Ministry of Energy and Petroleum
Kenya Electricity Generating Company PLC

Project for Strengthening Operation and Maintenance Capacity of Olkaria Geothermal Power Stations Using IoT Technology in the Republic of Kenya

Project Completion Report

February 2025

Japan International Cooperation Agency (JICA)

Kyuden International Corporation
West Japan Engineering Consultants, Inc.

Republic of Kenya Basic Information

Capital	Nairobi
Languages	Swahili, English, and many local languages which are used depending on the tribe or region
Area	583,000 km^2 (about 1.5 times the size of Japan)
Population	55.1 million (World Bank, 2023), Population growth rate: 2% (World Bank, 2023)
Economic Indicators	GDP (Gross Domestic Product) US$107.4 billion (US$1,950/person, World Bank, 2023), Economic growth rate (real) :5.4% (2023 World Bank)
Major trade items	exports: 67.5 million U.S. dollars, imports: 195.9 million U.S. dollars (2021 World Bank)
Social conditions	Religion: Christianity Islam other traditional religions, etc., Price increase: 7.7% (World Bank, 2023), Average life expectancy: 62 years (World Bank, 2022)
Natural conditions	Climate: Tropical savanna, temperate summer rain, etc.; Temperature: 10-25° Celsius, Annual precipitation: 726 mm (World Bank, 1991-2020), Rainy season: March to May, Dry seasons: December to February, June to October.

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Abbreviation

	Abbreviation	Definition
A	AAS	Atomic Absorption Spectrometry
	AI	Annual Inspection
	ASS	Automatic Synchronous System
	AVR	Automatic Voltage Regulator
C	C/P	Counter Part
	CBM	Condition Based Maintenance
	CEO	Chief Executive Officer
	COVID-19	Coronavirus disease
D	DCS	Distributed Control System
	De-SH	Desuperheater
E	EOP	Emergency Oil Pump
	EPMA	Electron Probe Microanalyzer
F	FRP	Fiber Reinforced Plastics
	FTA	Fault Tree Analysis
G	GRA	Geological Resource Assessment Division
H	HPLC	High Performance Liquid Chromatography
	HW	Hot Well
I	ICP	Inductively Coupled Plasma
	ICT	Information and Communication Technology
	IoT	Internet of Things
J	JCC	Joint Coordination Committee
	JICA	Japan International Cooperation Agency
K	KenGen	Kenya Electricity Generating Company
	KfW	Kreditanstalt für Wiederaufbau
L	LC	Liquid Chromatography
	LCV	Level Control Valve
M	MD	Managing Director
	MoEP	Ministry of Energy and Petroleum
	M/M	Minutes of Meeting
N	NCG	Non-Condensable Gas
O	OEM	Original Equipment Manufacturer
	OHM	Overhaul Maintenance
	OJT	On-The-Job Training
	OPMS	Operation Management System
	O&M	Operation & Maintenance
P	PDCA	Plan, Do, Check, Act
	PDM	Project Design Matrix
	pH	hydrogen ion exponent
	PO	Plan of Operation
R	R/D	Record of Discussion
S	SAP-PM	SAP Plant Maintenance module
	SDGs	Sustainable Development Goals
	SNS	Social Networking Service
	SSC	Specific Steam Consumption
	SUS	Steel Use Stainless
T	TBM	Time Based Maintenance
	TFT	Tracer Flow Testing
	TS	Technical Service

U	UNIDO	United Nations Industrial Development Organization
W	WBT	Wet Bulb Temperature
	WJEC	West Japan Engineering Consultants, Inc.
X	XRD	X-Ray Diffraction
	XRF	X-Ray Fluorescence

1. Project Background and Overview

1.1. Background

The Republic of Kenya (hereinafter referred to as "Kenya") has one of the largest economies and industrialization rates in the East African region. The economy has maintained a solid and high economic growth rate, except in 2020, when it was significantly affected by the spread of COVID-19. Kenya's GDP per capita is approximately US$1,952 (world Bank: 2023), which is among the highest in the East African region, and the GDP growth rate is steady at approximately 5%. Against the backdrop of high economic growth, peak demand in FY2022/23 was 2,149 MW, increasing at an annual rate of about 4.5%. In contrast, total installed generating capacity was 3,490 MW in 2023. Of this total, the installed capacity of major power sources was 25% hydroelectric, 27% geothermal, 18% thermal, 13% wind, 12% solar, and 5% other power sources in 2023. As of fiscal year 2022/23, the proportion of annual electricity generation was 45% geothermal, 19% hydroelectric, 17% wind, 3% solar, 11% thermal, and 5% other sources. Meanwhile, the country's electrification rate is 75%, and although it is improving year by year, 2.5 million households still do not have access to electricity. Kenya's geothermal power potential is estimated to be 7,000 MW, and the country's Ministry of Energy and Petroleum (hereinafter referred to as MoEP), in its "Kenya Vision 2030," the country's development plan for the period 2008-2030, has plans to increase geothermal development to 5,000 MW by 2030, while the Ministry's 10-Year Development Plan for the Power Sector (2014-2024)" also positions the development of the Olkaria geothermal field as an essential project for the achievement of the above plan. In order for the Kenya Electricity Generating Authority (hereinafter referred to as "KenGen"), which is responsible for geothermal development, and operation and management of the Olkaria geothermal field, and to expand its activities in neighboring countries, it is necessary to establish a management cycle based on the operation and maintenance data, such as properly monitor equipment in the power station, monitor the condition of the geothermal wells, and conduct more precise repairs. In addition, an IoT system was installed at the Olkaria power station as part of an IoT infrastructure development project supported by the United Nations Industrial Development Organization (UNIDO) for KenGen, which is positioned as a collaborative project with JICA. In this project, the JICA expert team provided KenGen with technical guidance on how to use IoT systems to properly collect and manage data related to O&M and reservoirs at the Olkaria geothermal power station and to improve the plant's operation and maintenance capabilities. The JICA expert team provided KenGen with technical guidance to acquire skills in data analysis and utilization and to improve efficient power station operations. The JICA expert team also supported KenGen to strengthen its internal training program system, so that after the project completion, KenGen will be able to deploy the acquired skills by itself and the aim is for the transferred technology by the JICA expert team to be firmly established in the operation and maintenance management of the Olkaria geothermal power station.

1.2. Project Overview

(1) Project name

The project for strengthening operation and maintenance capacity of Olkaria geothermal power station using IoT technology.

(2) Implementation period

Phase I: 6th April 2020 – 31st March 2021

Phase II: 1st September 2021 – 31st March 2025

(3) Target power stations

Olkaria geothermal power stations: Ⅰ-AU4, Ⅰ-AU5, Ⅱ-1, Ⅱ-2, Ⅱ-3, Ⅳ-1, Ⅳ-2, Ⅴ-1, Ⅴ-2

1.2.1. Overall Goal

Performance of KenGen's Olkaria geothermal power stations is improved.

1.2.2. Project Purpose

Technical management of KenGen's Olkaria geothermal power stations is improved.

1.2.3. Outputs

[Output 1] O&M capacity of power stations is strengthened.

[Output 2] Reservoir management capacity is strengthened.

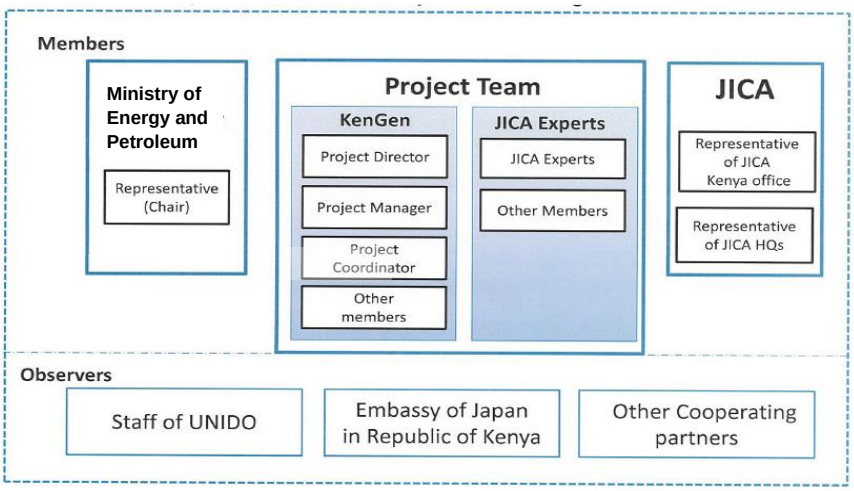
1.3. Implementation System

1.3.1. Related Organizations

The main organizations involved in this project were MoEP, KenGen, and JICA.

