard is connected with related equipment by control cable.

(1) Measurement of insulation resistance
Comprehensive insulation resistance of principal and relevant systems and field equipment including connecting terminals shall be measured. It shall be carried out according to the inspection items specified separately in 2.(2) of this article.

(2) Field equipment open and close operation test
It shall be checked that open and close command signals from control systems operate only intended field equipment and cause no abnormality.

(3) Interlock test
Field equipment shall be checked to properly operate corresponding to interlock conditions.

(4) Protection relay operation and alarm indication test

It shall be checked that protection relays and control systems are properly connected to primary equipment, and that fault indication and alarm as well as operation of relevant equipment properly correspond to the relay or control system operation.

6. Comprehensive Test with PT Circuits

It shall be carried out in actual operation conditions in which the switchboard is connected with related equipment by control cable.

(1) Measurement of insulation resistance

It shall be checked with earth circuits being disconnected that comprehensive circuits including PT, control cables and distribution boards are properly insulated (with no short circuits or ground faults). It shall be carried out according to the inspection items specified separately in 2.(2) of this article..

(2) Polarization test

It shall be checked that the secondary circuit of PT that is connected with control cable conforms to the design.

(3) Transforming ratio test

By applying voltage to the primary circuit of PT, voltage and phase angle shall be measured at PT test terminals in distribution boards that are connected to the secondary (tertiary) circuit of PT in order to check that transforming ratio and connection between the PT and distribution board are proper.

(4) Load measurement

With the subject PT being fully loaded, the secondary circuit of PT shall be applied with the rated voltage, and comprehensive load including distribution board and control cable shall be measured in order to check that it is the same level as design value.

(5) Simultaneous operation check

In case that transformation ratios for two or more PT are simultaneously measured, it shall be checked that the secondary circuits of each PT are properly connected to distribution boards by rendering a knife switch or circuit breaker “Off.”

7. Comprehensive Test with CT Circuits

It shall be carried out in actual operation conditions in which the switchboard is connected with related equipment by control cable.

(1) Measurement of insulation resistance

It shall be checked with earth circuits being disconnected that comprehensive circuits including CT, control cables and distribution boards are properly insulated (with no short circuits or ground faults). It shall be carried out according to the inspection items specified separately in 2.(2) of this article.

(2) Polarization test

It shall be checked that the secondary circuit of CT that is connected with control cable conforms to the design.

(3) Transforming ratio test

By applying current to the primary circuit of CT, current and phase angle shall be measured at CT test terminals in distribution boards that are connected to the secondary (tertiary) circuit of CT in order to check that transforming ratio and polarization as well as connection between the CT and distribution board are proper.

(4) Load measurement

With the subject CT being fully loaded, the secondary circuit of CT shall be applied with the rated current and comprehensive load including distribution board and control cable shall be measured in order to check that it is the same level as design value.

(5) Core check

While primary current is flowing through CT in a transformation ratio test, the secondary circuit of CT shall be suddenly short circuited at the terminal block, and it shall be checked that the reading of ampere meter connected to distribution board drop to zero, thus the subject CT is connected to a proper destination.

Chapter 5 Completion Inspection

Section 1 General

Article 41. General provision

Completion inspection for facilities of overhead transmission lines, underground transmission lines and substations shall be carried out according to Chapter 5 in Part 2 in Technical Regulation Vol.5 and this Guideline.

Section 2 Overhead Transmission Line

Article 42. Measurement of insulation resistance

Insulation resistance of overhead transmission lines shall satisfy inspection items in the following table.

Table 42 Inspection of insulation of overhead transmission line

Items	Method	Acceptance criteria
Insulation resistance of overhead transmission lines	Measurement	- Insulation resistance measured by the megger shall be more or equal to the following values. - Between each phase and the ground : $4 \times 10^6 \Omega$ - Between a phase and the other phases : $8 \times 10^6 \Omega$ - The value measured at one minute after the measurement was started shall basically be adopted. In case that the value is not stable, it should be measured after the value becomes stable. - Use 2,500V megger for testing.

Article 43. Phase test

Phase test of overhead transmission lines shall be complied with Article 19 in this Guideline.

Article 44. Power-frequency operating voltage test

Dielectric strength of overhead transmission lines shall satisfy inspection items of power frequency withstand voltage test in the following table.

Table 44 Inspection of power frequency withstand voltage test

Item	Method	Acceptance criteria
Dielectric strength	Document	- Insulators shall be confirmed that they have prescribed dielectric strength by records of factory test.
	Measurement	- Overhead transmission line shall be confirmed that measured voltage between conductors energized by power frequency voltage (voltage normally operated in the line) and the ground which is recorded after one and ten minutes are not significantly different from power frequency voltage.

Section 3 Underground Transmission Lines

Article 45. Appearance inspection (Route exploration)

Appearance of cable lines shall satisfy inspection items in the following table.

Table 45 Inspection of appearance of cable

Items	Method	Acceptance criteria
Appearance	Visual inspection	- Kind, nominal cross sectional area and number of cables shall be in accordance with the specification. - The position of connection boxes and terminal boxes shall be in accordance with the specification. - Fixed condition of the cable, connection boxes, terminal boxes and the grounding conductor shall be in accordance with the specification. - The steel cover of the cable well shall not be damaged, and the installed condition of the cable room shall be in accordance with the specification. - Installed position and condition of the oil supply system shall be in accordance with the specification. - Operating performance and installed condition of alarm system shall be in accordance with the specification.

Article 46. Measurement of insulation resistance

Insulation resistance of the cable shall be complied with Article 18 in this Guideline.

Article 47. Phase check

Phase test of underground transmission lines shall be complied with Article 19 in this Guideline.

Article 48. (moved to Article 26-a1)

Article 49. Clearance between live part and fence or wall

The clearance between live part exposed from cable lines and the fence or the wall shall be complied with Article 50 in this Guideline.

Section 4 Substation Equipment

Article 50. Visual inspection

1. State of installation of equipment which generates arc

It shall be checked that the equipment which generates arc such as circuit breaker and disconnector is isolated from combustibles at a safe enough distance. The criteria of isolating distance between the equipment which generates arc and combustibles are shown in Table 50.

Table 50 Criteria of isolating distance between the equipment which generates arc and combustibles

Nominal voltage	Isolating distance *
7kV and less	1m and more
More than 7kV	2m and more
In case that the direction and length of arc are restricted so that there is no fear of fire and the nominal voltage is 35kV and less.	1m and more

* Note: The above distance shall not be applied when fireproof materials are installed between the equipment which generates arc and combustibles.

2. State of installation of charged part

It shall be carried out according to the inspection items specified separately in Article 335, 337, 338, and 343 of Volume 1.

3. Testing of installation of fence, wall

The height of fence and wall, and the various types of minimum clearance such as protective barrier clearance, boundary clearance, minimum height over accessible area and building clearance shall be carried out according to the inspection items specified separately in Article 335, 337, 338, 343 and 349 of Volume 1.

Article 51. Measurement of grounding resistance

Grounding resistance shall be measured to confirm that the measured value meets standards provided in Article 572 of the Volume 1.

Article 52. Supervisory and control test

1. Switching test

By operating circuit breaker, disconnector, etc. which are controlled from the control room or load dispatch center, it shall be checked that each equipment works properly and the indication in the control room or load dispatch center changes correspondingly. In addition, switching indicator of the controlled equipment shall also be checked to work properly.

2. On-load tap changer test

By giving tap-changing instruction from the control room or load dispatch center to the transformer, it shall be checked that the tap changes in accordance with the instruction. It shall be carried out according to the inspection items specified separately in item 8. (1) of Article27.

3. Protective device test, Alarm indication test

By activating relay compulsorily for every protective device or alarm device, it shall be checked that the operation of the related equipment and the indication in the control room or load dispatch center correspond exactly to the design diagram.

4. Actual Loading Test for protective relay and control equipment

As a final check using voltage and current on actual power system, the following tests shall be implemented.

(1) Voltage and phase check

It shall be confirmed that the phase arrangement meets the design diagram by measuring and comparing the voltage of testing line and another charged line. The voltage shall be measured at test terminals on distribution boards.

(2) Voltage, current and phase angle measurement

Voltage, current and phase shall be measured at test terminals on distribution boards. It shall be confirmed that the measured voltage and current are appropriate considering the PT and CT ratio and that the phase differences between measured values are appropriate considering the polarity and connection of PT and CT.

(3) Directional test

It shall be confirmed that the direction, polarity and phase difference of measured voltage and current are appropriate.

(4) Residual current and voltage measurement

Residual current and voltage shall be measured to confirm that the measured value corresponds to the imbalance if there is an imbalance among three phase current or voltage.

(5) Id (differential current) check

Differential current shall be measured to confirm that the measured value is nearly equal to 0 in a normal state.

Article 53. Interlock test

It shall be carried out according to the inspection items specified separately in Article 31.

Article 54. (moved to Article 27-34, 36-38)

Article 55. (deleted)

Article 56. *M*easurement of noise and vibration

(1) Measurement of noise and vibration

Noise and vibration level shall be measured at the boundary of a substation yard. It shall be confirmed that the measured value is within the local regulation such as Table 56-1 and 56-2. In case of measurement, the influence of sound sources besides the substation shall be excluded.

Table 56-1 Maximum permissible noise levels in public and residential areas

(dB)

Area	Time		
	From 6am to 6pm	From 6pm to 10pm	From 10pm to 6am
1. The places requiring special silence: hospitals, schools, libraries, sanatorium, churches, temples	50	45	40
2. Residential areas, hotels, resorts, administrative offices	60	55	50
3. Residential areas alternated with commercial, service, productive areas	75	70	50

Table 56-2 Sound pressure levels at working places

Working place	Equivalent sound pressure level (dBA)	Sound level at octaves of medium frequencies (Hz), not exceeding (dB)							
		63	125	250	500	1000	2000	4000	8000
At working, production places	85	99	92	86	83	80	78	76	74
Remote control room, experimental rooms with noise resources	80	94	87	82	78	75	73	71	70
Remote control room, experimental rooms without noise resources	70	87	79	72	68	65	63	61	59
Functional rooms (accounting, statistics etc.)	65	83	74	68	63	60	57	55	54
Research, design, computer, experimental and data treatment rooms	55	75	66	59	54	50	47	45	43

Chapter 6 Periodic Inspection

Section 1 General

Article 57. General provision

Periodic inspection for facilities of overhead transmission lines, underground transmission lines and substations shall be carried out according to Chapter 6 in Part 2 in Technical Regulation Vol.5 and this Guideline.

Article 58. Frequency of periodic inspections

Frequency of periodic inspection shall be in accordance with Chapter 6 in Part 2 in Technical Regulation Vol.5.

Section 2 Overhead Transmission Line

Article 59. The inspection item

Overhead transmission lines shall basically be confirmed by visual inspection that they has no abnormality or defect such as damage, crack and corrosion, etc. on periodic inspection items shown in the following table.

Table 59 Periodic inspection of overhead transmission line

Items	Contents of inspection
Steel tower	- Metallic members of the steel tower have no damage, transformation or remarkable rust. - Bolts have no falling off, loosening or remarkable rust.
Concrete pole	- The pole has no damage or crack. - The pole is not inclined.
Foundation	- The concrete of the foundation has no damage or crack - The foundation is not exposed due to outflow of the earth and sand. - The foundation is not buried due to inflow of the earth and sand. - Condition of the ground around the foundation is not changed.
Stay wire (Guy wire)	- The wire has no loosening or remarkable rust. - The strands of the wire are not snapped. - Condition of the ground around the foundation of the wire is not changed.
Grounding conductor	- The grounding conductor has no damage or remarkable rust. - The strands of the grounding conductor are not snapped. - The grounding resistance is not deteriorated. (Refer to Article 11 in this Guideline)
Insulator	- The insulator has no damage, crack, remarkable pollution, trace of arc or remarkable rust. - Unusual noise such as leak noise is not loud.

Items	Contents of inspection
Power conductor and overhead grounding conductor	- The conductors have no damage, melting, kink, remarkable vibration or corrosion. - The strands of the conductors are not loosened or snapped. - Clearance is not shortened from live parts of the power conductor to the body or the arm of the pole or the steel tower due to transformation of the jumper parts or incline of the string of suspended insulators.
Linked parts attached to insulators	- Linked parts have no damage, crack, transformation, loosening, abrasion or remarkable rust. - The arcing horns have no damage, melting or remarkable rust.
Guard fence	- The poles or wire net of the fence have no damage and remarkable rust.
Accessories of the conductor (Damper and spacer, etc.)	- Accessories have no damage, crack, transformation, loosening, abrasion or remarkable rust.
Warning signal and lamp	- The warning signal has no damage or deterioration. - The warning lamp is not damaged, nor its light bulb is not burnt out.

Section 3 Underground Transmission Line

Article 60. The inspection item for underground cable

Underground transmission lines shall be confirmed by visual inspection basically that they has no abnormality or defect such as damage, oil leakage and corrosion, etc. on periodic inspection items shown in the following table.

Table 60 Periodic inspection of underground cable

Item	Contents of inspection
Cable (Including the cable off-set part)	- The cable has no oil leakage. - The cable has no damage, expansion or transformation. - Bending condition of the cable is not abnormal. - Off-set parts is not abnormally transformed. - Clearance from the cable to other cables is not abnormal.
Protective board against water penetrating	- The board has no damage or corrosion. - Condition of the fixed board is not abnormal. - The board has no water leakage.
Cable rack, support hardware and insulator for bearing the cable	- They have no damage, transformation or remarkable rust. - Bolts and nuts of them are not loosened. - Fixed condition and position of them are not abnormal. - Condition of buffer material is not abnormal.
Protective pipe	- The protective pipe has no damage, corrosion, crack or transformation. - Bolts and nuts of them are not loosened.
Grounding conductor	- The grounding conductor has no damage or remarkable rust. - The strands of the grounding conductor are not snapped.

Item	Contents of inspection
Protective board against small animals	- The board has no damage, corrosion, crack or transformation. - Condition of fixed board is not abnormal. - Bolts and nuts of them are not loosened.
Sign label	- The sign label is not fallen off. - The sign label has no damage or transformation. - Condition of fixed sign label is not abnormal.

Article 61. The inspection item for cable terminal

The terminal boxes of underground transmission lines shall be confirmed by visual inspection basically that they has no abnormality or defect such as damage, oil leakage and corrosion, etc. on periodic inspection items shown in the following table.

Table 61 Periodic inspection of terminal box

Items	Contents of inspection
Terminal (Including the attached flat plate)	- The strands of the conductor connected to the terminal are not snapped. - The terminal has no damage, crack, corrosion or transformation. - Bolts and nuts of terminal are not loosened. - Heat detective tapes are not fallen off, detached or discolored.
Water protective cover	- The cover has no damage, remarkable rust or transformation. - Condition of fixed cover is not abnormal. - The cover has no leakage of compound or oil
Insulator and support insulator	- The insulators are not polluted. - The insulators have no damage, crack or arc trace. - The insulators have no leakage of compound or oil.
Covered part by lead	- The covered part has no oil leakage. - The covered part has no damage, crack or transformation.
Support hardware (Steel pedestal, Cleat and bracket, etc.)	- The support hardware has no damage, transformation or remarkable rust. - Bolts and nuts of the support hardware are not loosened. - Condition and position of fixed support hardware are not abnormal. - Condition of buffer material is not abnormal.
Brunch box	- The box has no oil leakage. - The box has no damage, crack, expansion, transformation or remarkable rust. - Bolts and nuts of the box are not loosened. - Corrosion prevention tapes are not detached or discolored. - The connector and the semi-stop valve have no defect.
Insulated tube	- The insulated tube is not polluted. - The insulated tube has no damage or transformation.

Items	Contents of inspection
Cable (Including the cable off-set part)	- The cable has no oil leakage. - The cable has no damage, expansion or transformation. - Bending condition of the cable is not abnormal. - Distance of the cable slipped down is not excessive. - Phase display tapes are not detached or discolored.
Protective pipe	- The protective pipe has no damage, corrosion, crack or transformation. - Bolts and nuts of them are not loosened.
Grounding conductor	- The grounding conductor has no damage or remarkable rust. - The strands of the grounding conductor are not snapped.
Sign label	- The sign label is not fallen off. - The sign label has no damage or transformation. - Condition of fixed sign label is not abnormal.
Protective equipment for protective covering outer sheath	- The equipment is not fallen off. - Bolts and nuts are not loosened. - Condition of fixed equipment is not abnormal. - The equipment is not overheated. - The equipment has no current leakage.

Article 62. The inspection item for cable joint

The connection boxes of underground transmission lines shall be confirmed by visual inspection basically that they has no abnormality or defect such as damage, oil leakage and corrosion, etc. on periodic inspection items shown in the following table.

Table 62 Periodic inspection of connection box

Items	Contents of inspection
Connection box	- The connection box has no leakage of compound or oil. - The connection box has no damage, crack, expansion or transformation. - Covered part by lead has no defect. - There is no abnormal sound and overheat. - The connector and the semi-stop valve have no defect. - There is no contact to other objects. - Condition of movement of the connection box is not abnormal. - The connection box is clean.
Cable (Including the cable off-set part)	- The cable has no oil leakage. - The cable has no damage, expansion or transformation. - Bending condition of the cable is not abnormal. - Clearance from the cable to other cables is not abnormal.
Support hardware and insulator for bearing the cable	- The support hardware has no damage, transformation or remarkable rust. - Bolts and nuts of the support hardware are not loosened. - Condition and position of fixed support hardware are not abnormal. - Condition of buffer material is not abnormal.

Items	Contents of inspection
Prevention equipment for cable slipped down	- The equipment has no damage or remarkable rust. - Condition of fixed them is not abnormal. - Distance of the cable slipped down is not excessive.
Clamp for joint (Only oil-filled cable)	- Clamps have no damage or remarkable rust. - Fixed condition of them is not abnormal. - Bolts and nuts are not loosened.
Bonding conductor	- The bonding conductor has no damage or remarkable rust. - The strands of the bonding conductor are not snapped. - Condition of fixed bonding conductor is not abnormal.
Grounding conductor	- The grounding conductor has no damage or remarkable rust. - The strands of the grounding conductor are not snapped.
Sign label	- The sign label is not fallen off. - The sign label has no damage or transformation. - Condition of fixed sign label is not abnormal.
Protective equipment for protective covering outer sheath	- The equipment is not fallen off. - Bolts and nuts are not loosened. - Condition of fixed equipment is not abnormal. - The equipment is not overheated. - The equipment has no current leakage.

Article 63. The inspection item for oil supply equipment

The oil supply system for underground transmission lines shall be confirmed by visual inspection basically that it has no abnormality or defect such as damage, oil leakage and corrosion, etc. on periodic inspection items shown in the following table.

Table 63 Periodic inspection of oil supply system

Items	Contents of inspection
Oil tank	- The oil tank has no oil leakage. - The oil tank has no gas leakage. - The oil tank has no damage or remarkable rust.
Oil meter and Gas meter	- The meters have no oil leakage. - The meters have no gas leakage. - The meters have no dew. - Valve condition is not abnormal. - Indication value is accurate. - Insulation resistance is not abnormal.
Breather (Absorbent of the humidity)	- The box of the breather has no damage or crack. - Oil is not deteriorated or discolored. - Absorbent is not discolored.
Support hardware and Foundation	- They have no damage, transformation or remarkable rust. - Bolts and nuts are not loosened. - Fixed condition and position of them are not abnormal.

Items	Contents of inspection
Insulation connector	- The insulation connector has no oil leakage. - The insulation connector has no damage or transformation. - Tapes are not discolored or detached.
Valve and panel	- They have no oil leakage. - They have no damage. - Valve condition is not abnormal. - Condition of packing is not abnormal.
Lead tube and connector	- They have no oil leakage. - They have no damage, crack or transformation. - Fixed condition of them is not abnormal.
Control cable	- The control cable has no damage. - Identification tapes are not abnormal. - Insulation resistance is not abnormal.
Control box	- The control box has no damage and remarkable rust. - Packed condition is not abnormal. - Bolts and nuts are not loosened. - Insulation resistance is no abnormal.
Alarm system	- Operating condition is not abnormal. - Indicating lamp and alarm is not abnormal. - Insulation resistance is not abnormal.
Grounding conductor	- The grounding conductor has no damage or remarkable rust. - The strands of the grounding conductor are not snapped.
Sign label	- The sign label is not fallen off. - The sign label has no damage or transformation. - Condition of fixed sign label is not abnormal.

Article 64. The inspection item for insulating oil analysis of Oil-filled Cable

The inspection for insulating oil of Oil-filled Cable shall be carried out based on instruction manual of manufacturer.

Section 4 Substation Equipment

Article 65. The inspection item for transformer

1. Visual Inspection

It shall be carried out according to the inspection items specified separately in Article 27.

2. Measurement of Insulation Performance

It shall be carried out according to the inspection items specified separately in Article 27.

3. Measurement of Winding Resistance

It shall be carried out according to the inspection items specified separately in Article 27.

4. Insulation Oil Test

(1) Insulation oil test in operation

Insulation performance of transformer insulation oil shall be checked to confirm that the performance complies with the criteria shown in Table 65-1.

Table 65-1 Quality standards of transformer oil in operation

No.	Items	Nominal Voltage (kV)				
		≤15	22,35	110	220	500
1	Breakdown voltage (kV/2.5mm) Not less than	25	30	55	55	60
2	Dielectric loss angle at 90°C (%) Not more than	-	-	7	7	5
3	Acidity (mgKOH/1g oil) Not more than	0.25	0.25	0.20	0.20	0.15
4	Water content (volume ppm) Not more than	-	-	30 25(1)	25	20
5	Content of impurities ISO 4406-1991	No (Visual observe)			-/17/14	-/15/12
6	Flash point temperature (°C)	Not decrease lower than 10% of new oil or not less than 125 °C				
7(2)	Dissolved acid - alkali content (mgKOH/1g oil) Not more than	0.014				
8	Total dissolved gas (3) (volume %) Not more than	-		4	2	2
9(*)	Surface tension at 25 °C (mN/m) Not less than	25	25	30	32	32
10(*)	Content of antioxidant (3) (%) Not less than	-		0.09		
11(*)	Content of 2-furfural (ppm) Not more than	-		10		

Note:

(1) For 110 kV transformer protected by a plastic film.

(2) Only carried out when acidity is more than 0.1mgKOH/1g oil.

(3) It is not required for transformers sealed or protected by a plastic film.

(*) Test is not mandatory.

(2) Transformers with voltage 110kV or more after energizing

Transformers with voltage 110 kV or more after energizing need oil sampling test shown in item 1, 2, 4 and 8 of Table 65-1 according to the following time limits:

1) For new transformers with voltage 110 kV and capacity less than 63MVA, the time limits of inspection are 10 days, 1 month and 6 months after energizing, and once a year.

2) For new transformers with voltage 110 kV and capacity 63MVA or more, and all transformers with voltage 220kV or 500kV, the time limits of inspection are 10 days, 1 month, 3 months and 6 months after energizing, and once a year.

3) Test item 8 in Table 65-1 determines not only total dissolved gas concentration but also component gas concentration. The limits of gas concentration and corresponding measures are instructed in item 5 of this article.

(3) Sampling interval

1) Insulation oil of transformers with voltage 110kV or more in operation needs to be sampled and analyzed once a year. The quality standards are shown in Table 65-1.

2) For transformers with voltage 110kV or more need to be checked the concentration of 2-furfural for the first time after 12 years of operation. Then, the sampling interval shall be determined in accordance with Table 65-2. If cellulose decomposition is diagnosed, the sampling interval of 2-furfural analysis shall be shortened.

Table 65-2 Sampling interval of 2-furfural analysis

Concentration of 2-furfural (ppm)	Items	Sampling interval
0 - 0.1	Normal transformer	12 years
0.1 - 1	Moderate decomposition of insulating materials	3 years
1 - 10	Strong decomposition of insulating materials	1 year
> 10	Biodegradation of insulating materials almost completely	-

3) Insulation oil of transformers with capacity up to 630kVA does not need to be checked in operation. Just check the oil in case that any problems related to insulation of transformers are detected.

4) Insulation oil of transformers with voltage up to 35kV and capacity exceeding 630kVA needs to be checked item 1, 3, 5, 6 and 7 in Table 65-1 every 3 years.

5) For transformers with separate OLTC compartment, insulation oil of OLTC needs to be checked according to instructions of manufacturer. If there are no manufacturer's instructions, the quality of oil shall meet the standards shown in Table 65-3 and item 6 of Table 65-1. The inspection of oil in transformer and in OLTC compartment shall be carried out together.

Table 65-3 Quality standards of oil in OLTC compartment in operation

No.	Items	Limited values			
		For OLTC connected to the neutral point	For OLTC connected to the beginning or middle of the coil Nominal voltage (kV)		
			≤ 35	110-220	500
1	Breakdown voltage (kV/2.5mm) Not less than	30	25	40	50
2	Water content (volume ppm) Not more than	40	-	35	30

(4) Insulation oil test after overhaul

1) Overhaul the transformer with oil changing: insulation oil in transformer shall be checked as same as the oil in new equipment before energizing that it meets the standards shown in Table 65-1.

2) Overhaul the transformer with oil filtering: insulation oil in transformer shall be checked that it meets the standards shown in item 1, 4, 6 and 7 in Table 27-8 and item 2, 3, 6 and 7 in Table 65-1.

3) Only insulation oil with acidity less than 0.1mmKOH/1g is allowed to use for transformers with voltage up to 110kV. Only insulation oil with acidity less than 0.05mmKOH/1g is allowed to use in transformers with voltage 220kV or more.

(5) Inspection in case of abnormal phenomena

When abnormal phenomena have occurred or combustible gas has detected by relay, insulation oil shall be checked that it meets the standards shown in Table 65-1.

(6) Addition of insulation oil in operation

In case that insulation oil needs to be added with new oil whose origin is not clear or whose origin is not as same as the existing oil, the new oil shall comply with the following principles:

1) For transformers with voltage 10kV or less and capacity less than 1000kVA, the additional oil shall be checked that it meets the standards shown in Table 27-8 and the amount of additional oil shall not be more than 10% of total oil.

2) For transformers with voltage 35kV or less and capacity 1000kVA or more, the additional oil with different origin is acceptable, but it shall meet the standards shown in Table 27-8.

3) For transformers with voltage 110kV or more, the additional oil shall have as same origin and same category as existing oil. The insulation oil received from different manufacture without specific instructions shall meet the standards shown in Table 27-8.

4) The additional oil shall be checked that it meets the following requirements:
The additional oil shall meet the standards shown in Table 27-8.

The antioxidant stability of the mixture of additional oil and used oil in transformer shall be checked. The testing oil shall have the same mixture ratio with existing oil in transformer. In case that the mixture ratio is unknown, the mixture ratio of testing oil shall be 50/50.

5) Before filling into transformer, the mixture of additional oil and used oil in transformer shall have lower dielectric loss angle (tanδ) and more oxidation resistance than used oil in transformer.

5. Dissolved gas analysis

(1) Purpose and application

The purpose of dissolved gas analysis in insulation oil is to detect the component gases generated in operation process of transformer, especially power transformer. These gases are result from overheat and decay of insulation materials (insulation oil and paper) due to high temperature, electric spark and arc. The products of these processes are H_2, CH_4, CO, CO_2, C_2H_4, C_2H_6 and C_2H_2 gases. These abnormal phenomena appear in transformer due to different causes, so the content and component of generated gases are also different.

From the result of chromatographic gas analysis, the content and component of generated gases can be identified, and the causes of gas generation can be determined. In dangerous case, the transformer shall be disconnected from the grid to avoid serious fault.

It is necessary to coordinate dissolved gas analysis and other experimental methods to determine the defect in transformer exactly.

(2) Limits of component gases

Limits of component gases are shown in Table 65-4.

Table 65-4 Concentration limits of dissolved key gas in insulation oil of transformer

(IEEE C57.104-2008)

		Dissolved key gas concentration limits (ppm)			
		Condition 1	**Condition 2**	**Condition 3**	**Condition 4**
Dissolved key gases	Hydrogen (H_2)	100	101 - 700	701 -1,800	> 1,800
	Methane (CH_4)	120	121 - 400	401 - 1,000	> 1,000
	Acetylene (C_2H_2)	1	2 - 9	10 - 35	> 35
	Ethylene (C_2H_4)	50	51 - 100	101 - 200	> 200
	Ethane (C_2H_6)	65	66- 100	101 - 150	>150
	Carbon monoxide (CO)	350	351 - 570	571 - 1,400	> 1,400
	Carbon dioxide (CO_2)	2,500	2,500 - 4,000	4,001 - 10,000	> 10,000
TKC		720	721 - 1,920	1,921 - 4,630	> 4,630

TKC: Total dissolved combustible gases (including: H_2, CH_4, CO, C_2H_4, C_2H_6 and C_2H_2).

Note 1:

Case 1: TKC below this level indicates the transformer is operating satisfactorily. Any individual combustible gas exceeding specified levels should prompt additional investigation.

Case 2: TKC within this range indicates greater than normal combustible gas level. Any individual combustible gas exceeding specified levels should prompt additional investigation. Fault may be present. Dissolved gas analysis shall be carried out more frequently and calculate the gas generating speed per day.

Case 3: TKC within this range indicates a high level of decomposition. Any individual combustible gas exceeding specified levels should prompt additional investigation. Faults are probably present. Dissolved gas analysis shall be carried out more frequently and calculate the gas generating speed per day.

Case 4: TKC exceeding this value indicates excessive decomposition of insulation materials (paper, oil or both of them). If the operation continues, it can damage or destroy the transformer.

Note 2:

A sudden gas appearance and the gas generation speed are more important than the amount of accumulated gas.

When the ratio of gas $CO_2/CO < 3$, it needs to consider the decomposition of insulation paper.

The appearance of remarkable amount of C_2H_2 means the occurrence of discharge (or arc). The appearance of small amount of C_2H_2 means overheating point (500 ^{o}C or higher). On detection of C_2H_2 in transformer oil, it needs weekly or even daily examinations to determine the gas generation speed, and consider the cause or decide to stop operation.

In the examination process, it needs to care about overload of the transformer (considering operation diary).

The limits of content of component gases are only used for recommendation to increase the frequency of examinations.

(3) Diagnosis of the category of defect based on component gas ratio

Diagnosis of the category of defect based on component gas ratio can be carried out according to Table 65-5, 6, 7, 8 and 65-9.

Table 65-5 Dissolved gas analysis interpretation table

(IEC60599-2007)

Case	Characteristic fault	Component gas ratio		
		C_2H_2/C_2H_4	CH_4/H_2	C_2H_4/C_2H_6
PD	Partial Discharge	NS(1)	< 0.1	< 0.2
D1	Discharge of low energy	>1	0.1 - 0.5	>1
D2	Discharge of high energy	0.6 - 2.5	0.1 - 1	>2
T1	Thermal fault $t < 300\,^{o}C$	NS(1)	>1 but NS(1)	<1
T2	Thermal fault $300\,^{o}C < t < 700\,^{o}C$	<0.1	>1	1-4
T3	Thermal fault $t > 700\,^{o}C$	<0.2(2)	>1	>4

(1) NS : Not Significant whatever the value.
(2) An increasing value of the amount of C_2H_2 may indicate that the hot spot temperature is higher than 1,000 ^{o}C.

Table 65-6 Dissolved gas analysis interpretation table (Rogers ratios)

[IEEE C57.104-2008]

Case	Characteristic fault	Component gas ratio		
		R2 C2H2/C2H4	R1 CH4/H2	R5 C2H4/C2H6
0	Unit normal	< 0.1	0.1 - 1.0	< 1.0
1	Low-energy density arcing PD*	< 0.1	<0.1	< 1.0
2	Arcing - High-energy discharge	0.1 - 0.3	0.1 - 1.0	> 3.0
3	Low temperature thermal	< 0.1	>0.1 to < 1.0	1.0 - 3.0
4	Thermal fault $t < 700\,^{o}C$	< 0.1	> 1.0	1.0 - 3.0
5	Thermal fault $t > 700\,^{o}C$	< 0.1	> 1.0	> 3.0

* There will be a tendency for the ratios R2 and R5 to increase to a ratio above 3 as the discharge develops in intensity.

Table 65-7 Dissolved gas analysis interpretation table (Doernenburg ratio)

[IEEE C57.104-2008]

Characteristic fault	Component gas ratio			
	R1 CH4/H2	R2 C2H2/C2H4	R3 C2H2/CH4	R4 C2H6/C2H2
Thermal fault	>1.0	<0.75	<0.3	>0.4
Discharge of low energy	<0.1	Not significant	<0.3	>0.4
Arcing - High-energy discharge	>0.1 to < 1.0	>0.75	>0.3	<0.4

Note: If at least one of the gas concentrations [ppm] for H2, CH4, C2H2, and C2H4 exceeds twice the values shown in the condition 1 of Table 65-4; Proceed to the above Doernenburg ratio check to determine validity of the ratio check.

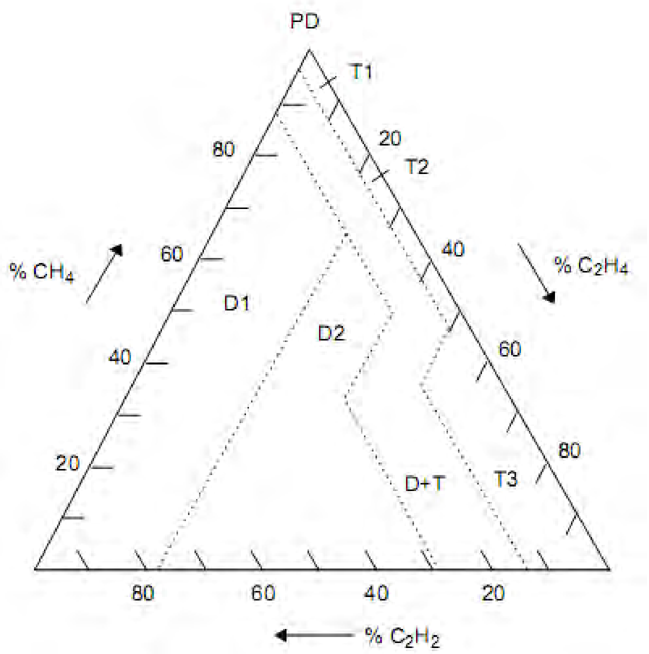
Table 65-8 Dissolved gas analysis interpretation table (Triangle Duval)

$$\% \, C_2H_2 = \frac{100\,x}{x+y+z}$$

$$\% \, C_2H_4 = \frac{100\,y}{x+y+z}$$

$$\% \, CH_4 = \frac{100\,z}{x+y+z}$$

x = concentration of C_2H_2 (ppm)
y = concentration of C_2H_4 (ppm)
z = concentration of CH_4 (ppm)

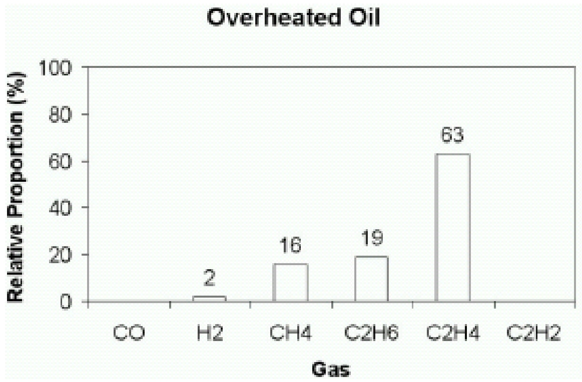
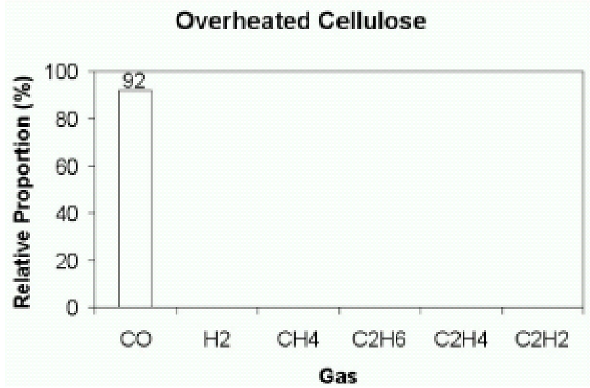
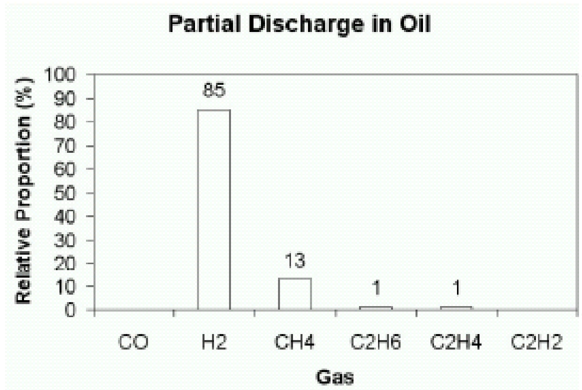
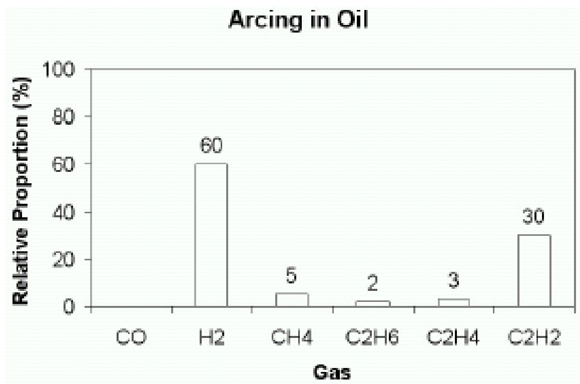


where:

PD	Partial Discharge
D1	Discharge of low energy
D2	Discharge of high energy
T1	Thermal fault (t < 300 °C)
T2	Thermal fault (300 °C < t < 700 °C)
T3	Thermal fault (t > 700 °C)

Table 65-9 Key gases evaluation

(IEEE C57.104-2008)

Thermal - Oil: Decomposition products include ethylene (C2H4) and methane (CH4), together with smaller quantities of hydrogen and ethane (C2H6). Traces of acetylene (C2H2) may be formed if the fault is severe or involves electrical contacts. Principal Gas : Ethylene (C_2H_4)	
Thermal - Cellulose: Large quantities of carbon dioxide and carbon monoxide are evolved from overheated cellulose. Hydrocarbon gases, such as methane and ethylene, will be formed if the fault involves an oil-impregnated structure. Principal Gas: Carbon Monoxide	
Electrical - Partial discharge: Low-energy electrical discharges produce hydrogen and methane, with small quantities of ethane and ethylene. Comparable amount of carbon monoxide and carbon dioxide may result from discharges in cellulose. Principal Gas: Hydrogen	
Electrical - Arcing: Large amounts of hydrogen and acetylene are produced, with minor quantities of methane and ethylene. Carbon dioxide and carbon monoxide may also be formed if the fault involves cellulose. Oil may be carbonized. Principal Gas: Acetylene	

(4) Combustible gas generating speed

Combustible gas generating rates (C) is shown as below;

$$C=\frac{TKC_2-TKC_1}{T}$$

Where

C : Combustible gas generating speed (ppm / day)

TKC1: Total amount of dissolved combustible gas for the first sample (ppm)

TKC2: Total amount of dissolved combustible gas for the second sample (ppm)

T: Time between two samples (day)

(5) The sampling intervals and operating procedures for various levels of the total amount of dissolved combustible gas (TKC)
It is shown in Table 65-10.

Table 65-10 The sampling intervals and operating procedures for various levels of the total amount of dissolved combustible gas (TKC)

(IEEE C57.104-2008)

<table>
<tr><th rowspan="2">Condition</th><th rowspan="2">TKC(1) (ppm)</th><th rowspan="2">TKC generating speed (ppm/day)</th><th colspan="2">Sampling intervals and operating procedures for gas generating speed</th></tr>
<tr><th>Sampling interval</th><th>Operating procedures</th></tr>
<tr><td rowspan="3">4</td><td rowspan="3">> 4,630</td><td>> 30</td><td>Daily</td><td rowspan="2">- Consider stop operation of transformer
- Consult with manufacturer</td></tr>
<tr><td>10 - 30</td><td>Daily</td></tr>
<tr><td>< 10(2)</td><td>Weekly</td><td>- Make a serious warning
- Analyze for individual gases
- Plan to stop operation of transformer
- Consult with manufacturer</td></tr>
<tr><td rowspan="3">3</td><td rowspan="3">1,921 - 4,630</td><td>> 30</td><td>Weekly</td><td rowspan="3">- Make a serious warning
- Analyze the component gases
- Plan stop operation of transformer
- Consult with manufacturer</td></tr>
<tr><td>10 - 30</td><td>Weekly</td></tr>
<tr><td>< 10(2)</td><td>Monthly</td></tr>
<tr><td rowspan="3">2</td><td rowspan="3">721 - 1,920</td><td>> 30</td><td>Monthly</td><td rowspan="3">- Make a warning
- Analyze the component gases
- Decide the dependence of load</td></tr>
<tr><td>10 - 30</td><td>Monthly</td></tr>
<tr><td>< 10</td><td>Quarterly</td></tr>
<tr><td rowspan="3">1</td><td rowspan="3">≤ 720</td><td>> 30</td><td>Monthly</td><td>- Make a warning
- Analyze the component gases
- Decide the dependence of load</td></tr>
<tr><td>10 - 30</td><td>Quarterly</td><td rowspan="2">- Continue normal operation</td></tr>
<tr><td>< 10</td><td>Normal</td></tr>
</table>

Note:

(1) The value in this column does not need to be taken into account in case of vacuum filtered.

(2) Depending on the gas generation speed, it is recommended to sample frequently.

6. On-load Tap Changer Inspection
It shall be carried out according to the inspection items specified separately in Article 27.
For insulation oil test, it shall be carried out according to the item 4 - (3) - 5) of this article.

7. Inspection of BCT
It shall be carried out according to the inspection items specified separately in Article 67.

8. Cooling System and auxiliary system Inspection
It shall be carried out according to the inspection items specified separately in Article 27.

9. Measurement of Transformation Ratio
It shall be carried out according to the inspection items specified separately in Article 27.

10. Measurement of No-load current and loss
It shall be carried out according to the inspection items specified separately in Article 27.

Article 66. The inspection item for Potential Transformer (PT)

1. Visual Inspection
It shall be carried out according to the inspection items specified separately in Article 28.

2. Measurement of Insulation Performance
It shall be carried out according to the inspection items specified separately in Article 28.

3. Measurement of Transformation Ratio
It shall be carried out according to the inspection items specified separately in Article 28.

4. Polarity Test
It shall be carried out according to the inspection items specified separately in Article 28.

5. Measurement of Winding resistance
It shall be carried out according to the inspection items specified separately in Article 28.

6. Insulation oil test in operation
- Insulation oil test shown in item 1-5 of Table 66-1 shall be carried out every 2 years for open type CT with voltage 110-500kV.
- Insulation oil test shown in item 1-5 of Table 66-1 shall be carried out every 4 years for open type PT with voltage 110-220kV, and every 5 years for open type PT with voltage 500kV.
- For CVT, breakdown voltage of insulation oil shall meet the standards of manufacturer's instructions. If there are no manufacturer's instructions, breakdown voltage shall not be less than 30kV.
- If it is necessary, item 7 of Table 66-1 shall be checked additionally.
- For measuring transformer with voltage 35kV or less, oil test shall be carried out only when a suspicious value related to oil quality is detected by an electrical test.
- For sealed type measuring transformer, oil test shall be carried out in accordance with manufacturer's instructions. When a suspicious value related to oil quality is detected by an

electrical test and oil test is carried out, the measured values shall meet the standards shown in Table 66-1.

- When it is needed to add or change insulation oil, the measures shall be taken in accordance with manufacturer's instructions. The quality of new oil shall meet the standards shown in Table 66-1.

Table 66-1 Quality standards of insulation oil for measuring transformers in operation

No.	Items	Nominal Voltage (kV)				
		≤15	22, 35	110	220	500
1	Breakdown voltage (kV/2.5mm) Not less than	25	30	55	55	70
2	Dielectric loss angle at 90°C (%) Not more than	-	-	7	5	5
3	Acidity (mgKOH/1g oil) Not more than	0.25	0.25	0.20	0.20	0.15
4	Dissolved acid - alkaline content (mgKOH/1g oil) Not more than	0.014				
5	Flash point temperature (°C)	Not decrease lower than 10% of initial value or not less than 125 °C				
6	Water content (volume ppm) Not more than	-		25		
7(*)	Dissolved gas content	-		Component of dissolved gases		
8(*)	Surface tension at 25 °C (mN/m) Not less than	25	25	30	32	32

Note:

- Item 4 : Only perform when acidity is more than 0.10mgKOH/1g oil.
- (*) Test is not mandatory.

The limits of concentration of component gases are shown in Table 66-2.

Table 66-2 Limits of concentration of component gases (ppm)

	C_2H_2	H_2	CH_4	C_2H_4	C_2H_6	CO	CO_2
CT	1-5	6-300	11-120	3-40	7-130	250-1100	800-4000
PT	4-16	70-1000	-	20-30	-	-	-

Note:
- CT : Current Transformer
- PT : Potential Transformer
- For rubber sealed CT with lower content of H_2 (± 20 ppm); metal sealed CT (± 30 ppm)

Article 67. The inspection item for Current Transformer (CT)

1. Visual Inspection

It shall be carried out according to the inspection items specified separately in Article 29.

2. Measurement of Insulation Performance

It shall be carried out according to the inspection items specified separately in Article 29.

3. Measurement of Transformation Ratio

It shall be carried out according to the inspection items specified separately in Article 29.

4. Polarity Test

It shall be carried out according to the inspection items specified separately in Article 29.

5. Measurement of Winding resistance

It shall be carried out according to the inspection items specified separately in Article 29.

6. Insulation oil test in operation

The details are specified in item 6 of Artilcle 66.

Article 68. The inspection item for Gas Circuit Breaker (GCB)

1. Visual Inspection

It shall be carried out according to the inspection items specified separately in Article 30. It shall be confirmed that gas leakage is not detected by checking the gas pressure gauge.

2. Measurement of Insulation Resistance

It shall be carried out according to the inspection items specified separately in Article 30. Standards of insulation resistance are in Table 68-1.

Table 68-1 Standards of insulation resistance

Test object	Nominal voltage (kV)	Standard (MΩ)		
		Good	Fair	Poor
Main circuit	110 and over	1,000 and more	250 - 1,000	Less than 250
	35 and less	500 and more	500 - 125	Less than 125
Control circuit		2 and more	0.5 - 2	Less than 0.5

Recommended action

- Good : Continue inspection in a normal interval.
- Fair : More frequent inspection.
- Poor : Check preceisely or replace.

3. Measurement of Contact Resistance for Direct Current

It shall be carried out according to the inspection items specified separately in Article 30.

4. Analysis of Decomposed Gas in SF6 Gas

Water content in SF6 gas enclosed in equipment shall be checked as directed by manufacturer. Maximum allowable moisture to ensure no dew condensation is converted to dew point not more than -5°C. (Converted to rated pressure of equipment at 20 °C) (refer to IEC62271-1: 2011) If there are no manufacturer's standards of moisture in SF6 gas sampled from equipment in operation, it shall meet the standard shown in table 68-2.

Table 68-2 Standards of SF6 gas in operation

(GB / T 8905-1996, IEC 60480-2004)

Items		**Standards**
Water content	The device which generates decomposed gas	Less than 300ppm
	The device which does not generate decomposed gas	Less than 1,000ppm
Content of decomposed gas	SO2	Less than 12ppm
	HF	Less than 25ppm

- For new equipment with voltage 126-550kV,water content in SF6 gas shall be checked 3-6 months after commissioning, then every 1-2 years.
- For new equipment with voltage 40.5-72.5kV, water content in SF6 gas shall be checked 1 year after commissioning, then every 2-3 years.

5. Opening and Closing Operation Test

It shall be carried out according to the inspection items specified separately in Article 30.

6. Measurement of Opening and Closing Characteristics

It shall be carried out according to the inspection items specified separately in Article 30.

7. Bushing CT Inspection

It shall be carried out according to the inspection items specified separately in Article 67.

Article 69. The inspection item for Gas Insulated Switchgear (GIS)

1. Visual Inspection

It shall be carried out according to the inspection items specified separately in Article 31.

2. Measurement of Insulation Resistance

It shall be carried out according to the inspection items specified separately in Article 31. Standards of insulation resistance are shown in Table 68-1.

3. Measurement of Contact Resistance for Direct Current

It shall be carried out according to the inspection items specified separately in Article 31.

4. Analysis of Decomposed Gas in SF6 Gas

It shall be carried out according to the inspection items specified separately in Article 68.

5. Opening and Closing Operation Test in Disconnector

It shall be carried out according to the inspection items specified separately in Article 31.

6. Arresters Inspection

It shall be carried out according to the inspection items specified separately in Article 72-a4.

7. PT inspection

It shall be carried out according to the inspection items specified separately in Article 66.

8. CT inspection

It shall be carried out according to the inspection items specified separately in Article 67.

Article 70. The inspection item for Vacuum Circuit Breaker (VCB)

1. Visual Inspection

It shall be carried out according to the inspection items specified separately in Article 32.

2. Measurement of Insulation Resistance

It shall be carried out according to the inspection items specified separately in Article 32. Standards of insulation resistance are shown in Table 68-1.

3. Measurement of Contact Resistance for Direct Current

It shall be carried out according to the inspection items specified separately in Article 32.

4. Opening and Closing Operation Test

It shall be carried out according to the inspection items specified separately in Article 32.

5. Measurement of Opening and Closing Characteristics

It shall be carried out according to the inspection items specified separately in Article 32.

6. Withstand Voltage Test of Vacuum Valve

Withstand voltage test of vacuum valve shall be carried out to check the vacuum degree of valve. In case of inspection, applying voltage shall be adjusted according to the manufacturers' instructions. The gap between main contacts shall be adjusted by manual handle according to the manufacturers' instructions if necessary. In these conditions for inspection, it shall be checked that discharge does not occur by applying the test voltage for specific time which is defined in manufactures' instructions.

7. Bushing CT inspection

It shall be carried out according to the inspection items specified separately in Article 67.

Article 71. The inspection item for Oil Circuit Breaker (OCB)

1. Visual Inspection

It shall be carried out according to the inspection items specified separately in Article 33.

2. Measurement of Insulation Resistance

It shall be carried out according to the inspection items specified separately in Article 33. Standards of insulation resistance are shown in Table 68-1.

3. Measurement of Contact Resistance for Direct Current

It shall be carried out according to the inspection items specified separately in Article 33.

4. Opening and Closing Operation Test

It shall be carried out according to the inspection items specified separately in Article 33.

5. Measurement of Opening and Closing Characteristics

It shall be carried out according to the inspection items specified separately in Article 33.

6. Insulation Oil Test

Insulation performance of OCB oil shall be checked to confirm that the performance complies with the criteria shown in Table 71.

Table 71 Standard of breakdown voltage of OCB oil in operation

(IEC60422)

Items	Nominal voltage (kV)	Limit value
Breakdown voltage (kV/2.5mm)	More than 72.5kV	More than 30
	72.5kV or less	More than 30

7. Bushing CT inspection

It shall be carried out according to the inspection items specified separately in Article 67.

Article 72. The inspection item for disconnector

1. Visual Inspection

It shall be carried out according to the inspection items specified separately in Article 34.

2. Measurement of Insulation Resistance

It shall be carried out according to the inspection items specified separately in Article 34. Standards of insulation resistance are shown in Table 68-1.

3. Measurement of Contact Resistance for Direct Current

It shall be carried out according to the inspection items specified separately in Article 34.

4. Opening and Closing Operation Test

It shall be carried out according to the inspection items specified separately in Article 34.

Article 72-a1 The inspection item for air compressor

It shall be carried out according to the inspection items specified separately in Article 35.

Article 72-a2 The inspection item for compact switch gear cubicle

1. Visual Inspection

It shall be carried out according to the inspection items specified separately in Article 36.

2. Measurement of Insulation Resistance
It shall be carried out according to the inspection items specified separately in Article 36. Standards of insulation resistance are shown in Table 68-1.

3. Sequence and Interlock Tests
It shall be carried out according to the inspection items specified separately in Article 36.

Article 72-a3 The inspection for power capacitor

1. Visual Inspection
It shall be carried out according to the inspection items specified separately in Article 37.

2. Measurement of Insulation Resistance
It shall be carried out according to the inspection items specified separately in Article 37. Standards of insulation resistance are shown in Table 68-1.

3. Condenser capacity measurement
It shall be carried out according to the inspection items specified separately in Article 37.

Article 72-a4 The inspection for surge arrester

It shall be carried out according to the inspection items specified separately in Article 38.

In case of measurement of insulation resistance, standards of insulation resistance are shown in Table 68-1.

Article 72-a5 The inspection item for battery system

It shall be carried out according to the inspection items specified separately in Article 39.

Article 73. The inspection item for protective relays and control equipment

Tests cited below shall be carried out for protective relays and control equipment in accordance with Article 40.

1. Unit Test
(1) Measurement of relay operate value
(2) Measurement of voltage and current characteristic
(3) Measurement of phase characteristic
(4) Measurement of operating time

2. DC Test
Measurement of insulation resistance
Standards of insulation resistance are shown in Table 68-1.

3. AC Test
(1) Secondary Circuit Test
1) Meter and relay operation test
2) Measurement of insulation resistance

(2) AC Circuit Test (Simulation Test)

1) Fault simulation test

4. Test with Field Equipment

Protective relay operation and alarm indication test

Part 3
Hydro power plants

Chapter 1 General Provision

Article 74. Definitions

As stipulated in the Technical Regulation.

Chapter 2 Organization and Management of Operation and Maintenance

Article 75. Organization

As stipulated in the Technical Regulation.

Article 76. Management of operation and maintenance

As stipulated in the Technical Regulation.

Chapter 3 In Progress Inspection

Article 77. Inspection documents (Documentation)

The inspector with all workers must provide the inspection documents for the confirmation of the inspection plan with working procedure base on the Technical Regulation Vol.4, Part 6, Chapter 1 Inspection rule in the power plant.

Article 78. Grounding resistance measurement

1. For methods of measurement of the grounding resistance value, it is preferable to use a resistance tester for small area of the grounding system or ac voltage drop method for large area of the grounding system for which grounding mesh (grid connection) is applied. (Refer to Figure78-1 Grounding Resistance Measurement Circuit by AC Voltage Drop Method)
2. Whether the combined resistance of the grounding system is not more than an expected value of ground resistance, and whether or not the estimated touch voltage and step voltage are safe or not, i.e. whether the grounding system of the power plant is safe or not must be confirmed.
3. The target for Grounding resistance value of power plant must be the design value for the grounding system of each power plant. (Refer to IEEE Std 80-2000)

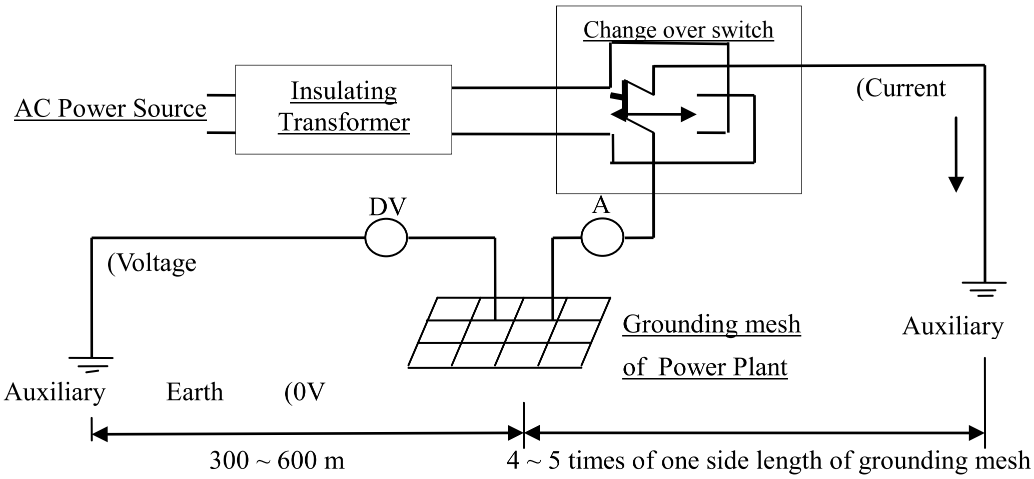


Figure 78-1 Grounding Resistance Measurement Circuit by AC Voltage Drop Method

Where,
DV: High impedance digital Volt meter, A: AC Ammeter

<The provisions of this article must refer to Article 51 in Part 2.>

(Reference Documents)

- ANSI / IEEE Std 81, IEEE Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System, 1983.
- ANSI / IEEE Std 142, Green Book- Grounding of Industrial and Commercial Power Systems, 1982.
- IEEE Std 80-2000, IEEE Guide for Safety in AC Substation Grounding, 2000.
- IEEE Std 367-1996, IEEE Recommended Practice for Determining the Electric Power Station Ground Potential Rise and Induced Voltage From a Power Fault, 1996.
- IEEE Std 487-2000, IEEE Recommended Practice for the Protection of Wireline Communication Facilities Serving Electric Supply Locations, 2000.
- IEEE Std 1590-2003, IEEE Recommended Practice for the Electric Protection of Optical Fiber Communication Facilities Serving, or Connected to, Electrical Supply Locations, 2004.
- NFPA 70, National Fire Protection Association, USA, 2005 ed.
- Internet Grounding Reference: www.sestech.com
- TCN 18-2006 Code for Electric Equipment Facilities issued by MOIT 11

Section 1 Generator/Generator-Motor

Article 79. Insulation resistance measurement

1. As the measurement device, meg-ohm meter or other equivalent devices built-in DC power source must be used.

The calibration voltages must be;

(1) 1,000V or 500V with low voltage equipment upto 1,000V.

(2) 2,500V with high voltage equipment over 1,000V.

(3) The calibration voltage can be 5,000V whenever required.

2. The measurement values must meet the Technical Requirements, with regard to the installation status, test environment, specifications, materials, structure, and capacities of power plant.
3. Polarization Index (P.I) is quotient of insulation resistance (Ir) value measured at 10 minutes and Ir value measured at 1 minute. (P.I = Ir 10 / Ir 1)

Recommended minimum value of polarization index (PI) and insulation resistance (IR) are as follows; (Refer to Table – 2 & 3 in Chapter 12 of IEEE Std.43-2000)

Thermal class	Minimum value P.I
A (100 °C)	1.5
B (120 °C)	2.0
F (140 °C)	2.0
H (165 °C)	2.0

Note: Temperature of the thermal class is measured by “ resistance method”.

<e.g.>

(1) In case of a dielectric test of stator coils : Insulation resistance measurements must be carried out as follows;

1) At normal, < 40°C, temperature, by 1,000 V meg-ohm meter : Over 100MΩ / phase;

2) Polarity index (P.I), Over 1.5.

Note: 1. The both measurement values of before and after tests are preferable that it is not so noticeable difference.

2. In case that the values of insulation resistance and P.I are lower than 100MΩ and 1.5, respectively, it is necessary to discuss the advisability of the dielectric test between Manufacture and Owner for judgment, which is carried out it or not.

(2) In case of a dielectric test of rotor coils: Insulation resistance measurements must be carried out as follows;

1) In case of a dielectric test of rotor coils: Insulation resistance measurements must be carried out as follows;

Note: 1. The same as Note 1 mentioned above in Item 3.

(3) In case of soft starting system, inverter, low voltage circuit, etc., insulation resistance measurements must be carried out for each voltage class as follows;

- Between Main circuit ~ earth,
- Between PT(PD), CT~ earth,
- Between each circuit of electrical equipment and/or earth.

4. Measurement of the insulation resistance

The measured resistance must be not less than the values identified in the Table 79-1, which is defined in the MOI Decree *No.48NL / KHKT 1987,"* Volume and standards for test, acceptance and hand over of electrical equipment".

Table 79-1 Minimal values of allowable insulation resistance

Object of test	Voltage of Meg-ohmmeter (V)	Standard
(1)	*(2)*	*(3)*
Stator coil, voltage up to 1,000 V	1,000	Value of insulation resistance of the connection must be not less than 0.5 mega-ohm when the temperature is from +10 to 30°C
Stator coil, voltage more than 1,000 V	2,500	Insulation resistance must satisfy the request of "Special Normative Course on Affirmation of the Electrical Connectability without drying for the rotary alternative electric machines". In the generators with water cooling system, the insulation resistance must be measured when the water is wholly drained from the stator coil.
Rotor coil	1,000 (500 is allowable)	Value of insulation resistance must be not less than 0.5 mega-ohm when the temperature is from +10 to 30°C. The commissioning of the rotors with hidden poles is allowable whenever their insulation resistance is not less than 2,000 ohm while the temperature is + 75°C, or 20,000 ohm while the temperature is +120°C,.
Bearing of generator and exciter	1,000	Value of insulation resistance measured at the housing when the lubricating pipes are completely assembled must be not less than 0.3 mega-ohm for hydropower generator, and not less than 1 mega-ohm for steam turbine generator. For the hydropower generator, the measurement must be proceeded if the structure of the machine is available.
Heat indicators - for the generators and the synchronical compensators with indirect cooling system for stator coils - for the generators and the synchronical compensators with direct cooling system for stator coils	 250 500	 Value of insulation resistance measured, including the resistance of connecting wires, must be not less than 1 mega-ohm Value of insulation resistance measured, including the resistance of connecting wires, must be not less than 0.5 mega-ohm
Exciting circuit of the generator and the exciter (excluding the rotor coil and the exciter)	1,000 (500 is allowable)	Value of insulation resistance measured, including the resistance of all connecting instruments, must be not less than 1 mega-ohm

5. Other measuring factor absorptivity/absorptance (K)

This is one of the confirmation for a draying condition of insulation resistance, which is carried out during measuring in Article 79-a1 Generator winding resistance measurement, item 4 Absorption current measurement.

The during beginning of the measurement of Article 79-a1, item 4 must be confirmed the absorptivity/absorptance (K) of the insulation resistance are as follows;

K is quotient of insulation resistance (Ir) value measured at 15 seconds and 60 seconds.

That is;
K = Ir 60s / Ir 15s.

However, a target of K is not fixed a calculation values, because it is difference depend on a Unit capacity, which is larger than the value of Polarization Index (P.I).

Therefore, the measuring factor absorptivity / absorptance (K) is reference data before measurement item 4 Absorption current measurement (Polarization Index (P.I), mentioned above.

Table 79-2 Insulation resistance before and after dielectric test (MΩ)

Phase	15 sec.	60 sec.	10 min	K (60sec/15sec)	PI (10min/1min)
A, (R), (U)					
B, (S), (V)					
C, (T), (W)					

(Reference Documents)
- 5.3 in IEEE Std. 43-2000, Recommended Practice for Insulation Resistance,
- IEEE Std 56-1977, Guide for Insulation Maintenance,
- IEEE Std C3-23-2003, Metal Enclosed Bus,
- IEC 60034-18 (1992), Functional evaluation of insulation system for rotating electrical machines,
- 2-1-2 in No.48NL / KHKT, Measurement of the insulation resistance.

Article 79-a1 Generator winding resistance measurement

1. The purpose of this measurement is to confirm the winding resistance which must have an effect on the electrical characteristics of the generator, i.e., measurement of winding temperature, calculation of generator loss, and calculation of internal voltage dollop of armature current, etc,.
2. The DC resistance of the rotor winding between slip-rings and of each complete phase winding of the generator stator must be measured at room temperature. The test must be made after sufficient standing period to ensure that all parts of the stator and rotor are at uniform temperature.
3. Resistance of standard winding temperature
   The resistance of standard winding temperature must be calculated based on an average temperature calculated by the same measuring temperatures, as follows,

$$R_1 = \{(T+\theta_1) / (T+\theta_2)\} R_2 \qquad (\Omega)$$

Where,

R_1 : Resistance of standard winding temperature *(θ_1 °C)*
R_2 : Resistance of measuring winding temperature *(θ_2 °C)*
T : Constant prescribed by insulation material
θ_1 : Standard winding temperature prescribed by heat-resistance class of the winding

(Reference Documents)
- 2-1-5 in No.48NL/KHKT, Measurement of resistance by Direct Current (DC)

4. Absorption current measurement

(1) The purpose of this measurement is to confirm a drying condition of the insulating materials.

(2) First of all, a measuring circuit of absorption current measurement must be carried out by an insulation resistance measurement (IRM) for confirmation before and after measuring, which is performed after separating all connecting circuit into the stator winding from outside .(Refer to Figure 79-a1-1 Example of Measuring Circuit)

(3) The measurement must be able to be performed whichever for the three (3) phases or shingle phase, however, in case of measuring each shingle phase, other two (2) phases must be connected to the guard-terminal of DC high voltage testing equipment (DCHVTE). And other conductors of devices and/or equipment with bus bars which are separated for all connecting circuit except measuring winding must be grounded completely. Especially, the filed winding must be grounded between slip rings with short circuit, and also the main shaft must be grounded completely.

(4) Before connecting the testing lead wire to the stator winding to be tested, testing equipment must be capable to generate testing voltage which must cause no trouble.
After connecting the testing lead wire to the stator winding to be tested, the test voltage must be applied by stepping voltage (normally 2~3kVDC). And temporal variation of the testing voltage and charging current must be recorded. The measuring time must be 10 min, normally.

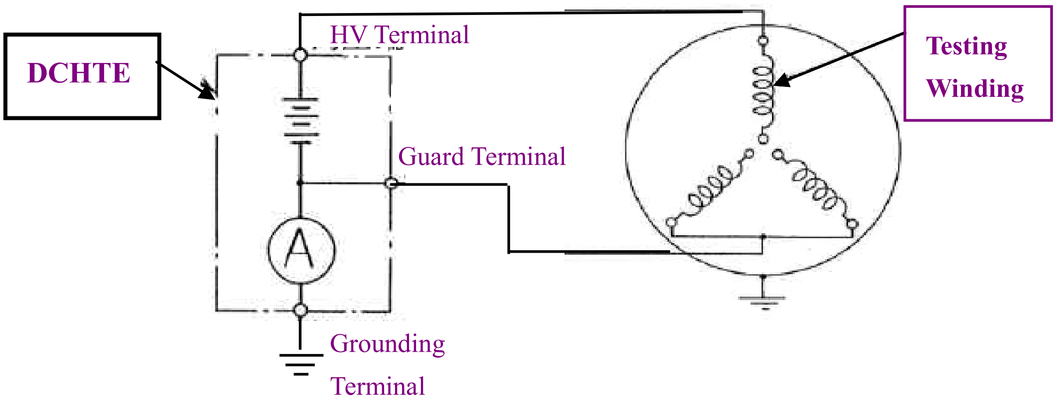


Figure 79-a1-1 Example of Measuring Circuit

(Reference Documents)

- IEEE Std 4a –2001., Techniques for High-Voltage Testing

Article 80. Dielectric test

1. Dielectric test voltage must be applied according to the values stated in Table-80-1 and confirmed withstand the necessary dielectric test voltage value under the regulated time.

Table 80-1 Dielectric Test Voltage under industrial power frequency

	Test Object	Characteristic of Electric Machines	Testing Voltage (V)
1	(1)	(2)	(3)
	- Stator Coil ≤	- Capacity less than 1kW (kVA) with nominal voltage less than 100 V	2 Un + 500
		- Capacity less than 10,000 kW (kVA)	2 Un + 1,000V (min. 1,500V)
		- Capacity more than 10,000 kW (kVA)	
		(1) Un ≤ 24,000 V	2 Un + 1,000V
		(2) Un › 24,000 V	Subject to agreement with manufacturer
2	Field windings of synchronous generators Started not induction motor	Up to including 500 V	10Ef (min. 1,500 V)
		Above 500 V	2Ef + 4000 V
	Started induction motor		
	When the machine is intended to be started either with the field windings short-circuited or connected across a resistance of value less than ten times the resistance of the winding		10Ef (min. 1,500 V, maxi. 3,500 V)
	When the machine is intended to be started either with the field windings connected across a resistance of value equal to, or more than, ten times the resistance of the winding, or with the field windings on open circuit with or without a field-dividing switch.		2Ef + 1,000 V (min.1,500 V)
3	- Stator coil of synchronous generators while the stator assembly proceeded at site (For hydropower generator, after the completion of coil assembly and insulating the connectors)		A repetition of the tests must be avoided if possible, but if a test is performed on a group of machines and apparatus, each having previously passed its withstand voltage test, the test voltage to be applied to such an electrically connected arrangement must be 80% of the lowest test voltage appropriate for any individual piece of the arrangement.
4	Exciter (except as below)		Withstand voltage must be of the values item. 2.
	Exception 1: Exciters of synchronous motors (including synchronous induction motors) if connected to earth or disconnected from the field windings during starting.		1,000 V + 2Ef (min.1,500 V)

Note: Un: Rated voltage Ef: Field voltage

(Reference Documents)

- 9.2 in IEC 60034-1 (2004), Rotating electrical machines, Part 1 Rating and performance
- 3.2 in IEEE Std 115 – 1995, Test Procedure for Synchronous Machines, Dielectric and partial discharge tests
- 2-1-4 in No.48NL/KHKT, Insulation test under step-up voltage at industrial frequency.

2. Dielectric test by DC current or other equivalent method

   In case that the industrial power frequency test voltage is not available, it may be carried out as follows.

   (1) Dielectric test voltage by DC current must be 1.7 times of root- mean- square (r.m.s) value given in industrial power frequency test voltage.

   (2) After finishing DC dielectric test, it is necessary to ground all testing circuit sufficiently.

3. In case of carrying out this test for the generator, each test voltage to be applied must be the voltage between the winding/coil of the generator and the earth after confirming the suitable value of insulation resistance which must be measured after testing the temperature of the generator. If the temperature test of the generator is not carried out, this test must be carried out after finishing the test of the no-load saturation test, or after making conclusion in discussion between Owner and manufacture.
4. The standard testing voltage must be maintained one (1) minute after reaching to the testing voltage in general.
5. In case of changing whole winding of the generator, it must be tested by the same process for new generator, however, in case of changing partial winding of the generator, it must be tested by a method agreed in the discussion between Owner and manufacture.

Article 81. Air gap measurement

The measuring points must be symmetrical 8 points of both upper (U) and lower (L) coils end portions.

For preventing damage by contact of stator and rotor, the air gap must be less than the value calculated by following formula:

(Measuring value Max.-Min.) / Average value ≤ 10%

<e.g.>

Upper side: Max.=21.5 (mm), Min.=19.5 (mm), Ave.=20.0 (mm),
= (21.5-19.5) / 20.0 = 10 (%) ≥ 10 (%)

In case of the measuring value is difference between both upper and lower coil end portion for the same point, it is necessary to confirm the measuring value of opposite side, e.g. Point 1 : 5, 2 : 6, 3 : 7 and 4 : 8, because it is consider that the shaft line of turbine / generator unit is not installed a vertically and center line of unit, completely.

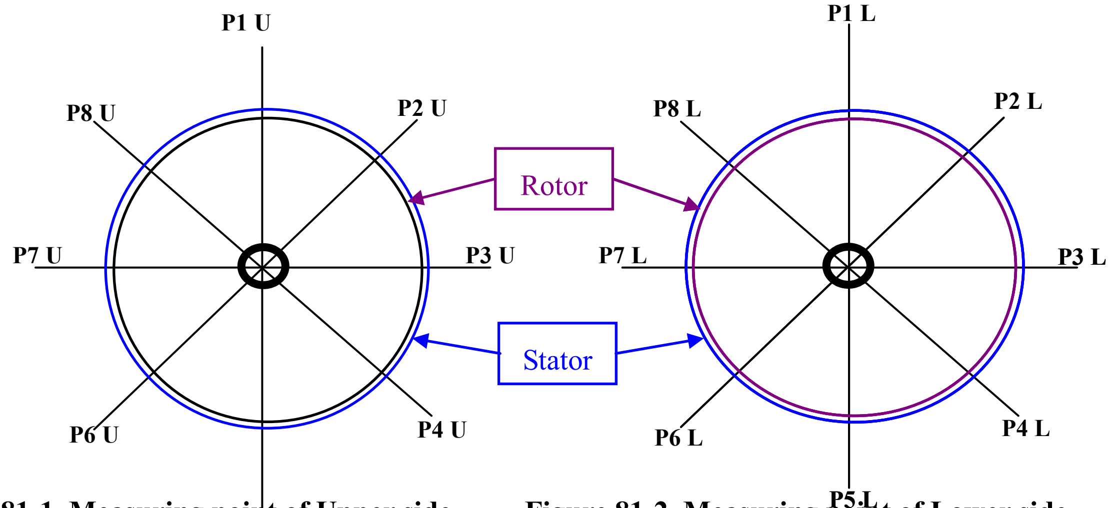


Figure 81-1 Measuring point of Upper side **Figure 81-2 Measuring point of Lower side**

* Measuring device: Inside micro meter/Equivalent measuring device

(Reference Documents)

- 2-1-7 in No.48NL/KHKT, measurement of the Air gap.

Article 82. Dielectric loss angle

1. The purpose of this measurement must confirm an initial characteristics of the dielectric loss angle (Tan δ) of stator windings. The initial measuring values must be used for judgment of the insulation deterioration for the insulation materials in the future.

(1) First of all, a measuring of circuit of Tan δ must be carried out by an insulation resistance measurement (IRM) for confirmation before and after measuring, which is performed after separating all connecting circuit into the stator winding from outside .

(2) The measurement must be able to be performed whichever for the three (3) phases or shingle phase, however, in case of measuring each shingle phase, other two (2) phases must be measured without grounding. And other conductors of devices and/or equipment with bus bars which are separated for all connecting circuit except measuring winding must be grounded completely. Especially, the filed winding must be grounded between slip rings with short circuit, and also the main shaft must be grounded completely.

(3) Before connecting the testing lead wire to the stator winding to be tested, testing equipment must be capable to generate the testing voltage which must cause no trouble.

(4) After connecting the testing lead wire to the stator winding to be tested, test voltage must be increased by gradation to maximum testing voltage which is kept for few seconds and stop to zero voltage.

(5) After that, Tan δ test is carried out by measuring one (1) of the Rated voltage (e.g. rated voltage $/\sqrt{3}$).

2. The target value for Tan δ of stator windings must be less than 3%.

-Dielectric loss angle (Tan δ) test is carried out with Schering bridge method.

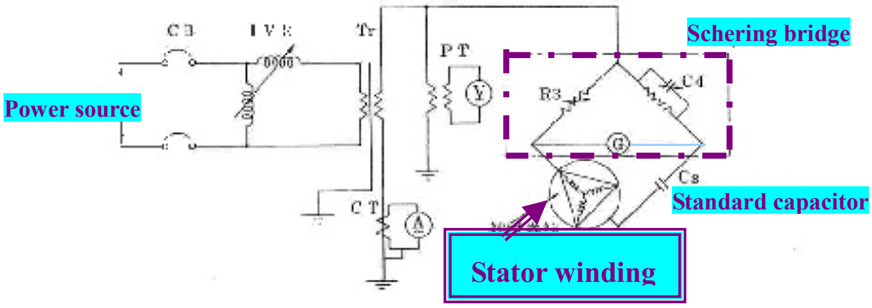


Figure 82-1 Example of Measuring Circuit (a)

-Dielectric loss angle (Tan δ) test is carried out with Tan δ meter.
(in case of connecting low voltage side)

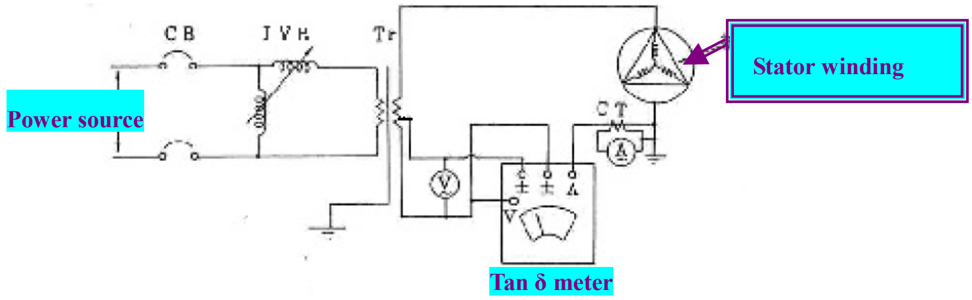


Figure 82-2 Example of Measuring Circuit (b)

Article 83. *(Deleted)*

Article 83-a1 Characteristic measurement of excitation system

< The provisions of this article must refer to Article 169 of Section 3 in Part 4>

(Additional Guideline for Excitation system of Part 3 Hydro power plant)

The Characteristic measurement of excitation system must be carried out for major items as follows;

(1) Performance determination of voltage detector
The out-put of the voltage detector must be confirmed to have a linear within applying range of the voltage, and detection accuracy sufficiently.

(2) Performance determination of DC constant voltage equipment
The DC constant voltage equipment which is power source for Automatic Voltage Regulator, (AVR) must be confirmed to operate correctly.

(3) Performance determination of an amplifier
The gain of the amplifier must be confirmed to comply the setting value for the gain of amplifier mostly.

(4) Performance determination of pulse phase shifter
The pulse phase shifter must be confirmed that the phase of gate pulse is suitable for out-put

signal of the amplifier and then the wave of the pulse is normal.

(5) Performance determination of thyristor rectifier
The thyristor rectifier must be confirmed abnormality by the transportation.

1) The control of the field out-put must be confirmed to operate the increase and decrease of input signal of the pulse generator.
2) The wave of field voltage measured by synchoscope must be confirmed that the all wave peak values are equal and all phases are ignited.

(6) Measurement of voltage adjusting range
The voltage setter, (90R) must be confirmed to operate correctly and to keep with the design value of the specification.

(7) Measurement of field voltage (current) adjusting range
The setting device for field voltage & current; (70E.R) must be confirmed to operate correctly and to keep within the design value of the specification.

(8) Static performance determination of reactive power adjusting devices
The detection and arithmetic units for adjusting control of reactive power (Automatic Reactive power Regulator: AQR & Automatic Power Factor Regulator: APFR) must be confirmed the specification of each performance and to keep within the design value.

(9) Performance determination t of limiting Voltage /Frequency
The detection and arithmetic units for Voltage / Frequency (V/F) must be confirmed the each performance to sufficient the specification and the function correctly.

(10) Performance determination of limiting Over current, Under & Over voltages
The detection and arithmetic units for over-current limiter, under & over-excitation limiters, (OCL, UEL & OEL), must be confirmed the each performance to sufficient the specification and the function correctly.

(11) Protection device operation test
The function of protection device must be confirmed operation according to the sequence control correctly.

(12) Performance determination of power system stabilizer
The function of power system stabilizer (PSS) must be confirmed the operation according to the design correctly.

(Reference Documents)

- IEEE Std 421-1-2007,. Definitions for excitation systems for synchronous machines

Section 2 Turbine/Pump-Turbine

Article 84. Hydraulic turbine system operation test

1. Wicket gate operation test

(1) By opening and closing operation, servomotor pressure must be measured by pressure gauge. Closing and opening time of servomotor stroke and closing property of servomotor must be measured at dry condition.
The both opening and closing times of the wicket gate operation device must be set out by the distribution valve or load limiter, etc,.

Opening and closing pressure of servomotor must be constant except at start and stop motions.

Opening and closing time of servomotor stroke and closing characteristic must be kept within design value.

(2) The servomotor stroke must be adjusted to a closing characteristic and opening and closing time of the auxiliary and main servomotors must be measured.
The characteristic of nonlinear closing of the main servomotor must be adjusted and measured by oscilloscope with stopwatch.

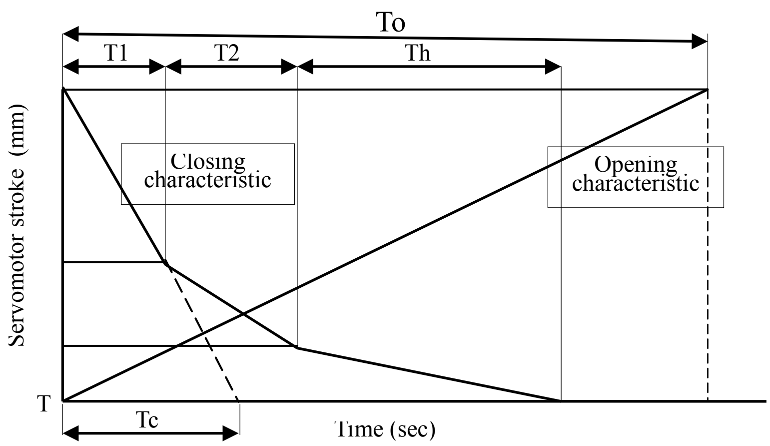


Figure 84-1 Example of Characteristic of nonlinear closing (Servomotor)

Table 84-1 Nonlinear closing time and Opening time

Time	Description	Time (sec)	Stroke (mm)
T1	1st closing time		
T2	2nd closing time		
Th	Buffer closing time		
Tc	Equivalent closing time		
To	Opening time		0 ~ full

2. Governor control characteristic test

(1) Input voltage and current of control unit must be set at the design value and change their values between the parameters of maximum head to minimum head.

(2) The governor control characteristic test must be carried out for all devices and equipment to be applied to the governor; e.g. immovable area, adjusting area of speed, adjusting area of permanent speed droop, detecting device of revolving speed, etc,

3. As the result, the characteristics of no-load opening, opening position of servomotor and load limiter depending on each output must be confirmed and kept within design value.

Article 85. Inlet valve operation test

1. Inlet valve sealing test

After installation of Inlet valve, sealing mechanism of upper stream side and down stream side must be confirmed for obtaining proper opening and closing pressure by using oscilloscope or pressure meter.

As the result, sealing mechanism must be operated without abnormality under the design value.