1.3.2. Implementation Structure

A Joint Coordination Committee (JCC), overseen by MoEP and consisting of KenGen, JICA, and a team of JICA experts, was established as the decision-making organization for the project.



[Source: Prepared by Expert Team]

Fig. 1.3-1 JCC Members and Project Team Structure

(1) Kenyan Implementation Structure

The following is a list of key counterpart assignments within the project team.

a. Project Director of this project on R/D and PDM

Ms. Rebecca Miano, Managing Director (MD) & Chief Executive Officer (CEO) (~September 2022)

Mr. Abraham Serem Acting MD & CEO (September 2022 - August 2023)

Eng. Peter Njenga, MD & CEO (from August 2023)

b. Project Manager for this project on R/D and PDM
Eng. Samson Kimani, Manager, Geothermal Operation Division (~June 2022)
Eng. Francis Makabwa, Manager, Geothermal Operations Division (July 2022 - November 2024)
Eng. Lawrence Mwagodi, Manager, Geothermal Operations Division (from December 2024)
The following are two managers, who are not project managers but are in the same position as the above project managers, in the Reservoir Management Department and Geothermal Resource Evaluation Department, to which Core members of the project belong.
Eng. Clety Bore, Manager, Reservoir Management and Steam Field Division
Mr. Kizito Oponde, Acting Manager, Geological Resource Assessment Division (GRA)

c. JICA focal points in the project not identified in the R/D and PDM
The following two individuals were appointed after the beginning of the project and are the KenGen side's substantive coordinators for power generation facilities and reservoir management and were responsible for coordinating with the team of experts and Core members.
Eng. Harrison Keter, Assistant Manager, Geothermal Operations Division
Eng. Vincent Koech, Assistant Manager, Reservoir Management and Steam Field Division

d. Key technology transfer recipients of this project (Core members)
17 mechanical engineers, electrical and control engineers, Geothermal Operation Division (names omitted).
Reservoir Engineers, Scientists (mainly geochemistry) Total 10*(names omitted)
* Breakdown: Reservoir Management and Steam Field Division (6 including a reservoir chemist), Geological Resource Assessment Division (3 geochemists), Geothermal Operation Division (1 plant chemist)

(2) Implementation system on the Japanese side
In this project, in addition to the JICA expert team, JICA dispatched a long-term expert to coordinate with counterparts for smooth progress of the project, liaise with JICA headquarters, JICA Kenya offices, the Japanese Embassy, the Kenyan government, other donors, and other relevant parties. This long-term expert also has provided advice and guidance on issues and areas related to project progress.

1.4. Equipment procurement

1.4.1. HPLC

In the first term, autoclave tests using brine from the Olkaria production well demonstrated that NDSs (Naphthalenedisulfonic Acid Disodium Salt) were properly detected, confirming that NDSs are effective as a new tracer and that the provision of HPLC, an analytical instrument, was appropriate. The HPLC was transported to Olkaria from Japan in January 2022 and installed in the reservoir chemistry laboratory in May 2022. Then, training in tracer test using HPLC was conducted in May 2022, November 2022, August 2023, and February 2024. Because columns were prone to clogging with the brine from Olkaria, the tubes and columns were replaced and a new method of filtering samples was devised. Also, although communication with supplier was difficult initially, it became possible to

conduct tracer test using a new tracer in Olkaria at last. KenGen needs to prepare consumables based on the PDM's inputs from the Kenyan side attached to the R/D of 21st November 2019.

1.4.2. Interactive whiteboards

In August 2020, due to travel restrictions caused by COVID-19, the JICA expert team considered providing technology transfer remotely from Japan to Olkaria geothermal power station. In order to promote understanding of the lecture content remotely and improve the effectiveness of the training, Interactive Whiteboards were introduced that not only enable materials to be shared and explained via PC screen sharing, but also allow for real-time, two-way writing on materials. One unit was installed in Japan and two units at the Olkaria geothermal power station. Because the work areas for reservoir management and power plant management are different and it is difficult to move equipment between the two work areas, two Interactive Whiteboards were installed at the Olkaria geothermal power station.

1.4.3. Addition of cooling tower and main steam piping temperature monitoring system

Olkaria geothermal Power station has repeatedly experienced power generation reductions due to cooling tower performance degradation and forced shutdowns due to leaks in the main steam pipes. In June 2022, KenGen requested JICA to install the monitoring equipment system and transfer the technology to solve these challeges. JICA determined that this monitoring equipment was essential to improve the operation of the Olkaria geothermal Power station, and approved it as additional equipment in October 2022.

1.4.4. The UNIDO IoT System

Reflecting the JICA-related basic study jointly conducted by Kyushu Electric Power and West Japan Engineering Consultants in 2017, the joint venture of Kyushu Electric Power and West Japan Engineering Consultants was entrusted by UNIDO with “Capacity Strengthening of Operations & Maintenance (O&M) with Internet of Things IoT (IoT) technologies for Olkaria Geothermal Power Station in Kenya” in 2018. This UNIDO IoT system consists of a data center (including a predictive trouble management system, performance management system, operational management system, and well data server) and a data collection and transmission system to enhance performance analysis of each Power station. In June 2022, UNIDO handed over this IoT system to KenGen.

2. Project activities

2.1. The first term

In the first term (April 2020 - March 2021), a training menu based on each activity was prepared to achieve the project goals. Due to the travel restrictions imposed by COVID-19, so the JICA expert team shared the contents with KenGen online and the technology transfer was conducted using online materials and videos.

(1) Power plant management

a. Activities

In the first term, travel to Kenya was suspended in order to the impact of COVID-19. Instead, lectures on basic technologies related to predictive trouble management and performance management, and video materials related to repair work such as overhaul maintenance, were produced and training was conducted online from Japan. The activities were as follows.

Table 2.1-1 Activities in the first term (Power plant management)

No.	Date	Subject
1	30th October 2020	・Calculation of generator output ・Use of trend charts for predictive management ・Performance management using correlation chart ・Trouble analysis using FTA
2	12th November 2020	・Trouble records of Olkaria geothermal Power station ・Operational data under specific conditions ・Operational data analysis
3	30th November 2020	・Concept of performance management using correlation chart ・Performance confirmation using actual operational data
4	14th December 2020	・Explanation of the operation of geothermal Power stations in Japan using video materials (Patrol: mechanical and electrical equipment, vibration measurement)
5	28th -29th January 2021	・Introduction of Kyushu Electric Power's efforts to maintain availability ・Steam turbine disassembly and assembly ・Introduction of steam turbine blade cleaning method ・Disassembly and inspection of pumps ・Question and answer session

[Source: Prepared by Expert Team]

b. Outputs

For the First Term, the JICA expert team prepared a menu based on each activity to achieve the project purpose, to share with KenGen for technology transfer. Also, materials and videos for web-based implementation were prepared. Although there were some instances where the online training did not allow for smooth question and answer sessions or exchange of opinions, Core members were highly skilled and understood the significance of this training well. All lectures on the technology transfer items prepared by the JICA expert team were able to be delivered. KenGen also fully understood each technical item and content provided by the JICA expert team. At the end of the First Term, however, the project purpose had not been achieved. Therefore, advanced training, including a review of the First Term in-depth, on technology transfer was necessary for the Second Term.

(2) Reservoir Management

a. Activities

As in the case of Power plant management, international travels were suspended. Instead, the JICA expert team prepared lecture materials and video materials related to reservoir management, such as methods for allocating blowout volume to each production well, reservoir modeling techniques, hydrothermal analysis techniques (including support for new tracer studies), and countermeasures for scale deposition, corrosion, and bacteria problems related to chemical management. Then the remote technology transfer program from Japan for KenGen took place with the materials. Additionally, the JICA expert team exchanged opinions with Core members based on the results of the chemical analysis of geothermal fluid and other samples sent from KenGen to Japan. The activities were as follows,

Table 2.1-2 Activities in the first term (Reservoir Management)