2. Inlet valve opening and closing test

Opening and closing pressure and operating time must be measured using pressure meter / gauge or oscilloscope with stopwatch.

This test must be performed after and before water injection in penstock.

As the result of test, operation mechanism must be moved smoothly at full stroke under the design value.

3. Measuring leakage water of inlet valve

After sealing of upper and lower side, the leakage water from drainage pipe of upstream side must be measured. The lower stream side, the leakage water must be measured at drainage pipe on casing. The leakage water must be checked with measuring time.

4. As the result of measurement, the leakage water quantity must be kept within design value.

* Measuring device: 1. pressure meter or oscilloscope with stopwatch.
2. Water measuring tank for drainage water.

Section 3 Auxiliary Equipment of Turbine/Generator

Article 86. Auxiliary equipment operation test

1. Auxiliary equipments are composed of oil supply system, water supply system and air supply system.

For smooth operation of generator, hydraulic turbine, following tests must be executed;

(1) Non-destructive test, hydraulic pressure test or other necessary test,

(2) Continuous operation test for pumping motors and compressor,

(3) Confirmation of safety valve operation,

(4) Confirmation of air tank and oil pressure tank capacity,

(5) Operational tests of mechanical brakes and rotor jacking device,

(6) Functional tests of electrical protection system; i.e. all alarm and tripping signals,

(7) Functional tests of turbine generator control system,

(8) Functional tests of air cooling system,

(9) Check of calibration and correct operation of all limit switches, thermometers, flow relays, pressure switches, switchgear mechanisms and other devices,

(10) Ancillary power system,

(11) Telecommunication system.

2. As the result of the inspection at operation test, capacity for each auxiliary equipment and the performance must satisfy the design value.

Article 86-a1 Neutral grounding equipment test

1. The neutral point of the generator must be earthed through following two (2) methods normally.

   (1) Single phase pole transformer grounding scheme,

   (2) Resistance grounding scheme.

2. The following items must be tested for each grounding scheme.

   (1) Single phase pole transformer grounding scheme.

      1) Characteristic test of Neutral grounding transformer (NGT):
      Dry type epoxy resin molded transformer of self-cooled type

      2) Characteristic test of protection equipment with secondary resistance,

   (2) Resistance grounding scheme.

      1) Characteristic test of Neutral grounding resistor (NGR),

      2) Characteristic test of protection equipment with current transformer,

(Reference Documents)

- IEC60076-11 Power Transformer

Article 86-a2 Fire extinguisher system test

1. A sufficient number of smoke and temperature detectors must be assembled on the both end of winding of generator. The fire extinguisher system must give a alarm when the temperature of winding exceed 150°C and indicate its location. When the temperature of winding exceed 200°C, the system gives alarm again, and the signal can connect to unit shutdown circuit with operating differential relay (87) of generator.

2. Fire extinguisher system for generator is two (2) methods, e.g. Water and Gas (CO_2) supply systems.

Section 4 Power Plant Equipment (PPE)

Article 87-a1 Operation control system test

< The provisions of this article must refer to Article40 of Section 4 of Chapter 4 in Part 2.>

(Refer to Vol.4 Part 4, Chapter 4 Article 91 Automatic start and stop tests)

(Refer to Vol.4 Part 4, Chapter 4 Article 93 Changeable operation mode)

Article 87-a2 Protective device test

< The provisions of this article must refer to Article 40 of Section 4 of Chapter 4 in Part 2.>

Article 87-a3 Switchgear operation test

< The provisions of this article must refer to Article 36, Section 4 in Part 2.>

Article 87-a4 Main circuit test of generator

< The provisions of this article must refer to Article 28~30, 34 and 64, Section 3 in Part 2.>

(Additional Guideline for Main circuit of generator (Part 3 Hydro power plant)

1. The main circuit between generator and step-up/main transformer for the generator/generator-motor is applied two (2) methods normally, such as, isled/insulated phase bus (IPB) or power cable (Oil field cable (OF cable) or Cross-linked polyethylene (XLPE) insulated vinyl sheath cable (CV cable)) with circuit breaker (CB), disconnecting switch (DS), voltage transformer (VT), current transformer (CT), etc,.
2. Closed bus-bar is separated IPB type for high voltage, large current and bus-duct type of phase division for small current.
   (1) Main circuit test of IPB type
      1) Visual inspection for bus-ducts, conductors, supporting insulators, earth bar of bus-ducts, etc.,
      2) Cleaning for supporting insulators, bus-ducts, etc.,
      3) Measurement of insulation resistance,
      4) Withstand voltage test (with generator.)

Article 87-a5 Overhead traveling crane

1. Running-in-trails with load and without load including inching operation test for the hoisting and lowering direction and/or the vertical movement;
   (1) Deflection of the main bridge girders: Test load at 125% of rated capacity. (Deflection of the bridge girders must be measured and compared with the guaranteed value and rated load test must be performed for the purpose of checking the safety only),
   (2) Brake operation tests with maintaining load,
2. All electrical measurements must be performed during operation tests mentioned above.

(Other elevating machinery may be same test as above, mostly.)

Article 87-a6 Main transformer test

1. Main transformer for the pumped storage power plant is applied in the both ways for the step-up and step-down voltages of the generating operation and pumping operation (motoring mode) respectively, with tap-changer equipment installed high-voltage side.

< The provisions of this article must refer to Article 27 in Part 2.>

Article 87-a7 High voltage power cable /bus duct test

< The provisions of this article must refer to Article 64, Section 3, Chapter 6 in Part 2.>

Article 87-a8 Switchyard equipment test

< The provisions of this article must refer to Section 4 Chapters 4, 5 and 6 in Part 2.>

Article 87-a9 Fire extinguisher system test

1. Automatic fire alarm system and fighting system
   In case of the fire extinguisher system with automatic water spray system installed in the powerhouse, the inspection or test must be executed for the following major components;
   (1) Fire alarm sensors, e.g. temperature detectors, smoke detectors, smoke beam detectors, etc.,
   (2) Strainers for water spray,
   (3) Control cabinets for the automatic water spray system,
   (4) Auto water spray system, etc.
2. Fire hose reel system
   The water source from the water supply pipes must be connected to the fire nose reel boxes and water supply fountains of the powerhouse.
   (1) Fire house reel boxes,
   (2) Fire fighting fountains,
   (3) Nozzle.
3. Potable and mobile extinguishers
   The required number of potable and mobile fire extinguisher with carbon dioxide, powder, etc., must be provided in the powerhouse.
   The carbon dioxide fire extinguishers must be in accordance with NFPA 12.
4. Fire barrier doors
   The purpose of fire barriers must be to limit the extent of the fire associated smoke and gasses.
5. Corrosion protection and painting
   The corrosion protection of the equipment i.e. surface preparation and paint application must be carried out.
6. Site tests
   The site tests must be executed two (2) stages, normally, as following;
   (1) Preliminary tests
   (2) Commissioning tests

(Reference Documents)

- BS3116-4 British Standard,
- The Codes 70 to 72, 90A of the National Fire Protection Association (NFPA) USA
- TCVN 5738: 1993 and TCVN 2622: 1995

Chapter 4 Completion Inspection

Article 88. Inspection document (Documentation)

< The provisions of this article must refer to Article 77 in Chapter 3.>

Article 88-a1 Insulation resistance measurement

< The provisions of this article must refer to Article 79 in Chapter 3.>

Article 89. Initial operation/run

The test must be carried out by opening of inlet valve and by a little opening of wicket gate for the initial run soon after confirmation of starting unit, and the wicket gate and inlet valve must be closed.

(1) As the result of initial run, it must be confirmed whether there is no abnormality on contacting between rotation and static parts, noise, foul smell, bearing temperature, and vibration with axial swing.

(2) After that, the turbine generator must be operated till the rated speed gradually to proceed with the test step-by-step carefully taking temperature of each bearing into consideration.

(3) After finishing measuring and confirmation of those situations mentioned above, the machine must be stopped by braking operation, manually.

(4) In case of pure pumped storage power station which does not have water for testing in the upper poundage, the initial operation/run of pump/turbine is carried out applying a starting system of the pumping direction.

(5) If the pure pumped storage power station has a water filling-pump for penstock and upper poundage, the test is carried out for initial operation/run from a direction of the generating mode after filling water to penstock and upper poundage.

Article 90. Bearing operation/run

1. Through continuous operation of the turbine generator under each revolving speed of 25%, 50%, 75% and 100% of rated speed by opening of inlet valve and opening of wicket gate, it must be confirmed until the bearing temperature saturate for each step taking no abnormality temperature rise, vibration, axial swing, noise, leakage water, leakage oil and bearing oil level, etc., into consideration.

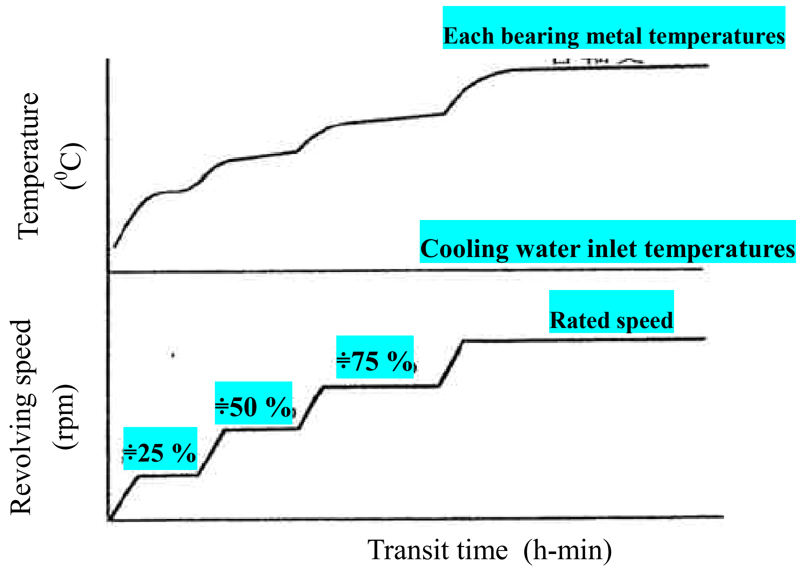


Figure 90-1 Example of Bearing operation/run

2. In case of pure pumped storage power station, the bearing operation/run of pump/turbine must be executed applying a starting system of the pumping direction.
3. The temperature of each guide and thrust bearing metals and generator windings must be measured with spare search coil installed in each guide and thrust bearing metals and generator windings.

Article 91. Automatic start and stop tests

1. Before starting this test, automatic synchronous device must be checked. Starting operation, rated load and stop operation must be controlled from generator control board based on the control block diagram of each operation mode.
2. Automatic start tests must be carried out to take a designated load of generator which is operated from starting to paralleling-in to the power system, automatically, by the control of master switch (#1) and load control switch (65P).
3. The major operating time and indicator of generator must be measured and confirmed for each step in accordance with the control block diagram of each operation mode.

<e.g.>

a. Major control items of generating mode are as follows;

(a) Unit :Standstill – Preparation :Complete – By-pass valve : Open – Inlet valve: Open – Wicket gate : Open (Starting position) – Unit: Start – Field circuit breaker: On (Speed > 90%) – Excitation control : Start – Automatic synchronizer : On (Generator voltage > 90%) – Generator circuit breaker : Close – Generating Operation (load)

(b) Generating Operation (load) – Wicket gate : Close – (No load position) – Generator circuit breaker : Open – Excitation control : Stop – Field circuit breaker: Open (Generator voltage ≈ 0%)– Inlet valve: Close – By-pass valve : Close – (Speed < 50%) – Electrical brake : On – Excitation control : Start – Field circuit breaker: On – (Speed < 20%) –

Mechanical brake : On – Unit : Stop – (Speed < 0%) –Mechanical brake : Off – Excitation control : Stop – Field circuit breaker: Off – Electrical brake : Off

b. Major control items of Pumping mode (by SFC) are as follows;

(a) Unit :Standstill – Preparation :Complete – Draft water depressing : Compete – Field circuit breaker: On– Excitation control : Start – SFC control : Start – Unit: Start – *(Speed > 90%)* –Automatic synchronizer : On (Generator voltage > 90%) – Generator circuit breaker : Close – SFC control : Stop – Draft air releasing: Complete – Priming pressure: Established – By-pass valve : Open – Inlet valve: Open – Wicket gate : Open – Pumping Operation (Optimum opening position of wicket gate).

(b) Pumping Operation – Wicket gate : Close – (No input power position) – Generator circuit breaker : Open – Excitation control : Stop – Field circuit breaker: Open (Generator voltage ≈ 0%)– Inlet valve: Close – By-pass valve : Close – (Speed < 50%) – Electrical brake : On – Excitation control : Start – Field circuit breaker: On – (Speed < 20%) – Mechanical brake : On – Unit : Stop – (Speed < 0%) –Mechanical brake : Off – Excitation control : Stop – Field circuit breaker: Off – Electrical brake : Off

4. As the result of this inspection, sequential control must be controlled without abnormality under the design value for operating time, operating machine and indicating devices of each step, completely.
5. In case of pumped power station, it is necessary to confirm the same test mentioned above and a changing control for each mode in accordance with changeable operation mode.

(Refer to Article 93 Changeable operation mode of Chapter 4 in Vol.4)

Article 92. Load and input rejection tests

1. The purpose of the load rejection test is to confirm shifting of the generating operation to the no-load operation after load rejection without abnormality in penstock pressure, revolving speed and generator voltage.
2. Operation of the load rejection is to shut down each unit during generating operation at each condition of 1/4, 2/4, 3/4 and 4/4 load. In case of the load rejection for the plural units connected to the same penstock line, it is recommended that one case is to reject the both units at same time and the other case is to reject the both units one by one with time lag. (for reference)
3. This test must be carried out at the normal, maximum and minimum head for each load condition. However, it is possible to delete the load rejection test for some condition of the normal and minimum head except the maximum head in accordance with discussion between Owner and Manufacture.
4. Before the load rejection test, the revolving speed, generator voltage and power factor must be kept at rated values as much as possible. And all control equipment, such as AVR, control device of over voltage, governor, etc. must be set in normal condition.
5. Each load and input rejection tests must be executed to start next test after stabilizing water level in the serge tank.

6. Each test must be conducted to measure each mater for operating and fluctuating condition of wicket gate, penstock pressure, revolving speed, generator voltage, etc,. and measured by oscilloscope.
7. The deflecting value of upper cover of turbine must be measured at both of the no-load and load rejections.
8. Input rejection test in the pumping mode must be executed
9. As the result of this test, hydraulic pressure rise of penstock, revolving speed and generator voltage must be kept within design values, which must be confirmed by momentary speed variation *(ΔN),* momentary pressure variation *(ΔP) or* maximum (minimum) water pressure value *(P_{max}. P_{min}.),* generator voltage variation *(ΔV)*,etc.. It must be confirmed that there is no abnormality and transferred the unit to no load operation smoothly.

Article 93. No load no excitation test

1. During generator normal operation, by operating protection relay for no load no excitation under the sequential control, it must be confirmed whether the operation of unit controller and excitation equipment ~~is~~ are changed to no load no excitation mode automatically.
2. Sequential control must be confirmed of no abnormality during changing generator operation.

Article 93-a1 Characteristic test of Generator

The characteristic tests of generator must be carried out to measure the following major items after finishing a phase rotation test, voltage established test, voltage adjusting test, etc,.

1. No load saturation characteristic test

(1) The generator is rotated at the rated speed.

(2) DC current of the field circuit gradually increases.

(3) Measuring the field current and terminal voltage up to 120 % of the rated voltage.

(4) The no load characteristic and balance of line voltage must be kept within the design value.

(5) The measurement of the no load saturation characteristic must be executed by the generator voltage control of one (1) way only because the no load saturation characteristic is including hysteresis characteristic.

<i.e.> In case of no-load measurement testing of Generator, the test must be carried out to take a characteristic curve of relationship between a terminal voltage and field current of the generator during the no-load operation with the rated speed.

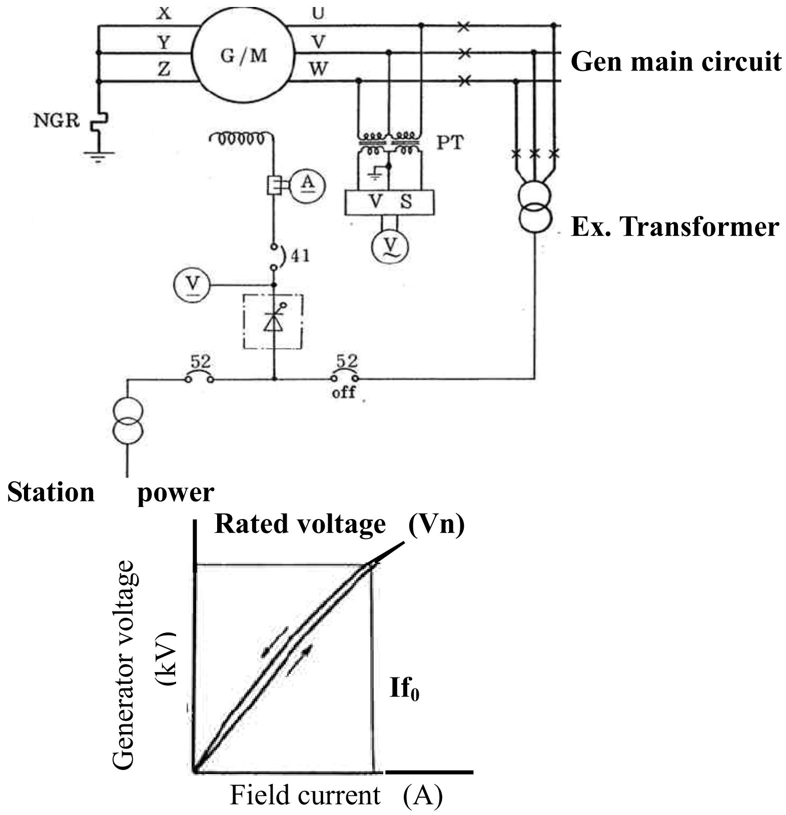


Figure 93-a1-1 Example of No load saturation characteristic test

2. Axial voltage measurement

The shaft current preventing device must be provided normally for all generators which are specified in the Technical Specifications.

(1) The axial voltage must be measured at the rated voltage under no load saturation characteristic test.

(2) The voltage must be measured between upper bearing and lower bearing **(V1)**, upper bearing and earth **(V2)**, and lower bearing and earth **(V3)**, as follows.

(3) Axial voltage must be measured when output terminal voltage up to the rated voltage.

(4) The measured voltage must be confirmed of no- abnormality comparing with normal condition.

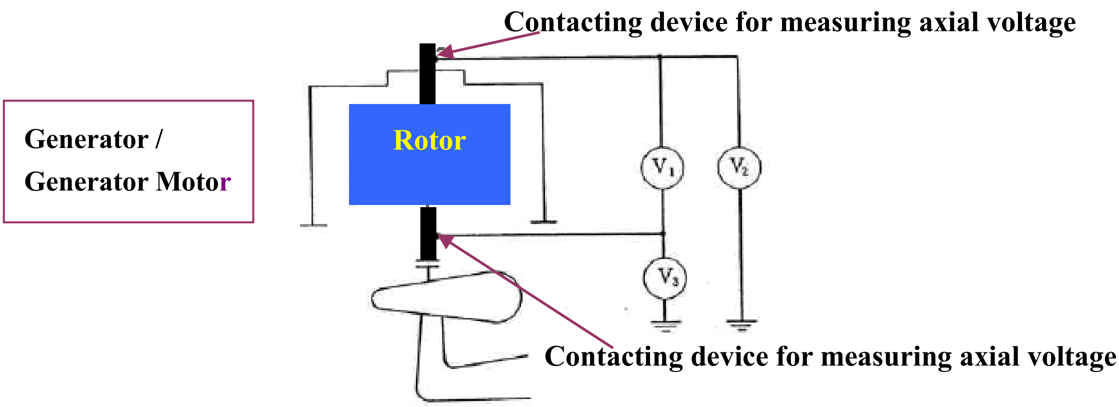


Figure 93-a1-2 Example of Axial voltage measurement

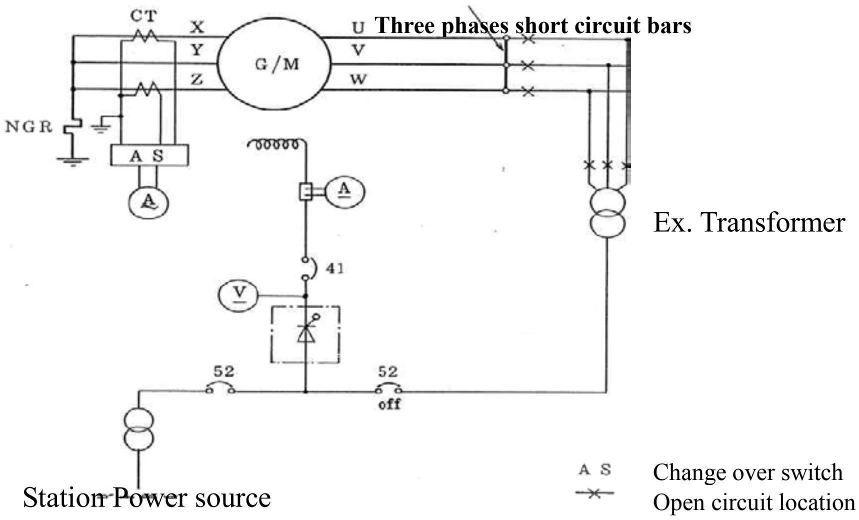
(Reference Documents)

- 2-11-11 in No.48NL/KHKT.

(Reference information: Shaft current preventing device)

1. Suitable preventing measures must be taken against burning of the bearing metal due to the shaft current.
2. Adequate insulation must be provided at the base of the upper bracket. In addition, perfect insulation must be provided for cooling water pipes, oil pipes and pressure conduits for thermometers, which may conceivably form closed circuits, if necessary. The insulation must be ensured by placing the two(2) insulators in series for each circuit. For confirming the goodness of the insulation by measuring the shaft voltage and insulation resistance, the wiring must be provided up to the suitable places. The position and construction of such insulation must be clearly indicated in the drawings.
3. Three phase short circuit test
   (1) Test method is to separate between generator and bus circuit at outlet terminal of stator coil or primary side of circuit breaker.
   (2) Generator side is short circuited at outside of stator coil.
   (3) The generator is rotated at rated speed and DC current is charging in excitation circuit.
   (4) Measuring field current and armature current reach to 100% of rated armature current.

<i.e.> In case of short-circuit measurement testing of Generator, the generator bus circuit must be connected by the short-circuit copper bar for the three-phases line-leads/conductors of the main generator circuit. And then, the test must be carried out to take a characteristic curve of relationship between armature current (short-circuit current) and field current of the generator.



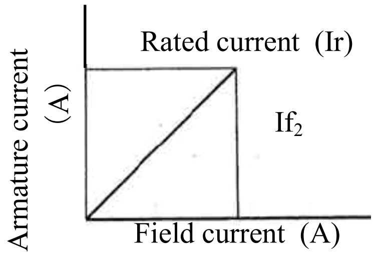


Figure 93-a1-3 Example of Three phase short circuit test

(5) As the result, the values of short circuit ratio and synchronous impedance must be kept within design value.

(6) Generator constants must be confirmed in accordance with the characteristics test of generator, such as no-load open-circuit test, Three-phase short circuit test, sudden three-phase short-circuit test, etc,.

Reference information:

The reactances , Xd , X'd , X''d , X'q , X"q , are identified as following;

(a) Xd It is derived from "No-load open-circuit test and three-phase short circuit test.

(b) X'd , It is derived from "Sudden three-phase short-circuit test. Or, it is derived from "Applied voltage recovery test" which is a "Type test "of "Sudden three-phase open-circuit test.

(c) X''d , It is derived from "Sudden three-phase short-circuit test or, it is derived from "Dalton-Cameron method", or, "Applied voltage recovery test".

(d) X'q , It is derived from "Low slip test". However, It is not provided in IEC.

(e) X"q It is derived from"Applied voltage test", or "Dalton-Cameron method". However, it, normally, is not carried after-installation test because of demanding test for generator at site, such as, "Sudden three-phase short-circuit test", and /or "Sudden three-phase open-circuit test" which are carried out on "Type test".)

(Reference Documents)
- 4 in IEEE Std 115 – 1995, Test Procedure for Synchronous Machines, Dielectric and partial discharge tests
- 11.1.2 in IEC 600034-2 (2007&2010), Rotating electrical machines, Part 2-1 Standard methods for determining losses and efficiency from tests, Part 2-2 Specific methods for determining separate losses of large machines from tests-Supplement to IEC 60034-2-1
- 2-1-9 in No.48NL/KHKT.

4. Excitation system operation test
   The operation tests for excitation system must be carried out for major items as follows;
   (1) Measurement of voltage adjusting range : 90R
       The voltage adjusting range (90R) must be confirmed in relation between each setting location and generated voltage at the no load operation of generator with rated speed, which are kept within design value.
   (2) Indicial response test :
       The dynamic characteristic of voltage control must be confirmed at the operation of no-loads.
   <i.e.> It is input to voltage output side of stepping purse during operation condition at no-load, rated speed and rated voltage.
       The result of time measurement till stability must be shortened within about 2 cycles.
   (3) Test of reactive power adjusting device :
       The adjusting control for reactive power must be carried out smoothly by automatic reactive power regulation (AQR).
   (4) Test of generator voltage establishment :
       The test of generator voltage establishment must be confirmed to establish the generator voltage smoothly by preliminarily exciting device which is operated by a speed detecting relay (#13).

Article 94. Emergency stop test (heavy electrical trouble)

1. By short circuiting the contacts of protection relay (e.g. generator differential relay, #87) for emergency stop, the sequential control of emergency stop must be checked.
2. Generator must be safely stopped complying with designed sequential control, i.e. generator circuit breaker: off, wicket gate: close, inlet valve: close, stopping turbine completely, in accordance with sequential control correctly.

Article 95. Quick stop test (heavy mechanical trouble)

1. By short circuiting the contacts of protection relay (e.g. hydraulic drop of pressure oil relay, #63Q3) for quick stop, the sequential control of quick stop must be checked.
2. Generator must be safely stopped complying with designed sequential control, i.e. wicket gate: close, generator circuit breaker: off, inlet valve: close, stopping turbine completely, in accordance with sequential control correctly.

3. In case of pumping mode, if the same trouble occurred as item 1, an emergency stop is=executed by hydraulic drop of pressure oil relay, (#63Q3).

Article 96. Load and input tests

1. Operation of the generator and pumping must be continued until the bearing temperature saturated at rated load condition, in which the revolving speed, generator voltage, load and power factor are kept at the rated values.
2. The measuring in the test must be also continued until saturation for temperature of generator windings and main circuit lines (e.g. IPB, Power cable, etc.), main transformer together with vibration of turbine and generator, leakage oil and water, noise, each temperature of each cooling water and condition of auxiliary equipment
3. As the result, it must be confirmed of continuous rated load and input operation without abnormality.

(Reference Documents)

-IEC 60034-4 (1985). Rotating electrical machines, Part 4 Amendment No.1

Article 97. Output test

1. As the method of this measurement, wicket gate servomotor stroke must be changed to measure the operation scope and output limitation under the load condition for each water level of maximum, rated, minimum heads.
2. During output test, the power factor must be preferable to keep the rated power factor. If it is difficult to keep the rated power factor, a constant value of power factor must be kept. And the adjusting load must be carefully controlled only in one way, i.e. there must not be over control exceeding the setting value and must not control to opposite side during increasing or decreasing.
3. During output test, the relationship between the no-load opening of wicket gate stroke and the difference water reposing device must be confirmed for testing water level (net head).
4. As the result of this test under each load operation condition, it must be confirmed whether there is no abnormality in vibration, swing of axis and hydraulic pressure.

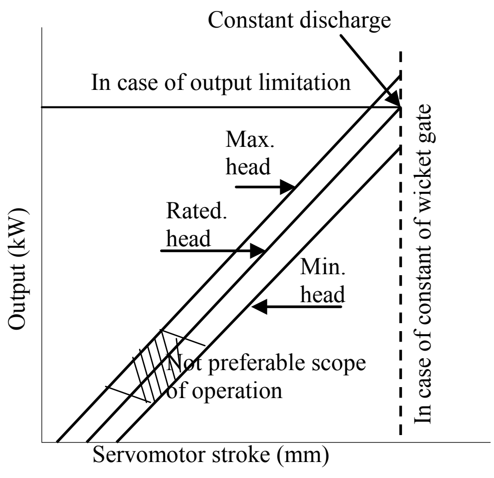


Figure 97-1 Example of Output test

Article 98. Pumping operation test

1. The pumping operation must be controlled and started under the stipulated starting method without time delay of starting equipment and stopped under the stipulated stopping sequence control without no abnormality.

(1) The major items of the pumping starting method are as follows;

1) Thyristor starting system,
2) Back-to buck (or Synchronous) starting system,
3) Directly coupled motor (or Pony motor) starting system,
4) Damper winding-reduced voltage starting system.

Recently, the combined system of the thyristor and back-to back starting is applied to the pumping starting system for the several units of pumped storage power plant.

Each pumping starting system have a different auxiliary equipment in accordance with a purpose of the starting method, therefore, a maintenance & operation manual must be prepared for each starting system base on the manufacture's instruction.

2. During this test, the synchronous condenser operation test must be also confirmed together with a test for the water depressing equipment without no abnormally.

Article 98-a1 Vibration measurement

1. The vibration of electrical machine must be measured at the mounting of the measuring point of the machine.
It is necessary to measure the vibration on the machine alone under properly determined test conditions without any influence from other equipment.

2. In the result of measurement, the vibration changes depending on the operation condition; therefore it must be compared with normal condition and its abnormality must be judged by the design criteria of the power plant.

3. The values of vibration are usually indicated to be 1/100 mm (0.01mm) for all (both) side of an amplitude, as follows.

Table 98-a1-1 Example of Vibration Values

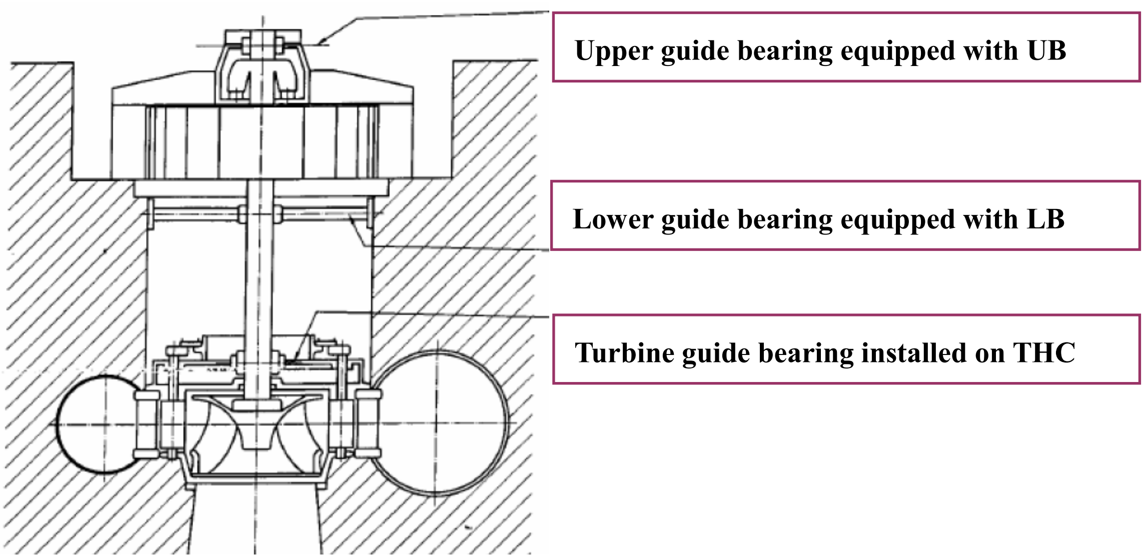
<table>
<tr><th rowspan="2">Revolving speed (min^{-1})</th><th rowspan="2">Type of generator</th><th colspan="2">Amplitude value</th><th rowspan="2">Shaft swinging (Reference value) *1</th></tr>
<tr><th>Upper bracket</th><th>Lower bracket</th></tr>
<tr><td rowspan="2">Lower 400 min^{-1}</td><td>Normal</td><td>15.0</td><td>2.5 → 5.0</td><td rowspan="4">Within 70 ~ 80 % for bearing clearance, metal temperature: not over 75 °C</td></tr>
<tr><td>Umbrella</td><td>15.0</td><td>10.0</td></tr>
<tr><td rowspan="2">Over 400 min^{-1}</td><td>Normal</td><td>10.0</td><td>2.5 → 4.0</td></tr>
<tr><td>Umbrella</td><td>10.0</td><td>7.5</td></tr>
</table>

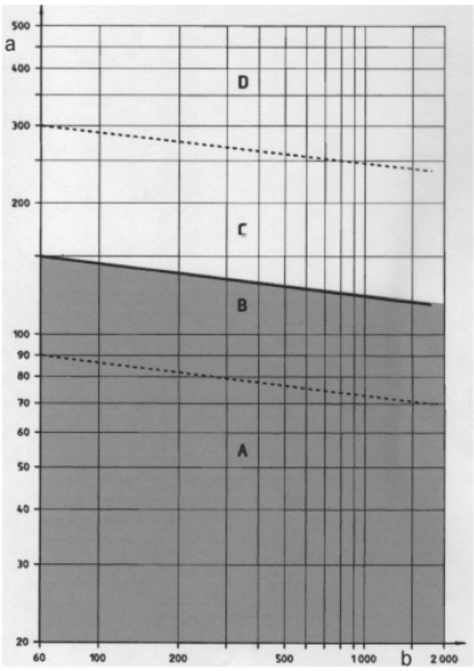
Note: *1 : The shaft swinging is measured at location of guide bearings during operating condition of rated revolving speed and rated output with in 75 °C of the bearing temperature.

4. Reference data of the International standard are as follows;

   (1) The maximum shaft vibration as measured near the turbine and generator guide bearings is within ISO 7919-5, zone “A” (Mechanical vibration - Evaluation of machine vibration by measurements on rotating shafts), when operating at rated speed, de-excited and any load.
   (2) Non rotating parts is within ISO 10816-5, zone “A” or zone boundary “A/B” (Mechanical vibration - Evaluation of machine vibration by measurements on non-rotating parts).
   (3) All components of the generator must be designed, constructed and balanced to avoid undue or harmful vibrations and resonances.

<e.g.> In case of vertical machine of conventional type (IM8421, IEC 60034-7), machine; upper guide bearing equipped with upper bracket (UB) installed upper the rotor, lower guide bearing equipped with lower bracket (LB) installed under the rotor, and turbine guide bearing installed on turbine head cover (THC).





ISO 7919-5:

a: Shaft maximum relative vibration displacement, (S_{max},μm)

b: Maximum service speed, (min-[1])

The vibrations on the rotating shaft of the unit must meet requirements of the ISO 7919-5,

Zone A: when the unit is operated in steady state conditions.

Zone C: For transient regimes (start, stop, quick and emergency shut downs), the values stated must apply.

Figure 98-a1-1 Example of Vibration test

(**Shaft swinging**: Refer to IEEE Std 1095 -1989 15.1.2)

5. Reference faction test: Overspeed test

    (1) The overspeed test is executed to examine a durable level of the bearing metals and a mechanical strength for rotating parts of turbine-generator. The level of overspeed and time are as follows in general.

No.	Type of Synchronous machine	Overspeed
1	All synchronous machine without below type	120 % of Max. rated revolving speed.
2	Auxiliary equipment to be connected directory to the main machine or turbine - generator, generator -motor by electrically or mechanically.	If no standard, it is a runaway speed, however, over 120 % of Max. rated revolving speed. *1
3	In case of execution of overspeed test for all type.	Testing time : 2 seconds

Note: *1: If an emergency protection relay of overspeed of 115% is installed, the overspeed of generator must be examined by overspeed of 115%.

(2) It is necessary to inspect completely for all inspection area and to consider protection wall.

(3) It is necessary to confirm, during testing without vibration, noise, temperature and anosmatic smell and smoke in the machine and behavior of the oil in the bearings.

(4) After testing, it is necessary to inspect completely whole situations of all area in which the variation occurred electrically and mechanically. And it is not allowed to find any permanent deformation, some trouble for normal operation and then the armature winding must be withstood the dielectric voltage test specified in the document.

(5) The overspeed test for the salient-pole synchronous machine is normally not necessary to be executed at site except the cylindrical-rotor synchronous machine. However, it is necessary to inspect in case of assignment or in case of decision after discussion between Owner and Manufacture.

(Reference Documents)

- IEEE Std.CP65-a56 20, Standardization of Conductor Vibration Measurements

- ISO 7919-5, 2005, Mechanical vibration – Evaluation of machine vibration by measurements on rotating shafts. Part -5 Machine sets in hydraulic power generating and pumping plants.

- ISO 10816-5, 2000, Mechanical vibration – Evaluation of machine vibration by measurements on non – rotating parts. Part -5 Machine sets in hydraulic power generating and pumping plants.

- TCVN 6962 / 2001 Vibration Standard,

- 2-11-11 in 48NL/KHKT,

Article 98-a2 Operating confirmation of power plant equipment

1. Though the major power plant equipment (PPE) in Section 4 has been executed to inspect / test before trial operation / run, they are finally inspected by visual check before starting and parallel-in of turbine / generator to the power system .

Article 98-a3 Trial operation/run

< The provisions of this article must refer to Article 174 of Section 3 in Part 4>

1. After successful termination of all commissioning tests, all units must be subject to a trial run period under the Contractor's supervision and responsibility.
2. During this period, Owner's personal must be made fully acquainted with the operation and routine maintenance of the equipment.
3. The trial run period must be two (2) months. After satisfactory performance tests of the equipment during commissioning tests and trial run period, a Provisional Acceptance Certificate (PAC) ["Certificate of Temporary Acceptance"] is issued by the Representative or Owner. On the date of issue of the PAC, the guarantee period begins.

Chapter 5 Periodic Inspection

Section 1 General

Article 99. General provision

1. Three types of periodic inspection

Three types of periodic inspections are stipulated in Technical Regulation Vol.5 as follows:

(1) Periodic Inspection for Flood Control
This periodic inspection is required for dams and spillways of hydropower plants pursuant to Article 14 of Decree No.72/2007/ND-DP, and related provisions are stipulated in Section 2 of Part 3 Chapter 5 in Technical Regulation Vol.5.

(2) Periodic Inspection for Dam Safety
This periodic inspection is required for safety of dams of hydropower plants pursuant to Article 17of Decree No.72/2007/ND-DP, and related provisions are stipulated in Section 3 of Part 3 Chapter 5 in Technical Regulation Vol.5.

(3) Periodic Inspection for Overall Power Plants Facilities
This periodic inspection is originally stipulated in Technical Regulation Vol.5 for overall hydropower facilities excluding dams and spillways which must follow the stipulation for the above two types of periodic inspections, and related provisions are stipulated in Section 4 of Part 3 Chapter 5 in Technical Regulation Vol.5.

2. Practice of periodic inspection

(1) Each type of periodic inspections is conducted by both ways of document examination and field inspection for all or some selected works. The details must refer to Section 2, Section 3 and Section 4 of this Chapter for the periodic inspection for flood control, periodic inspection for dam safety and periodic inspection for overall power plant facilities respectively.

(2) Each type of periodic inspection is conducted by a competent authority together with the plant owner and the competent authority is responsible to evaluate the result of inspections and notify

the evaluation result to the plant owner for taking appropriate actions depending on the evaluation results and the requirements stipulated in the relevant articles.

3. Evaluation criteria for results of periodic inspection

In paragraph 2. of this article, classification for results of periodic inspection is described. The Authority evaluates the results and may order change in frequency of inspection as stipulated in Article 100a-11. An interpretation of Table 99-1 is as follows.

Rating A: There is no nonconformance with the Technical Regulation Vol. 5, which means that hydro civil works are kept in excellent condition and that any problem may hardly occur even if frequency of inspection is expanded.

Rating B: Minor nonconformance is detected and desirable to be rectified, which means that the nonconformance may not affect function of the works even if it is left unrepaired immediately and that any problem may hardly occur even if frequency of inspection is expanded.

Rating C: Detected nonconformance is not serious but must be rectified before the succeeding periodic inspection, which means that the nonconformance may not affect function of the works immediately but it is desirable to rectify it so that it may not get worse.

Rating D: Detected nonconformance is serious, and must be rectified immediately, which means that the nonconformance may affect function of the works immediately if it is left unrepaired and that frequency of inspection must be shortened to see if the nonconformance is repaired correctly and it may not recur.

Article 100. Frequency of periodic Inspections *(Deleted)*

Section 2 Periodic Inspection for Flood Control

Article 100-a1 General provision

Article 100-a1 stipulates the provisions according to Article 14 of Decree No.72/2007/ND-CP.

Article 14 of Decree No.72/2007/ND-CP regulates inspection of a dam before and after the flood season as follows.

Article 14. Inspection of dam

2. *Periodical inspection prior to and after annual flood season:*
    a) *Each year, at the time prior to the flood season, it needs to carry out general inspection, assessment on dam stability; close coordination with Steering Committees on Flood, Typhoon Prevention of ministries, sectors, localities in order to prepare or update, supplement alternatives for protection of dam against floods, typhoons and protection of downstream areas against floods, typhoons.*
    b) *At time after termination of the flood season, it needs to carry out inspection in order to find out damages (if any); monitoring progress of outstanding problems of dam; drawing experience on protection against flood, typhoons; proposing measures and plans for repairing, overcoming such damages, outstanding problems;*
    c) *The time for inspection prior to the flood season and after flood season are specified as follows:*
        - *April and November for provinces in the Northern, Northern Central regions;*

- *April and December for provinces in Highland, Eastern South;*
- *August and January for Central Coastal areas.*

Article 10 of Circular No.34/2010/TT-BCT regulates inspection of spillway gates before the flood season as follows.

Article 10. Hydropower reservoir operation procedure

4. Trial test for gates of the structures

a, Procedure of dry test for gates is prepared by dam's owner depending on the characteristics of the structures and conduct this test at least once a year before the flood season. Repair works for the gates after dry test shall be finished before the annual flood season;

b, Procedure of wet test for gates is prepared by dam's owner. Depending on hydrological conditions and the characteristics of each structure, the gates wet test can be carried out by beginning of flood season but shall not affect to the downstream area when discharging water through the spillway.

Based on the above articles, frequency and items of the periodic inspection for flood control are provided in the following articles.

Article 100-a2 Frequency of inspection

Article 100-a2 stipulates the provisions according to Article 14 of Decree No.72/2007/ND-CP.

Each year prior to and after the flood season, periodic inspection for flood control must be carried out in accordance with the requirement in Decree No.72/2007/ND-DP.

The time for inspection prior to and after the flood season is specified as follows.

- Provinces in northern and northern central regions: April and November
- Provinces in highland and south eastern regions: April and December
- Provinces in central coastal areas: August and January

Article 100-a3 Inspection on dams

Details of inspection are provided as follows.

1. Appearance for concrete dams

(1) Settlement or horizontal movement of the dam which can be recognized by visual checking of alignment at the crest of the dam is not observed;

Inspectors of the Owner must observe the crest of a dam to see if any block is out of the alignment in vertical and horizontal directions. The extent of displacement which can be observed visually by a human's eyes would be significant, so in case such displacement is observed visually, the Owner must conduct detailed investigations to find the cause of the displacement and must consult with an expert to take measures, if necessary.

(2) Erosion which may affect the safety and stability of dam body is not observed at around abutment of the dam due to water flow;

Inspectors of the Owner must investigate around abutment of a dam to see if any part of the abutment is eroded. In case the extent of erosion is significant and it is expected that erosion may affect the safety and stability of dam body, the Owner must conduct detailed investigations to find the cause of the erosion and must consult with an expert to take measures, if necessary.

(3) Newly developed cracks or progress of existing conspicuous cracks, which exceed estimated number, is not observed on the dam and in the inspection gallery;

Inspectors of the Owner must investigate the surface of a dam and inside of an inspection gallery, if available, to see if cracks developed newly or the existing cracks progressed by comparing the present investigation results with the previous ones. Before starting the investigation, the Owner must prepare a standard which provides criteria for extent of cracks, their length and width, to be recorded. In case the extent of cracks is significant and it is expected that cracks may affect the safety and stability of dam body, the Owner must conduct detailed investigations to find the cause of the cracks and must consult with an expert to take measures, if necessary.

Allowable crack opening of concrete structures in view of durability and water proofing are as shown in Table 100-a3-1.

Table 100-a3-1 Allowable crack opening

Unit: mm

Allowable size of crack opening		Durability			Water proofing
	Environment[1)]	Strict	General	Mild	
	Other causes[2)]				
Need to repair	Big	> 0.4	> 0.4	> 0.6	> 0.2
	Middle	> 0.4	> 0.6	> 0.8	> 0.2
	Small	> 0.6	> 0.8	> 1.0	> 0.2
No need to repair	Big	< 0.1	< 0.2	< 0.2	< 0.05
	Middle	< 0.1	< 0.2	< 0.3	< 0.05
	Small	< 0.2	< 0.3	< 0.3	< 0.05

Note 1) Environment of concrete structures in view of rusting of reinforcing bars and other steel parts.

Note 2) Other causes mean the extent of damage to durability and water proofing of concrete structures, and evaluated by the following factors.

- Depth of cracks;
- Pattern of cracks;
- Depth of reinforcing bars embedded in concrete;
- Existence of paint on the surface of concrete;
- Material of concrete;
- Mixture of concrete; and
- Existence of construction joints of concrete.

An example of inspection criteria for cracks in a concrete dam is as follows.

1) Inspection of cracks

- ➢ Location and scale of cracks must be recorded on a drawing of a dam;
- ➢ Length and width of cracks must be measured; and
- ➢ A relation between depth of cracks and existence of water leakage must be recorded.

Instruments to measure cracks are as follows.

- − Length: A convex ruler, steel tape, etc.
- − Width: A ruler, crack gauge, etc.
- − Depth: A piano wire, ruler, etc.

All cracks visible to the naked eye must be recorded on a drawing of a dam. Regarding cracks with their width of more than approximately 0.2 mm, their width and length must be recorded. Based on the previous inspection records, cracks must be judged if their extent advanced or not.

Major points to inspect cracks are as follows.

a. For simple cracks
Length, width and depth of cracks must be measured and existence of water leakage must be inspected as shown in Figure 100-a3-1;

Major cracks must be recorded as “(M)” on a drawing to classify cracks; and

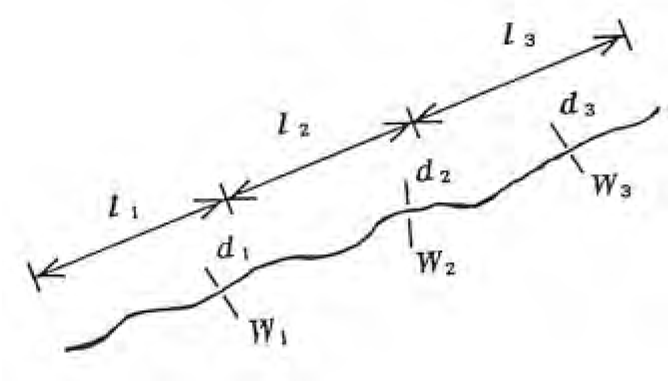
Cracks with water leakage must be recorded as “(L)”.

where,

l: Length of crack (m)

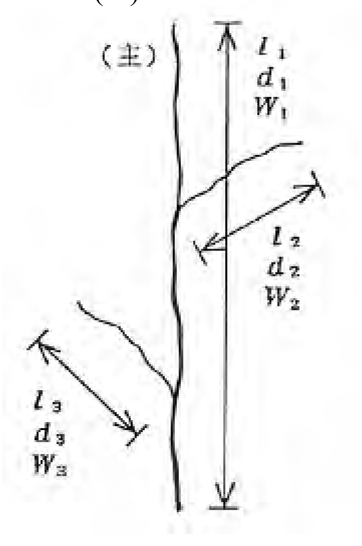
W: Maximum width of crack (mm)

d: Maximum depth of crack (cm)



Simple cracks

(M)



Branching cracks

Figure 100-a3-1 Typical cracks

b. For branching cracks
Branching cracks must be distinguished from major cracks;

Length, width and depth of cracks must be measured and existence of water leakage must be inspected as shown in Figure 100-a3-1;

Major cracks must be recorded as “(M)” on a drawing to classify cracks; and

Cracks with water leakage must be recorded as “(L)”.

2) Inspection of water leakage from cracks

- Location of water leakage from cracks must be recorded on a drawing of a dam;
- Extent of water leakage from cracks must be observed; and
- Quantity of water leakage must be measured, if possible.

3) Inspection of opening of joints

- Opening of joints must be measured and recorded on a drawing of a dam;
- Depth, extent of progress and existence of water leakage from cracks must be observed, if necessary; and
- Opening of joints must be evaluated considering influence of temperature.

Instruments to measure opening of joints are as follows.

- Extent of opening: A convex ruler, ruler, etc.
- Depth: A piano wire, ruler, etc.

All maximum opening of joints must be measured and extent of water leakage must be recorded, if any, as shown in Figure 100-a3-2.

where,

L_1: Length of a crack

W_1: Maximum opening in the crack of L_1 (mm)

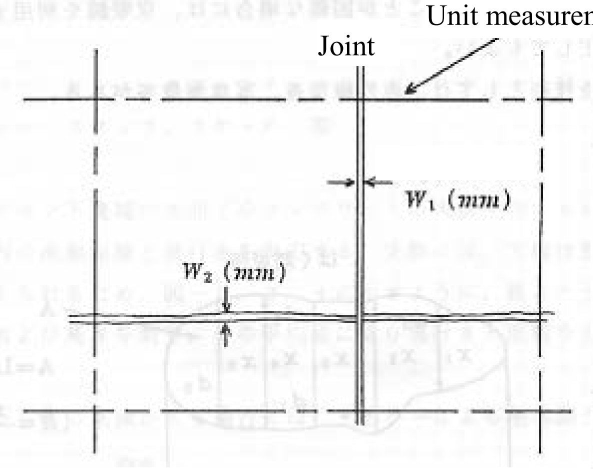


Figure 100-a3-2 Opening of joints

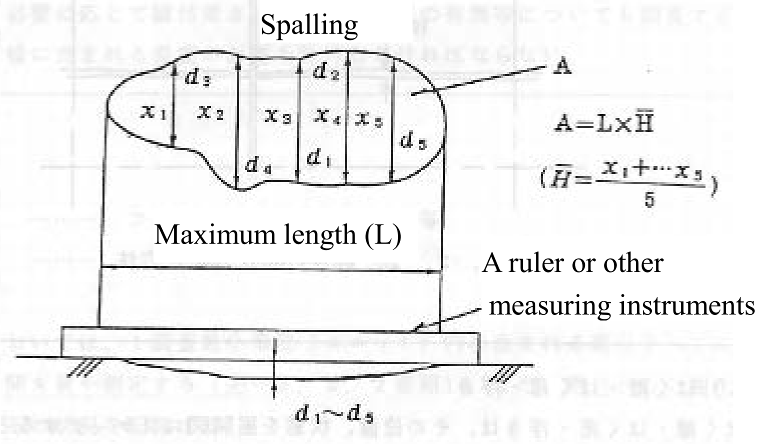


Figure 100-a3-3 Spalling

Records of opening of joints must be evaluated after compensation as shown in the following formula.

$\Delta W = -L \times \Delta T \times \alpha c$

where,

ΔW: Compensation of opening of joints

L: Length of a block of a dam body

ΔT: Difference of temperature from the previous measurement

Add "+" if temperature of this time is higher than the previous time and add "-" if temperature of this time is lower than the previous time. In using air temperature for compensation, air temperature must be measured in the early morning to eliminate influence of sunshine. Temperature of dam concrete can be measured at ay time.

αc: Coefficient of thermal expansion of concrete, it may be regarded as $1x10^{-5}$

4) Inspection of spalling (voluntary)

- Location and condition of spalling must be observed and recorded on a drawing of a dam; and
- Depth and area of spalling must be measured.

Instruments to measure spalling are as follows.

- Depth: A convex ruler, ruler, hammer, etc.
- Area: A convex ruler, steel tape, staff gauge, etc.

Depth and area of all observable spalling must be measured when more than one piece of spalling can be observed on the area subject to observation.

Depth and length must be measured at more than five locations of spalling to calculate depth and area as shown in Figure 100-a3-3.

An area of poor quality concrete due to a trouble in casting must be also measured for evaluation together with spalling area.

5) Inspection of frictional wear (voluntary)

Friction wear is a phenomenon that the surface of concrete is scraped off. It belongs to erosion and appears in the part where water with high velocity flows over such as spillway chute.

- Location and condition of frictional wear must be observed and recorded on a drawing of a dam; and
- Depth and area of frictional wear must be observed.

A method of measurement is same as that of spalling.

6) Inspection of scoring (voluntary)

Scoring is a phenomenon that holes are made on the surface of concrete. It belongs to erosion and appears in the part where direction and/or velocity of water flow change suddenly such as a stilling basin of spillway.

- Location and condition of scoring at the end of a spillway chute below the surface of water must be observed and recorded on a drawing of a dam; and
- Depth and area of scoring must be measured.

Instruments to measure scoring are as follows.

- Depth: A staff gauge, ruler, etc.
- Area: A convex ruler, steel tape, staff gauge, etc.

Area and depth of scoring must be measured on the area subject to observation.

Depth and length must be measured at more than five locations of scoring to calculate depth and area as shown in Figure 100-a3-4.

Measurement by divers must be conducted if a location subject to observation is located at deep water.

7) Inspection of neutralization (voluntary)
Neutralization is a phenomenon that alkalinity of concrete reduces due to intrusion of carbon dioxide. It is a kind of ~~belongs to~~ deterioration and appears in the surface of concrete in the dry condition.

The extent of neutralization for a spillway pier and other reinforced concrete structure of a dam, and not a dam body, must be inspected in the following way.

Depth of neutralization must be measured as follows.

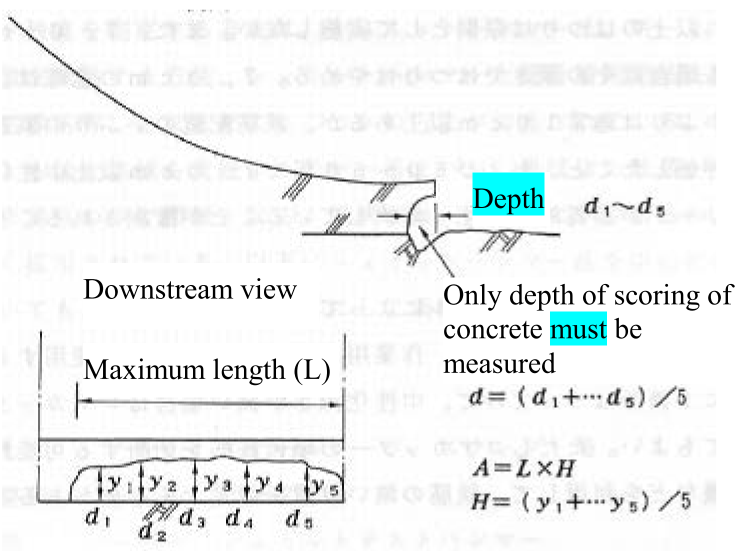
- Peel concrete off the surface;
- Spray a chemical reagent; and
- Measure an extent of neutralization from color of concrete.

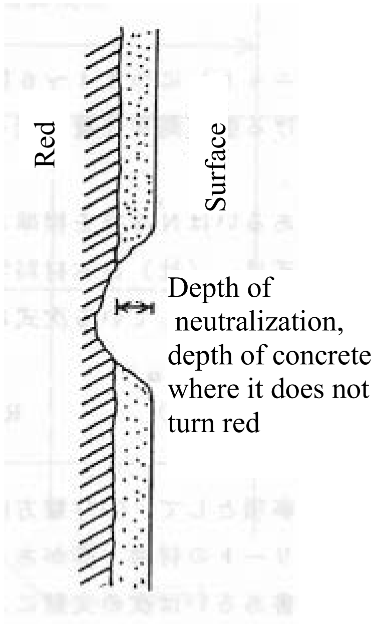
Instruments to measure neutralization are as follows.

- Measurement of location: A steel tape, staff gauge, convex ruler, etc.
- Peeling: An electric pick hammer, core cutter, etc.
- Chemical reagent: a phenolphthalein solution diluted with alcohol with a concentration of 1%
- Spraying: A spray

Depth of neutralization must be measured at six locations; namely at two locations on each of right and left side walls and at one location on each of upstream and downstream side walls of the spillway pier.

Depth of neutralization must be measured by depth from the surface, so concrete must be peeled off the surface and a chemical reagent must be sprayed on the peeled surface. Concrete where a chemical reagent is sprayed turns red if concrete has alkalinity, however, the concrete does not turn red if it is neutralized. Depth of neutralization can be measured by the depth where concrete does not turn red.





Concrete where the surface is peeled off must be filled with non-contraction mortar.

Figure 100-a3-4 Scoring **Figure 100-a3-5 Neutralization**

(4) Massive or deep deterioration of concrete due to the alkali-aggregate reaction or water quality of the reservoir or any other causes is not observed on the surface of the dam.

Inspectors of the Owner must investigate the surface of a dam to see if any massive or deep deterioration of concrete due to the alkali-aggregate reaction or any other causes have been developed. In case the extent of deterioration is significant and it is expected that deterioration may affect he safety and stability of dam body, the Owner must conduct detailed investigations to find the cause of the deterioration and must consult with an expert to take measures, if necessary.

Alkali aggregate reaction Erosion

Figure 100-a3-6 Typical deterioration of concrete

(5) Leakage from joints of concrete dam and seepage from drainage boreholes to reduce uplift is stable.

Inspectors of the Owner must investigate joints and drainage boreholes to see if quantity of leakage and seepage increased. For evaluating the investigation results, the Owner must prepare a standard which provides reference criteria of amount and property of leakage and seepage water based on design calculations and records obtained during construction stage and the initial period of operation stage. In case leakage or seepage water increased or decreased unreasonably or exceeded the reference criteria or showed turbidity or any change in quality, the Owner must conduct detailed investigations to find the cause of change in quantity or quality of the leakage and seepage and must consult with an expert to take measures, if necessary.

An example of inspection sheet is shown in **Table 100-a3-2**.

Table 100-a3-2 Inspection sheet of concrete dam
Inspection of joints

Name of dam : XX Dam Inspection date : yy/mm/dd

Joint No.	Location	Reservoir water level	Leakage from joint (l/min)	Remarks
XX	EL.YY	EL.ZZ		Water color, turbidity, or any other information to be recorded

Inspection of drain hole

Name of dam : XX Dam Inspection date : yy/mm/dd

Drain hole No.	Location	Reservoir water level	Seepage from drain hole (l/min)	Remarks
XX	EL.YY	EL.ZZ		Water color, turbidity, or any other information to be recorded

The Owner must record amount and quality of leakage from joints and seepage from drainage holes in a concrete dam at every periodical inspection and observe tendency of those amount and quality. In case amount or quality of leakage from joints and seepage from drainage holes changes unreasonably compared with that of the previous record, the Owner must conduct detailed investigation at the place in which such unreasonable change occurred.

2. Appearance for fill dams

(1) Deep or wide cracks or massive deteriorations which may affect the safety and stability of dam are not observed at the crest or the slopes of fill dam;

Inspectors of the Owner must investigate the surface of embankment to see if deep or wide cracks or massive deterioration developed newly or the existing cracks or deterioration progressed by comparing the present investigation results with the previous ones. For conducting the investigation effectively, the Owner may prepare a standard which provides reference criteria for extent of cracks or deterioration, their length, width, depth and extent, to be recorded. In case that the extent of cracks or deterioration is significant and it is expected that cracks or deterioration may affect the safety and stability of dam body, the Owner must conduct detailed investigations to find the cause of the cracks or deterioration and must consult with an expert to take measures, if necessary.

An example of inspection sheet is shown in Table 100-a3-3.

Table 100-a3-3 Inspection sheet of cracks for fill dam

Name of dam : XX Dam Inspection date : yy/mm/dd

Station No.	Elevation	Upstream or Downstream	Dimension of cracks	Photo

The Owner must record dimensions of cracks or massive deteriorations at every periodical inspection and observe growth of those cracks or deteriorations. In case those cracks or deteriorations grow significantly, the Owner must conduct detailed investigation at the place in which such significant change occurred.

(2) Sliding, erosion, sinkholes, bulging or uneven settlement is not observed at the crest or the slopes or toe of fill dams;

Inspectors of the Owner must investigate the crest, slopes and toe of embankment to see if sliding, erosion, sinkholes, bulging or uneven settlement is noticed by visual inspection. In case the extent of sliding, erosion, sinkholes, bulging or uneven settlement is significant and it is expected that such defects may affect the safety and stability of dam body, the Owner must conduct detailed investigations to find the cause of the defects and must consult with an expert to take measures, if necessary.

An example of inspection sheet is shown in Table 100-a3-4.

Table 100-a3-4 Inspection sheet of sliding, erosion or settlement for fill dam

Name of dam : XX Dam Inspection date : yy/mm/dd

Station No.	Elevation	Upstream or Downstream	Dimension of deformation	Photo

The Owner must record dimensions of sliding, erosion, sinkholes, bulging or uneven settlement at the crest or the slopes or toe of fill dams at every periodical inspection and observe advance of those defects. In case those defects advance significantly, the Owner must conduct detailed investigation at the place in which such significant defects occurred.

(3) Seepage is not observed at the slopes or toe of fill dams and leakage water at the toe of fill dams does not have turbidity.

Inspector of the Owner must investigate the slopes or toe of embankment to see if seepage is observed and if leakage water at the toe of fill dams is turbid by visual inspection. In case seepage is observed at the slopes or toe of embankment or leakage water at the toe of embankment is turbid, the Owner must conduct detailed investigations to find the cause of such seepage or turbid leakage water and must consult with an expert to take measures, if necessary.
An example of inspection sheet is shown in Table 100-a3-5.

Table 100-a3-5 Inspection sheet of seepage for fill dam

Name of dam : XX Dam　　　　Inspection date : yy/mm/dd

Location.	**Elevation**	**Reservoir Water Level**	**Amount of seepage (l/ min)**	**Extent of turbidity of seepage water**	**Photo**

The Owner must record amount and extent of turbidity of seepage or leakage water at the slopes or toe of embankment at every periodical inspection and observe change in amount or extent of turbidity of seepage or leakage water. In case amount or extent of turbidity of seepage or leakage water changes significantly, the Owner must conduct detailed investigation at the place in which such significant seepage or leakage occurred.

(4) There are no plants or trees on the crest or the slopes, excluding those specified in the design.

Inspectors of the Owner must investigate the crest and the slopes to see if there are plants or trees excluding those planted according to the design. In case there are plants or trees on the crest or the slopes which may affect to the required property of embankment, the Owner must take countermeasures to maintain the appropriate condition of embankment and must consult with an expert regarding the countermeasures to be taken, if necessary.

Article 100-a4 Inspection on spillways

This inspection must be conducted before the flood season to confirm if spillways fulfill their function during the flood season. Major inspection items and their purposes are as follows:

1. Impediment such as driftwoods left during flood, excessive growth of grass and weed, trees, debris, or landslide deposits is not observed at an approach part and chute channel of spillway;

   These impediments may obstruct opening or closing of spillway gates and reduce discharge capacity by increasing roughness coefficient of the spillway. In case these impediments are found at an approach part and chute channel of spillway, the Owner must remove them. The Owner must maintain the condition of spillways not only before the flood season but also whenever flood occurs.

2. Erosion of spillway chute which may damage safety of spillway and its foundation is not observed;

   A spillway chute must be so maintained that it may not be damaged during flood discharge. In case erosion of spillway chute is so serious that may damage safety of spillway and its foundation, the Owner must conduct detailed investigations to find the cause of erosion of spillway chute and must consult with an expert to take measures, if necessary. It often takes a long time to repair a spillway chute, so the Owner must inspect the extent of erosion of spillway chute from time to time during the flood season and must form a repair plan to complete the repair works surely before start of the next flood season, if necessary.

3. Deterioration of spillway concrete which may lead to successive erosion or structural instability is not observed;

   In case deterioration of spillway concrete is so serious that may cause successive erosion or structural instability, the Owner must conduct detailed investigations to find the cause of deterioration of spillway concrete and must consult with an expert to take measures, if necessary.

4. Cracks or spalling in spillway concrete which may lead to washout of fine materials behind the concrete slab, erosion on concrete surface, increase of cracks, or structural instability of spillway chute and walls is not observed;

   High velocity flow over a small scale of crack or spalling in spillway concrete structures may cause cavitation and deteriorate them into a large scale crack or spalling, scoring, or washout of materials below the concrete slab. These kinds of defects must be repaired before the flood season.

5. Misalignment or deformation of spillway chute and walls is not observed. Once those misalignment or deformation are found, causes of such abnormal condition must be investigated, clarified and removed properly, and such abnormal condition must be immediately repaired so as to secure structural safety and smooth water flow;

   These kinds of defects may disturb smooth flow or cause cavitation similar to Paragraph 4, and deteriorate concrete structures. The probable cause and measures of the defects are as follows.

   Error of construction; Take proper measures to make the surface of a chute and wall even and smooth so that their misalignment or deformation may not disturb a flow condition and that the concrete may not be damaged by cavitation depending on actual conditions to be clarified by inspection and investigation.

   Settlement of chute; Take proper measures so that a chute can maintain its normal state by eliminating cause of settlement depending on actual conditions to be clarified by inspection and investigation.

   Deformation or displacement of side walls; Take proper measures to keep walls at proper state by eliminating or coping with the cause of deformation or displacement depending on actual conditions.

   In repairing concrete structures, minimum thickness of concrete must be secured and newly placed concrete must contact firmly with the existing one so that it may not eroded by high velocity flow.

6. Relative displacement such as gaps and offset at the joints which may lead to successive erosion due to cavitation is not observed;

   These kinds of defects may disturb smooth flow or cause cavitation similar to Paragraph 4, and deteriorate concrete structures. The probable cause and measures of the defects are as follows.

   Displacement of chute and opening of gap; A gap must be filled with concrete or other suitable material to make the surface of a chute even and smooth.

   Settlement of chute; Take proper measures so that a chute can maintain its normal state by eliminating cause of settlement.depending on actual conditions to be clarified by inspection and investigation.

7. Undermining around the spillway outlet due to discharge which may damage safety of dam and appurtenant structures located near the spillway outlet is not observed;

   Advance in undermining around the spillway outlet may make a spillway chute and/or a dam unstable. The hollow due to undermining must be filled with concrete or other suitable materials and measures must be taken to prevent the undermined part from collision of water discharged from the spillway.

8. Drainage system is workable properly, in case spillway chute or walls are equipped with drainage system to reduce back pressure;

   Clogging of drainage system may increase back pressure and uplift, and lead to displacement of the spillway chute and side walls. In case drainage holes are clogged, these must be washed by pressurized water. In case it is difficult or impossible to recover drainage system, drainage holes must be newly drilled or anchors must be installed so that the spillway chute and side walls may not displace.

9. Inspection on spillway gates must be conducted following the provisions in Article 114, Article 115 and Article 116 of Section 4-5 “Hydromechanical Equipment”.

   Spillway gates must be opened to discharge flood when necessary. Any inoperative state of spillway gate(s) in flood may cause overtopping of a dam.

Section 3 Periodic Inspection for Dam Safety

Article 100-a5 General provision

This article stipulates the provisions according to Article 8 of Circular No.34/2010/TT-BCT. Frequency and inspection items vary according to reservoir capacity. Inspection items are provided in Articles 100-a8 and 100-a9.

According to Article 8 of Circular No.34/2010/TT-BCT, the following items are involved in the periodic inspection for dam safety.

(1) Assessment on results of dam management works;

  a. The implementation of hydropower reservoir operation procedure is approved by the competent authorities;

  b. The implementation of operation procedure of spillway’s gate (if any), intake gate; records of operation procedure, gate operation test of structures (operation diaries);

  c. The organization of monitoring, collecting, documenting of the meteorological, hydrological elements in reservoirs area, the condition of seepage, leakage at dam body, dam foundation, dam abutment, dam translocation, crack condition, slide condition occurred at body, foundation and surroundings of structures; sedimentation status of reservoir;

  d. The provisions execution on maintenance, overhaul for each structure, part of structure and equipment related to dam safety;

  e. Dam inspection: routine inspection, periodic inspection before and after the flood season; sudden inspection, detailed observations for dam must be carried out; and

  f. The repair, improvement of dam.

(2) Check and analysis of dam monitoring data;

  a. Collecting monitoring data of dam, headworks, waterways from construction, operation phase to the report preparation time for inspection;

  b. Listing out the installed monitoring instruments, quantity, working status, repair time, evaluating measurement methods, reliability of methods, its measurement interval;

c. Analyzing and evaluating the measured and monitored data at each monitoring location, monitoring data are shown as tables and charts. Accordingly, carrying out analysis and evaluation for working status of the structures, and forecasting the development tendency of dam translocation (vertical or horizontal translocation…), finding out main reasons impacting on the value if sudden changes of monitoring data occur;

d. Setting the actual saturation line and comparing with design saturation line for case of earth dams, rock dams; evaluating uplift at foundation of concrete dams;

e. Based on the data monitored since the construction phase or the latest inspection time, evaluating the dam safety status and forecasting the safety decrease of dam (if any); and

f. Recommending or proposing on the monitoring, measurement works in the future regarding instruments, additional monitoring items (type, quantity), repair, reliability improvement for existing instruments, measurement interval.

(3) Check and assessment of quality and safety of a dam

a. Calculating, checking the dam stability based on structure current status corresponding to normal water level, surcharge water level (design flood, examined flood level) and other cases in accordance with structure design regulations;

b. Calculating and checking dams or part of structures of which working status change suddenly, abnormally based on their monitoring results of seepage, dam translocation, or for cases of dams which are damaged seriously or were damaged earlier and developed under negative tendency; and

c. Proposing measures to ensure the stability and safety for construction works.

(4) Check of the situation of reservoir sedimentation

a. Analyzing and evaluating the sedimentation status of reservoir based on monitoring and measurements data collected in the past; distributing sedimentation based on the observation section of reservoir sedimentation, forecasting sedimentation and service life of the reservoir;

b. Analyzing and evaluating the causes of the increase or decrease in the amount of sedimentation in the reservoir; and

c. Proposing measurement, monitoring interval for reservoir sedimentation: number and location of the sedimentation measuring, monitoring.

(5) Recalculation of flood flow into a reservoir and review on flood control capacity of a reservoir according to the present dam design regulations and to the latest meteorological and hydrological data

a. Collecting and supplementing data of meteorology, hydrology and changes in topography, geomorphology, land cover of vegetation in the reservoir area from the design phase or from the latest inspecting times to report preparation time for the dam safety inspection;

b. Calculating and checking again the designed flood flow, examined flood (including flood model, flood-peak flow, total flood flow) and comparing with the update of monitoring data of meteorology, hydrology in the operating phase; and

c. Calculating and checking the flood discharge capability of the spillway and comparing with designed flood flow and examined flood which have been inspected.

(6) Assessment of works in relation to prevention and protection of dam against floods and typhoons.

a. Collecting latest data of meteorology and hydrology, and records of typhoons;

b. Estimating the probable most unfavorable flood pattern and flood discharge plan against the flood;

c. Estimating flood in case of a dam breach;

d. Investigating distribution of population and social infrastructure downstream of a reservoir;

e. Preparing a hazard map in case of the maximum flood discharge and a dam breach; and

f. Preparing an evacuation program in case of severe flood discharge from a dam which may inundate the downstream area and in case of a dam breach in cooperation with the relevant municipalities.

Article 100-a6 Frequency of inspection

This article is prepared according to Article 7 of Circular No.34/2010/TT-BCT. Frequency varies according to reservoir capacity.

The first inspection must be conducted during the one year period starting from the date one year after the date when the reservoir water level reaches the normal high water level as shown in Figure 100-a6-1 regardless of reservoir capacity. It is recommended that the first inspection is conducted in earliest stages as the initial conditions of a dam must be confirmed as early as possible.

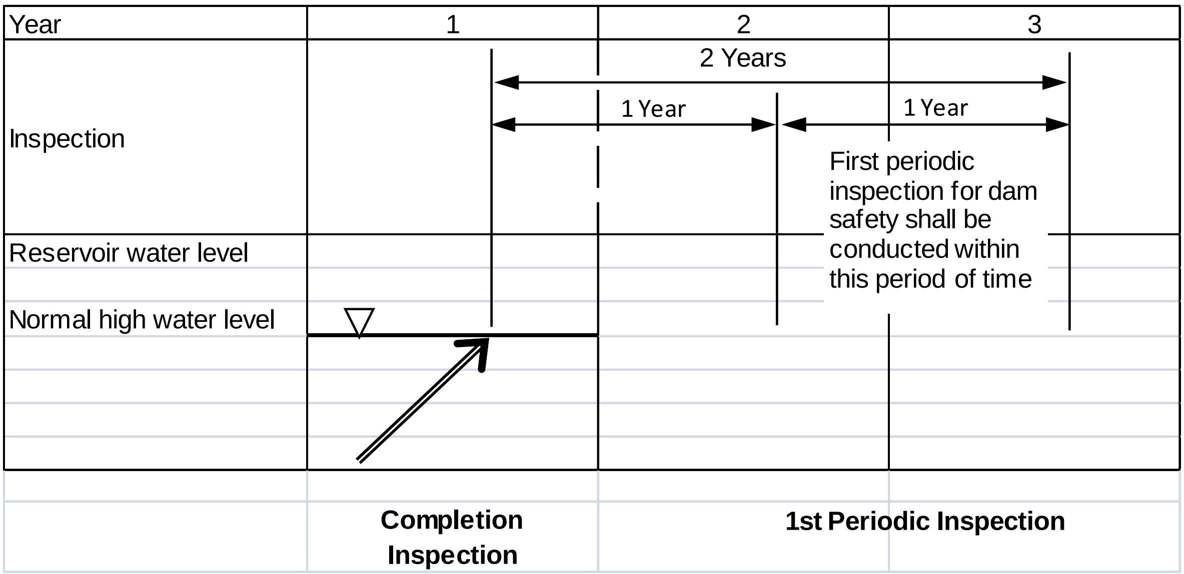


Figure 100-a6-1 Timing of first periodic inspection for dam safety

Time for the second or subsequent inspection varies with reservoir capacity and smaller dams and reservoirs have shorter frequency of inspection because the conditions of those dams and reservoirs tend to change faster than larger dams and reservoirs.

Article 100-a7 (Article 100-a7) Inspection process for dams

Only visual inspection of dams cannot recognize progress of aging or changing in conditions of a dam and reservoir though visual inspection is important for safety inspection of a dam. It is important to analyze data of dam monitoring which is conducted periodically so that the Owner can recognize the extent of aging or change in conditions of a dam and reservoir and confirm their status related to safety. Basically, all monitoring items which are conducted in the dam and reservoir must be analyzed. Among the monitoring data, important data are settlement and deformation of a dam, leakage, uplift and sedimentation of a reservoir. As for a fill dam, data of pore pressure and seepage line are also important, and change in groundwater level of the surrounding area of a dam is also important.

Article 100-a8 Concrete dams

Major inspection items and a measurement method are recommended as follows.

1) Leakage and seepage

   – Leakage and seepage from drains in concrete dams

     Leakage and seepage from drains is measured manually, for example, directly at a drain hole with a graduated cylinder.

   – Leakage from joints in concrete dams

     Leakage from joints is measured manually, for example, directly at a joint with a graduated cylinder.

   – Leakage and seepage from inspection galleries

     Leakage and seepage water is collected to a ditch and quantity of water is measured by a triangular weir (V-notch weir) which is equipped in suitable locations so that quantity of leakage water from each area of a dam can be measured. Quantity of leakage and seepage water is measured manually or automatically, for example, with an automatic water level recorder of a float type, water pressure meter type, or other types.

2) Uplift

   Uplift is measured by a water pressure gauge. An inspector of the Owner closes a valve of a drain hole in a gallery, leaves it closed for a sufficient time until the scale on a pressure gauge installed in a valve gets settled and reads the scale in case a valve is installed in a drain hole to measure uplift.

3) Displacement of dam body

   – Displacement of downstream slope

     Displacement of downstream slope is measured by targets installed on the surface of the slope.

   – Displacement of dam body

     Displacement of a dam body is measured by collimation and/or plumb lines installed in a dam body.

   – Opening of joints in concrete dams

   Opening of transverse and longitudinal joints in a concrete dam is measured by a joint gauge installed on a joint of blocks or a mark put across the blocks. Relative displacement of adjoining blocks is measured manually or automatically.

Generally, stress and strain vary according to a local situation, which indicate a local phenomenon, while displacement consists of cumulative strain of each part of a structure, which indicates the overall situation.

Inspection items are divided into the following two categories;

a) Measured values showing a situation in the whole structure of a dam such as total amount of leakage (item 1) above) and displacement (item 3) above)

b) Measured values showing a situation in a local point of a dam such as stress and uplift (item 2) above)

Even if inspection items of b) show abnormal values, it is judged that these values may not show disorder in the whole structures of a dam as long as these abnormal values are not remarkable or inspection items of a) do not show abnormal values. However, in case inspection items of b) show extremely abnormal values and the part where extremely abnormal values are measured has serious defects, detailed inspection and investigation must be conducted and immediate measures must be taken as it is estimated that the whole structure is in a critical condition. In that case, measurement values of b) are indispensable to investigate causes of the defects and to study repair works of them.

Some of the above values are caused by plural factors. For example, displacement of a dam body of concrete gravity dams or arch dams in upstream and downstream direction is mainly caused by hydrostatic pressure of the reservoir water and temperature. In such cases, influence of each factor must be analyzed separately in order to detect the major cause of irregular phenomenon.

The state of hydro civil structure must be evaluated not only by monitoring data itself but also by its tendency in variation. Frequency of official inspection which may be 7 years or 10 years is far beyond the required frequency for monitoring to analyze safety and stability of the structure and the results of routine inspection stipulated in Technical Regulation Vol.4 must be used to supplement information. It is important not only to continue routine monitoring of hydro civil structure but also to analyze a tendency of change in monitoring data, and the Owner must take proper measures against faults and disorders found in the monitoring records, if any.

Article 100-a9 Fill dams

Major inspection items and a measurement method are recommended as follows.

1) Leakage and seepage

   - Leakage and seepage from inspection galleries

   Leakage and seepage water is collected to a ditch and quantity of water is measured by a triangular weir (V-notch weir) which is equipped in suitable locations so that quantity of leakage and seepage water from each area of a dam can be measured. Quantity of leakage and seepage water is measured manually–or automatically, for example, with an automatic water level recorder of a float type, water pressure meter type, or other types.

2) Pore pressure

   Pore pressure is measured by a pore pressure gauge or piezometer embedded in an impervious zone of a fill dam.

3) Displacement of dam body

   - Displacement of downstream slope

     Displacement of downstream slope is measured by targets installed on the surface of the slope.

   - Settlement of crest in fill dams

     Settlement of the crest in a fill dam is measured by targets installed on the crest.

Generally, stress and strain vary according to a local situation, which indicate a local phenomenon, while displacement consists of cumulative strain of each part of a structure, which indicates the overall situation.

Inspection items are divided into two categories;

a) Measured values showing a situation in the whole structure of a dam such as total amount of leakage (item1) above) and displacement (item 3) above)

b) Measured values showing a situation in a local point of a dam such as pore pressure (item 2) above)

Even if inspection items of b) show abnormal values, it is judged that these values may not show disorder in the whole structures of a dam as long as these abnormal values are not remarkable or inspection items of a) do not show abnormal values. However, in case inspection items of b) show extremely abnormal values and the part where extremely abnormal values are measured has serious defects, detailed inspection and investigation must be conducted and immediate measures must be taken as it is estimated that the whole structure is in a critical condition. In that case, measurement values of b) are indispensable to investigate causes of the defects and to study repair works of them.

Some of the above values are caused by plural factors. For example, displacement of a dam body in upstream and downstream direction is mainly caused by hydrostatic pressure of the reservoir water. In such cases, influence of each factor must be analyzed separately in order to detect the major cause of irregular phenomenon.

The state of hydro civil structure must be evaluated not only by monitoring data itself but also by its tendency in variation. Frequency of official inspection which may be 7 years or 10 years is far beyond the required frequency for monitoring to analyze safety and stability of the structure and the results of routine inspection stipulated in Technical Regulation Vol.4 must be used to supplement information. It is important not only to continue routine monitoring of hydro civil structure but also to analyze a tendency of change in monitoring data, and the Owner must take proper measures against faults and disorders found in the monitoring records, if any.

Section 4 Periodic Inspection for Overall Power Plants Facilities

Section 4-1 General

Article 100-a10 General

In Section 2 and Section 3 of this Chapter, requirements in periodic inspection for a dam and spillway are stipulated. In Section 4 of this Chapter, requirements in periodic inspection for hydropower civil structure other than dam and spillway, that is, waterways and a powerhouse, hydromechanical equipment except spillway gates and electrical equipment are regulated.

Article 100-a11 Frequency of inspection

1. If hydro civil structure has defects or a part in poor quality, trouble may occur in the early stage of operation. So the first periodic inspection for overall power plants facilities must be carried out one year after commencement of operation because defects or a part in poor quality may be damaged soon after design load acts on the structure. Or the first periodic inspection for overall power plants facilities must be carried out when the reservoir water level reaches the normal high water level because the largest hydrostatic pressure which accounts for major part of design loads in the normal condition, initially acts on the structure when the reservoir water level firstly reaches the normal high water level.