Session	Date	Subject
1	1st October 2020	・Explanation of the work plan ・Explanation and discussion on the first transport of sample water
2	15th October 2020	・Discussion on the selection and transportation of the first sample water ・Explanation and discussion on scale, corrosion, bacteria, etc.
3	28th October 2020	・Discussion on the conceptual model of the Olkaria reservoir
4	12th November 2020	・Discussion on tracer (fluorescein) analysis ・Discussion on scale, corrosion, bacteria, etc.
5	16th December 2020	・Discussion on tracer (fluorescein) analysis ・Interviews and discussions on bacterial countermeasures ・Discussions on the second round of sample water transport ・Video training on hot water sampling and silica analysis
6	14th January 2021	・Introduction of reservoir monitoring in Japan ・Lecture on the necessity and interpretation of well characterization curves ・Training on blowout volume allocation methods ・Training on pressure monitoring well layout ・Training on pressure monitoring well layout ・Consultation on transportation of the second analysis sample
7	29th January 2021	・The second discussion on transportation of analytical samples ・Video training on tracer (fluorescein) analysis and caustic soda injection into cooling tower overflow water
8	9th February 2021	・Lecture on reservoir conceptual model ・Confirmation of the status of the transportation of the second analysis sample
9	25th February 2021	・Training on the placement of pressure monitoring observation wells ・Explanation and discussion of autoclave test results for the consideration of new tracers ・Explanation and discussion on scale, corrosion, bacteria, etc.
10	16th March 2021	・Training on scale, corrosion, bacteria, etc. ・Description of the second phase of training

[Source: Prepared by Expert Team]

b. Outputs

Each of these topics was a technology required to implement reservoir management at the Olkaria geothermal Power station. Also, it was expected to satisfy the Project Purpose by detecting reservoir changes appropriately based on the knowledge of geochemistry and reservoir engineering with the skill level at 4 or higher, which allow them to apply the acquired technology in actual work. Since the training in First Term was limited to web-based, some activities could not be implemented as originally planned. However, in the feedback on the technical report by Core members, they commented that the training was effective in transferring technology to KenGen, as their skill levels improved through the acquisition of new knowledge. In the second term of the project, the Project purpose would be achieved by providing highly effective training using interactive whiteboards.

2.2. Power station Operation and Maintenance Activities and Results

2.2.1. Activity1-1 Review and analyze the current status and issues of O&M in Olkaria I (Units 4 and 5), Olkaria II (Units 1, 2 and 3), Olkaria IV (Units 1 and 2) and Olkaria V (Units 1 and 2)

(1) Background

Through the online training in the first phase, the JICA expert team were able to sort out what was suitable for remote implementation and what was difficult to achieve remotely. In particular, the technology transfer related to OHM is practical training, and it was difficult to implement remotely even with the aid of electronic whiteboards and video materials. In the second phase, it was planned to implement OJT for OHM at the three plants on-site. However, for Olkaria I-AU4,5, OHM was conducted in 2022, and for Olkaria II units 1,2 and 3, OHM was conducted from 2021 to 2022. As for Olkaria IV, an upgrade plan including Olkaria I-AU is underway, and OHM is expected to be implemented in 2025 or later. Olkaria V is a newly constructed plant and is undergoing annual inspections, and the OHM implementation date has not yet been determined.

(2) Analysis of initial issues of O&M at Olkaria geothermal power station

The JICA expert team conducted a baseline survey of the overall operation status, etc. for the Olkaria geothermal power station, including gathering information on the maintenance schedule for the implementation of on-site OJT at the power stations. The JICA expert team interviewed KenGen members at the Olkaria geothermal power stations, including Core members, to grasp and analyze the initial O&M status before the technology transfer and identified issues in November 2021.

a. Initial issues in O&M

- Similar troubles had frequently occurred at the Olkaria geothermal Power station, leading to a prolonged shutdown.
- The root cause of the troubles had not been investigated and permanent countermeasures had not been taken.

- Lack of information sharing among KenGen members, such as in response to problems etc., and work procedures and know-how were not accumulated, which resulted in an impact on work efficiency and technology transfer.
- Past maintenance records and reports were not stored in a fixed location, making it difficult to access past data.
- O&M data was not fully utilized and was not reflected in performance management and facilities management.
- Trend management for aging and performance deterioration had not been implemented, and there were issues in terms of predictive maintenance to minimize risk and cost of countermeasures.
- The procedure manual on power station operation and maintenance was based on the manufacturer's manuals that were used when the power station were built. As there were no updates or corrections, there were issues with sharing and improving technology and know-how based on practical experience.

b. Analysis of trouble history at Olkaria geothermal power station

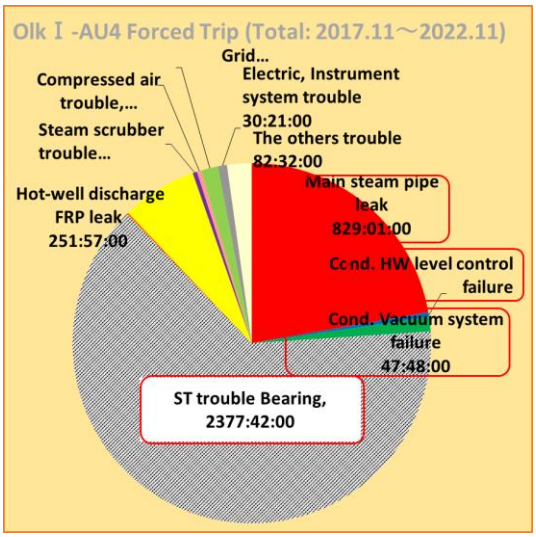
Based on historical trouble data for the Olkaria geothermal power stations over the previous five years (November 2017-November 2022), the JICA expert team analyzed trouble frequency and outage times for each unit. First, based on the trouble history data for the past five years, troubles were classified into the following 13 categories, and the number of shutdowns and each forced shutdown time were totaled for each plant. The average number of occurrences of each trouble item and its forced shut down time were then determined, and the average annual shut down time for each plant was calculated. Based on the results, the annual average shut down and loss of annual plant availability for the entire Olkaria geothermal power station was calculated.

Table 2.2-1 Olkaria geothermal power station average annual trouble hours and loss of annual plant availability

NO.	Trouble	OLK II Trouble history (Nov 2017-Nov 2022)			OLK I-AU#5 Trouble history (Nov 2017~Nov 2022)			OLKIV Trouble history (Feb 2018-Nov 2022)			OLK V Trouble history (Jan 2020-Nov 2022)			Average Annual shut down hours	Loss of Annual Availability
		OLK II			OLK I -AU			OLKIV			OLK V				
		Ave annual number of occurrences	Ave shut down hours per time	Ave Annual shut down hours	Ave annual number of occurrences	Ave shut down hours per time	Ave Annual shut down hours	Ave annual number of occurrences	Ave shut down hours per time	Ave Annual shut down hours	Ave annual number of occurrences	Ave shut down hours per time	Ave Annual shut down hours		
1	Main steam pipe leak	0.79	54:25	42:48	5.90	38:45	228:41	2.48	36:27	90:31	0.34	2:46	0:56	90:44	1.036%
2	Cond. HW level control failure	2.56	3:25	8:45	2.06	6:22	13:08	1.86	18:55	35:14	3.60	4:14	15:14	18:05	0.207%
3	Cond. Vacuum system failure	1.38	6:40	9:11	2.65	6:16	16:38	0.21	4:38	0:57	0.51	3:57	2:02	7:12	0.082%
4.1	ST trouble: Bearing	0.66	29:21	19:15	0.20	2233:42	439:16	0.00	0:00	0:00	0.17	9:38	1:39	115:02	1.313%
4.2	ST trouble: Blade damage	0.13	6387:59	837:30	0.00	0:00	0:00	0.00	0:00	0:00	0.00	0:00	0:00	209:22	2.390%
4.3	ST trouble: Others (instrument issue etc)	1.44	16:29	23:45	0.00	0:00	0:00	0.21	3:28	0:43	0.17	1:08	0:11	6:10	0.070%
5	Hot-well pump trouble	0.26	17:55	4:42	0.49	1:08	0:33	0.00	0:00	0:00	0.69	11:22	7:47	3:15	0.037%
6	Hot-well discharge FRP leak	0.79	25:14	19:51	0.69	17:59	12:23	1.34	66:33	89:31	0.00	0:00	0:00	30:26	0.348%
7	Steam scrubber trouble	2.43	1:21	3:16	1.47	1:18	1:55	0.00	0:00	0:00	1.03	0:22	0:23	1:23	0.016%
8	Compressed air trouble	0.39	3:53	1:31	0.59	6:46	3:59	1.24	13:24	16:38	0.00	0:00	0:00	5:32	0.063%
9	Switch gear fire repair	0.07	1480:28	97:03	0.00	0:00	0:00	0.00	0:00	0:00	0.00	0:00	0:00	24:15	0.277%
10	Grid instability, shut down on request by NCC	1.90	9:16	17:38	1.47	8:47	12:57	0.52	79:09	40:56	4.97	5:02	25:03	24:09	0.276%
11	Electric, Instrument system trouble	2.43	7:04	17:10	0.88	20:08	17:49	1.24	9:16	11:30	2.91	259:50	756:57	200:51	2.293%
12	Generator trouble	0.46	28:08	12:54	0.00	0:00	0:00	0.00	0:00	0:00	0.69	1:40	1:09	3:30	0.040%
13	The others trouble	1.64	23:46	38:57	2.36	12:05	28:32	0.62	17:11	10:40	0.86	27:24	23:29	25:24	0.290%
14	Scheduled shutdown (hr)	0.98	195:42	192:26	0.29	105:58	31:15	1.14	158:24	180:16	1.03	139:32	143:27	136:51	1.562%