2. If no defects are found or slight defects are found in the first periodic inspection for overall power plants facilities, it is unusual for facilities to have trouble soon after the previous inspection, so an interval of the next periodic inspection can be extended to three years.
3. If serious non-conformance which must be rectified immediately is detected, it is desirable that the next periodic inspection is carried out in the interval shorter than three years to confirm if non-conformity is rectified properly.
4. It takes time for dewatering and water filling of waterway, so it is allowed that the interval of a periodic inspection for waterway under dry condition is extended as long as possible up to six years depending on the result of latest inspection.

Article 101. General *(Deleted)*

Article 102. Concrete dams *(Deleted)*

Article 103. Fill dams *(Deleted)*

Article 104. Spillway *(Deleted)*

Section 4-2 Waterways

Article 105. Pressurized waterways

Guideline for Paragraph 1 "Scope of application"

In this article, items of a periodic inspection are stated for civil works and appurtenant structures of each type of pressurized waterways.

Detailed inspection items are described in the following paragraphs.

Guideline for Paragraph 2 "Unlined tunnel"

The following abnormal phenomena must not be observed in an unlined tunnel:

1. Rock mass around tunnel
   - The inner surface of an unlined tunnel must be stable because it works as lining. If a rockfall is observed inside a tunnel, an inspector must trace the origin of falling rock and observe conditions of the origin and suitable measures must be considered.
2. Abnormal leakage or seepage
   - Abnormal leakage out of a tunnel may cause decrease in water discharge for power generation and loosen bedrock surrounding the tunnel which may cause collapse of surrounding rock.
   - Abnormal seepage may damage the inner surface of the tunnel and disturb inspection.
3. Erosion
   - Excessive erosion may damage structural safety of the tunnel and increase roughness coefficient which leads to decrease in discharge capacity.
4. Sedimentation
   - Excessive deposit of sediment may decrease the sectional area of the tunnel which lead to decrease in discharge capacity of the tunnel and sediment flowing with water may wear the inner surface of the tunnel.

Rockfall from tunnel surface

Figure 105-1 Typical deterioration of unlined tunnel

Guideline for Paragraph 3 “Concrete-lined tunnel”

The following abnormal phenomena must not be observed in a concrete-lined tunnel:

1. Leakage or seepage
   - Excessive leakage out of a tunnel may loosen bedrock surrounding the tunnel and cause decrease in water discharge for power generation.
   - Excessive seepage may damage the lining concrete.
2. Cracks, spalling, or deformation of concrete lining
   - Cracks, spalling, or deformation of concrete lining may damage strength of lining concrete and increase roughness coefficient which leads to decrease in discharge capacity.
3. Abrasive erosion
   - Excessive abrasive erosion may damage strength of lining concrete and increase roughness coefficient which leads to decrease in discharge capacity.
4. Sedimentation
   - Excessive settlement of sediment may decrease the sectional area of the tunnel which lead to decrease in discharge capacity of the tunnel and sediment flowing with water may wear the inner surface of the tunnel.

Water leakage from lining concrete

Erosion of lining concrete

Difference in level of lining concrete

Cracks in lining concrete

Figure 105-2 Typical deterioration of concrete-lined tunnel

Guideline for Paragraph 4 "Steel-lined tunnel"

The following abnormal phenomena must not be observed in the pressure lining part of a steel-lined tunnel:

1. Deformation
   - Deformation of the pressure lining part may be caused by loads which were not considered in design. So the cause of the deformation must be investigated assuming all possible loading phenomena. Furthermore the maximum stress which would act on the pressure lining part by the action of stress concentration must be estimated. Based on the investigation of the cause and estimation of the maximum stress, necessary countermeasure must be conducted for the purpose of prevention of reappearance and/or expanding of the deformation.
2. Deterioration of the coating and corrosion of the pipe shell
   - The corrosion of the pipe shell must be avoided. Effective coating can stop progress of the corrosion. Thus the coating must be checked frequently by means of observation, measuring thickness and so on.
   - Typical items at the visual check for coating are whether the following phenomena occurred or not;
     - Blistering
     - Cracking
     - Peeling
     - Chalking
3. Water leakage
   - Water leakage from pressure lining part of a steel-lined tunnel may cause increasing corrosion, expanding cracks and failure for the pipe shell.
   - When the water-leakage is observed, suitable investigation of the leak and effective countermeasure must be conducted as soon as possible.

Guideline for Paragraph 5 "Steel penstock"

The following abnormal phenomena must not be observed outside of exposed steel penstock:

1. Deformation
   - Deformation of the pressure lining part may occur by loads which were not considered in design. So the cause of the deformation must be investigated assuming all possible loading phenomena. Furthermore the maximum stress which would act on the pressure lining part by the action of stress concentration must be estimated. Based on the investigation of the cause and estimation of the maximum stress, necessary countermeasure must be conducted for the purpose of prevention of reappearance and/or expanding of the deformation.
2. Defect at welded joint
   - Defects at welded joint tend to occur because of undercut, overlap which cause stress concentration due to its geometrical configuration, and it also affect the base metal near the welded joint.
   - Cracks at a welded joint are not difficult to find by visual inspection because coating is also cracked.

- When cracks are found, sufficient measure is needed as well as repair of them.

3. Defect at bolted and riveted joint
   - With the same reason as welded joint, bolted and riveted joint of a penstock must be checked regarding the phenomena such as rust, deterioration and dropped out.
4. Deterioration of the coating and corrosion of the pipe shell
   - The corrosion of the pipe shell must be avoided. Effective coating can stop progress of the corrosion. Thus the coating must be checked frequently by means of observation, measuring thickness and so on.
   - Typical items at the visual check for coating are whether the following phenomena occurred or not;

   - Blistering
   - Cracking
   - Peeling
   - Chalking

5. Water leakage
   - Water leakage from pressure lining part of a penstock may cause increasing corrosion, expanding cracks and failure for the pipe shell.
   - When the water-leakage is observed, suitable investigation of the leak and effective countermeasures, for example replacing packings if the water leakage occurs at an expansion joint and repairing welding portion if the water leakage occurs at a welding part of the pipe shell, must be conducted if the result of the investigation indicates anticipating serious damage to the penstock..
6. Shell thickness of aged and exposed penstock
   - In general, thickness of penstock shell decreases with age due to rust caused by deterioration of the coating. Aged steel penstocks must be checked in their thickness at representative points by a nondestructive test such as an ultrasonic thickness gauge etc., and must comprehend the tendency of the thickness as a time-series data.

<u>Guideline for Paragraph 6 “Reinforced plastic penstock”</u>

1. Leakage from joints
   - In general, the joint of the pipe shell has function of expansion joint. When trashes are left at the joint, the trash may hinder the expansion and contradiction of the pipe shell, and it may cause water leakage. Thus, the trashes especially those sinking at the joint of the reinforced plastic penstock must be removed.
   - Joints of a reinforced plastic penstock must be maintained so as to have water tightness sufficiently and to keep movable as designed.
2. Deterioration, damage or abrasion
   - Reinforced plastic penstock may gradually decrease outer protection layer due to abrasion and so on. If the abrasion reaches inner structural layer, the strength of the penstock will decrease below the required strength in the design. So a reinforced plastic penstock must be inspected in its thickness of the pipe shell routinely.

3. Fracture strength (stiffness)
    - Reinforced plastic penstock may gradually decrease its fracture strength. In order to comprehend the strength, there is a method that measures the strain change during dewatering and water filling and estimates the fracture strength based on the comparison of the strain change value with initial value.

<u>Guideline for Paragraph 7 “Air valve”</u>

- When air valve is turned to close, attention is needed to avoid jamming garbage into the valve, because it is a cause of water leakage after water-filling into a waterway.
- When the valve is open, air flow may be blocked because of gathering grasses, leafs of tree and/or something garbage at the blow part of the valve. This status may bring down a serious trouble for the power plant for example buckling of the penstock. To avoid such troubles, flowing of the valve must be cleaned or protection devices must be installed.
- In general, air valves are operated at corrosion-prone conditions. Air valves must be installed considering measures against corrosion.

<u>Guideline for Paragraph 8 “Penstock supports”</u>

- Penstock supports including anchor block must be checked for cracks, deterioration of concrete and displacement periodically. If defects are observed at the inspection, those defects must be repaired immediately.
- If a defect progresses after repair, cause of the defect must be investigated and appropriate measures must be taken.

Article 106. Unpressurized waterways

<u>Guideline for Paragraph 1 “Scope of application”</u>

In this article, items of a periodic inspection are stated for each type of major unpressurized waterways such as an open channel, unpressurized tunnel and culvert.

Detailed inspection items are described in the following paragraphs.

<u>Guideline for Paragraph 2 “Open channel”</u>

The following abnormal phenomena must not be observed in an open channel:

1. Side slope
    - The side walls of the channel must be stable to keep smooth flow of water. If cracks, spalling of lining concrete or stone paving, or any other damage is observed, an inspector must identify the location of damage and observe conditions of the side walls, and suitable measures must be considered.
    - The side slopes above the channel must be stable to prevent soil, rock, or any other impediments from entering the channel. If a rockfall, landslide or any other collapse or unstable situation of the slope is observed, an inspector must identify the collapse and observe conditions of the slope, and suitable measures must be considered.
2. Erosion
    - Excessive erosion may damage structural safety of the channel and increase roughness coefficient which leads to decrease in discharge capacity.

3. Sedimentation
   - Excessive deposit of sediment may decrease the sectional area of the channel which leads to decrease in discharge capacity of the channel and sediment flowing with water may wear the inner surface of the channel.
4. Leakage or seepage
   - Abnormal leakage out of a channel may cause decrease in water discharge for power generation and loosen bedrock or ground surrounding the channel which may cause collapse of foundation of the channel and/or side slopes.
   - Abnormal seepage may damage the inner surface of the channel and disturb inspection.

Guideline for Paragraph 3 "Unpressurized tunnel"

The following abnormal phenomena must not be observed in an unpressurized tunnel:

1. Cracks, spalling, or deformation of concrete lining
   - Cracks, spalling, or deformation of concrete lining may damage strength of lining concrete and increase roughness coefficient which leads to decrease in discharge capacity.
2. Rock mass around tunnel
   - The inner surface of an unlined tunnel must be stable because it works as lining. If a rockfall is observed inside a tunnel, an inspector must trace the origin of falling rock and observe conditions of the origin and suitable measures must be considered.
3. Erosion
   - Excessive abrasive erosion may damage strength of lining concrete and increase roughness coefficient which leads to decrease in discharge capacity.
4. Sedimentation
   - Excessive settlement of sediment may decrease the sectional area of the tunnel which leads to decrease in discharge capacity of the tunnel and sediment flowing with water may wear the inner surface of the tunnel.

Guideline for Paragraph 4 "Culvert"

The following abnormal phenomena must not be observed in a culvert:

1. Cracks, spalling, or deformation of concrete lining
   - Cracks, spalling, or deformation of concrete lining may damage strength of lining concrete and increase roughness coefficient which leads to decrease in discharge capacity.
2. Erosion
   - Excessive abrasive erosion may damage strength of lining concrete and increase roughness coefficient which leads to decrease in discharge capacity.
3. Sedimentation
   - Excessive settlement of sediment may decrease the sectional area of the tunnel which leads to decrease in discharge capacity of the tunnel and sediment flowing with water may wear the inner surface of the tunnel.

Guideline for Paragraph 5 "Pipe conduit"

The following abnormal phenomena must not be observed outside of exposed steel pipe conduit:

1. Deformation
    - Deformation of the steel pipe conduit may occur by loads which were not considered in the design stage. So the cause of the deformation must be investigated assuming all possible loading phenomena. Furthermore the maximum stress which would act on the steel pipe conduit by the action of stress concentration must be estimated. Based on the investigation of the cause and estimation of the maximum stress, necessary measures must be taken for the purpose of prevention of reappearance and/or progress of the deformation.
2. Defect at welded joint
    - Defects at welded joint tend to occur because of undercut, overlap which cause stress concentration due to its geometrical configuration, and it also affect the base metal near the welded joint.
    - It is not so difficult to find cracks at a welded joint by visual inspection because coating is also cracked.
    - When cracks are found, sufficient measure must be taken as well as repair of them.
3. Defect at bolted and riveted joint
    - With the same reason as welded joint, bolted and riveted joint of a steel pipe conduit must be checked regarding the phenomena such as rust, deterioration and dropped out.
4. Deterioration of the coating and corrosion of the pipe shell
    - The corrosion of the pipe shell must be avoided. Effective coating can stop progress of the corrosion. Thus the coating must be checked frequently by means of observation, measuring thickness and so on.
    - Typical items at the visual check for coating are whether the following phenomena occurred or not;
  - Blistering
  - Cracking
  - Peeling
  - Chalking
5. Water leakage
    - Water leakage from a steel pipe conduit may cause increasing corrosion, expanding cracks and failure for the pipe shell.
    - When the water-leakage is observed, suitable investigation of the leak and effective countermeasures, for example replacing packings if the water leakage occurs at an expansion joint and repairing welding portion if the water leakage occurs at a welding part of the pipe shell, must be conducted if the result of the investigation indicates anticipating serious damage to the steel pipe conduit.
6. Shell thickness of aged and exposed steel pipe conduit
    - In general, thickness of exposed steel pipe conduit shell decreases with age due to rust caused by deterioration of the coating. Aged exposed steel pipe conduit must be checked in their thickness at representative points by a nondestructive test such as an ultrasonic thickness gauge etc., and must comprehend the tendency of the thickness as a time-series data.

Section 4-3 Appurtenant Structures to Waterways

Article 107. Intakes and outlets

This article describes inspection items of intakes and outlets for hydro civil structures.

The following abnormal phenomena must not be observed at intakes and outlets:

1. Damage, deformation cracks or abrasive erosion
    - Excessive damage may obstacle normal operation of the structure.
    - Excessive deformation may decrease discharge capacity, and disturb smooth opening and closing of the gates.
    - Cracks of structure concrete may damage strength and durability of structure and lining concrete, and those in lining concrete may increase roughness coefficient which leads to decrease in discharge capacity.
    - Excessive abrasive erosion may damage strength of lining concrete and increase roughness coefficient which leads to decrease in discharge capacity.
    - If damage, deformation cracks or abrasive erosion is observed on the structure, an inspector must observe location and conditions of such defects and suitable measures must be considered.
2. Sedimentation
    - Excessive settlement of sediment in front of intakes and outlets may impede smooth inflow and outflow of water, and that inside the channel or tunnel may decrease the sectional area which leads to decrease in discharge capacity of the channel or tunnel and sediment flowing with water may wear the inner surface of the channel or tunnel.

Article 108. Settling basins

This article describes inspection items of settling basins.

The following abnormal phenomena must not be observed in settling basins:

1. Damage, deformation cracks or abrasive erosion
    - Excessive damage may obstacle normal operation of the structure.
    - Excessive deformation may obstacle smooth water flow and lead to water leakage.
    - Cracks of structure concrete may damage strength and durability of structure and lining concrete, and those in lining concrete may lead to water leakage.
    - Excessive abrasive erosion may damage strength of lining concrete and increase roughness coefficient which leads to decrease in discharge capacity.
    - If damage, deformation cracks or abrasive erosion is observed on the structure, an inspector must observe location and conditions of such defects and suitable measures must be considered.
2. Facilities to remove sediment
    - Sand particles may settle down to the bottom of settling basins between the entrance and exit of the basins as designed, and deposited sediments may be discharged out of the basins as designed.

3. Sedimentation
    - Excessive settlement of sediment may impede their normal function. If excessive sedimentation is observed in the settling basin, increase in content of sediment in inflow water or any other causes are assumed. In the case that excessive sedimentation occurs in a short time, the interval of discharging sediment out of settling basins must be shortened to keep their normal function and an operation plan of the facilities must be revised.

Article 109. Surgetanks and headtanks

This article describes inspection items of surgetanks and headtanks.

The following abnormal phenomena must not be observed at surgetanks and headtanks:

1. Damage, deformation cracks or abrasive erosion
    - Excessive damage may obstacle normal operation of the structure.
    - Excessive deformation may obstacle smooth water flow and lead to water leakage.
    - Cracks of structure concrete may damage strength and durability of structure and lining concrete, and those in lining concrete may lead to water leakage.
    - Excessive abrasive erosion may damage strength of lining concrete and increase roughness coefficient which leads to decrease in discharge capacity.
    - If damage, deformation cracks or abrasive erosion is observed on the structure, an inspector must observe location and conditions of such defects and suitable measures must be considered.
2. Collapse, landslides or seepage
    - Collapse and/or landslides of slopes above the surgetanks and headtanks may bring inflow of debris into the structures, which impedes normal operation of the structures.
    - Abnormal seepage may damage the inner surface of the structure and disturb inspection.
3. Damage, deformation corrosion pitting or deterioration
    - Excessive damage, deformation corrosion pitting or deterioration of steel shells or steel liners for steel or steel-lined surgetanks may deteriorate structural safety of surge tanks and headtanks.

Article 110. Spillways at headtanks

This article describes inspection items of spillways at headtanks.
The following items must be observed and confirmed at spillways at headtanks:

1. Excessive water
    - Excessive water caused by output change at power plant must be discharged downstream safely through the spillway. As excessive water seldom overflows a spillway, the function must be confirmed at a load rejection test which is conducted at the commissioning test.
    - Energy dissipaters must function properly as designed.
2. Steel pipe
    - In case that steel pipe is employed as spillway of headtank, the provisions of Article 105 on steel penstocks must be applied.

Section 4-4 Powerhouses

Article 111. Structures of powerhouses

Guideline

This article describes inspection items of powerhouses.

The following abnormal phenomena must not be observed at the concrete structures such as underground walls and foundations of powerhouses:

1. Deformation, cracks or excessive seepage
    - Excessive deformation of surrounding rock may damage stability of power house structures.
    - Cracks of structure concrete may damage strength and durability of structure, and may lead to water leakage from surrounding bedrock or ground.
    - Excessive seepage of water from surrounding bedrock or ground which exceeds capacity of drainage may damage normal operation of electromechanical equipment in the powerhouse.
    - If deformation, cracks or excessive seepage is observed at the concrete structures such as underground walls and foundations of powerhouses, an inspector must observe location and conditions of such defects and suitable measures must be considered.
2. Deformation, cracks or damage
    - Excessive deformation at walls or posts to support overhead cranes may impede smooth traveling of overhead cranes.
    - Cracks at walls or posts to support overhead cranes may damage stability and durability of concrete structure.
    - Damage at walls or posts to support overhead cranes may interrupt
    - If deformation, cracks or damage is observed at walls or posts to support overhead cranes, an inspector must observe location and conditions of such defects and suitable measures must be considered.

Article 112. Rock supports

This article describes inspection items of rock supports at arch and sidewalls in underground powerhouses and appurtenant caverns.

The following abnormal phenomena must not be observed at rock supports:

1. Deformation or cracks
    - Excessive deformation at arch and sidewalls in underground powerhouses and appurtenant caverns may be caused by progress of loosening in surrounding bedrock or ground or reduction in support force of rock anchors and rock bolts.
    - Excessive deformation may cause spalling of concrete lining or shotcrete, which damages structural safety of concrete lining or shotcrete, and may impede normal function of power generation.

- Cracks at arch and sidewalls in underground powerhouses and appurtenant caverns may cause spalling of concrete lining or shotcrete, which damages structural safety of concrete lining or shotcrete, and may bring water leakage from surrounding bedrock or ground, which damages safety of electromechanical equipment.
- If deformation or cracks is observed at arch and sidewalls in underground powerhouses and appurtenant caverns, an inspector must observe location and conditions of such defects and suitable measures must be considered.

2. Drop out of heads of rock anchors or rockbolts
   - Drop out of heads of rock anchors reduces tensile load acting on them and drop out of heads of rockbolts loses support of loosen rocks on the surface, which damages stability of underground powerhouse cavern.
   - If drop out of heads of rock anchors is observed at arch and sidewalls in underground powerhouses and appurtenant caverns, an inspector must observe location and conditions of such defects and suitable measures must be considered.
3. Seepage
   - Excessive seepage loosens meshing effects of rock surrounding the powerhouse cavern, which may damage mechanical stability, and seepage exceeding drainage capacity inundates the powerhouse, which may damage equipment and disable power generation.
   - If excessive seepage is observed at arch and sidewalls in underground powerhouses and appurtenant caverns, an inspector must observe location and conditions of such defects and suitable measures must be considered.
4. Unlined powerhouse caverns
   - Instability of the surrounding rock mass causes rockfall, which may damage structural stability, safety and normal function of powerhouses.
   - If symptoms for serious instability of the surrounding rock mass such as cracks on the surface of caverns, falling of fragments of shotcrete and rock, etc. are observed at arch and sidewalls in underground powerhouses and appurtenant caverns, an inspector must observe location and conditions of such defects and suitable measures must be considered. Typical observation items of caverns are; displacement of caverns; cracks on the surface of caverns; and existence of falling of shotcrete and rock fragments.

Article 113. Slope stability around powerhouses

This article describes inspection items of slope stability around powerhouses.

The following abnormal phenomena must not be observed slope at around powerhouses:

- Collapse, landslides or excessive seepage
  - Collapse and/or landslides of slopes around powerhouses may damage normal function and structural safety of powerhouses. In case collapse and/or landslides of slopes may give fatal damage to powerhouses, installation of drainage works, reinforcement of the slope, or any other measures to control landslide must be taken in advance, and behavior of the slope must be observed by instruments. Especially, stability of the slope must be watched carefully after heavy rain or earthquake.

- If Collapse, landslides or excessive seepage is observed at slopes around powerhouses, an inspector must observe location and conditions of such defects and suitable measures must be considered.

Section 4-5 Hydromechanical Equipment

Article 114. Gates and valves

1. Gates or valves work normally and smoothly
    - When the operation condition is inspected, the following items must be checked.
  - If a gate can be operated at a constant velocity and be operated smoothly.
  - If a gate can be operated without abnormal vibration or abnormal sound.
  - If a gate is hooked evenly, water tightness is retained certainly and resting device can be operated certainly.
2. Deterioration, damages or deformation on gate leaves and guide frames that could be estimated to cause failure in structural safety must not be observed
    - As the main girders and gate arms are main portion of a gate, defects (such as deformations or deflections) of the members may conduce to the structural failure.
    - In general, defects of the skin plate may not conduce to the destruction of the whole gate, but it may cause water leakage.
3. Deterioration or defects for coating on steel surface that cause accelerating corrosion for the steel must not be observed
    - Corrosion at the bottom of the gate may occur rapidly, and corrosion caused by galvanic corrosion may seriously occur at the limited part of a gate. Attention must be paid to these phenomena sufficiently at the inspection.
    - Deterioration of the coating causes corrosion of the base metal, so condition of the coating must be checked. The coating must be checked frequently by means of observation, measuring thickness and so on.
    - Typical items at the visual check for coating are whether the following phenomena occurred or not;
  - Blistering
  - Cracking
  - Peeling
  - Chalking
4. Water-tightness that is sufficient for storage of water is maintained for gates and valves
    - Seal part of a gate may lose the function because it must endure friction, pressure, deterioration, deformation and damage caused by intervened trashes, so conditions of the seal part must be checked regularly.
5. Pedestals
    - Pedestals usually endure main part of forces by water pressure against gates, so conditions of the pedestals must be checked and maintained to operate them certainly.

- ➢ If lubrication at the seal part of a pedestal is insufficient, the bush may be seized. Furthermore, it may cause the gate operation disabled. Attention must be paid to the condition of the lubrication sufficiently.
- ➢ Damage, deformation, ablation, lubrication and cracks at welded part must be checked at trunnion pins, brackets of bearing part of radial gates.

Article 115. Gate hoists

1. Basic conditions
   - ➢ Operating method and limit value of gate hoists are different in each model, so inspection procedure must be determined for each device satisfying the requirement of inspection items listed in Article 115 of the Technical Regulation Vol.5.
   - ➢ Suitable procedure for inspection on gate hoist must be planned in order to keep the function of the gate that the gate can be operated as normally and safety.
   - ➢ When defects of the hoist are found, they must be investigated as needed and they must be repaired immediately.
   - ➢ Inspection of gate operation is implemented not only for the purpose of comprehending status during operation but also keeping functions in good condition such as anti-corrosion and anti-dust at the internal of the devices.
2. Wire rope winding type
   - ➢ Typical check items at the periodic inspection for hoist by visual inspection are as follows:
   - Lubricant condition (including gear, wire rope),
   - Condition of rust,
   - Looseness and dropout of bolts,
   - Temperature rise of the lubricant and bearings,
   - Condition of electric devices,
   - Condition of wire rope (including strands),
   - Position and operation condition of limit switches,
   - Operation condition of brakes,
   - Tooth contact condition of gears, and
   - Others.
3. Hydraulic type
   - ➢ Typical check items at the periodic inspection for hoist are as follow:
   - Abnormal vibration and sound at a hydraulic pump, a hydraulic cylinder and valves,
   - Temperature rise of oil,
   - Hydraulic pressure,
   - Velocity of a hydraulic cylinder,
   - Oil leak from hydraulic pipes, valves and packings.

Article 116. Standby power supply

- Operating method and limit value of standby power supplies are different in each model, so inspection procedure must be determined for each device satisfying the requirements of inspection items listed in Article 116 of the Technical Regulation Vol.5.
- When a combustion engine is installed as a standby power supply, abnormal vibration and/or abnormal noise occur during raising the rotation speed to the rated speed, and the abnormal phenomenon tones down after reaching the rated speed in many cases. So, it is recommended to conduct the inspection on operation of diesel engine generator operation inspection might be conducted including event when rotation speed is changing.

Article 117. *(Missing)*

Section 4-6 Reservoir and River Environment at Downstream of Dams

Article 118. Slope stability

This article describes inspection items of slope stability around a reservoir.

The following abnormal phenomena must not be observed at slope around a reservoir:

1. Signs of collapse or landslide at reservoir area
    - If signs of collapse or landslide are missed and left untreated, outburst of collapse or landslides may bring serious damage around a reservoir or to a dam.
    - In case signs of collapse or landslide are observed at reservoir area, the Owner must inform related authorities of the incident and immediately take measures to prevent downstream area from being damaged by collapse or landslide.
2. Signs of collapse or landslide of slope at downstream area of a dam and power plant caused by operation of a power plant
    - If signs of collapse or landslide are missed and left untreated, outburst of collapse or landslides may bring serious damage to the downstream area of the dam and power plant.
    - In case signs of collapse or landslide are observed at the downstream area of the dam and power plant, the Owner must inform related authorities of the incident and immediately take measures to prevent downstream area from being damaged by collapse or landslide.

Article 119. Sedimentation in reservoir

This article describes inspection items of sedimentation in a reservoir.

The following abnormal phenomena must not be observed at a reservoir:

1. Flood damage
    - Sedimentation may raise water level around inlet and upstream of a reservoir during flood, which may cause flood damage to the public around the said area.
    - The Owner must measure the situation of sedimentation in a reservoir periodically and calculate its amount, influence on effective capacity or flood control capacity of the reservoir, and influence to the upstream area in terms of rise in water level during various discharge levels of flood. If a rise in the riverbed elevation in the upstream area may raise

flood water level and it may increase flood damage to the riverine area, the Owner must take proper measures.

2. Influence to a dam
    - Sedimentation may induce dangerous influences to a dam such as excess of sediment load acting on a dam body, malfunction of a low level outlet, or any other bad influences. Such sedimentation situation must be checked by latest survey record on sedimentation and proper measures must be taken in case dangerous sedimentation pattern is observed.
    - The Owner must observe the situation of sedimentation near the dam and confirm if sediment load exceeds design value.

Article 120. Erosion of riverbed and riverside

This article describes inspection items of erosion of riverbed and riverside.

The following abnormal phenomena must not be observed at riverbed and riverside at downstream of a dam and power plant:

1. Erosion of riverbed and riverside
    - Erosion at riverbed or riverside at downstream of a dam and power plant due to power generation and flood release may damage surrounding environment.
2. Progress of erosion
    - Progress of erosion at riverbed or riverbank at downstream of a dam and power plant must be monitored and protection measures must be taken against notable erosion so that it may not advance to the extent of damaging stability of riverbank.
    - If power generation and flood release cause erosion at riverbed or riverside at downstream of a dam and power plant, the Owner must take proper measures such as protection of riverbed and riverside, change in river flow route to reduce erosion, or any other steps.

Article 120-a1 Water quality in reservoir

This article describes inspection items of water quality in a reservoir.

- Water quality in a reservoir must be measured by proper methods and at proper interval in order to check if it deteriorates or not.
- In case it is observed that water quality in a reservoir deteriorate significantly, the Owner must take proper measures to prevent it from getting worse.

Section 4-7 Measuring Instruments

Article 121. Condition and performance of measuring instruments

This article describes inspection items of measuring instruments.

The following abnormal phenomena must not be observed at measuring instruments:

1. Conditions of measuring instruments
   - Measuring instruments or relevant structures must be maintained properly so that they may not be seriously damaged. In case these instruments or relevant structures are found seriously damaged, the Owner must repair it or exchange the damaged one for new one.
2. Location of measuring instruments
   - Measuring instruments and relevant structures must be installed at a safe and stable place.
   - Measuring instruments and relevant structures must be installed at a site free from unfavorable obstacles for measuring in surrounding environment such as severe sedimentation etc., to maintain normal function.
3. Protection of measuring instruments
   - Measuring instruments and relevant structures must be protected adequately from natural accidents or artificial disturbances to maintain normal function. In this regard, the Owner must apply and maintain the measures for protecting the instruments and their surrounding circumstances.

Article 122. Calibration of equipment

This article describes inspection items of calibration of equipment

1. Official calibration
   - The Owner must commission an authorized company or organization which is qualified for calibration of equipment to conduct official calibration at a designated interval to maintain accuracy of equipment and guarantee its accuracy.
2. Check of instruments
   - The Owner must utilize other independent measurements to confirm normality of the measuring instruments used in monitoring and observation of performance of facilities, if applicable.

Section 4-8 Generator, Hydraulic turbine and Other auxiliaries

Article 123. Frequency of periodic inspection

1. Periodic inspection must be normally planned for the inspection of “Normal and Precision/Detail” for each electrical facilities with “Patrol/Visual inspection”.
2. Periodic inspection frequency must be extended in accordance with improvement of the quality of insulation material and the strength of the mechanical materials in recent years.
3. The years shown as “Periodic ordinary inspection (year)” in the Table 123-1 are the target of the maximum inspection period. Therefore, the periodic inspection frequency must be decided by the actual situation of each power plant.
4. In case of founding trouble or accident on the electrical facilities during patrol or by an alarm system, a temporary inspection must be carried out, which is necessary to be executed in a short working time, taking safety management into consideration, because the temporary inspection must be performed without planning working.

Table 123-1 Frequency of periodic inspections

Equipment	Periodic ordinary inspection (year)	Special inspection (reference)(year)
(1) Generator and apparatus		
Generator	3	Same as hydraulic turbine
Cooling system	3	Same as hydraulic turbine
Exciter	3	Same as generator
AVR	3	Same as generator except control devise (1/2 of generator)
Starting system	3	Same as generator
(2)Hydraulic turbine system		
Hydraulic turbine	3	
-Francis, Pelton	3	14～17 for Overhaul inspection
-Kaplan, Tubular	3	12～15 for Overhaul inspection
-Pump	3	11～15 for Overhaul inspection
Inlet valve	3	2 times of hydraulic turbine
Oil pressure, lubrication system	3	Same as hydraulic turbine
Governor	3	1/2 of hydraulic turbine
Hydraulic turbine operating control and auxiliary system	3	Same as hydraulic turbine

Article 124. Inspection documents (Documentation)

<The provisions of this article must refer to the technical regulation Vol.4 Part 6 in Chapter 1.>

Article 125. Visual inspection

1. Visual inspection must be executed periodically for major equipment e.g. turbine, governor, inlet valve and generator and is carried out one time in one or two weeks normally.
2. Patrol must be executed periodically once or twice per weak normally, however, the patrol of new power plant must be carried out with daily inspection for all equipment in the power plant in order to confirm operating condition of machine/equipment, indicator, recorder, main/auxiliary relays of electrical/mechanical type, inside condition of cubicle/board, etc.,

Article 126. Insulation resistance measurement

<The provisions of this article must refer to Article 79 in Chapter 3.>

Article 127. Dielectric test

<The provisions of this article must refer to Article 80 in Chapter 3.>

Article 128. Axial voltage measurement

<The provisions of this article must refer to Article 93-a1 Item-2 in Chapter 4.>

Article 129. Vibration measurement

<The provisions of this article must refer to Article 98-a1 in Chapter 4.>

Article 130. Hydraulic turbine inspection

1. The maintenance and repair

   The maintenance and repair for the electrical equipment must be generally executed in the following two (2) ways;

   - Planning maintenance (PM): It must be carried out in accordance with a schedule after resulting of inspection for a preventive maintenance and / or a purpose of recovering function.
   - Temporary maintenance (TM): It must be carried out in case of occurring trouble or accident.

2. Follow-up examination

All inspection items must be made to obtain data for the follow-up examination with a statistical table and reference figure for maintenance and operation of the power plant.

(1) Hydraulic turbine

1) For the spiral casing, speed ring, wicket gates, runner, upper draft tube, etc., some cracks may appear due to metal fatigue caused by fluctuation of pressure water or pulsation of the water flow and some corrosion may occur due to cavitation, though the degree of cracking and corrosion is different depending on operating time of equipment and/or the water quality.

2) The following inspections for major items of the hydraulic turbine must be executed to repair periodically in order to maintain function/performance of the turbine as keep as possible.

   - Runner: Cavitation corrosions must be checked for dimensions of length, wide and deeps with some sketches of the location.
     The provisions of this item must refer to Article 98 of Chapter 4, Part 4 in Vol.4.
   - Main shaft: Rust, loosening bolts of shaft cover and a dirty must be checked. And Sealed gap of main shaft sealed packing must be checked.
   - Guide bearing: Contamination of lubrication oil, contents and purification must be done.
   - Turbine cover: Loosening of bolts and nuts, damage of sheet liner, wicket gate sealed packing and a dirty must be checked.
   - Spiral casing, Speed ring: Painting discoloration, welding parts, packing of manhole must be checked.
   - Draft tube: Damages with cavitation corrosion, rust and packing of manhole must be checked.

- Wicket gate operation mechanism: Shear pins, non destructive inspection and damages must be checked. Damage of vanes and shaft must be checked. Side and shutter gap and packing must be checked.
  The provisions of this item must refer to Article 84 of Section 2 in Chapter 3.

3) Troubles in the items mentioned above may make a cause of an efficiency drop and/or increasing vibration, and then there is a possibility to growth an accident.
4) Though the cavitation corrosion and/or abrasion for the equipment is repaired by a proper welding work, it must be necessary to decide a suitable repairing time and period of welding work taking the result of inspection and proper welding process into consideration.
5) (For reference study,) The economical repairing cycle is determined by comparing the estimated cost of the electric energy loss due to efficiency drop and the repairing cost including the estimated cost of energy loss due to overflowing of water during repairing.

(2) Governor

1) The following major inspection items of the governor must be executed to repair the governor periodically by confirming its characteristics together with control system by applying an oscilloscope.

- Electrical and mechanical control parts, rust, loosening of terminals and wire / lever, insulation resistance of control circuit and heater must be checked visually.
- Calibration of meters, operation of the protection relay must be checked.
- Opening and closing stroke of auxiliary servomotor and main servomotor must be checked to operate servomotors in suitable relation between the both servomotors.
  The provisions of this item must refer to Article 84 of Section 2 Turbine / Pump-Turbine.
- Input voltage and current of control unit must be set at the designed value and change their values between the parameters of maximum head to minimum head, then the servomotor stroke must be measured.
- Characteristics of no-load opening, opening position depend on each outputs must be checked with net-head and kept within design value.

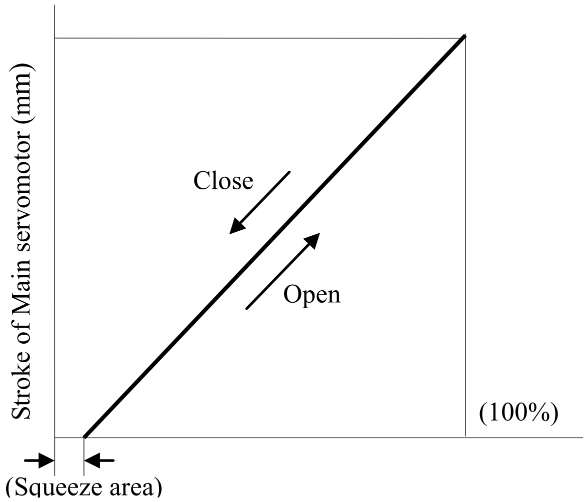


Figure 130-1 Relation between the both servomotors

Article 131. Inlet valve inspection

1. Visual inspection

(1) Outside of inlet valve

1) Damages, rust, condition of anchor bolts, leakage oil, position of electromechanical display, operating condition of control valve, etc., for control structure must be checked.

(2) Inside of inlet valve

1) Damages, rust, erosion, discoloration, crevice in seat surface of valve body, condition of sealed packing, abrasion part, etc., must be checked.

2. Opening and closing inspection

<The provisions of this article must refer to Article 85 in Chapter 3>

3. Leakage water measurement

<The provisions of this article must refer to Article 85 in Chapter 3>

(Reference data for the quantity of leakage water)

Table 131-1 Quantity of Leakage Water

Type of Inlet Valve	Seal Material Method	Quantity of Leakage Water (ℓ / min)	Note
Biplane	Rubber	1 / 200 PD	P = Max, Static Water Head (m) D = Diameter of Inlet Valve (m)
Butterfly	Rubber	1 / 50 PD	
Butterfly	Metal	1 / 5 PD	
Rotary	Metal	1 / 250 PD	
Rotary	Rubber	1 / 200 PD	

Article 131-a1 Generator inspection

< The provisions of this article must refer to Chapter 4 of Section 3 in Part 4>

Major items related periodic inspection and tests for Salient-pole synchronous generator, which is applied to hydraulic power plant, are as follows, however, major testing item related generator must be referred to each Article defined in previous Chapter;

1. The purpose of maintenance, repair and follow-up examination is same as GL description of Article 130 Hydraulic turbine inspection in Section 4-8 of Chapter 5.

(1) Salient-pole synchronous generator

1) The component of the generator, such as the collector/slip ring, spider of rotor, upper and lower end coils of stator, cooler tubes & cooler tube supports, upper and lower brackets, etc., must be inspected to confirm appearing some clacks by fatigue from a fluctuation and vibration during the operation with frequent starting and stopping including tripping by accidents.

2) The following major items of the generator must be executed to inspect and repair periodically in order to maintain function / performance of the generator as keep as possible.

a. Collector/slip rings and bush gear with carbon-dust collector device;

   (a) To inspect a contacting face of the collector/slip rings, a contacting face of the brushes, and carbon-dust collector device,

   (b) To clean brush-holders, collector/slip rings, and filters with carbon-dust collector device,

   (c) To measure the insulation resistance between collector/slip ring and bush gear without brush, the remaining dimension of brush length and the brush pressure of brush pressure device.

b. Upper oil reservoir installed on upper bracket with upper guide bearing;

   (a) To inspect a guide bearing, oil leakage from oil reservoir, supporting device of bracket soleplates, contamination and contents with metal particles of lubrication oil, oil vapour collecting device,

   (b) To measure a gap of guide bearing, an insulation resistance for guide bearing supports,

   (c) To clean a oil reservoir and a oil cooling system installed in oil reservoir, bracket.

c. Rotor with generator shaft:

   (a) To inspect a poles with poles supporting cotter/wedges, an insulation and supporting facilities for connecting leads between pole windings and slip rings, a clack of spider, damper windings, a brake rings, a clack and rust of generator shaft with its shaft journal,

   (b) To measure an insulation resistance of field windings including connecting leads between pole windings and slip rings, an insulation resistance of generator shaft earthing device,

   (c) To clean a rotor with poles, a spider, a generator shaft line.

d. Stator with soleplates part:

   (a) To inspect a damage of stator winding, coil end connection & parallel connection rings with supporting materials, terminals of phase and neutral leads, slot packing wedges, rim ducts of ventilation, soleplates with earthing material, dial temperature relay,

   (b) To measure an insulation resistance of stator winding, temperature search coils,

   (c) To clean a stator, soleplate part.

e. Lower oil reservoir installed on lower bracket or unit supporting con with combined thrust and lower guide bearings:

   (a) To inspect a combined thrust and lower guide bearings, oil leakage from oil reservoir, supporting device of bracket soleplates, contamination and contents with metal particles of lubrication oil, oil vapour collecting device,

   (b) To measure a gap of guide bearing, an insulation resistance for guide bearing supports,

   (c) To clean an oil reservoir and a oil cooling system installed in oil reservoir, bracket.

f. Mechanical brake and hydraulic jacks equipment with brake-dust device :

(a) To inspect a sequence diagram of braking system, operation of brake cylinder, operation of jack-up by manually oil pressure operating equipment, brake-dust collecting device,

(b) To measure a value of pressure and upheaval dimension for jack-up,

(c) To clean a mechanical brake and hydraulic jacks equipment, brake-dust device.

g. Air coolers:

(a) To inspect a sequence diagram of air cooling system, no leakage water of cooling system,

(b) To measure a quantity of cooling water for air coolers,

(c) To clean air cooling system.

h. Oil coolers for oil reservoir:

(a) To inspect a sequence diagram of oil cooling system, no leakage oil and water of cooling system,

(b) To measure a quantity of cooling water,

(c) To clean an oil coolers.

i. Electric heaters installed in generator pit:

(a) To inspect sequence diagram of control system, a heater device,

(b) To measure an insulation resistance of all heaters, capacity of heating load,

(c) To clean a heater device.

J. Fire extinguisher system:

Fire extinguisher system for generator is two (2) methods, e.g. Water and Gas (CO_2) supply systems. The detecting system of fire is almost same, that is, both smoke and temperature detectors with sprinkler must be arranged on the both end of winding of the generator.

(In case of water supply system)

(a) To inspect sequence diagram after interlock for the operating valve of discharging water by electric circuit and mechanical operation. (Refer to Article 86-a2, Part 3 of Vol.5)

(b) To clean a control cubicle, both smoke and temperature detectors, sprinklers.

k. Generator pit:

(a) Internal inspection:

For the operation test of generator which is performed after inspection and cleaning, the generator pit must be confirmed a completely an internal inspection of generator for cleanliness, absence of loose objects and locking of nuts, and then, repairing paints on the floor.

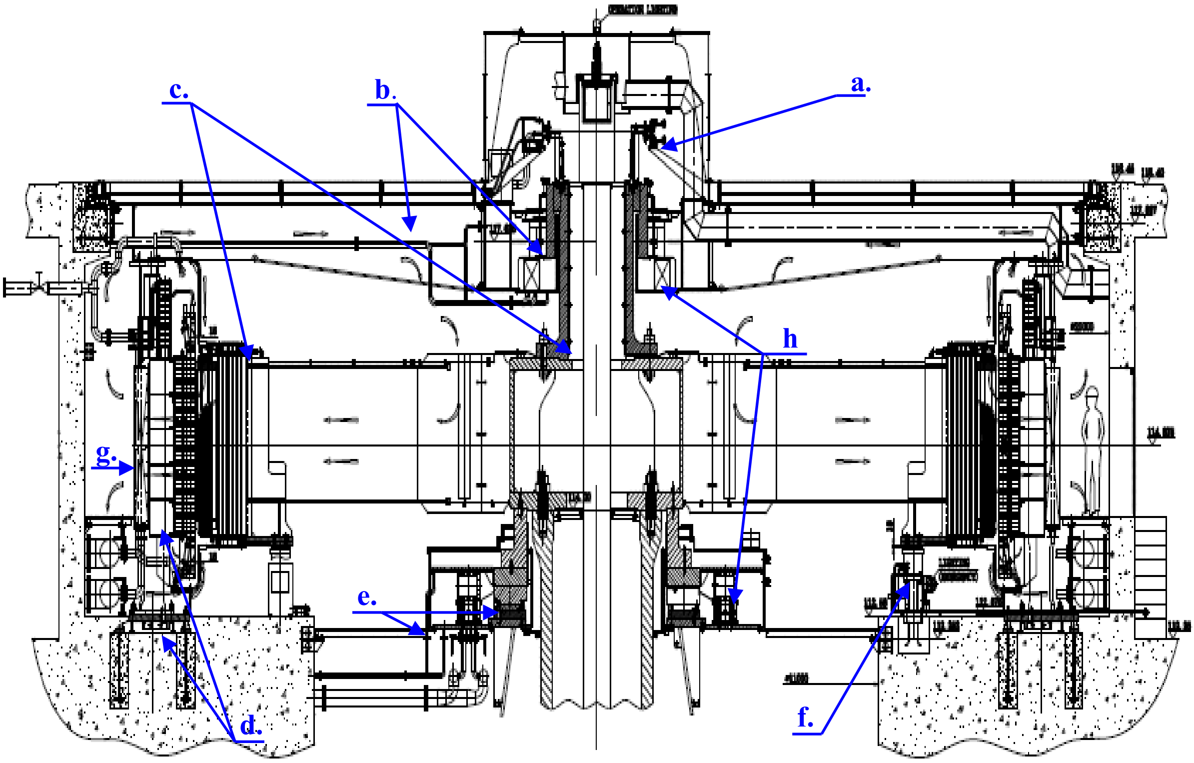


Figure 131-a1 Vertical Shaft, Three-phase Synchronous Generator (Example of Generator pit of Hydraulic power plant)

Article 132. Auxiliary equipment operation test

<The provisions of this article must refer to Article 86 in Chapter 3>

Article 133. Automatic start and stop test

<The provisions of this article must refer to Article 91 in Chapter 4>

Article 133-a1 Trial operation/run

<The provisions of this article must refer to Article 98-a3 in Chapter 4>

Reference Vietnamese Documents

Number	Issued	Title
TCN 18	2006	Code for Electric Equipment Facilities issued by MOIT 11
Decree No.72/2007/ND-CP	2007	Decree on Management of Dam Safety
Circular No.34/2010/TT-BCT	2010	Circular regulating on the management of dam safety for hydropower structures
Decree, No.48NL / KHKT	1987	Ministry of Energy, Volume and Standards for Test, Acceptance and Hand Over of Electrical Equipment

Reference International Documents

Number	Issued	Title
ISO 7919-5	2005	Mechanical vibration – Evaluation of machine vibration by measurements on rotating shafts. Part -5 Machine sets in hydraulic power generating and pumping plants.
ISO 10816-5	2000	Mechanical vibration – Evaluation of machine vibration by measurements on non – rotating parts. Part -5 Machine sets in hydraulic power generating and pumping plants.
IEC 60034-1	2004	Rotating electrical machines, Part 1 Rating and performance
IEC 60034-2-1	2007	Rotating electrical machines, Part 2-1 Standard methods for determining losses and efficiency from tests
IEC 60034-2-2	2010	Rotating electrical machines, Part 2-2 Specific methods for determining separate losses of large machines from tests- Supplement to IEC 60034-2-1
IEC 60034-4	1985	Rotating electrical machines, Part 4 Amendment No.1
IEC 60034-18	1992	Rotating electrical machines, Part 18 Functional evaluation of insulation system
IEC 60076-11	2004	Power Transformer- Part 11 Dry-type transformers
IEEE Std 4a	2001	Techniques for High-Voltage Testing
IEEE Std.C3-23	2003	Metal Enclosed Bus
IEEE Std. 43	2000	Recommended Practice for Insulation Resistance
IEEE Std.56	1977	Guide for Insulation Maintenance
IEEE Std.CP65-a56	2000	Standardization of Conductor Vibration Measurements
IEEE Std 80	2000	IEEE Guide for Safety in AC Substation Grounding
IEEE Std 115	1995	Test Procedure for Synchronous Machines, Dielectric and partial discharge tests
IEEE Std 367	1996	IEEE Recommended Practice for Determining the Electric Power Station Ground Potential Rise and Induced Voltage From a Power Fault,
IEEE Std 421-1	2007	Definitions for excitation systems for synchronous machines
IEEE Std 487	2000	IEEE Recommended Practice for the Protection of Wire line Communication Facilities Serving Electric Supply Locations
IEEE Std. 1590	2003	IEEE Recommended Practice for the Electric Protection of Optical Fiber Communication Facilities Serving, or Connected to, Electrical Supply Locations, (2004).
ANSI / IEEE Std 81	1983	IEEE Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System
ANSI / IEEE Std 142	1982	Green Book- Grounding of Industrial and Commercial Power Systems
BS 3116-4	1974	British Standard, Specification for automatic fire alarm system in buildings. Control and indicating equipment
NFPA Code 70 to 72, 90A	2005	National Fire Protection Association, USA

Part 4
Thermal Power Plants

Chapter 1   General Provisions

Article 134.   Definitions

1. The technical regulation Vol.2 stipulates the minimum technical requirement in the view point of safety and security, for example “the pressure vessel or boiler must be withstand the rupture due to high pressure”. According to this requirement, the boiler with safety valve is purchased under the purchase specification or the EPC Contract to prevent the destruction due to over-pressure.
2. After then, the boiler is operated safely in line with the requirement of the technical regulation Vol.4 and inspected in line with the requirement of the technical regulation Vol.5 according to the administration manual which is established by each power plant voluntarily.
3. ***“Administration manual”*** means the concrete rule which is established with reference to TCVN, old norms, international standards, regional standards, company standards, manufacturer’s O&M manual and guidelines and applied to all activities in each power plant by Owner...
4. ***“Inspection”*** means the activity to confirm the absence of failure, problem and risk that may reach to the severe accident, incident and disaster and confirm the soundness of facilities.
5. ***“Completion inspection”*** means the activity to confirm the conformity to the technical regulation and the requirement of purchase order or EPC Contract before commercial operation.
6. ***“Periodic inspection”*** means the major inspection which is performed intentionally during outage. Interval of inspection may be decided by Owner depending on the status of each facility voluntarily
7. ***“Routine inspection”*** means the minor check of facility which is performed during operation.
8. ***“Routine maintenance”*** means the minor maintenance such as the minor repair, tightening or replacement which is performed during operation.
9. ***“Emergency inspection”*** means the extraordinary check of facility and equipment after shut-down such as abnormal vibration of steam turbine, leakage from boiler tube, etc.

Chapter 2   Organization and Documentation

Article 135.   Organization

It must be confirmed that the organization stipulated in the technical regulationVol.4 Part2 taking account of following provisions fulfill the requirement.

1. The original administration manuals (O&M manuals) must be developed at each power plant (each company).
2. The organization of each power plant and the power of each position must be stipulated in the administration manual clearly. It must be provided for usual case and emergency case.

Article 136. Documentation

It must be confirmed that the documentation stipulated in the technical regulation Vol.4 Part2 taking account of following provisions fulfill the requirement.

1. The administration procedure of documentation such as drawings, records, documents and books which is necessary to operate and maintain power plant must be provided in the administration manual.
2. The necessary certificates, drawing, records, documents, O&M manuals and books which are necessary to operate and maintained the each power plant must be collected and reserved by each power plant.
3. The record of major inspection must be gathered and reserved as the inspection record for the reference of next inspection. (If points of concern are included in results of previous periodic inspection, it must be confirmed they are reflected on this periodic inspection.)

Chapter 3 Completion Inspection

Section 1 General Provision

Article 137. General provision

1. The power plant which is objected to national project must be confirmed according to the given procedure for national project by authorized peoples.
2. The other power plant which is not objected to national project must be confirmed that they conform to the requirement of related technical regulation based on the EPC Contract or purchase order by Owner or his representative.

Section 2 Mechanical Equipment

Article 138. General completion inspection

It must be confirmed that status of fulfillment of requirements on general completion inspection stipulated in the technical regulation taking account of following provisions.

1. Power plants must confirm according to the administration manual.
2. Results of inspections on each equipment must be recorded.

Article138-a1 General of boiler (Inspection during construction)

1. Purpose

It must be confirmed that boiler and safety valve are manufactured based on implementation plan of power plant and required welding inspection of tube etc. is conducted.

2. Inspection procedure and criterion

Inspection items	Procedure	Criterion
Boiler and safety valve	It must be confirmed specification by construction drawing and nameplate etc.	It must be met implementation plan of power plant.
Foundation of boiler	It must be confirmed by actual value and foundation working drawings.	It must be met foundation description of implementation plan and drawings of foundation condition.
Tube etc. required welding inspection	It must be confirmed record of welding inspection or certificate of compliance.	It must be taken welding inspection.

Article138-a2 Material inspection of boiler (Inspection during construction)

1. Purpose

   It must be confirmed that each materials of boiler are met implementation plan of power plant.

2. Inspection procedure and criterion

Inspection items	Procedure	Criterion
Each part of boiler (Drum, header tube and safety valve)	It must be confirmed materials of these parts by record of material test etc.	It must be met implementation plan of power plant.

Article138-a3 Structure and external appearance inspection of boiler (Inspection during construction)

1. Purpose

   It must be confirmed that each parts of boiler are manufactured based on construction drawing of implementation plan and there is no defect in welded parts.

2. Inspection procedure and criterion

Inspection items	Procedure	Criterion
(1) Water separator (2) Water separator drain tank (3) Header (4) Manifold (5) Flash tank	(1) It must be confirmed that each parts of boiler is manufactured based on construction drawing. (2) It must be confirmed status of welded parts and damage of material surface by visual	(1) It must be met implementation plan of power plant. (2) It must be confirmed no defect and damage by visual check. (3) When preliminary

Inspection items	Procedure	Criterion
(6) Boiler tube (7) Economizer tube (8) Furnace wall tube (9) Super-heater tube (10) Re-heater tube (11) Support tube (12) Spray (13) Safety Valve (14) Piping attached to boiler (15) Other main valve	check. (3) It must be opened inspection plate of drum and header and confirmed following defects regarding internal and external surface of these parts. 1) Defect of shape 2) Damage of material surface 3) Defect of welded part 4) Interfusion of foreign object (4) It must be confirmed following items regarding tube. 1) Status of welded parts 2) Damage of material surface 3) Tube disarrangement 4) Curvature 5) Pore space of fin 6) Status of support 7) Expansion joint (5) It must be confirmed following items regarding safety valve by visual check and nondestructive test etc. 1) Installation position 2) Status of installation 3) Damage of material surface 4) Foreign object 5) Defect of valve casing 6) Damage of disc sheet 7) Curvature of valve stem 8) Status of contact face 9) Defect of spring (6) When preliminary inspection is conducted, it must be confirmed report of it.	inspection is conducted, it must be confirmed that there is not following defects by report of it. 1) Defect of shape 2) Damage of material surface 3) Defect of welded part 4) Interfusion of foreign object

Article138-a4 Boundary dimension inspection of boiler (Inspection during construction)

1. Purpose

It must be confirmed that boundary dimension of each parts of boiler is manufactured based on implementation plan of power plant.

2. Inspection procedure and criterion

Inspection items	Procedure	Criterion
Each part of boiler [Drum, header tube and safety valve]	It must be confirmed boundary dimension and shape of each part by actual measurement or measuring record at manufacturing plant and power plant.	It must be met implementation plan of power plant.

Article138-a5 Assembling and installation condition inspection of boiler (Inspection during construction)

1. Purpose

   It must be confirmed that measured value and horizontality of each part is within acceptable value regarding condition of assembling and installation of boiler.

2. Inspection procedure and criterion

Inspection items	Procedure	Criterion
Each part of boiler [Drum, header tube and safety valve]	It must be confirmed by actual measurement or installation record.	It must be confirmed that measured value is within acceptable value.

Article138-a6 Hydraulic pressure test (Inspection during construction)

1. Purpose

It must be confirmed that pressure parts of boiler and auxiliaries are resisted 1.5 times of maximum allowable working pressure and there is no water leakage in these parts.

2. Test item and method

(1) Test item

Pressure parts of boiler and auxiliaries

(2) Test method

Hydraulic test with 1.5 times of maximum allowable working pressure

3. Hydraulic pressure test procedure (Sample)

(3) Preparation

1) Scope of hydraulic pressure test of each system must be confirmed.
2) Area with same pressure range must be pressurized at the same time and tested.
3) Purified water added hydrazine must be used.
4) The status of valves (open and close) and air vent must be confirmed.
5) The gag or cap for safety valve to withstand test pressure must be provided.
6) Necessary volume of purified water must be prepared for this test.

(4) Pressurization procedure

1) Temperature of pressurized water must be set over 5 degree C to prevent freeze.
2) Rate of pressure increase must be set not more than 0.5MPa, keep over 30 minutes after getting up to regulated pressure (1.5 times of maximum allowable working pressure) and taken the test.

(5) Check procedure

1) Mainly welded parts and each part must be checked by using flash lamp, hand mirror, test hammer and wire brush.
2) Welded parts at power plant must be identified in white color and welded parts at manufacturing plant must be identified in yellow color.

(6) Depressurization procedure

1) Hydraulic pressure must be depressurized on the rate of pressure decrease not more than 0.5 MPa/min by controlling blow flow after completing test.
2) Operation status of wastewater treatment system must be confirmed because a large amount of wastewater is generated after this test.

4. Criterion

It must be confirmed that pressure parts of boiler and auxiliaries are withstood this test and there is no water leakage in these parts.

5. Scope of hydraulic pressure test

Scope of hydraulic pressure test is shown as follows;

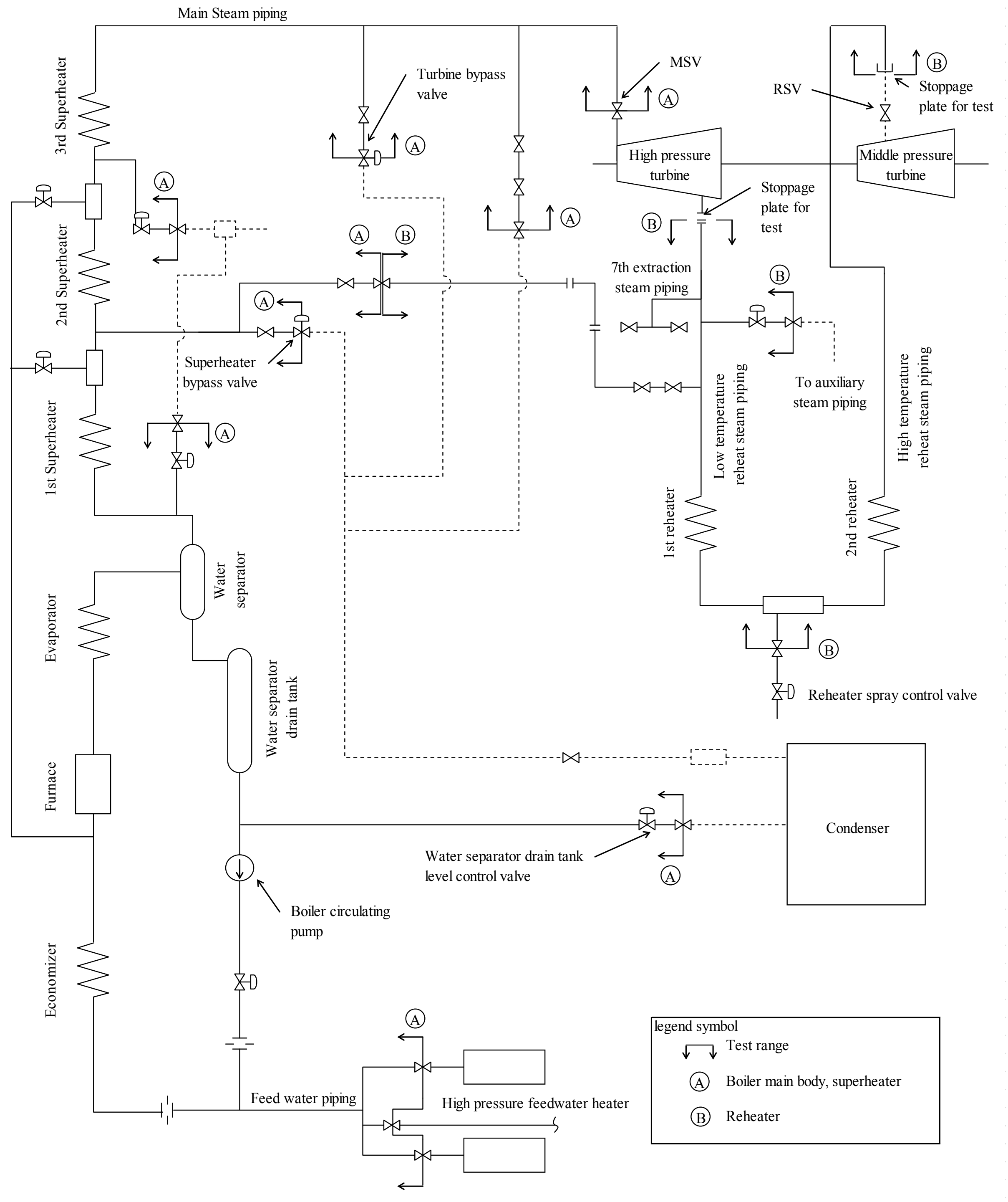


Figure 138-a6-1 Scope of hydraulic pressure test

6. Pressurization schedule of hydraulic pressure test

Pressurization schedule of hydraulic pressure test is shown as follows;

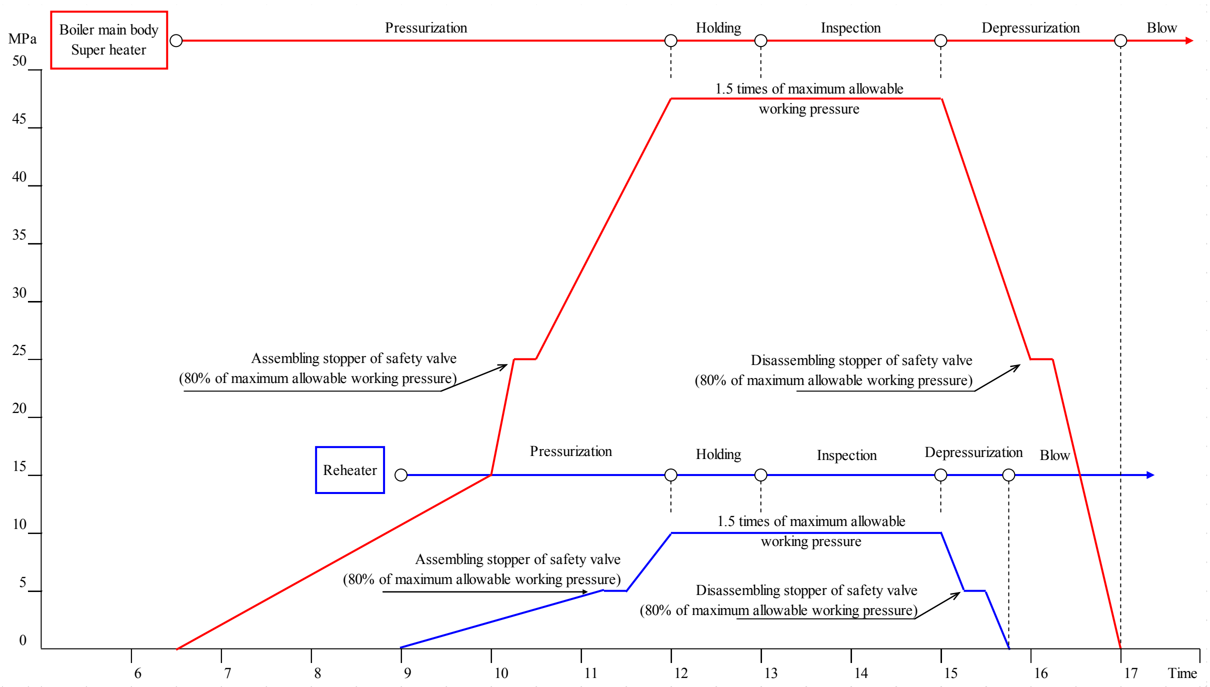


Figure 138-a6-2 Pressurization schedule of hydraulic pressure test

Article138-a7 General of steam turbine (Inspection during construction)

1. Purpose

It must be confirmed that steam turbine and condenser are manufactured based on implementation plan of power plant and required welding inspection of piping attached to steam turbine is conducted.

2. Inspection procedure and criterion

Inspection items	Procedure	Criterion
(1) Steam turbine and condenser	(1) It must be confirmed specification by construction drawing and nameplate etc.	(1) It must be met implementation plan of power plant.
(2) Foundation of steam turbine	(2) It must be confirmed by actual value and foundation working drawings etc.	(2) It must be met foundation description of implementation plan and drawings of foundation condition.
(3) Piping of steam turbine and piping attached to steam turbine required welding inspection	(3) It must be confirmed record of welding inspection or certificate of compliance.	(3) It must be taken welding inspection.
(4) Pressure parts of steam turbine	(4) It must be confirmed no defects by hydraulic pressure test.	(4) It must be confirmed that there is no defect in record of hydraulic pressure test.

Article138-a8 Material inspection of steam turbine (Inspection during construction)

1. Purpose

It must be confirmed that each materials of steam turbine and condenser are met implementation plan of power plant.

2. Inspection procedure and criterion

Inspection items	Procedure	Criterion
(1) Each part of steam turbine (Casing, disc, diaphragm, nozzle hole, blade, rotor and piping) (2) Condenser	It must be confirmed materials of these parts by record of material test etc.	It must be met implementation plan of power plant.

Article138-a9 Structure and external appearance inspection of steam turbine (Inspection during construction)

1. Purpose

It must be confirmed that each parts of steam turbine are manufactured based on construction drawing of implementation plan and there is no defect in welded parts.

2. Inspection procedure and criterion

Inspection items	Procedure	Criterion
(1) Casing (2) Disc (3) Diaphragm (4) Nozzle hole (Including stationary blade) (5) Moving blade (Including shroud and lacing wire) (6) Rotor (7) Coupling (8) Bearing (9) Labyrinth packing (10) Piping (11) MSV (12) CV (13) RSV (14) ICV (15) Governor	(1) It must be confirmed that each parts of steam turbine is manufactured based on construction drawing referring to following items by visual check. 1) Finishing (Surface roughness) 2) Fouling 3) Change in color 4) Rust 5) Foreign object 6) Fracture 7) Dent 8) Deformation 9) Scratch 10) Corrosion 11) Abrasion 12) Loose of bolt	(1) It must be confirmed each part of steam turbine is met construction drawing of implementation plan.

Inspection items	Procedure	Criterion
(16) Emergency Governor (17) Rupture disk	(2) It must be confirmed following items when cast steel is used to casing, MSV, RSV and CV etc. 1) Structural required weld 2) Repair welding of defect 3) Chipping finished (3) It must be overhauled and inspected MSV, RSV and CV etc. (4) It must be confirmed following items regarding structural welding part and repair welding part by visual check and record etc. 1) Serious defect 2) Required stress relief (5) It must be confirmed following item by measurement, visual check and record etc. when conducting chipping finished. 1) Remaining thickness is more than acceptable value.	

Article138-a10 Boundary dimension inspection of steam turbine (Inspection during construction)

1. Purpose

It must be confirmed that boundary dimension of each part of steam turbine is met implementation plan of power plant.

2. Inspection procedure and criterion

Inspection items	Procedure	Criterion
Each part of steam turbine (Casing, disc, diaphragm, nozzle hole (stationary blade), blade, rotor and piping)	It must be confirmed boundary dimension and shape of each part by actual measurement or measuring record at manufacturing plant and power plant.	It must be met implementation plan of power plant.

Article138-a11 Assembling and installation condition inspection of steam turbine (Inspection during construction)

1. Purpose

It must be confirmed that condition of assembling and installation of steam turbine is proper.

2. Inspection procedure and criterion

Inspection items	Procedure	Criterion
(1) Assembling condition 1) Pore space of flange face of casing 2) Pore space between moving blade and stationary blade 3) Pore space of labyrinth packing 4) Boundary dimension of bearing 5) Pore space of bearing	(1) It must be confirmed assembling condition by measured record at manufacturing plant or power plant.	(1) It must be confirmed that assembling condition is met implementation plan and measured value is within acceptable value.
(2) Installation condition 1) Horizontality of flange face of casing 2) Circularity of casing inside 3) Centering of rotor 4) Horizontality of rotor 5) Installation condition of condenser	(2) It must be confirmed installation condition by measured record at power plant.	(2) It must be confirmed that installation condition is met implementation plan and measured value is within acceptable value.

Article138-a12 General of gas turbine (Inspection during construction)

1. Purpose

It must be confirmed that gas turbine is manufactured based on implementation plan of power plant and required welding inspection of piping attached to gas turbine is conducted.

2. Inspection procedure and criterion

Inspection items	Procedure	Criterion
(1) Gas turbine	(1) It must be confirmed specification by construction drawing and nameplate etc.	(1) It must be met implementation plan of power plant.
(2) Foundation of gas turbine	(2) It must be confirmed by actual value and foundation working drawings etc.	(2) It must be met foundation description of implementation plan and drawings of foundation condition.
(3) Piping attached to gas turbine required welding inspection	(3) It must be confirmed record of welding inspection or certificate of compliance.	(3) It must be taken welding inspection.
(4) Pressure parts of gas turbine	(4) It must be confirmed no defects by hydraulic pressure test.	(4) It must be confirmed that there is no defect in record of hydraulic pressure test.

Article138-a13 Material inspection of gas turbine (Inspection during construction)

1. Purpose

It must be confirmed that each materials of gas turbine are met implementation plan of power plant.

2. Inspection procedure and criterion

Inspection items	Procedure	Criterion
Each part of gas turbine (Casing, disc, diaphragm, blade, rotor and piping)	It must be confirmed materials of these parts by record of material test etc.	It must be met implementation plan of power plant.

Article138-a14 Structure and external appearance inspection of gas turbine (Inspection during construction)

1. Purpose

It must be confirmed that each parts of gas turbine are manufactured based on construction drawing of implementation plan and there is no defect in welded parts.

2. Inspection procedure and criterion

Inspection items	Procedure	Criterion
(1) Gas turbine 1) Casing 2) Disc 3) Diaphragm 4) Stationary blade 5) Moving blade 6) Rotor 7) Labyrinth packing 8) Combustor 9) Fuel shutoff valve 10) Fuel control valve 11) Bearing 12) Reduction gear 13) Piping (2) Compressor 1) Casing 2) Moving blade 3) Stationary blade 4) Rotor 5) Bearing 6) Piping	(1) It must be confirmed that each parts of gas turbine is manufactured based on construction drawing referring to following items by visual check. 1) Finishing (Surface roughness) 2) Fouling 3) Change in color 4) Rust 5) Foreign object 6) Fracture 7) Dent 8) Deformation 9) Scratch 10) Corrosion 11) Abrasion 12) Loose of bolt (2) It must be confirmed following items when cast steel is used to parts of gas turbine 1) Structural required weld 2) Repair welding of defect 3) Chipping finished (3) It must be confirmed following items regarding structural welding part and repair welding part by visual check and record etc. 1) Serious defect 2) Required stress relief (4) It must be confirmed following item by measurement, visual check and record etc. when conducting chipping finished. 1) Remaining thickness is more than acceptable value.	(1) It must be confirmed each part of gas turbine is met construction drawing of implementation plan.

Article138-a15 Boundary dimension inspection of gas turbine (Inspection during construction)

1. Purpose

It must be confirmed that boundary dimension of each part of gas turbine is met implementation plan of power plant.

2. Inspection procedure and criterion

Inspection items	Procedure	Criterion
Each part of gas turbine [Casing, disc, diaphragm, blade, rotor and piping]	It must be confirmed boundary dimension and shape of each part by actual measurement or measuring record at manufacturing plant and power plant.	It must be met implementation plan of power plant.

Article138-a16 Assembling and installation condition inspection of gas turbine (Inspection during construction)

1. Purpose

It must be confirmed that condition of assembling and installation of gas turbine is proper.

2. Inspection procedure and criterion

Inspection items	Procedure	Criterion
(1) Assembling condition 1) Pore space of flange face of casing 2) Pore space between moving blade and stationary blade 3) Pore space of labyrinth packing 4) Boundary dimension of bearing 5) Pore space of bearing	(1) It must be confirmed assembling condition by measured record at manufacturing plant or power plant.	(1) It must be confirmed that assembling condition is met implementation plan and measured value is within acceptable value.

Inspection items	Procedure	Criterion
(2) Installation condition 1) Horizontality of flange face of casing 2) Circularity of casing inside 3) Centering of rotor 4) Horizontality of rotor	(2) It must be confirmed installation condition by measured record at power plant.	(2) It must be confirmed that installation condition is met implementation plan and measured value is within acceptable value.

Article 139. Safety valve test

1. Confirmation of the installation status, etc.

(1) The specifications of safety valve such as type, popping pressure, and relieving capacity must be confirmed visually through identification plate, etc.

(2) The installation location, numbers and installation status of safety valve must be confirmed visually.

2. Operation test (Case : Variable pressure once-through boiler)

(1) Checking before operation test
Calibration of pressure gauge for safety valve test must be checked by calibration record etc.

(2) Safety valve test

1) Boiler safety valve and super-heater outlet safety valve
Popping pressure of safety valve must be confirmed by using hydraulic jack because popping pressure of safety valve is set more than boiler maximum allowable working pressure.

a. Operation status of boiler must be checked before starting safety valve test.

b. Boiler main steam pressure must be increased to proper pressure.

c. Operation status of boiler must be confirmed stable. (in case that boiler operation status is not stable, safety valve test must not been conducted.)

d. Hydraulic jack must be installed on safety valve.

e. Hydraulic pressure of hydraulic jack must be increased by degrees and safety valve must be operated by pulling valve stem of safety valve by means of hydraulic jack.

f. When safety valve is operated, power plant staff must confirm pressure of boiler main steam (pressure A) and hydraulic pressure of hydraulic jack.

g. Hydraulic pressure must be decreased to 0 (zero) as well as safety valve is operated.

h. Power plant staff must confirm that safety valve is reseated and boiler is operated stable. (in case that operation status of boiler is not stable, power plant staff must confirm cause of trouble and operate boiler stable.)

i. Power plant staff must confirm popping pressure by means of above pressure A and hydraulic jack conversion pressure. And power plant staff must confirm that popping pressure is within acceptable value and conclude this test.

When test result is not appropriate, safety valve must be adjusted if necessary.

2) Super-heater outlet relief valve

a. Operation status of boiler must be checked before starting test.
b. Boiler main steam pressure must be increased to proper pressure.
c. Operation status of boiler must be confirmed stable. (in case that operation status of boiler is not stable, safety valve test must not been conducted.)
d. Hydraulic pressure of hydraulic tester must be increased by degrees and relief valve must be operated by signal from pressure detector.
e. When relief valve is operated, hydraulic pressure of hydraulic tester must be stopped increasing and popping pressure must be confirmed by hydraulic pressure.
f. Hydraulic pressure of hydraulic tester must be decreased by degrees and reseating pressure must be confirmed by hydraulic pressure.
g. Popping and reseating pressure must be within acceptable value, operation status of boiler must be confirmed stable and this test must be concluded. (in case that operation status of boiler is not stable, power plant staff must confirm cause of trouble and operate boiler stable.)

When test result is not appropriate, safety valve must be adjusted if necessary.

3) Re-heater inlet and outlet safety valve

Popping pressure, reseating pressure, blow down pressure, rate of blow down, stem of safety valve must be confirmed. Chattering and steam leak at popping and reseating must be confirmed.

a. Operation status of boiler must be checked before starting test.
b. Test fixture for safety valve test must be prepared.
c. Water separator pressure must be increased to proper pressure.
d. Operation status of boiler must be confirmed stable. (in case that operation status of boiler is not stable, safety valve test must not been conducted.)
e. After confirming that drain valves of high and low temperature reheat steam piping are opened full, test valve for reheat safety valve must be opened slightly to warmed up re-heater.
f. Drain valves of high and low temperature reheat steam piping must be opened slightly after warming up and reheat steam pressure must be increased by operating test valve.
g. Reheat steam pressure must be held and Test fixture for safety valve test must be installed to safety valves not to be tested.
h. Reheat steam pressure must be increased by opened test valve for reheat safety valve. When Reheat steam pressure is more than 75% of popping pressure, safety valve to be tested must be blown out.

i. Stem measuring equipment must be installed after safety valve to be tested is blown out. Reheat steam pressure must be increased until safety valve is operated.

j. When safety valve is operated, popping pressure must be confirmed and test valve for reheat safety valve must be closed. When safety valve is closed, reseating pressure must be confirmed.

k. When reheat steam pressure is decreased, test valve must be opened slightly, reheat steam pressure must be held and stem must be measured.

l. Popping pressure, reseating pressure, blow-down pressure, rate of blow down, stem of safety valve must be confirmed within acceptable value, operation status of boiler must be confirmed stable and this test must be concluded. (in case that operation status of boiler is not stable, power plant staff must confirm cause of trouble and operate boiler stable.)

When test result is not appropriate, safety valve must be adjusted if necessary.

Article 140. Alarm device test

1. Boiler-related alarm device

(1) Purpose

It must be confirmed that defect for control system, pressure and temperature etc. related boiler equipment are detected and alarm system is operated normally.

(2) Unit operation status

Under unit operation

Under unit trip

(3) Test procedure and point to be checked (example)

Test item	**Test procedure**	**Point to be checked**		
		Set value	**Operating value**	**Indicator**
Feed water rate low	a) Imitation signal is inputted through input terminal of feed water rate alarm adjuster at boiler converter panel. b) Feed water rate is confirmed by recorder (Boiler-Turbine-Generator panel) at alarming.	X X t/h + AA - AA	t/h	Feed water rate low
FDF bearing lubricant oil pressure low	a) Valve of bearing lubricant oil pressure switch is closed. b) Temporary blow valve is opened and bearing lubricant oil pressure is decreased. c) Bearing lubricant oil pressure is confirmed by temporary pressure gauge at alarming.	X.XX Pa + A.AA - A.AA	Pa	FDF abnormal

Test item	Test procedure	Point to be checked		
		Set value	Operating value	Indicator
Steam temperature high of super-heater outlet	a) Imitation signal is inputted steam temperature adjuster at APC panel. b) Steam temperature is confirmed by recorder at alarming.	X X °C + AA - AA	°C	Steam temperature high of super-heater outlet

(4) Evaluation criteria

It must be confirmed that alarms and necessary indications are appeared normally.

2. Steam turbine-related alarm device

(1) Purpose

It must be confirmed that defect for control system, pressure and temperature etc. related steam turbine equipment are detected and alarm system is operated normally.

(2) Unit operation status

Under unit operation

Under unit trip

(3) Test procedure and point to be checked (example)

Test item	Test procedure	Points to be checked		
		Set value	Operating value	Indicator
Rotor vibration high	a) Interlock switch for rotor vibration high is deselected. b) Output terminal of turbine revolution monitoring switch in turbine supervisory instrument panel is left open and condition of “turbine revolution more than XXXX rpm” is prepared. c) Signal cable of rotor vibration detector in turbine supervisory instrument panel is unfixed. d) Output form test signal generator is connected to above unfixed terminal block (c) and imitation signal is inputted. e) Vibration value is confirmed through recorder at alarming.	Turbine revolution More than XXX X rpm AA/100 mmp-p + AA/100 - AA/100	mmp-p	Rotor vibration high
Bearing lubricant oil pressure low	a) Valve of bearing lubricant oil pressure switch is closed. b) Temporary blow valve is opened and bearing lubricant oil pressure is decreased. c) Bearing lubricant oil pressure is confirmed by temporary pressure gauge at alarming.	X.XX Pa + A.AA - A.AA	Pa	Bearing lubricant oil pressure low

Test item	Test procedure	Points to be checked		
		Set value	Operating value	Indicator
Condenser vacuum low	a) Condenser vacuum pump is stopped at going up vacuum. b) Vacuum control valve is opened, condenser vacuum is decreased gradually and operating value at alarming is confirmed by vacuum manometer.	X X mmHg + AA - AA	mmHg	Condenser vacuum low

(4) Evaluation criteria

It must be confirmed that alarms and necessary indications are appeared normally.

3. Gas turbine-related alarm device

(1) Purpose

It must be confirmed that defect for control system, pressure and temperature etc. related gas turbine equipment are detected and alarm system is operated normally.

(2) Unit operation status

Under unit operation

Under unit trip

(3) Test procedure and point to be checked (example)

Test item	Test procedure	Point to be checked		
		Set value	Operating value	Indicator
Rotor vibration high	a) Interlock switch for rotor vibration high is deselected. b) Output terminal of turbine revolution monitoring switch in turbine supervisory instrument panel is left open and condition of "turbine revolution more than XXXX rpm" is prepared. c) Signal cable of Rotor vibration detector in turbine supervisory instrument panel is unfixed. d) Output form test signal generator is connected to above unfixed terminal block (c) and imitation signal is inputted. e) Vibration value is confirmed through recorder at alarming.	Turbine revolution More than XXX X rpm AA/100 mmp-p + AA/100 - AA/100	mmp-p	Rotor vibration high
Bearing lubricant oil pressure low	a) Valve of bearing lubricant oil pressure switch is closed. b) Temporary blow valve is opened and bearing lubricant oil pressure is decreased. c) Bearing lubricant oil pressure is confirmed by temporary pressure gauge at alarming.	X.XX Pa + A.AA - A.AA	Pa	Bearing lubricant oil pressure low

(4) Evaluation criteria

It must be confirmed that alarms and necessary indications are appeared normally.

Article 141. Interlock test

1. Boiler-related interlock test

(1) Furnace purge interlock

1) Purpose

It must be confirmed that furnace purge is operated normally and boiler is ignited after completing furnace purge to prevent furnace explosion at boiler starting.