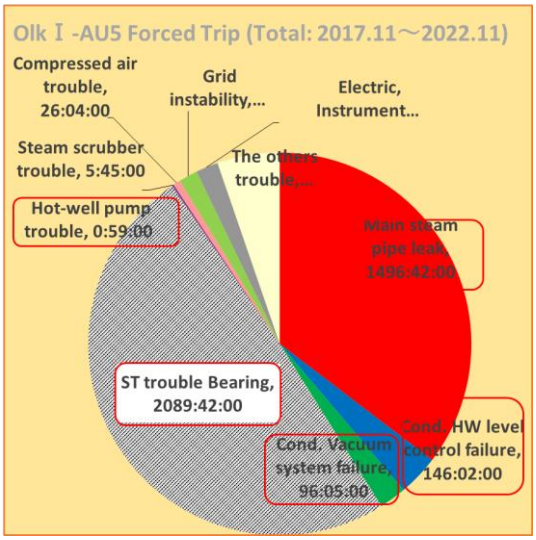
[Source: Prepared by Expert Team]

As shown in the figure below, similar troubles occur frequently, although the forced outage time differs for each unit.



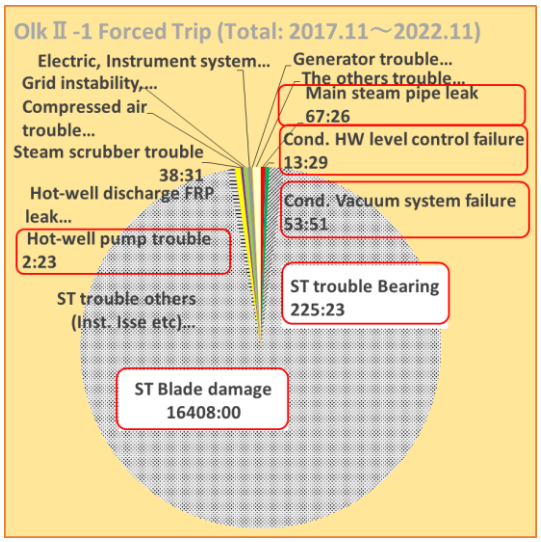
[Source: Prepared by Expert Team]

Fig. 2.2-1 Olkaria I-AU4 forced outage time



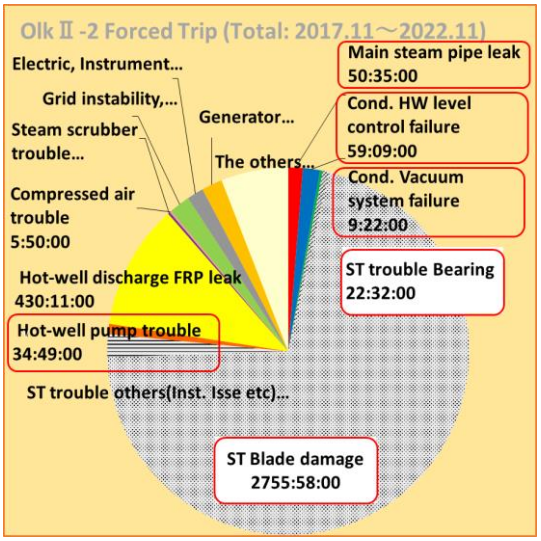
[Source: Prepared by Expert Team]

Fig. 2.2-2 Olkaria I-AU5 forced outage time



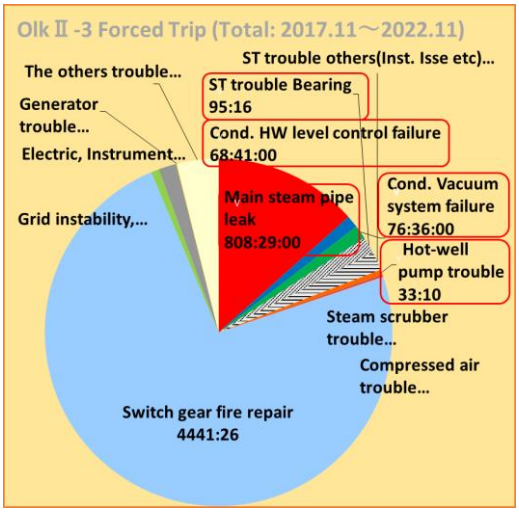
[Source: Prepared by Expert Team]

Fig. 2.2-3 Olkaria II-1 forced outage time



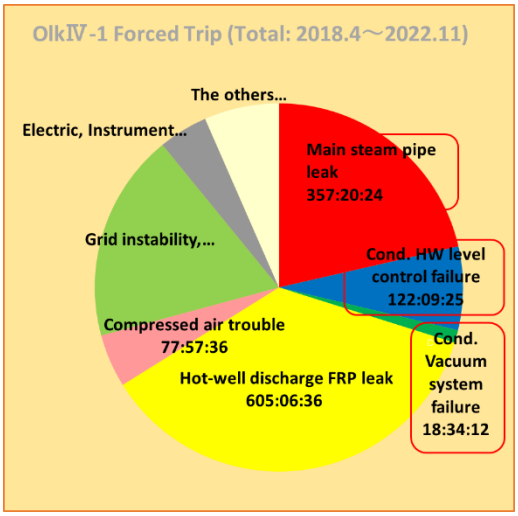
[Source: Prepared by Expert Team]

Fig. 2.2-4 Olkaria II-2 forced outage time



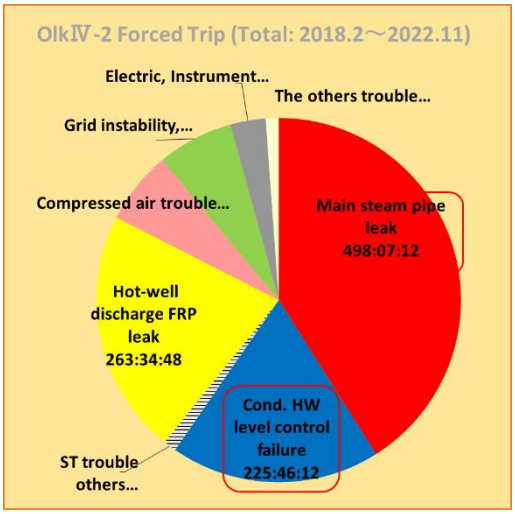
[Source: Prepared by Expert Team]

Fig. 2.2-5 Olkaria II-3 forced outage time



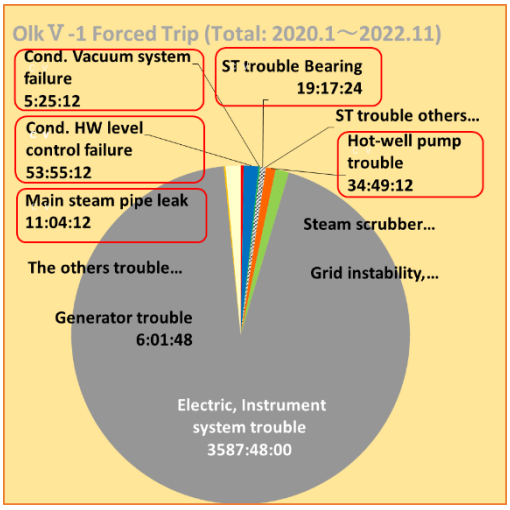
[Source: Prepared by Expert Team]

Fig. 2.2-6 Olkaria IV-1 forced outage time



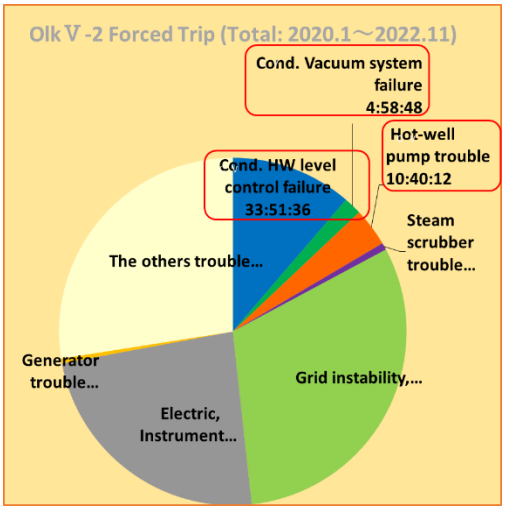
[Source: Prepared by Expert Team]