2) Unit operation status

a. Under boiler stop

b. Under turbine stop

3) Test procedure and point to be checked (example)

Item	Test procedure	Point to be checked
Confirmation of condition of furnace purge	- MFT - Nonuse of igniter - Nonuse of light oil burner - Nonuse of heavy oil burner - Not less than 1 FDF operating - Not less than 1 IDF operating - Heavy oil/light oil transfer valve : light oil side - Stop of all coal pulverizers - 2 GRFs operating - Not less than XX% MCR of air mass flow	- - "MFT" : On - - Nonuse - - Nonuse - Nonuse - "Operating" : On - "Operating" : On - Light oil side - "Stopping" : On - "Operating" : On - Air mass flow : XX% MCR - "Operating permission of furnace purge" : On
Confirmation of start impossibility of furnace purge	- less than XX% MCR of air mass flow - Push "furnace purge" button - Not less than XX% MCR of air mass flow	- "Operating permission of furnace purge" Off - "Operating permission of furnace purge" Off - "Operating permission of furnace purge" On - Air mass flow : XX% MCR
Starting of furnace purge	- Push "furnace purge" button - Opening of all air registers - Opening of all inlet dampers of wind boxes - Opening of all gas distributing dampers	- "Operating" : on - Set opening - Set opening - Full opening

Item	Test procedure	Point to be checked
Confirmation of leak check of ignition light oil system	- Light oil pump is started by pushing "starting of ignition light oil system" button. - When pressure before light oil shut off valve is not less than stipulated value, ignition light oil shut off valve is opened. - When ignition light oil pressure is not less than stipulated value, ignition light oil shut off valve is closed. - When ignition light oil pressure is not less than XX pa for A minutes, leak check of ignition light oil system is completed.	- Light oil pump : Operating - Ignition light oil shut off valve : Open - Ignition light oil shut off valve : Close - Pressure : XX pa - Pressure of igniter header : XX pa XX minutes after leak check
Confirmation of leak check of light oil system	- Light oil leak check valve is opened after pushing "Operating of light oil system" button. When light oil pressure is less than stipulated value, light oil leak check valve is closed. - When light oil pressure is not less than XX pa for A minutes, leak check of light oil system is completed.	- Light oil leak check valve : Open - Light oil leak check valve : Close - Pressure : XX pa - Pressure of burner header : XX pa XX minutes after leak check
Confirmation of completion of furnace purge	- Furnace purge is completed in XX minutes after leak check is finished.	- Completion of furnace purge : On - Time of purge : XX minutes
Confirmation of ignition impossibility of igniter (before MFT reset)	- No.X ignition of igniter - No.X ignition of igniter - No.X ignition of igniter	- Impossibility of ignition - Impossibility of ignition - Impossibility of ignition
Confirmation of MFT reset	- After furnace purge, ignition light oil system leak check and light oil system leak check are completed, imitation signal of light oil feed rate is increased not less than XX t/h and MFT reset is confirmed.	- Feed water feed rate : XX t/h - MFT : Off - Completion of ignition light oil system starting : On - Completion of light oil system starting : On

4) Evaluation criteria

It must be confirmed that each equipment is operated and alarms and necessary indications are appeared normally.

(2) MFT interlock

1) Purpose

It must be confirmed that boiler interlock (MFT) is operated normally due to trouble having an effect on boiler combustion and interlock of each boiler related equipment is operated normally due to MFT. It must be confirmed that alarms and necessary indications are appeared normally.

2) Unit operation status

a. Under boiler stop

b. Under turbine stop

3) Test procedure and point to be checked (example)

<MFT due to loss of all flame>

a. Test procedure

Light oil burner, heavy oil burner and pulverized coal burner are extinguished sequentially; MFT is operated by extinguishing last burner.

b. Status confirmation

Point to be checked	**Confirmation procedure**			
	Before test	**Check**	**After test**	**Check**
No.X - IDF	Operation		Operation	
No.X – FDF	Operation		Operation	
No.X – PAF	Operation		Stop	
No.X – GRF	Operation		Operation	
No.X – IDF blade	Auto %		Auto %	
No.X – FDF blade	Auto %		Auto %	
No.X – PAF blade	Auto %		Auto %	
No.X – IDF outlet damper	Full open		Full open	
No.X – FDF outlet damper	Full open		Full open	
No.X – PAF outlet damper	Full open		Full close	
No.X – GRF outlet damper	Full open		Full open	
XX stage air register	Open		Full open	
XX stage air register	Open		Full open	
No.X – light oil pump	Operation		Stop	
No.X – heavy oil pump	Operation		Stop	
Light oil shut off valve	Full open		Full close	
Heavy oil shut off valve	Full open		Full close	
Igniter shut off valve	Full open		Full close	
XX stage light oil burner	On		Off	
XX stage heavy oil burner	On		Off	
XX stage igniter	On		Off	
M-BFP	Operation		Stop	
No.X – BFPT	Reset		Stop	
No.X – BFPT booster pump	Operation		Stop	

Point to be checked	Confirmation procedure			
	Before test	Check	After test	Check
No.X – super-heater spray control valve	Auto %		Auto %	
Re-heater spray control valve	Auto %		Auto %	
Re-heater spray shut off valve	Full open		Full close	
No.X – re-heater spray valve	Full open		Full close	
De-SOx bypass damper	Full close		Full open	
No.X – De-NOx ammonia shut off valve	Full open		Full close	
No.X – coal pulverizer	Operation		Stop	
No.X – coal feeder	Operation		Stop	
No.X – coal pulverizer outlet damper	Full open		Full close	
No.X – coal pulverizer primary air damper	Auto %		Auto %	
No.X – coal pulverizer hot air damper	%		%	
No.X – coal pulverizer cold air damper	%		%	
No.X – coal pulverizer inlet air shut off damper	Full open		Full close	
No.X – coal pulverizer seal air fan	Operation		Stop	
No.X – primary air heater outlet gas damper	Auto %		Auto %	
No.X – primary air heater inlet gas damper	Full open		Full close	
No.X – coal pulverizer cold air extraction damper	Full open		Full close	

c. Alarm confirmation

Alarm items	Place	Check
No.X – De-NOx equipment trip	Boiler-Turbine-Generator panel	
No.X – De-SOx equipment trip	Boiler-Turbine-Generator panel	
De-SOx bypass damper open	Boiler-Turbine-Generator panel	
No.X – PAF trip	Boiler-Turbine-Generator panel	
Heavy oil pump trip	Boiler-Turbine-Generator panel	
Light oil pump trip	Boiler-Turbine-Generator panel	
MFT	Boiler-Turbine-Generator panel	
All fuel loss trip	Boiler-Turbine-Generator panel	
Burner abnormal	Boiler-Turbine-Generator panel	
M-BFP trip	Boiler-Turbine-Generator panel	
No.X – BFPT trip	Boiler-Turbine-Generator panel	
Light oil pump C/C trip	Boiler-Turbine-Generator panel	

4) Evaluation criteria

It must be confirmed that each equipment is operated and alarms and necessary indications are appeared normally according to interlock.

2. Steam turbine-related interlock test

(1) Trip due to condenser vacuum low

1) Purpose

It must be confirmed that main steam stop valve and re-heater steam stop valve etc. are operated normally according to steam turbine trip due to condenser vacuum low.

2) Unit operation status

Under steam turbine stopping

3) Test procedure and point to be checked (example)

a. Test procedure

No.- X and No.- Y vacuum low test valve are opened slightly, degree of vacuum of pressure switch inlet is decreased. It must be confirmed that alarm of condenser vacuum low and turbine trip.

b. Status confirmation

Point to be checked		**Confirmation procedure**			
		Before test	**Check**	**After test**	**Check**
Steam turbine		Reset		Trip	
Protection equipment test panel	No.-X	-		Trip	
	No.-Y	-		Trip	
Condenser vacuum				Alarm mmHg	
	No.-X	mmHg		Trip mmHg	
	No.-Y	mmHg		Trip mmHg	
Emergency shut off hydraulic pressure		Pa		Pa	
Main steam stop valve		Full open		Full close	
Control valve		%		%	
Reheat steam stop valve		Full open		Full close	
Intercept valve		%		%	
Ventilator valve		Full close		Full open	
BFP steam shut off valve		Full open		Full close	
No.X – extraction check valve		Full open		Full close	

c. Alarm confirmation

Alarm items	Place	Check
Condenser vacuum low trip	Boiler-Turbine-Generator panel	
Emergency shut off hydraulic pressure low trip	Boiler-Turbine-Generator panel	
Condenser vacuum low	Boiler-Turbine-Generator panel	
Turbine protection equipment detector operation	Boiler-Turbine-Generator panel	

4) Evaluation criteria

It must be confirmed that each equipment and valves etc. are operated and alarms and necessary indications are appeared normally according to interlock.

3. Gas turbine-related interlock test

(1) Trip due to exhaust gas temperature high

1) Purpose

It must be confirmed that fuel shut off valve and control valve etc. are operated normally according to gas turbine trip due to exhaust gas temperature high.

2) Unit operation status

Under gas turbine stopping

3) Test procedure and points to be checked (example)

a. Test procedure

(a) It must be confirmed that lock out rely is reset.

(b) It must be simulated that gas turbine is started.

(c) It must be simulated that generator is synchronized.

(d) It must be simulated that exhaust gas temperature is higher than acceptable value.

(e) It must be confirmed that this system is operated normally according to interlock of gas turbine and following status of system and transmitted alarm are appropriate.

b. Status confirmation

Point to be checked	**Confirmation procedure**			
	Before test	**Check**	**After test**	**Check**
No.X Fuel shut off solenoid valve	Reset		Trip	
No.X Fuel shut off solenoid valve	Reset		Trip	
No.X shut off oil shut off solenoid valve	Reset		Trip	
No.X shut off oil shut off solenoid valve	Reset		Trip	
Fuel shut off valve	-		Full close	
No.X fuel control valve	-		Full close	
No.X fuel control valve	-		Full close	
Generator circuit breaker	-		Shut off	
Field circuit breaker	-		Shut off	

c. Alarm confirmation

Alarm items	**Place**	**Check**
Gas turbine trip	Gas turbine panel	
Trip for Gas turbine exhaust gas temperature high	Gas turbine panel	
Run back for exhaust gas temperature high	Gas turbine panel	

4) Evaluation criteria

It must be confirmed that each equipment and valves etc. are operated and alarms and necessary indications are appeared normally according to interlock.

4. Auxiliaries-related interlock test

(1) Purpose

It must be confirmed that automatic start test of auxiliary oil pump, emergency oil pump and control oil pump.

(2) Unit operation status

Under unit XXX

(3) Test procedure and point to be checked (example)

1) Test procedure

Test item	**Test procedure**	**Point to be checked**		
		Set value	**Operating value**	**Indicator**
Turning oil pump	a. This test is conducted under rated rotating speed of steam turbine. b. Switch of turning oil pump is set to “Automatic position”. c. Test valve of bearing oil pressure low of turbine is opened gradually and turning oil pump is operated automatically. d. Test valve is restored, turning oil pump is stopped and switch of it is set to “Automatic position”.	X.XX Pa + A.AA - A.AA	Pa	“Turning oil pump starting automatically” “Gas turbine oil pump outlet pressure low ”
Auxiliary oil pump	a. Switch of auxiliary oil pump is set to “Automatic position”. b. Test valve of bearing oil pressure low of turbine is opened gradually and auxiliary oil pump is operated automatically. c. Test valve is restored, auxiliary oil pump is stopped and switch of it is set to “Automatic position”.	X.XX Pa + A.AA - A.AA	Pa	“Auxiliary oil pump starting automatically” “Gas turbine oil pump outlet pressure low ”
Emergency oil pump	a. Switch of turning oil pump is set to “Lock position” and switch of emergency oil pump is set to “Automatic position”. b. Test valve of bearing oil pressure low of turbine is opened gradually and emergency oil pump is operated automatically. c. Test valve is restored, emergency oil pump is stopped and switch of it is set to “Automatic position”.	X.XX Pa + A.AA - A.AA	Pa	“Emergency oil pump starting automatically” “Gas turbine oil pump outlet pressure low ”

Test item	Test procedure	Point to be checked		
		Set value	Operating value	Indicator
Control oil pump	a. Switch of control oil pump is set to "Automatic position". b. Test valve of oil pressure low is opened gradually, pressure switch for alarm is operated and control oil pump is operated automatically. c. Test valve is restored, control oil pump is stopped and switch of it is set to "Automatic position".	X.XX Pa + A.AA - A.AA	Pa	"Control oil pump starting automatically" "Gas turbine oil pump outlet pressure low "

(4) Evaluation criteria

It must be confirmed that each equipment is operated and alarms and necessary indications are appeared normally according to interlock.

5. Coal supply system-related interlock test

It must be referred to Article 146-a1 in this Guideline.

6. Exhaust gas treatment equipment-related interlock test

It must be referred to Article 146-a7 in this Guideline.

7. Unit interlock test

(1) Unit trip due to stop of all BFPTs

1) Purpose

It must be confirmed that MFT, turbine trip and parallel off of generator are operated normally due to boiler trouble.

2) Unit operation status

a. Under unit XXX

3) Test procedure and point to be checked (example)

a. Test procedure

Push button "Emergency stop of BFPT" of Boiler-Turbine-Generator panel is pushed and following unit trip flow must be confirmed.

"All BFPTs trip" → "MFT on" → "Opening of generator circuit breaker"

b. Status confirmation

Point to be checked	Confirmation procedure			
	Before test	Check	After test	Check
MFT Reset	Reset		Trip	
M-BFP	Operation		Stop	
Flame (burner, igniter)	On		Off	
Fuel shut off valve	Full open		Full close	
Igniter shut off valve	Full open		Full close	
Re-heater spray shut off valve	Full close		Full close	

Point to be checked		Confirmation procedure			
		Before test	**Check**	**After test**	**Check**
Master trip valve (Turbine trip test)	A	Trip on		Trip off	
	B	Trip on		Trip off	
Mechanical trip valve	Oil trip	Trip off		Trip on	
	Reset	Trip off		Trip on	
Turbine reset		Reset		Trip	
Main steam stop valve		Full open		Full close	
Re-heater steam stop valve		Full open		Full close	
Intercept valve		Full open		Full close	
Ventilator valve		Full close		Full close	
Emergency blow down valve		Full close		Full close	
Control valve		% open		% open	
Extraction check valve		Open		Close	
Generator circuit breaker		On		Off	
Field circuit breaker		On		Off	

c. Alarm confirmation

Alarm items	Place	Check
MFT	Boiler-Turbine-Generator panel	
Trip of all BFPTs	Boiler-Turbine-Generator panel	
Feed water feed rate low	Boiler-Turbine-Generator panel	
Abnormal of M-BFP	Boiler-Turbine-Generator panel	
M-BFP inlet pressure low	Boiler-Turbine-Generator panel	
Fuel shut off valve close	Boiler-Turbine-Generator panel	
Igniter shut off valve	Boiler-Turbine-Generator panel	

4) Evaluation criteria

It must be confirmed that each equipment and valves etc. are operated and alarms and necessary indications are appeared normally according to interlock.

(2) Unit trip due to turbine bearing oil pressure low

1) Purpose

It must be confirmed that turbine trip, MFT, and parallel off of generator are operated normally due to turbine trouble.

2) Unit operation status

a. Under unit XXX

3) Test procedure and point to be checked (example)

a. Test procedure

Test valve of bearing oil pressure low is opened, oil pressure is decreased and following unit trip flow must be confirmed.

"Bearing oil pressure low" → "Turbine trip" → "86G" → "Opening of generator circuit breaker"

b. Status confirmation

Point to be checked		Confirmation procedure			
		Before test	Check	After test	Check
Main steam stop valve		Full open		Full close	
Control valve		% open		% open	
Re-heater steam stop valve		Full open		Full close	
Intercept valve		Full open		Full close	
Ventilator valve		Full close		Full open	
86G	A	Reset		Trip	
	B	Reset		Trip	
Generator circuit breaker		On		Off	
Field circuit breaker	XX	On		Off	
	XX	On		Off	
Auxiliary transformer circuit breaker	XX	On		Off	
	XX	On		Off	

c. Alarm confirmation

Alarm items	Place	Check
Turbine trip	Boiler-Turbine-Generator panel	
Bearing oil pressure low	Boiler-Turbine-Generator panel	
86G	Boiler-Turbine-Generator panel	

4) Evaluation criteria

It must be confirmed that each equipment and valves etc. are operated and alarms and necessary indications are appeared normally according to interlock.

Article 142. Speed governor working range test

1. Purpose

Speed range (upper limit and lower limit) within which speed governor can adjust under the condition of no-load operation of steam turbine must be confirmed.

2. Unit operation status

No load operation of steam turbine

3. Test procedure and point to be checked (example)

Steam turbine must be set in the state of no-load operation and output of speed governor must be changed to the lower limit. Then, rotating speed of steam turbine must be confirmed under this condition. In the same way, output of speed governor must be changed to the upper limit. Then, rotating speed of steam turbine must be confirmed under this condition.

(1) EHC

Test item	Test procedure	Point to be checked		
		Set value	**Operating value**	**Indicator**
Lower limit	Push button of “Close” of governor setting station and lead to lower limit	X rpm (± A)	rpm	Lower limit lamp lighting
Higher limit	Push button of “Open” of governor setting station and lead to higher limit	X rpm (± A)	rpm	Higher limit lamp lighting

(2) MHC

Test item	Test procedure	Point to be checked		
		Set value	**Operating value**	**Indicator**
Lower limit	Lead synchronized handle to lower limit (floor of steam turbine)	X rpm (± A)	rpm	Temporary revolution indicator
Higher limit	Lead synchronized handle to higher limit (floor of steam turbine)	X rpm (± A)	rpm	Temporary revolution indicator

4. Evaluation criteria

Operation limit of speed governor must be confirmed that it is as same as designed.

Article 143. Emergency governor test

1. Emergency governor oil trip test

(1) Purpose

It must be confirmed that emergency governor is operated by locking out over speed trip and putting test pressure.

(2) Unit operation status

No load operation of steam turbine

(3) Test procedure and point to be checked (example)

1) In case of confirming oil trip hydraulic pressure (Steam turbine field)

Test procedure	Point to be checked		
	Set value	**Operating value**	**Indicator**
Test lever is positioned “Test position” and held. Mechanical over speed trip test valve is opened gradually; hydraulic pressure of mechanical over speed trip test is gone up gradually. It must be confirmed emergency governor is operated, hydraulic pressure of mechanical over speed trip is decreased and indicator is lighted.	-	AAA Pa	(Steam turbine field) - Emergency governor is operated WL : lighting (BTG panel) Mechanical over speed trip

Test procedure	Point to be checked		
	Set value	**Operating value**	**Indicator**
After confirming, test valve is closed.	-	AAA Pa	(Steam turbine field) - Emergency governor is operated WL : lighting (BTG panel) Mechanical over speed trip
It must be confirmed hydraulic pressure of mechanical over speed trip is returned after turbine is reset by turbine reset lever.			
Test lever is operated at normal potion.			

2) In case of confirming oil trip rotating speed (BTG panel)

Test procedure	Point to be checked		
	Set value	Operating value	Indicator
Turbine rotating speed is decreased to XXX rpm.	AAA rpm (below AA%)	AAA rpm (AA %)	- "Turbine trip" : lighting - RL of "Over speed turbine trip" : lighting GL of "Emergency governor test oil trip" : lighting
Push button of "Lock Out" is pushed.			
It must be confirmed rotating speed after holding push button of "Oil Trip" and steam turbine is tripped.			

(4) Evaluation criteria

Rotating speed of steam turbine at operating emergency governor must be lower than 1.11 times of rated rotating speed. All valves must be operated in accordance with designated interlock, and alarms and necessary indications must be appeared normally.

2. Emergency governor operation test

(1) Purpose

It must be confirmed that emergency governor is operated to prevent abnormal rise of steam turbine rotating speed.

(2) Unit operation status

No load operation of steam turbine

(3) Test procedure and point to be checked (example)

<table>
<tr><th rowspan="2">Test procedure</th><th colspan="3">Point to be checked</th></tr>
<tr><th>Set value</th><th>Operating value</th><th>Indicator</th></tr>
<tr><td>After changing valves, steam turbine under control valves must be confirmed.</td><td rowspan="7">XXXX ± AA rpm</td><td rowspan="7">First time
BBB rpm

Second time
BBB rpm</td><td rowspan="7">Turbine trip : Alarm on

Over-speed trip : Alarm on

Main stop valve : Close

Control valve : % -> %

Reheat stop valve : Close

Emergency blow down valve : Close

Ventilator valve : Close</td></tr>
<tr><td>Button of “Over-speed test” must be pushed. (Upper limit of governor and electric over-speed trip etc. must be lifted.)</td></tr>
<tr><td>Lever of turbine floor must be to be operated “test” and locked.</td></tr>
<tr><td>Button of “Increase” of governor setting station must be pushed, rotating speed of steam turbine must be increased and trip of steam turbine must be tripped at set value.</td></tr>
<tr><td>After tripping, “Over-speed test” must be lifted.</td></tr>
<tr><td>After lower than rated rotating speed of steam turbine, Lever of turbine floor must be operated to normal position and it must be reset on control board (Boiler, Turbine and Generator board)</td></tr>
<tr><td>Rotating speed of steam turbine must be gone up. After changing valves, steam turbine must be kept rated rotating speed.</td></tr>
</table>

(4) Evaluation criteria

Rotating speed of steam turbine at operating emergency governor must be lower than 1.11 times of rated rotating speed. All valves must be operated in accordance with designated interlock, and alarms and necessary indications must be appeared normally.

Article 144. Load dump test

Make sure that control by governor functions well and there is nothing abnormal with turbine rotating speed, generator voltage, etc., when shedding the load from the load operation. And make sure that turbine and generator are safely transferred to no-load operation.

This article must not be applied to power generating unit with induction generator.

1. Power generating unit by steam turbine

With regard to the related valves, conduct operation test prior to load dump test by using the testing equipment installed at each individual valve to make sure that all the valves function well.

Conduct load dump test at four stages of 25% output or minimum output required for stable operation, 50% output, 75% output, and 100% output of rating load.

Before load dump, check the steam temperature, steam pressure, and flow rate, and make sure by visual examination or actual measurement that nothing abnormal such as operational values of turbine, generator (to raise generator voltage) and so on is detected. After load dump until settling to no-load, make sure that nothing abnormal with each individual section is detected.

When speed transits to stable, everything is normal with each section and all the individual devices are operating properly. While the test, operational values are the variable values which have no impact on safety of unit.

Besides, make sure that the turbine speed neither reaches the tripping speed at which the emergency governor functions, nor vibrates continuously.

2. Power generating unit by gas turbine (don't apply to combination devices with generator)
Except for the following, do the same as that for "1. Power generating unit by steam turbine".

(1) Conduct load dump test on gas turbine system in the state that outside air temperature is close enough to the design temperature to ensure gas turbine output.

(2) When performance confirmation of speed governor is required at 100% output or intermediate output under the typical condition such as the control method with maximum increase rate of rotating speed, etc. and load dump test under the output concerned is difficult to be conducted, if it is assessed that the testing results at the possible output can substitute the required confirmation, load dump test under the output concerned can be conducted.
In this case, immediately conduct load dump test, when the load dump test becomes possible.

(3) In case that it is assessed that result of load dump test for the same type of gas turbine can be available, the maximum increase rate of rotating speed may be confirmed on the basis of operation chart of the gas turbine concerned and the test result of the same type of gas turbine after conducting load dump test at the possible output.

It must be confirmed that in transition to the permanent speed, everything is normal with each section and all the individual devices are operating properly, and operational values are the variable values which have no impact on safety.

Article 145. Load test

1. Power generating unit by steam turbine
Make sure by visual examination and with permanent instruments that there is no problem with any sections while turbine generator is operating at 100% output.

Make sure that there is no problem at each section while boiler operates continuously with 100% (rated output) at the status closest to rated steam temperature and pressure during 72 hours. In this case, the Boiler is considered as over the load test.

In case that there is sub-combustion method, when the operation is continued from that by main combustion method, continuous operation by the sub-combustion method can be completed for suitable period based on the status of combustion technology if nothing abnormal is identified in particular with any sections. In this case, with regard to steam turbine, boiler, auxiliary facilities, etc. confirm whether measuring points are appropriate, what measurement methods are applied, whether instruments have adequately been calibrated, and whether operation is carried out in accordance with design specifications.

Installation of devices must carry out in accordance with specifications and respond to technical requirements. It must be confirmed that the operational values of all the sections of mechanical and electrical equipment are appropriate. Concentration of flue gas must meet the current emission regulations.

2. Power generating unit by gas turbine

Except for the following, do the same as that for “1. Power generating unit by steam turbine”.

(1) Conduct load test on gas turbine system under the condition that outside air temperature is close enough to the designed one to ensure gas turbine 100% output.

(2) When load test less than 100% output is difficult, if it is assessed that testing results at the possible output can substitute the required confirmation, load test under the output concerned can be conducted.
In this case, immediately conduct load test, when the load test becomes possible.

(3) In case that it is assessed that result of load test for the same type of gas turbine can be available, the status of equipment may be confirmed on the basis of operation chart of the gas turbine concerned and test result of the same type of gas turbine after conducting load test at the possible output.

(4) Measure the flue gas (sulfur oxides and nitrogen oxides).
Installation of devices must carry out in accordance with specifications and respond to technical requirements. It must be confirmed that the operational values of all the sections of mechanical and electrical equipment are appropriate. Concentration of flue gas must meet the current emission regulations.

Article 146. Others

1. Gas turbine under 10 MW which is assembled in manufacturing plant

When checking quality control in the manufacturing plant, it must be confirmed quality control manual developed by manufacture on following items and evaluated whether it is appropriate or not.

(1) Point to be checked
   1) Purpose
   2) Organization
   3) Work responsibility
   4) Scope of application
   5) Applicable regulation and standard
   6) Measures and policies etc.

2. Other inspections

When conducting other inspections according to Owner’s decision in terms of safety, it must be requested manufacture to submit inspection manual, confirmed following items with manufacture and conducted inspection taking account of safety.

   1) Purpose
   2) Organization
   3) Work responsibility

4) Inspection (test) condition

5) Inspection (test) schedule

6) Inspection (test) procedure etc.

Article146-a1 Coal handling facilities

1. Interlock test

(1) Purpose

It must be confirmed that related equipment for coal unloading, feeding and supplying system are operated reliably according to interlock and alarms and necessary indications are appeared normally.

(2) Unit operation status

Under unit stop

(3) Test procedure and point to be checked (example)

1) Emergency stop of coal unloading system

a. Test procedure

Belt conveyors for coal unloading system are operated in automatic mode and button of "Emergency stop" is pushed. It must be confirmed that each equipment of unloading system is stopped urgently.

b. Status confirmation

Point to be checked	Confirmation procedure			
	Before test	**Check**	**After test**	**Check**
Coal unloading system	Operation		Stop	
No.1 Unloader	Operation		Stop	
No.2 Unloader	Operation		Stop	
No.1 Belt conveyor	Operation		Stop	
No.2 Belt conveyor	Operation		Stop	
No.1 Stacker	Operation		Stop	
No.2 Stacker	Operation		Stop	

c. Alarm confirmation

Alarm item	Alarm transmission	Place
Emergency stop of conveyor system	Yes / No	Unloading control board
Major failure of unloading system	Yes / No	Unloading control board
Major failure of local control board	Yes / No	Unloading control board
Major failure of N0.1 unloader	Yes / No	Unloading control board
Major failure of N0.2 unloader	Yes / No	Unloading control board
Major failure of No.1 stacker	Yes / No	Unloading control board
Major failure of No.2 stacker	Yes / No	Unloading control board
Major failure of No.1 reclaimer	Yes / No	Unloading control board
Major failure of No.2 reclaimer	Yes / No	Unloading control board
Failure of unloading sampling system	Yes / No	Unloading control board
Failure of loading sampling system	Yes / No	Unloading control board

2) Emergency stop of coal feeding system

a. Test procedure

Belt conveyors for coal feeding system are operated in automatic mode and pull cord switch is operated by intention. It must be confirmed that each equipment of feeding system is stopped urgently.

b. Status confirmation

Point to be checked	Confirmation procedure			
	Before test	Check	After test	Check
Coal feeding system	Operation		Stop	
No.1 Reclaimer	Operation		Stop	
No.2 Reclaimer	Operation		Stop	
No.1 Belt conveyor	Operation		Stop	
No.2 Belt conveyor	Operation		Stop	

c. Alarm confirmation

Alarm item	Alarm transmission	Place
Emergency stop of conveyor system	Yes / No	Feeding control board
Major failure of feeding system	Yes / No	Feeding control board
Major failure of N0.1 Reclaimer	Yes / No	Feeding control board
Major failure of N0.2 Reclaimer	Yes / No	Feeding control board

3) Emergency stop of coal supplying system

a. Test procedure

Belt conveyors for coal supplying system are operated in automatic mode and belt incline detector is operated by intention. It must be confirmed that each equipment of supplying system is stopped urgently.

b. Status confirmation

Point to be checked	Confirmation procedure			
	Before test	Check	After test	Check
Coal supplying system	Operation		Stop	
No.1 Belt feeder	Operation		Stop	
No.2 Belt feeder	Operation		Stop	
No.1 Constant feed ware	Operation		Stop	
No.2 Constant feed ware	Operation		Stop	
No.1 Crasher	Operation		Stop	
No.2 Crasher	Operation		Stop	
No.1 Belt conveyor	Operation		Stop	
No.2 Belt conveyor	Operation		Stop	

c. Alarm confirmation

Alarm item	Alarm transmission	Place
Emergency stop of conveyor system	Yes / No	Supplying control board
Major failure of supplying system	Yes / No	Supplying control board
Major failure of local control board	Yes / No	Supplying control board

Alarm item	Alarm transmission	Place
Major failure of No.1 Belt feeder	Yes / No	Supplying control board
Major failure of No.2 Belt feeder	Yes / No	Supplying control board
Major failure of No.1 Constant feed ware	Yes / No	Supplying control board
Major failure of No.2 Constant feed ware	Yes / No	Supplying control board
Major failure of No.1 Crasher	Yes / No	Supplying control board
Major failure of No.2 Crasher	Yes / No	Supplying control board

(4) Evaluation criteria

It must be confirmed that each equipment is operated steadily according to interlock system and alarms and necessary indications are appeared normally.

2. Alarm test

(1) Purpose

It must be confirmed that alarm for related equipment of coal unloading, feeding and supplying system are operated normally.

(2) Unit operation status

Under unit stop

(3) Test procedure and point to be checked (example)

Test items	Test procedure	Point to be checked		
		Set value	Operating value	Alarm indication
Unloader Emergency stop of support leg	Button of “Emergency stop of support leg” of unloader must be pushed.	-	-	- Major failure of unloader
Belt conveyor Plugging of chute	Chute switch of belt conveyor must be operated by manual.	-	-	- Major failure of unloading system - Failure of conveyor system
Stacker Incline of boom conveyor belt	Incline detector of boom conveyor belt must be operated by manual.	-	-	- Minor failure of stacker
Reclaimer Detecting of obstacle on traveling rail	Detector of obstacle on traveling rail must be operated by manual.	Lower than 3m		- - Major failure of reclaimer
Belt conveyor Incline of belt	Incline switch of belt of belt conveyor must be operated by manual.	-	-	- Major failure of supplying system - Failure of conveyor system

(4) Evaluation criteria

It must be confirmed that alarms and necessary indications are appeared normally.

Article146-a2 Oil handling facilities

1. Interlock test

(1) Purpose

It must be confirmed that related equipment for oil handling facility system are operated reliably according to interlock and alarms and necessary indications are appeared normally.

(2) Unit operation status

Under unit stop

(3) Test procedure and point to be checked (example)

1) Operation test for emergency shut off valve

a. Test procedure

Emergency shut off system for storage tank inlet and out and oil pipeline is closed by central control room and local operation panel. It must be confirmed that it is operated reliably.

b. Status confirmation

Item	Test procedure	Point to be checked
Shut off valve for oil receiving pipeline of storage tank	It must be confirmed it is closed by central control room.	- Control room panel open → close - Shut off valve open → close - Operating time s
Shut off valve for oil supplying pipeline storage tank	It must be confirmed it is closed by local control operation panel.	- Control room panel open → close - Shut off valve open → close - Operating time s
Shut off valve for oil pipeline	It must be confirmed it is closed by local control operation panel.	- Control room panel open → close - Shut off valve open → close - Operating time s

(4) Evaluation criteria

It must be confirmed that each equipment is operated steadily according to interlock system and alarms and necessary indications are appeared normally.

2. Alarm test

(1) Purpose

It must be confirmed that alarm for related equipment of oil handling system are operated normally.

(2) Unit operation status

Under unit stop

(3) Test procedure and point to be checked (example)

1) Pressure high of storage tank

a. Test procedure

(a) Storage tank pressure must be simulated normally.

(b) High pressure alarm switch of storage tank must be connected to test system and pressure must be increased gradually by simulated input.

(c) Storage tank pressure must be confirmed at alarming.

b. Point to be checked

Set value	Operating value	Alarm indication
XXX mmHg + AA - BB	mmHg	Storage tank pressure High - Low

2) Oil level high of storage tank

a. Test procedure

(a) It must be simulated that storage tank level is normal.

(b) Liquid level indicator is rolled up. Alarm and storage tank level at alarming must be confirmed.

b. Point to be checked

Set value	Operating value	Alarm indication
XXX mm + AA - BB	mm	Storage tank level High - Low

Article146-a3 Gas handling facilities

1. Interlock test

(1) Purpose

It must be confirmed that related equipment for gas handling facility system are operated reliably according to interlock and alarms and necessary indications are appeared normally.

(2) Unit operation status

Under unit stop

(3) Test procedure and point to be checked (example)

1) Operation test for emergency shut off valve

a. Test procedure

Emergency shut off system for storage tank inlet and out and gas pipeline is closed by central control room and local operation panel. It must be confirmed that it is operated reliably.

b. Status confirmation

Item	Test procedure	Point to be checked
Shut off valve for gas receiving pipeline of storage tank	It must be confirmed it is closed by central control room.	- Control room panel open → close - Shut off valve open → close - Operating time s
Shut off valve for gas supplying pipeline storage tank	It must be confirmed it is closed by local control operation panel.	- Control room panel open → close - Shut off valve open → close - Operating time s
Shut off valve for gas pipeline	It must be confirmed it is closed by local control operation panel.	- Control room panel open → close - Shut off valve open → close - Operating time s

(4) Evaluation criteria

It must be confirmed that each equipment is operated steadily according to interlock system and alarms and necessary indications are appeared normally.

2. Alarm test

(1) Purpose

It must be confirmed that alarm for related equipment of gas handling system are operated normally.

(2) Unit operation status

Under unit stop

(3) Test procedure and point to be checked (example)

1) Pressure high of storage tank

a. Test procedure

(a) It must be simulated that storage tank pressure is normal.

(b) High pressure alarm switch of storage tank must be connected to test system and pressure must be increased gradually by simulated input.

(c) Storage tank pressure at alarming must be confirmed.

b. Point to be checked

Set value	Operating value	Alarm indication
XXX mmHg + AA - BB	mmHg	Storage tank pressure High - Low

2) Gas temperature high of storage tank

a. Test procedure

(a) It must be simulated that storage tank temperature is normal.

(b) High temperature alarm switch of storage tank must be connected to test system and temperature must be increased gradually by simulated input.

(c) It must be confirmed that storage tank temperature at alarming must be confirmed.

b. Point to be checked

Set value	Operating value	Alarm indication
XXX ℃ + AA - BB	℃	Gas temperature of storage tank High

(4) Evaluation criteria

It must be confirmed that alarms and necessary indications are appeared normally.

3. Safety test

(1) Purpose

It must be confirmed that gas detector is operated normally.

It must be confirmed that gas is odorized as planned by sampling it in gas pipeline.

(2) Unit operation status

1) Under unit stop

2) Under unit operation

(3) Test procedure and point to be checked (example)

1) Operation test of gas detector

a. Test procedure

It must be confirmed that alarm appears normally and operating value of alarm after gas detector sucks in flammable gas.

Point to be checked	Point to be checked		
	Set value	Operating value	Alarm indication
A portion of storage tank	XXX ppm ± YYY	ppm	- Gas detector panel - Control room panel
B portion of storage tank	XXX ppm ± YYY	ppm	- Gas detector panel - Control room panel
Around of storage tank	XXX ppm ± YYY	ppm	- Gas detector panel - Control room panel
A portion of pipeline	XXX ppm ± YYY	ppm	- Gas detector panel - Control room panel
B portion of pipeline	XXX ppm ± YYY	ppm	- Gas detector panel - Control room panel

2) Gas odorizing check test in gas pipeline

a. Test procedure

It must be confirmed that odor after fuel gas is sampled from gas pipeline and it is diluted by air to normal concentration.

Item	Odor
A portion of pipeline	Yes / No
B portion of pipeline	Yes / No

(4) Evaluation criteria

It must be confirmed that gas detector is operated steadily and alarms and necessary indications are appeared normally. It must be confirmed that gas in pipeline is odorized as planned and odor is detected.

Article146-a4　Liquefied gas handling facilities

1. Interlock test

(1) Purpose

It must be confirmed that related equipment for liquefied gas handling facility system are operated reliably according to interlock and alarms and necessary indications are appeared normally.

(2) Unit operation status

Under unit stop

(3) Test procedure and point to be checked (example)

1) Emergency stop of vaporizer due to seawater feed rate low

a. Test procedure

Seawater feed rate control valve of vaporizer is closed by manual gradually. It must be confirmed that alarm of abnormal low of seawater feed rate is appeared and vaporizer is tripped.

b. Status confirmation

Point to be checked	Confirmation procedure			
	Before test	Check	After test	Check
Seawater feed rate of vaporizer	T/h		Alarm T/h Trip T/h	
Seawater pressure	Pa		Alarm Pa	
Operation of vaporizer	operation		stop	
Shut off valve of vaporizer inlet	open		close	
Shut off valve of vaporizer outlet	open		close	

c. Alarm confirmation

Alarm item	Alarm transmission	Place
Trip of vaporizer	Yes / No	Liquefied gas control board
Seawater feed rate abnormal low of vaporizer	Yes / No	Liquefied gas control board
Seawater feed rate low of vaporizer	Yes / No	Liquefied gas control board
Seawater pressure low of vaporizer	Yes / No	Liquefied gas control board

2) Operation test for emergency shut off valve

a. Test procedure

Emergency shut off system for storage tank inlet and out and gas pipeline is closed by central control room and local operation panel. It must be confirmed that it is operated reliably.

b. Status confirmation

Item	Test procedure	Point to be checked
Shut off valve for LNG receiving pipeline of storage tank	It must be confirmed it is closed by central control room.	- Control room panel open → close - Shut off valve open → close - Operating time s
Shut off valve for LNG supplying pipeline storage tank	It must be confirmed it is closed by local control operation panel.	- Control room panel open → close - Shut off valve open → close - Operating time s
Shut off valve for gas pipeline	It must be confirmed it is closed by local control operation panel.	- Control room panel open → close - Shut off valve open → close - Operating time s

(4) Evaluation criteria

It must be confirmed that each equipment is operated steadily according to interlock system and alarms and necessary indications are appeared normally.

2. Alarm test

(1) Purpose

It must be confirmed that alarm for related equipment of liquefied gas handling system are operated normally.

(2) Unit operation status

Under unit stop

(3) Test procedure and point to be checked (example)

1) Pressure high of storage tank

a. Test procedure

(a) Storage tank pressure must be simulated normally.

(b) High pressure alarm switch of storage tank must be connected to test system and pressure must be increased gradually by simulated input.

(c) Storage tank pressure must be confirmed at alarming.

b. Point to be checked

Set value	**Operating value**	**Alarm indication**
XXX mmHg + AA - BB	mmHg	Storage tank pressure High - Low

2) Gas temperature low of vaporizer outlet

a. Test procedure

(a) Vaporizer temperature must be simulated normally.

(b) Low temperature alarm switch of vaporizer must be connected to test system and temperature must be decreased gradually by simulated input.

(c) Vaporizer temperature must be confirmed at alarming.

b. Point to be checked

Set value	**Operating value**	**Alarm indication**
XXX °C + AA - BB	°C	Gas temperature of vaporizer outlet Low

3) Level high of storage tank

a. Test procedure

(a) Storage tank level must be simulated normally.

(b) Liquid level indicator is rolled up. Alarm and storage tank level at alarming must be confirmed.

b. Point to be checked

Set value	**Operating value**	**Alarm indication**
XXX mm + AA - BB	mm	Storage tank level High - Low

(4) Evaluation criteria

It must be confirmed that each equipment and valves are operated steadily according to interlock system alarms and necessary indications are appeared normally.

3. Safety test

(1) Purpose

It must be confirmed that gas detector is operated normally.

It must be confirmed that gas is odorized as planned by sampling it in gas pipeline.

(2) Unit operation status

1) Under unit stop

2) Under unit operation

(3) Test procedure and point to be checked (example)

1) Operation test of gas detector

a. Test procedure

It must be confirmed that alarm appears normally and operating value of alarm after gas detector sucks in flammable gas.

Point to be checked	Point to be checked		
	Set value	**Operating value**	**Alarm indication**
A portion of storage tank	XXX ppm ± YYY	ppm	- Gas detector panel - Control room panel
B portion of storage tank	XXX ppm ± YYY	ppm	- Gas detector panel - Control room panel
Around of storage tank	XXX ppm ± YYY	ppm	- Gas detector panel - Control room panel
Around of vaporizer	XXX ppm ± YYY	ppm	- Gas detector panel - Control room panel
A portion of pipeline	XXX ppm ± YYY	ppm	- Gas detector panel - Control room panel
B portion of pipeline	XXX ppm ± YYY	ppm	- Gas detector panel - Control room panel

2) Gas odorizing check test in gas pipeline

a. Test procedure

It must be confirmed that odor after fuel gas is sampled from gas pipeline and it is diluted by air to normal concentration.

Item	Odor
A portion of pipeline	Yes / No
B portion of pipeline	Yes / No

(4) Evaluation criteria

It must be confirmed that gas detector is operated steadily and alarms and necessary indications are appeared normally. It must be confirmed that gas in pipeline is odorized as planned and odor is detected.

Article146-a5　Coal-ash treatment facilities

1. Interlock test

(1) Purpose

It must be confirmed that related equipments for coal-ash treatment equipment system are operated reliably according to interlock and alarms and necessary indications are appeared normally.

(2) Operation status

Under system stopping

(3) Test procedure and points to be checked (example)

1) Test procedure

a. It must be confirmed that coal-ash treatment system is operated normally.

b. Button of "Emergency stop" must be pushed.

c. It must be confirmed that this system is operated normally according to inter lock of emergency stop and following status of system and transmitted alarm are appropriate.

2) Status confirmation

a. Related blowers are stopped. (e.g. transfer blower, vacuum blower etc.)

b. Related valves are closed. (e.g. hopper outlet valve etc.)

3) Alarm confirmation

Alarm item	Alarm transmission	Place
Emergency stop	Yes / No	Coal-ash treatment control board

(4) Evaluation criteria

It must be confirmed that each equipment is operated steadily according to interlock system and alarms and necessary indications are appeared normally.

2. Alarm test

(1) Purpose

It must be confirmed that alarm for related equipment of coal-ash treatment system are operated normally.

(2) Operation status

Under system stopping

(3) Test procedure and points to be checked (example)

1) Hopper level high

a. Test procedure

(a) It must be confirmed that alarm device is operated normally.

(b) It must be connected to contact point concerning hopper level high mandatorily.

(c) Operation of this system and transmitted alarm must be confirmed.

b. Points to be checked

Alarm indication	Alarm transmission	Place
Hopper level high	Yes / No	Coal-ash treatment control board

2) Differential pressure high of bag filter (Plugging of bag filter)

a. Test procedure

(a) It must be confirmed that alarm device is operated normally.

(b) It must be connected to contact point concerning differential pressure high of bag filter mandatorily.

(c) Operation of this system and transmitted alarm must be confirmed.

b. Points to be checked

Alarm indication	Alarm transmission	Place
Differential pressure high	Yes / No	Coal-ash treatment control board

Article146-a6 Feed-water treatment facilities

1. Interlock test

(1) Purpose

It must be confirmed that related equipments for feed-water treatment equipment system are operated reliably according to interlock and alarms and necessary indications are appeared normally.

(2) Operation status

Under system stopping

(3) Test procedure and points to be checked (example)

1) Test procedure

a. It must be confirmed that feed-water treatment system is operated normally.

b. Button of “Emergency stop” must be pushed.

c. It must be confirmed that this system is operated normally according to inter lock of emergency stop and following status of system and transmitted alarm are appropriate.

2) Status confirmation

a. Related devices are stopped. (e.g. vacuum degasifier etc.)

b. Related pumps are stopped. (e.g. filtrate water pump, chemical mixing pump etc.)

c. Related valves are closed. (e.g. vacuum degasifier inlet valve etc.)

3) Alarm confirmation

Alarm item	Alarm transmission	Place
Emergency stop	Yes / No	Feed-water treatment control board

(4) Evaluation criteria

It must be confirmed that each equipment is operated steadily according to interlock system and alarms and necessary indications are appeared normally.

2. Alarm test

(1) Purpose

It must be confirmed that alarm for related equipment of feed-water treatment system are operated normally.

(2) Operation status

Under system stopping

(3) Test procedure and points to be checked (example)

1) Chemicals tank level high and low

a. Test procedure

(a) It must be confirmed that alarm device is operated normally.

(b) It must be connected to contact point concerning chemicals tank level high and low mandatorily.

(c) Operation of this system and transmitted alarm must be confirmed.

b. Points to be checked

Alarm indication	Alarm transmission	Place
Chemicals tank level high and low	Yes / No	Feed-water treatment control board

2) Control air pressure high and low

a. Test procedure

(a) It must be confirmed that alarm device is operated normally.

(b) It must be connected to contact point concerning control air pressure high and low mandatorily.

(c) Operation of this system and transmitted alarm must be confirmed.

b. Points to be checked

Alarm indication	Alarm transmission	Place
Control air pressure high and low	Yes / No	Feed-water treatment control board

Article146-a7 Environmental facilities

1. Mechanical dust collector

(1) Alarm test

1) Purpose

It must be confirmed that alarm for related equipment of mechanical dust collector system are operated normally.

2) Operation status

Under system stopping

3) Test procedure and points to be checked (example)

a. Particulate concentration high

(a) Test procedure

a) It must be confirmed that alarm device is operated normally.

b) It must be connected to contact point concerning particulate concentration high mandatorily.

c) It must be confirmed that related alarm is transmitted.

(b) Points to be checked

Alarm indication	Alarm transmission	Place
Particulate concentration high	Yes / No	Boiler-Turbine-Generator panel

b. Hopper level high

(a) Test procedure

a) It must be confirmed that alarm device is operated normally.

b) It must be connected to contact point concerning hopper level high mandatorily.

c) It must be confirmed that related alarm is transmitted.

(b) Points to be checked

Alarm indication	Alarm transmission	Place
Hopper level high	Yes / No	Boiler-Turbine-Generator panel

4) Evaluation criteria

It must be confirmed that alarms and necessary indications are appeared normally.

2. Electric precipitator

(1) Interlock test

1) Purpose

It must be confirmed that related equipments for electric precipitator system are operated reliably according to interlock.

2) Operation status

Under system stopping

3) Test procedure and points to be checked (example)

a. Test procedure

(a) It must be confirmed that status of electric precipitator system is normally.

(b) It must be simulated that this system is stopped.

(c) It must be confirmed that this system is operated normally according to inter lock of system stopping and following status of system are appropriate.

b. Status confirmation

(a) Hammering system for discharge electrode is stopped.

(b) Hammering system for collecting electrode is stopped.

(c) Electrode driven system is stopped.

(d) Ash cleaning system for collecting electrode is stopped.

4) Evaluation criteria

It must be confirmed that each equipment is operated steadily according to interlock system.

(2) Alarm test

1) Purpose

It must be confirmed that alarm for related equipment of electric precipitator system are operated normally.

2) Operation status

Under system stopping

3) Test procedure and points to be checked (example)

a. Particulate concentration high

(a) Test procedure

a) It must be confirmed alarm device is operated normally.

b) It must be connected to contact point concerning particulate concentration high mandatorily.

c) It must be confirmed that related alarm is transmitted.

(b) Points to be checked

Alarm indication	**Alarm transmission**	**Place**
Particulate concentration high	Yes / No	Boiler-Turbine-Generator panel

b. Overload of electric precipitator transformer

(a) Test procedure

a) It must be confirmed that alarm device is operated normally.

b) It must be connected to contact point concerning overload of electric precipitator transformer mandatorily.

c) It must be confirmed that related alarm is transmitted.

(b) Points to be checked

Alarm indication	**Alarm transmission**	**Place**
Overload of electric precipitator transformer	Yes / No	Boiler-Turbine-Generator panel

c. Short circuit of electric precipitator transformer

(a) Test procedure

a) It must be confirmed that alarm device is operated normally.

b) It must be connected to contact point concerning short circuit of electric precipitator transformer mandatorily.

c) It must be confirmed that related alarm is transmitted.

(b) Points to be checked

Alarm indication	Alarm transmission	Place
Short circuit of electric precipitator transformer	Yes / No	Boiler-Turbine-Generator panel

4) Evaluation criteria

It must be confirmed that alarms and necessary indications are appeared normally.

3. De-NOx equipment

(1) Interlock test

1) Purpose

It must be confirmed that related equipments for De-NOx equipment system are operated reliably according to interlock.

2) Operation status

Under system stopping

3) Test procedure and points to be checked (example)

a. Test procedure

(a) It must be confirmed that status of De-NOx equipment system is normally.

(b) It must be simulated that this system is stopped.

(c) It must be confirmed that this system is operated normally according to inter lock of system stopping and following status of system are appropriate.

b. Status confirmation

(a) Ammonia flow control valve is closed.

(b) Ammonia dilution air valve is closed.

(c) Ammonia vaporizer is stopped.

4) Evaluation criteria

It must be confirmed that each equipment is operated steadily according to interlock system.

(2) Alarm test

1) Purpose

It must be confirmed that alarm for related equipment of De-NOx equipment system are operated normally.

2) Operation status

Under system stopping

3) Test procedure and points to be checked (example)

a. NOx concentration high

(a) Test procedure

a) It must be confirmed that alarm device is operated normally.

b) It must be connected to contact point concerning NOx concentration high mandatorily.

c) It must be confirmed that related alarm is transmitted.

(b) Points to be checked

Alarm indication	**Alarm transmission**	**Place**
NOx concentration high	Yes / No	Boiler-Turbine-Generator panel

b. Residual ammonia concentration high

(a) Test procedure

a) It must be confirmed that alarm device is operated normally.

b) It must be connected to contact point concerning residual ammonia concentration high mandatorily.

c) It must be confirmed that related alarm is transmitted.

(b) Points to be checked

Alarm indication	**Alarm transmission**	**Place**
Residual ammonia concentration high	Yes / No	Boiler-Turbine-Generator panel

c. Ammonia gas pressure low

(a) Test procedure

a) It must be confirmed that alarm device is operated normally.

b) It must be connected to contact point concerning ammonia gas pressure low mandatorily.

c) It must be confirmed that related alarm is transmitted.

(b) Points to be checked

Alarm indication	**Alarm transmission**	**Place**
Ammonia gas pressure low	Yes / No	Boiler-Turbine-Generator panel

4) Evaluation criteria
It must be confirmed that alarms and necessary indications are appeared normally.

4. De-SOx equipment

(1) Interlock test

1) Purpose
It must be confirmed that related equipments for De-SOx equipment system are operated reliably according to interlock.

2) Operation status
Under system stopping

3) Test procedure and points to be checked (example)

a. Test procedure

(a) It must be confirmed that status of De-SOx equipment system is normally.

(b) It must be simulated that this system is stopped.

(c) It must be confirmed that this system is operated normally according to inter lock of system stopping and following status of system are appropriate.

b. Status confirmation

(a) De-SOx fan is stopped.

(b) Absorber circulation pump is stopped.

(c) De-SOx inlet damper is closed.

(d) Absorber inlet damper is closed.

4) Evaluation criteria

It must be confirmed that each equipment is operated steadily according to interlock system.

(2) Alarm test

1) Purpose

It must be confirmed that alarm for related equipment of De-SOx equipment system are operated normally.

2) Operation status

Under system stopping

3) Test procedure and points to be checked (example)

a. SOx concentration high

(a) Test procedure

a) It must be confirmed that alarm device is operated normally.

b) It must be connected to contact point concerning SOx concentration high mandatorily.

c) It must be confirmed that related alarm is transmitted.

(b) Points to be checked

Alarm indication	**Alarm transmission**	**Place**
SOx concentration high	Yes / No	Boiler-Turbine-Generator panel

b. Absorber inlet gas temperature high

(a) Test procedure

a) It must be confirmed that alarm device is operated normally.

b) It must be connected to contact point concerning absorber inlet gas temperature high mandatorily.

c) It must be confirmed that related alarm is transmitted.

(b) Points to be checked

Alarm indication	Alarm transmission	Place
Absorber inlet gas temperature high	Yes / No	Boiler-Turbine-Generator panel

c. De-SOx fan lubricant oil pressure low

(a) Test procedure

a) It must be confirmed that alarm device is operated normally.

b) It must be connected to contact point concerning De-SOx fan lubricant oil pressure low mandatorily.

c) It must be confirmed that related alarm is transmitted.

(b) Points to be checked

Alarm indication	Alarm transmission	Place
De-SOx fan lubricant oil pressure low	Yes / No	Boiler-Turbine-Generator panel

4) Evaluation criteria

It must be confirmed that alarms and necessary indications are appeared normally.

5. Waste water treatment equipment

(1) Interlock test

1) Purpose

It must be confirmed that related equipments for waste water treatment equipment system are operated reliably according to interlock and alarms and necessary indications are appeared normally.

2) Operation status

Under system operating

3) Test procedure and points to be checked (example)

a. Test procedure

(a) It must be confirmed that waste water treatment system is operated normally.

(b) Button of “Emergency stop” must be pushed.

(c) It must be confirmed that this system is operated normally according to inter lock of emergency stop and following status of system and transmitted alarm are appropriate.

b. Status confirmation

(a) Related pumps are stopped. (e.g. chemical dosing pump, waste water pump etc.)

(b) Related devices are stopped. (e.g. mixing machine, compressor, blower etc.)

(c) Related valves are closed. (e.g. waste water inlet valve, treated water outlet valve etc.)

c. Alarm confirmation

Alarm item	Alarm transmission	Place
Emergency stop	Yes / No	Waste water treatment control board

4) Evaluation criteria

It must be confirmed that each equipment is operated steadily according to interlock system and alarms and necessary indications are appeared normally.

(2) Alarm test

1) Purpose

It must be confirmed that alarm for related equipment of waste water treatment system are operated normally.

2) Operation status

Under system stopping

3) Test procedure and points to be checked (example)

a. Discharge water quality

(a) Test procedure

a) It must be confirmed that alarm device is operated normally.

b) It must be connected to contact point concerning discharge water quality mandatorily.

c) Items of discharge water quality are shown as follows;

- pH
- COD (Chemical Oxygen Demand)
- Turbidity
- Oil content

(b) Points to be checked

Alarm indication	Alarm transmission	Place
pH abnormal	Yes / No	Waste water treatment control board
COD High	Yes / No	Waste water treatment control board
Turbidity High	Yes / No	Waste water treatment control board
Oil content High	Yes / No	Waste water treatment control board

b. Chemicals tank level high and low

(a) Test procedure

a) It must be confirmed that alarm device is operated normally.

b) It must be connected to contact point concerning chemicals tank level high and low mandatorily.

c) Chemicals tanks of waste water treatment equipment are shown as follows;

- Sulfuric acid tank
- Dilute sulfuric acid tank
- Caustic soda
- Flocculating agent tank

(b) Points to be checked

Alarm indication	Alarm transmission	Place
Sulfuric acid tank level High - Low	Yes / No	Waste water treatment control board
Dilute sulfuric acid tank level High - Low	Yes / No	Waste water treatment control board
Caustic soda level High - Low	Yes / No	Waste water treatment control board
Flocculating agent tank level High - Low	Yes / No	Waste water treatment control board

4) Evaluation criteria
It must be confirmed that alarms and necessary indications are appeared normally.

Article146-a8 Welding

1. Welding inspection procedure

(1) Material of welding portion (material inspection)
Following items must be confirmed before groove inspection.

It must be confirmed that welding material for each part must be as designed and met the design technical regulation as below. When it is confirmed on site, it must be confirmed by visual check and measuring equipment if needed.

1) It must be checked up inspection manual* and inspection record etc. (including mill certificate).
   * Inspection manual : it is defined inspection procedure and evaluation criteria etc by each power plant.
2) It must be checked up stencil or punch mark of material and mill certificate.
3) It must be confirmed that chemical composition and mechanical strength of welding base metal are met standard etc.
4) It must be checked up mill certificate and the design technical regulation.
5) It must be confirmed that identification mark and number of material etc. for traceability are engraved.

(2) Groove of welding part (groove inspection)
It must be confirmed before welding.

1) Status of groove face

a. It must be confirmed that defect (lamination etc.) and fouling (moisture, oil, coating and rust etc.) are not on groove face.

b. It must be confirmed that crack and glaring undercut is not on tack welding part.

c. It must be confirmed that welding procedure and welder for track welding are met the design technical regulation and the Vietnamese voluntary standards (TCVN) or design guideline or related voluntary standards when track welding part is composed of welding part.

2) Figure of groove and size of each part

a. It must be confirmed that figure and size (including leg) of groove are met the Vietnamese voluntary standards (TCVN) or design guideline or related voluntary standards and inspection manual.

b. It must be confirmed that joint setting, offset of butt welding is met the Vietnamese voluntary standards (TCVN) or design guideline or related voluntary standards.

c. It must be confirmed that butt welding for welding base metal of different thickness is met the Vietnamese voluntary standards (TCVN) or design guideline or related voluntary standards.

d. It must be confirmed that width and depth is met inspection manual at back chipping.

3) Type and installation status of weld insert or backing metal

a. It must be confirmed that type and installation status of weld insert or backing metal are met inspection manual when they are used.

(3) Welding work and welding equipment (welding work inspection)
It must be confirmed before proof pressure test.

1) Welding procedure

a. It must be conducted objective tests regarding welding procedure stipulated in Vietnamese voluntary standards (TCVN), design guideline and related voluntary standards and passed the tests.

2) Qualification for welder
It must be confirmed that it is met one provision among following items.

a. It must be conducted objective tests regarding qualification for welder stipulated in Vietnamese voluntary standards (TCVN), design guideline and passed the tests.

b. It must be conducted tests stipulated in reference international voluntary standards and passed the tests in case of welder not using automatic welding machine.

(a) Example

a) JIS Z 3801 (1997): Standard qualification procedure for manual welding technique

b) JIS Z 3811 (2000): Standard qualification procedure for welding technique of aluminum and aluminum alloy

c) JIS Z 3821 (2001): Standard qualification procedure for welding technique of stainless steel

d) JIS Z 3841 (1997): Standard qualification procedure for semi-automatic welding technique

3) Inspection of welding structure

a. It must be confirmed that welding condition is complied with inspection manual.

b. It must be confirmed that actual welding procedure is checked up procedure confirmed by above (3) 2) b (a).

c. It must be confirmed that type of welding equipment is checked up actual welding procedure.

d. It must be confirmed that validity period of welder is checked up actual welding period.

e. It must be confirmed that qualification of welder is checked up actual welding area.

f. It must be confirmed that welding procedure on test panel is checked up actual welding procedure.

(4) Heat treatment after welding (Heat treatment inspection)
It must be confirmed before proof pressure test.

1) Heat treatment equipment

a. It must be confirmed that heat treatment is met the Vietnamese voluntary standards (TCVN) or design guideline or related voluntary standards.

2) Inspection
It must be confirmed that temperature record (heat treatment chart) is met following provision.

a. In case of heat treatment after welding which is met the Guideline.

(a) It must be confirmed that heating and cooling velocity is met inspection manual and the Vietnamese voluntary standards (TCVN) or design guideline or related voluntary standards.

(b) It must be confirmed that retention temperature is met inspection manual and the Vietnamese voluntary standards (TCVN) or design guideline or related voluntary standards.

(c) It must be confirmed that holding time is met inspection manual and the Vietnamese voluntary standards (TCVN) or design guideline or related voluntary standards.

b. It must be confirmed that provision which is defined in the Vietnamese voluntary standards (TCVN) or design guideline or related voluntary standards is met inspection manual.

c. It must be confirmed that test piece is treated with heat after welding under identical conditions with typical coupling in case of conducting mechanical test.

d. It must be confirmed that following provision is described in heat treatment chart.

(a) Type of control system

(b) Heating equipment

(c) Temperature range and feed speed of heat treatment chart

(d) Installation position of thermocouple

(5) Nondestructive test

It must be confirmed before proof pressure test.

1) Test operator

It must be confirmed that test operator is met following provision before nondestructive test.

a. Qualified person based on the Vietnamese voluntary standards (TCVN) or design guideline or related voluntary standards

(a) Example

a) NDIS 0601 (2000, Guideline for test operator qualification and certification of Non-destructive testing)

b) JIS Z 2305 (2001, Non-destructive testing - Qualification and certification of personnel)

b. Qualified person based on qualification test

2) Nondestructive test

a. Radiograph test

It must be confirmed internal defect (crack, incomplete penetration and blowhole etc.) in plate.

(a) It must be confirmed that test condition etc. described in inspection procedure is met the guideline.

(b) Radiography (film) is checked by film illuminator and welding defect is checked. It must be confirmed that this result is met the Vietnamese voluntary standards (TCVN) or design guideline or related voluntary standards.

(c) Height of reinforcement of weld and finishing of coupling must be confirmed by shading of welding part of radiography (film) if necessary.

b. Ultrasonic test

It must be confirmed internal defect (crack, incomplete penetration etc.) in plate.

(a) After ultrasonic test equipment is calibrated by using reference block, welding defect is checked. It must be confirmed that this result is met the Vietnamese voluntary standards (TCVN) or design guideline or related voluntary standards.

(b) Scanning direction is operated so that ultrasonic wave can be introduced into all welding area. In case of angle beam testing, testing is operated in orthogonal and parallel direction for weld line wherever possible.

c. Magnetic particle test

It must be confirmed surface defect and internal defect of near surface.

(a) After magnetic particle test equipment is calibrated by using standard test block, welding defect is checked. It must be confirmed that this result is met the Vietnamese voluntary standards (TCVN) or design guideline or related voluntary standards.

d. Penetrant test

It must be confirmed open defect on face of weld.

(a) Test must be witnessed by test operator from cleaning treatment as a general rule, welding defect is checked. It must be confirmed that this result is met the Vietnamese voluntary standards (TCVN) or design guideline or related voluntary standards.

(b) In case that uneven development, incomplete and excessive cleaning, retest must be operated from pre-cleaning.

(6) Mechanical test (Mechanical inspection)

It must be confirmed before proof pressure test.

1) Mechanical test equipment

It must be confirmed that test equipment to be used is defined in inspection manual.

2) Mechanical test

It must be confirmed that type, number and colleting position of manufactured test piece in inspection manual are met the Vietnamese voluntary standards (TCVN) or design guideline or related voluntary standards and inspection manual.

a. Coupling tensile test

(a) Figure, face condition and number of test piece must be confirmed by visual check. Size of it must be confirmed by slide gauge.

(b) Test piece must be installed on test equipment and maximum tensile load must be read out. It must be confirmed that this result is met the Vietnamese voluntary standards (TCVN) or design guideline or related voluntary standards.

b. Bending test

(a) Figure, face condition and number of test piece must be confirmed by visual check. Size of it must be confirmed by slide gauge.

(b) Size and figure of fixture must be confirmed by visual check and slide gauge.

(c) After bending test piece, defect on face of weld part must be confirmed by visual check and length of crack must be measured. It must be confirmed this result is met the Vietnamese voluntary standards (TCVN) or design guideline or related voluntary standards.

c. Impact test

(a) Figure, face condition and number of test piece must be confirmed by visual check. Size of it must be confirmed by slide gauge.

(b) It must be confirmed that notch of test piece is installed in appropriate part by etching.

(c) It must be confirmed that test procedure and test temperature are met the Vietnamese voluntary standards (TCVN) or design guideline or related voluntary standards.

(d) Absorbed energy is calculated by angle of fall of hammer and angle of rise of hammer after cutting off test piece. It must be confirmed this result is met the

Vietnamese voluntary standards (TCVN) or design guideline or related voluntary standards.

(7) Proof pressure test (Proof pressure inspection)

It must be confirmed after all tests (form material test to mechanical test) are completed.

a. Proof pressure test

It must be confirmed that it is resisted regulated pressure and is not leaked during proof pressure test.

(a) It must be confirmed number of pressure gauge, installation position, and validity period and calibration table before test. It must be confirmed zero point of pressure gauge in the vicinity of proof pressure test if necessary.

(b) After keeping pressure regulated in the Vietnamese voluntary standards (TCVN) or design guideline or related voluntary standards, it must be confirmed that weld part is not leaked by visual check.

(c) In case that test is not operated by using pressure regulated in the Vietnamese voluntary standards (TCVN) or design guideline or related voluntary standards, test must be operated by high pressure wherever possible and nondestructive test must be operated on behalf of proof pressure test.

b. Visual test

It must be conformed as well as proof pressure test or after completing all tests. However, in case that visual test is not operated at last, it may be operated in advance.

(a) It must be confirmed that finishing condition of weld part is met the Vietnamese voluntary standards (TCVN) or design guideline or related voluntary standards by visual check. It must be confirmed that trace of temporary installing fixture is cleaned up and deformation of weld work piece is not significant by visual check.

(b) In case of finding defect, magnetic particle test and penetrant test must be operated if necessary.

Section 3 Electrical Equipment

Article 147. Visual inspection

It must be inspected by visual inspection or documents that electrical equipment is installed properly according to the construction plan. Items of the visual inspection are as follows:

1. Checking of grounding

It must be inspected that grounding conductor is connected to electrical equipment at the required point. The required points are referred to Article 16-8, Article 16-9, Article 16-13, Article 16-14, Article 17-1, Article 17-2, Article 17-3, Article 231-5, Article 237-7, Article 238-9, and Article 243-2 of the volume two of the guideline.

2. Countermeasure against electric arc

It must be inspected that electrical equipment which produces electric arc is installed according to Article 16-12 of the volume two of the guideline.

3. Countermeasure against live parts

It must be inspected that personnel cannot have easily access to a live part of electrical equipment. This is referred to Article 231-5, Article 238-5, Article 238-8, and Article 238-9 of the volume two of the guideline; however, it is desirable to check not only these but also whole electrical equipment.

4. Protective devices

It must be inspected that a required protective device for major electrical equipment such as a generator and transformer is properly installed. The required protective device is referred to Article 234-3, Article 237-1, and Article 237-2 of the volume two of the guideline.

5. Overcurrent circuit breakers

It should be inspected that an overcurrent circuit breaker to protect electrical equipment and cables is installed in the required point and open and closed position of the overcurrent circuit breaker can be identified easily. The required point is referred to Article 17-5, Article 17-6, Article 240-2, Article 240-4, Article 240-5, and Article 243-2 of the volume two of the guideline.

6. Ground-fault circuit breakers (interrupter or residual current devices)

It must be inspected that a ground-fault circuit breaker (interrupter or residual current device) to disconnect power line automatically when ground fault occurs is installed in the required point. The required point is referred to Article 17-7, Article 240-4, and Article 240-5 of the volume two of the guideline.

7. Arresters

It must be inspected that a (lightning surge) arresters is installed at the connecting point between a thermal power plant and overhead power wires or at the point close to this. This is referred to Article 237-7 of the volume two of the guideline.

8. Prohibition of entry to a thermal power plant and countermeasure against live parts

It must be inspected that prohibition of entry to a thermal power plant and countermeasure against live parts are taken according to Article 231-5 of the volume two of the guideline.

9. Prevention of hazard

It must be inspected that facilities for insulating oil spill prevention are installed around a transformer which is connected to a solidly grounded neutral system. This is referred to Article 20-1 of the volume two of the guideline.

10. Installation of pressure vessels

It must be inspected that pressure vessels of gas insulated equipment are installed according to Article 234-1 of the volume two of the guideline.

11. Installation of electrical facilities

It must be inspected that electrical facilities are installed according to the design documents of the construction plan.

12. Criterion

All Results of above inspections must be good.

Article 148. Measurement of grounding resistance

Grounding resistance must be measured in order to inspect that grounding system is effectively grounded.

1. Measurement method

Grounding resistance (impedance) of grounding system, such as a horizontal-grid (four-mesh), in a thermal power plant must be measured by the fall-of-potential method. If a new grounding system was installed (extended) and a new power generating unit was installed in the existing power plant, a continuity test between a new grounding system and the existing can be applied instead of the grounding resistance measurement. The fall-of-potential method is referred to the Institute of Electrical and Electronics Engineers (IEEE) standard 81-1983 (IEEE Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System Part 1: Normal Measurements).

2. Criterion

The grounding resistance must be less than the value defined in Article 16-8, Article 16-9, Article 16-13, Article 16-14, and Article 16-15 of the volume two of the guideline and a design grounding resistance value. If the continuity test is applied, there must be an electrical connection between the grounding systems

3. Reference

The design grounding resistance value is usually determined for safety based on the resistivity of the soil, the magnitude of the fault current, acceptable touch and step voltage, etc. It is important that the system is effectively grounded. With regard to the design grounding resistance, IEEE Standard 80-2000 (IEEE Guide for Safety in AC Substation Grounding) is informative and required grounding resistance for large substation, but a thermal power plant, is about 1 ohm or less according to this standard. An example of grounding resistance measurement records is shown in Figure 148-1 and an example of grounding resistance measurement circuit is shown in Figure 148-2.

Grounding resistance measurement records

<table>
<tr><td colspan="2">Date, Time</td><td colspan="2">1 May. 2012
14:00 – 14:30</td><td>Humidity
(%)</td><td>56.0</td><td>Measured by</td><td>XXX</td></tr>
<tr><td colspan="2">Weather Condition</td><td colspan="2">Fine</td><td>Measureme
nt Point</td><td>XXX</td><td>Checked by</td><td>XXX</td></tr>
<tr><td colspan="2">Temperature
(degree in Celsius)</td><td colspan="2">24</td><td>Ground
condition</td><td>Dry</td><td>Approved by</td><td>XXX</td></tr>
<tr><td rowspan="2">No</td><td rowspan="2">Direction of
Measured
Current</td><td colspan="2">Measured Voltage
(V)</td><td>Calculated
Voltage (V)</td><td rowspan="2">Measured
Current
Is (A)</td><td rowspan="2">Ground
Resistance
(Ohm)</td><td rowspan="2">Applied
Voltage
(V)</td></tr>
<tr><td>Vo</td><td>Vs1/Vs2</td><td>Vs</td></tr>
<tr><td>1</td><td>Forward</td><td>0.555</td><td>1.202</td><td>0.945</td><td>10.0</td><td>0.0944</td><td>88</td></tr>
<tr><td>2</td><td>Reverse</td><td>0.554</td><td>1.204</td><td>0.945</td><td>10.0</td><td>0.0945</td><td>88</td></tr>
<tr><td>3</td><td>Forward</td><td>0.553</td><td>2.050</td><td>1.909</td><td>20.0</td><td>0.0955</td><td>180</td></tr>
<tr><td>4</td><td>Reverse</td><td>0.555</td><td>2.048</td><td>1.909</td><td>20.0</td><td>0.0954</td><td>180</td></tr>
<tr><td>5</td><td>Forward</td><td>0.557</td><td>2.956</td><td>2.861</td><td>30.0</td><td>0.0954</td><td>267</td></tr>
<tr><td>6</td><td>Reverse</td><td>0.556</td><td>2.957</td><td>2.861</td><td>30.0</td><td>0.0954</td><td>267</td></tr>
<tr><td colspan="2">Design Resistance
(Ω)</td><td>0.10</td><td colspan="2">Measured Resistance
at 30 A (Ω)</td><td>0.095</td><td>Result</td><td>Good</td></tr>
<tr><td colspan="3">Measurement Instrument</td><td colspan="5">Refer to attached file</td></tr>
<tr><td colspan="8">Note
Vo: Measured Voltage at Is=0
Vs1: Measured Voltage at forward current
Vs2: Measured Voltage at reverse current</td></tr>
</table>

Figure 148-1 An Example of grounding resistance measurement records

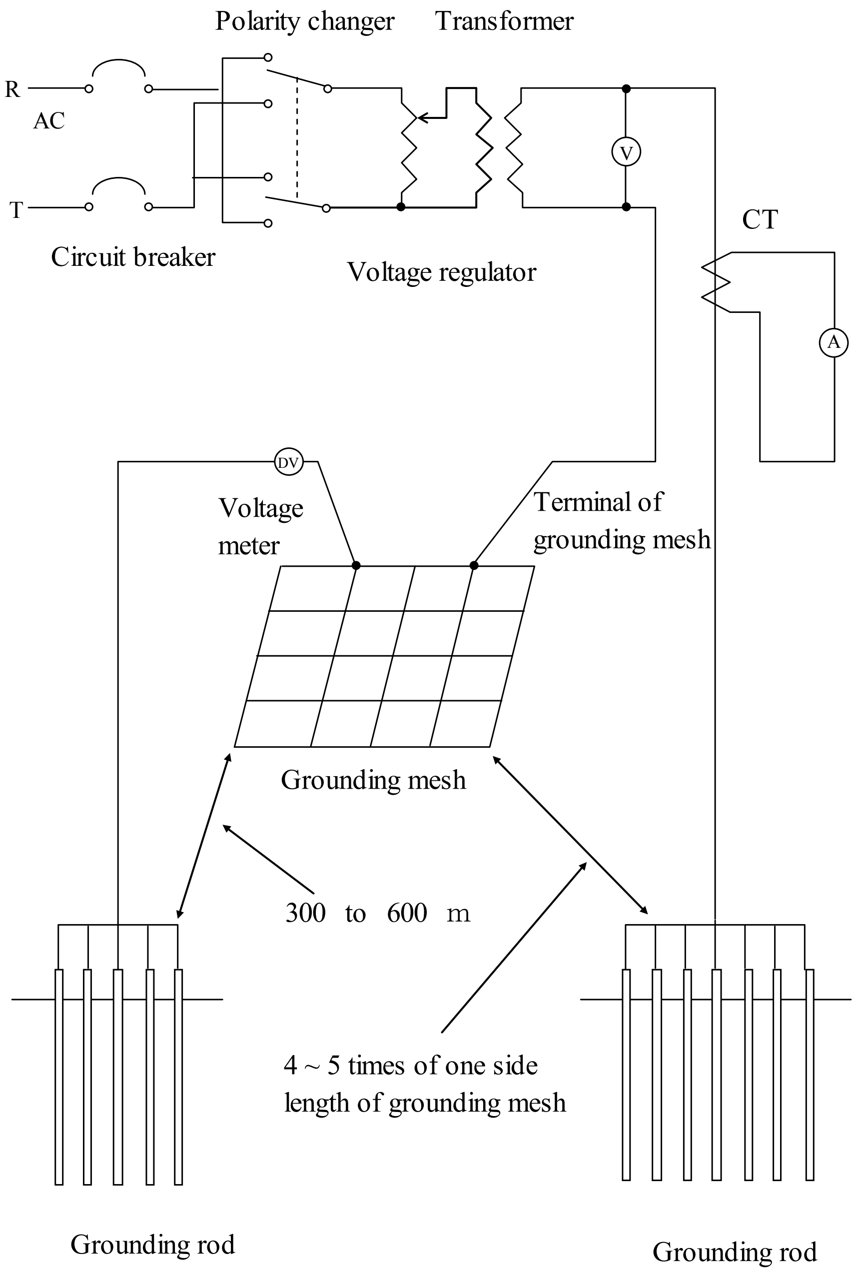


Figure 148-2 An example of grounding resistance measurement circuit (by AC fall-of-potential Method)

Article 149. Measurement of insulation resistance

Insulation resistance should be measured in order to inspect the condition of insulation of power line and electrical equipment.

1. Measurement method

(1) Insulation resistance of a generator excitation circuit must be measured in the circuits for voltages up to 1000 V.

(2) Insulation resistance of the circuit in which dielectric strength test is performed must be measured before and after its test in the circuits for voltages exceeding 1000 V.

(3) Insulation resistance must be measured with an insulation resistance tester (megger or megohmmeter) specified in the Japanese Industrial Standards (JIS) C 1302 or the International Electrotechnical Commission (IEC) 61557-2. A test voltage of 500 Vdc is applied for the circuits for voltages up to 1000 V and a test voltage of 1000 Vdc is applied for the circuits for voltages exceeding 1000 V.

(4) "1 minute value" after having applied the test voltage is obtained as an insulation resistance value.

When a pointer of the insulation resistance tester does not stand still in short time because of high capacitance of equipment for example a long underground cable, a value after the pointer has stood still is obtained, however, it is not necessary to apply the test voltage exceeding 3 minutes continuously.

(5) Major Items to be recorded and confirmed are as follows:

- Date and time,
- Weather condition,
- Temperature,
- Humidity,
- Location (Point of measurement),
- Insulation resistance value,
- Insulation resistance tester used in the measurement.

A calibration test certificate of the insulation resistance tester is also verified. An example of insulation resistance measurement test records including dielectric strength test is shown in Figure 150-1.

2. Criteria

(1) Circuits for voltages up to 1000 V

The insulation resistance must conform to the value defined by table 10 of Article 238 of the volume two of the technical regulation. Nevertheless, it is desirable that the insulation resistance is at least 1 Mega ohms.

(2) Circuits for voltages exceeding 1000 V

The circuit in which dielectric strength test is performed must be insulated from the ground and other circuits. If it is a multi-core cable, it must be insulated from other conductors, and if it is a transformer, it must be insulated from other windings.

As for daily maintenance or inspections, Article 219 of operation and maintenance guideline is referred.

Article 150. Dielectric strength test

Dielectric strength test must be performed in order to inspect that the electrical equipment has the specified dielectric strength but it is acceptable not to perform this test provided that it is verified that dielectric strength test was carried out according to the standard specified in advance at the manufacturing factory, testing laboratory, etc. before installation.

The electrical equipment to be tested is what defined in Article 16-4 and Article 16-5 of the volume two of the guideline such as a power line, transformer, rotating machine, switch, circuit breaker and capacitor. The dielectric strength voltage test is also called high-potential or dielectric withstand test. An example of dielectric strength test records including insulation resistance measurement is shown in Figure 150-1.

1. Test method

There are two options as follows:

(1) A test voltage defined in Table 2, Table 3, Table 4, Table 5 and Table 6 of the volume two of the guideline is applied continuously for 10 minutes depending on a kind of the electrical equipment and its operating voltage.

(2) A test voltage defined in IEC standards is applied continuously for one minute depending on a kind of the electrical equipment and its operating voltage.

Note:

However, a normal operating voltage can be applied between a main circuit of the electrical equipment and ground instead of the test voltage if it is verified that dielectric strength test was carried out by an equivalent method mentioned above at the manufacturing factory, testing laboratory, etc. The normal operating voltage means the voltage applied between the main circuit and ground under normal condition.

2. Criteria

(1) The electrical equipment must withstand the test voltage and must be insulated from the ground without abnormal condition by means of measuring insulation resistance after this test.

(2) If the normal operating voltage is applied, the electrical equipment must withstand this voltage without abnormal condition.

Insulation resistance measurement and dielectric strength test records

Date, Time	5 Dec. 2011 10:30 – 12:00		Temperature (degree in Celsius)		13.8	Measured by	XXX
Weather Condition	Fine		Humidity (%)		74.0	Checked by	XXX
Location	Insulation resistance					Approved by	XXX
Generator stator wiring and IPB	Before dielectric strength test (MΩ)			After dielectric strength test (MΩ)		Result	
Phase U	100			100		Good	
Phase V	100			100		Good	
Phase W	100			100		Good	
Dielectric strength test							
Location	-	Test device		Test voltage		Leakage current	-
Generator stator wiring and IPB	Time (min)	Input voltage (V)	Input current (A)	Reading voltage (V)	Calculated voltage (V)	Reading current (A)	Result
Phase U	1	110	50.0	55	27,500	2.24	Good
	5	109	50.0	55	27,500	2.23	
	9	109	50.0	55	27,500	2.23	
Phase V	1	110	50.8	55	27,500	2.25	Good
	5	109	50.8	55	27,500	2.25	
	9	109	50.8	55	27,500	2.25	
Phase W	1	110	51.6	55	27,500	2.27	Good
	5	109	51.6	55	27,500	2.27	
	9	109	51.6	55	27,500	2.27	
Measurement Instrument		Refer to attached file					
Note:							

Figure 150-1 An Example of insulation resistance measurement/dielectric strength test records

3. Notice before the test

(1) Installation of the equipment, wirings, connection (special connection for test is also included) and grounding circuit should be checked carefully before the test.

(2) In general, arresters and grounding capacitors are disconnected from the circuit to be tested. Depending on the voltage condition, VT and CT may be isolated from the circuit.

(3) The equipment which is not required to be tested (already finished) is recommended to be disconnected from the circuit to be tested because high stress may be applied to the equipment.

(4) The capacity of the test equipment should be selected considering the capacitance of the circuit to be tested. In other words, test area and circuit should be checked considering the length and capacitance of the cables.

(5) Insulation resistance is recommended to be measured before the test. If the resistance is low, bushings or insulators are dried and cleaned or changed to the new ones.

4. Notice during the test

(1) Test condition should be informed relevant staff of. Circuit to be tested should be separated by fences or ropes etc for safety.

(2) Supervisors should be stationed to monitor the test.

(3) The voltage and current should be monitored carefully. If they changed rapidly, it may be the sign of electrical breakdown.