Fig. 2.2-7 Olkaria IV-2 forced outage time



[Source: Prepared by Expert Team]

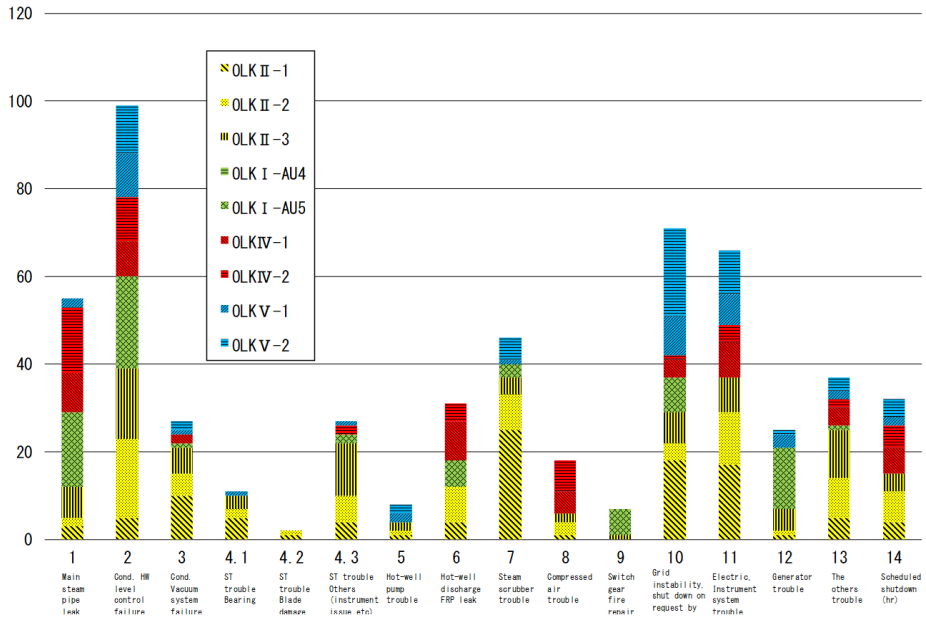
Fig. 2.2-8 Olkaria V-1 forced outage time



[Source: Prepared by Expert Team]

Fig. 2.2-9 Olkaria V-2 forced outage time

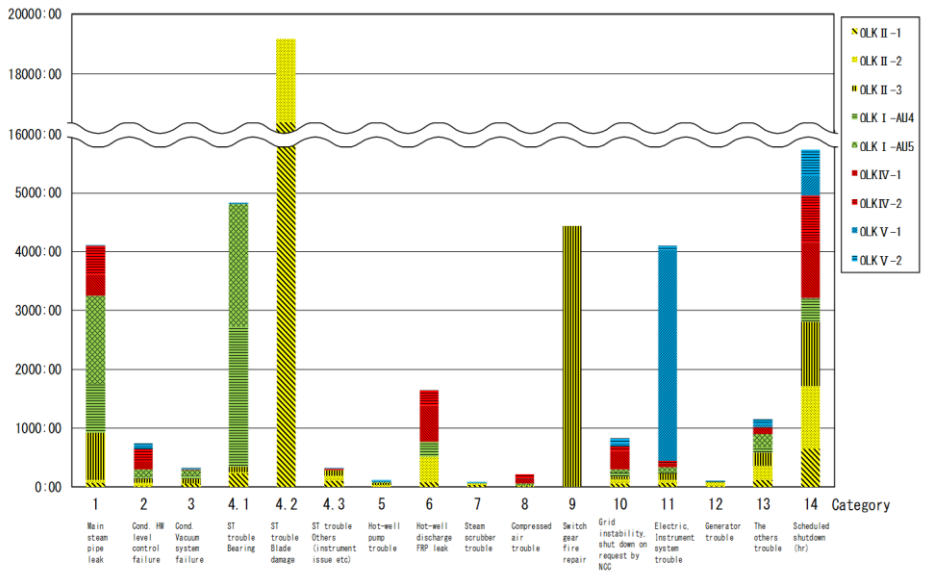
The graph below shows the number of trouble occurrences for each plant, based on the 13-category trouble history. The number of shut down due to troubles such as condenser HW level control failure and main steam pipe leaks are high, and these troubles occur at multiple power stations at the Olkaria geothermal power station.



[Source: Prepared by Expert Team]

Fig.2.2-10 Number of troubles at Olkaria Geothermal Power Station by unit and trouble category

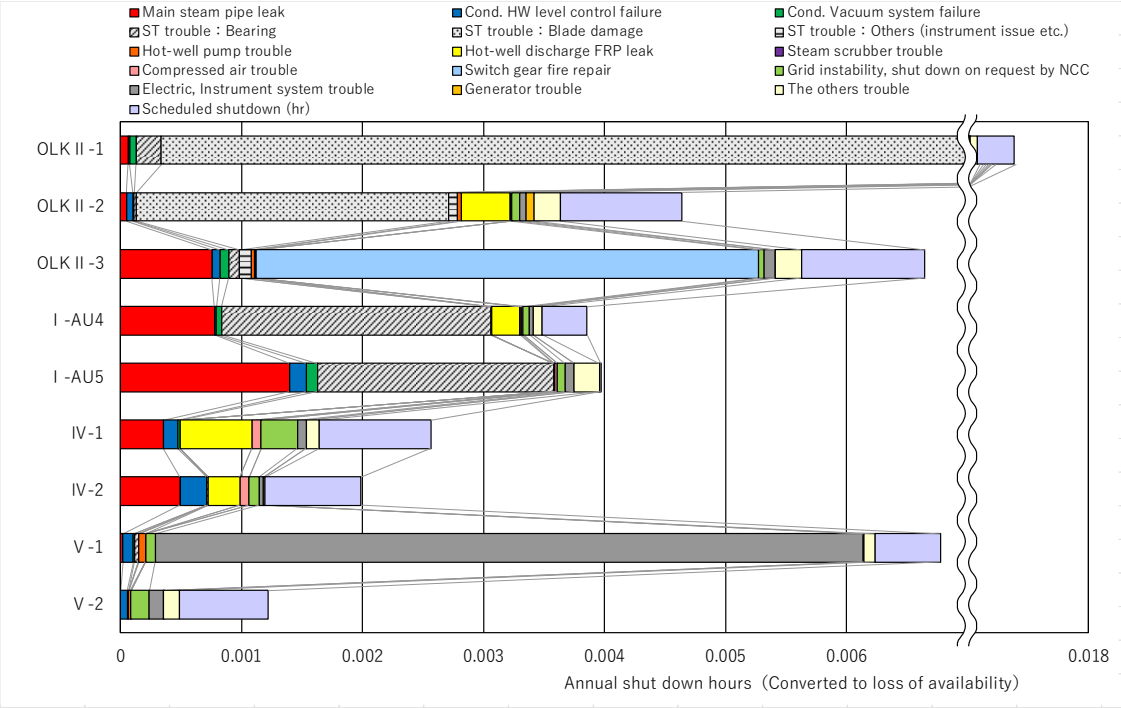
The graph below also shows the downtime of each plant based on the 13-catigory trouble history. Troubles related to steam turbines have a significant impact on shout down hours, because restoration work takes time.



[Source: Prepared by Expert Team]

Fig. 2.2-11 Forced shut down hours at Olkaria Geothermal Power Station by unit and trouble category

The graph below shows the average annual shut down hours for each power station based on the 13-category trouble history, converted to loss of annual plant availability. Trouble related to steam turbines and main steam pipe leaks have occurred at Olkaria II and I-AU, which have been in operation for a long time.



[Source: Prepared by Expert Team]

Fig. 2.2-12 Average annual shut down hours at Olkaria geothermal power station by unit and trouble category (Converted to loss of plant availability)

c. Consideration of technology transfer items

Taking into account the trouble history data for the Olkaria Geothermal Power Plant over the past five years, the technology transfer items were considered based on the results of an analysis of the frequency of troubles and shut down hours at each power station. Core members and the JICA expert team used the FTA (Fault Tree Analysis) method to analyze the potential causes of the troubles that occurred at Olkaria power station in the past, either those that occurred frequently or those that occurred infrequently but had a significant impact on plant availability. The team analyzed the potential causes of the troubles using the FTA method and considered the details of technology transfer.

Table 2.2-2 Major Troubles and Technology Transfer Items at Olkaria Geothermal Power station

Major Troubles	Contents	Potential Causes	Technology Transfer Items
(a) Main steam piping leakage issue	Erosion and corrosion occur on the pipe inner surface due to spray water in the main steam pipe	・ Poor water quality of turbine blade wash and De-SH spray water	・ Improvement of water quality ・ Examination of turbine blade wash procedure

		・Errors in Turbine blade wash Procedure	・Suspension of De-SH spray water injection and its effects on turbine
(b) Condenser HW level control failure including HW pump trouble	HW pump trips due to high condenser HW level caused by LCV control failure	・LCV control setting value failure ・Poor transmitter calibration of LCV	・Valve adjustment procedure ・Instrument calibration procedure
(c) Condenser vacuum system failure	Backup ejector not functioning.	・Solenoid valve operation failure	・Testing procedures to maintain facility reliability
(d) ST trouble (bearing issue, blade damage)	Damage to ST bearing without EOP automatic startup due to black out in the Power station. Possibility of fatigue material life or influence by corrosive components in steam	・Lack of maintenance of DC power supply and related equipment ・The blade material strength limit has been reached	・Establish maintenance procedures and policies for DC power supplies and battery ・Concept of spare rotor possession
FRP pipe leakage	Cracks and leaks in FRP circulating water piping	・Faulty workmanship, defective materials	・Work procedure to stop leakage without plant shutdown
Scrubber water level high	When condensate flowed in the scrubber during plant startup, the condensate water level became very high.	・Insufficient warming of steam piping before plant start up	・Allow sufficient warming up time for steam pipe

[Source: Prepared by Expert Team]

In addition, the following four items were included in the Objectively Verifiable Indicators of the Overall Goal on the PDM as major troubles because they occur particularly frequently and have a large impact when they occur.

(a) Main steam piping leakage issue

(b) Condenser HW level control failure including HW pump trouble

(c) Condenser vacuum system failure

(d) ST trouble (bearing issue, blade damage)

Regarding the FRP pipe leakage, KenGen changed the material of the circulating water pipe from FRP to SUS material, and the JICA expert team conducted a technology transfer of the FRP temporary repair procedure. For the scrubber water level high, the team confirmed with the steam field team the procedure for warming up the steam pipes before plant start-up, and decided to ensure sufficient warming-up time.

The following table shows the average annual shut down hours related to the four major troubles and their impact on the annual plant availability. As of the start of the project, if these troubles

were resolved and equipment reliability was improved, the annual plant availability would improve by approximately 5%.

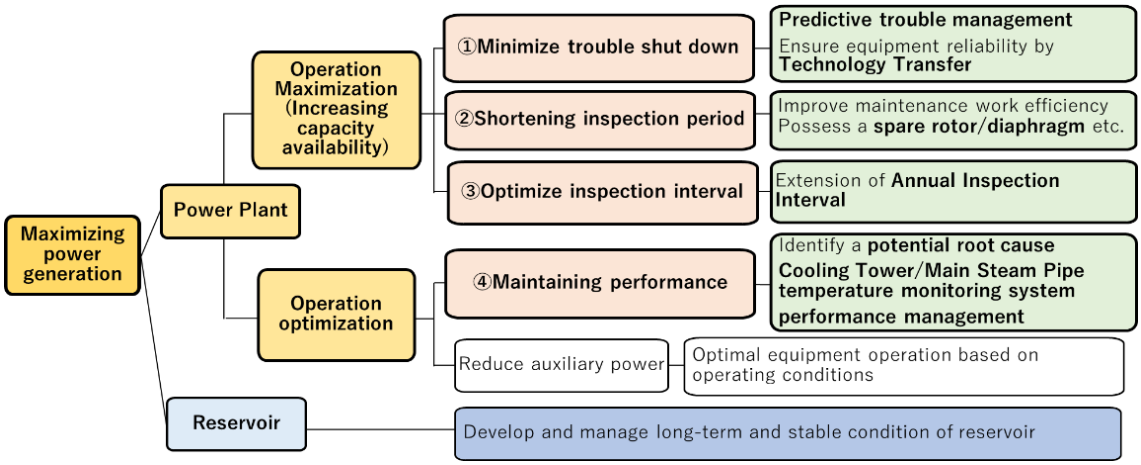
Table 2.2-3 Average annual shutdown hours and loss of annual plant availability for the four(4) major troubles

	Four (4) major troubles	Ave. annual shutdown hours	Loss of annual plant availability
(a)	Main steam pipe leak	90h44m30s/year	1.036%
(b)	Condenser HW level control failure including HW pump trouble	21h21m43s/year	0.244%
(c)	Cond. Vacuum system failure	7h12m29s/year	0.082%
(d)	ST trouble(bearing issue, blade damage)	324h25m18s/year	3.703%
Total		**443h44m/year**	**5.065%**

[Source: Prepared by Expert Team]

(3) Achievements, results, and challenges of technology transfer

Based on the analysis of past troubles at the Olkaria geothermal Power station, the JICA expert team discussed with Core members a policy for technology transfer with a view to achieving the project goals. As a result, the JICA expert team decided to implement a policy of technology transfer and local OJT based on O&M data in order to maximize the amount of electricity generated by the Olkaria Power station under long-term and stable reservoir management. The Power plant management team proposed the following four basic concepts for technology transfer to Core members, which were accepted.



[Source: Prepared by Expert Team]

Fig. 2.2-13 Concept of technology transfer to achieve project goals

① Minimize Trouble shut down

Implemented technology transfer related to predictive trouble management systems and equipment reliability assurance, with the goal of reducing the occurrence of major troubles and minimizing Power station shut down hours

② Shortening inspection period

In order to improve plant availability, the concept of shortening the process by introducing spare rotor and spare diaphragms was transferred to Core members, aiming to shorten the OHM

and the annual inspection period. In addition, Core members learned the concept of critical path and optimize the maintenance process.

③ Optimization of inspection interval

In order to improve the plant's operating rate, Core members aim to extend the annual inspection interval at the Olkaria geothermal power station from the current one year to more than one year, and optimize the inspection period based on O&M data..

④ Maintaining performance

Core members were to acquire performance management skills. In addition, a cooling tower and main steam pipe temperature monitoring system was to be installed in the Olkaria geothermal Power station, aiming to achieve safe operation and improve plant availability through efficient cooling tower maintenance management and monitoring of main steam piping using IoT technology.

2.2.2. Activity 1-2 predictive trouble management training based on IoT data analysis

In general, the longer a Power station delays detection of problems, the greater the impact and the higher the cost of response. In this section, the JICA expert team transferred technology on a series of thinking methods for early detection of troubles in each facility of the Olkaria Geothermal Power station and consideration of countermeasures.

(1) Basic technology

While the JICA expert team was able to understand the high level of Core members' technical capabilities during the discussion of plant operation with them, the JICA expert team was also able to confirm some technical items the Core members did not understand adequately. These two (2) items were related to turbine inlet pressure, heat drop, and main steam flow rate, and chemical mechanisms related to scale and corrosion. Even if these technical understandings can be applied to detect the signs of trouble or performance degradation, any lack of technical understanding will hinder the implementation of countermeasures using FTA. From this recognition, training was conducted on the two (2) items, and subsequent tests and reports confirmed that most Core members had a high level of understanding.

(2) Predictive trouble management

Plant equipment and instrumentation show signs before conditions become severe enough to affect power generation. Predictive trouble management aims to minimize the impact on power generation by detecting signs of conditions before they affect power generation for each item of plant equipment. From this perspective, the JICA expert team transferred the following technologies. Tests and reports were used to assess understanding of the technology transfer content, and a high level of understanding was achieved by the majority of Core members.

① Necessity of predictive trouble management

In power generation plants, the longer the delay in detecting troubles, the greater the impact and the higher the cost of response, so it is important to detect various signs of trouble as early as possible. For example, bearings in rotating equipment generally first make a slight noise before breaking or stopping, due to a rise in temperature. If an anomalous noise can be detected, trouble can be avoided by simple measures such as "greasing up," but if the signs are overlooked, the equipment could stop working, and in the worst-case scenario, the Power station could be shut

down. In the future, Core members will train and guide the concept of predictive management to the members who actually work on-site, such as plant operators. Therefore, the JICA expert team shared this concept with Core members in lectures to promote their understanding.

② Management of predictive trouble data

The confirmation of operating data is important for predictive trouble management. There are two types of "operational data", one type that shows a constant value regardless of the operating conditions, and another type that changes with the operating conditions. The JICA Expert Team gave a lecture on the importance of monitoring operational data that always shows a constant value, not only checking within the control value, but also monitoring to see if the daily operational data is approaching the upper (lower) limit of the control value. They also explained how to check the data that changes with the operation state using control indicators, in addition to empirical methods.