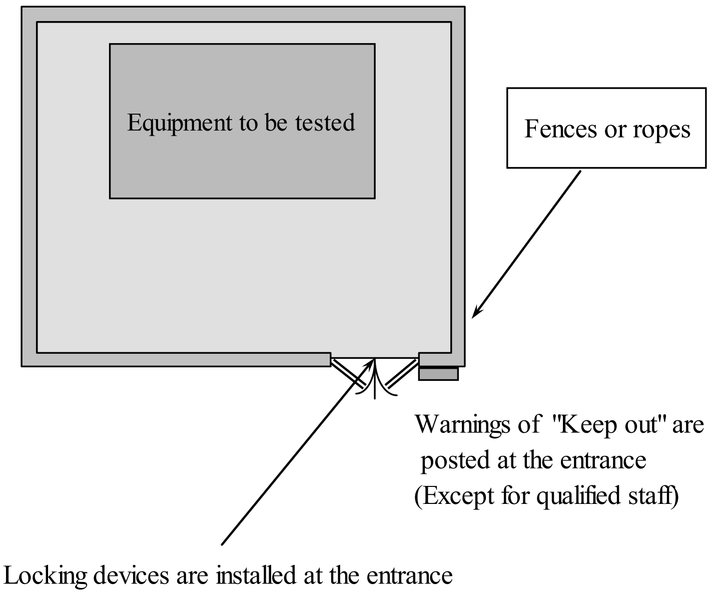


Figure 150-2 An example of the safety measure during dielectric strength test

Article 151. Protective device test

Protective device test should be performed in order to inspect that an associated circuit breaker is tripped, and associated alarm devices such as an alarm indicator and annunciator are properly and correctly initiated by activation of a protective relay when abnormal condition occurs in the electrical equipment or facilities. The protective device to be tested is what protects electrical equipment and power lines of exceeding 1000 V form abnormal condition such as overcurrent, ground fault and internal failure, including what defined in Article 237-1 and Article 237-2 of the volume two of the guideline.

1. Test method

(1) Operating characteristics test of the protective relay must be performed by a test device. An example of list of operating characteristics of protective relays is shown in Table 151-1.

(2) A protection circuit consists of the protective device and wiring connected to instrument transformers, auxiliary relays, lockout relays, trip coils of circuit breakers, etc. It is essential that the entire protection circuit form beginning to end is tested to ensure integrity of total circuit.

(3) One reliable method is to divide the protection circuit into segments and to test each segment separately. It is essential for this method that there is not a lack of segment of the protection circuit by protection segments overlap including individual components test. For example, after test of individual protective components, the protection circuit from an instrument transformer to a protective relay board is tested by primary injection method which is performed by injecting primary current and/or voltage into the primary windings of the instrument transformer to inspect proper ratio, phase and polarity. And the protection circuit from the protective relay board to a circuit breaker, fault indicator and/or annunciator is tested by secondary injection method which is performed by injecting secondary current and/or voltage into the test plugs or test block on the protective relay board to emulate the secondary outputs of the instrument transformer. An example of check sheet of total protection circuit test is shown in Figure 151-1.

(4) Alarm devices such as an alarm indicator and annunciator must be tested at the same time as the total protection circuit test or separately. If the injection method is not applicable to a detecting device such as a temperature sensor and pressure switch, the alarm device test is performed by the other appropriate method depending on a kind of the detecting device such as manual contact closing. An example of check sheet of alarm device test is shown in Figure 151-2.

(5) It is desirable to inspect protective devices which protect electrical equipment and power lines for voltages up to 1000 V form abnormal condition.

2. Criteria

(1) Operating characteristics test of the protective relay

The operating characteristics of the protective relay must be within the specified values by the standard such as IEC and JIS, and must be also within manufacture's specification value.

(2) Total protection circuit test

The associated circuit breaker must be tripped, and the associated alarm devices such as an alarm indicator and annunciator must be properly and correctly initiated by activation of a protective relay according to the schematic diagrams (protective wiring diagrams).

(3) Alarm device test

The associated alarm devices such as an alarm indicator and annunciator must be properly and correctly initiated by activation of the detecting device according to the schematic diagrams (protective wiring diagrams).

Table 151-1 An example of list of operating characteristics of protective relays

Relays to be tested	Test item	Test content
Overcurrent relay	Minimum operating current	Time overcurrent element and instantaneous element are measured at the setting tap.
	Operating time	After the tap is set at the setting tap, operating time is measured at 200%, 300%, 500% and 700% current.
Ground fault overcurrent relay	Minimum operating current	After the tap is set at the setting tap, minimum operating current is measured.
	Operating time characteristic	Operating time is measured 130% and 400% current of setting tap.
Over/Under voltage relay	Minimum (maximum) operating current	This value is measured at the setting tap.
	Operating time	Over voltage relay: operating time is measured at 120% of setting tap Under voltage relay: operating time is measured at 70% of setting tap
Biased differential relay	Minimum operating current	This value is measured at the set value.
	Operating time	Operating time is measured when current increases from 0% to 300% rapidly at the set value.
	Operating characteristic	Second or first value of current is measured when first or second value of current is fixed.
Ground fault over voltage relay	Minimum operating voltage	This value is measured at the setting value.
	Operating time	Operating time is measured at 150% of minimum setting value, maximum setting time, setting voltage
Ground fault directional relay	Minimum operating current	After the tap is set at the setting tap, this value is measured at 150% zero phase voltage at the maximum activation phase angle.
	Minimum operating voltage	After the tap is set at the setting tap, this value is measured at 150% zero phase current at the maximum activation phase angle.
	Operating time	After the tap is set at the setting tap, zero phase voltage is set to 150% and operating time is measured at the current of 130% and 400%
	Phase angle	After the tap is set at the setting tap, phase angles is measured at 150% zero phase voltage and 1000% zero phase current. Lead and lag phase angle are measured.

Check sheet of total protection circuit test

No	Test Item	Test Preparation	Test Operation
10	1A P/C Transformer overcurrent (51TA)	Position of Lockout relay and Circuit breakers 51TAX: Reset 3-1A/H: Close/Red lamp 3-1A/L: Close/Red lamp	(1) Phase R: Inject test current into test plugs for 51TA Test current at fault condition: 6.3 A (300%) (2) Reset 51TAX manually after test (3) Phase S: same as above (4) Phase T: same as above Note: This test is performed by the segmented method after having confirmed the current transformer circuit from the current transformer to the protective relay board.

Operation after Test	Annunciator/Fault indicator	Computer display/printout	Result
Lockout relays 51TAX: Trip Circuit breakers 3-1A/H: Trip/Green lamp 3-1A/L: Trip/Green lamp	Annunciator 1A P/C Transformer fault: ON 1HA M/C Feeder fault: ON M/C, P/C Lockout Relay Trip: ON Fault indicator (Relay) LED: ON	1A P/C Transformer overcurrent 51TAX: ON 1A P/C Transformer Trip: ON M/C, P/C Lockout Relay Trip: ON	

Figure 151-1 An example of check sheet of total protection circuit test

Check sheet of alarm device test

Location	No	Test Item	Detecting device	Setting value	Actual
BTG	1A	Abnormal condition of Circuit breaker for Main transformer	-	-	-
	1B	Abnormal condition of Cooling system for Main transformer	-	-	-
	1C	Main transformer Pitot relay closed	96P2MX	3 .5 L	-
	1D	Main transformer Relief valve open	63QMX	50 kPa	-
	1E	Main transformer Arrester discharged	30LA-1 30LA-2 30LA-3	-	-
	2A	Main transformer Windings fault	87MX	Differential 40%	Differential 40%

Test Operation	Annunciator	Computer display/pri ntout	Date	Result
Refer to attached file	Buzzer: X	X	2 Mar. 2012	Good
Refer to attached file	Buzzer: X	X	2 Mar. 2012	Good
Make contact by a magnet	Buzzer: X	X	2 Mar. 2012	Good
Make contact manually	Buzzer: X	X	2 Mar. 2012	Good
Push test button	Buzzer: X	X	2 Mar. 2012	Good
Fault simulation by relay testing device	Buzzer: X	X	2 Mar. 2012	Good

Figure 151-2 An example of check sheet of alarm device test

Article 151-a1. Circuit breaker test

A circuit breaker test must be performed in order to inspect that the circuit breaker with pneumatic or hydraulic system, its auxiliary equipment and its driving energy system is capable of safety operating.

This test is applied to circuit breakers with fluid-operated mechanism such as pneumatic and hydraulic system. An example of circuit breaker test records is shown in Figure 151-a1-1.

1. Test method

(1) Stored energy operation test

This test is performed to inspect capability of attached tanks (reservoir, receiver). Accumulators are included in the attached tanks (reservoir, receiver), and hereafter, the same in this article.

It must be inspected that the circuit breakers is capable for complete closing and opening operation consecutively at least once (circuit breakers required for reclosing duty: two times or more) without energy supply.

This test is performed under the condition that the attached tank is isolated from energy supply such as compressed air and hydraulic pump operation, for example, by closing supply valves.

In addition, if a breaker is equipped with low and high pressure interlocking device for preventing imperfect closing or opening, it must be inspected that the circuit breaker and its position indicator operate properly by means that pressure devices to block a closing or opening circuit are actuated or deactuated by reducing or increasing the attached tank pressure.

(2) Automatic start/stop control test of fluid pumping device
The fluid pumping device means pump, compressor, controlled valve, etc. Following measurements must be taken under the condition that the fluid pumping device operates automatically.

- A pressure at starting of the fluid pumping device on a drop in pressure
- A pressure at cut-off of the fluid pumping device on a rise in pressure

For example, the pressure at starting of the fluid pumping device is obtained after a pressure has decreased gradually by opening a blow off valve of the attached tank slowly. The blow off valve is closed after the fluid pumping device has started. The pressure at cut-off of the fluid pumping device is obtained after the pressure has risen gradually.

(3) Functional performance test of safety relief valve of the attached tank
Opening pressure of safety relief valve of the attached tank must be measured.

For example, pressure rises gradually by manual operation of the fluid pumping device after having closed the outlet stop valve to shut off the fluid supply for the attached tank, and an opening pressure of the safety relief valve is measured.

If this test was already performed at the manufacturing factory, etc, it is acceptable to verify a test records instead of this test.

2. Criteria

(1) Stored energy operation test
The circuit breaker must be operated as required times or more, and the associated alarm devices such as an alarm indicator and annunciator must be properly and correctly initiated by activation of a detecting device according to the schematic diagrams (protective wiring diagrams).

(2) Automatic start/stop control test of fluid pumping device
Automatic start/stop control must be operated within the limits of set pressure.

(3) Functional performance test of safety relief valve of the attached tank
The operating pressure of the safety relief valve must be not more than the maximum allowable operating pressure of the attached tank.

Circuit breaker test records

1. Stored energy operation test

Phase	Hydraulic pressure					Result	Criterion
	Initial (MPa)	After 1st closed (MPa)	After 1st opened (MPa)	After 2nd closed (MPa)	After 2nd opened (MPa)		
A	31.5	30.3	28.8	28.0	26.8	Good	The circuit breaker is capable two times operations
B	31.5	30.2	28.7	28.0	26.7	Good	
C	31.5	30.3	28.7	28.1	26.9	Good	

	Phase	System	Locking pressure (Activation) (MPa)	Locking pressure (Criteria)	Rest pressure (Deactivation) (MPa)	Reset pressure (Criteria)	Result
Close lockout	A	A	27.0	27.0 MPa (Allowable error: ± 1.0 MPa)	28.0	From 0.5 to 1.2 MPa plus activation value	Good
		B	26.9		27.9		
	B	A	26.7		27.8		
		B	26.9		27.8		
	C	A	26.8		27.8		
		B	26.9		27.7		
Trip lockout	A	A	25.5	25.5 MPa (Allowable error: ± 1.0 MPa)	26.5	From 0.5 to 1.5 MPa plus activation value	Good
		B	25.4		26.3		
	B	A	25.2		26.2		
		B	25.3		26.3		
	C	A	25.3		26.3		
		B	25.4		26.4		

2. Automatic start/stop control test of hydraulic pumps

	Phase A (MPa)	Phase B (MPa)	Phase C (MPa)	Criteria	Result
Starting pressure	31.8	31.7	31.8	31.7 MPa (Allowable error: ± 1.0 MPa)	Good
Cut-off pressure	33.7	33.6	33.6	33.7 MPa (Allowable error: ± 1.0 MPa)	Good

3. Functional performance test of relief valve of the attached tank

Phase	Opening Pressure (MPa)	Criterion	Result
A	37.0	37.5 MPa (Allowable error rang: 36.0 to 37.5 MPa)	Good
B	37.2		Good
C	37.0		Good

Figure 151-a1-1 An example of circuit breaker test records

Article 152. Protective device test for hydrogen and seal oil

Test for protective (detecting) device for hydrogen and seal oil must be performed during shutdown of a generator in order to inspect that associated alarm devices are activated, and appropriate protective actions to prevent a possibility of hydrogen explosion after hydrogen has leaked can be taken.

This test is applied to generators with hydrogen cooling and seal oil system. An example of seal oil system is shown in Figure 152-1. A check sheet form of this test is almost same as Figure 151-2 (An example of check sheet of alarm device test).

1. Test items

(1) Items shown in table 152-1 must be tested, and also it is desirable that test items of manufacture recommendations are taken into consideration, because these are different depending on design of generators and auxiliary systems.

Table 152-1 Test items

Test item	Main purpose of protective (detecting) device	Method (for example)
Hydrogen gas purity: Low	Not to encroach upon the upper explosive limit	Simulation of hydrogen gas purity detection device
Hydrogen pressure: High/Low	High: Not to leak hydrogen gas from the generator to atmosphere Low: Not to decrease the insulating capability of hydrogen gas and its cooling capacity	Actual activation of pressure switches caused by filling the generator with instrument air.
Outlet pressure of main seal oil pump: Low	Not to leak hydrogen gas from the generator to atmosphere	Actual Activation of a pressure switch after operation of a test valve

(2) Following items are recommended to be tested in general; however, these are not all inclusive because there are different depending on design of generators and auxiliary systems.

- Differential pressure between hydrogen and seal oil: Low
- Vacuum tank vacuum: Low
- Vacuum tank oil level: High/Low
- Drain enlargement tank level: High
- Hydrogen temperature: High
- Generator casing liquid level: High
- Main seal oil pump: Trip

  (When this fault occurs, an emergency seal oil pump must start up automatically.)
- Recirculating seal oil pump: Trip
- Vacuum pump: Trip
- Emergency seal oil pump: Overload
- Strainer Differential pressure: High
- Hydrogen cylinder pressure: Low
- Loss of ac power supply

- Loss of dc power supply

2. Criteria

(1) The associated alarm devices such as an alarm indicator and annunciator must be properly and correctly initiated by activation of a protective (detecting) device according to the schematic diagrams (protective wiring diagrams).

(2) When outlet pressure of main seal oil pump is low, in addition to the above, an emergency seal oil pump must start up automatically.

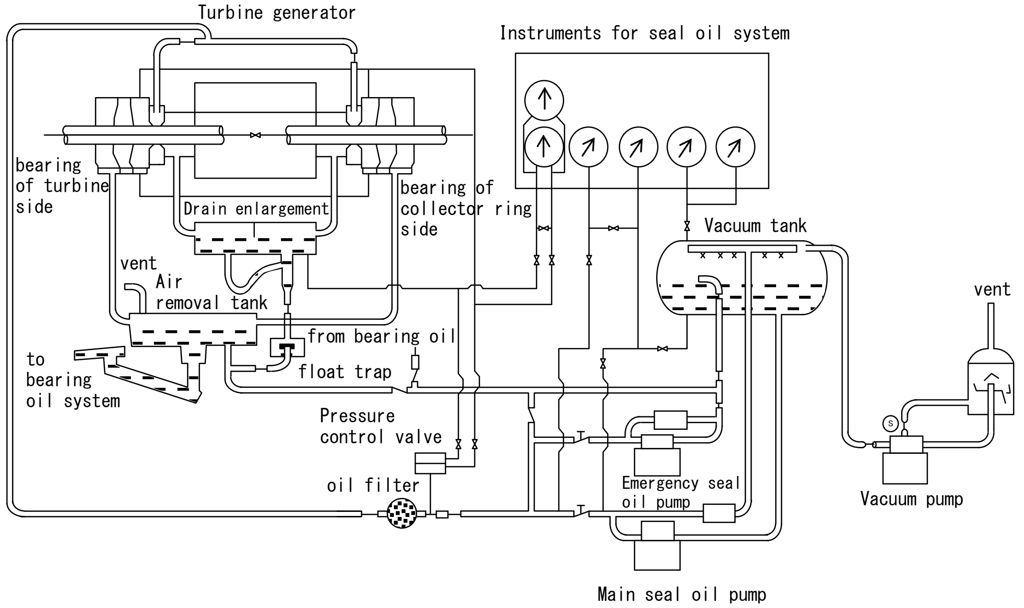


Figure 152-1 An example of sealing oil system

Article 153. Protective device test for the stator cooling system of generator

Test for protective (detecting) device for stator cooling water system must be performed during shutdown of a generator in order to inspect that associated alarm devices are activated, and appropriate protective actions to prevent overheating of stator windings and associated components can be taken.

This test is applied to generators with a stator cooling water system. A check sheet form of this test is almost same as Figure 151-2 (An example of check sheet of alarm device test).

1. Test items

It is desirable that test items of manufacture recommendations are taken into consideration, because these are different depending on design of generators and auxiliary systems. Following items are recommended to be tested; however, these are not all inclusive.

- Cooling water pump outlet pressure: Low *1
- Cooling water inlet pressure to generator: Low *2
- Cooling water inlet flow to generator: Low
- Cooling water inlet temperature to generator: High
- Cooling water outlet temperature from generator: High *3

- Cooling water storage tank level: High/Low
- Cooling water pump: Trip *1
- Cooling water conductivity: High
- Cooling water differential pressure across filters and strainers: High
- Loss of ac power supply
- Loss of dc power supply

Note:

*1: If this alarm occurs, a stand-by cooling water pump must start up automatically.

*2: If the pressure drops more after this alarm has occurred, “turbine run back” must be initiated automatically.

*3: If the temperature rises more after this alarm has occurred, “turbine run back” must be initiated automatically.

2. Criterion

The associated alarm devices such as an alarm indicator and annunciator must be properly and correctly initiated by activation of a protective (detecting) device according to the schematic diagrams (protective wiring diagrams).

Article 154. Unit interlock test

As for electrical equipment such as a generator, major transformers and bus-bars of metal clad switchgears, its interlock test must be performed in order to inspect that when abnormal condition occurs in the equipment or facilities, associated circuit breakers are operated, and associated alarm devices and interlock system are initiated by activation of the protective relays, and they are properly and correctly. The interlock means sequential trip which is, for example, to trip a main circuit breaker for a generator internal failure, or to trip a generator for a steam turbine trip, and an example of block diagram for interlock (sequential trip) is shown in Figure 154-1.

In addition, the interlock test for electrical equipment must be performed after all protective device tests have been performed and verified. An example of check sheet of interlock test is shown in Figure 154-2.

Unit interlock test must be performed after the interlock test for electrical equipment in order to inspect that when abnormal condition occurs in a power plant, associated circuit breakers are operated, and associated alarm devices and interlock (sequential trip) system between a generator, a turbine and a boiler are initiated by activation of the protective devices, detecting device, etc., and they are properly and correctly. Unit interlock test is also referred to Article 141.

1. Interlock test items for electrical equipment

(1) The Interlock test items are what initiate major circuit breakers trip by activation of a protective device, and these are listed below, but are not limited to, because these are different depending on design and configuration of electrical equipment. Therefore, it is desirable that test items of manufacture recommendations are taken into consideration
  - Generator short-circuit [biased or percentage differential relay]
  - Generator reverse phase current

- Generator ground
- Generator field loss
- Generator short-circuit [backup generator distance relay]
- Generator exciter major malfunctions
- Main (step-up, generator) transformer internal failure [biased or percentage differential relay]
- Unit auxiliary (unit service, station auxiliary) transformer internal failure [biased or percentage differential relay]
- Unit auxiliary (unit service, station auxiliary) transformer overcurrent
- Unit auxiliary (unit service, station auxiliary) transformer ground
- Station start-up (service) transformer internal failure [biased or percentage differential relay]
- Station start-up (service) transformer overcurrent
- Station start-up (service) transformer ground
- Excitation transformer internal failure [biased or percentage differential relay]
- Excitation transformer overcurrent
- Bus-bars overcurrent of metal clad switchgear
- Turbine trip

Note: Inside of the brackets means a protective relay.

(2) The other test items to be recommended are listed below.

- Generator/ Main (step-up, generator) transformer over excitation [volts per hertz relay]
- Major power (step-down) transformers internal failure [biased or percentage differential relay]
- Major power (step-down) transformers overcurrent
- Automatic start of an emergency generator and automatic power transfer to an emergency power bus for essential auxiliaries in the event of a loss of station service power [under voltage relay]

2. Unit Interlock test items

The unit Interlock test items are same as preceding paragraph; selected items in them are generally performed as this test.

3. Interlock test method

This test is generally performed during a unit (boiler, turbine and generator) shutdown by activating the protective relay such as the following:

- Injecting simulation current and/or voltage, or
- Activating digital protective relay by using a force function (forced control), or
- Activating electro-mechanical protective relay by making contact manually.

In addition, whole necessary preparation must be performed and confirmed prior to this test. Necessary preparations are listed below, but there are not all inclusive because these are different depending on design and configuration:

- Electrical and/or mechanical lockout of a circuit breaker: trip/closing

- Disconnection of power line
- Power supply: on/off
- Cable connection: jumper/lift
- Position of a circuit breaker: operation/test
- Lockout of a protective relay or signal: on/off
- Simulation of synchronism between a generator and a grid
- Lockout relay: reset

4. Criteria

(1) Interlock test items for electrical equipment

The associated circuit breaker must be operated, and the associated alarm devices such as an alarm indicator and annunciator must be properly and correctly initiated by activation of a protective relay according to the block diagram for interlock (sequential trip) and schematic diagrams (protective wiring diagrams).

(2) Unit Interlock test

In addition to the above, the associated interlock (sequential trip) system between a generator, a turbine and a boiler must be properly and correctly initiated according to the block diagram for interlock (sequential trip) and schematic diagrams (protective wiring diagrams)

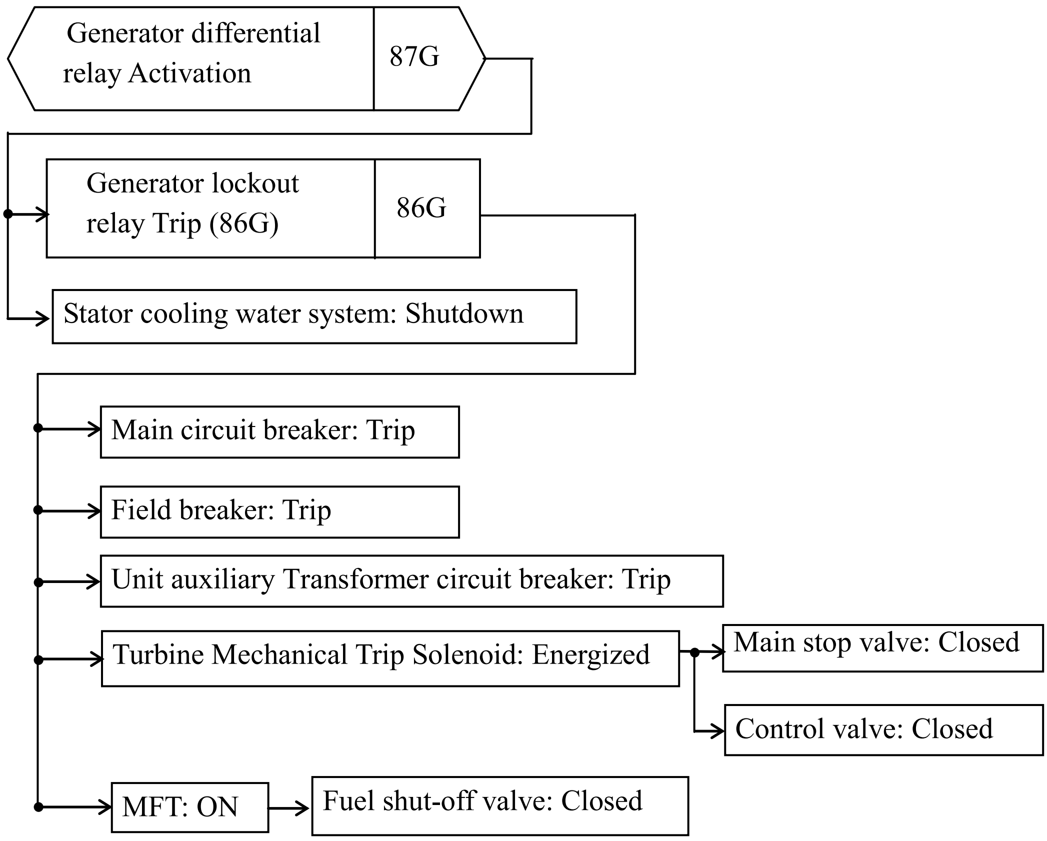


Figure 154-1 An example of block diagram for interlock (sequential trip)

Check sheet of interlock test (Electrical Equipment)

No	Test Item	Test Preparation	Test Operation
1	Generator Internal Fault (87G)	Lockout relays 86G1A: Reset 86G1B: Reset Circuit breakers 20-120: Close 41E: Close 4-2HA/L: Close 4-2HB/L: Close 4-2AT: Open/Auto 4-2BT: Open/Auto 3-2A/H: Close 3-2A/L: Close 3-2B/H: Close 3-2B/L: Close 3-2A/T: Open 3-2B/T: Open 3-2E/N: Open 3-2E/E: Close	(1) Activation of digital biased differential relay (87G) with test mode a. Activate 87G of system A with forced control by manual operation b. Activate 87G of system B with forced control by manual operation (2) Reset 86G1A and 86G1B manually after test

Operation after Test	Fault indicators	Computer display/printout	Result
Lockout relays 86G1A: Trip 86G1B: Trip Circuit breakers 20-120: Trip/Green lamp 41E: Trip/Green lamp 4-2HA/L: Trip/Green lamp 4-2HB/L: Trip/Green lamp 4-2AT: Close/Red lamp 4-2BT: Close/Red lamp Related signals Stator cooling water pump 2A trip signal: ON Stator cooling water pump 2B trip signal: ON Main fuel trip signal: ON Main turbine master trip solenoid signal: ON	Generator windings fault: ON Turbine-generator lockout relay: ON Disturbance Recorder: ON	Generator internal fault: ON Turbine-generator lockout relay: ON Disturbance Recorder: ON	

Figure 154-2 An example of check sheet of interlock test

Article 155.

(Nothing)

Article 156.

(Nothing)

Article 157. Measurement of noise and vibration

1. Noise

(1) Objective

Measurement of noise level caused by a thermal power plant must be performed in order to confirm the compliance with TCVN 5949.

(2) Method

Measurement method is stipulated in the standard TCVN 5964, TCVN 5965 and TCVN 6399, and the following items for measurement are for reference.

1) Points to be measured

On the site boundary of the thermal power plant

2) Measuring instrument

It is recommended that a sound level meter specified by IEC 61672-1 (Sound level meters – part 1: specifications) or JIS C 1509 (Sound level meters) is used as the measuring instrument.

3) Other measuring method

- International Organization for Standardization (ISO) 1996-1 (Acoustics - Description, measurement and assessment of environmental noise - Part 1: Basic quantities and assessment procedures)
- JIS Z 8731 (Acoustics - description and measurement of environmental noise)

4) Record items

- Measurement date and time
- Measured noise levels
- Climate conditions during measurement (temperature, humidity, wind direction, wind velocity and weather)
- Measurement points with a sketch
- Height of measurement points
- Plant (unit) operating condition (shutdown or output: Mega Watts)
- Measurement condition (noise of the other source, buildings, topography)
- Features, fluctuation and kinds of noise source
- Measurement instruments (type, manufacture, Characteristics of sound level meters, sampling Interval)

(3) Criterion

Measured noise levels must not exceed the maximum allowable noise levels which are stipulated in TCVN 5949:2005.

2. Vibration

(1) Objective

Measurement of vibration level caused by a thermal power plant must be performed in order to confirm the compliance with TCVN 6962.

(2) Method

Measurement method is stipulated in the standard TCVN 6963, and the following items for measurement are for reference.

1) Points to be measured

On the site boundary of the thermal power plant

2) Measuring instrument

It is recommended that a vibration level meter specified by JIS C 1510 (Vibration level meters) is used as the measuring instrument.

3) Other measuring method

JIS Z 8735 (Methods of measurement for vibration level)

4) Record items

- Measurement date and time
- Measured vibration levels
- Climate conditions during measurement (temperature, humidity and weather)
- Measurement points with a sketch
- Height of measurement points
- Plant (unit) operating condition (shutdown or output: Mega Watts)
- Measurement condition (ground surface condition at mounting of vibration sensor, noise of the other source, topography)
- Features, fluctuation and kinds of vibration source
- Measurement instruments (type, manufacture)

(3) Criterion

Measured vibration levels must not exceed the maximum allowable vibration levels which are stipulated in TCVN 6962:2001.

Chapter 4 Periodic Inspection

Section 1 General Provision

Article 158. General provisions

1. It must be confirmed that status of damage and operation etc. of thermal power facilities meets with the technical regulation taking account of this Guideline.
2. Power plants may refer to international standards (voluntary standards) regarding the pressure vessels, lifting, fire fighting and other devices in addition to Vietnamese mandatory regulations and voluntary standards.

Article 159. Frequency of periodic inspections

1. The status of power plant varies depending on the type of system, type of fuel, whether new or old, whether design is good or bad, whether production is good or bad. The frequency of periodic inspections must be decided based on the technical regulations taking account of operational status of each power plant. Therefore, frequency of periodic inspection is not major problem, since the condition of each power plant is different.

   For example, frequency of periodic inspection of boiler at a power plant can be regulated 2 years; on the other hand it of boiler at B power plant can be regulated 3 years because it of boiler is regulated within six (6) years in the technical regulation.

2. However, if power purchase agreement is concluded and time of periodic inspection is regulated in it, it must be regulated frequency of periodic inspection in line with it.
3. ***"Risk based maintenance"***: When applying the new maintenance technology and conventional one to existing machines, it is necessary to formulate a maintenance plan so as to be compatible, such as maintenance cost and the rate of utilization. It can be mentioned the approach based on RBM (Risk Based Maintenance) as a method to establish the maintenance plan. The concept is shown in Figure 159-1. Maintenance costs will increase depending on the number of menu to perform maintenance; on the other hand, the probability that equipment will be broken will decrease. Accordingly, the amount of damage that is caused by broken equipment, the risk of accidents, will be reduced. Here, the necessary cost during operation of the unit, cost of economic risks is deemed as the sum of maintenance costs and accident risk, which type of bathtub curve as shown in Figure 159-1. It is deemed that the maintenance plan at the minimized point of economic risk curve is the best plan in this technique. System which supports the optimization of the maintenance plan based on this concept has been developed.

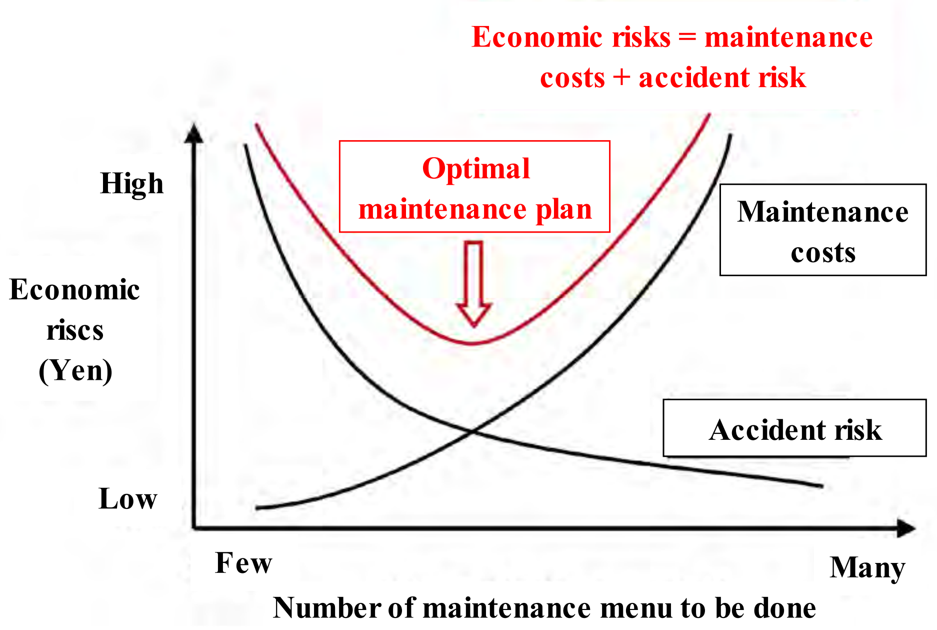


Figure 159-1 Concept of optimizing for maintenance planning based on RBM

4. ***"Periodic inspection of boiler"***: It takes 50 ~ 200days to perform periodic inspection that is required the replacement of boiler pressure part , though it is depending on the output of unit and replacement range. For example, replacement of re-heater and hot super-heater is performed in many units which have passed 100,000hours total operation time. The replacement of cold super-heater, economizer, water wall tube and the like is also expected in the case more than 200,000 hours operation time is extended further as shown in Figure 159-2. It will be the important issue to shortening the construction period in case if it is required long periods of time.

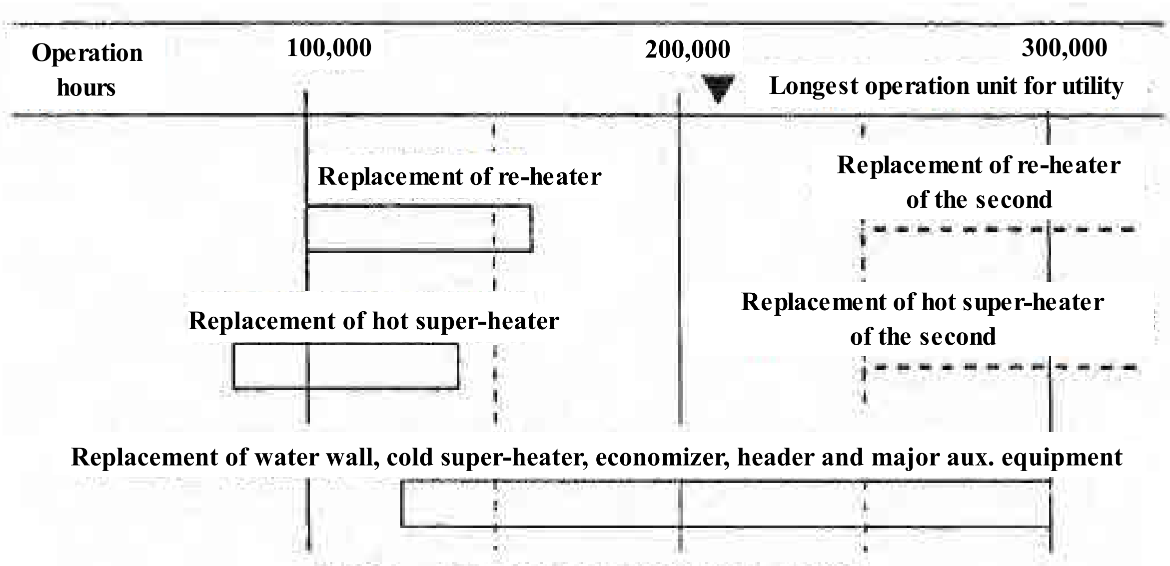


Figure 159-2 Location and timing of replacement of pressure part of boiler

5. ***"Management of gas turbine hot part"***:

(1) Type of inspection

Two kinds of inspection, "Full scale inspection" and "combustor inspection" are set as the inspection of gas turbine equipments and are performed. "Full scale inspection" is the inspection to decompose and open-up entire facility of gas turbine (GT, compressor, combustor), to inspect, repair, assemble and perform function testing and the like. "Combustor inspection" is the partial inspection to perform the inspection for combustor, repair, assemble and perform function testing and the like

(2) Interval of inspection

The inspection interval of GT hot parts is determined and the inspection is performed in the number of years considering the demand of power. In case of GT of GE, full scale inspection is carried out once in 3 years and combustor inspection is carried out once a year as shown in Figure 159-3-(b).

It is possible to review the interval considering the operation experience, inspection result (status of deterioration and damage) and the recommended one according to the GER-3620 which is recommended by GE, though full scale inspection has been carried out once in 2 years at the beginning of operation.

For the purpose of further reduction of inspection costs, full scale inspection once in 3 years and combustor inspection once in 1.5 years have also started operation as shown in Figure 159-3-(c).

In case of GT of MHI, full scale inspection is carried out once in 2 years and combustor inspection is carried out once a year as shown in Figure 159-4. The full scale inspection for the second year is considered whether an extension is possible as well as GT of GE.

The reduction of the number and time of shut-down and high occupancy contribute significantly to reduce fuel costs and CO_2 emissions, since combined cycle has a high thermal efficiency.

The continuous and further consideration of full scale inspection and combustor inspection is required.

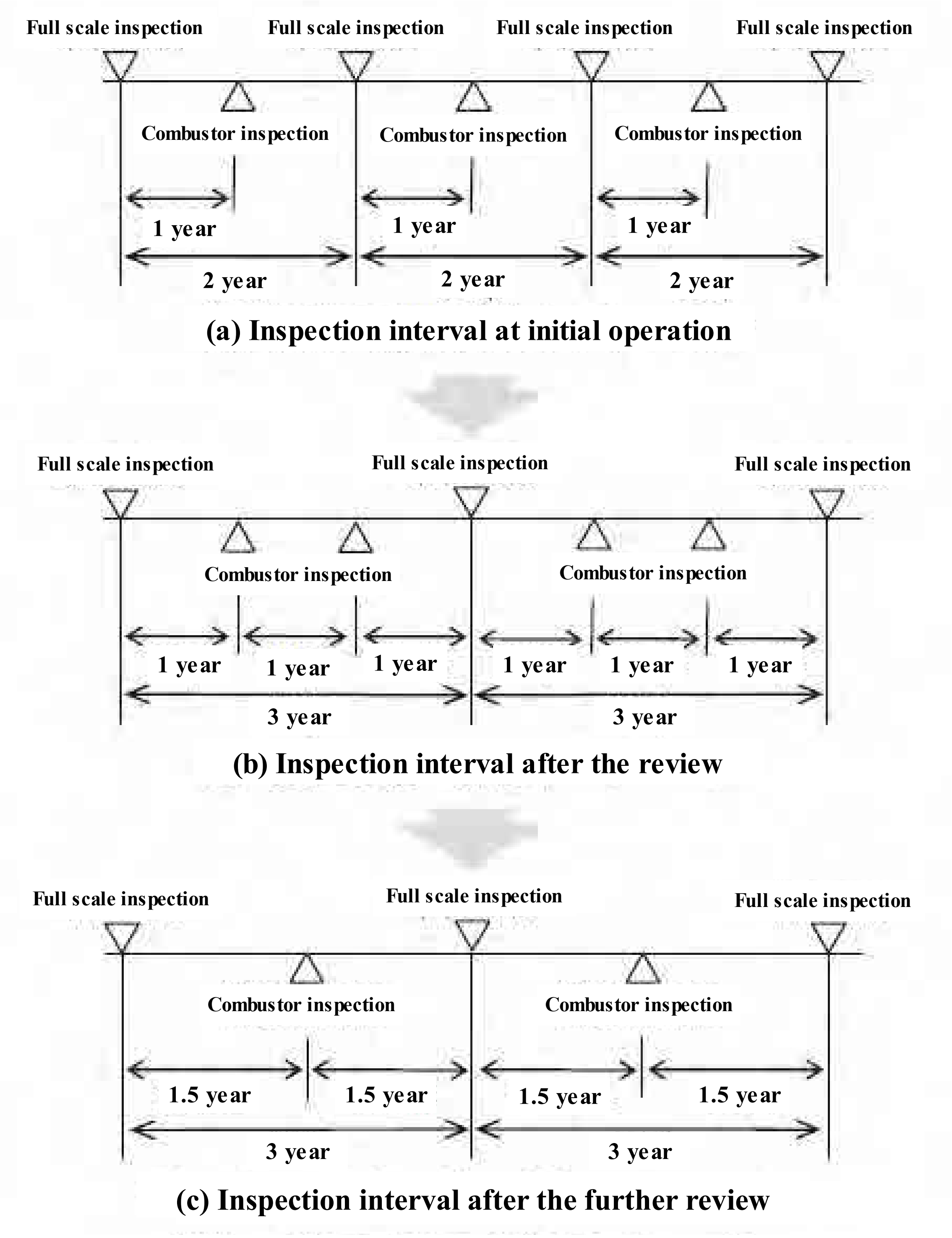


Figure 159-3 Inspection interval of GE type gas turbine

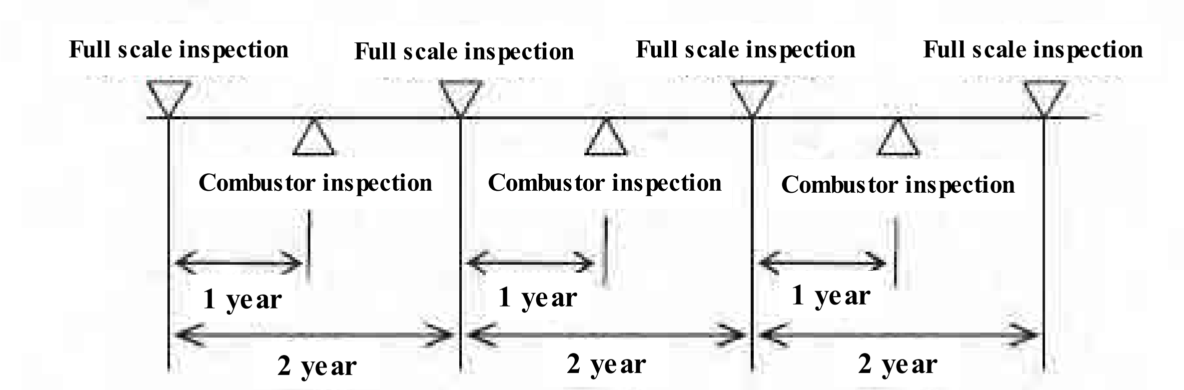


Figure 159-4 Inspection interval of MHI type gas turbine

6. ***"Periodic inspection of safety valve"***:

(1) Japanese regulation and standard

Table 159-1 Japanese regulation of interval for safety valve inspection

Law, regulation, rule and standard	Application	Inspection interval
Electric Business Act	Periodic voluntary inspection	Period not exceeding 2 years (de-composition, inspection, operation test)
	Periodic inspection	1~2 years
	Routine inspection	Once a day (leakage from seat)
Ordinance on safety of boiler and pressure vessels	Performance test	Once a year
High pressure gas safety law	Safety inspection and periodic voluntary inspection	(1) 4 years (full amount type) (2) 2 years (full amount type, lift type excluding low lift type) (3) a year (low lift type)
Guideline for spherical gas holder	Maintenance, periodic inspection, valve (safety valve)	Once a year (operation test) , to perform every 2 years and to overhaul in case of malfunction

Law, regulation, rule and standard	Application	Inspection interval
Guideline for LNG storage tank	Maintenance, patrol and inspection	Visual inspection: once a year Operation test: confirmation of operation pressure
Guideline for LNG facility	Maintenance, patrol and inspection	Visual inspection: once a month Operation test: confirmation of operation pressure

Reference: P-2 of "Maintenance of safety valve"No.54 of Technical report of Fukui seisakusho

(2) International standard

Table 159-2 International standard of interval for safety valve inspection

Law, regulation, rule and standard	Application	Inspection interval
ASME	Section-7 "Recommended guidelines for the care of power boilers" C4.110 Safety valve for section-1	Once a year (Safety valve)
	C4.200 Safety relief valves or relief valves C4.220 Inspection and maintenance foe section-7	More than 6 month and not longer than 2 years (safety valve and relief valve)
API	RP510: "Pressure vessel inspection code: maintenance, inspection, rating, repair and alteration" 6.6 pressure relieving device	Max. 5 year for normal process (possible to extend until 10 years in case for clean and no corrosive)
	RP576: "Inspection of pressure relieving devices" Section-5 Frequency and time of inspection 5.1.2 Normal basis	Within the duration that is capable to maintain its function as safety valve
Lloyd's resister	Annual survey Part-1/ Chapter-2 Classification regulation Section-3: Special survey 3.5.9 – 3.5.12	4~5 years
	Intermediate survey 3.5.2 – 3.5.3	2~3 years
Bureau Veritas	Annual survey Section 2-12 Surveys related to liquefied gas carrier cargo area 2-122: Annual survey	4~5 years
	2-123 Intermediate survey	2~3 years
Det Nolske Veritas (DNV)	Annual survey A300	4~5 years
	Intermediate surveys A400	2~3 years

Reference: P-2 of "Maintenance of safety valve"No.54 of Technical report of Fukui seisakusho

Section 2 Mechanical Equipment

Article 160. Boiler

1. Steam drum

(1) Confirmation of status of erosion, corrosion and crack

It must be confirmed that erosion, corrosion and crack at following part in steam drum. Erosion, corrosion and crack portion must be ground down and welded when it is minor damage. It must be repaired at site by welding when it has serious damage. It must be refer to Article 167-a9 of this Guideline when welding if necessary.

1) Weld line
2) Weld part
3) Manhole
4) Vicinity of hole edge of nozzle stub
5) Tube expansion

(2) Confirmation of plugging of piping

It must be confirmed that plugging of piping at following part relative to steam drum. Appropriate measures must be taken depending on degree of defect when detecting plugging at following part.

1) Connecting piping for water level gauge and pressure gauge etc.
2) Drain and blow piping
3) Chemical dosing piping
4) Feed water inner tube

(3) Confirmation of status of deposition

It must be confirmed that ingredient and volume etc. of deposition in steam drum. It is recommended that they are analyzed chemically by specialized agency if necessary. Analysis results must be confirmed and appropriate measures must be taken, if necessary.

(4) Confirmation of status of seal at internal device seat face

Status of seal at internal device seal face based on status of erosion, corrosion and crack at weld part must be confirmed.

(5) Confirmation of status of mounting of internal device and defect of other parts

Status of mounting of internal device and defect of other parts must be confirmed.

(6) MT inspection

It is recommended that inspection interval is regulated and MT inspection is conducted. (sample of inspection interval : every 8 years or 60,000 ~ 80,000 hrs)

1) MT inspection : typical of weld part of nozzle stub external surface and weld part of longitudinal joint/circumferential joint external surface

2) MT inspection : weld part of nozzle stub inner face

(some welded internal device are disassembled : number of disassembled internal device is decided by power plant)

http://www.nde.net/index-2b.html

Photo 160-1 MT inner face of expansion part

http://www.acousticeye.com/en-us/product/acoustic-eye-dolphin-tube-inspection-solution.asp

Photo 160-2 Inspection of drum internal

2. Water drum
   It must be referred to above “1. Steam drum”

3. Header (Economizer, Super-heater and Re-heater)

(1) External inspection of header and lifting ring of header.

External inspection of header and lifting ring of header must be conducted. When heat insulator prevents inspection, it must be disassembled.

1) Confirmation of status of erosion, corrosion and crack

It must be confirmed that erosion, corrosion and crack in header. It must be ground down and welded erosion, corrosion and crack portion when it is minor damage. It must be repaired by welding at site when it is major damage.

2) Confirmation of status of leak at weld part and tube expansion

It must be confirmed that leak at weld part and tube expansion in header. It must be taken appropriate measures depending on degree of defect when detecting defect in header.

3) Confirmation of status of crack at seat part of inspection hole

It must be confirmed that crack at seat part of inspection hole in header. It must be taken appropriate measures depending on degree of defect when detecting defect in header.

4) Confirmation of status of deposition

It must be confirmed that ingredient and volume etc. of deposition in header. It is recommended that they are analyzed chemically by specialized agency if necessary. It must be confirmed analysis results and taken appropriate measures if necessary.

(2) Internal inspection

No less than 2 typical headers must be selected and be conducted internal inspection to them every other periodic inspection.

1) Confirmation of status of erosion, corrosion and crack

It must be confirmed that erosion, corrosion and crack in header. It must be ground down and welded erosion, corrosion and crack portion when it is minor damage. It must be repaired by welding at site when it is major damage.

2) Confirmation of status of deposition

Ingredient and volume etc. of deposition in header must be confirmed. It is recommended that they are analyzed chemically by specialized agency if necessary. Analysis results and taken appropriate measures must be confirmed, if necessary.

(3) Detailed inspection

It is recommended that PT & MT inspection are conducted after 80,000 hours of accumulated operating hours.

1) PT inspection : typical weld part of header nozzle stub and weld part of supporter

2) MT inspection : typical weld part of header longitudinal joint/circumferential joint external surface

http://www.inspection-robotics.com/site/index.cfm?id_art=64186&vsprache=EN&CFID=7266869&CFToken=68320510

Photo 160-3 UT of external surface of stub

http://www.erda.org/fieldservices.htm

Photo 160-4 PT of stub on header

4. Tube

(1) Evaporation tube

1) External inspection of tubes inside furnace

External inspection of tubes inside furnace must be conducted.

a. Confirmation of status of erosion, corrosion and crack (weld part, tube expansion and other part.)

Erosion, corrosion and crack of evaporating tubes must be confirmed. Erosion, corrosion and crack portion must be ground down and welded when it is minor damage. It must be replaced with new tube or panel when it is major damage.

b. Confirmation of status of tube incurve and tube swelling and disturbance of tube row
   Tube incurve and tube swelling and disturbance of tube row must be confirmed. Appropriate measures must be taken depending on degree of defect when detecting defect at evaporating tubes.

c. Confirmation of status of deposition
   Ingredient and volume etc. of deposition at evaporating tube must be confirmed. It is recommended that they are analyzed chemically by specialized agency if necessary. Analysis results must be confirmed and appropriate measures must be taken, if necessary.

d. Confirmation of status of damage due to soot blower
   Tube damage due to steam flow of soot blower must be confirmed. Steam flow of soot blower is extremely big and there is a possibility that tube is worn away and leaked. Therefore, tube subject to soot blower must be checked carefully. Appropriate measures must be taken depending on degree of defect when detecting defect at evaporating tubes.

e. Confirmation of status of ash cut
   Ash-cut of evaporation tubes must be confirmed. Appropriate measures must be taken depending on degree of defect when detecting defect at evaporation tubes.

f. Confirmation of status of damage of fin, supporter, hanger etc.
   Damage (burnout, crack, deformation) of fin, supporter, hanger etc must be confirmed. Appropriate measures must be taken depending on degree of defect when detecting defect at evaporation tubes.

2) Visual inspection of tubes around burner.
   a. Visual inspection of tubes around burner by assembling scaffolding to burner level, using gondola and equivalent means every other periodic inspection must be conducted. It must be paid close attention to safety of worker by utilizing personnel safety nets, harness etc. for high-place work.

3) Visual inspection of evaporation tube to top of furnace
   a. Inspection interval must be regulated and visual inspection of evaporation tube to top of furnace must be conducted by assembling scaffolding. It must be regulated inspection interval depending on fuel, operation status of power plant etc. It must be paid close attention to safety of worker by utilizing personnel safety nets, harness etc. for high-place work.

4) Measurement of radial thickness of tube
   a. Measurement of typical radial thickness of evaporation tube affected by steam cut in case of no countermeasure for tube erosion must be conducted. Appropriate measures must be taken depending on degree of defect when radial thickness is less than acceptable value.

5) Internal inspection of water tube
   a. It is recommended that inspection interval is regulated depending on operation status of power plant etc. and water tube inside is inspected to the extent possible.

b. Confirmation of status of deposition

Ingredient and volume etc. of deposition inside evaporation tube must be confirmed. It is recommended that they are analyzed chemically by specialized agency if necessary. Analysis results must be confirmed and taken appropriate measures must be taken if necessary.

6) Internal inspection of sample tube

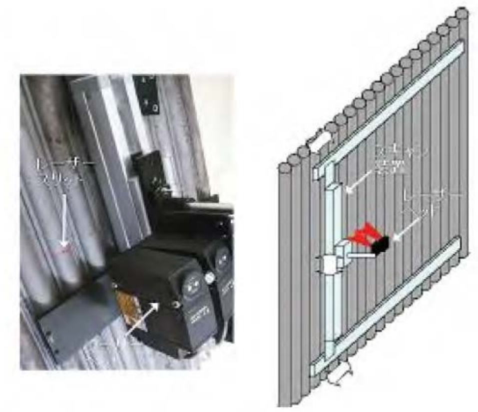
a. It is recommended that inspection interval is regulated depending on operation status of power plant etc. , sample tube is picked after boiler stop and tube inside is inspected. Status of scale deposition and conducted metallographic structure inspection must be checked. Additional inspection must be conducted according to results of above inspection.

7) Detailed inspection

a. It is recommended that PT inspection is conducted to typical weld portion of connection part between tube and tube after 80,000 hours of accumulated operating hours if necessary.

http://testex-ndt.com/technical-papers/asme-power-2008-boiler-paper/

Photo 160-5 LFET inspection



Reference: P-115 of Vol.63 May/2012: Journal TEMPES

Figure 160-1 Laser measuring of tube thickness

(2) Super-heater, Re-heater and Economizer tube

1) External inspection of super-heater, re-heater and economizer tube.

External inspection of super-heater, re-heater and economizer tube must be conducted.

a. Confirmation of status of erosion, corrosion and crack (weld part, tube expansion and other part.)

Erosion, corrosion and crack of super-heater, re-heater and economizer tubes must be confirmed. Erosion, corrosion and crack portion must be ground down and welded when it is minor damage. It must be replaced with new tube or panel when it is major damage.

b. Confirmation of status of tube incurve and tube swelling and disturbance of tube row

   Tube incurve and tube swelling and disturbance of tube row must be confirmed. Appropriate measures must be taken depending on degree of defect when detecting defect at these tubes.

c. Confirmation of status of deposition

   It must be confirmed that ingredient and volume etc. of deposition at super-heater, re-heater and economizer tube. It is recommended that they are analyzed chemically by specialized agency if necessary. Analysis results must be confirmed and appropriate measures must be taken, if necessary.

d. Confirmation of status of damage due to soot blower

   Tube damage due to steam flow of soot blower must be confirmed. Steam flow of soot blower is extremely big and there is a possibility that tube is worn away and leaked. Therefore, tube subject to soot blower must be checked carefully. Appropriate measures must be taken depending on degree of defect when detecting defect at these tubes.

e. Confirmation of status of damage of fin, supporter, hanger etc.

   Damage (burnout, crack, deformation) of fin, supporter, hanger etc. must be confirmed. Appropriate measures must be taken depending on degree of defect when detecting defect at super-heater, re-heater and economizer tubes.

2) Inspection of tube by touch.

   a. Inspection of super-heater, re-heater and economizer tube must be conducted by touch in case of no countermeasure for tube erosion.

3) Measurement of radial thickness of tube.

   a. Measurement of typical radial thickness of super-heater, re-heater and economizer tube must be conducted in case of no countermeasure for tube erosion. Appropriate measures must be taken depending on degree of defect when radial thickness is less than acceptable value.

4) Internal inspection of sample tube

   a. It is recommended that inspection interval is regulated depending on operation status of power plant etc. , sample tube is picked after boiler stop and tube inside is inspected. Status of scale deposition must be checked and metallographic structure inspection must be conducted. It must be conducted additional inspection according to results of above inspection.

5) Detailed inspection

   a. It is recommended that PT inspection is conducted to typical weld portion of connection part between tube and tube after 80,000 hours of accumulated operating hours if necessary.

6) Measurement of radial thickness of tube.

a. It is recommended that measurement of typical radial thickness of super-heater, re-heater tube. It must be taken appropriate measures depending on degree of defect when radial thickness is less than acceptable value.

5. Safety valve

(1) Disassembly and inspection

It must be conducted disassembly and inspection for safety valve of drum, super-heater and re-heater and electric relief valve every other periodic inspection.

1) Confirmation of damage of valve body and valve sheet

It must be confirmed damage of valve body and valve sheet. It must be taken appropriate measures depending on degree of defect when detecting defect at safety valve.

2) Confirmation of crack of weld part

It must be confirmed crack of weld part. It must be conducted nondestructive test if necessary. It must be taken appropriate measures depending on degree of defect when detecting defect at safety valve.

3) Confirmation of foreign objects

It must be confirmed foreign objects in safety valve at disassembling and assembling. It must be assembled safety valve carefully not to mix foreign objects in safety valve.

4) Confirmation of curvature of valve stem and abrasion of stem edge

It must be confirmed curvature of valve stem and abrasion of stem edge at disassembling and assembling. It must be assembled safety valve carefully not to mix foreign objects in safety valve.

Reference: P-5 of “Maintenance of safety valve”No.54 of Technical report of Fukui seisakusho

Photo 160-6 Eccentricity of outlet piping

Reference: P-5 of “Maintenance of safety valve”No.54 of Technical report of Fukui seisakusho

Photo 160-7 Dust bighting on the seat surface

Reference: P-5 of "Maintenance of safety valve"No.54 of Technical report of Fukui seisakusho

Photo 160-8 Destruction of spring

Reference: P-5 of "Maintenance of safety valve"No.54 of Technical report of Fukui seisakusho

Photo 160-9 Steam cut of disc

http://www2.ocn.ne.jp/~kaneuchi/seibi.html

Photo 160-10 Overhaul and inspection of safety valve

http://blogs.yahoo.co.jp/boilerservice_co_ltd/26942689.html

Photo 160-11 Blowing test of safety valve

6. Boiler main stop valve, Feed water stop valve

(1) It must be disassembled and conducted inspection of boiler main stop valve and feed water stop valve in case that erosion occurs at valve body and seat of them.

1) Confirmation of damage of valve body and valve seat

It must be confirmed damage of valve body and valve seat and status of contact face. It must be taken appropriate measures depending on degree of defect when detecting defect at these valves.

2) Confirmation of crack and erosion of valve head

It must be confirmed crack and erosion of valve head. It must be conducted nondestructive test at inspecting crack if necessary. It must be ground down and welded crack and erosion portion when it is minor damage. It must be removed to manufacture factory and maintained it when it is major damage.

3) Confirmation of damage of weld part

It must be confirmed damage of weld part. It must be conducted nondestructive test at inspecting damage if necessary. It must be taken appropriate measures depending on degree of defect when detecting defect at these valves.

4) Confirmation of damage of seal ring and gland packing

It must be confirmed damage of seal ring and gland packing. It must be changed with new seal ring and gland packing when they are damaged.

5) Confirmation of status of deposition

It must be confirmed that ingredient and volume etc. of deposition at these valves. It is recommended that they are analyzed chemically by specialized agency if necessary. It must be confirmed analysis results and taken appropriate measures if necessary.

6) Operation of open-close test

It must be conducted open-close test of valves. It must be checked valve and conducted appropriate measures when valve movement is not normal.

Reference: Brochure of Okano Valve

Photo 160-12 Main steam isolation valve

http://www.kigs.jp/db/isan.php?kno=7&ino=26&PHPSESSID=

Photo 160-13 Main steam isolation valve

7. Boiler circulation pump

(1) Disassembly and inspection

It must be conducted external inspection. It must be regulated inspection interval and conducted disassembly and open inspection if necessary.

1) Confirmation of status of bearing and shaft

a. It must be confirmed sticking, damage of contact face, status of lubricant oil, bend of shaft and foreign objects etc. It must be taken appropriate measures depending on degree of defect when detecting defect at bearings.

2) Confirmation of status of casing

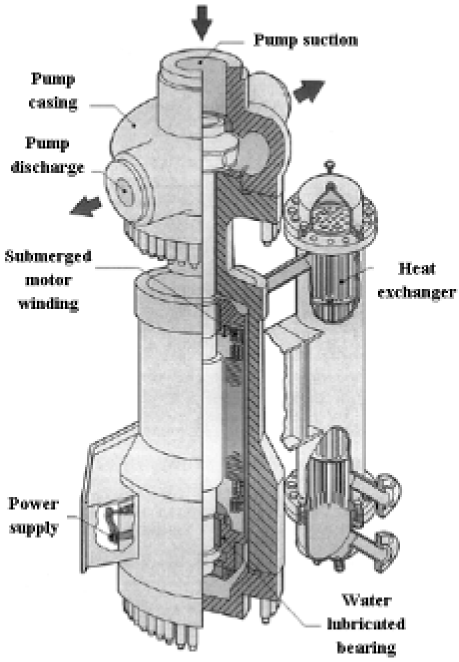
a. It must be confirmed erosion and corrosion of inside face, damage of bolts and status of gland packing etc. It must be ground down and welded erosion and corrosion portion when it is minor damage. It must be removed to manufacture factory and maintained it when it is major damage. It may be maintained them and used continuously when defects in bolts and gland packing are minor. It must be exchanged to new parts when defects in bolts and gland packing are major.

3) Confirmation of status of gear coupling

a. It must be confirmed status of contact face, crack, centering and movement of shaft etc. It must be taken appropriate measures depending on degree of defect when detecting defect at gear coupling.

http://www.fieldsystems.com/turbine-overhauls/

Photo 160-14 Finished seat of BCP



Reference P-7 of Journal No.56 Aug. /2005 of TEMPES

Figure 160-2 Submerge wet motor type BCP

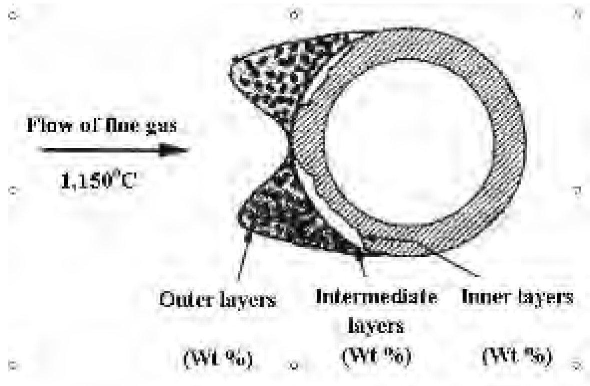
Article160-a1 Material damages and diagnosis technique of SC and USC boiler

In power industry, a lot of SC boilers and USC boilers are adopted and use condition of boiler tube is severe increasingly because steam condition of boiler is high temperature and pressure compared to conventional condition. Thus, material damages and diagnosis technique of boiler tube is explained as follows.

1. High temperature corrosion (Coal ash corrosion)

When low melting sulfur compound (alkali iron sulfate) is produced high temperature super-heater and re-heater, boiler tube is corroded. As the result of status of corrosion and fouling on super-heater tube made by austenitic stainless steel, abundance of Sodium (Na), Potassium (K) and Sulfur (S) is higher than other ingredient and it presumes that low melting alkali iron sulfate ((NaK)3Fe(SO4)3) is produced. Corrosion by alkali iron sulfate is affected by concentration of SO2 in exhaust gas. Thus, when using high sulfur coal, it must be paid attention to high temperature corrosion. Effective countermeasure to prevent corrosion is to change material such as adoption of 25Cr steel.

Reference: P-17 of Vol.62 Jul. /2011 of Journal TEMPES

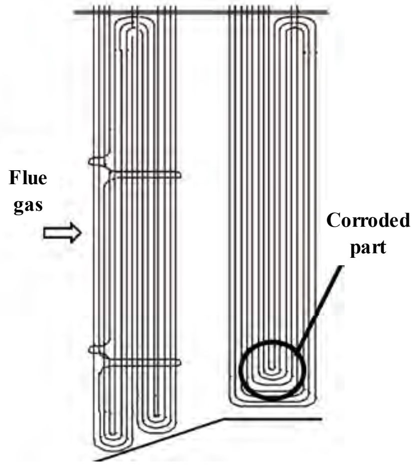


Reference: P-17 of Vol.62 Jul. /2011 of Journal TEMPES

Figure 160-a1-1 Coal ash corrosion

2. High temperature corrosion (Vanadium attack)

There is a possibility that low melting Na2O-V2O5 chemical compound is produced and corroded with accelerating speed by Vanadium and Sodium etc. in heavy oil at high temperature super-heater and re-heater of oil-fired boiler. Corrosion is produced at bending parts of piping spacer installation parts which products of combustion are attached. Mechanism of corrosion is accelerated oxidization based on oxygen supply by oxidation-reduction of Na2O-V2O5 chemical compound and destruction of oxide film by melting. In general, accelerated oxidization by Na2O-V2O5 chemical compound calls “Vanadium attack” because chemical compound is different by attached parts and fuel aspect. When there is a possibility that Vanadium attack is produced, chemical compound including mainly Calcium (Ca) and Magnesium (Mg) is attached fuel to prevent to product low melting Vanadium chemical compound.



Reference: P-17 of Vol.62 Jul. /2011 of Journal TEMPES

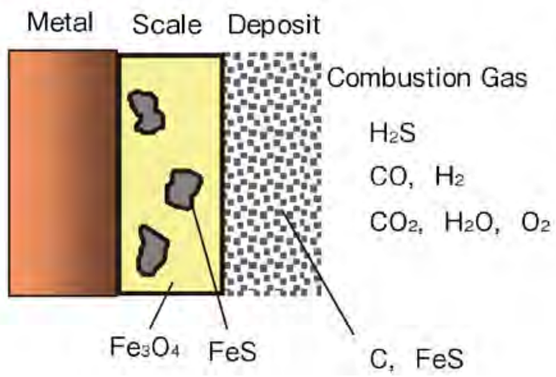
Figure 160-a1-2 Corroded part of SH

Reference: P-17 of Vol.62 Jul. /2011 of Journal TEMPES

Photo 160-a1-1 Exterior of generated corrosion due to Vanadium attack

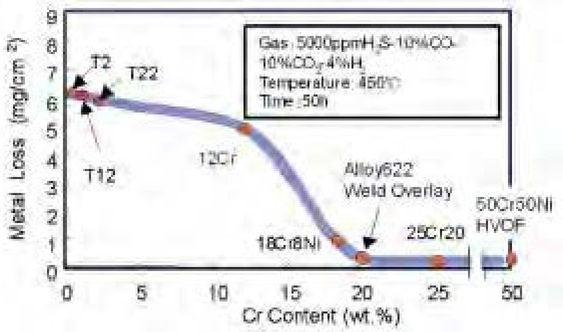
3. Sulfidation corrosion

Boiler is burned in lack of combustion air by 2 stage combustion and low NOx burner to prevent to produce NOx at combustion. In this case, there is a possibility that gas corrosion is produced by hydrogen sulfide (H2S) at water wall tube near burner. Material including more than 18% of Chromium (Cr) can prevent sulfidation corrosion. Thus, surfacing treatment by thermal spray of 50Cr50Ni and cladding by welding of Alloy 622 is conducted as countermeasure of corrosion.



Reference: P-18 of Vol.62 Jul. /2011 of Journal TEMPES

Figure 160-a1-3 Sulfide corrosion on water wall



Reference: P-18 of Vol.62 Jul. /2011 of Journal TEMPES

Figure 160-a1-4 Relation sulfide corrosion/ amount of Cr

4. Steam oxidation

Steam oxidation scale is produced inside of super-heater and re-heater tube, header and piping of boiler. Trouble due to steam oxidation is blockage of tube by accumulating peeled scale and erosion of steam turbine parts by peeled scale. Steam oxidation of ferritic steel and austenitic stainless steel is explained as follows.

(1) Ferritic steel

Scale of low alloy steel or high Chromium (Cr) ferritic steel is composed of isopachous internal and external layer. External layer scale is magnetite (Fe3O4) and internal layer scale is spinel type oxide including Fe and Cr. Growth behavior is indicated by following parabola law.

$d^2 = Kp \times t$

$\mathrm{Log}\, Kp = a / T \times b$

d : thickness of scale (μm), Kp : parabola speed (μm^2 /h), t : time (h)

T : absolute temperature (K), a & b : constant number

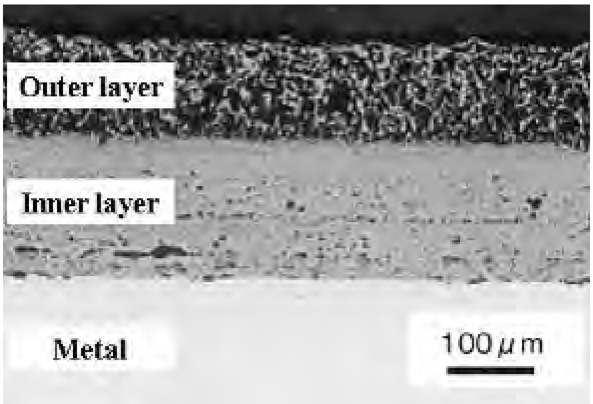
Growth speed of scale depends on Chromium volume in material, and it is large when temperature of material is high. When measuring thickness of scale at periodic inspection, metal temperature in use can be presumed by using above formula and remaining life assessment by creep damage analysis can be conducted.

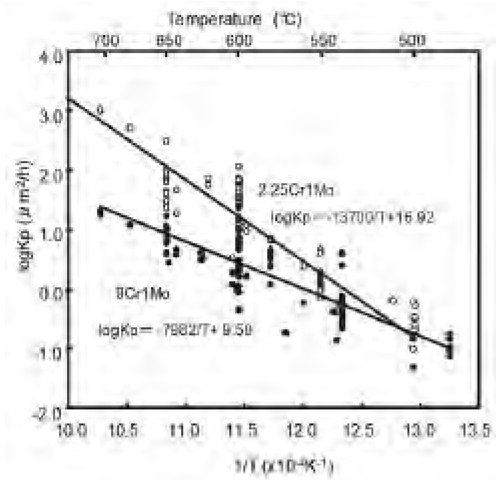
(2) Austenitic stainless steel

In austenitic stainless steel, when thickness of internal layer scale is 50μm, external layer scale is started peeling. Thus, growth behavior of scale depends on thickness of internal layer scale. Thickness of internal layer scale is decreased in connection with increase of Chromium volume. However, growth of scale is prevented by conducting cold working inside of low Chromium tube. Spreading of Chromium by cold working is facilitated at metal parts near internal surface of tube and protective film of Chromium oxide is produced on surface from usage early stage. Therefore, cold working is most efficient countermeasure of steam oxidation scale in austenitic stainless steel.

5. Scale overheat

Overheat damage due to inhibition of heat transmission by thick scale become actually recently. When scale is produced thick, metal temperature due to inhibition of heat transmission by scale is increased, corrosion is accelerated by steam oxidation of tube inside and high temperature oxidization of tube outside. Therefore, it must be assessed creep damage in consideration of theses metal temperature rise and corrosion. There is a possibility that creep damage is accelerated due to inhibition of heat transmission by lift and lamination layer of inside steam oxidation scale in actual boiler.





Reference: P-19 of Vol.62 Jul. /2011 of Journal TEMPES

Photo 160-a1-2 Cross section of scale

Reference: P-19 of Vol.62 Jul. /2011 of Journal TEMPES

Figure 160-a1-5 Arrhenius plot of constant rate of radiation between Cr-Mo steel and 9Cr steel

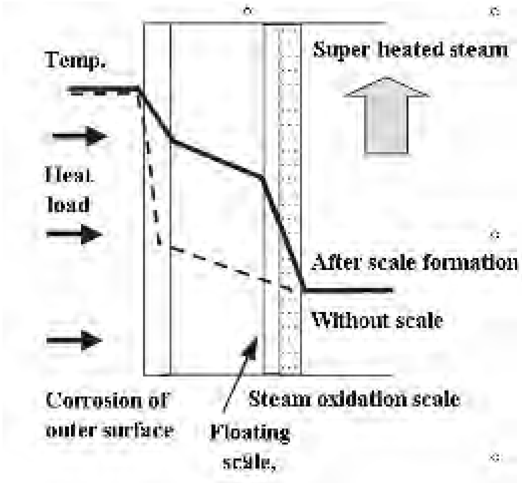
6. CWT scale

SC boiler and USC boiler is once-through boiler mainly and water treatment of them changes AVT to CWT. Because CWT scale is composed of thin hematite (αFe_2O_3) scale less than 2μm and thin oxidization scale ($(Fe, Cr)\ _3O_4$) less than 20μm, surface of scale is smooth and differential pressure rise is prevented. However, when particulate hematite (αFe_2O_3) scale is attached, overheat damage and circumferential crack (elephant skin) is produced. Particulate scale is micro-particle less than 3μm and is attached on oxidization scale. The results of creep damage analysis in case that particulate scale is attached are shown as follows;

Table 160-a1-1 The results of creep damage analysis

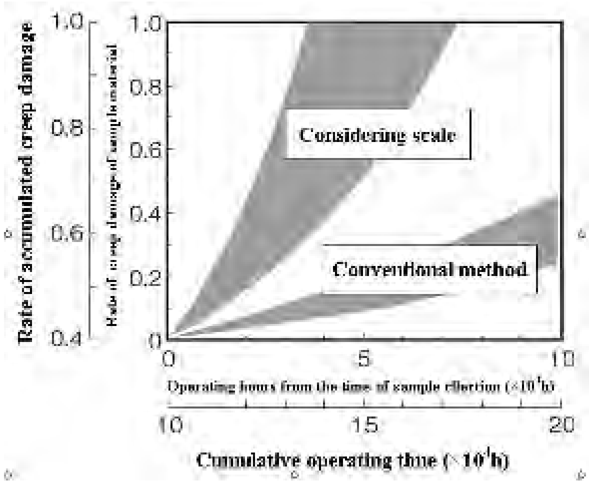
Metal temperature (^oC)	Creep life (hours)
460 (base)	Over 100 X 10^4
540 (+80)	3 – 6 X 10^4

As shown in above table, when metal temperature is increased by particulate scale, creep life is reduced severely. This trouble is confirmed at power plant which average concentration of Fe in feed water at inlet of economizer is more than 2 ppb. Therefore, it is recommended that concentration of Fe in feed water is reduced as countermeasure of this trouble.



Reference: P-20 of Vol.62 Jul. /2011 of Journal TEMPES

Figure 160-a1-6 Schematic sectional view of scale formation on heat transfer tube



Reference: P-21 of Vol.62 Jul. /2011 of Journal TEMPES

Figure 160-a1-7 Evaluation of creep damage

7. Inspection procedure

High strength high Cr steel is adopted to material of main steam piping and high temperature reheat steam piping in connection with installing SC and USC boiler. However, wall thickness of high strength high Cr steel is incrassate in connection with increasing steam temperature and pressure, steam leak at fine grain area of welding heat-affected part due to creep damage such as crack is concerned and proper damage diagnosis technique is required. Inspection procedure of damage parts is important with a view to this situation and inspection device of piping inside and inapproachable area is developed recently. Inner ultrasonic testing (UT) method and ultrasonic noise method are explained as follows;

(1) Inner ultrasonic testing method

Wall thickness of super-heater, re-heater and economizer tube is inspected by ultrasonic method. However, inspection of a lot of boiler tube is difficult because they are installed at high location and supplemental work such as cleaning of scale requires much time. Inner ultrasonic testing method is in practical use to enhance working efficiency and reliability at inspecting this boiler tube. Current this method can go through bending part of 35mm in radius smoothly and measure thickness of tube, inspection operator can confirm measuring result rapidly inputting measuring data in personal computer. Outline of inner ultrasonic testing method is shown in Figure 160-a1-8.

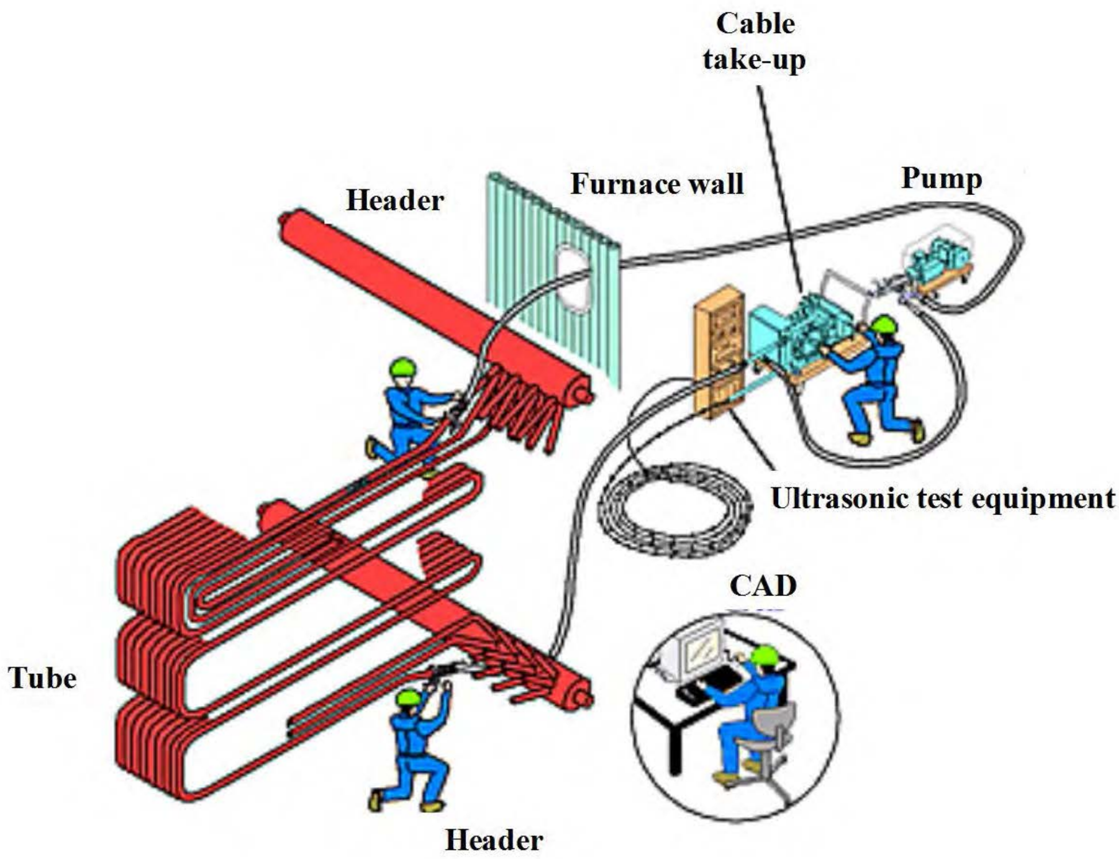


Figure 160-a1-8 Outline of inner ultrasonic testing method (MHI)

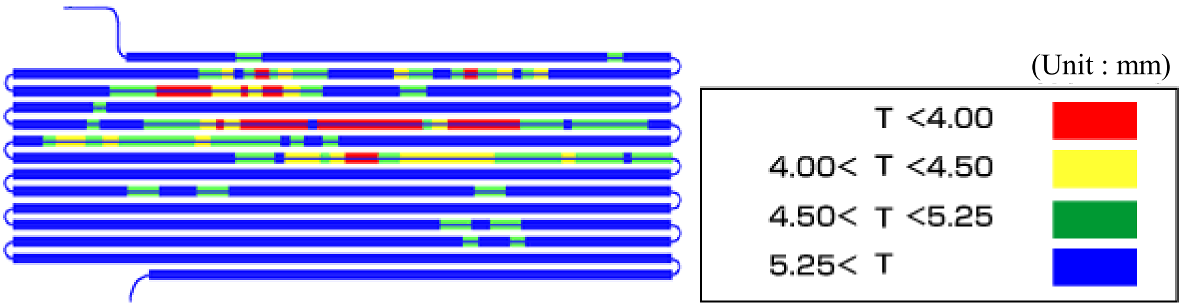


Figure 160-a1-9 Sample of measuring result of boiler tube

(2) Ultrasonic noise method

In creep damage, voids are produced at grain boundary, they are increased, grew, coupled and became micro-cracks, micro-cracks are coupled, grew and fractured. Inner ultrasonic testing method is useful for detecting crack and dent, but it is difficult to detect creep damage before micro-crack such as creep void. Therefore, ultrasonic noise method is developed to detect these minute creep damage. This method analyzes back scattered noise reflected by minute damage such as void when ultrasonic is passed through material inside. Measured noise value is increased based on accumulation of creep damage shown in Figure 160-a1-10, this method is utilized it’s characteristic.

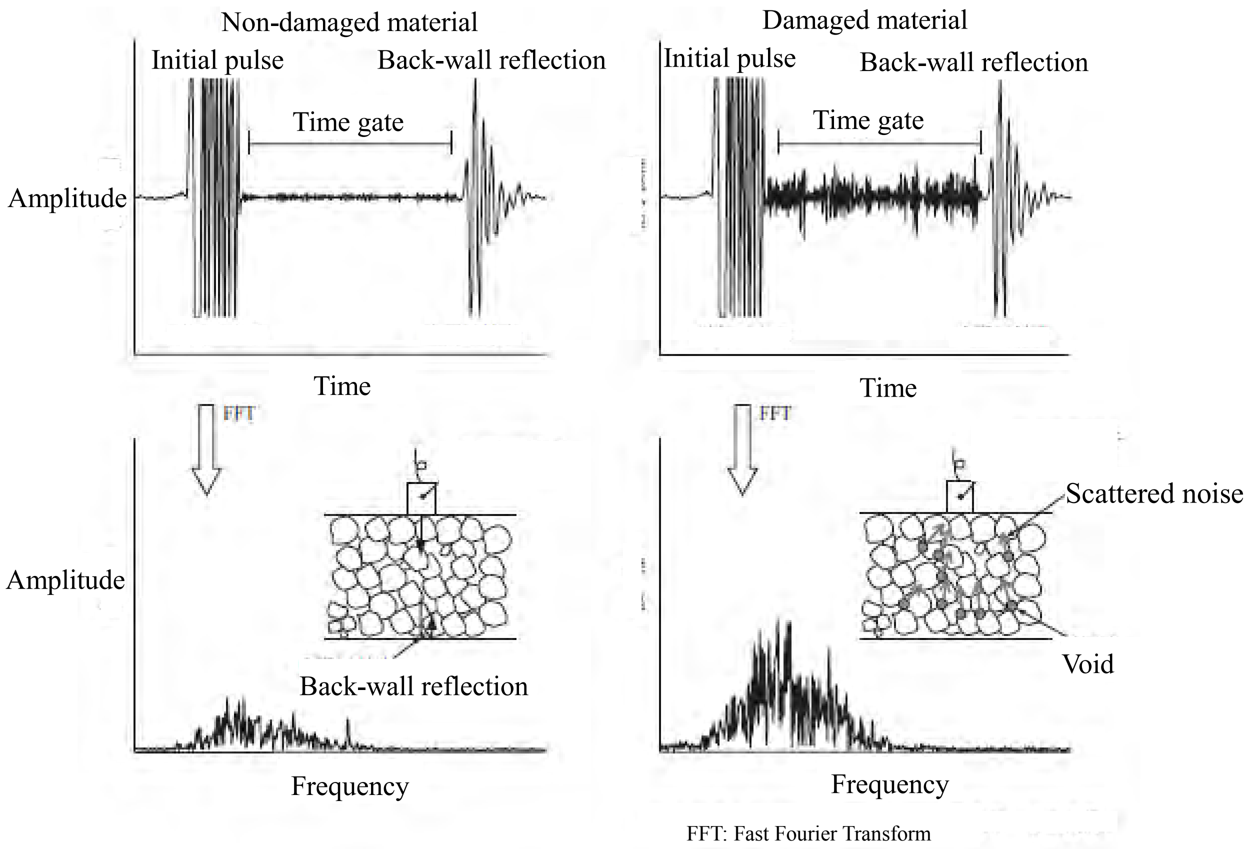


Figure 160-a1-10 Fundamental principle of ultrasonic noise method

http://powerccl.co.uk/boiler-corrosion.html

Photo 160-a1-3 Acid chloride corrosion

http://www.ameshistoricalsociety.org/stories/moore3.htm

Photo 160-a1-4 Multiple tube rupture

http://www.gewater.com/handbook/boiler_water_systems/fig16-1.jsp

Photo 160-a1-5 Over-heating due to deposit

http://www.matcoinc.com/failure-analysis/electric-power

Photo 160-a1-6 Crack on partition wall

Article160-a2 Fluidized bed boiler

1. General of fluidized bed boiler

In fluidized bed boiler, fluidization gas (air etc.) is supplied to combustion chamber filling bed materials (silica sand (inert particle), limestone and ash of combustion) through under dispersion plate and fluidized bed is produced. Combustion reaction at low temperature (800~900^{o}C) and desulfurization reaction by limestone are conducted in this fluidized bed.

Fluidized condition of particle in combustion chamber depends on diameter of particle and velocity of fluidization gas and classifies “Bubbling fluidized bed”, ”Circulating fluidized bed” and ”Air transport”.

Type of fluidized bed boiler is classified by fluidized condition of particle in combustion chamber and operation pressure as follows;

- Bubbling fluidized bed boiler
- Circulating fluidized bed boiler
- Pressurized fluidized bed boiler

2. Inspection of fluidized bed boiler

Basically, structure of fluidized bed boiler is same as it of conventional boiler. Major trouble items of boiler are as follows;

- Abrasion
- Corrosion
- Fatigue
- Creep

In fluidized bed boiler, it must be confirmed particularly following trouble and parts because boiler tube is contacted with bed materials.

(1) Trouble

1) Abrasion

2) Corrosion

(2) Inspection parts

1) Furnace (Evaporator)

a. Header

b. Tube

2) Super-heater

a. Header

b. Tube

3) Re-heater

a. Header

b. Tube

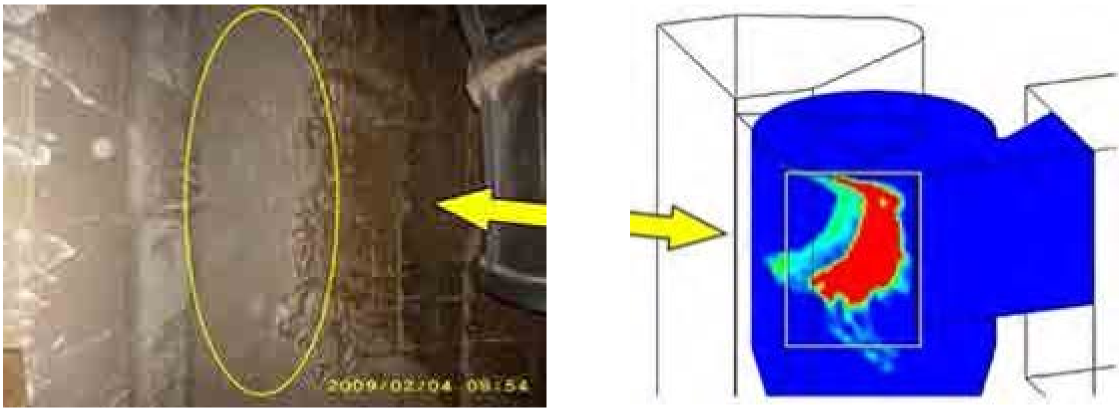
(3) Inspection procedure

1) Visual check

2) Detailed inspection for abrasion and corrosion of tube

3) Measurement of radial thickness

4) Inspection of welded parts of header and tube And others



http://www.bios-bioenergy.at/en/cfd-simulations.html

Photo 160-a2-1 Erosion of CFB wall

http://www.conformaclad.com/PG010_English.html

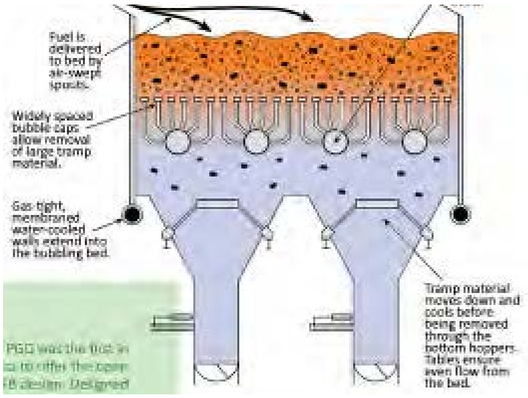
Photo 160-a2-2 Refractory failure

http://www.conformaclad.com/PG010_English.html

Photo 160-a2-3 Erosion of water wall

http://www.conformaclad.com/PG010_English.html

Photo 160-a2-4 Coating failure



http://www.babcock.com/library/pdf/e1013161.pdf

Photo 160-a2-5 Ash removal system

Article 161. Boiler auxiliary equipment

1. Feed water pump

(1) Feed water pump

1) External inspection

It must be conducted external inspection for damage and crack of pump body etc. It must be taken appropriate measures depending on degree of defect when detecting defect at pump. It must be open inspection depending on degree of defect if necessary.

2) Operation test

It must be conducted operation test according to following procedure and confirmed following items to detect defects of pump. It must be taken appropriate measures depending on degree of defect when detecting defect at pump.

a. Test procedure

(a) It must be confirmed following items as preparation of start up.

a) Auxiliary device and related valves are powered.

b) Oil transfer pump for BFPT is automatic position.

c) Oil tank gas extraction device for BFPT is operated.

d) Oil cooler for BFPT is ready for start up.

(b) BFPT is filled by feed water.

a) Deaerator level

b) BFP seal water pump is automatic position.

(c) Turning device is started up.

a) Oil pressure (high and low pressure control oil, bearing oil)

b) Outlet oil temperature of oil cooler

(d) BFPT is vacuumized.

(e) BFPT is reset position.

(f) BFPT is started up.

b. Point to be checked

(a) Pump feed rate

(b) Pump outlet pressure

(c) Bearing temperature

(d) Abnormal vibration

(e) Abnormal noise etc.

3) Open inspection

It is recommended that inspection interval is regulated depending on operation status of power plant etc. and open inspection for following items is conducted.

a. Confirmation of corrosion, erosion and crack

It must be confirmed corrosion, erosion and crack of each pump parts after disassembling. It must be ground down and welded corrosion, erosion and crack portion when it is minor damage. It must be removed to manufacture factory and maintained it when it is major damage.

b. Confirmation of foreign objects and sticking damage of rotating parts

It must be confirmed foreign objects and sticking damage of rotating parts after disassembling. It must be taken out foreign objects and taken appropriate measures depending on degree of defect when detecting defect at rotating parts.

c. Confirmation of status of deposition

It must be confirmed that ingredient and volume etc. of deposition at this pump at disassembling. It is recommended that they are analyzed chemically by specialized agency if necessary. It must be confirmed analysis results and taken appropriate measures if necessary.

d. Confirmation of gap of each pump part

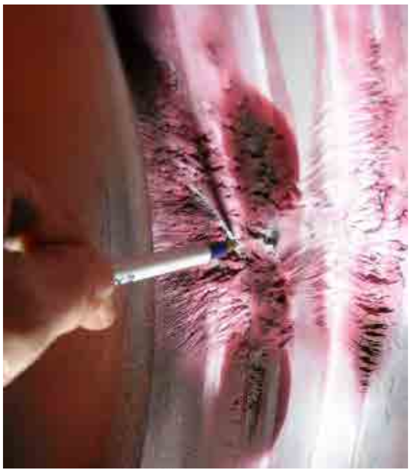
It must be confirmed gap of each pump parts according to regulated gap. It must be amended appropriate gap when detecting abnormal gap at each pump parts.

e. Confirmation of curvature of pump shaft

It must be confirmed curvature of pump shaft after disassembling. It must be taken appropriate measures depending on degree of defect when detecting defect at each pump parts.

http://www.cfsusa.net/2010/01/boiler-feed-pump-repair/

Photo 161-1 Inspection of BFP internal



http://www.cfsusa.net/2010/01/boiler-feed-pump-repair/

Photo 161-2 Damage of BFP casing

http://www.cfsusa.net/2010/01/boiler-feed-pump-repair/

Photo 161-3 Repair welding of flange seat

http://www.cfsusa.net/2010/01/boiler-feed-pump-repair/

Photo 161-4 Repair of seat surface

(2) Steam turbine of driving

1) Operation test

It must be conducted operation test and confirmed following items to detect defects of steam turbine. It must be taken appropriate measures depending on degree of defect when detecting defect at pump. It must be referred to above 2) Operation test of (1) Feed water pump

a. Bearing temperature

b. Revolution

c. Abnormal vibration

d. Abnormal noise etc.

2) Open inspection

It is recommended that inspection interval is regulated depending on operation status of power plant etc. and open inspection for following items is conducted.

a. Confirmation of corrosion, erosion, crack, abrasion, deformation, dent and foreign object

It must be confirmed of corrosion, erosion, crack, abrasion, deformation, dent and foreign object of each steam turbine parts after disassembling. It must be taken appropriate measures depending on degree of defect when detecting defect at each steam turbine parts.

b. Confirmation of damage of blade and blade root etc.

It must be confirmed damage of blade and blade root etc. after disassembling. It must be taken out taken appropriate measures depending on degree of defect when detecting defect at blade and blade root etc.

c. Confirmation of damage of steam strainer and steam control valve etc.

It must be confirmed damage (abrasion and deformation etc.) of steam strainer and steam control valve etc. after disassembling. It must be taken appropriate measures depending on degree of defect when detecting defect at steam strainer and steam control valve etc.

d. Confirmation of evidence of steam and oil leakage

It must be confirmed evidence of steam and oil leakage after disassembling and cause of leakage when detecting it. It must be taken appropriate measures depending on degree of defect when detecting defect at steam turbine of feed water pump.

e. Confirmation of status of deposition

It must be confirmed that ingredient and volume etc. of deposition at steam turbine of feed water pump at disassembling. It is recommended that they are analyzed chemically by specialized agency if necessary. It must be confirmed analysis results and taken appropriate measures if necessary.

f. Confirmation of contact face of journal and thrust bearing

It must be confirmed contact face (partial contact) of journal and thrust bearing after disassembling. It must be taken appropriate measures depending on degree of defect when detecting defect at journal and thrust bearing.


http://www.mhicompressor.com/en/topics/2010/second_half/20110201.html

Photo 161-5 BFP (MHI)

http://www.fieldsystems.com/blog-1/bid/77582/Steam-Turbine-Repair-Steamship-Feedwater-Governor-Valve-Overhaul

Photo 161-6 Pitting of turbine blade

http://www.fieldsystems.com/blog-1/bid/77582/Steam-Turbine-Repair-Steamship-Feedwater-Governor-Valve-Overhaul

Photo 161-7 Pitting of turbine blade

http://www.fieldsystems.com/blog-1/bid/77582/Steam-Turbine-Repair-Steamship-Feedwater-Governor-Valve-Overhaul

Photo 161-8 Turbine shaft

http://www.fieldsystems.com/blog-1/bid/77582/Steam-Turbine-Repair-Steamship-Feedwater-Governor-Valve-Overhaul

Photo 161-9 Speed trip governor

2. Fun (Forced draft fan, Induced draft fan, Gas recirculation fan and Gas mixing fan)

(1) Fan

1) External inspection

It must be conducted external inspection for damage of casing etc. It must be taken appropriate measures depending on degree of defect when detecting defect at fan. It must be open inspection depending on degree of defect if necessary.

2) Operation test

It must be conducted operation test according to following procedure and confirmed following items to detect defects of fan. It must be taken appropriate measures depending on degree of defect when detecting defect at fan.

a. Test procedure

(a) It must be confirmed related dampers and gates are opened stipulated opening.

(b) It must be confirmed related equipments are operated.

a) Air heater

b) Electric precipitator

c) Lubricant and control oil pumps etc.

(c) It must be operated fans in a moment and confirmed defect of fans.

(d) It must be operated fans at no load and confirmed defect of fans.

(e) It must be operated fans at load and confirmed defect of fans.

b. Point to be checked

(a) Wind pressure

(b) Bearing temperature

(c) Abnormal vibration

(d) Abnormal noise etc.

3) Open inspection

It is recommended that inspection interval is regulated depending on operation status of power plant etc. and open inspection for following items is conducted.

a. Confirmation of damage, corrosion and abrasion of blade and casing

It must be confirmed damage, corrosion and abrasion of blade and casing. It must be taken appropriate measures depending on degree of defect when detecting defect at blade and casing.

b. Confirmation of corrosion and abrasion of vane and damper and defect of drive mechanism

It must be confirmed corrosion and abrasion of vane and damper and defect of drive mechanism for damper system. It must be taken appropriate measures depending on degree of defect when detecting defect at damper system.

c. Confirmation of damage, contact face (partial contact), abrasion and bending of bearing

   It must be confirmed damage, contact face (partial contact), abrasion and bending of bearing. It must be taken appropriate measures depending on degree of defect when detecting defect at bearing.

d. Confirmation of defect of oil pumps, status of lubricant oil and plugging of strainer for lubricant oil system

   It must be confirmed defect of oil pumps, status of lubricant oil and plugging of strainer for lubricant oil system. It must be taken appropriate measures depending on degree of defect when detecting defect at lubricant oil system.

e. Confirmation of status of deposition

   It must be confirmed that ingredient and volume etc. of deposition at fan. It is recommended that they are analyzed chemically by specialized agency if necessary. It must be confirmed analysis results and taken appropriate measures if necessary.

http://www.thielschfes.com/media/1152/Fan.pdf

Photo 161-10 Typical cracking of fan

http://www.thielschfes.com/media/1152/Fan.pdf

Photo 161-11 Typical cracking of fan

Table 161-1 Content of inspection for fan at the periodic inspection

Oblect	Inspection items	Inspection method	Criteria	Measure at the non-conformity
Impeller	Status of dust adhesion	VT		Remove dust completely
	Imbalance adjustment	Portable balancer	No crack at large bearing vibration	Field balancing
	Material and crack on weld part	VT, PT, MT		Repair, reinforcement in minor case or replacement
	Existence of deformation or other damage	VT		Reinforcement or replacement
	Wear situation	VT, measurement of thickness		Repair welding, replacement of liner
	Corrosion situation	VT, PT, measurement of thickness	No crack, abnormal corrosion	Replacement of material, repair in case of minor
Main shaft	Damage on bearing	VT		Hand finish correction in minor case
	Wear of shaft seal	VT		Hand finish correction in minor case
	Bends	Dial gauge	less than 0.05mm of shaft waggle	Correction, replacement
	Crack	VT, PT, MT	No crack	Replacement
	Wear and corrosion	VT		Replacement in cse of large wear, corrosion
	Tightness of axle nut			Correction
Bearing	Touching of metal and peeling	VT, PT		Correction, replacement
	Measurement of bearing clearance	Lead wire, feeler gauge	Gap up and down, thrust	Correction, replacement
	Wear and deformation of oil ring	VT		Repair welding, replacement of liner
	Clearance between bearing gland and shaft	Feeler gauge	Uniform on the circumference	Correction of alignment
Casing	Clearance between impeller and casing	Dimentional inspection	No contact	Correction of installation, slignment
	Wear situation	VT, measurement of thickness	No abnormal wear	Repair welding, replacement of liner
	Corrosion situation	VT	No crack, abnormal corrosion	Replacement (material)
	Deformation and crack	VT, PT		Reinforcement, repair welding
	Status of dust adhesion	VT		Removal of dust
Shaft seal	Wear and deterioration of packing	VT		Replacement
	Clearance between seal and shaft	VT		Correction and replacement
Damper inlet vane	Operational status of link (hysteresis)	VT		Removal od rust, replacement of pin
	Lubrication of bearing and sliding parts	Grease-gun		Correction of contact part
	Clearance between case and vanes	VT		

3. Combustion equipment (Burner)

(1) Coal firing

1) External inspection

It must be conducted external inspection for damage of coal fired combustion from inside furnace. It must be taken appropriate measures depending on degree of defect when detecting defect at coal fired combustion.

2) Open inspection

It is recommended that inspection interval is regulated depending on operation status of power plant etc. and open inspection for following items is conducted.

a. Confirmation of damage and abrasion of inner casing, outer casing, burner nozzle and swirler

It must be confirmed damage and abrasion of inner casing, outer casing, burner nozzle and swirler of coal fired burner. It must be taken appropriate measures depending on degree of defect when detecting defect at inner casing, outer casing, burner nozzle and swirler of coal fired burner.

b. Confirmation of defect of operating portion

It must be confirmed defect of operating portion of coal fired burner. It must be taken appropriate measures depending on degree of defect when detecting defect at operating portion of coal fired burner.

c. Confirmation of damage of resister damper

It must be confirmed defect of resister damper of coal fired burner. It must be taken appropriate measures depending on degree of defect when detecting defect at resister damper of coal fired burner.

http://www.piburners.com/prodBW14.html

Photo 161-12 Burner repair (B&W)

http://www.piburners.com/prodBW14.html

Photo 161-13 Burner repair (B&W)

(2) Oil firing

1) External inspection

It must be conducted external inspection for damage of oil fired combustion from inside furnace. It must be taken appropriate measures depending on degree of defect when detecting defect at oil fired combustion.

2) Open inspection

It is recommended that inspection interval is regulated depending on operation status of power plant etc. and open inspection for following items is conducted.

a. Confirmation of damage and abrasion of burner tip, burner nozzle and diffuser

It must be confirmed damage and abrasion of burner tip, burner nozzle and diffuser of oil firing burner. It must be taken appropriate measures depending on degree of defect when detecting defect at burner tip, burner nozzle and diffuser of oil firing burner.

b. Confirmation of defect of operating portion

It must be confirmed defect of operating portion of oil firing burner. It must be taken appropriate measures depending on degree of defect when detecting defect at operating portion of oil firing burner.

c. Confirmation of damage of resister damper

It must be confirmed defect of resister damper of oil firing burner. It must be taken appropriate measures depending on degree of defect when detecting defect at resister damper of oil firing burner.

http://www.tradekorea.com/product-detail/P00030866/LOW_NOx_STEAMJET_GAS_OIL_COM__BURNER.html

http://www.schmidtassociatesinc.com/pages/power_plant.html

Photo 161-14 Gas/Oil burner

(3) Gas firing

1) External inspection

It must be conducted external inspection for damage of gas fired combustion from inside furnace. It must be taken appropriate measures depending on degree of defect when detecting defect at gas fired combustion.

2) Open inspection

It is recommended that inspection interval is regulated depending on operation status of power plant etc. and open inspection for following items is conducted.

a. Confirmation of damage and abrasion of burner nozzle

It must be confirmed damage and abrasion of burner nozzle of gas firing burner. It must be taken appropriate measures depending on degree of defect when detecting defect at burner nozzle of gas firing burner.

b. Confirmation of defect of operating portion

It must be confirmed defect of operating portion of gas firing burner. It must be taken appropriate measures depending on degree of defect when detecting defect at operating portion of gas firing burner.

c. Confirmation of damage of resister damper

It must be confirmed defect of resister damper of gas firing burner. It must be taken appropriate measures depending on degree of defect when detecting defect at resister damper of gas firing burner.

http://www.industry-animated.org/photoindex/boiler_burner.htm

Photo 161-15 Inspection of gas burner

Photo 161-16 Construction of gas burner

Table 161-2 Content of inspection for coal burner at periodic inspection

Inspection items	Inspection method	Criteria	Measure at the non-conformity
Wear-resistantliner section	VT	(1) Amount of wear must be within the acceptable ran (2) Repair or new replacement of wear-resistant part must be planned in the next periodic inspection according to the amount of wear measurement results	(1) Repair by overlay welding when overlay welding type is applying (2) New replacement in case of wear-resistant cast iron type or ceramic type
Nozzle tip (wear-resistant and heat-resistant specification)	VT	Amount of wear must be within the acceptable range No peeling, crack and deformation	New replacement , since most burner are using pressure-resistant and wear-resistant cast iron or ceramic
Coal burner body	VT	No wear, cracks and fracture	Partial repair or new replacement of defective part according to the manufacture's instruction manual
Sweiler	VT	No cracks, deformation and fixation of moving parts	
Burner thought, rectifier tube	VT	No cracks and deformation	
Ignition burner	VT	No deformation and damage	
Monitoring tube (frame detector, peephole)	VT	No deformation and damage	
Damper, etc.	VT	No deformation and fixation of moving parts	
Burner duct	VT	No abnormal deposits of coal, ash and foreign matter	To remove sediment
Opening of burner outlet (inside the furnace)	VT	No adhesion of clinker	To remove clinker

4. Pipe attached to boiler

(1) Measurement of pipe thickness

It must be conducted measurement of pipe thickness based on measurement program developed by the Owner. It is conducted to pipe portion having potential to corrode and erode in steam and water piping. It must be taken appropriate measures depending on degree of defect when detecting defect at pipe attached to boiler.

(2) Assessment of remaining life

It must be conducted remaining life based on results of pipe thickness measurement conducted during the last periodic inspection and so on, or it must be checked and reviewed the finished assessment of remaining life.

Power plant equipments are exposed to severe environment under high pressure and temperature, degradation and damage are accumulated on them and when they are not maintained, several troubles and failures are occurred. The assessment of remaining life is technology of forecasting time to be had troubles and failures based on measurement result of degradation of equipment and important technology for inspecting power plant equipment. Major assessments of remaining life have shown as below:

1) Breaking test

2) Hardness measurement method

3) Ultrasonic method

4) Electric resistance method

(3) Developing of future measurement program

It must be developed and revised measurement program of pipe thickness if necessary. It must be taken account of following items when developing and revising measurement program of pipe thickness.

1) Time of future periodic inspection

2) Period of future periodic inspection (period of boiler stopping)

3) Procedure of assessment of remaining life

4) Period of preparation of assessment of remaining life (preparation during boiler stopping)

Article 162. Steam turbine

1. Casing

(1) High and middle pressure casing

Upper part of high and middle pressure casing must be removed, and inspection of them must be conducted without removing diaphragm and labyrinth packing.

1) Confirmation of erosion and corrosion

It must be confirmed erosion and corrosion of high and middle pressure casing. It must be ground down and welded erosion and corrosion portion when it is minor damage. It must be removed to manufacture factory and maintained it when it is major damage.

2) Confirmation of deformation

It must be confirmed deformation of high and middle pressure casing. It must be considered carefully measures for this damage because this damage has an effect on steam turbine operation when it is major damage. It must be removed to manufacture factory and maintained it when it is major damage. It must be ground down and welded deformation portion when it is minor damage.

3) Confirmation of contact face between rotating parts and stationary parts

It must be confirmed contact face between rotating parts and stationary parts of high and middle pressure casing. It must be welded contact portion when it is confirmed if necessary.

4) Confirmation of crack of each parts

It must be confirmed crack of each part of high and middle pressure casing. It must be ground down and welded crack portion when it is minor damage. It must be removed to manufacture factory and maintained it when it is major damage.

5) Confirmation of status of deposition

It must be confirmed that ingredient and volume etc. of deposition at high and middle pressure casing. It is recommended that they are analyzed chemically by specialized agency if necessary. It must be confirmed analysis results and taken appropriate measures if necessary.

6) Confirmation of evidence of steam leakage

It must be confirmed evidence of steam leakage after disassembling and cause of leakage when detecting it. It must be taken appropriate measures depending on cause of leakage when detecting defect at high and middle pressure casing.

7) Confirmation of crack and abrasion etc. of bolt and nut

It must be confirmed crack and abrasion etc. of bolt and nut of high and middle casing. It must be removed it depending on degree of defect when detecting defect at bolt and nut of high and middle pressure casing.

8) Confirmation of clearance of each part

It must be confirmed clearance of each part of high and middle pressure casing. When clearance is not appropriate, it has an effect on power generation efficiency. It must be apply regulated clearance to each part when detecting improper clearance at high and middle pressure casing.

(2) Low pressure casing

Upper part of low pressure casing must be removed and inspection of them must be conducted without removing diaphragm and labyrinth packing. It must be referred to above provisions as maintenance items for low pressure casing.

(3) PT and UT inspection

It must be conducted PT and UT inspection if necessary.

1) PT inspection

It must be conducted PT inspection for weld part of steam turbine casing, corner parts of inner and outer face of high and middle pressure inner and outer casing, and stay of low pressure outer casing. It must be ground down and welded crack portion when it is minor damage. It must be removed to manufacture factory and maintained it when it is major damage.

2) UT inspection

It must be conducted PT inspection for weld part of steam turbine casing and thickness inspection of balance piping etc. It must be ground down and welded crack portion when it is minor damage. It must be removed to manufacture factory and maintained it when it is major damage.

3) Measurement of strain of horizontal coupling face

It must be conducted measurement of strain of horizontal coupling face of steam turbine casing. When there is strain at horizontal coupling face, it has an effect on power generation efficiency. It must be taken appropriate measures depending on degree of defect when detecting defect at horizontal coupling face of steam turbine casing.

(4) Detailed inspection

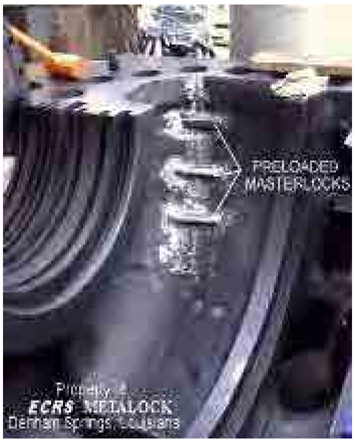
It is recommended that inspection interval is regulated and MT inspection is conducted for high stress portion of steam turbine casing.

(sample of inspection interval : every 8 years or 60,000～80,000 hrs)

Reference: Lock-N-Stitch

http://www.mdaturbines.com/repairs/turbine-repair

Reference: Lock-N-Stitch



http://www.casting-repairs.com/Turbine%20Casings.html

Photo 162-1 Repair of HP turbine casing

2. Rotor, turbine disk and rotating blade

(1) Rotor

Within the opened range of casing, it must be inspected following items by quietly rotating rotor without removing it.

1) Confirmation of rotor position, alignment and fluctuation

It must be confirmed rotor position, alignment and fluctuation of steam turbine rotor. It must be taken appropriate measures depending on degree of defect when detecting defect at steam turbine rotor.

2) Confirmation of corrosion and erosion

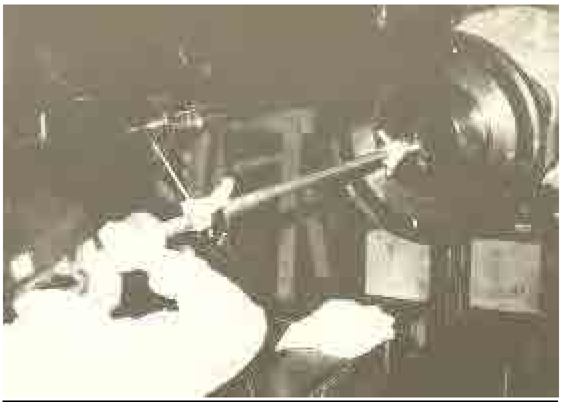
It must be confirmed erosion and corrosion of steam turbine rotor. It must be ground down erosion and corrosion portion when it is minor damage. It must be removed to manufacture factory and maintained it when it is major damage.

3) Confirmation of status of deposition

It must be confirmed that ingredient and volume etc. of deposition at steam turbine rotor. It is recommended that they are analyzed chemically by specialized agency if necessary. It must be confirmed analysis results and taken appropriate measures if necessary.

4) Confirmation of contact between rotor and stationary part

It must be confirmed contact between steam turbine rotor and stationary part. It must be taken appropriate measures depending on degree of defect when detecting defect at contact between steam turbine rotor and stationary part.

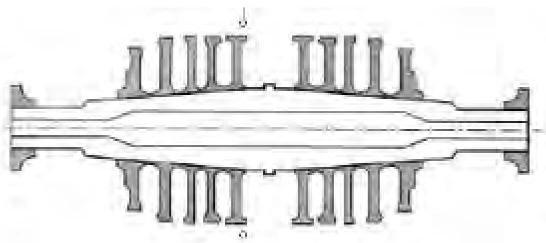


http://www.reinhartassoc.com/Assets/PDFs/TSB/STE01.pdf

Photo 162-2 Bore scope inspection of rotor

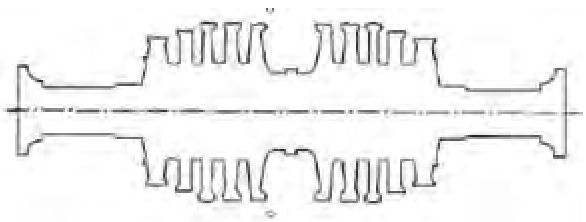
http://www.nde.com/paper55.htm

Photo 162-3 Bore inspection of rotor



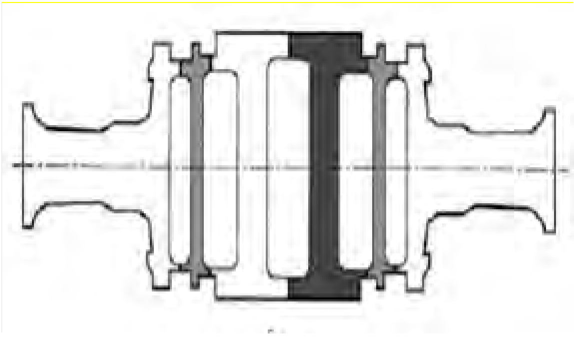
Reference: P-3 of "Steam turbine corrosion and deposits problems and solutions" by Jonas, Inc.: The 37th turbo-machinery symposium 2008

Figure 162-1 Construction of shrunk-on disc type rotor



Reference: P-3 of "Steam turbine corrosion and deposits problems and solutions" by Jonas, Inc.: The 37th turbo-machinery symposium 2008

Figure 162-2 Construction solid type rotor



Reference: P-3 of "Steam turbine corrosion and deposits problems and solutions" by Jonas, Inc.: The 37th turbo-machinery symposium 2008

Figure 162-3 Construction of welded type rotor

http://www.power-technology.com/contractors/balancing/oasis-alignment/oasis-alignment3.html

Photo 162-4 Laser tracker inspection of rotor

(2) Turbine disk

Within the opened range of casing, it must be inspected following items by quietly rotating rotor without removing it.

1) Confirmation of corrosion and erosion

It must be confirmed erosion and corrosion of turbine disk of steam turbine. It must be ground down and welded erosion and corrosion portion when it is minor damage. It must be removed to manufacture factory and maintained it when it is major damage.

2) Confirmation of clearance of blade portion and gap of each part

It must be confirmed clearance of blade portion and gap of each part of turbine disk of steam turbine. When clearance and gap is not appropriate, it has an effect on power generation efficiency. It must be apply regulated clearance and gap when detecting improper clearance and gap at turbine disk of steam turbine.

3) Confirmation of contact between turbine disk and stationary part

It must be confirmed contact between turbine disk and stationary part of steam turbine. It must be taken appropriate measures depending on degree of defect when detecting defect at contact between turbine disk and stationary part of steam turbine.

4) Confirmation of status of deposition

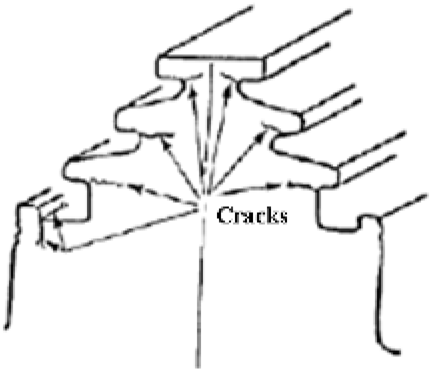
It must be confirmed that ingredient and volume etc. of deposition at turbine disk of steam turbine. It is recommended that they are analyzed chemically by specialized agency if necessary. It must be confirmed analysis results and taken appropriate measures if necessary.

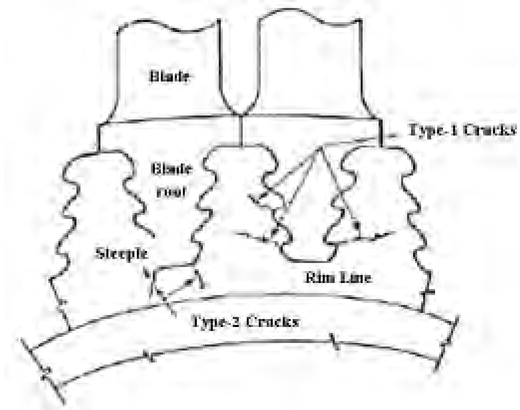
http://www.verbund.com/bg/en/blog/2012/06/03/turbine-revision-duernrohr

http://www.laborelec.be/ENG/wp-content/uploads/PDF/NDT-for-steam-turbines.pdf

Photo 162-5 Inspection of blade root

Photo 162-6 Eddy current test of blade root



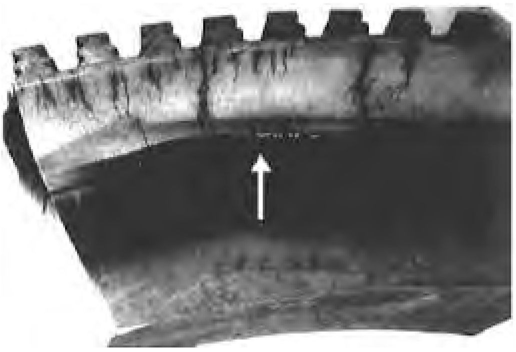


Reference: P-9 of "Steam turbine corrosion and deposits problems and solutions" by Jonas, Inc.: The 37th turbo-machinery symposium 2008

Reference: P-9 of "Steam turbine corrosion and deposits problems and solutions" by Jonas, Inc.: The 37th turbo-machinery symposium 2008

Figure 162-4 Crack on notch entry dovetail

Figure 162-5 Crack on axial entry fir tree



Reference: P-15 of "Steam turbine corrosion and deposits problems and solutions" by Jonas, Inc.: The 37th turbo-machinery symposium 2008

Reference: P-15 of "Steam turbine corrosion and deposits problems and solutions" by Jonas, Inc.: The 37th turbo-machinery symposium 2008

Photo 162-7 Crack on turbine disc

(3) Rotating blade and dovetail

Within the opened range of casing, it must be inspected following items by quietly rotating rotor without removing it.

1) Confirmation of corrosion and erosion

   It must be confirmed erosion and corrosion of rotating blade and dovetail of steam turbine. It must be ground down erosion and corrosion portion when it is minor damage. It must be removed to manufacture factory and maintained it when it is major damage.

2) Confirmation of clearance related rotating blade

   It must be confirmed clearance between rotating blade and stationary blade or tip clearance of steam turbine. When clearance is not appropriate, it has an effect on power generation efficiency. It must be apply regulated clearance when detecting improper clearance at rotating blade of steam turbine.

3) Confirmation of contact between rotating blade and stationary part

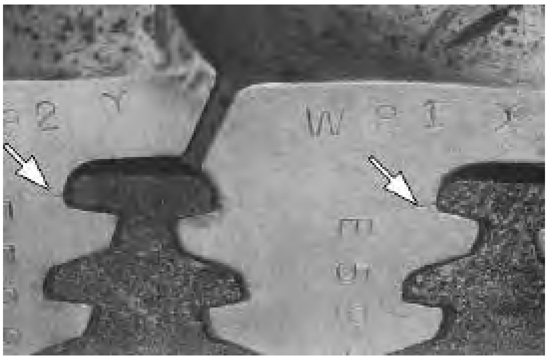
   It must be confirmed contact between rotating blade and stationary part of steam turbine. It must be taken appropriate measures depending on degree of defect when detecting defect at contact between steam turbine rotating blade and stationary part of steam turbine. It must be removed to manufacture factory and maintained it when it is major damage.

4) Confirmation of status of deposition

   It must be confirmed that ingredient and volume etc. of deposition at rotating blade and dovetail of steam turbine. It is recommended that they are analyzed chemically by specialized agency if necessary. It must be confirmed analysis results and taken appropriate measures if necessary.

Reference: P-28 of "90MW GE steam turbine project": SULZER

Photo 162-8 Re-blading of LP rotor



Reference: P-10 of "Steam turbine corrosion and deposits problems and solutions" by Jonas, Inc.: The 37th turbo-machinery symposium 2008

Photo 162-9 Crack on dovetail of blade

(4) Shroud ring and lacing wire

Within the opened range of casing, it must be inspected following items by quietly rotating rotor without removing it.

1) Confirmation of erosion and loose of shroud

It must be confirmed erosion and loose of shroud of steam turbine. It must be taken appropriate measures depending on degree of defect when detecting defect at shroud of steam turbine

2) Confirmation of damage of lacing wire

It must be confirmed damage (breakage etc.) of lacing wire. It must be taken appropriate measures depending on degree of defect when detecting defect at lacing wire of steam turbine

http://www.idspektr.ru/10_ECNDT/reports/1_12_08.pdf

Photo 162-10 UT of blade attachment (Siemens)

Reference: P-289of "90MW GE steam turbine project": SULZER

Photo 162-11 Shroud installation

(5) PT and UT inspection

1) PT inspection

It must be conducted PT inspection for curvature portion of rotor outer surface, shroud ring and weld portion of rotating blade stub etc. It must be ground down damaged portion when it is minor damage. It must be removed to manufacture factory and maintained it when it is major damage.

2) UT inspection

It must be conducted UT inspection for blade groove of rotor etc. of steam turbine. It must be ground down damaged portion when it is minor damage. It must be removed to manufacture factory and maintained it when it is major damage.

(6) Detailed inspection

It is recommended that inspection interval is regulated and material inspection and measurement of hardness are conducted for high stress portion.
(sample of inspection interval : every 8 years or 60,000～80,000 hrs)

3. Diaphragm, nozzle, stationary blade

(1) Diaphragm (stationary blade)

It must be conducted inspection with diaphragm fixed in steam turbine casing.

1) Confirmation of corrosion and erosion

It must be confirmed corrosion and erosion of diaphragm of steam turbine. It must be ground down erosion and corrosion portion when it is minor damage. It must be removed to manufacture factory and maintained it when it is major damage.

2) Confirmation of crack

It must be confirmed crack of diaphragm of steam turbine. It must be ground down erosion and corrosion portion when it is minor damage. It must be removed to manufacture factory and maintained it when it is major damage.

3) Confirmation of status of deposition

It must be confirmed that ingredient and volume etc. of deposition at diaphragm of steam turbine. It is recommended that they are analyzed chemically by specialized agency if necessary. It must be confirmed analysis results and taken appropriate measures if necessary.

4) Confirmation of status of horizontal coupling face

It must be confirmed status (steam leakage) of horizontal coupling face of diaphragm of steam turbine and cause of leakage when detecting it. It must be taken appropriate measures depending on cause of leakage when detecting defect at diaphragm of steam turbine.

Reference: P-8 of "90MW GE steam turbine project": SULZER

Photo 162-12 Completed diaphragm

Reference: P-8 of "90MW GE steam turbine project": SULZER

Photo 162-13 Replacement of vanes

(2) Nozzle (stationary blade)

It must be conducted inspection of first stage of nozzle at the upper part of high and middle pressure. It must be referred to above provisions as maintenance items for nozzle of steam turbine.

http://khia.belzona.com/view.aspx?id=804

Photo 162-14 Inspection of stationary blade holder casing

http://www.engrreview.com/Editorial_pages/2009/sep_09/power_technofocu-04.html

Photo 162-15 Clack on nozzle

http://www.fieldsystems.com/steam-path/

Photo 162-16 ST nozzle before repair

http://www.fieldsystems.com/steam-path/

Photo 162-17 Clack on nozzle diaphragm

(3) PT inspection and measurement of gap

It must be PT inspection and measurement of gap for diaphragm and nozzle of steam turbine if necessary.

1) PT inspection

It must be conducted PT inspection for diaphragm and nozzle of steam turbine. It must be ground down damaged portion when it is minor damage. It must be removed to manufacture factory and maintained it when it is major damage.

2) Measurement of gap

It must be conducted measurement of gap for diaphragm and nozzle of steam turbine. When gap is not appropriate, it has an effect on power generation efficiency. It must be apply regulated gap to each parts when detecting improper gap at diaphragm and nozzle of steam turbine.

4. Bearing

(1) External inspection

It must be conducted external inspection for bearing of steam turbine.

1) Confirmation of oil gap

It must be confirmed oil gap for bearing of steam turbine. When oil gap is not appropriate, it has an effect on operating steam turbine. It must be apply regulated gap when detecting improper gap at bearing of steam turbine.

2) Confirmation of contact to turbine rotor

It must be confirmed contact to turbine rotor and contact width etc. for bearing of steam turbine. When they are not appropriate, bearing and rotor for steam turbine are damaged. It must be confirmed cause of defect for bearing of steam turbine and taken measures depending on this cause.

3) Confirmation of spherical gap

It must be confirmed spherical gap for bearing of steam turbine. When spherical gap is not appropriate, it has an effect on operating steam turbine. It must be apply regulated gap when detecting improper gap at bearing of steam turbine.

4) Confirmation of thrust gap

It must be confirmed thrust gap for bearing of steam turbine. When thrust gap is not appropriate, it has an effect on operating steam turbine. It must be apply regulated gap when detecting improper gap at bearing of steam turbine.

5) Confirmation of contact to thrust bearing pad

It must be confirmed contact to thrust bearing pad for bearing of steam turbine. When they are not appropriate, bearing and rotor for steam turbine are damaged. It must be confirmed cause of defect for bearing of steam turbine and taken measures depending on this cause.

http://www.machinerylubrication.com/Read/865/turbine-lube-system

Photo 162-18 Damaged journal bearing

http://www.machinerylubrication.com/Read/865/turbine-lube-system

Photo 162-19 Damaged thrust bearing

http://www.mdaturbines.com/repairs/turbine-bearings

Photo 162-20 Repair of taper land

http://www.mdaturbines.com/parts/bearings

Photo 162-21 Measuring of taper land

5. Main valve (Main stop valve, reheat stop valve and governor valve)

(1) Open inspection

It must be disassembled each individual main valve and conducted inspection for strainer, valve body, valve seat, etc of them.

1) Confirmation of crack, erosion and abrasion

It must be confirmed crack, erosion and abrasion for valve stem, casing, weld part, bolt and nut of main valve. It must be ground down erosion and crack portion when it is minor damage. It must be removed to manufacture factory and maintained it when it is major damage. It must be taken appropriate measures depending on degree of defect when detecting defect at main valve of steam turbine.

2) Confirmation of contact to valve, valve seat and valve stem

It must be confirmed contact to valve, valve seat and valve stem of main valve. When they are not appropriate, steam leakage is occurred. It must be confirmed cause of steam leakage of main valve and taken measures depending on this cause.

3) Confirmation of status of deposition

It must be confirmed that ingredient and volume etc. of deposition at main valve of steam turbine. It is recommended that they are analyzed chemically by specialized agency if necessary. It must be confirmed analysis results and taken appropriate measures if necessary.

4) Confirmation of erosion and abrasion for gland packing

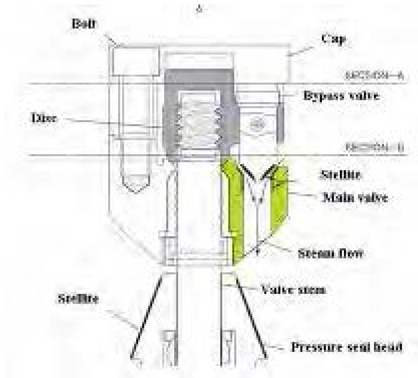
It must be confirmed erosion and abrasion for gland packing of main valve. It must be exchanged to new gland packing if necessary. It must be taken appropriate measures depending on degree of defect when detecting defect at gland packing of main valve.

(2) PT inspection

It must be conducted PT inspection for valve disc, valve stem, valve seat and welded part etc. of main valve if necessary. It must be taken appropriate measures depending on degree of defect when detecting defect at main valve of steam turbine.

http://www.fieldsystems.com/turbine-overhauls/

Photo 162-22 Repair of MSV seat



http://www.mdaturbines.com/parts/turbine-parts/

Figure 162-6 Repair of MSV seat

http://www.powerhousemechanical.com/services/major-minor-inspections/

Photo 162-23 Inspected GV

http://www.power-technology.com/contractors/fabrication/field-system/field-system3.html

Photo 162-24 Inspected MSV

6. Emergency stop device

(1) External inspection

It must be conducted external inspection for crack, corrosion and abrasion etc. of emergency governor and tripping device, etc. It must be taken appropriate measures depending on degree of defect when detecting defect at emergency governor and tripping device, etc.

(2) Open inspection

It is recommended that inspection interval is regulated and open inspection is conducted

1) Emergency stop device

a. Confirmation of status of trip lever pin and lock bolt
It must be confirmed status of trip lever pin and lock bolt of emergency stop device. It must be taken appropriate measures depending on degree of defect when detecting defect at trip lever pin and lock bolt of emergency stop device.

b. Confirmation of deformation of spring
It must be confirmed deformation of spring of emergency stop device. It must be exchanged to new spring when the deformation is major. It must be taken appropriate

measures depending on degree of defect when detecting defect at spring of emergency stop device.

c. Confirmation of damage and corrosion of sliding surface of spindle
It must be confirmed damage and corrosion of sliding surface of spindle of emergency stop device. It must be taken appropriate measures depending on degree of defect when detecting defect at sliding surface of spindle of emergency stop device.

2) Governor

a. Confirmation of sludge and foreign object of strainer and oil orifice etc.
It must be confirmed sludge and foreign object of strainer and oil orifice etc. of governor. It must be removed sludge and foreign object when detecting them at strainer and oil orifice etc. of governor. It must be confirmed cause of foreign object if necessary.

Confirmation of damage, abrasion and deformation of bearing, lever, spindle, spring and pin

It must be confirmed damage, abrasion and deformation of bearing, lever, spindle, spring and pin of governor. It must be exchanged to new parts when damage, abrasion and deformation are major. It must be taken appropriate measures depending on degree of defect when detecting defect at bearing, lever, spindle, spring and pin of governor.

b. Confirmation of crack and deformation of diaphragm
It must be confirmed crack and deformation of diaphragm of governor. It must be exchanged to new diaphragm when crack and deformation are major. It must be taken appropriate measures depending on degree of defect when detecting defect at diaphragm of governor.

7. Condenser

(1) Visual inspection
It must be opened condenser water box and conducted visual inspection of inside and condenser tubes.

1) Condenser water box and tube plate

a. Confirmation of corrosion
It must be confirmed corrosion of tube plate of partition wall. It must be taken appropriate measures depending on degree of defect when detecting defect at tube plate of partition wall.

b. Confirmation of status of deposition
It must be confirmed that deposition at condenser water box and tube plate. It is recommended that they are analyzed chemically by specialized agency if necessary. It must be confirmed analysis results and taken appropriate measures if necessary.

c. Confirmation of exfoliation and damage of lining
It must be confirmed exfoliation and damage of lining of condenser water box. It must be exchanged to new lining if necessary. It must be taken appropriate measures depending on degree of defect when detecting defect at lining of condenser water box.

2) Condenser tube

a. Confirmation of corrosion and erosion

It must be confirmed corrosion and erosion of inner face of condenser tube. It must be exchanged new condenser tube or attached stoppage plug to damaged condenser tube when corrosion and erosion of inner face is major. It must be taken appropriate measures depending on degree of defect when detecting defect at condenser tube.

b. Confirmation of status of deposition

It must be confirmed that deposition at inner face of condenser tube. It is recommended that they are analyzed chemically by specialized agency if necessary. It must be confirmed analysis results and taken appropriate measures if necessary.

http://www.cti-ind.com/faq.htm

Photo 162-25 Plugging of tubes

http://www.ndt-ed.org/EducationResources/HighSchool/Electricity/eddycurrenttesting.htm

Photo 162-26 Eddy current testing

http://www.concosystems.com/services/video-probe-inspection

Photo 162-27 Video proves inspection

http://www.concosystems.com/services/video-probe-inspection

Photo 162-28 Fouling in the tube

Article162-a1 Remaining life diagnosis technique of steam turbine

1. Remaining life diagnosis technique

Remaining life diagnosis is intended to predict the remaining life after evaluating the life at the periodic inspection, and carried out for the main equipment of aged thermal power plant operation time exceeds 100,000 hours. The methods of diagnosis are non-destructive inspection, analysis and destructive inspection. Because in many parts it can be diagnosed in a relatively short period and it can also do regular monitoring, it has been promoted to principal diagnosis by non-destructive inspection. Table 162-a1-1 shows an example of remaining life diagnosis technique by non-destructive inspection.

Table 162-a1-1 The remaining life diagnosis technique by non-destructive inspection

Damage pattern / Method	Creep	Fatigue	Embrittlement	Remarks
Electrical resistance method	X			
Hardness measurement method	X			
Organization observation method	X			Replica
Micro crack measurement method		X		Replica
Etch method			X	Replica

2. Life evaluation method of low-pressure turbine rotor

Life evaluation of low-pressure turbine rotor is important to analyze the crack initiation and progression from corrosion pits. Therefore, as the first phase of the maintenance management of the low-pressure turbine rotor, to understand the damage state of the corresponding, at the time of inspection of sampling rotor blades, the application of the replica method to the implantable of turbine rotor blade is recommended together with the chemical analysis of the precipitates. Figure 162-a1-1 shows the flow of this remaining life evaluation. In addition, figure 162-a1-2 shows the example of the application of the replica method in blade groove of rotor wheel.

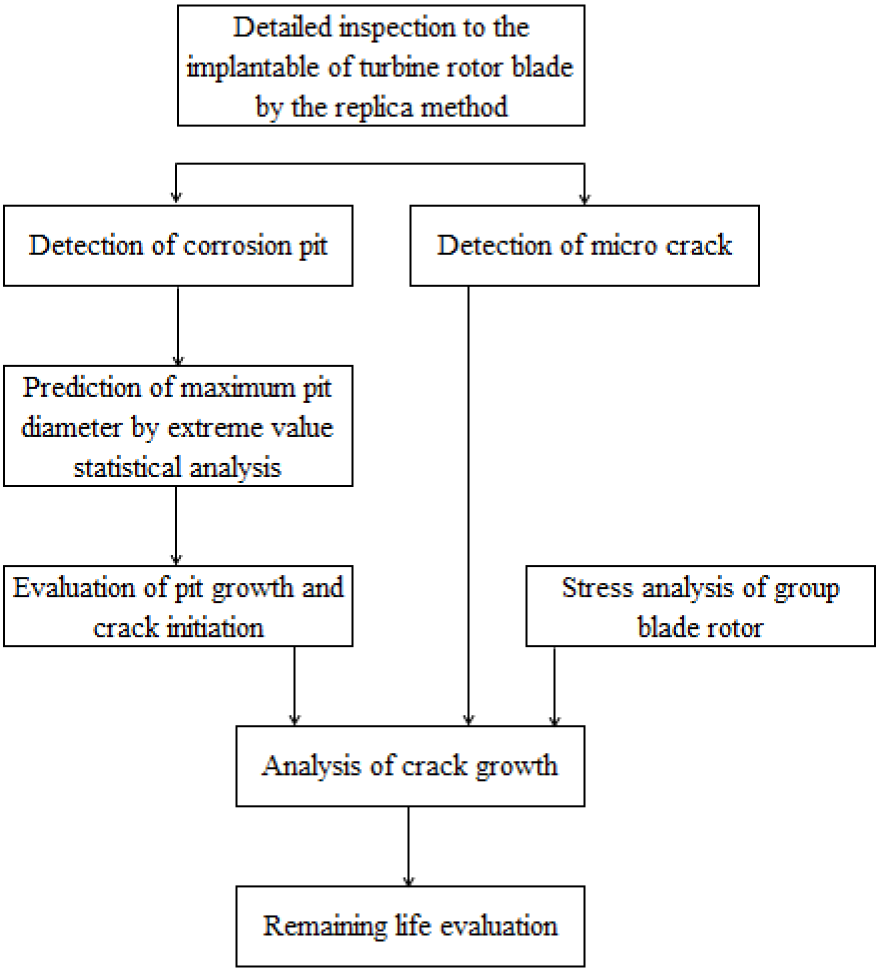


Figure 162-a1-1 Remaining life evaluation

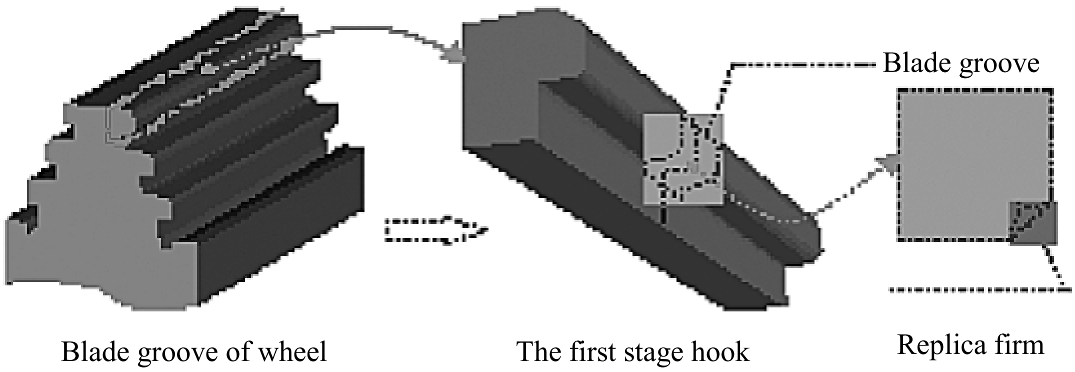


Figure 162-a1-2 The application of the replica method in blade groove of rotor wheel

Article 163. Steam turbine auxiliary equipment

1. Tube attached to steam turbine

It must be conducted the following management for tube thickness in consideration of status of each tube if necessary.

(1) Measurement of pipe thickness

It must be conducted measurement of pipe thickness based on measurement program developed by the Owner. It is conducted to pipe portion suspected corrosion wastage in steam piping. It must be taken appropriate measures depending on degree of defect when detecting defect at pipe attached to steam turbine.

(2) Assessment of remaining life

It must be conducted remaining life based on results of pipe thickness measurement conducted during the last periodic inspection and so on, or it must be checked and reviewed the finished assessment of remaining life.

Power plant equipments are exposed to severe environment under high pressure and temperature, degradation and damage are accumulated on them and when they are not maintained, several troubles and failures are occurred. The assessment of remaining life is technology of forecasting time to be had troubles and failures based on measurement result of degradation of equipment and important technology for inspecting power plant equipment. Major assessments of remaining life have shown as below:

1) Breaking test

2) Hardness measurement method

3) Ultrasonic method

4) Electric resistance method

(3) Developing of future measurement program

It must be developed and revised measurement program of pipe thickness if necessary. It must be taken account of following items when developing and revising measurement program of pipe thickness.

1) Time of future periodic inspection

2) Period of future periodic inspection (period of boiler stopping)

3) Procedure of assessment of remaining life

4) Period of preparation of assessment of remaining life (preparation during boiler stopping)

Article 164. Gas turbine (internal combustion)

1. Compressed combustion gas supply equipment and its auxiliary equipment

The auxiliary equipment of compressed combustion gas supply equipment is the equipment that supplies compressed gas for combustion to gas turbine together with gas compressor proper.

It must be regulated overhaul and inspection interval based on manufacture manual and actual operation status etc. and conducted overhaul and inspection of gas compressor.

(1) Gas compressor

1) Overhaul and inspection

It must be conducted overhaul and inspection of gas compressor on following parts and defects. These parts may be maintained and used continuously when defects in gas compressor are minor. It must be exchanged to new parts when defects in gas compressor are major. If inspection is periodically conducted by means of time management and so on according to the equipment properties, inspection must be conducted as long as it may be necessary.

a. Reciprocal engine type

(a) Frame

a) Clearance measurement of bearing and crosshead

b) Crack and deformation of connecting rod

c) Lubricant oil volume

(b) Cylinder

a) Fluctuation of cylinder

b) Abrasion and damage of piston ring, packing and seal ring etc.

c) Clearance measurement of piston outer shape and piston end

(c) Lubricant oil system

a) Gear and bearing of oil pump

b) Erosion, leakage and crack of oil cooler tube

(d) Airtight test by using nitrogen (After assembling)

(e) Leak test by gas detector (After assembling)

b. Turbo engine type

(a) Gas compressor body

a) Damage and abrasion of rotor, bearing, casing and impeller etc.

b) Alignment

(b) Lubricant oil system

a) Gear and bearing of oil pump

b) Erosion, leakage and crack of oil cooler tube

(c) Airtight test by using nitrogen (After assembling)

(d) Leak test by gas detector (After assembling)

http://www.siemens.com/press/en/presspicture/?press=/en/presspicture/2009/oil_gas/eog20030801-01.htm

http://www.power-technology.com/contractors/powerplantequip/turbo/

Photo 164-1 Fuel gas compressor for GT

(2) Gas receiver, gas cooler and oil separator

1) Appearance check

It must be conducted appearance check of gas receiver, gas cooler and oil separator on following part. These parts may be maintained and used continuously when defects in gas receiver, gas cooler and oil separator are minor. It must be exchanged to new parts when defects in gas receiver, gas cooler and oil separator are major.

a. Status of rust, deformation and damage at each part of gas receiver, gas cooler and oil separator body

(a) External surface

(b) Contact point with auxiliary devices

(c) Painting etc.

b. Status of crack and damage at foundation of gas receiver, gas cooler and oil separator

c. Status of deformation and fracture of manhole, water spray bar, atmospheric escape pipe etc.

d. Status of peeling and fracture of sealing agent under gas receiver, gas cooler and oil separator

http://www.seo-koatsu.co.jp/product/product02.html

Photo 164-2 Fuel gas heater

http://www.yasec.co.jp/product/nekou/land_asmu/land_asme.html

Photo 164-3 GT cooling air cooler

(3) Safety valve

1) Appearance check

It must be conducted appearance check of safety valve on following defects. These parts may be maintained and used continuously when defects in safety valve are minor. It must be exchanged to new parts when defects in safety valve are major.

a. Corrosion and erosion of safety valve body

b. Abrasion of safety valve body

c. Damage of safety valve body etc.

2) Overhaul and inspection

It must be conducted overhaul and inspection of safety valve on following parts and defects. These parts may be maintained and used continuously when defects in safety valve are minor. It must be exchanged to new parts when defects in safety valve are major.

a. Abrasion of valve body, valve seat, valve stem, and seal

b. Crack, foreign object and corrosion of valve body and seat

c. Interference and free length of spring

d. Position of adjust ring

e. Crack, deformation, curvature and contact on edge of stem etc.

(4) Piping

It must be conducted appearance check of piping on following defects. These parts may be maintained and used continuously when defects in piping are minor. It must be exchanged to new parts when defects in piping are major.

1) Corrosion of piping

2) Deformation of piping

3) Damage of piping etc.

2. Casing

It must be regulated overhaul and inspection interval based on manufacture manual and actual operation status etc. and conducted overhaul and inspection of casing.

(1) Horizontally split gas turbine

1) Overhaul and inspection

It must be conducted overhaul and inspection of casing on following parts and defects by removing upper part of casing. These parts may be maintained and used continuously when defects in casing are minor. It must be removed to manufacture factory and maintained it or exchanged to new parts when defects in casing are major.

a. Crack and erosion of inner casing

b. Leakage of oil, compressed air and combustion gas from casing

c. Sliding contact with rotor

d. Fouling and foreign object in casing

e. Rust on outer casing etc.

2) PT inspection and clearance gap measurement

It must be conducted PT inspection and clearance gap measurement on following parts if necessary. As the results of PT inspection, these parts may be maintained and used continuously when defects in casing are minor. It must be removed to manufacture factory and maintained it or exchanged to new parts when defects in casing are major. In case that clearance gap is not met with acceptable value, it must be applied regulated gap to each part.

a. Inner face of casing and major bolts at PT inspection

b. Clearance gap between rotating blade tip and casing (tip clearance)

http://www.locknstitch.jp/lns/power.html

http://www.locknstitch.jp/lns/power.html

Photo 164-4 Repair of GT outlet casing

http://www.locknstitch.jp/lns/power.html

Photo 164-5 Repair of GT outlet casing

http://turbinesint.com/steam-gas-turbine/

Photo 164-6 Overhaul of GT

(2) Cylinder casing gas turbine

It must be conducted overhaul and inspection of compressor part, combustion chamber part and turbine part on following parts and defects. These parts may be maintained and used continuously when defects in them are minor. It must be removed to manufacture factory and maintained it or exchanged to new parts when defects in them are major.

1) Crack and erosion of inner compressor part, combustion chamber part and turbine part

2) Leakage of oil, compressed air and combustion gas from compressor part, combustion chamber part and turbine part

3) Sliding contact with rotor

4) Fouling and foreign object in combustion gas from compressor part, combustion chamber part and turbine part

5) Rust on outer combustion gas from compressor part, combustion chamber part and turbine part etc.

http://www.fabricatingandmetalworking.com/2010/05/two-for-the-price-of-one/

Photo 164-7 Inspection of LP casing

http://www.myyellowcoat.com/featured-articles/aerospace-improved-manufacturing/

Photo 164-8 Inspection of combustor casing

3. Rotor, turbine disk, rotating blade

It must be regulated overhaul and inspection interval based on manufacture manual and actual operation status etc. and conducted overhaul and inspection of rotor, turbine disk and rotating blade.

In general, the integration method to bind discs which is planted blades by bolts is adopted in stead of forging a single rotor for gas turbine as shown in Figure 164-1.

(1) Horizontally split gas turbine

It must be conducted overhaul and inspection of rotor, turbine disk, rotating blade on following parts and defects by quietly rotating rotor without removing it. It must be conducted PT inspection if necessary. These parts may be maintained and used continuously when defects in them are minor. It must be removed to manufacture factory and maintained it or exchanged to new parts when defects in them are major.

1) Rotor

a. Crack, erosion and corrosion

b. Contact with diaphragm and labyrinth seal

c. Sliding contact on journal part

d. Fouling etc.

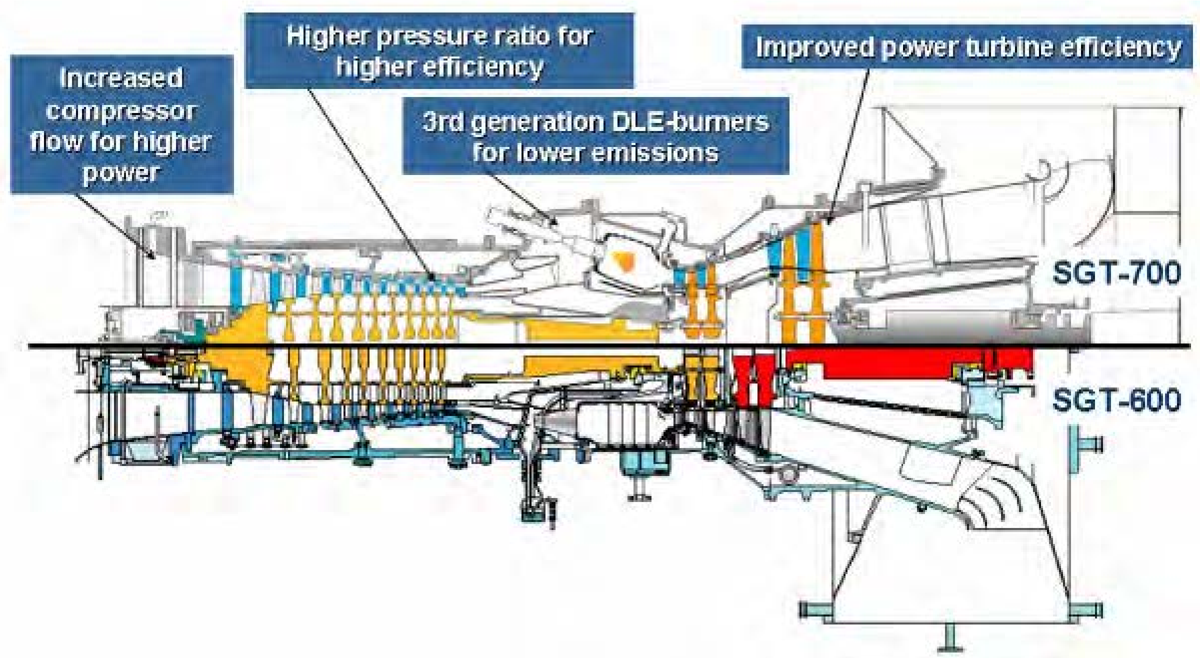


Figure 164-1 Typical cross section of gas turbine (Siemens)

2) Turbine disk

a. Crack, erosion and corrosion

b. Contact with diaphragm and labyrinth seal

c. PT inspection

d. Fouling etc.

http://www.laborelec.be/ENG/news_tag/blade-crack/

Photo 164-9 UT of GT disc

http://www.woodgroupnews.com/WoodNewsQ32011/English/WoodNews-Quarter3-2011.aspx

Photo 164-10 VT inspection of GT disc

http://www.energy.siemens.com/hq/en/services/power-generation/product/sgt5-400f-v94-3a/lifetime-extension.htm

http://www.ccj-online.com/bg/companies/advanced-turbine-support/

Photo 164-11 UT of GT disc

3) Rotating blade and blade dovetail

   a. Crack, erosion and corrosion

   b. Damage due to foreign object

   c. PT inspection

   d. Blockage and damage of cooling air hole

   e. Peeling of thermal barrier coating

   f. Fouling etc.

The typical deterioration and damage to the surface on the blades in the view point of maintenance is the metal reduction due to high temperature oxidation, though the factor of replacement life of blades in the view point of design is the creep damage, since they are used for a long period of time at high temperature and centrifugal force condition.

In particular, the blade tip portion and the front edge portion of 1st stage are remarkable as shown in Photo 164-14. In addition, it is a problem of thermal fatigue cracks occur around the blade tip or cooling vents.

It cannot be seen particular deterioration and damage on both GT systems of GE type and MHI type other than the minor deterioration of coating except the 1st stage. Inspection method at the time of inspection is visual inspection (hereinafter, VT), fluorescent inspection (hereinafter, FPT) and a dimensional inspection for both GE type and MHI type. The necessity of repair is determined based on the existence of deterioration and damage and criterion for repair. The main repair method is the repair welding for thickness reduction part due to oxidation and blending repair of crack part.

http://www.act-texas.com/areas-of-excellence/inspection/

Photo 164-12 UT of GT blades

http://www.act-texas.com/areas-of-excellence/inspection/

Photo 164-13 PT of GT blades

Reference: P-5 of No. 61 Journal Dec. /2010: TEMPES

Photo 164-14 1st stage blade GE type GT

http://www.aircraftpowermaintenance.com/index.php?page=inspection

Photo 164-15 FPT of GT blades

4) Section where counterweight is installed

a. Loose of counterweight

(2) Cylinder casing gas turbine

It must be conducted overhaul and inspection of rotor, turbine disk, rotating blade and so on of compressor and turbine part on following parts and defects. It must be conducted PT inspection if necessary. These parts may be maintained and used continuously when defects in them are minor. It must be removed to manufacture factory and maintained it or exchanged to new parts when defects in them are major.

1) Rotor

a. Crack, erosion and corrosion

b. Contact with diaphragm and labyrinth seal

c. Sliding contact on journal part

d. Fouling etc.

2) Turbine disk

a. Crack, erosion and corrosion

b. Contact with diaphragm and labyrinth seal

c. PT inspection

d. Fouling etc.

3) Rotating blade and blade dovetail

a. Crack, erosion and corrosion

b. Damage due to foreign object

c. PT inspection

d. Blockage and damage of cooling air hole

e. Peeling of thermal barrier coating

f. Fouling etc.

4. Diaphragm, nozzle, stationary blade

It must be regulated overhaul and inspection interval based on manufacture manual and actual operation status etc. and conducted overhaul and inspection of diaphragm, nozzle and stationary blade.

(1) Horizontally split gas turbine

It must be conducted overhaul and inspection of diaphragm, nozzle, and stationary blade by removing nozzle only at upper part on following parts and defects. It must be conducted PT inspection if necessary. These parts may be maintained and used continuously when defects in them are minor. It must be removed to manufacture factory and maintained it or exchanged to new parts when defects in them are major.

1) Diaphragm

a. Deformation

b. Inspection and cleaning of horizontal coupling face and insert part at casing

c. Blockage of cooling air hole

d. Inspection and cleaning of support and pin etc.

http://www.act-texas.com/areas-of-excellence/vane-nozzle-repair/

http://www.act-texas.com/areas-of-excellence/mechanical/

Photo 164-16 Diaphragm of GT

2) Stationary blade

a. Crack, erosion and corrosion

b. Damage due to foreign object

c. PT inspection

d. Blockage and damage of cooling air hole

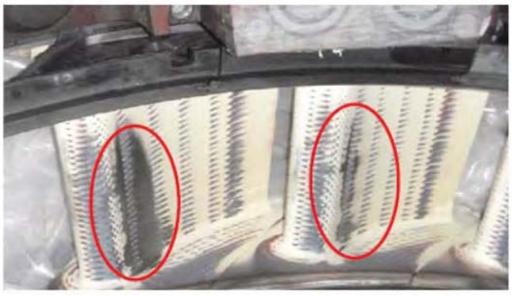
e. Peeling of thermal barrier coating

f. Fouling etc.

The morphology of typical deterioration and damage of stationary vane is the thermal fatigue crack due to thermal stress during-start-up, and occur on the blade and sidewall. In addition, it can be recognized local oxidation and creep deformation of sidewall (fall).

It can be observed a slight detachment of coating due to the very severe condition, although thermal barrier coating (TBC) has been given on the 1st stage stationary banes of GT class 1,300^{o}C and 1,500 ^{o}C. Photo 164-17 is the 1st stage stationary blades of GT of MHI (class 1,500 ^{o}C) which were used approximately 5,000hours. The slight wear (black section) can be seen on the TBC of blade surface.

The deterioration and damage after the 2nd stage of stationary vanes is slight, though it is observed some degree of thermal fatigue crack. The inspection method is the VT, PT, dimension inspection and repair welding on crack part.



Reference: P-5 of No. 61 Journal Dec. /2010: TEMPES

Photo 164-17 1st stage blade MHI type GT (1,500°C class)

Photo 164-18 Stationary blade of GT

(2) Cylinder casing gas turbine

It must be conducted overhaul and inspection of diaphragm, nozzle, stationary blade and so on of compressor part and turbine part on following parts and defects. It must be conducted PT inspection if necessary. These parts may be maintained and used continuously when defects in them are minor. It must be removed to manufacture factory and maintained it or exchanged to new parts when defects in them are major.

1) Diaphragm

a. Deformation

b. Inspection and cleaning of horizontal coupling face and insert part at casing

c. Blockage of cooling air hole

d. Inspection and cleaning of support and pin etc.

2) Stationary blade

a. Crack, erosion and corrosion

b. Damage due to foreign object

c. PT inspection

d. Blockage and damage of cooling air hole

e. Peeling of thermal barrier coating

f. Fouling etc.

5. Bearing

It must be regulated overhaul and inspection interval based on manufacture manual and actual operation status etc. and conducted overhaul and inspection of bearing.

(1) Horizontally split gas turbine

It must be conducted external inspection of bearing and conducted overhauled and inspection it on following parts and defects when taking out rotor as needed. These parts may be maintained and used continuously when defects in bearing are minor. It must be removed to manufacture factory and maintained it or exchanged to new parts when defects in bearing are major.

1) Oil gap
2) Contact to turbine rotor
3) Spherical gap
4) Thrust gap
5) Contact to thrust bearing pad etc.

http://www.realservices.com/images/Spotlight-Saves/GPP-2119-Save-03.gif

http://www.machinerylubrication.com/Read/626/contamination-control-technologies

Photo 164-19 Varnish formation on GT bearing

http://turboresearch.wordpress.com/

Photo 164-20 Babbitt repair

http://www.locknstitch.jp/lns/power.html

Photo 164-21 Crack on bearing housing

(2) Cylinder casing gas turbine

Bearing must be disassembled and inspection must be conducted.

It must be conducted overhauled and inspection of bearing on following parts and defects when taking out rotor as needed. These parts may be maintained and used continuously when defects in bearing are minor. It must be removed to manufacture factory and maintained it or exchanged to new parts when defects in bearing are major.

1) Oil gap

2) Contact to turbine rotor

3) Spherical gap

4) Thrust gap

5) Contact to thrust bearing pad etc.

6. Emergency governor

(1) Horizontally split gas turbine and Cylinder casing gas turbine

1) External inspection

It must be conducted external inspection for crack, corrosion and abrasion etc. of emergency governor and tripping device etc. It must be taken appropriate measures depending on degree of defect when detecting defect at them.

2) Open inspection

It is recommended that inspection interval is regulated and open inspection is conducted

a. Emergency stop device

(a) Confirmation of status of trip lever pin and lock bolt

It must be confirmed status of trip lever pin and lock bolt of emergency stop device. It must be taken appropriate measures depending on degree of defect when detecting defect at rip lever pin and lock bolt of emergency stop device.

(b) Confirmation of deformation of spring

It must be confirmed deformation of spring of emergency stop device. It must be exchanged to new spring when the deformation is major. It must be taken appropriate measures depending on degree of defect when detecting defect at spring of emergency stop device.

(c) Confirmation of damage and corrosion of sliding surface of spindle

It must be confirmed damage and corrosion of sliding surface of spindle of emergency stop device. It must be taken appropriate measures depending on degree of defect when detecting defect at sliding surface of spindle of emergency stop device.

b. Governor

(a) Confirmation of sludge and foreign object of strainer and oil orifice etc.

It must be confirmed sludge and foreign object of strainer and oil orifice etc. of governor. It must be removed sludge and foreign object when detecting them at strainer and oil orifice etc. of governor. It must be confirmed cause of foreign object if necessary.

(b) Confirmation of damage, abrasion and deformation of bearing, lever, spindle, spring and pin

It must be confirmed damage, abrasion and deformation of bearing, lever, spindle, spring and pin of governor. It must be exchanged to new parts when damage, abrasion and deformation are major. It must be taken appropriate measures depending on degree of defect when detecting defect at bearing, lever, spindle, spring and pin of governor.

(c) Confirmation of crack and deformation of diaphragm

It must be confirmed crack and deformation of diaphragm of governor. It must be exchanged to new diaphragm when crack and deformation are major. It must be taken appropriate measures depending on degree of defect when detecting defect at diaphragm of governor.

7. Reduction gear

It must be regulated overhaul and inspection interval based on manufacture manual and actual operation status etc. and conducted overhaul and inspection of reduction gear.

(1) Cylinder casing gas turbine

1) Open or disassembled inspection

It must be overhauled and confirmed reduction gear on following parts and defects. These parts may be maintained and used continuously when defects in reduction gear are minor. It must be exchanged to new parts when defects in reduction gear are major.

a. Crack of gear

b. Abnormal contact on gear

c. Abrasion of gear

d. Damage of bearing

e. Leakage of oil etc.

http://www.gereports.com/made-in-texas/

Photo 164-22 Gearbox for GE gas turbine

http://www.traderscity.com/board/products-1/offers-to-sell-and-export-1/lm6000-turbine-generator-gearbox-20006/

Photo 164-23 Gearbox for GE LM6000

http://www.azumatekko.com/products15.html

Photo 164-24 Emergency fuel shut-off valve

http://www.pcne.eu/article/fuel-shutoff-valve/?a=print

Photo 164-25 Fuel shutoff valve for GT

8. Rules on technical maintenance

It must be regulated overhaul and inspection interval based on manufacture manual and actual operation status etc. and conducted overhaul and inspection of following equipments.

(1) Turbine and blades, heat exchangers, valves, dampers, accessories

1) Turbine and blades

It must be referred to paragraph 3 and 4 of Article 164 in this Guideline.

2) Heat exchangers

It must be overhauled and confirmed heat exchanger on following parts and defects. These parts may be maintained and used continuously when defects in heat exchanger are minor. It must be exchanged to new parts when defects in heat exchanger are major.

a. Erosion of heat exchanger tube

b. Deformation of heat exchanger tube

c. Leakage of heat exchanger tube   etc.

The degradation of the high temperature parts progresses while superimposed the time-dependent degradation such as creep and number dependent degradation such as low–cycle fatigue, etc. Therefore, the management by means of “equivalent operation hours” that is used the law of liner damage is applied as the guideline for the operation of high temperature parts.

This is the method to evaluate by means of converting the number dependent degradation to the time dependent degradation by using the coefficient.

The evaluation formula for typical equivalent operation is shown as follows. Each factor has been specified for each high temperature parts and the lifetime consumption is different for each component in the same operating history.

By this, it becomes possible to calculate the life consumption of high temperature parts by a simple formula through the actual operation hours, fuel type, and number of start-up, load shedding and the like.

$$Ho = H + A \times \left(N + B \times L_r + C \times T + D \times L_c\right)$$

where

Ho	: Equivalent operating hours	(hr)
H	: Actual operating hours	(hr)
A	: Conversion factor of equivalent operating hours	—
N	: Actual number of start-up	(times)
B	: Number of load shedding	(times)
Lr	: Conversion factor of load shedding	—
C	: Number of trip	(times)
T	: Conversion factor of trip	—
D	: Number of sudden load change	(times)
Lc	: Conversion factor of sudden load change	—

$$Ma\text{int}enance \quad \text{int}erval(hours) = \frac{24{,}000}{Ma\text{int}enance \quad Factor}$$

where

$$Ma\text{int}enance \quad Factor = \frac{FactoredHours}{ActualHours}$$

Factored Hours: $(K + M \times I) \times (G + 1.5D + A_1H + 6P)$

Actual hours : $(G + D + H + P)$

G	: Annual based load operating hours on gas fuel
D	: Annual based load operating hours on distillate fluid
H	: Annual operating hours on heavy fuel
A_1	: Heavy fuel severity factor (Residual A_1=3 to 4, Crude A_1=2 to 4)
P	: Annual peak load operating hours
I	: Percent water/steam injection performance to inlet air flow
$M\&K$	: Water/Sam injection constants

Table 164-1 Hot gas path inspection (hours-based criterion): GE-3620J

M	K	Control	Steam injection	N_2H_3 Material
0	1	Dry	< 2.2%	GTD-222, FSX-414
0	1	Dry	< 2.2%	GTD-222
0.18	0.6	Dry	< 2.2%	FSX-414
0.18	1	Wet	< 0%	GTD-222
0.55	1	Wet	< 0%	FSX-414

$$Maintenance \quad interval(starts) = \frac{S}{Maintenance \quad Factor}$$

where

$$Maintenance \quad Factor = \frac{FactoredStarts}{ActualStarts}$$

$$Factored\ Starts{:}\ (0.5NA+NB+1.3NP+20E+2F+\sum_{i=1}^{\eta} a_T T_i)$$

$$Actual\ Starts : (NA + NB + NP + E + F + T)$$

S	: Maximum starts-based maintenance interval (model size dependent)
NA	: Actual number of part load start/stop cycles (<60% load)
NB	: Actual number of normal base load start/stop cycles
NP	: Actual number of peak load start/stop cycles
E	: Actual number of emergency starts
F	: Actual number of fast load starts
T	: Actual number of trips
a_T	: Trip severity factor=f (Load)(see fig-21)
η	: Number of trip categories (i.e. fuel load, part load, etc.)

Table 164-2 Hot gas path inspection (starts-based criterion) MS6001/7001/9001: GE-3620J

Model series	S	Model series	S
MS6B/MS7EA	1,200	MS9E	900
MS6FA	900	MS7F/7FA/9F/9FA	900

Table 164-3 Recommended inspection items of gas turbine

Equipment		Periodic inspection	Mid term inspection	Combustor inspection
Gas turbine	Casing	●	●	
	Rotor, disc	●	●	
	Diaphragm, vane	●	●	
	Blade	●	●	
	Bearing	●		
	Coupling	●		
	Emergence stop device	●		
Compressor		●		
Combustor		●	●	●
EHC governor	Actuator	●		
	Servo valve, etc.	●		
	Strainer	●	●	
Lubrication equipment		●		
Starting equipment		●		
Suction & exhaust equipment		●	●	
Extraction & cooling air system		●		

● : Target of inspection

3) Valves

It must be conducted overhaul and inspection of valve on following parts and defects. These parts may be maintained and used continuously when defects in it are minor. It must be exchanged to new parts when defects in it are major.

a. Crack, abrasion, curvature and deformation of vale stem, valve element and inner face of valve casing

b. Abrasion, corrosion and crack of valve disc and valve seat

4) Dampers

It must be conducted overhaul and inspection of damper on following parts and defects. These parts may be maintained and used continuously when defects in it are minor. It must be exchanged to new parts when defects in it are major.

a. Deformation of damper

b. Sticking of damper

c. Damage of link mechanics etc.