③ The method of checking data that changes with operating conditions using management indicators

Since it was difficult to present all of the management indicators, the JICA expert team introduced some of the major indicators to confirm understanding. The following are the main management indicators introduced, and Core members can set their own indicators based on these examples.

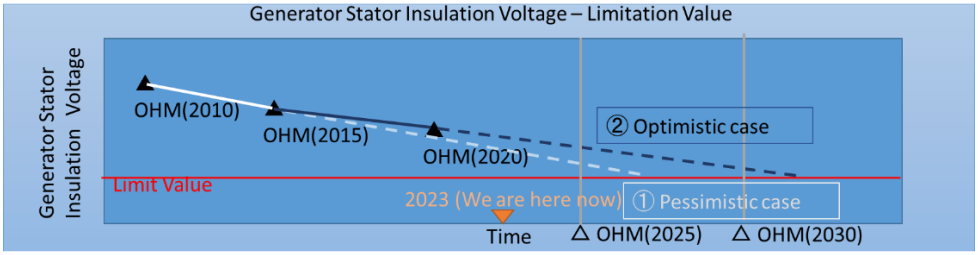
【Examples of Management Indicators】

- Correlation between SSC that indicates the steam required to generate 1kWh and WBT
- Correlation between main steam flow rate and generator output
- Cooling tower performance (efficiency)
- Cooling tower performance (approach temperature)
- Turbine nozzle blockage rate

④ Monitoring operating conditions from a long-term perspective.

Some power generation facilities require monitoring over a period of several years. For example, insulation measures for generators, which are important equipment, should be considered from a safety perspective, but they also have a large impact on costs.

The JIAC expert team explained how to monitor the insulation of generators (stator and rotor) and how to deal with it, using as an example, and Core members were able to deepen their understanding of the relationship between cost and risk through discussions on how to deal with this case. As Core members commented to the JICA expert team that it is important to check based on data, the JICA expert team believed that ore members' thinking was deepened through these discussions.



[Source: Prepared by Expert Team] Fig.2.2-14 Evaluation concept of Generator lifespan (For reference)

(3) FTA

In discussions with Core members, the JICA expert team identified several issues regarding FTA implementation procedure.

[KenGen's issues on FTA implementation procedure.]

The following issues occurred due to a lack of understanding of the basic FTA implementation procedure. The JICA expert team explained the process, and had Core members conduct a case study based on their own trouble events and implement an FTA. As a result, several FTAs with a high level of completion were identified. The JICA expert team expects that the concept of FTA will spread within KenGen, especially among Core members who created these FTAs.

- **Lack of multilateral perspectives in the implementation of FTA:** FTAs should be carried out by as many parties as possible, rather than by one individual or a small number of people, to investigate the causes more thoroughly.
- **Lack of thoroughness in identifying the causes of FTA:** When digging deeper into each issue, it is necessary to investigate as far as possible. This is because if the cause is not identified, the same trouble will recur.
- **Lack of records of FTA reviews and their inadequacy:** The results and process of FTA reviews were not being recorded at Olkaria and the trouble cases, and FTA results were not being shared. Records should be kept as a reference in case similar troubles occur in the future. Records can be used as future internal training materials and for human resource development. As there is a possibility that similar troubles may occur at other Power stations, the information should be shared and included in countermeasures.

(4) Main steam pipe temperature monitoring system

In the past, steam leaks from the steam pipes have occurred at Olkaria Geothermal Power station and there is a possibility of steam leaks from the main steam pipe in the future. As steam pipe leaks can lead to serious accidents, the JICA expert team proposed to KenGen a monitoring system that could detect steam leaks as a precursor detection technology. The system consists of optical fiber cables along the main steam pipes and can be detected temperature increases in the event of a steam leak. This monitoring system was installed at Olkaria II-3 in May 2024. The JICA expert team also trained members of Olkaria II-3 on the detection method in October 2024. A post-technology transfer comprehension test confirmed a high level of understanding by almost all Core members.

2.2.3. Activity 1-3 Performance Management Training Based on IoT Data Analysis

(1) Basic technology

Same as described in 2.2.2 Activity 1-2 (1)

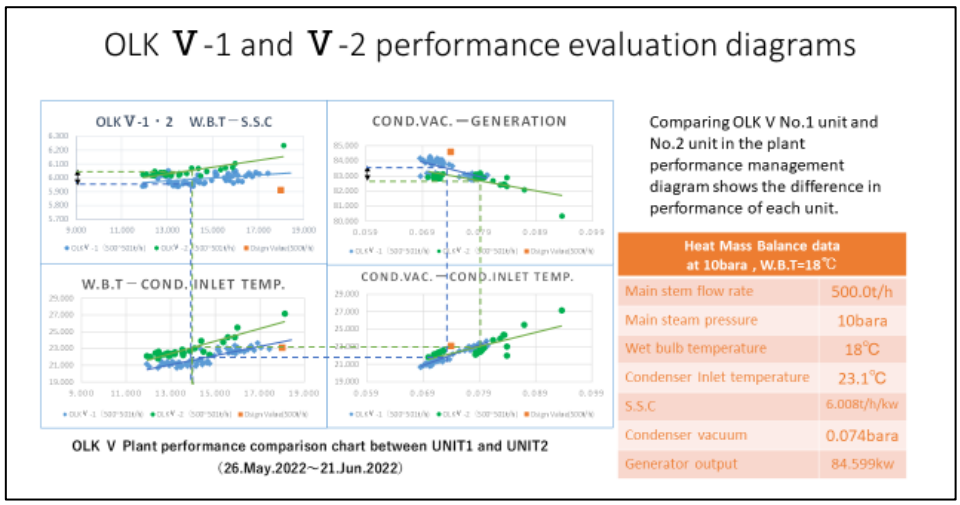
(2) Performance Management

The most important challenge for geothermal power stations is to ensure high plant availability. Performance management technology is important for maintaining high plant availability. However, because condition monitoring requires skill and experience, there is a need for a method that can be

easily used by non-experienced engineers to monitor conditions. Therefore, the JICA expert team introduced a technology, developed (and patented) in Japan, for the first time overseas. This technology was transferred. Tests and reports were used to assess understanding of the technology transfer content, and a high level of understanding was achieved by most Core members.

① Performance management system

By displaying each major parameter on four correlation diagrams, the condition of the geothermal Power station can be determined. The technology transferred is a method of evaluation using this system, in which the four correlation diagrams are combined to evaluate where the factors that cause performance degradation lie. In the technology transfer, examples of frequent events that occur in geothermal plants were introduced, and the condition of the plant was assessed using actual data from Olkaria.



[Source: Prepared by Expert Team]

Fig. 2.2-15 Four quadrants correlation diagram

② NCG exhaust system management system

In discussing "Power station performance management" with Core Members, the JICA expert team was asked for advice on how to monitor the NCG exhaust system. According to Core members, there had been multiple failures of this equipment in the past, and it was difficult to narrow down the trouble factors. Core members were now able to narrow down some of the factors that could be assumed in this evaluation method. In addition, by utilizing the data stored in the UNIDO IoT system, Core members actually created a correlation diagram and evaluated the current status of the factory's NCG exhaust system and the JICA expert team found no problems during the data collection period used. The JICA expert team recommended Core members to regularly monitor the status of the NCG exhaust system. Regarding the method using this correlation diagram, the core members recognized it as a system that could detect any trouble phenomenon that they wanted to detect, not just the NCG exhaust system.