5) Accessories

It must be conducted overhaul and inspection of accessories. These parts may be maintained and used continuously when defects in them are minor. It must be exchanged to new parts when defects in them are major.

(2) Protection equipment and automatic controlling system

1) Protection equipment

It must be referred to paragraph 6 of Article 164 in this Guideline.

2) Automatic controlling system

It must be conducted inspection following systems of gas turbine and confirmed that it is operated normally. It must be confirmed cause of defect when detecting defect at following systems and taken appropriate measures depending on degree of defect.

a. Automatic start controlling system

b. Automatic output controlling system

c. Automatic rotating speed controlling system

d. Automatic fuel controlling system

e. Automatic air mass flow (Inlet Guide Vane) controlling system

f. Automatic temperature controlling system etc.

(3) Fuel burner (Combustor)

It must be examined and checked tightness, output of fuel burner and spraying angle of fuel at nozzles of burner. Moreover, it must be conducted overhaul and inspection on following parts and defects of combustor. These parts may be maintained and used continuously when defects in combustor are minor. It must be transported casing to manufacture factory and maintained it or exchanged to new parts when defects in combustor are major.

1) Abrasion, crack, dent and burnout of internal and external cylinder

2) Plugging, abrasion, crack and burnout of burner nozzle

3) Burnout of swirler

4) PT inspection

5) Peeling of thermal barrier coating etc.

http://www.washino-kiko.co.jp/japanese/product/pratt-and-whitney.html

Photo 164-26 FPT of GT combustor

http://www.mitec-ndt.co.jp/business/various_testing/nondestructive/penetrant.html

Photo 164-27 PT of GT combustor

(4) Auxiliary and emergency oil pump

It must be conducted overhauled and inspection of auxiliary and emergency oil pumps on following parts and defects. These parts may be maintained and used continuously when defects in them are minor. It must be exchanged to new parts when defects in them are major. It must be referred to paragraph 4 of Article 141 in this Guideline regarding interlock test of auxiliary and emergency oil pump.

1) Abrasion, crack, erosion and corrosion of impeller

2) Damage of bearing and contact with bearing

3) Abrasion and damage of gland packing

4) Damage of inner casing

5) Abrasion damage of coupling etc.

(5) Grease, fuel, air and water filter.

It must be conducted overhauled and inspection of grease, fuel, air and water filter. It must be cleaned them when these filters are plugging, polluted and damaged. It must be exchanged to new filter when these pollution or damage is major.

9. Check of governor

It must be referred to paragraph 6 of Article 164 in this Guideline.

10. Check of gas temperature

It must be conducted inspection of inter lock of following protection temperature device system. It must be confirmed they are operated normally. If they are not operated normally, it must be confirmed cause of trouble and taken appropriate measures. Parts of protection temperature device may be maintained and used continuously when defects in them are minor. It must be exchanged to new parts when defects in them are major.

(1) Protection temperature device system

1) System of outlet gas temperature high

2) System of deviation high of blade pass gas temperature

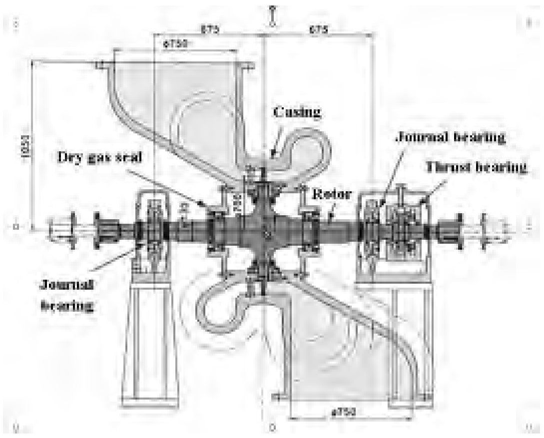
(2) Point to be checked

(1) Operation of interlock system

(2) Alarm regarding interlock

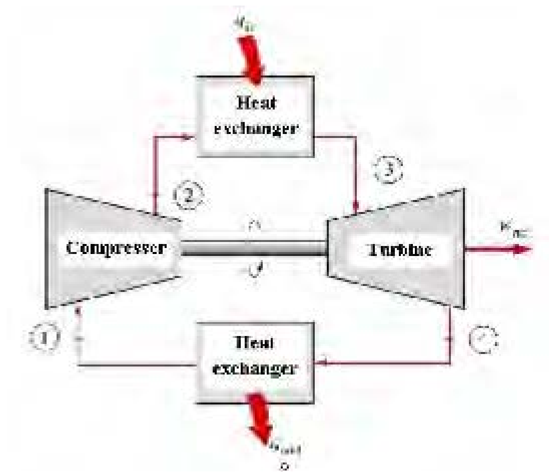
Article 165. Gas turbine (external combustion)

There is no big difference on construction of gas turbine between the internal combustion type and the external combustion type gas turbine, though the closed cycle type or separate combustor type are applicable except that it does not have a combustor on the body as shown Figure 165-1, 2. However, the operation condition is not strict compared with internal combustion type unless special conditions such as dust containing gas, since the inlet gas temperature of turbine is less than 900°C, in general. Therefore, the test items, contents and criterion may be pursuant to the external combustion type gas turbine.



http://www.sciencedirect.com/science/article/pii/S1359431112001445

Figure 165-1 External combustion Helium turbine



http://www.mhhe.com/engcs/mech/cengel/thermodead/graphics/ppt/CHPT08/sld016.htmhttp://www.powerhousemechanical.com/services/major-minor-inspections/

Figure 165-2 Closed cycle gas turbine

Article 166. Independent super-heater

1. Independent super-heater body

(1) Visual inspection of outer surface of tube

Visual inspection for following items of the outer surface of tubes must be conducted. Erosion and corrosion portion must be ground down when it is minor damage. Appropriate measures must be taken depending on degree of defect when detecting defect at outer surface of tube of independent super-heater.

1) erosion of tube

2) corrosion of tube

3) crack of tube

4) damage of tube etc.

(2) Inspection of header

Inspection holes at header must be opened and be conducted inspection for following items of header of independent super-heater. Appropriate measures must be taken depending on degree of defect when detecting defect at outer surface of header of independent super-heater.

1) erosion of header

2) corrosion of header

3) crack of header

4) damage of header etc.

(3) Nondestructive inspection

Typical parts of tubes must be selected and be conducted nondestructive inspection for them or inspection of pipes after cutting off them if necessary. Appropriate measures must be taken depending on degree of defect when detecting defect at tube of independent super-heater.

2. Heavy oil combustion equipment, forced draft fan, soot blower, Steam receiver (including drain separator)

(1) Visual inspection of outer surface of tube

Visual inspection must be conducted for following items of the outer surface of tubes. Erosion and corrosion portion must be ground down when it is minor damage. Appropriate measures must be taken depending on degree of defect when detecting defect at outer surface of tube of independent super-heater auxiliary equipment.

1) erosion of tube

2) corrosion of tube

3) crack of tube

4) damage of tube etc.

(2) Inspection of header

Inspection holes at header must be opened and be conducted inspection for following items of header of independent super-heater. Appropriate measures must be taken depending on degree of defect when detecting defect at outer surface of header of independent super-heater auxiliary equipment.

1) erosion of header

2) corrosion of header

3) crack of header

4) damage of header etc.

(3) Nondestructive inspection

Typical parts of tubes must be selected and be conducted nondestructive inspection for them or inspection of pipes after cutting off them if necessary. Appropriate measures must be taken depending on degree of defect when detecting defect at tube of independent super-heater auxiliary equipment.

3. Tube attached to independent super-heater

The following management for tube thickness must be conducted in consideration of status of each tube if necessary.

(1) Measurement of pipe thickness

Measurement of pipe thickness must be conducted based on measurement program developed by the Owner. It is conducted to pipe portion suspected corrosion wastage in steam piping. Appropriate measures must be taken depending on degree of defect when detecting defect at pipe attached to independent super-heater.

(2) Assessment of remaining life

Assessment of remaining life must be conducted based on results of pipe thickness measurement conducted during the last periodic inspection and so on, or it must be checked and reviewed the finished assessment of remaining life.

Power plant equipments are exposed to severe environment under high pressure and temperature, degradation and damage are accumulated on them and when they are not maintained, several troubles and failures are occurred. The assessment of remaining life is technology of forecasting time to be had troubles and failures based on measurement result of degradation of equipment and important technology for inspecting power plant equipment. Major assessments of remaining life have shown as below:

1) Breaking test
2) Hardness measurement method
3) Ultrasonic method
4) Electric resistance method

(3) Developing of future measurement program

It must be developed and revised measurement program of pipe thickness if necessary. It must be taken account of following items when developing and revising measurement program of pipe thickness.

1) Time of future periodic inspection
2) Period of future periodic inspection (period of boiler stopping)
3) Procedure of assessment of remaining life
4) Period of preparation of assessment of remaining life (preparation during boiler stopping)

Article 167-a1 Steam accumulator

1. Steam accumulator body

(1) Internal inspection

It must be opened manhole and conducted internal inspection for following items of steam accumulator. It must be ground down erosion and corrosion portion when it is minor. It must be taken appropriate measures depending on degree of defect when detecting defect at inner face of steam accumulator.

1) erosion of steam accumulator
2) corrosion of steam accumulator
3) crack of steam accumulator
4) damage of steam accumulator etc.

(2) Inspection of internal facilities

It must be taken out internal facilities and conducted inspection for following items every other periodic inspection. It must be taken appropriate measures depending on degree of defect when detecting defect at internal facilities of steam accumulator.

1) erosion of internal facilities
2) corrosion of internal facilities
3) crack of internal facilities
4) damage of internal facilities etc.

2. Tube attached to steam accumulator

It must be conducted the following management for tube thickness in consideration of status of each tube if necessary.

(1) Measurement of pipe thickness

It must be conducted measurement of pipe thickness based on measurement program developed by the Owner. It is conducted to pipe portion suspected corrosion wastage in steam piping. It must be taken appropriate measures depending on degree of defect when detecting defect at pipe attached to steam accumulator.

(2) Assessment of remaining life

It must be conducted remaining life based on results of pipe thickness measurement conducted during the last periodic inspection and so on, or it must be checked and reviewed the finished assessment of remaining life.

Power plant equipments are exposed to severe environment under high pressure and temperature, degradation and damage are accumulated on them and when they are not maintained, several troubles and failures are occurred. The assessment of remaining life is technology of forecasting time to be had troubles and failures based on measurement result of degradation of equipment and important technology for inspecting power plant equipment. Major assessments of remaining life have shown as below:

1) Breaking test
2) Hardness measurement method
3) Ultrasonic method
4) Electric resistance method

(3) Developing of future measurement program

It must be developed and revised measurement program of pipe thickness if necessary. It must be taken account of following items when developing and revising measurement program of pipe thickness.

1) Time of future periodic inspection
2) Period of future periodic inspection (period of boiler stopping)
3) Procedure of assessment of remaining life
4) Period of preparation of assessment of remaining life (preparation during boiler stopping)

Article167-a2　Coal handling facilities

1. Unloader

It must be regulated overhaul and inspection interval based on manufacture manual and actual operation status etc. and conducted overhaul and inspection of unloader.

(1) Abrasion and wear of bearing

It must be confirmed abrasion and following wears of bearing of unloader. These parts may be maintained and used continuously when wears of bearing are minor. It must be exchanged to new parts when wears of bearing are major.

1) Abrasion of bearing
2) Sticking of bearing
3) Damage of contact face of bearing
4) Status of lubricant oil of bearing
5) Foreign objects in bearing　etc.

(2) Abrasion of turn table and driving chain of bucket elevator

It must be confirmed abrasion and following defects in turn table and driving chain of bucket elevator of unloader. These parts may be maintained and used continuously when defects in turn table and driving chain of bucket elevator are minor. It must be exchanged to new parts when defects in turn table and driving chain of bucket elevator is major.

1) Abrasion of turn table and driving chain of bucket elevator
2) Crack of turn table and driving chain of bucket elevator
3) Status of lubricant oil of turn table and driving chain of bucket elevator
4) Damage of turn table and driving chain of bucket elevator　etc.

(3) Abrasion and wear of hydraulic equipment

It must be confirmed abrasion and following defects in hydraulic equipment of unloader. These parts may be maintained and used continuously when defects in hydraulic equipment are minor. It must be exchanged to new parts when defects in hydraulic equipment are major.

1) Abrasion of hydraulic equipment
2) Status of lubricant oil of hydraulic equipment
3) Damage of contact face of hydraulic equipment
4) Damage of hydraulic equipment　etc.

http://www.thyssenkrupp.com/en/presse/bilder.html&photo_id=832

Photo 167-a2-1 Bucket type unloader

http://www.visualphotos.com/image/1x3747038/coal_unloader_continuous_coal_unloader_working_in

Photo 167-a2-2 Wheel type unloader

2. Stacker

It must be regulated overhaul and inspection interval based on manufacture manual and actual operation status etc. and conducted overhaul and inspection of stacker.

(1) Abrasion and wear of bearing

It must be confirmed abrasion and following wears of bearing of stacker. These parts may be maintained and used continuously when wears in bearing are minor. It must be exchanged to new parts when defects in bearing are major.

1) Abrasion of bearing
2) Sticking of bearing
3) Damage of contact face of bearing
4) Status of lubricant oil of bearing
5) Foreign objects in bearing etc.

(2) Abrasion and wear of traveling rail

It must be confirmed abrasion and following wears of traveling rail of stacker. These parts may be maintained and used continuously when wears of traveling rail are minor. It must be exchanged to new parts when wears of traveling rail are major.

1) Abrasion of traveling rail
2) Crack of traveling rail
3) Abnormal contact of traveling rail etc.

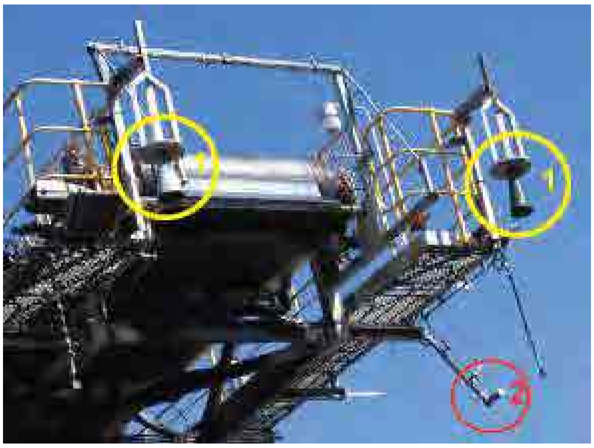
(3) Abrasion and wear of chute liner

It must be confirmed abrasion and following wears of chute liner of stacker. These parts may be maintained and used continuously when wears of chute liner are minor. It must be exchanged to new parts when wears of chute liner are major.

1) Abrasion of chute liner
2) Crack of chute liner

3) Falling of chute liner

4) Damage of chute liner etc.



http://www.hawkmeasure.com/files/Boomprotection.pdf

Photo 167-a2-3 Boom luffing control and microwave switch for boom protection

http://www.hawkmeasure.com/files/Boomprotection.pdf

Photo 167-a2-4 Stacker

3. Reclaimer

It must be regulated overhaul and inspection interval based on manufacture manual and actual operation status etc. and conducted overhaul and inspection of reclaimer.

(1) Abrasion and wear of bearing

It must be confirmed abrasion and following wears of bearing of reclaimer. These parts may be maintained and used continuously when wears in bearing are minor. It must be exchanged to new parts when defects in bearing are major.

1) Abrasion of bearing

2) Sticking of bearing

3) Damage of contact face of bearing

4) Status of lubricant oil of bearing

5) Foreign objects in bearing etc.

(2) Abrasion and wear of traveling rail

It must be confirmed abrasion and following wears of traveling rail of reclaimer. These parts may be maintained and used continuously when wears of traveling rail are minor. It must be exchanged to new parts when wears of traveling rail are major.

1) Abrasion of traveling rail

2) Crack of traveling rail

3) Abnormal contact of traveling rail etc.

(3) Abrasion and wear of chute liner

It must be confirmed abrasion and following wears of chute liner of reclaimer. These parts may be maintained and used continuously when wears of chute liner are minor. It must be exchanged to new parts when wears of chute liner are major.

1) Abrasion of chute liner

2) Crack of chute liner

3) Falling of chute liner

4) Damage of chute liner etc.

http://www.imscontracting.com/experience/industrial-experience/

http://www.imscontracting.com/experience/industrial-experience/

Photo 167-a2-5 Replacement of bucket wheel drive

http://www.bmgtampa.com/vulcanizing.html

http://www.bmgtampa.com/vulcanizing.html

Photo 167-a2-6 Replacement of reclaimer belt

4. Belt conveyor

It must be regulated overhaul and inspection interval based on manufacture manual and actual operation status etc. and conducted overhaul and inspection of belt conveyor.

(1) Abrasion and wear of bearing

It must be confirmed abrasion and following wears of bearing of belt conveyor. These parts may be maintained and used continuously when wears in bearing are minor. It must be exchanged to new parts when defects in bearing are major.

1) Abrasion of bearing

2) Sticking of bearing

3) Damage of contact face of bearing

4) Status of lubricant oil of bearing

5) Foreign objects in bearing etc.

(2) Abrasion and wear of reduction gear

It must be confirmed abrasion and following wears of reduction gear of belt conveyor. These parts may be maintained and used continuously when wears in reduction gear are minor. It must be exchanged to new parts when defects in reduction gear are major.

1) Abrasion of reduction gear

2) Crack of reduction gear

3) Sticking of contact face of reduction gear

4) Damage of contact face of reduction gear

5) Status of lubricant oil of reduction gear

6) Foreign objects in reduction gear etc.

(3) Abrasion and wear of pulley lining

It must be confirmed abrasion and following wears of pulley lining of belt conveyor. These parts may be maintained and used continuously when wears in pulley lining are minor. It must be exchanged to new parts when defects in pulley lining are major.

1) Abrasion of pulley lining

2) Crack of pulley lining

3) Damage of pulley lining etc.

http://www.ccplindia.in/belt-conveyor-maintenance.htm

http://belterz.com/conveyor-belt-maintenance/

Photo 167-a2-7 Repair of belt conveyor

5. Coal bunker

It must be regulated overhaul and inspection interval based on manufacture manual and actual operation status etc. and conducted overhaul and inspection of coal bunker.

(1) Confirmation of corrosion and abrasion of inner face of steel plate and other parts

It must be confirmed corrosion and abrasion of inner face of steel plate and other parts. It must be ground down corrosion portion and welded it when it is minor damage. It must be taken appropriate measures depending on degree of defect when detecting defect at inner face of steel plate and other parts of coal bunker.

(2) Confirmation of falling of lining

It must be confirmed falling of lining of coal bunker. It must be removed in coal bunker surely because there is a possibility that fallen lining is plugged up coal gate. It must be welded new lining steadily to fallen portion.

(3) Confirmation of abrasion and damage of roller, gate plate, bearing and gear of coal gate

It must be confirmed abrasion and damage of roller, gate plate, bearing and gear of coal gate. These parts may be maintained and used continuously when abrasion and damage of parts are minor. It must be exchanged to new parts when abrasion and damage are major.

http://www.flickr.com/photos/26212362@N06/2548321003/

Photo 167-a2-8 Inspection of coal bunker lining

http://www.informa.com.au/download/Yallourn.pdf

Photo 167-a2-9 Lining of coal bunker

6. Coal feeder

It must be regulated overhaul and inspection interval based on manufacture manual and actual operation status etc. and conducted overhaul and inspection of coal feeder.

(1) Confirmation of defect in reduction gears

It must be confirmed following defects in reduction gears of coal feeder. These parts may be maintained and used continuously when defects in reduction gears are minor. It must be exchanged to new parts when defects in reduction gear are major.

1) Abrasion of reduction gears
2) Crack of reduction gears
3) Abnormal contact of reduction gears
4) Foreign objects of reduction gears

(2) Confirmation of abrasion and wear of table partition plate and chute liner

It must be confirmed abrasion and wear of table partition plate and chute liner of coal feeder. These parts may be maintained and used continuously when defects in table partition plate and chute liner are minor. It must be exchanged to new parts when defects in table partition plate and chute liner are major.

(3) Confirmation of defect in chute

It must be confirmed following defects in chute of coal feeder. These parts may be maintained and used continuously when defects in chute are minor. It must be exchanged to new parts when defects in chute are major.

1) Abrasion of chute

2) Damage of chute

http://www.yamato-scale.co.jp/en/product/pdf/17_1.pdf

Photo 167-a2-10 Removed weighing conveyor for inspection

http://www.yamato-scale.co.jp/en/product/pdf/17_1.pdf

Photo 167-a2-11 Coal feeder

7. Coal pulverizer

It must be regulated overhaul and inspection interval based on manufacture manual and actual operation status etc. and conducted overhaul and inspection of coal pulverizer.

(1) Pulverize section

1) Confirmatory inspection

It must be conducted test and confirmed following items of coal pulverizer by checking electric current etc to check pulverization capacity (gap between pulverizing turn table and pulverizing roller etc.) .

a. Electrical power consumption of coal pulverizer

b. Vibration of coal pulverizer

c. Outlet oil pressure of coal pulverizer roller load hydraulic oil pump

2) Open inspection

It must be regulated overhaul and inspection interval based on manufacture manual and actual operation status etc. and conducted overhaul and inspection of pulverize section of coal pulverizer.

a. Confirmation of crack, abrasion and falling of liner and wedge bar

It must be confirmed crack, abrasion and falling of liner and wedge bar of coal pulverizer. These parts may be maintained and used continuously when defects in liner and wedge bar are minor. It must be exchanged to new parts when defects in liner and wedge bar are major. It must be removed fallen liner and wedge in coal pulverizer surely.

b. Confirmation of crack, abrasion, deformation and wear of ring, ball and roller

It must be confirmed crack, abrasion, deformation and wear of ring, ball and roller of coal pulverizer. These parts may be maintained and used continuously when defects in ring, ball and roller are minor. It must be exchanged to new parts when defects in ring, ball and roller are major.

c. Confirmation of abrasion and wear of roller shaft, roller bearing and pin

It must be confirmed abrasion and wear of roller shaft, roller bearing and pin of coal pulverizer. These parts may be maintained and used continuously when defects in roller shaft, roller bearing and pin are minor. It must be exchanged to new parts when defects in roller shaft, roller bearing and pin are major.

http://www.rpmandassociates.com/CoalPulverizerTables.aspx

Photo 167-a2-12 Rebuilt segment

http://www.rpmandassociates.com/CoalPulverizerRolls.aspx

Photo 167-a2-13 Template inspection

(2) Separator (including seal box)

It must be regulated overhaul and inspection interval and conducted overhaul and inspection of separator of coal pulverizer.

1) General

a. Confirmation of defect in pressure detector pipe

It must be confirmed following defect in pressure detector pipe of coal pulverizer. These parts may be maintained and used continuously when defects of parts are minor. It must be exchanged to new parts when defects are major.

(a) Crack of pressure detector pipe

(b) Abrasion of pressure detector pipe

(c) Plugging of pressure detector pipe

b. Confirmation of crack and deformation of seal box

It must be confirmed crack and deformation of seal box of coal pulverizer. These parts may be maintained and used continuously when defects of parts are minor. It must be exchanged to new parts when defects are major.

c. Confirmation of plugging of seal box and seal air piping

It must be confirmed plugging of seal box and seal air piping of coal pulverizer. It must be removed plugging of seal box and seal air piping and confirmed that it is operated normally. It must be exchanged to new parts if necessary.

2) Horizontal type coal pulverizer

a. Confirmation of defect of ribbon conveyor

It must be confirmed defect of ribbon conveyor of coal pulverizer. It must be taken appropriate measures depending on degree of defect when detecting defect at ribbon conveyor of coal pulverizer.

b. Confirmation of crack, abrasion and wear of trunnion piping and coarse coal separator

It must be confirmed crack, abrasion and wear of trunnion piping and coarse coal separator of coal pulverizer. These parts may be maintained and used continuously when defects of parts are minor. It must be exchanged to new parts when defects are major.

c. Confirmation of abrasion and fracture of flight bar

It must be confirmed abrasion and fracture of flight bar of coal pulverizer. These parts may be maintained and used continuously when defects of parts are minor. It must be exchanged to new parts when defects are major.

3) Vertical type coal pulverizer

a. Confirmation of fouling, abrasion and wear of coarse coal separator vane

It must be confirmed fouling, abrasion and wear of coarse coal separator vane of coal pulverizer. It must be removed fouling from coarse coal separator vane and confirmed that it is operated normally. These parts may be maintained and used continuously when defects of parts are minor. It must be exchanged to new parts when defects are major.

b. Confirmation of fouling, abrasion and wear of foreign object discharging chute

It must be confirmed fouling, abrasion and wear of foreign object discharging chute of coal pulverizer. It must be removed fouling from foreign object discharging chute and confirmed that it is operated normally. These parts may be maintained and used continuously when defects of parts are minor. It must be exchanged to new parts when defects are major.

c. Confirmation of fouling, abrasion and wear of rotary separator blade

It must be confirmed fouling, abrasion and wear of rotary separator blade of coal pulverizer. It must be removed fouling from rotary separator blade and confirmed that it is operated normally. These parts may be maintained and used continuously when defects of parts are minor. It must be exchanged to new parts when defects are major.

(3) Drive section

It must be regulated overhaul and inspection interval and conducted overhaul and inspection of drive section of coal pulverizer.

1) Confirmation of defect in main shaft, pinion shaft, bearing and sealed section

It must be confirmed following defect in main shaft, pinion shaft, bearing and sealed section of coal pulverizer. These parts may be maintained and used continuously when defects of parts are minor. It must be exchanged to new parts when defects are major.

a. Crack of main shaft, pinion shaft, bearing and sealed section

b. Abrasion of main shaft, pinion shaft, bearing and sealed section

c. Wear of main shaft, pinion shaft, bearing and sealed section

2) Confirmation of crack, abrasion and contact of gear

It must be confirmed crack, abrasion and contact of gear of coal pulverizer. These parts may be maintained and used continuously when defects of parts are minor. It must be exchanged to new parts when defects are major.

(4) Lubricant oil system

It must be regulated overhaul and inspection interval and conducted overhaul and inspection of lubricant oil system of coal pulverizer.

1) Confirmation of degradation of lubricant oil

It must be confirmed degradation of lubricant oil of coal pulverizer. It must be confirmed degradation of lubricant oil of degasification tower. It must be exchanged to new lubricant oil or charged additional lubricant oil when it is significant degradation or decreasing lubricant oil volume is large. When lubricant oil is exchanged or charged, it must be charged regulated lubricant oil brand and oil volume based on manufacture's recommendation or actual operation status. If other lubricant oil is exchanged or charged, there is a possibility that pulverizer cannot generate qualified performance.

2) Confirmation of sludge and foreign object in sump

It must be confirmed sludge and foreign object in sump of coal pulverizer. It must be removed sludge from sump.

3) Confirmation of defect in oil pump and strainer

It must be confirmed following defect in oil pump and strainer of coal pulverizer. These parts may be maintained and used continuously when defects of parts are minor. It must be exchanged to new parts when defects are major.

a. Crack of oil pump
b. Abrasion of oil pump
c. Oil leakage of oil pump
d. Plugging of strainer

http://www.ubetechno.co.jp/enterprises/mill/maintenance

Photo 167-a2-14 Repaired white metal

http://www.ubetechno.co.jp/enterprises/mill/maintenance

Photo 167-a2-15 Removal of roller tire

http://www.rpmandassociates.com/CoalPulverizerJournals.aspx

Photo 167-a2-16 Bearing failure

http://www.rpmandassociates.com/CoalPulverizerJournals.aspx

Photo 167-a2-17 Laser repair of Journal shaft

Table 167-a2-1 Content of inspection for pulverizer at the periodic inspection

Oblect	Inspection items	Inspection method	Criteria	Measure at the non-conformity
PA air	Wear situation of scraper	VT, measurement	Clearance between	To replace scraper with new one
	Status of deposits of coal, ash and foreign matter	VT	No abnormal deposition	To remove deposition
	Status of junction with PA air duct	VT	No burning, crack, distortion	To repair after confirmation or replacement
Crushing part	Status of wear resistant part such as crushing roller and table	VT, measurement	Amount of wear to be within tolerance	Repair welding in case of welding type, replace with new one in case of wear resistant casr iron
			To plan repairing or raplacement of wear resistant part in the next periodic inspection according to the measurement result of amount of wear	
	Status of lubricant for bearing of crushing roller	VT	No foreign matter such as iron in lubrication oil	Overhaul and inspection of roller bearing unit
			To change lubricant with new one at every periodic inspection	
	Status of primary air vent hole	VT	No crack and abnormal wear	Repair welding or replacement with new one
	Status of clearance between crushing table and mill casing	VT, measurement	No intrusion of freign matter	To repair after removal of foreign matter, confirmation
			No nallow place locally	
	Status of wear of mill casing	VT	No place with abnolmal wear	To repair after confirmation
	Status of pressure device for crushing roller	VT	No abnormal wear	To repair after removal of foreign matter, confirmation
			No intrusion of foreign matter and abnormal wear on sliding part and moving part	
	Status of installation of crushing roller and pressure device	VT	To be according to the design value	To adjust to suit design value
Separator of pulverized coarse coal	Status of wing for pulverized coarse coal separator	VT	No abnormal wear	Repair welding or replacement with new one
	Status of drive unit for separator of pulverized coarse coal separator	VT	No damage, wear, blockage	To repair after confirmation or replacement with new one
			Proper lubricant to be supplied to bearing and driving part	
Mill outlet	Status of outlet damper	VT	No abnolmal wear	To repair after confirmation
			No large clearance on working face of damper	
Others	Deposition of coal and pulverized coal	VT	No abnormal deposition	To remove deposition
	Status of dust seal/oil seal	VT	No abnormal wear, intrusion of foreign matter, deformation, damage	To replace with new seal
	Gas/air leakage	VT	No leakage on flange, piping connection, moving part and penetration part	To repair after confirmation
	Oil leakage	VT	No leakage of lubricant for bearing, reduction gear, pressure device for crushing roller	To repair after confirmation
	Oil level	VT	Specified amount of oil to be supplied to bearing, oil unit and pressure unit	To make-up required to level
			To be confirmed specified oil level	It is necessart to overhaul and inspect, if large amount of foreign matter such as iron powder is contained.
			To be replaced with new oil at every periodic inspection	
	Tightness of bolt	Hammering	No loose	To tighten up

8. Pulverized coal piping

(1) Open inspection

It must be regulated overhaul and inspection interval and conducted overhaul and inspection of pulverized coal piping.

1) Confirmation of pulverized coal leak

It must be confirmed pulverized coal leakage of pulverized coal piping. It must be maintained this leakage portion when detecting coal leakage. It must be maintained this portion when detecting piping portion suspected coal leakage at inspection of pulverized coal piping.

2) Confirmation of abrasion of each portion (especially, bent piping, distributor and orifice)

It must be confirmed abrasion of each portion of pulverized coal piping. These parts may be maintained and used continuously when defects of parts are minor. It must be exchanged to new parts when defects are major.

3) Confirmation of defect in purge equipment

It must be confirmed defect in purge equipment of pulverized coal piping. These parts may be maintained and used continuously when defects of parts are minor. It must be exchanged to new parts when defects are major.

Article167-a3 Oil handling facilities

1. Heavy oil pump, light oil pump

It must be confirmed defect in pump by checking pump outlet oil pressure. When it is high or low compared to rated oil pressure, it must be overhauled and inspected.

It must be regulated overhaul and inspection interval based on manufacture manual and actual operation status etc. and conducted overhaul and inspection of heavy oil pump and light oil pump.

(1) Confirmation of abrasion of each part of rotor

It must be overhauled and confirmed abrasion of following each part of rotor of heavy oil pump and light oil pump. Rotor may be maintained and used continuously when defects of rotor are minor. It must be exchanged to new parts when defects are major.

1) Contact surface to gear and casing

2) Contact surface to bearing etc.

(2) Confirmation of damaged status of shaft, bearing and mechanical seal

It must be overhauled and confirmed following damaged status of shaft, bearing and mechanical seal of heavy oil pump and light oil pump. Shaft, bearing and mechanical seal may be maintained and used continuously when defects of shaft, bearing and mechanical seal are minor. It must be exchanged to new parts when defects are major.

1) Shaft

Abrasion, crack, corrosion and damage

2) Bearing

Abrasion, corrosion and damage

3) Mechanical seal

Abrasion, corrosion and damage

(3) Confirmation of abrasion status of oil seal and other parts

It must be overhauled and confirmed following abrasion status of oil seal and other parts of heavy oil pump and light oil pump. These parts may be maintained and used continuously when defects of them are minor. It must be exchanged to new parts when defects are major.

1) Oil seal

2) Impeller

3) Inner face of casing

4) Coupling etc.

http://www.sanko-pump.co.jp/item02_e.html

Photo 167-a3-1 Twin gear pump

http://www.seekpart.com/company/53779/products/2011720162041209.html

Photo 167-a3-2 Oil transfer gear pump

2. Heavy oil heater

It must be regulated overhaul and inspection interval based on manufacture manual and actual operation status etc. and conducted overhaul and inspection of heavy oil heater.

(1) Confirmation of corrosion and erosion of main body and tube

It must be overhauled and confirmed corrosion and erosion of main body and tube of heavy oil heater. It must be checked carefully on this matter because corrosion and erosion of tube raises tube leakage. It must be ground down corrosion and erosion portion and welded it when it is minor damage. It must be exchanged to new parts when defects are major.

(2) Confirmation of crack and wear of expanded tube part

It must be overhauled and confirmed crack and wear of expanded tube part of heavy oil heater. It must be ground down crack and welded it when it is minor damage. It must be exchanged to new parts when defects are major.

(3) Confirmation of crack and wear of tube plate and divider plate

It must be overhauled and confirmed crack and wear of tube plate and divider plate of heavy oil heater. It must be ground down crack and welded it when it is minor damage. It must be exchanged to new parts when defects are major.

http://www.calgavin.com/heat-exchanger-solutions/hitran-systems/benefits/

http://www.calgavin.com/heat-exchanger-solutions/hitran-systems/benefits/

Photo 167-a3-3 Heavy oil heater

3. Piping and valve

It must be regulated overhaul and inspection interval based on manufacture manual and actual operation status etc. and conducted overhaul and inspection of piping and valve.

(1) Defect and fouling of strainer

It must be overhauled and confirmed defect and fouling of strainer. It must be cleaned plugged strainer and removed fouling from it. It must be exchanged to new strainer when plugging or damage of strainer is major.

(2) Leakage of valve

It must be overhauled and confirmed leakage of valve on following part. These parts may be maintained and used continuously when defects in valve are minor. It must be exchanged to new parts when defects in valve are major.

1) Gland packing

2) Flange surface (Packing)

3) Valve sheet etc.

(3) Breakage of valve, coupling and flexible tube etc.

It must be overhauled and confirmed breakage valve, coupling and flexible tube etc. of following part. These parts may be maintained and used continuously when defects in valve are minor. It must be exchanged to new parts when defects in valve are major.

1) External appearance of valve (including painting)

2) External appearance of coupling (including painting)

3) External appearance of flexible tube (expansion and contraction part) etc.

Article167-a4　Gas handling facilities

1. Gas piping and valve

It must be regulated overhaul and inspection interval based on manufacture manual and actual operation status etc. and conducted overhaul and inspection of gas piping and valve.

(1) Gas leakage check of piping, valve and burner

It must be overhauled and confirmed gas leakage check of piping, valve and burner on following part according to following test procedure. It must be maintained leakage part or exchanged to new parts properly to stop leakage when detecting leakage of gas because it cause fire.

1) Confirmatory part

a. Coupling between burner and piping

b. Coupling between valve and piping etc.

2) Airtight test procedure

a. It must be used air and nitrogen etc. which is not hazardous.

b. It must be conducted test by gas pressure more than maximum allowable working pressure.

c. It must be used bubble solution such as soap water etc. or gas for airtight test for leakage inspection of weld part and flange etc.

(2) Inspection of relief valve and safety valve

It must be overhauled and confirmed status of relief valve and safety valve on following part. These parts may be maintained and used continuously when defects in valve are minor. It must be exchanged to new parts when defects in valve are major.

1) Abrasion of relief valve and safety valve

2) Erosion and corrosion of relief valve and safety valve

3) Damage of relief valve and safety valve etc.

(3) Operating status and leakage of shutoff valve

It must be overhauled and confirmed operating status and leakage of shutoff valve according to following description.

1) Operating status of shutoff valve

After inspection, it must be conducted operation test of shutoff valve and confirmed it is operated properly. If it is not operated properly, it must be inspected shutoff valve once again and maintained defect of it or exchanged it to new parts. It must be conducted operation test until operating status of it is properly.

2) Leakage of shutoff valve

It must be overhauled and confirmed leakage of shutoff valve on following part according to following test procedure. These parts may be maintained and used continuously when defects in valve are minor. It must be exchanged to new parts when defects in valve are major.

a. Confirmatory part

(f) Gland part

(g) Coupling between valve and piping etc.

b. Airtight test procedure

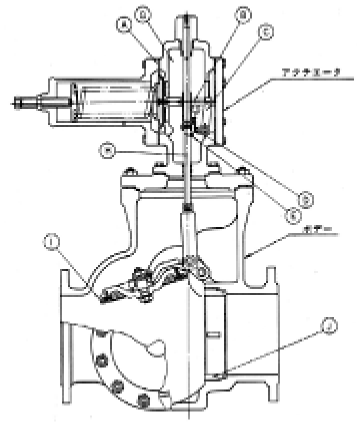
(a) It must be used air and nitrogen etc. which is not hazardous.

(b) It must be conducted test by gas pressure more than maximum allowable working pressure.

(c) It must be used bubble solution such as soap water etc. or gas for airtight test for leakage inspection of weld part and flange etc.

http://www.tokicotechno.co.jp/catalog_download/pdf/m1020.pdf

Photo 167-a4-1 High pressure shut-off valve



http://www.tokicotechno.co.jp/catalog_download/pdf/m1303.pdf

Photo 167-a4-2 Swing type shut-off valve

Article167-a5 Liquefied gas handling facilities

1. Vaporizer

It must be regulated overhaul and inspection interval based on manufacture manual and actual operation status etc. and conducted overhaul and inspection of vaporizer.

(1) Appearance check and overhaul

It must be conducted appearance check, overhaul and inspection of vaporizer on following part. These parts may be maintained and used continuously when defects in vaporizer are minor. It must be exchanged to new parts when defects in vaporizer are major.

1) Open rack

a. Panel

(a) Status of erosion of heat exchanger tube header

(b) Status of deformation of heat exchanger tube

(c) Status of foreign object (sea grass, seashell) on panel surface etc.

b. Others

(a) Status of foreign object (sea grass, seashell) in trough of sprinkler system

(b) Measurement of radial thickness of auxiliary piping if necessary

(c) Status of rubber lining etc.

2) Wet type

a. Heater exchanger

(a) Status of erosion of heat exchanger tube header etc.

b. Others

(a) Inspection of spark gap of burner

(b) Inspection of coating inside tank etc.

(2) Overhaul of safety valve

It must be conducted overhaul and inspection of safety valve on following part. These parts may be maintained and used continuously when defects in safety valve are minor. It must be exchanged to new parts when defects in safety valve are major.

1) Overhaul and inspection

a. Crack, abrasion, foreign object and corrosion of disc and sheet

b. Interference and free length of spring

c. Position of adjust ring

d. Crack, deformation, curvature and contact on edge of stem etc.

2) Operation test

After assembling, it must be conducted operation test by using nitrogen according to following procedure and confirmed it is operated properly. If it is not operated properly, it must be inspected safety valve once again and maintained defect in it or exchanged it to new parts. It must be conducted operation test until operating status of it is properly.

a. It must be conducted safety valve test by using temporary operation test system.

b. It must be opened Valve-A gradually and pressurized safety valve.

c. It must be confirmed popping pressure when safety valve is operated and closed valve-A and confirmed reseating pressure.

http://www.zz-fujikoatsu.co.jp/service/index.html

http://www.kansai.jsme.or.jp/mecha2012/company/detail2.php?no=ha_08

Photo 167-a5-1 Inspection of safety valve

(3) Operation test of some gas detectors

It must be conducted operation test of typical gas detectors according to following procedure. These parts may be maintained and used continuously when defects in gas detector are minor. It must be exchanged to new parts when defects in gas detector are major.

1) It must be confirmed that gas detectors operate normally by this test.

2) It must be used test gas at operation test.

3) It must be confirmed that time lag to transmit alarm is within 30 seconds by using gas 1.6 times as consistency as alarm set value.

4) It must be confirmed that it is within 60 seconds in case of particular gas.

5) If operation test of gas detector is conducted periodically, you may confirm this test result instead of operation test.

http://www.chiyodasecurity.jp/intro_gm.html

Photo 167-a5-2 Open inspection of LNG vaporizer

http://www.chiyodasecurity.jp/intro_gm.html

Photo 167-a5-3 Open inspection of air fin vaporizer

2. Storage Tank

It must be regulated overhaul and inspection interval based on manufacture manual and actual operation status etc. and conducted overhaul and inspection of storage tank.

(1) Appearance check

It must be conducted appearance check of storage tank on following part. These parts may be maintained and used continuously when defects in storage tank are minor. It must be exchanged to new parts when defects in storage tank are major.

1) Status of rust, deformation and damage at each part of storage tank body

a. Storage tank external surface

b. Contact point with auxiliary devices

c. Painting etc.

2) Status of crack and damage at foundation of storage tank

3) Status of deformation and fracture of manhole, water spray bar, atmospheric escape pipe etc.

4) Status of peeling and fracture of sealing agent under storage tank

(2) Settling measurement

1) It must be conducted settling measurement and confirmed differential settlement is occurred.

2) It must be confirmed following part of storage tank in case of significant differential settlement.

a. Thickness of bottom of storage tank

b. Damage, crack and erosion etc. of weld part etc.

3) It must be maintained defect in storage tank in case of confirming it.

4) If settling measurement is conducted periodically, you may confirm this test result instead of settling measurement.

(3) Overhaul and inspection of safety valve

It must be conducted overhaul and inspection of safety valve on following part. These parts may be maintained and used continuously when defects in safety valve are minor. It must be exchanged to new parts when defects in safety valve are major.

1) Overhaul and inspection

a. Crack, abrasion, foreign object and corrosion of disc and sheet

b. Interference and free length of spring

c. Position of adjust ring

d. Crack, deformation, curvature and contact on edge of stem etc.

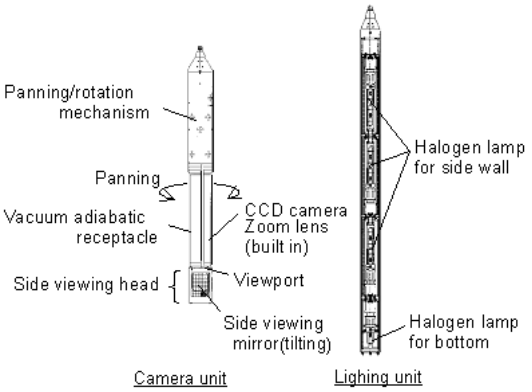
2) Operation test

After assembling, it must be conducted operation test by using nitrogen according to following procedure and confirmed it is operated properly. If it is not operated properly, it must be inspected safety valve once again and maintained defect in it or exchanged it to new parts. It must be conducted operation test until operating status of it is properly.

a. It must be conducted safety valve test by using temporary operation test system.

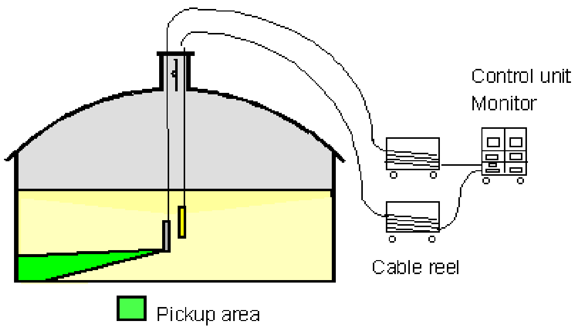
b. It must be opened Valve-A gradually and pressurized safety valve.

c. It must be confirmed popping pressure when safety valve is operated and closed valve-A and confirmed reseating pressure.



http://www.tokyo-gas.co.jp/techno/stp3/02a3_e.html

Photo 167-a5-4 Basic structure of the observation device (TOKYO GAS)



http://www.tokyo-gas.co.jp/techno/stp3/02a3_e.html

Photo 167-a5-5 System of observation device

3. Gas piping

It must be regulated overhaul and inspection interval based on manufacture manual and actual operation status etc. and conducted overhaul and inspection of gas piping.

(1) Operation test of some gas detectors

It must be conducted operation test of typical gas detectors according to following procedure. These parts may be maintained and used continuously when defects in gas piping are minor. It must be exchanged to new parts when defects in gas piping are major.

1) It must be confirmed that gas detectors operate normally by this test.

2) It must be used test gas at operation test.

3) It must be confirmed that time lag to transmit alarm is within 30 seconds by using gas 1.6 times as consistency as alarm set value.

4) It must be confirmed that it is within 60 seconds in case of particular gas.

5) If operation test of gas detector is conducted periodically, you may confirm this test result instead of operation test.

(2) Settling measurement

1) It must be conducted settling measurement and confirmed differential settlement is occurred.

2) It must be confirmed settling value by using spirit level through settling rod in case of underground gas piping.

3) It must be confirmed settling value of foundation in case of gas piping on the ground.

4) It must be confirmed following part of gas piping on the ground in case of significant differential settlement.

a. Thickness of bottom of gas piping

b. Damage, crack and erosion etc. of weld part etc.

5) It must be maintained defect in gas piping in case of confirming it.

6) If settling measurement is conducted periodically, you may confirm this test result instead of settling measurement.

(3) Corrosion current measurement

1) It must be conducted corrosion current measurement and confirmed corrosion of underground gas piping.

2) If settling corrosion current measurement is conducted periodically, you may confirm this test result instead of corrosion current measurement.

4. Gas compressor

It must be regulated overhaul and inspection interval based on manufacture manual and actual operation status etc. and conducted overhaul and inspection of gas compressor.

(1) Overhaul and inspection

It must be conducted overhaul and inspection of gas compressor on following part. These parts may be maintained and used continuously when defects in gas compressor are minor. It must be exchanged to new parts when defects in gas compressor are major. If overhaul and inspection are conducted periodically by managing operating time etc. according to feature of equipment, you may confirm this result instead of overhaul and inspection.

1) Reciprocal engine type

a. Frame

(a) Clearance measurement of bearing and crosshead

(b) Crack and deformation of connecting rod

(c) Lubricant oil volume

b. Cylinder

(a) Fluctuation of cylinder

(b) Abrasion and damage of piston ring, packing and seal ring etc.

(c) Clearance measurement of piston outer shape and piston end

c. Lubricant oil system

(a) Gear and bearing of oil pump

(b) Erosion, leakage and crack of oil cooler tube

d. Airtight test by using nitrogen (After assembling)

e. Leak test by gas detector (After assembling)

2) Turbo engine type

a. Gas compressor body

(a) Damage and abrasion of rotor, bearing, casing and impeller etc.

(b) Alignment

b. Lubricant oil system

(a) Gear and bearing of oil pump

(b) Erosion, leakage and crack of oil cooler tube

c. Airtight test by using nitrogen (After assembling)

d. Leak test by gas detector (After assembling)

5. Valve

It must be regulated overhaul and inspection interval based on manufacture manual and actual operation status etc. and conducted overhaul and inspection of valve.

(1) Shut off valve

It must be conducted overhaul and inspection of shut off valve on following part. These parts may be maintained and used continuously when defects in it are minor. It must be exchanged to new parts when defects in it are major.

1) Valve body

a. Crack, abrasion, curvature and deformation of stem, valve element and inner face of valve casing

b. Abrasion, corrosion and crack of disc and seat

2) Drive system

a. Rust, damage and infiltration of rainwater

3) Operation test

After assembling, it must be conducted operation test of shutoff valve and confirmed it is operated properly. If it is not operated properly, it must be inspected shutoff valve once again and maintained defect of it or exchanged it to new parts. It must be conducted operation test until operating status of it is properly.

(2) General valve

It must be referred to above 1) Valve body of (1) Shut off valve.

6. Loading arm

It must be regulated overhaul and inspection interval based on manufacture manual and actual operation status etc. and conducted overhaul and inspection of loading arm on following part. These parts may be maintained and used continuously when defects in it are minor. It must be exchanged to new parts when defects in it are major.

(1) Loading arm body

1) Crack and damage of bearing and weld part

2) Erosion and peeling of painting

3) Curvature of arm

(2) Oil pressure system

1) Abrasion of rotor, bearing and oil seal of oil pump

2) Abrasion, corrosion and leakage of relief valve and selector valve

3) Plugging and fouling of oil filter

(3) Oil pressure cylinder

1) Abrasion and damage of arm drive oil pressure cylinder and oil pressure piping swing elbow

http://www.niigata-ls.co.jp/jp/products/loading_arm/cs/index.html#pagetop

Photo 167-a5-6 Inspection of loading arm

http://www.niigata-ls.co.jp/jp/products/loading_arm/cs/index.html#pagetop

Photo 167-a5-7 Inspection of loading arm link

Table 167-a5-1 Recommended interval of periodic inspection for loading arm

http://www.niigata-ls.co.jp/jp/products/loading_arm/cs/interval.html

Part	Fluid	Interval of periodic inspection
Swivel joint	Heavy oil/ clued oil	Once in 4~6 years
	Kerosene/ light oil	Once in 3~4 years
	Gasoline/ naphtha	Once in 3~4 years
	Room temperature LPG	Once in 3~4 years
	Low temperature LPG	Once in 2~3 years
	LNG	Once in 5~7 years
Hydraulic equipment	Replacement of hydraulic oil	Once in 1~3 years
	Hydraulic cylinder	Once in 3~5 years
	Hydraulic unit	Once in 4~5 years
	Replacement of filter element	Once in 1~3 years
	Hydraulic oil hose	Once in 4~5 years
Wire cable	Cable fitting and turnbuckle	Once in 5 years
	Wire cable	Those when abnormalities are observed or which is older than 10 years after delivery unless without no damage on the exterior.
Bolt & nut	30% sampling inspection	Once in 5 years
	Replacement	Those when abnormalities are observed or which is older than 10 years after delivery unless without no damage on the exterior.
Others	Machinery equipment, electrical system	Once in 4~5 years
	Balance unit	Those when abnormalities are observed or which is older than 10 years after delivery unless without no damage on the exterior.

Article167-a6 Coal-ash treatment facilities

1. Coal-ash treatment facilities

It must be regulated overhaul and inspection interval based on manufacture manual and actual operation status etc. and conducted overhaul and inspection of coal-ash treatment facilities on following part and defect. These parts may be maintained and used continuously when defects in it are minor. It must be exchanged to new parts when defects in it are major.

(1) Defect in diaphragm, lot, dust seal, pulley, bearing, leaf (spring plate) and belt of vibrator

1) Abrasion

2) Erosion and corrosion

3) Crack

4) Damage etc.

(2) Defect in vane, bearing, casing, damper, spray nozzle and air seal etc. of dustless unloader

1) Abrasion

2) Erosion and corrosion

3) Crack

4) Damage etc.

(3) Status of rotor, bearing and spray nozzle etc. of rotary feeder

1) Abrasion

2) Erosion and corrosion

3) Crack

4) Damage etc.

Article167-a7 Feed-water treatment facilities

1. Pretreatment equipment

(1) Coagulation sedimentation tank

It must be regulated overhaul and inspection interval based on manufacture manual and actual operation status etc. and conducted overhaul and inspection of coagulation sedimentation tank on following part and defect. These parts may be maintained and used continuously when defects in it are minor. It must be exchanged to new parts when defects in it are major.

1) Status of sediment

It must be cleared deposited sediment at the bottom of coagulation sedimentation tank. When disposing of it, it must be complied with government and province law.

2) Status of painting

It must be confirmed peeling of painting and rust of each part of coagulation sedimentation tank. It must be painted these parts because external surface of coagulation sedimentation tank is guarded against degradation (rust and corrosion). When it is significant rust, it must be exchanged to new parts.

3) Crack of concrete

It must be confirmed crack and damage of concrete part of coagulation sedimentation tank. When it is significant damage of foundation, it must be maintained these parts properly consulting with civil engineer.

(2) Blending machine

It must be regulated overhaul and inspection interval based on manufacture manual and actual operation status etc. and conducted overhaul and inspection of blending machine on following part and defect. These parts may be maintained and used continuously when defects in it are minor. It must be exchanged to new parts when defects in it are major.

1) Wear and painting of main body frame

It must be confirmed wear and peeling of painting of main body frame of blending machine. It must be painted these parts because external surface of blending machine is guarded against degradation (rust and corrosion). When it is significant wear or rust, it must be exchanged to new parts.

2) Abrasion of bearing and reduction gear

It must be confirmed abrasion, crack and damage of bearing and reduction gear of blending machine. It must be confirmed abrasion and damage of contact surface of rotor with bearing and reduction gear. When it is significant damage, it must be exchanged to new parts.

3) Deformation and wear of casing and rotor

It must be confirmed deformation and wear of casing and rotor of blending machine because deformation and wear of rotor cause damage of bearing. When it is significant damage, it must be exchanged to new parts.

(3) Filter

It must be regulated overhaul and inspection interval based on manufacture manual and actual operation status etc. and conducted overhaul and inspection of filter on following part and defect. These parts may be maintained and used continuously when defects in it are minor. It must be exchanged to new parts when defects in it are major.

1) Pollution of filter media

It must be confirmed pollution of filter media. It must be exchanged to new filter media when it is significant pollution. When filter media is exchanged, it must be charged regulated filter media based on manufacture's recommendation or actual operation status. If other filter media is charged, there is a possibility that filter can not generate qualified performance.

2) Decrease of filter media

It must be confirmed decreasing volume of filter media. It must be charged to new filter media when decreasing volume of filter media is significant. When filter media is charged, it must be charged regulated volume based on manufacture's recommendation or actual operation status. If charging filter media is low or large, there is possible that filter can not generate qualified performance.

3) Defect in water catchment and spray equipment

It must be confirmed following defects in each part of water catchment and spray equipment.

a. Abrasion

b. Erosion and corrosion

c. Crack

d. Damage etc.

(4) Chemical pump

It must be regulated overhaul and inspection interval based on manufacture manual and actual operation status etc. and conducted overhaul and inspection of chemical pump on following part and defect. These parts may be maintained and used continuously when defects in it are minor. It must be exchanged to new parts when defects in it are major.

1) Plunger type

a. Abrasion of plunger

It must be confirmed abrasion of plunger of plunger type chemical pump. It must be confirmed contact surface of casing and packing gland with plunger. It is recommended that it is confirmed erosion and corrosion of plunger of chemical pump.

b. Defect in ball check and ball sheet

It must be confirmed following defect in ball check and ball sheet of plunger type chemical pump. When it is significant defect, it must be exchanged to new parts.

(a) Abrasion

(b) Erosion and corrosion

(c) Crack etc.

c. Defect in speed reduction mechanism

It must be confirmed following defect in speed reduction mechanism of plunger type chemical pump. When it is significant defect, it must be exchanged to new parts.

(a) Abrasion

(b) Crack

(c) Erosion and corrosion

(d) Damage etc.

2) Diaphragm type

a. Abrasion of plunger

It must be confirmed abrasion of plunger of diaphragm type chemical pump. It must be confirmed contact surface of casing and packing gland with plunger. It is recommended that it is confirmed erosion and corrosion of plunger of chemical pump.

b. Defect in ball check and ball sheet

It must be confirmed following defect in ball check and ball sheet of diaphragm type chemical pump. When it is significant defect, it must be exchanged to new parts.

(a) Abrasion

(b) Erosion and corrosion

(c) Crack etc.

c. Degradation, abrasion and crack of Diaphragm

It must be confirmed of degradation, abrasion and crack of diaphragm of diaphragm type chemical pump. When it is significant defect, it must be exchanged to new parts.

2. Demineralizer

(1) Resin tower

It must be regulated overhaul and inspection interval based on manufacture manual and actual operation status etc. and conducted overhaul and inspection of resin tower on following part and defect. These parts may be maintained and used continuously when defects in it are minor. It must be exchanged to new parts when defects in it are major.

1) Quantity, performance, pollution level and particle size of resin

It must be confirmed quantity, performance, pollution levels and particle size of resin of resin tower. It must be exchanged to new resin or charged additional resin when it is significant pollution or decreasing resin volume is large. When resin is exchanged or charged, it must be charged regulated resin brand and resin volume based on manufacture's recommendation or actual operation status. If other resin is exchanged or charged, there is a possibility that resin tower can not generate qualified performance.

2) Breakage of internal device

It must be confirmed breakage and crack of internal device of resin tower. When it is significant defect, it must be exchanged to new parts.

3) Wear of rubber lining

It must be confirmed wear and crack of rubber lining of resin tower. When it is significant defect, it must be exchanged to new parts.

(2) Degasification tower

It must be regulated overhaul and inspection interval based on manufacture manual and actual operation status etc. and conducted overhaul and inspection of degasification tower on following part and defect. These parts may be maintained and used continuously when defects in it are minor. It must be exchanged to new parts when defects in it are major.

1) Wear of rubber lining

It must be confirmed wear and crack of rubber lining of resin tower. When it is significant defect, it must be exchanged to new parts.

2) Abrasion of nozzle

It must be confirmed abrasion and crack of nozzle of degasification tower. When it is significant defect, it must be exchanged to new parts. It is recommended that it is confirmed erosion and corrosion of nozzle of degasification tower.

3) Degradation of lubricant oil

It must be confirmed degradation of lubricant oil of degasification tower. It must be exchanged to new lubricant oil or charged additional lubricant oil when it is significant degradation or decreasing lubricant oil volume is large. When lubricant oil is exchanged or charged, it must be charged regulated lubricant oil brand and oil volume based on manufacture's recommendation or actual operation status. If other lubricant oil is exchanged or charged, there is a possibility that degasification tower can not generate qualified performance.

(3) Purified water tank

It must be regulated overhaul and inspection interval based on manufacture manual and actual operation status etc. and conducted overhaul and inspection of purified water tank on following part and defect. These parts may be maintained and used continuously when defects in it are minor. It must be exchanged to new parts when defects in it are major.

1) Wear of inside coating

It must be confirmed wear and peeling of inside coating of purified water tank. It must be painted these parts because internal surface of purified water tank is guarded against degradation (rust and corrosion). When it is significant damage, it must be exchanged to new parts.

2) Defect in level indicator

It must be confirmed following defect in level indicator of purified water tank. When it is significant defect, it must be exchanged to new parts.

a. Indication fault of level indicator

b. Erosion of level indicator

c. Corrosion of level indicator etc.

3) Deformation of tank

It must be confirmed deformation of purified water tank because there is a possibility that it causes water leakage from purified water tank and erosion at deformation part. When it is significant damage, it must be exchanged to new parts.

3. Condensate demineralizer

(1) Demineralization tower

It must be regulated overhaul and inspection interval based on manufacture manual and actual operation status etc. and conducted overhaul and inspection of demineralization tower on following part and defect. These parts may be maintained and used continuously when defects in it are minor. It must be exchanged to new parts when defects in it are major.

1) Wear of distributor of water service and resin transfer

It must be confirmed wear of distributor of water service and resin transfer of demineralization tower. When it is significant defect, it must be exchanged to new parts.

2) Wear of water catchment system

It must be confirmed wear of water catchment system of demineralization tower. When it is significant defect, it must be exchanged to new parts.

3) Peeling and wear rubber lining

It must be confirmed peeling, wear and crack of rubber lining of demineralization tower. When it is significant defect, it must be exchanged to new parts.

(2) Resin strainer

It must be regulated overhaul and inspection interval based on manufacture manual and actual operation status etc. and conducted overhaul and inspection of resin strainer on following part and defect. These parts may be maintained and used continuously when defects in it are minor. It must be exchanged to new parts when defects in it are major.

1) Plugging and fouling of wire sheet

It must be overhauled and confirmed plugging and fouling of wire sheet of resin strainer. It must be cleaned plugged strainer and removed fouling from it. It must be exchanged to new strainer when plugging or damage of strainer is major.

2) Discharged resin at bottom

It must be overhauled and confirmed discharged resin at bottom of resin strainer. It must be charged additional resin to resin strainer when it is discharged resin volume is large. When resin is charged, it must be charged regulated resin brand and resin volume based on manufacture's recommendation or actual operation status. If other resin is charged, there is a possibility that resin strainer can not generate qualified performance. Moreover, when it is discharged resin volume is significant large, it must be confirmed the reason why resin is discharged significantly and maintained it.

3) Leakage by hydraulic pressure test

It must be confirmed leakage from resin strainer by hydraulic pressure test. When conducting pressure test, it must be paid attention to following items.

a. It must be conducted pressure test by using water pressure regulated based on manufacture's recommendation or actual operation status.

b. It must be kept above water pressure for canonical time.

c. It must be confirmed leakage from flange or connecting part etc. of resin strainer.

(3) Regeneration tower

It must be regulated overhaul and inspection interval based on manufacture manual and actual operation status etc. and conducted overhaul and inspection of regeneration tower on following part and defect. These parts may be maintained and used continuously when defects in it are minor. It must be exchanged to new parts when defects in it are major.

1) Quantity, performance, pollution level and particle size of resin

   It must be confirmed quantity, performance, pollution levels and particle size of resin of regeneration tower. It must be exchanged to new resin or charged additional resin when it is significant pollution or decreasing resin volume is large. When resin is exchanged or charged, it must be charged regulated resin brand and resin volume based on manufacture's recommendation or actual operation status. If other resin is exchanged or charged, there is a possibility that regeneration tower can not generate qualified performance.

2) Breakage of inside device

   It must be confirmed breakage and crack of internal device of regeneration tower. When it is significant defect, it must be exchanged to new parts.

3) Wear of rubber lining And others

   It must be confirmed wear and crack of rubber lining of regeneration tower. When it is significant defect, it must be exchanged to new parts.

Article167-a8 Environmental facilities

1. Mechanical dust collector

It must be regulated overhaul and inspection interval based on manufacture manual and actual operation status etc. and conducted overhaul and inspection of regeneration tower on following part and defect. These parts may be maintained and used continuously when defects in it are minor. It must be exchanged to new parts when defects in it are major.

(1) Status of fouling and sediment

   It must be overhauled and confirmed status of fouling and sediment inside mechanical dust collector and cleaned and removed fouling and sediment from it. It must be confirmed that ingredient and volume etc. of fouling and sediment inside mechanical dust collector. It is recommended that they are analyzed chemically by specialized agency if necessary. It must be confirmed analysis results and taken appropriate measures if necessary.

(2) Leakage of corner seal and airlock damper

   It must be confirmed leakage of corner seal and airlock damper of mechanical dust collector. When finding leakage from these parts, it must be maintained leakage point by using sealing agent etc. When it is significant defect, it must be exchanged to new parts.

(3) Corrosion and abrasion of cyclone separator and guide vane

   It must be confirmed corrosion and abrasion of cyclone separator and guide vane of mechanical dust collector. When it is significant defect, it must be exchanged to new parts. Moreover, when corrosion and abrasion of cyclone separator and guide vane is significant, it must be analyzed surface of corrosion and abrasion chemically and taken appropriate measures if necessary.

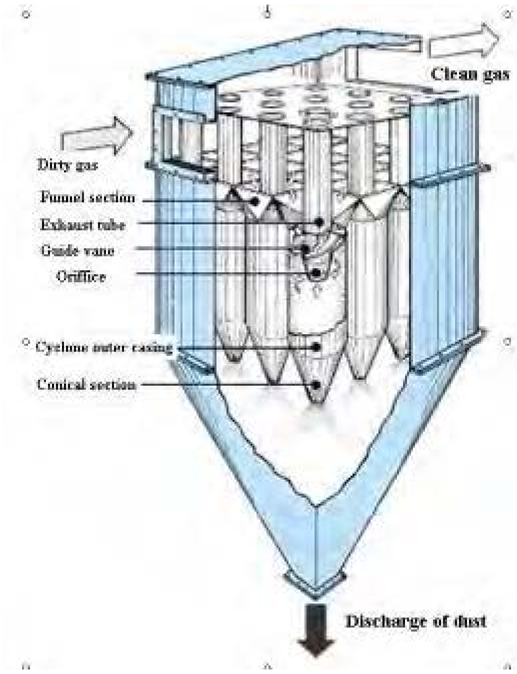


Photo 167-a8-1 Mechanical dust collector

2. Electric precipitator

(1) Main body

It must be regulated overhaul and inspection interval based on manufacture manual and actual operation status etc. and conducted overhaul and inspection of main body of electric precipitator on following part and defect. These parts may be maintained and used continuously when defects in it are minor. It must be exchanged to new parts when defects in it are major.

1) At disassembling

a. Fouling and gap size of collecting electrode and discharge electrode

(a) Fouling of collecting electrode and discharge electrode

It must be confirmed fouling of collecting electrode and discharge electrode and cleaned and removed fouling from it. It must be confirmed that ingredient and volume etc. of fouling of collecting electrode and discharge electrode. It is recommended that they are analyzed chemically by specialized agency if necessary. It must be confirmed analysis results and taken appropriate measures if necessary.

(b) Gap size of collecting electrode and discharge electrode

It must be confirmed gap size of collecting electrode and discharge electrode. When measured gap size is smaller or larger than regulated gap size, it must be maintained it to regulated gap size. Regulated gap size is based on manufacture's recommendation or actual operation status. When it is significant defect, it must be exchanged to new parts.

b. Disconnection of discharge electrode wire

It must be confirmed disconnection of discharge electrode wire. When discharge electrode wire is disconnected, it can not discharge electricity and electric precipitator can not generate qualified performance. When it is significant defect, it must be exchanged to new parts.

2) After cleaning

a. Corrosion and abrasion of collecting electrode and discharge electrode, looseness of bolt and spline and peeling of welding

(a) Corrosion and abrasion of collecting electrode and discharge electrode

It must be confirmed corrosion and abrasion of collecting electrode and discharge electrode. When corrosion and abrasion of collecting electrode and discharge electrode is significant, charge of them is unstable and electric precipitator can not generate qualified performance. When it is significant defect, it must be exchanged to new parts.

(b) Looseness of bolt and spline and peeling of welding

It must be confirmed looseness of bolt and spline and peeling of welding. When confirming looseness of bolt and spline, it must be tighten them. If bolt and spline are major damaged (crack, abrasion and erosion etc.), it must be exchanged to new parts. When confirming peeling of welding, it must be re-welded.

b. Bending of collecting electrode and discharge electrode, disconnection of wire and irregularity of between electrode

It must be confirmed bending of collecting electrode and discharge electrode, disconnection of wire and irregularity of between electrodes. If there are above defects in Electric precipitator, collecting electrode and discharge electrode can not work normally and electric precipitator can not generate qualified performance. When it is significant defect, it must be exchanged to new parts.

(2) Hammer device

It must be regulated overhaul and inspection interval based on manufacture manual and actual operation status etc. and conducted overhaul and inspection of hammer device of electric precipitator on following part and defect. These parts may be maintained and used continuously when defects in it are minor. It must be exchanged to new parts when defects in it are major.

1) Bending of shaft and abrasion of bearing

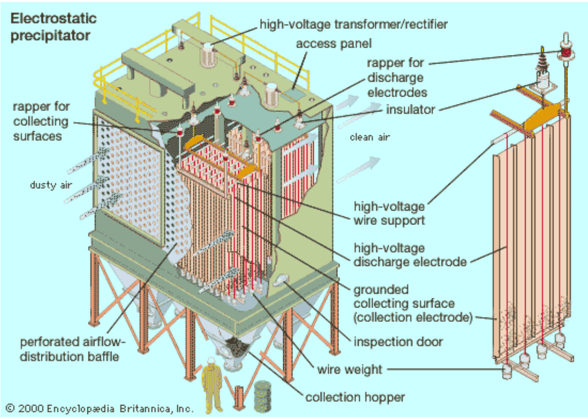
It must be confirmed bending of shaft and abrasion of bearing. When it is significant defect, it must be exchanged to new parts.

2) Crack and wear of insulator and looseness of terminal area

It must be confirmed crack and wear of insulator and looseness of terminal area. When it is significant defect, it must be exchanged to new parts.

3) Corrosion, abrasion, crack and deformation of hammer, coupling rod and slide portion

It must be confirmed corrosion, abrasion, crack and deformation of hammer, coupling rod and slide portion. When it is significant defect, it must be exchanged to new parts. After maintaining, it must be conducted operation test of hammer device and confirmed it operated normally.



http://worldofpowerplants.blogspot.jp/

Photo 167-a8-2 Construction of typical EP

http://www.tradeindia.com/fp429854/Retrofitting-Of-Electrostatic-Precipitator.html

Photo 167-a8-3 Replacement of dust collection plate

http://www.rpcenvironmental.com/

Photo 167-a8-4 Inspection of dust collection plate

http://www.spe.shi.co.jp/change.html

Photo 167-a8-5 Hammering mechanism

3. De-NOx equipment

(1) Gas duct

It must be regulated overhaul and inspection interval based on manufacture manual and actual operation status etc. and conducted overhaul and inspection of gas duct of De-NOx equipment on following part and defect. These parts may be maintained and used continuously when defects in it are minor. It must be exchanged to new parts when defects in it are major.

1) Fouling and sediment

It must be confirmed fouling and sediment in gas duct and cleaned and removed them. It must be confirmed that ingredient and volume etc. of fouling in gas duct. It is recommended that they are analyzed chemically by specialized agency if necessary. It must be confirmed analysis results and taken appropriate measures if necessary. Moreover, it must not be washed gas duct and opened manhole except for maintenance because catalyst of De-NOx equipment degrades the performance when catalyst absorbs moisture.

2) Leakage of air and gas

It must be confirmed leakage of air and gas from gas duct. When finding leakage part, it must be maintained it and stopped air and gas leakage.

3) Abrasion and corrosion of inside of duct

It must be confirmed abrasion and corrosion of each part in gas duct. It must be maintained because abrasion and corrosion in gas duct causes gas leakage. When it is significant defect, it must be exchanged to new parts.

(2) Reactor

It must be regulated overhaul and inspection interval based on manufacture manual and actual operation status etc. and conducted overhaul and inspection of reactor of De-NOx equipment on following part and defect. These parts may be maintained and used continuously when defects in it are minor. It must be exchanged to new parts when defects in it are major.

1) Fouling and sediment

It must be confirmed fouling and sediment in reactor. It must be cleaned and removed them immediately after opening manhole to prevent catalyst from moisture absorption and solidification. It must be confirmed that ingredient and volume etc. of fouling in reactor. It is recommended that they are analyzed chemically by specialized agency if necessary. It must be confirmed analysis results and taken appropriate measures if necessary.

2) Abrasion and corrosion of inside of duct

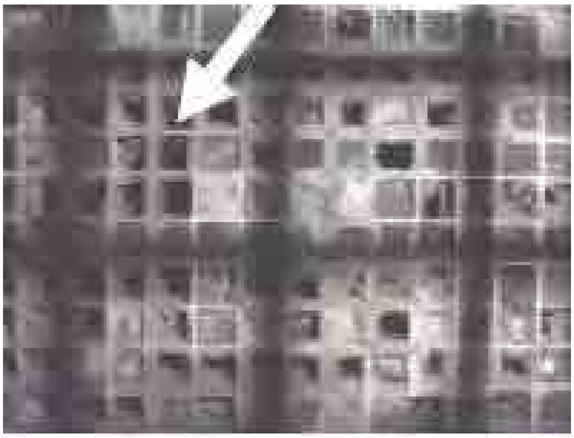
It must be confirmed abrasion and corrosion of each part in gas duct. It must be maintained because abrasion and corrosion in gas duct causes gas leakage. When it is significant defect, it must be exchanged to new parts.

3) Plugging of catalyst

It must be confirmed plugging of catalyst in reactor and cleaned and removed sediment to keep performance of catalyst. It must be regulated inspection interval and conducted performance inspection to confirm degradation of catalyst. NOx concentration from De-NOx equipment can not meets emission regulation when catalyst deteriorates and degrades the performance. Therefore, it must be exchanged to new catalyst when confirming that performance of catalyst can not be kept until next periodic inspection.

Reference: P-2 Sept/2007: TEMPES

Photo 167-a8-6 Blockage of catalyst



Reference: P-2 Sept/2007: TEMPES

Photo 167-a8-7 Blockage and membrane peeling

4. De-SOx equipment

(1) Fan

It must be regulated overhaul and inspection interval based on manufacture manual and actual operation status etc. and conducted overhaul and inspection of fan of De-SOx equipment on following part and defect. These parts may be maintained and used continuously when defects in it are minor. It must be exchanged to new parts when defects in it are major.

1) Before cleaning

a. Dust

It must be confirmed status of dust of fan and cleaned and removed dust to keep performance of fan.

b. Thermal insulation

It must be confirmed peeling and damage of thermal insulation of fan. It must be maintained thermal insulation to keep efficiency and safety for power plant staff.

2) After cleaning

a. Corrosion and crack of each portion

It must be confirmed corrosion and crack of each portion of fan. It must be conducted PT and MT inspection for vane of fan if necessary. When it is significant defect, it must be exchanged to new parts.

b. Bending and abrasion of rotor

It must be confirmed bending and abrasion of rotor of fan. When it is significant defect, it must be exchanged to new parts.

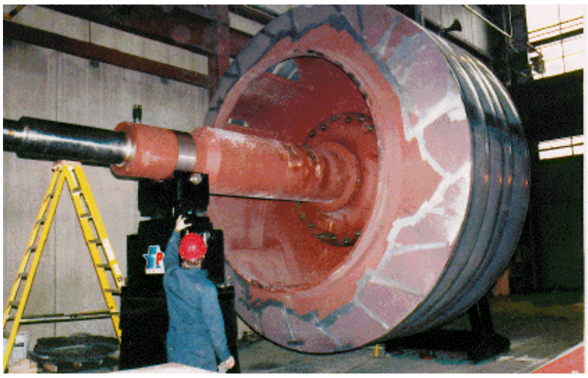
3) After assembling

a. Measurement of gap size of each portion

It must be measured gap size of each portion of fan. When gap size is smaller or larger than regulated gap size, each portion of fan is damaged or efficiency of fan is degraded. Therefore, it must be set gap size up as regulated size. Regulated gap size is based on manufacture's recommendation or actual operation status.

b. Measurement of fluctuation, balance and centering of rotor

It must be measured fluctuation, balance and centering of rotor of fan. When these measuring values are smaller or larger than regulated values, each portion of fan is damaged or efficiency of fan is degraded. Therefore, it must be set measuring values up as regulated values. Regulated values are based on manufacture's recommendation or actual operation status.



http://www.primemachine.com/balance.htm

Photo 167-a8-8 Field balancing

http://www.vafmechanical.com/portland-or-fan-repair-services-.htm

Photo 167-a8-9 Axial flow fan

(2) Cooling tower

It must be regulated overhaul and inspection interval based on manufacture manual and actual operation status etc. and conducted overhaul and inspection of cooling tower of De-SOx equipment on following part and defect. These parts may be maintained and used continuously when defects in it are minor. It must be exchanged to new parts when defects in it are major.

1) Falling and peeling of acid proof portion

It must be confirmed falling and peeling of acid proof portion of cooling tower. When confirming these defects, it must be conducted acid proof to these portions. If acid proof process is not conducted, inside cooling tower is corroded. It must be conducted preparation for acid proof process properly because it is different according to acid proof process type and acid proof process is conducted in cooling tower steadily.

2) Sedimentation of dust

It must be confirmed sedimentation of dust in cooling tower and cleaned and removed dust to keep performance of cooling tower.

3) Abrasion and falling of rectification grid and spray nozzle

It must be confirmed abrasion and falling of rectification grid and spray nozzle of cooling tower. When finding fallen spry nozzle, it must be confirmed whether other device is damaged by falling spray nozzle or not. It must be confirmed status of spray by streaming regulated cooling water to keep performance of cooling tower. When it is significant defect, it must be exchanged to new parts.

(3) Absorber

It must be regulated overhaul and inspection interval based on manufacture manual and actual operation status etc. and conducted overhaul and inspection of absorber of De-SOx equipment on following part and defect. These parts may be maintained and used continuously when defects in it are minor. It must be exchanged to new parts when defects in it are major.

1) Filling type

a. Wear and adherence of crystallized crustation of rectification grid inlet

It must be confirmed following wear and adherence of crystallized crustation of rectification grid inlet of absorber. When it is significant defect, it must be exchanged to new parts.

(a) Corrosion of rectification grid inlet

(b) Erosion of rectification grid inlet etc.

b. Wear and adherence of crystallized crustation of guide vane

It must be confirmed following wear and adherence of crystallized crustation of guide vane of absorber. When it is significant defect, it must be exchanged to new parts.

(a) Corrosion of guide vane

(b) Erosion of guide vane etc.

2) Spray type

a. Plugging, abrasion and corrosion of spray nozzle

Plugging, abrasion and corrosion of spray nozzle of absorber must be confirmed. After inspection and maintenance, it must be confirmed that spray can stream regulated flow volume to keep performance of absorber. When it is significant defect, it must be exchanged to new parts.

b. Adherence of crystallized crustation of oxidative air nozzle

Adherence of crystallized crustation of oxidative air nozzle of absorber must be confirmed. When it is significant defect, it must be exchanged to new parts.

3) Jet bubbling type

a. Fouling, abrasion and wear of deck

Fouling, abrasion and wear of deck of absorber must be confirmed. When it is significant defect, it must be exchanged to new parts.

b. Abrasion, wear and fouling of gas riser

Abrasion, wear and fouling of gas riser of absorber must be confirmed. When it is significant defect, it must be exchanged to new parts.

http://www.aquadevice.com/nippon/03pump_ym.htm

Photo 167-a8-10 Inspection of desulfurization pump

http://www.aim-shokai.co.jp/business/index.html

Photo 167-a8-11 Flake lining de-sox dust removal tower

Article 167-a9 Welding

It must be referred to Article 146-a8 of this Guideline.

Article 167-a10 Test and calibration of valve

It must be referred to Article 139 of this Guideline.

Article 167-a11 Trial operation

It must be conducted that following trial operation and confirmed equipment is operated normally. If it is not operated normally, appropriate measures must be taken depending on trouble. When conducting trail operation, it must be conducted at 100% output if at all possible.

1. Boiler

(1) Pressure raising

1) Test procedure

a. It must be confirmed that all related valves are closed not to leak.

b. It must be supplied feed water to boiler by water feed pump and pressurized by feed water pump.

c. It must be pressurized and de pressurized by regulated pressure rate. It must be decreased pressure rate at near maximum allowable working pressure.

d. It must be held hydraulic pressure during regulated time and confirmed following points.

2) Points to be checked

a. Hydraulic pressure

b. Leakage from boiler

c. Deformation of boiler etc.

(2) Furnace purge interlock test

It must be referred to paragraph 1 (1) of Article 141 in this Guideline.

(3) Ignition and pressurization test

1) Test procedure

a. It must be confirmed that boiler protection instrument is operated normally.

b. It must be confirmed that each auxiliary equipment is operated normally

c. The completion of preparation of ignition fire must be confirmed.

d. Ignition and pressurizing of boiler must be conducted and confirmed following points.

2) Point to be checked

a. Pressure, temperature and feed rate of feed water, steam, air and exhaust gas

b. Status of flame

c. Quality of feed water

d. Leakage from boiler and auxiliary equipments etc.

(4) Operation test of safety valve

1) It must be conducted operation test for safety valve, when safety valve for drum, super-heater and re-heater are disassembled for inspection. It must be assembled them and conducted operation during no-lode operation of boiler. It may be used hydraulic jack for operation test.

2) It must be confirmed that popping, reseating and blow down pressure of safety valves at operation test and they are operated correctly at regulated pressure.

3) It must be referred to Article 139 of this guideline.

(5) Operation test of boiler circulating pump

1) Confirmation of abnormal of boiler circulation pump

a. It must be conducted operation test according to following procedure and confirmed abnormal of boiler circulation pump. It must be taken appropriate measures depending on degree of defect when detecting defect at this pump.

(a) Test procedure

a) It must be confirmed that boiler circulation pump is filled by feed water.

b) It must be confirmed that water filling pump is ready for start up.

It must be checked water filling pump and water filling system (related valves etc.).

c) It must be confirmed water separator drain tank level is normally.

d) It must be reestablished monitoring instruments, interlock system and inlet and outlet pressure gauge of boiler circulation pump.

e) It must be started boiler circulation pump in a moment, started it continuously and confirmed abnormal of pump.

(b) Point to be checked

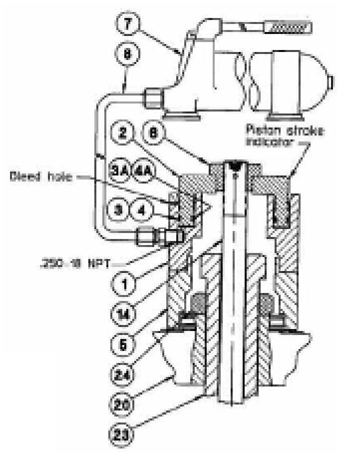
a) Abnormal noise

b) Abnormal vibration

c) Pump outlet pressure

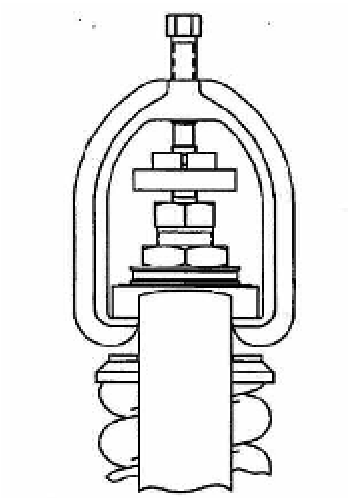
d) Pump cooling water temperature

e) Pump cooling water feed rate etc.



http://www.tycovalves-usa.com/ld/isv3147a%20cromc-6201-us.pdf

Photo 167-a11-1 Hydraulic jacking device



http://www.tycovalves-usa.com/ld/isv3147a%20cromc-6201-us.pdf

Photo 167-a11-2 Safety valve gag

(6) Load test

It must be referred to Article 145 in this Guideline.

2. Steam turbine

(1) Main valve operation test

1) Test procedure

a. Test staff must be distributed at central control room and main valve area.

b. Full-open and full-close test must be conducted from operating at central control room.

c. Slightly open must be conducted from operating at central control room.

d. Following point must be confirmed in above tests.

2) Point to be checked

a. Opening (valve travel) and time of open to close

b. Indication light, opening indicator and limit switch

c. Operating hydraulic pressure

d. Oil leakage etc.

(2) Emergency governor oil trip test

It must be referred to Article 143 in this Guideline.

(3) Operation test emergency stop device

It must be conducted operation test on emergency stop device after reassembling in case of disassembled and open inspection. It must be confirmed that it is operated normally. It must be confirmed cause of defect when detecting defect at emergency stop device and taken appropriate measures depending on degree of defect.

1) Confirmation before operation test

a. Revolution speed of steam turbine (rated revolution speed)

b. Indication light of "Master trip test" : lighting

c. Indication light of "Release of lock out " : lighting

d. Indication light of "Lock out" : lighting out

e. Indication light of "Oil trip " : lighting out

f. Indication light of "Reset " : lighting

g. Indication light of "During reset" : lighting out

2) Test procedure

a. It must be pushed PB of "Lock out".

b. It must be confirmed that indication light of "Lock out" is lighted and "Release of lock out" is lighted out.

It must be confirmed that lock out valve is positioned lock out at steam turbine area.

c. It must be pushed PB of "Oil trip".

d. It must be confirmed that indication light of "Trip" is lighted and "Reset" is lighted out.

It must be confirmed that steam turbine is not tripped.

e. It must be pushed PB of "Reset" continuously until indication light of "Reset" is lighted.

f. It must be confirmed that status following indication light.

(a) Indication light of "Reset " : lighted

(b) Indication light of "During reset" : lighted out → lighted → lighted out

(c) Indication light of "Trip " : lighted out

g. It must be pushed PB of "Release of lock out".

h. It must be confirmed that indication light of "Release of lock out" is lighted and "Lock out" is lighted out.

It must be confirmed that lock out valve is positioned release of lock out at steam turbine area.

It must be referred to Article 143 in this Guideline.

(4) Load test

It must be referred to paragraph 1 of Article 145 in this Guideline.

3. Gas turbine

(1) Spin test

1) Test procedure

a. It must be confirmed that preparation before spin test is completed on following items.

(a) Turning equipment for gas turbine is operated.

(b) Gas pressure in generator is more than acceptable value of staring.

(c) Header pressure of control air and house air is more than acceptable value.

(d) Control and house air compressor is operated.

(e) Stator cooling system is operated.

(f) Closed cooling system is operated.

(g) Seal oil pump system is operated.   etc.

b. Each part of gas turbine must be inspected by increasing and decreasing gas turbine rotating speed.

c. It must be complied manufacture manual about increasing rotating speed.

d. Gas turbine must be tripped when detecting trouble on it.

2) Point to be checked

a. Abnormal noise

b. Vibration

c. Oil leakage from torque converter

d. Starting motor current   etc.

(2) Starting and stopping test for gas turbine

1) Test procedure

a. It must be confirmed that the results of spin test for gas turbine is normal.

b. Gas turbine must be started by igniting combustors and inspected each part of it.

c. Gas turbine must be tripped when detecting trouble on it.

2) Point to be checked

a. Abnormal noise

b. Vibration

c. Lubricant oil pressure and temperature

d. Exhaust gas temperature

e. Rotating speed etc.

(3) Operation test for gas turbine

1) Operation test on emergency stop device

It must be conducted operation test on emergency stop device according to following procedure after reassembling in case of disassembled. It must be confirmed that it is operated normally. It must be confirmed cause of defect when detecting defect at emergency stop device and taken appropriate measures depending on degree of defect.

a. Preparation before test

(a) It must be conducted automatic start up test for following pumps.

a) Gas turbine auxiliary pump

b) Gas turbine emergency oil pump

(b) It must be confirmed status of gas turbine.

a) Under gas turbine operating (no load and rated rotating speed)

b) It must be confirmed following items before and after test.

Point to be checked	**Before test**	**After test**
Rotating speed	rpm	rpm
Fuel shut off valve	%	%
Fuel flow control valve	%	%
Inlet guide vane	%	%
Compressor bleed valve	Full close	

b. Test procedure

(a) It must be pushed test PB and raised gas turbine rotating speed.

(b) It must be confirmed gas turbine rotating speed when emergency governor is operated.

(c) It must be confirmed its rotating speed is within acceptable value.

Item	**Acceptable value**	**Operating value**
Rotating speed	Acceptable value : 110% + 0% - 1%	rpm %

(d) It must be confirmed related alarms are transmitted.

Alarm item	**Alarm transmission**	**Place**
Gas turbine trip	Yes / No	Gas turbine control panel

2) Operation test of reduction gear

It must be conducted operation test on reduction gear after reassembling in case of open or disassembled inspection. It must be confirmed that it is operated normally. It must be confirmed cause of defect when detecting defect at reduction gear and taken appropriate measures depending on degree of defect.

3) Operation test of gas compressor

It must be conducted operation test and confirmed following items to detect defects in gas compressor. It must be taken appropriate measures depending on degree of defects when detecting defect in gas compressor proper.

a. Gas compressor outlet pressure

b. Gas compressor outlet temperature

c. Lubricant oil temperature

d. Lubricant oil pressure

e. Abnormal vibration

f. Abnormal noise etc.

(4) Load test

It must be referred to paragraph 2 of Article 145 in this Guideline.

Section 3 Electric Equipment

Article 167-a12 Degree and frequency of periodic inspection of the generator

Technical regulation of inspection classifies the degree of periodic inspection for a generator into 3 kinds of inspections, as follows:

1. Major inspection

Major inspection is performed on each of generator components in detail after disassembly with removal of the rotor. Because a rotor of a generator is connected with a prime mover such as a steam turbine by a coupling, it is efficient to disassemble a generator at the same time with a prime mover.

Interval of periodic inspection of generators and motors and their auxiliary equipment is within 6 years by technical regulation of Article 159. As for major inspection, following points are recommended to be taken into consideration.

If a generator is disassembled, maintenance space for both a prime mover and a generator must be taken into consideration. Generally, maintenance of a turbine and a generator requires quality management such as preventing intrusion of foreign matter or moisture. For this reason, maintenance is performed in the building and maintenance space at the turbine floor must be planned and prepared.

(1) Maintenance schedule

Removal of the rotor requires machines such as an overhead travelling crane. This is common to a steam turbine and a gas turbine, therefore, schedule of using overhead travelling crane is recommended to be taken into consideration.

Moreover, the schedule for vibration adjustment after disassembly, being coupled with a turbine, is recommended to be taken into consideration.

(2) Record of failure

The overcurrent causes deterioration of stator coil winding especially at the coil end and the rotor. Moreover, field loss or negative phase current causes deterioration of rotor surface by eddy current. According to the degree of failure, major inspection is recommended to be performed.

2. Minor inspection

Minor inspection is performed on each of major generator components in detail after disassembly without removal of the rotor.

Since the rotor is not removed, major generator components such as bearings, seal rings, coolers, and gland seal are inspected in addition to simple inspection items.

3. Simple inspection

Simple inspection is mainly performed on water leak, oil leak, stator end-windings, their supports and other components in the generator casing after only removal of manhole covers.

Simple inspection is performed when major or minor inspection is not performed during the periodic inspection.

Therefore, an example of inspection order after the commencement of the operation is as follows:

1st year: Major inspection
2nd year: Simple inspection
3rd year: Minor inspection
4th year: Simple inspection
5th year: Major inspection

Article 168. Generator

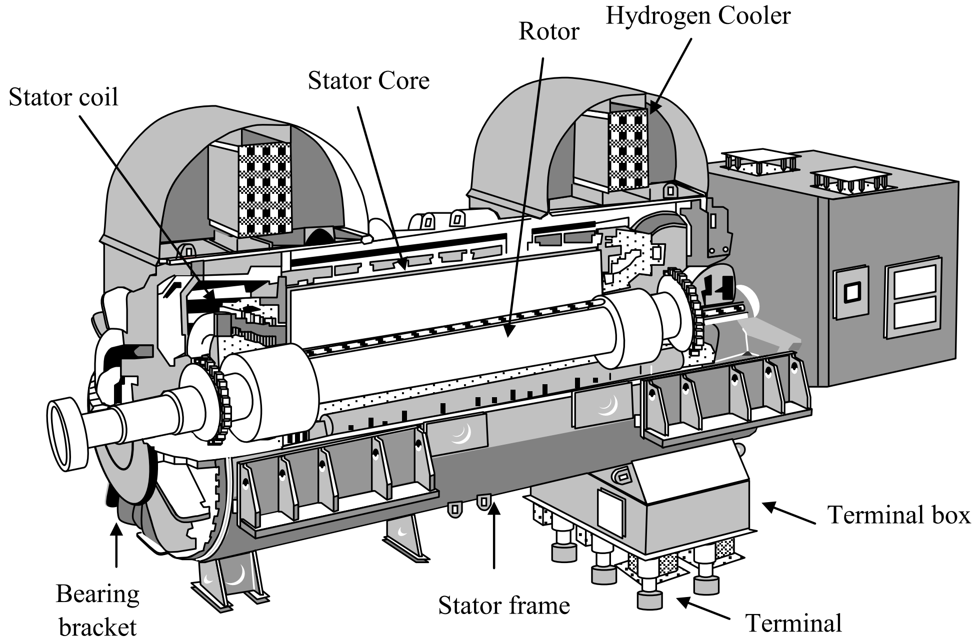


Figure 168-1 An example of hydrogen cooled generator

An example of hydrogen cooled generator which is generally used for a thermal power plant is shown Figure 168-1.

1. Simple inspection

Simple inspection is stipulated by technical regulation, and moreover, insulation resistance at the stator coil winding, the rotor coil winding, exciter coil winding, and temperature detecting devices is measured.

2. Major inspection and minor inspection

In addition to visual inspections, items from the manufacture are recommended to be taken into inspection items.

Moreover, insulation resistance at the windings or wires such as stator coil windings, the rotor coil windings, exciter coil windings, and temperature detecting devices, is measured.

(1) Notice in disassembling

1) Measure for preventing intrusion of foreign matter or moisture must be taken.

2) The number of tools brought inside the generator must be a minimum and confirmed that they are taken out from the generator.

3) Insulation resistance must be measured before disassembly and during inspection periodically. Insulation resistance varies depending on the humidity or temperature. If the measured value is extremely low, cleaning, drying or inspection of insulation must be performed.

When the voltage is up to 1000 V, the value of insulation resistance is specified in Article 238 of technical regulations Volume 2. However, this value is the minimum requirement; therefore, this value must be not less than the value specified by the manufacturer and Article 238 of technical regulations Volume 2.

(2) Stator

In addition to visual inspections, items from the manufacture are recommended to be taken into inspection items.

1) Check of existence of oil, or water, or other foreign matter

Existence of oil or water suggests abnormal condition of seal oil equipment, or cooler, or bearings or stator cooling system.

Therefore, if these substances are found in the generator, seal oil equipment, or cooler, or bearings, or stator cooling system are recommended to be inspected in detail.

Moreover, alarm devices for oil and water leakage are recommended to be inspected.

2) The wedge of the stator coil

Electromagnetic vibration is suppressed by the wedge at the core slot part. If this is in the loose condition and left for a long time, an electromagnetic and mechanical vibration is applied to the coil and this vibration may cause insulator abrasion which may occasionally lead to electric breakdown.

3) Stator core

Flaw and residue by local heating at the stator core are recommended to be inspected.

Stator core is laminated with thin and insulated steel plates. If this insulation is deteriorated, eddy current flows among steel plates, and this may cause core burn out.

Insulation at the stator core lamination may be deteriorated by excessive heat or foreign particles. From the viewpoint of excessive heat, stator core end is recommended to be inspected in detail, because temperature of this part rises during lead power factor operation of the generator, as stipulated Article 262 of guideline vol.4.

Moreover, stator cooling ducts are recommended to be inspected in order to prevent cooling gas from being blocked by dust or particles.

4) Stator coil end winding and its support

Electromagnetic vibration is suppressed by the bindings at the stator coil end. If the coil end is in the loose condition and left for a long time, an electromagnetic and mechanical vibration is applied to the coil and this vibration may cause insulator abrasion which may occasionally lead to electric breakdown.

Since coil end part is supported by bindings, mechanical strength is weaker compared with center of the coil. Thus, overcurrent causes deterioration or distortion of stator coil winding especially at the coil end. Moreover, load change causes thermal expansion and contraction at the coil end part and this may cause looseness of stator coil end. An example of cross section of stator coil end is shown in Figure 168-2.

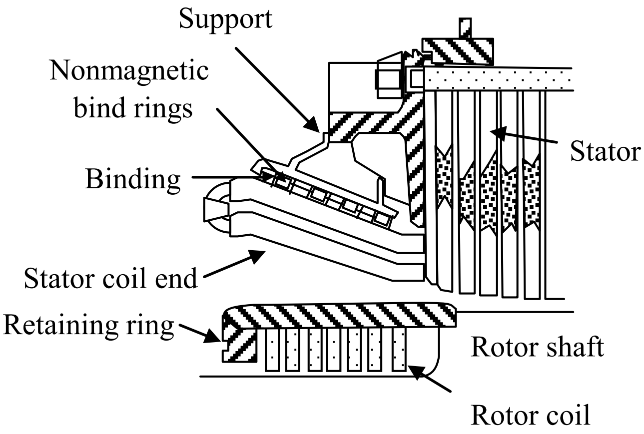


Figure 168-2 An example of cross section of stator coil end

5) Stator winding insulation

It is important for a generator to secure safe operation. The insulation performance of the stator winding influences the reliability of generator operation and generator lifetime. Insulation performance falls by the various stress under generator operation. Therefore, periodical insulation diagnostic is recommended in order to assess a residual life. An example of insulation diagnostic of the generator is classified to the following four items. In addition, a result of the insulation diagnostic must be evaluated according to manufacture criteria because it depends on the design.

a. Dielectric absorption test (insulation resistance measurement and polarization index (PI))

By applying DC voltage to the stator windings for 10 minutes, the insulation resistance property is calculated. The ratio between insulation resistance reading at 10 minutes and the reading at one minute produces PI. If the insulator is in moist or dirty condition, this value approaches one and becomes a high value in the dry condition. When PI is less than 2.0 it is generally required to dehydrate the stator wiring prior to other insulation diagnostics.

b. AC current measurement test

By applying AC voltage between the stator winding and ground, the voltage-current characteristic is measured. If partial discharge occurs, electric current will increase rapidly. When this phenomenon appears within the rated voltage, the deterioration is progressing.

c. Dissipation factor (tan delta) test (Dielectric loss measurement)

The power loss produced when AC voltage is applied to an insulator was classified into the loss by leakage current, the loss by dielectric polarization, and the loss by partial discharge. The actual current at this time lag the ideal charging current by very small angle which is called a loss angle and the tangent of the loss angle is dissipation factor. The dissipation factor is measured at low voltage which partial discharge does not occur, and at the rated voltage. If separations, voids or cracks occur in the insulating layer by deterioration, the difference between these dissipation factors will increase.

d. Partial discharge

Partial discharge is measured by electric discharge pulse which generates by applying AC voltage to the stator windings.
When the amount of electric charges in the partial discharge reaches predetermined value, this is called partial discharge inception voltage. When predetermined voltage is applied, maximum amount of electric charges is called maximum electric-discharge (Q_{max}).
Q_{max} increases as the deterioration progresses. This method is suitable for detection of the largest void in the insulation.

e. Stator coil life time estimation

Using results of an insulation diagnostics, dielectric strength (breakdown voltage) of stator wiring is assumed as shown in Figure168-3.
Insulation is deteriorated by integral various stress during operation in every case and also deteriorated suddenly by water intrusion from the brazed portion of the clip in water-cooled stator wiring. It is recommended to carry out vacuum and pressure leak test and capacitance mapping.
As for dielectric strength, more than (2E+1) kV (E: Rated voltage) is necessary for operation of a generator, because this value is specified in IEC60034-1.
Residual life evaluation changes depending on the design conditions such as insulation material and operating conditions as shown in Figure 168-4.
Therefore, advice or recommendation from the manufacturer must be taken.

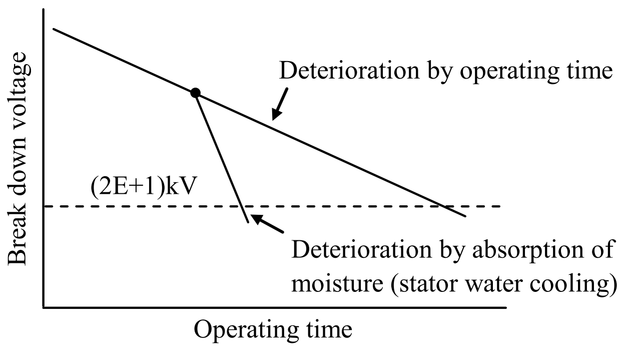


Figure 168-3 An example of breakdown voltage

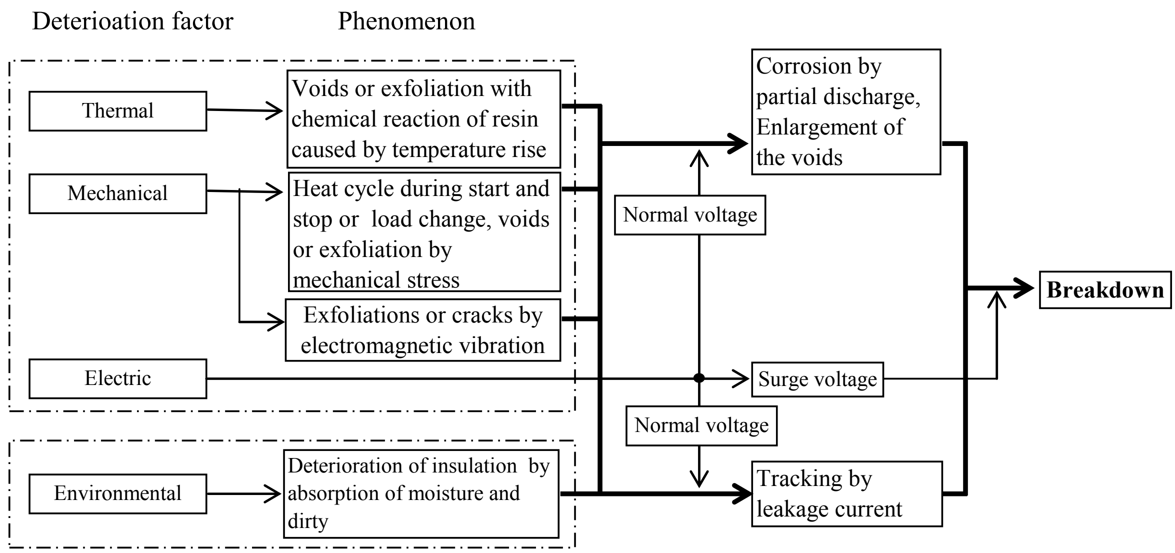


Figure 168-4 An example of deterioration mechanism of stator winding

(3) Rotor

In addition to visual inspections, items from the manufacture are recommended to be taken into inspection items.

Since a generator rotor is rotating with high speed, very high stress is applied to the generator rotor. Following points are recommended to be inspected. In addition to major inspection, special inspection (overhaul is included) is recommended according to the manufacture recommendation.

1) Shaft center hole

Shaft center hole is the part where stress is very high. Therefore, it is necessary to check the existence of a crack at this part, by the non-destructive-inspection method. As a result of the inspection, when a crack is discovered near the center hole, lifetime must be evaluated.

2) Shaft (journal)

Shaft journal part transmits the torque of the prime mover and also failure torque caused by power system. Thus, fatigue by the torque is accumulated. Therefore, damage in this part is recommended to be inspected. For this reason, it is necessary to inspect journal with visual inspection and non destructive method periodically in order to confirm security.

3) Rotor wedge and rotor teeth

Each rotor wedge of a turbine generator is held by rotor teeth and withstands the important duty holding the turbine-rotor coil under rotation such as 3,000 min^{-1}. Rotor wedge and rotor teeth operate under very severe conditions due to the high stress generated by centrifugal force.

Moreover, the temperature rise and corrosion by unusual operations (unbalanced load operation, overexcited operation, etc.) triggers initial cracks. Under such operation, a careful inspection is required for the wedges made of aluminum alloy with high tensile strength, and also for rotor teeth made of cast iron.

Under usual operations, wedges and rotor teeth of a turbine generator are recommended to be inspected in major inspection by non-destructive method such as ultrasonic.

4) Retaining ring (End ring)

The material of retaining ring is non-magnetic steel for electromagnetic reason at the coil end and this is mounted on the rotor by shrinkage fitting.

For this reason, even during the rotor stands still, stress corrosion cracking may be caused due to the stress by shrinkage fitting, high contamination of carbon in the non-magnetic steel, and moisture.

Therefore, surrounding temperature of a retaining ring is to be held higher than ambient temperature to keep moisture out of the retaining ring while it remains removed.

The measure for stress corrosion cracking is to replace the retaining ring with improved material such as the 18 Mn – 18 Cr which increases the percentage of a constituent of chromium (Cr) to the manganese (Mn). It is recommended for the retaining ring that the visual and ultrasonic inspections are carried out in major inspection.

In order to detect the crack, the retaining ring must be pulled out from the rotor. Thus, as for inspection time, advice from the manufacture is recommended to be taken into consideration depending on the material of the retaining ring. An example of cross section of retaining ring is shown in Figure 168-5.

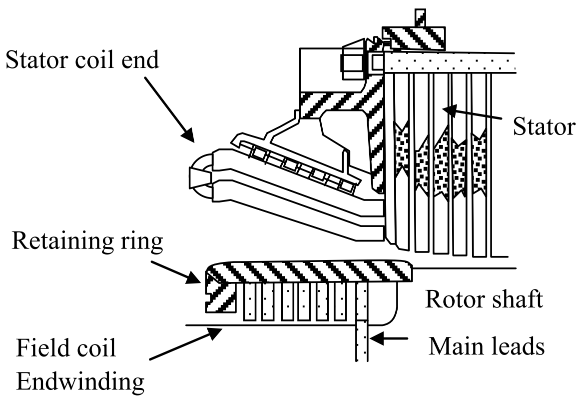


Figure 168-5 An example of cross section of retaining ring

5) Rotor coil

Insulation deterioration at the rotor coil is caused by mechanical, electric, and thermal factors, mainly centrifugal force depending on the operating hour.

Therefore, rotor coil and coil end windings are recommended to be inspected.

Moreover, copper particles may be generated by the operation such as start-up and shutdown, and these particles may cause layer short depending on the conditions of turn to turn insulation between the coils. Therefore, existence of copper particles is also recommended to be inspected.

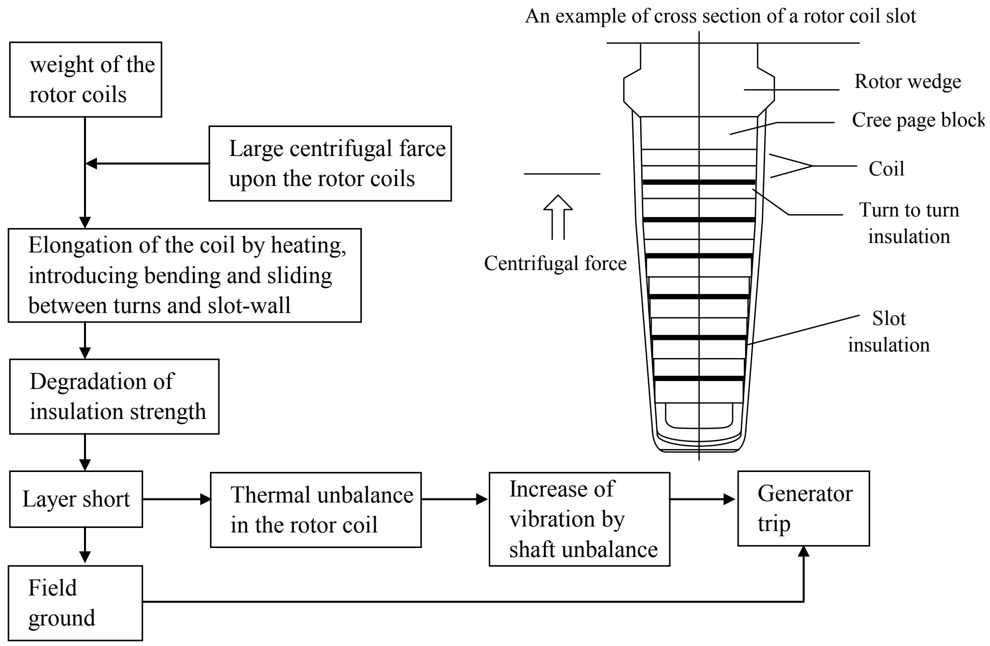


Figure 168-6 An example of deterioration mechanism of rotor slot coil and slot configuration

6) Vibration adjustment

After, inspection, vibration is adjusted if necessary, using balance weight. Vibration may be caused by the coupling connecting errors, or dimension errors of pedestals or base, or thermal unbalance of the rotor.

7) Lead

Main lead is recommended to be inspected because this item is important to supply field current.

Moreover, flexible leads of pole connectors are recommended to be inspected because high centrifugal force is applied.

Insulation resistance is also measured at both flexible leads and main lead.

8) Air gap measurement

Air gap between the stator and rotor is must be installed within allowable value. Unbalance of air gap causes unbalance voltage between the phases, electromagnetic vibration, rubbing or contact between the stator and rotor.

Thus, air gap measurement is recommended.

(4) Bearings

Bearings and their surroundings need inspections of the crack or abrasion at the metal and particles existence caused by temperature and vibration.

Following items are recommended to be checked.

1) External inspection and open inspection

2) Damage, defacement, abrasion, corrosion and state of installation of each part

3) Measuring of gap

4) Damage of insulator for the shaft current preventing equipment

5) Oil leakage

6) Oil flushing

7) Measuring insulation resistance

(5) Bearing bracket

Damage, defacement, abrasion, corrosion and state of installation of each part are inspected.

(6) Hydrogen and air coolers

1) Damage, pollution, abrasion, corrosion of cooling pipes

2) Clean up inside (as necessary)

3) Leakage test (as necessary)

4) Inspection of tube inside by fiber-scope (as necessary)

5) Inspection of tube by eddy current examination (as necessary)

6) Replacement of packing

(7) Bushing and surroundings

1) Damage, pollution of lead bushing and insulator

2) Discoloration of flexible lead by over heat

3) Locking condition of bolts

4) Damage, pollution of insulator

5) Inspection of packing

6) Damage, pollution of neutral point cover

(8) Fan

1) Damage or distortion of fan blades

2) Damage or distortion of fan shroud

3) Existence of attachments at cooling path

(9) Measurement of shaft voltage

Voltage is generated at the bearing part of the rotor due to the electromagnetic unbalance between the stator and the rotor, and the electric charge by steam to the turbine blades. To protect corrosion at the bearing, shaft voltage is recommended to be measured.

Article 169. Excitation system

Excitation system must be inspected depending on its type.

1. Rotating exciter

(1) AC exciter with rotating rectifiers (Brushless exciter)

1) Housing

a. Check of damage

To prevent foreign matters intrusion to the exciter, damage, defacement, and condition of installation of each part are inspected.

b. Air filter

AC exciter may be cooled by air taken from outside, therefore, air filters on the housing are recommended to be cleaned or exchanged.

2) Rotating rectifiers and surroundings

Rotating rectifiers, resistors, fuses, and capacitors are recommended to be inspected because these items are important to supply field current.

Following items are inspected

a. Damage, defacement, and state of installation of each part

b. Measurement of resistance (Forward direction)

c. Measurement of insulation resistance (Reverse direction)

3) Stator

Following items are inspected

a. Damage, defacement, and state of installation of each part

b. Measurement of insulation resistance

4) Rotor

Following items are inspected

a. Damage, defacement, and state of installation of each part

b. Measurement of insulation resistance

5) Permanent magnet generator

Following items are recommended to be inspected.

a. Check of damage or discoloration at stator (winding, core), rotor windings, rotor (visual, ultrasonic examination, magnetic particle examination)

b. Check of the slag at bolts, wedges, and balance weights

c. Gap measurement (between rotor and stator)

d. Measurement of insulation resistance

6) Bearings

Bearings and their surroundings need inspections of the crack or abrasion at the metal and particles existence caused by temperature and vibration.

Following items are recommended to be inspected.

a. External inspection and open inspection

b. Damage, defacement, abrasion, corrosion and state of installation of each part

c. Measuring of gap

d. Damage of insulator for the shaft current preventing equipment

e. Oil flushing

7) Air coolers

An AC exciter may have air coolers, therefore, following items are recommended to be inspected.

a. Damage, pollution, abrasion, corrosion of cooling pipes

b. Clean up inside (as necessary)

c. Leak check (as necessary)

d. Inspection of tube inside by fiber-scope (as necessary)

e. Inspection of tube by eddy current examination (as necessary)

f. Replacement of packing

(2) AC exciter with stationary rectifiers (Commutatorless exciter)

Brushes and collector rings are added to the items of brushless exciter.

1) Brush

Failure of a brush or a collector ring may cause field loss and loss of synchronization .Thus; these items are recommended to be inspected carefully.

To prevent failure, field current at the contact between the brush and the collector ring must not be concentrated in a small contact point.

Generally, brush is made of carbon, therefore, following items are recommended to be inspected.

a. Check of abrasion at the contact

b. Check of contacting with collector rings

c. Adjustment of contacting pressure

d. Condition of brush holder

e. Cleaning

f. Periodic exchange

2) Collector ring

a. Abrasion on the surface

b. Cleaning

c. Measurement of insulation resistance

The rest items are referred to the items of brushless exciter.

(3) AC exciter with stationary rectifiers (Independent excitation type)

Inspection items may be changed depending on equipment. However, they are almost the same as AC exciter with stationary rectifiers (Commutatorless exciter)

For example, following items may be added.

1) Commutator

a. Abrasion on the surface

b. Cleaning

c. Measurement of insulation resistance

2) Motor

This item is referred to Article 173 of this guideline

2. Static exciter

(1) Housing

1) Check of damage

To prevent foreign matters intrusion to the exciter, damage, defacement, and condition of installation of each part are inspected.

2) Air filter

AC exciter may be cooled by air taken from outside, therefore, air filters on the housing are recommended to be cleaned or exchanged.

(2) Thyristors and surroundings

Thyristors, resistors, fuses, and capacitors are recommended to be inspected.

Moreover, cooling fans for thyristors are recommended to be inspected, and bearings and filters of the fans are exchanged depending on the conditions.

(3) Brush

Failure of a brush or a collector ring may cause field loss and loss of synchronization .Thus; these items are recommended to be inspected carefully.

To prevent failure, field current at the contact between the brush and the collector ring must not be concentrated in a small contact point.

Generally, brush is made of carbon, therefore, following items are recommended to be inspected.

1) Check of abrasion at the contact
2) Check of contacting with collector rings
3) Adjustment of contacting pressure
4) Condition of brush holder
5) Cleaning
6) Periodic exchange

(4) Collector ring

1) Abrasion on the surface
2) Cleaning
3) Measurement of insulation resistance

Article 170.

(Nothing)

Article 171.

(Nothing)

Article 172. Auxiliary equipment of generator

Generally, auxiliary equipment of the generator means seal oil system, stator cooling water system, hydrogen supply system and nitrogen sealing system.

In addition to visual inspections, items from the manufacture are recommended to be taken into inspection items. Inspection items are selected depending on the machine condition and inspection schedule.

1. Seal oil system

(1) Pump

1) After disassembling, damage of each part is checked and repaired.
2) Mechanical seal or an O ring is exchanged.

(2) Motor

This item is referred to Article173 of this guideline.

(3) Valves

1) After disassembling, valve sheet, diaphragm, bellows are inspected and repaired.
2) In the case of control valves, set values are checked.

(4) Tanks

Cleaning and check of foreign matter is performed.

(5) Pipes

Damage of each part is checked.

(6) Instruments

This item is referred to Article174-a1 of this guideline. For safety, the meter and the switch of seal oil pressure (or pressure difference between seal oil pressure and generator pressure) must be calibrated and adjusted.

(7) Measurement of oil flow

Oil flow is checked.

(8) Filters

After disassembling, filters are cleaned or exchanged depending on the condition.

(9) Check of oil leakage

Bolts, packing, corrosion of pipes, etc are inspected and repaired.

(10) Seal casing

1) Check of oil leak
2) Check of abrasion, damage, distortion at the seal ring and the gland
3) Measurement of gap
4) Check of abrasion at the oil deflector
5) Measurement of insulation resistance at insulator of the casing, insulating bolts and insulating washers

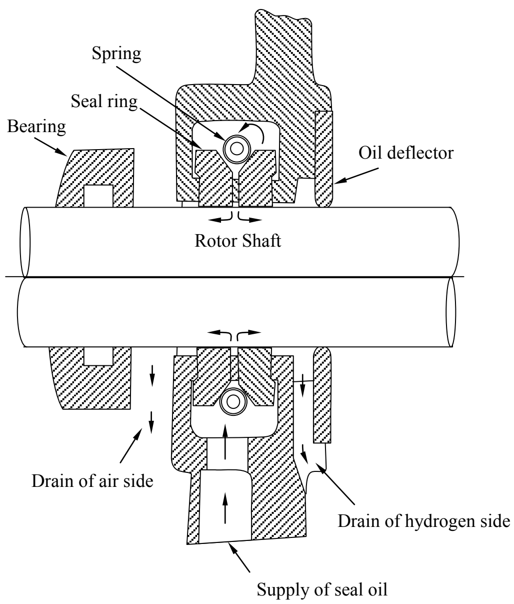


Figure 172 An example of seal casing

2. Stator cooling water system

(1) Pump

1) After disassembling, damage of each part is checked and repaired.

2) Mechanical seal or O ring is exchanged.

(2) Motor

This item is referred to Article173 of this guideline.

(3) Control valve

1) After disassembling, valve sheet, diaphragm, bellows are inspected and repaired.

2) Set value is checked.

(4) Instruments

This item is referred to Article 174-a1 of this guideline.

(5) Filters

After disassembling, filters are cleaned or exchanged.

(6) Ion exchange resin regeneration or exchange

This item is necessary to maintain cooling water quality. Degradation of cooling water quality may cause insulation deterioration and electrical failure.

(7) Pipes

Damage of each part is checked.

3. Hydrogen supply system

(1) Instruments

This item is referred to Article 174-a1 of this guideline. For safety, the hydrogen purity meter must be calibrated and adjusted.

(2) Gas drier

1) Regeneration

2) Interlock test

3) Measurement of insulation resistance

4) Measurement of conduction

(3) Valves

1) After disassembling, valve sheet, diaphragm, bellows are inspected and repaired.

2) In the case of control valves, set value is checked. Leak test may be conducted as necessary.

3) Packing is exchanged as necessary.

(4) Pipes

Damage of each part is checked. Leak test may be conducted as necessary.

(5) Supply of hydrogen

Hydrogen is replenished to the storage as necessary.

4. Carbon dioxide supplying device

(1) Damage, defacement, and state of installation of each part

(2) Measurement of insulation resistance

Electric heater in vaporizer and water separator are measured.

(3) Measurement of conduction for lead in vaporizer and water separator

(4) Supply of carbon dioxide

Carbon dioxide is replenished to the storage as necessary.

5. Nitrogen seal system

(1) Valves

The pressure reducing valve, solenoid valves, the ball valve etc are relevant. Leak test may be conducted as necessary.

(2) Pipes

Damage of each part is checked.

(3) Operation check

This system is used only in the case of emergency, therefore, operation is recommended to be tested.

(4) Supply of nitrogen

Nitrogen is replenished to the storage as necessary.

6. Neutral grounding system

(1) Damage, defacement, and condition of installation of each part are inspected.

(2) Resistance of grounding device and insulation resistance are measured.

7. Surge absorber

(1) Damage, defacement, and condition of installation of each part are inspected.

(2) Resistance of current-limiting devices and insulation resistance are measured.

Article 172-a1 Degree and frequency of periodic inspection of the motor

The scale of inspections are classified to major inspection and minor inspection as stipulated Article 172-a1of the inspection technical regulation.

Major inspection means inspection performed in the constant period. This period must be conformed to instruction manuals from manufacturer, and guideline of the period may be approximately four years. However, priority of machines, results of past inspections and operating status are recommended to be taken into consideration. For example, motors which start and stop very frequently may be inspected in the period shorter than the manual specification.

In general, major inspection is performed at the same time with the periodic inspection, because most of motors do not operate.

Minor inspection means inspection performed between major inspections. As stipulated above, after disassembly of the bearing bracket of a motor, the motors are inspected focusing on the stator end-windings, bearings and their surroundings.

Article 173. Motor

The fundamental of a periodic maintenance is routine inspections in accordance with inspection list items and also supervisory which is performed in the proper period.

This supervisory period must be conformed to instruction manuals from the manufacturer, and guideline of the period may be approximately four years.

A motor is a rotating and electromagnetic machine; therefore, technical regulation requires that there is not obstruction due to looseness of end-winding and wedges of stator, etc. These items may often have deterioration in the operation.

1. Main inspection items and points

In addition to visual inspection, items from the manufacture or manuals are recommended to be taken into inspection items.

Following items may be inspected.

(1) Damage, defacement, and state of installation of each part

External inspection and open inspection must be performed on each part.

(2) The wedge of the stator coil, stator coil end winding

Electromagnetic vibration is suppressed by the wedge at the core slot part and by the bindings at the stator coil end. Coil insulation, wedge, a spacer, bindings, etc. consist of insulators, and there may be looseness of the wedge of the stator coil, or stator coil end caused by the electromagnetic vibration, heat cycle, etc. during operation.

If this looseness is left for a long time, an electromagnetic and mechanical vibration is applied to the coil and this vibration may cause insulator abrasion which may occasionally lead to electric breakdown.

Therefore these items must be inspected periodically.

(3) Insulation deterioration

Measurement of insulation resistance of windings is the basic inspection commonly performed in order to inspect the condition of motor insulation. The theory of electrical insulation measurement is to treat the electric motor as a capacitor. A DC voltage is applied between the motor windings and the motor frame, the insulation acts as the capacitor dielectric. Leakage from the windings to ground is measured and shown as resistance in a resistance tester.

Moreover, insulation resistances of space heaters are recommended to be inspected.

To inspect insulation deterioration of stator windings, similar methods described in Article 168 are used.

(4) Looseness of rotor bars and axial directional movement

External inspection and open inspection must be performed to confirm damage, defacement, and state of installation of the rotor.

In the case of squirrel cage induction motor which have rotor bars, heat stress, electromagnetic force, centrifugal force, etc. are overlapped on rotor bars, short-circuit ring and their silver solder part due to the inrush electric current at the time of starting.

Thus fatigue is accumulated depending on the number of starting.

As a result, looseness may appear in a rotor bar, the whole-rotor bar may move in the orientation of an axis, or the part with silver solder part and a short-circuit ring may exfoliate partially.

If operation continues in this condition, it may progress to crack or breakage of the rotor bar or the short-circuit ring, and its edge may be spread in the radial direction with the centrifugal force, may do damage to the stator coil, and may cause electric breakdown.

Therefore, these periodical inspections are important.

(5) Inspection of bearings

Bearings and their surroundings need inspections of the crack at the journal and the existence of particles caused by temperature and vibration.

Following items are recommended to be checked.

1) External inspection and open inspection

2) Damage, defacement, and state of installation of each part

3) Oil leakage

4) Oil level (Or quantity of grease)

5) The movement, and distortion of an oil ring

6) Oil blackening, or discoloration of grease

Moreover, in the case of slide bearings, oil flushing must be conducted.

(6) Inspection of dust attachment to stator coil and -core ventilating-duct

Dust attachment to the stator coil reduces heat conduction, and dust attachment to core ventilating-duct reduces the amount of cooling ventilations.

Both cause temperature rise, therefore, when there is dust attachment, it must be cleaned with the interval depending on the dust content, or measure must be taken to prevent dust intrusion.

(7) Inspection of a cooling fan and the acoustical absorbent material of the motor

Since acoustical absorbent material is consumable stores, it is recommended to be exchanged depending on the condition at the time of inspection.

(8) Exchange of consumable stores

Bearings and packing are also recommendations items for exchanging.

Article 174. Trial operation

It must be conducted following trial operation and confirmed that equipment is operated normally. If it is not operated normally, appropriate measures must be taken depending on troubles. When conducting trail operation, it must be performed at 100% load if possible, or as much load as possible.

1. Generator

(1) Generator in no load condition

1) Objective

Before parallel in, the generator is operated in no load condition in order to check that there is no abnormal condition in the components.

2) Test procedure

Test procedure should conform to the instruction manual from the manufacture. However, it may be as follows:

a. After generator inspection is finished, power and control cables are connected.

b. Each connection of cable and the terminal is checked.

c. It must be confirmed that protective devices operate during failure. (Protective device test stipulated in Article 151 has already been finished)

d. The coupling between the generator and the turbine is connected.

e. Following items are checked before start-up.

(a) Temperatures indicated by thermometers for windings and casing are almost equal to ambient temperature.

(b) Auxiliary systems, such as shaft seal system, cooling system are operating without abnormal conditions.

(c) Quantity of bearing oil is checked at the flow sites and temperature is specified value.

(d) There is no abnormal sound, such as rubbing, contacting sound during the turning of the shaft.

f. During turbine start-up, vibration is checked from zero speed to the rated speed.

g. It is recommended to pass the critical speed of the generator and the turbine as soon as possible.

h. If the vibration is above allowable value, the turbine and generator is shut down in order to adjust vibration.

i. If the vibration is within allowable value, voltage is applied by AVR.

j. If necessary, following AVR characteristics may be tested.

   (a) Voltage establishment test

   (b) Transient response test

   (c) Voltage setting range test

   (d) Automatic follow-up test

3) Items to be checked during no load operation

a. Vibration is below the value specified by the manufacturer or the standard.

b. The bearing temperature is the value specified by the manufacturer.

c. The bearing oil temperature is controlled at the value specified by the manufacturer.

d. Winding temperature is below the value specified by the manufacturer and temperature limit restricted by insulation classification.

e. No activation of protective relays is confirmed.

f. The voltage of the generator is regulated within the limit specified by the manufacturer.

g. Temperature in the generator is controlled at the specified value.

h. No leakage of hydrogen is confirmed.

i. Pressure in the generator is maintained at the specified value.

j. Hydrogen purity in the generator is maintained above the specified value.

k. Quantity of sealing oil is maintained at the specified value.

l. Pressure of sealing oil is maintained at the specified value. (The pressure difference between sealing oil and the hydrogen in the generator is also maintained at the specified value)

m. Stator cooling water conductivity is maintained at the specified value.

(2) Generator in load condition

1) Objective

After parallel in, the generator is operated in load condition in order to check that there is no abnormal condition in the components. As stipulated before, it must be performed at 100% load if possible, or as much load as possible.

2) Test procedure

Test procedure should conform to the instruction manual from the manufacture. However, it may be as follows:

a. After turbine start-up and establishment of generator voltage, the synchroscope is used for parallel in.

b. The generator is paralleled in the grid in the following conditions.

   (a) The difference of voltage between the generator and the grid is within allowable value.

   (b) The difference of phase between the generator and the grid is within allowable value.

   (c) Frequency between the generator and the grid is the same.

   (d) Phase rotation between the generator and the grid is the same.

   (e) Notice: If all the conditions described above are not satisfied, the generator must not be paralleled in, because the generator is destructed by the large current caused by difference of voltage or phase, or loss of synchronism may be caused.

c. After parallel in, the load of the generator is increased to the test load.

d. Following items are checked during the load operation.

3) Items to be checked for the generator

   a. Vibration is below the value specified by the manufacturer or the standard. (Vibration may change due to the change of rotor temperature depending on the load.)

   b. The bearing temperature is the value specified by the manufacturer.

   c. The bearing oil temperature is controlled at the value specified by the manufacturer

   d. Winding temperatures of rotor and stator are below the value specified by the manufacturer and temperature rise limit restricted by insulation.

   e. No activation of protective relays is confirmed.

   f. The voltage of the generator is regulated within the limit specified by the manufacturer.

   g. Armature and field currents are not more than the rated value.

   h. Temperature in the generator is controlled at the specified value.

   i. No leakage of hydrogen is confirmed.

   j. Pressure in the generator is maintained at the specified value.

   k. Hydrogen purity in the generator is maintained above the specified value.

   l. Quantity of sealing oil is maintained at the specified value.

   m. Pressure of sealing oil is maintained at the specified value. (The pressure difference between sealing oil and the hydrogen in the generator is also maintained at the specified value)

   n. Stator cooling water conductivity is maintained at the specified value.

   o. Stator cooling water pressure is maintained at the specified value.

   p. Stator cooling water temperature is less than the specified value at the winding outlet.

2. Motor

(1) Motor no load trial operation

1) Objective

Before load operation, the motor is operated to check that there is no abnormal condition in the components of the motor in the no load condition.

2) Test procedure

a. After motor inspection is finished, power and control cables are connected.

b. Each connection of cable and the terminal is checked

c. It must be confirmed that protective devices operate during failure. (Protective device test stipulated in Article 151 has already been finished)

d. The coupling between the motor and the load is kept disconnected.

e. Rotating direction is checked by operation for a few seconds.

f. If the rotating direction is correct, the motor is operated for the time specified by manufacture. (In general, it may be 30 to 60 minutes) If the rotating direction is wrong, rotating direction is confirmed again after cables are reconnected.

g. Following items are checked during no load operation

3) Items to be checked

a. The rotating direction is conform to the provisions (direction indicated on the motor)

b. Current is less than the rated value.

c. Vibration is below the value specified by the manufacturer or the standard.

d. Bearing temperature is below the value specified by the manufacturer.

e. Casing temperature is below the value specified by the manufacturer.

f. Winding temperature is below the value specified by the manufacturer and temperature limit restricted by insulation classification. (If measurement is possible)

g. No activation of protective relays is confirmed.

(2) Motor load operation

1) Objective

The motor is operated to check that there is no abnormal condition in the components of the motor in the load condition.

2) Test procedure

a. After motor no load operation is finished, the motor is connected with the load at the coupling.

b. Each connection of the coupling such as bolts is checked.

c. Centering between the load and the motor is performed.

d. It must be confirmed that protective devices operate during failure. (Protective device test stipulated in Article 151 has already been finished)

e. Rotating condition of the motor and the load is checked by operating for a few seconds.

f. If the rotating condition is good, the motor is operated for the time specified by manufacture. (In general, it may be 60 to 120 minutes) If the rotating condition is bad, adjustment such as centering is required.

g. Following items stipulated next are checked.

3) Items to be checked during load operation

a. The rotating direction conforms to the provisions (direction indicated on the motor)

b. Current is not more than the rated value.

c. Vibration is below the value specified by the manufacturer or the standard.

d. Bearing temperature is below the value specified by the manufacturer.

e. Casing temperature is below the value specified by the manufacturer.

f. Winding temperature is below the value specified by the manufacturer and temperature limit restricted by insulation classification. (if measurement is possible)

g. No activation of protective relays is confirmed.

h. No abnormal condition is confirmed in the electric system.

Article 174-a1 Inspection of measuring instruments

Measuring instruments must be inspected, calibrated, and adjusted by the end of periodic inspection and before the plant operation.

During inspection, it must be considered not only what facilities are restored correctly but also what reliability of facilities is maintained.

General points to notice are that the measuring instruments are suitable to confirm the security of boilers, turbines, generators, and their auxiliaries, whether measuring instruments are calibrated, measuring methods are correct, and the facility is operating under design specification.

In order to attain these duties, measuring instruments are used for the verification of outputs of processes against specified requirement such as security of facilities. A thermal power plant must ensure that where measuring instruments are used for verification, they are calibrated and maintained to accepted standards, giving confidence to the results of the inspection.

The thermal power plant must consider other means to eliminate all potential errors from measuring processes, for verification of process outputs to minimize the need for control of measuring instruments, and to add confidence for inspection.

1. Necessary items

Followings are necessary in the management of measuring instruments during periodic inspection.

(1) Items of measurements are clarified and measuring instruments are suitable for the measurement.

(2) Inspections are implemented according to the method of preceding item (1).

(3) Records of inspections and calibrations are filed and kept.

(4) As for measuring instruments, following requirements must be satisfied.

   1) Procedure to manage measuring instruments has been established, and measuring instruments are calibrated and adjusted according to this procedure.

   2) Measuring instruments are adjusted or adjusted again as necessary.

   3) Calibration status can be confirmed. (Calibrated or under calibration, or not calibrated)

   4) Measuring instruments are safeguarded from adjustments that would invalidate the calibration.

(5) If measuring instruments are subsequently found that they are out of calibration and corrective action was taken, they must have the validity of previous results re-assessed.

(6) Measuring instruments are protected from damage and deterioration during handling, maintenance and storage.

(7) If the computer software is used in the measurement of specified requirements, it must be validated prior to use.

2. Implement of inspection

The periodic inspection is positioned as the core of maintenance. Each measuring instrument must be inspected based on the “Periodic-inspection standard” and the “Periodic-inspection manual” which must have been established beforehand by the thermal power plant. Working items are recommended to be selected into the items which can be done only at the time of plant shutdown.

Following works may be necessary so that the facility secure the safe and efficient operation and maintain the functions enough until the next inspection.

(1) Plan

   1) Inspection item

   Periodic inspection list items are determined based on the data obtained during daily operations and inspections, manufacture’s recommendations, result of previous inspection, manuals etc.

   2) Management

   Periodic inspection is performed by manufacturers, maintenance companies, etc.

   Therefore, in order to maintain required quality, following points must be confirmed before periodic inspection by the thermal power plant and manufacturers, maintenance companies, etc., from the point of quality, safety, and schedule management.

   a. Order and distribution conditions of parts, material, tools

b. Operating condition, maintenance condition, problem

c. Schedule arrangement between the relevant work and periodic inspection

(2) Do

1) Activation or performance test

Activation and performance of each device are checked. Also, it is confirmed that the performance which the system must have essentially is satisfied.

2) Calibration and adjustment

All instruments in the thermal power plant must be calibrated and adjusted during the periodic inspection.

As instruments which are related with the security of thermal power plant, management in calibration must satisfy the necessary items described in preceding paragraph 1.

"Calibrations" is a series of work which ensure the relationship between the value pointed by the instrument and value of the standard.

As a result of calibration, the work which makes an output of the instrument suitable for the desirable condition is called "adjustment".

"Calibrations" and "adjustment" is necessary to maintain the accuracy of instruments. If the accuracy of instruments is not proper value, the process value may exceed the allowable value as shown in .Figure 174-a1-3. Therefore, criterion of accuracy should be decided before calibration and adjustment.

Usually, work items are classified into following two items.

a. An individual instrument calibration and adjustment

Measuring instruments are calibrated and adjusted at several specific points including minimum and maximum scale values within the instrument’s operating range.
Generally, reference standard input is increased from minimum to maximum value and decreased from maximum to minimum value due to hysteresis characteristics of instruments.
IEC61298-2 is referred for calibration of an individual instrument.

b. Loop test

After the individual instrument calibration and adjustment are completed, and wirings and piping are connected completely, each loop of the instrumentation is checked at the indicator on a display in the central control room just before the thermal power plant operates.
Depending on the result, output of instrument may be adjusted.
If there is no abnormal instrument in particular, operation of the plant starts.

3) Traceability

Traceability is required when measuring instruments are calibrated and maintained to accepted standards, giving confidence to the inspection results.

Traceability means that the result of calibration is traceable to the device certificated by international or national standards.

Therefore, procedures to manage measuring instruments such as “Periodic-inspection standard” and the “Periodic-inspection manual” must stipulate that measuring instruments must be calibrated and adjusted under the condition traceability is established.

However, if there is no international or national standard, the basis used for calibration must be recorded.

4) Repair and overhaul

For the purpose of performance recovery, instruments are repaired and overhauled. Parts of instruments which have life time such as capacitors, filters, diaphragm, fuses, and fan bearings at the control panel, packing between the pipes, are recommended to be exchanged at the specific interval. These items and interval must be referred to instruction manuals from the manufacturer and result of visual inspection. Moreover, the stock controls of parts and spare parts, etc. are needed for troubles during operation.

5) Replacement

For the improvement in reliability, some equipment is recommended to be replaced at the specific interval.

For example, the manufacture of digital control unit may stop the manufacturing the relevant equipment sooner or later, due to the update of machines. The manufacture may continue the supply of parts for the relevant equipment during some time (in many cases, from 5 to 10 years); however, this is too short, considering life time of the thermal power plant.

In this case, the stock controls of for many parts and spare parts, etc. are needed considering troubles during operation.

For reliability, arranging the schedule of periodic inspection, the relevant control unit is recommended to be replaced in approximately 15 years after installation.

Moreover, in the case of equipment such as computer servers, stop of the manufacturing may be earlier, therefore, frequent communication with the manufacturer is necessary.

An example of loop test in the control system is shown in Figure 174-a1-1 and an example of record of calibration and adjustment is shown in Figure 174-a1-2. Figure 174-a1-4 shows a flow chart of calibration and adjustment.

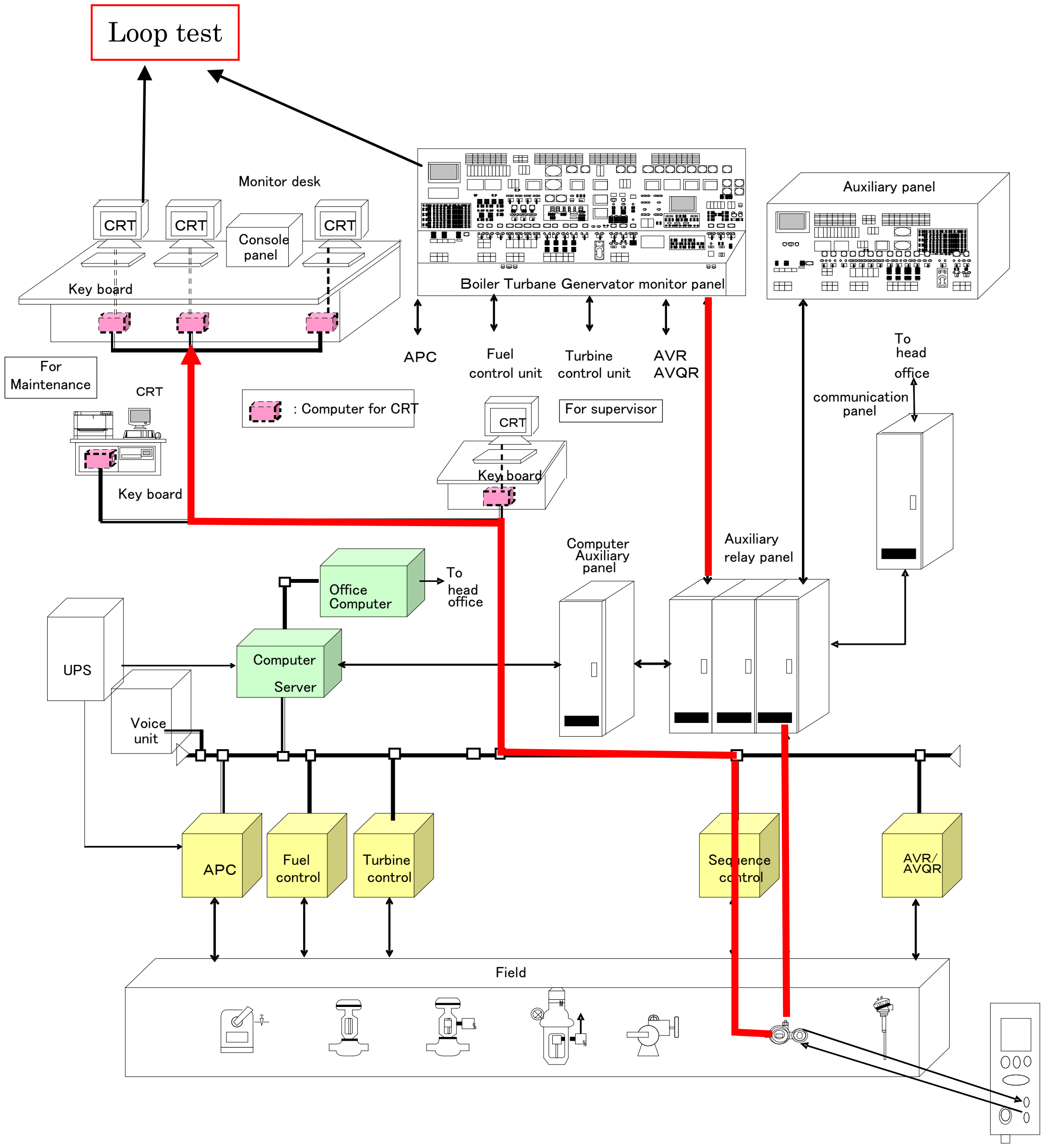


Figure 174-a1-1 An example of loop test in the control system

Calibration and adjustment of transmitter

Weather	Cloudy	Environmental limits		Error (%)		Result	Checked by
Tem (℃)	24	Tem (℃)	-30 to 80	allowable	±0.5%	Good	AKB
Hum (%)	31	Hum (%)	0 to 100	Total error	**0.00%**		

Name of instruments		**Condenser vacuum**	Date	2011/5/18
Tag No.		**PT-205**	Tester	ABC
Spec	Place	Under the condenser	Sequence No.	R137
	Manufacturer	Y	Range	-100 to 0 kPa
	Type	EJX110	Head correction	—
	Accuracy	±0.10%		

Items			Unit	Measured value							
			%	0	25	50	75	80			
Standard value		Input	kPa	0.0	-25.0	-50.0	-75.0	-80.0			
		Output	DC mA	20.00	16.00	12.00	8.00	7.20			
		Indication	kPa	0.0	-25.0	-50.0	-75.0	-80.0			
Individual Trans- -mitter calibration		Standard input	**DC mA**	**20.00**	**16.00**	**12.00**	**8.00**	**7.20**		Maximum error	Cable No.
	B	Ascent	DC mA	20.02	16.02	12.02	8.02	7.22		0.12%	R137Z02
		Descent	DC mA	20.02	16.02	12.02	8.02	7.22			
		Error	%	0.12	0.12	0.12	0.12	0.12			
	A	Ascent	DC mA	20.00	16.00	12.00	8.00	7.20		0.00%	Terminal X1-18,19
		Descent	DC mA	20.00	16.00	12.00	8.00	7.20			
		Error	%	0.00	0.00	0.00	0.00	0.00			
Indicator		Standard input	**kPa**	**0**	**-25**	**-50**	**-75**	**-80**		Maximum error	PI-205
	B	Ascent	kPa	0.0	-25.0	-50.0	-75.0	-80.0		0.00%	
		Descent	kPa	0.0	-25.0	-50.0	-75.0	-80.0			
		Error	%	0.00	0.00	0.00	0.00	0.00			
	A	Ascent	kPa								Turbine panel
		Descent	kPa								
		Error	%								
Recorder		Standard input	**kPa**	**0**	**-25**	**-50**	**-75**	**-80**		Maximum error	P-I005
	B	Ascent	kPa	-0.10	-25.06	-50.00	-74.97	-79.98		-0.10%	
		Descent	kPa	-0.10	-25.06	-50.00	-74.97	-79.98			
		Error	%	-0.10	-0.06	0.00	0.03	0.02			
	A	Ascent	kPa								
		Descent	kPa								
		Error	%								
Computer		Standard input	**kPa**	**0**	**-25**	**-50**	**-75**	**-80**		Maximum error	No. T001
	B	Ascent	kPa	0	-25	-50	-75	-80		0.00%	
		Descent	kPa	0	-25	-50	-75	-80			
		Error	%	0.00	0.00	0.00	0.00	0.00			
	A	Ascent	kPa								
		Descent	kPa								
		Error	%								

【Remarks】
B: Before calibration and adjustment
A: After calibration and adjustment

Standard instruments for calibration

No.	Name	Type	Product number	Remarks
QS 1	Digital multi meter	73402	T1H4063	
QS 5	Pressure calibrator	DPI610	61027647	

Figure 174-a1-2 An example of record of calibration and adjustment

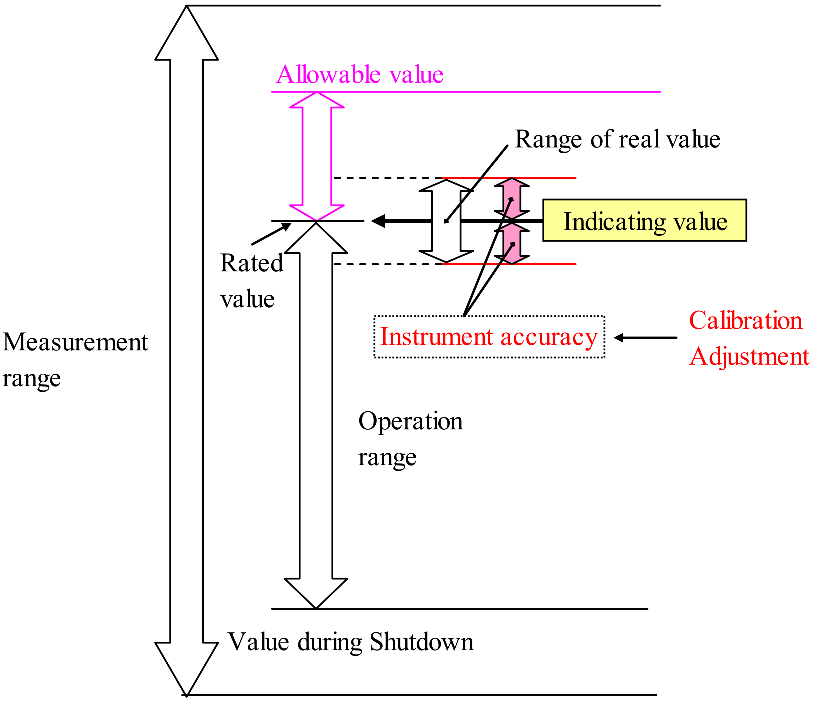
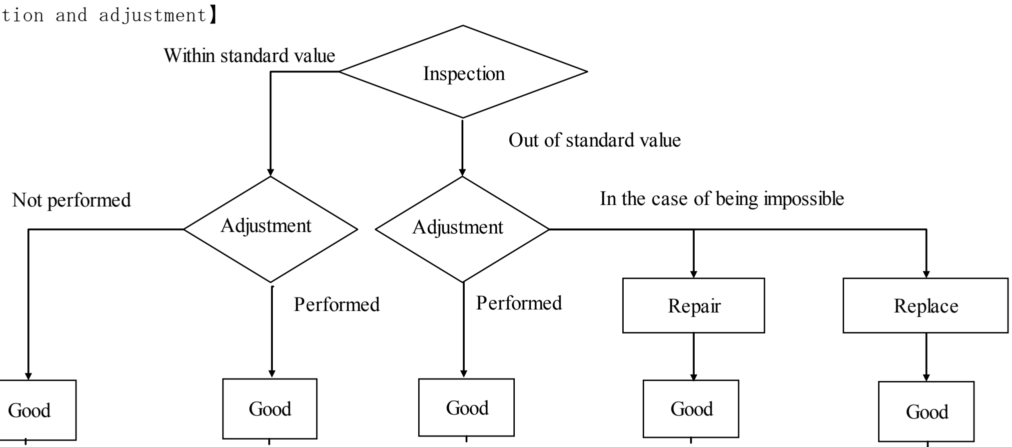


Figure 174-a1-3 An example of the concept for indicating value

【Flow of calibration and adjustment】



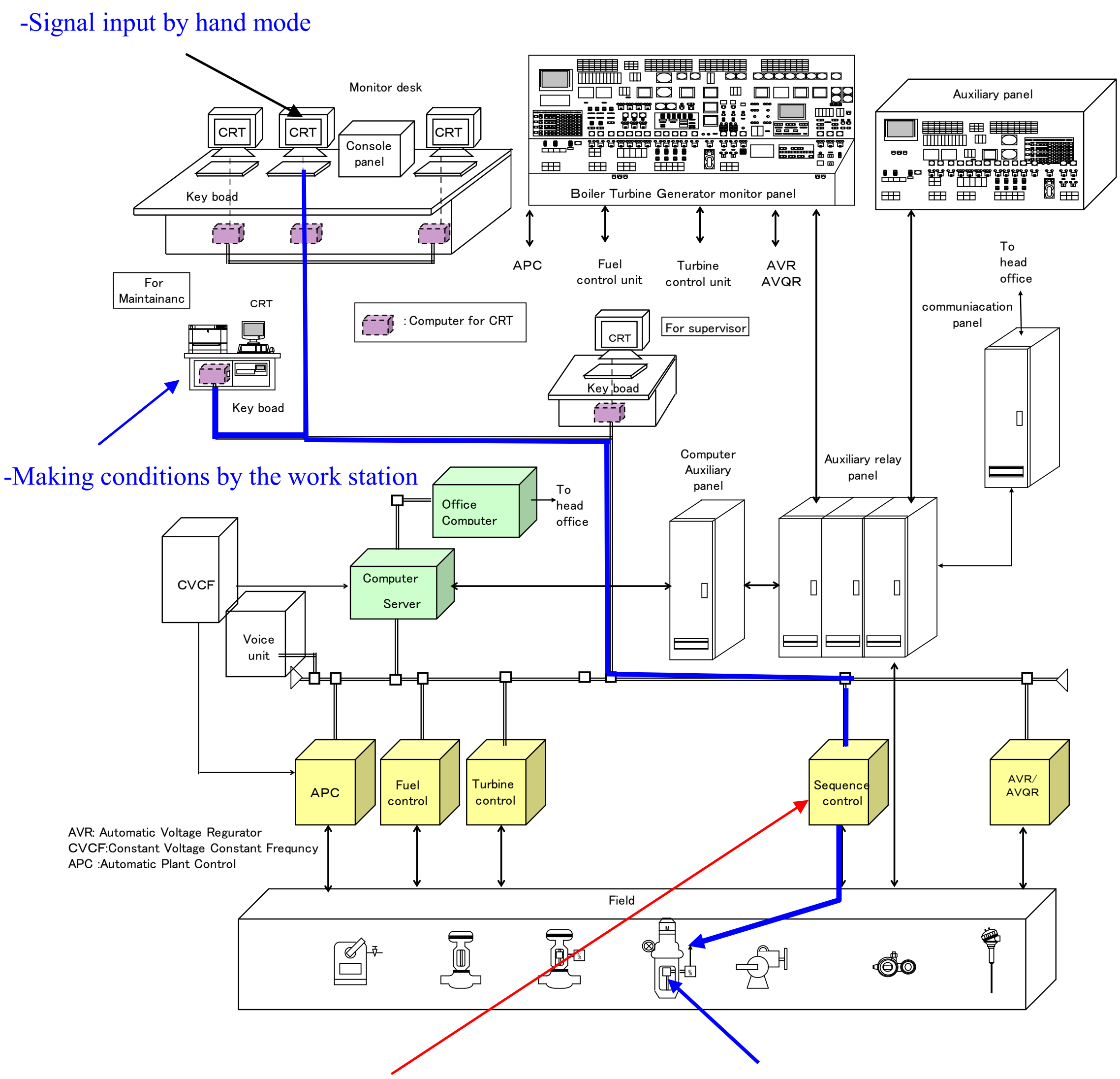
Inspection record									
Adjustment	Not performed		**Performed**		Performed		**Performed**		**Performed**
Result	Good		Good		Good		**Good**		**Good**
Reassessment of previous result	NR		NR		R		R		R

G:Good
R:Required
NR:Not Required

Figure 174-a1-4 An example of flow chart of the calibration and adjustment

6) Control devices

Control devices are inspected in the periodic inspection in order to secure safe operation. Figure 174-a1-5 shows an example of the control device inspection.



(1) In general, software remains unchanged except the case modification is performed.

(2) In some cases, signals may not be outputted due to the plant condition.(logic inside is referred by the work station or CRT etc)

-Valve opening

-Output signal from controller are checked

Figure 174-a1-5 An example of the control device inspection

7) Examples of inspection items

Followings Table174-a1-3 and 4 are examples of periodic inspection items.

Table174-a1-1 An example of inspection items (Boiler control system)

Items	Contents	Remarks
Analogue processor	1 Input/output characteristic test, adjustment	
	2 Cleaning and visual inspection	Inspected by pulling out from the equipment
Analogue transducer	1 Input/output characteristic test, adjustment	
System cabinet	1 Slag checking of each terminal	
	2 Cleaning at the connectors	
	3 Cleaning of the cooling fans and filters	
	4 Visual inspections of wirings in the panel	
	5 Exchange of cooling fans	
System power source	1 Input /output voltage measurement, adjustment	
	2 Meter adjustment	
	3 Check of protective function	
	4 Exchange of cooling fans	
	5 Exchange of electrolytic capacitor	12 years interval
Digital processor	1 Program check, comparison	Log check is included
	2 Cleaning and visual inspection	(Check of operating indicator)
Controller	1 Visual inspection of connectors and cards	
	2 Input/output characteristic test, adjustment	
	3 Program check, comparison	
	4 Operation check	
	5 Battery, RAM exchange	5 years interval
Indicator	1 Calibration	
	2 Cleaning and visual inspection	
Operating panels and terminals	1 Calibration	
	2 Cleaning	
Maintenance tool	1 Cleaning and visual inspection	
Auxiliary relays (for protection circuit)	1 Measurement of contact resistance by relay checking device	4 years interval

Table174-a1-2 An example of inspection items (Boiler control system)

Items	Contents	Remarks
Relays (for general circuit)	1 Measurement of contact resistance by relay checking device	
Power source (Distributors)	1 Check of instrumental indirect errors in the loop test	
	2 Exchange of electrolytic capacitor	12 years interval
Annunciator	1 Input/output characteristic test, adjustment	
Simulation	1 Activation check of actuators and control valves by remote operation	
Load test	1 Check of load test	
Transient characteristic test	1 Load response test	
	2 Check of unit startup and shutdown	
	3 Automatic frequency control test	
	4 Check of BFP service in and out	
	5 Check of wet dry transition	
Trial operation and total adjustment	1 Alarm protective device test	APC function test such as “operating terminal lock” is included.
	2 Unit interlock test	
	3 Check of unit startup and shutdown	
	4 Check of unit normal operation	
	5 Back up of program and parameter	

Article 174-a2 Protective device test

This guideline is same as Article 151.

Article 174-a3 Protective device test for hydrogen and seal oil

This guideline is same as Article 152.

Article 174-a4 Protective device test for the stator cooling system of generator

This guideline is same as Article 153.

Article 174-a5 Unit interlock test

This guideline is same as Article 154.

Reference Vietnamese standard

Number	Issued	Title
TCVN3949	1984	Coal for pulverized coal burning boilers in power stations. Specifications
TCVN4395	1986	Non-destructive testing. Radiographic testing of welded joints in metallic materials using X and gamma-rays
TCVN5400	1991	Welded joints. General requirements of sampling for mechanical test
TCVN5401	1991	Welded joints. Bending test method
TCVN5401	2010	Destructive tests on welds in metallic materials. Bend tests
TCVN5402	1991	Welded joints. Blow-bending test method
TCVN5402	2010	Destructive tests on welds in metallic materials. Impact test. Test specimen location, notch orientation and examination
TCVN 5949	2005	Acoustics - Noise in public and residential areas Maximum allowable noise level
TCVN 5964	1995	Acoustics - Description and measurement of environmental noise - the main quantities and measurements
TCVN 5964	1995	Acoustics - Description and measurement of environmental noise - application of noise limits.
TCVN6008	2010	Pressure equipment. Welded. Technical requirements and testing methods
TCVN6154	1996	Pressure vessels. Safety engineering requirements of design, construction, manufacture. Testing methods
TCVN6155	1996	Pressure vessels. Safety engineering requirements of erection, use, repair
TCVN6156	1996	Pressure vessels. Safety engineering requirements of erection, use, repair. Testing method
TCVN6159	1996	Pipe lines for vapor and hot water. Test methods
TCVN6290	1997	Gas cylinders. Cylinders for permanent gases. Inspection at time of filling
TCVN 6399	1998	Acoustics - Description and measurement of environmental noise - how to get the appropriate data to use for the territory
TCVN 6962	2001	Vibration and shock - Vibration emitted by activities of construction works and industry production - The maximum allowable level in the environment of public and residential areas
TCVN 6963	2001	Vibration and shock- Vibration emitted by construction works and industrial productions - Method of measurement
TCVN 7704	2007	Boilers. Technical requirement of design, construction, manufacture, installation, operation, maintenance

Reference Japanese standard

Number	Issued	Title
JIS B 8041	2000	Gas turbines - Acceptance test
JIS B 8042-8	2001	Gas turbines - Procurement - Part 8 : Inspection, testing, installation and commissioning
JIS B 8102	2002	Steam turbines - Acceptance test
JIS B 8105	2004	Steam turbines - Acceptance test - Thermal performance verification tests of retrofitted steam turbines
JIS B 8210	2009	Safety devices for protection against excessive pressure-Direct spring loaded safety valves for steam and gas service
JIS B 8265	2010	Construction of pressure vessel-General principles
JIS B 8266	2006	Alternative standard for construction of pressure vessels
JIS B 8285	2010	Welding procedure qualification test for pressure vessels
JIS B 8301	2000	Rotodynamic pumps - Hydraulic performance acceptance tests - Grades 1 and 2
JIS B 8330	2000	Testing methods for turbo-fans
JIS B 8340	2000	Testing methods for turbo blowers and compressors
JIS B 8341	2008	Displacement compressors-Acceptance tests
JIS C 1302	2002	Insulation resistance testers
JIS C 1509	2005	Sound level meters -- Part 1: Specifications
JIS C 1510	1995	Vibration level meters
JIS G 0583	2012	Automated eddy current examination of steel pipes and tubes
JIS G 0584	2004	Ultrasonic examination for arc welded steel pipes
JIS G 0587	2007	Method for ultrasonic examination for carbon steel and low alloy steel forgings
JIS G 0801	2008	Ultrasonic testing of steel plates for pressure vessels
JIS H 0515	1992	Eddy current inspection of titanium pipes and tubes
JIS H 0516	1992	Ultrasonic inspection of titanium pipes and tubes
JIS Z 2305	2001	Non-destructive testing — Qualification and certification of personnel
JIS Z 2320-1	2007	Non-destructive testing-Magnetic particle testing-Part 1: General principles
JISZ2343-1	2001	Non-destructive testing - Penetrant testing - Part 1 : General principles - Method for liquid penetrant testing and classification of thepenetrant indication
JIS Z 3040	1995	Method of qualification test for welding procedure
JIS Z 3060	2002	Method for ultrasonic examination for welds of ferritic steel
JIS Z 3104	1995	Methods of radiographic examination for welded joints in steel
JIS Z 3801	1997	Standard qualification procedure for manual welding technique

Number	Issued	Title
JIS Z 3811	2000	Standard qualification procedure for welding technique of aluminium and aluminium alloy
JIS Z 3821	2001	Standard qualification procedure for welding technique of stainless steel
JIS Z 3841	1997	Standard qualification procedure for semi-automatic welding technique
JIS Z 8731	1999	Acoustics - Description and measurement of environmental noise
JIS Z 8735	1981	Methods of measurement for vibration level

Reference International standard

Number	Issued	Title
ISO 1996-1	2003	Acoustics - Description, measurement and assessment of environmental noise - Part 1: Basic quantities and assessment procedures
ISO 2314	2009	Gas turbines - Acceptance test
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ISO 5389	2009	Turbocompressors - Performance test code
ISO 9000	2005	Quality management systems -- Fundamentals and vocabulary
ISO 9906	1999	Rotodynamic pumps - Hydraulic performance acceptance tests - Grades 1 and 2
ISO 10675-1	2008	Non-destructive testing of welds - Acceptance levels for radiographic testing - Part 1: Steel, nickel, titanium and their alloys
ISO 10675-2	2010	Non-destructive testing of welds - Acceptance levels for radiographic testing - Part 2: Aluminum and its alloys
ISO 11666	2010	Non-destructive testing of welds - Ultrasonic testing - Acceptance levels
ISO 13123	2011	Metallic and other inorganic coatings - Test method of cyclic heating for thermal-barrier coatings under temperature gradient
ISO 15626	2011	Non-destructive testing of welds - Time-of-flight diffraction technique (TOFD) - Acceptance levels
ISO 21009	2008	Cryogenic vessels - Static vacuum-insulated vessels - Part 1: Design, fabrication, inspection and tests
ISO 23277	2006	Non-destructive testing of welds - Penetrant testing of welds - Acceptance levels
ISO 23278	2006	Non-destructive testing of welds - Magnetic particle testing of welds - Acceptance levels
ISO 24497-3	2007	Non-destructive testing - Metal magnetic memory - Part 3: Inspection of welded joints
ISO/TS 24817	2006	Petroleum, petrochemical and natural gas industries - Composite repairs for pipework - Qualification and design, installation, testing and inspection
IEC 60255-1	2009	Measuring relays and protection equipment - Part 1: Common requirements
IEC 60255-12	1980	Electrical relays - Part 12: Directional relays and power relays with two input energizing quantities
IEC 60255-13	1980	Electrical relays - Part 13: Biased (percentage) differential relays
IEC 60255-16	1982	Electrical relays - Part 16: Impedance measuring relays
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Number	Issued	Title
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IEC 60359	2001	Electrical and electronic measurement equipment - Expression of performance
IEC 60034-1	2010	Rotating electrical machines - Part 1: Rating and performance
IEC60953-1	1990	Rules for steam turbine thermal acceptance tests. Part 1: Method A - High accuracy for large condensing steam turbines
IEC60953-2	1990	Rules for steam turbine thermal acceptance tests. Part 2: Method B - Wide range of accuracy for various types and sizes of turbines
IEC60953-3	2001	Rules for steam turbine thermal acceptance tests - Part 3: Thermal performance verification tests of retrofitted steam turbines
IEC 61064	1991	Acceptance tests for steam turbine speed control systems
IEC61298-2	2008	Process measurement and control devices - General methods and procedures for evaluating performance - Part 2: Tests under reference conditions
IEC 61557-1	2007	Electrical safety in low voltage distribution systems up to 1 000 V a.c. and 1 500 V d.c. - Equipment for testing, measuring or monitoring of protective measures - Part 1: General requirements
IEC 61557-2	2007	Electrical safety in low voltage distribution systems up to 1 000 V a.c. and 1 500 V d.c. - Equipment for testing, measuring or monitoring of protective measures - Part 2: Insulation resistance
IEC 61672-1	2002	Sound level meters - Part 1: Specifications
IEEE Std 4	1995	IEEE Standard Techniques for High-Voltage Testing
IEEE Std 43	2000	IEEE Recommended Practice for Testing Insulation Resistance of Rotating Machinery
IEEE Std 62.2	2004	IEEE Guide for Diagnostic Field Testing of Electric Power Apparatus - Electrical Machinery
IEEE Std 81	1983	IEEE Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System
IEEE Std 95	2002	IEEE Recommended Practice for Insulation Testing of AC Electric Machinery (2300 V and Above) With High Direct Voltage
IEEE Std 112	2004	IEEE Standard Test Procedure for Polyphase Induction Motors and Generators
IEEE Std 115	2009	IEEE Guide: Test Procedures for Synchronous Machines Part I--Acceptance and Performance Testing Part II-Test Procedures and Parameter Determination for Dynamic Analysis
IEEE Std 120	1989	IEEE Master Test Guide for Electrical Measurements in Power Circuits
IEEE Std 286	2000	IEEE Recommended Practice for Measurement of Power Factor Tip-Up of Electric Machinery Stator Coil Insulation
IEEE Std 433	2009	IEEE Recommended Practice for Insulation Testing of AC Electric Machinery with High Voltage at Very Low Frequency
IEEE Std 434	2006	IEEE Guide for Functional Evaluation of Insulation Systems for AC Electric Machines Rated 2300 V and Above

Number	Issued	Title
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ASME BPVC-I	2010	BPVC Section I-Rules for Construction of Power Boilers
ASME BPVC-V	2010	BPVC Section V-Nondestructive Examination
ASME BPVC-VIII-1	2010	BPVC Section VIII-Rules for Construction of Pressure Vessels Division 1
ASME BPVC-VIII-2	2010	BPVC Section VIII-Rules for Construction of Pressure Vessels Division 2-Alternative Rules
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ASME PTC 6	2004	Steam Turbines
ASME PTC 6.2	2011	Steam Turbines in Combined Cycles
ASME PTC 20.1	1977	Speed And Load-Governing Systems For Steam Turbine-Generator Units
ASME PTC 20.2	1986	Overspeed Trip Systems Of Steam Turbine-Generator Units
ASME PTC 25	2008	Pressure Relief Devices