(3) FTA

Same as described in 2.2.2 Activity 1-2 (3)

(4) Cooling tower temperature monitoring system

The JICA expert team analyzed Olkaria's past operating data and recognized that the decline in cooling tower performance was a major issue. In addition, through interviews with Core members, it was confirmed that scaling of the cooling tower fill packs and clogging of the water nozzles were also issues. Therefore, the JICA expert team installed a system to measure temperature distribution by placing optical fiber cables in a plane direction in the cooling tower. This system can grasp and visualize the temperature distribution on a flat surface inside the cooling tower. Core members are now able to understand the deterioration conditions of cooling tower performance as shown in the table below. In May 2024, the cooling tower monitoring system was installed at Olkaria II-3 and began accumulating operational data to be used for technology transfer. In October 2024, the JICA expert team conducted technology transfer to Olkaria II-3 members on its detection method based on approximately four (4) months of operational data. In a survey of comprehension levels after the technology transfer, eleven (11) out of twenty-two (22) trainees achieved level 4 targets or above, which allow them to apply the acquired technology in actual work and of those eleven (11), three (3) were at level 5, and they acquired skills to be able to teach other KenGen members using in-house training materials prepared by the JICA expert team

Table2.2-4 Events and countermeasures related to cooling tower performance degradation

Event	Countermeasure
Clogging of fill packs	Replacement of the detected clogged fill packs
Clogging of Sprinkler nozzle	Temporary adjustment of the water balance and cleaning of the detected spray nozzle area
Improper temperature distribution in the cooling tower	Adjustment of the water balance in the tower
Improper water volume balance between cooling towers	Adjustment of the water balance between cooling towers

[Source: Prepared by Expert Team]

2.2.4. Activity 1-4 Training on repair work and maintenance planning

(1) Online training

In April 2022, travel restrictions due to COVID-19 were relaxed, and in order to conduct efficient technology transfer in May 2022, video materials were produced on the acquisition of basic technologies related to predictive trouble management, performance management and key points of repair work, and online lectures on operation and maintenance were conducted

Specific activities were as follows.

Table 2.2-5 Online Training Results

Sessions	Date	Contents and (Time)
1	8 April 2022	Interactive Whiteboard and FTA training instruction session (2hrs)
2	14 April 2022	Performance management session (Part1) (2hrs)
3	21 April 2022	Performance management session (Part2) (2hrs)
4	27 April 2022	FRP repair session (2hrs)
5	11 May 2022	Hydrogen Sulfide Control/Handling of Differential Pressure Transmitter at Geothermal Power stations session (2hrs)
6	13 May 2022	Predictive trouble/Performance management session (2hrs)

7	20 May 2022	Turbine assembly work session (2hrs)

[Source: Prepared by Expert Team]

(2) Training on repair skills and maintenance planning

Based on the four basic concepts related to maintenance management discussed with Core members, the following technology transfer was carried out.

① Minimize Trouble shut down

a. Fault Tree Analysis (FTA)

Similar troubles occurred at the Olkaria Power station, and it is believed that root cause analysis was insufficient and permanent measures were insufficient. Therefore, the JICA expert team transferred technology to core members using FTA as a method to extract root causes and develop permanent countermeasures online in April 2022, and on-site in May 2022 and February 2023, using actual problems that occurred at the Olkaria geothermal power stations as a subject. In February 2023, a large steam turbine bearing vibration was observed at Olkaria II-3, and Core members conducted an FTA and held online discussions with a team of JICA experts on the root cause and proposed countermeasures. As a result, Core members conducted visual inspection and balancing of the steam turbine blades and the shaft vibration value remained below the alarm level. In August 2024, the event of steam turbine No.1 bearing high temperature occurred at Olkaria II-3, and Core members gathered 20 engineers and technicians of Instrument and electrical, mechanical from the Olkaria geothermal Power station to conduct the FTA. Each member was asked about the root causes and countermeasures were discussed by all members. As a result, the cause was quickly identified, the No.1 bearing of the steam turbine was replaced with new one, and the steam turbine was returned normal operation. Therefore, at least the FTA that was transferred is established at Olkaria II. To promote the horizontal deployment of FTA at all Olkaria geothermal power stations, Core members, including Assistant Managers at each Power station, need to discuss countermeasures based on the results of FTA analysis and incorporate them into their own work when a trouble occurs that leads to a decrease in power generation or performance at least. the challenge for KenGen is to implement FTA when a problem occurs to identify the root cause and develop and implement countermeasures.

b. Main steam piping leakage issue

The spray water injected into the main steam pipe is condensate from the cooling tower tank, where geothermal steam mixes with the cooling water inside the condenser, and the condensate is highly acidic due to the effects of hydrogen sulfide contained in the steam, so water quality adjustment is necessary. Due to delays in procuring materials and equipment for the chemical injection device, it became difficult to adjust the water quality of the condensate from the cooling tower tank, and the spray water was causing problems in the operation of the power station, such as corrosion of the steam pipes, scale build-up on the steam turbine blades, and clogging of the cooling tower packing. The JICA expert team confirmed with the OEM of the main steam pipe that the impact on the plant due to the shutdown of the steam piping with

reduced hot water was small and negligible, and that the injection of reduced hot water with low pH caused corrosion and pipe erosion, and that pipe corrosion could lead to iron contamination in the main steam, thereby promoting silica scale adhesion on the steam turbine blades. The JICA expert team then lectured Core members on the effects of strongly acidic condensate water being injected into the main steam piping and its impact on the power generation equipment, etc., and conducted discussions on the importance of pH control to deepen understanding. The JICA expert team also lectures to Core members that the impact on steam turbine efficiency when main steam de-warming is stopped is negligible and very small. The JICA expert team also proposed guidelines for water injection shutdown operations to Core members and requested them to monitor the operational data of the steam turbine based on the guidelines in the future. Note that spray water injection of De-SH is not currently being implemented in Olkaria I-AU and IV.

c. Condenser HW level control failure

Through discussions with Core members on the potential causes of the condenser level control valve trouble, the JICA expert team lectured Core members on the investigation procedure in the event of a control valve failure, and transferred technology on the procedure for identifying the failure position, adjustment procedure, and the recording format and how to fill it out. The JICA expert team and Core members then deepened their understanding through discussions. The challenge for KenGen is to apply the inspection procedures proposed by the JICA expert team when control valve failures occur in the future.

d. Condenser vacuum system failure

Through discussions with Core members, the JICA expert team decided to examine a procedure to ensure reliability of the condenser vacuum system, since the configuration of the vacuum system differs at each plant and the causes of the trouble are diverse. On the other hand, due to a lack of information such as control logic diagrams and instruction manuals, it was not possible to secure enough information to safely carry out automatic start-up tests of the system during normal operation of the Power station. The JICA expert team and the core members discussed and decided to transfer the technology to Core members on how to check the reliability of the condenser vacuum system when the Power station is shut down for annual inspections such as programed shut down. Based on the guidelines prepared by the JICA expert team for the annual inspection of Olkaria I-AU5 in October 2024, Core members confirmed the operation test on site and developed the test procedure.

e. ST bearing issue

Trouble with the bearings of the steam turbines occurred at Olkaria II and I-AU, and these plants were forced to shut down for a long period of time. So, the JICA expert team analyzed the trouble factors using FTA with Core members and discussed the technology transfer details. The emergency generator did not start properly, and the batteries were dead. As a result, the JICA expert team provided technology transfer of maintenance procedures for the DC power supply and battery system to ensure the reliability of the equipment. In addition, since failures

with steam turbines can lead to long-term shutdowns, spare rotors are usually secured to minimize restoration work in Japan. The JICA expert team provided technology transfer to Core members and Assistant Managers on the concept and benefits of owning spare rotors and a method to maintain them. As a result, KenGen understood the importance of spare rotors and was applying to MoEP for a spare rotor for Olkaria II budgeting for 2024-2025, but the 2024-2025 budget was postponed due to budgetary constraints of the Kenyan government. KenGen plans to include a spare rotor for Olkaria II in the contract for the rehabilitation of Olkaria II, maintain a used rotor in the uprate projects for Olkaria I-AU and IV and a hold spare rotor, and to include a spare rotor for Olkaria V in the budget for 2025-2026.

② Shortening inspection period

a. Introduction of spare rotor and shortening of OHM schedule process

According to the past trouble history of the Olkaria geothermal Power station, the bearing damage troubles occurred in the steam turbine due to loss of emergency power, and OHM was performed. KenGen assumed that the planned OHM would be 60 days, but replacing burnt bearings or replacing damaged blades requires time for parts procurement, etc., and the plant had been shut down for nearly two years. Considering KenGen's parts procurement situation, the long operating period of the Power station, and aged deterioration of the power generation facilities, the JICA expert team conducted a technology transfer to Core members on the benefits of holding a spare rotor and thereby shortening the OHM period. KenGen members, including Core members, understood the improvement of equipment reliability by owing spare rotors. Through training in Japan, some Core members learned about the storage conditions and operation methods of spare rotors at geothermal Power station in Japan. Subsequently, KenGen members understood the importance of spare rotors and KenGen was in the process of applying for inclusion in the budget for FY 2024/2025. On the other hand, in Olkaria I-AU and IV, the uprating project funded by KfW is in progress, and the upgrade turbine will be installed in Olkaria IV-1 from 2025 onward, and the used blades and rotor will be removed from the turbine. The used blades and rotor can be used as a spare rotor in case of emergency, although the pressure and temperature settings will be different after the uprate is implemented. The training material of the JICA expert team was stored in the KenGen system folder as technical manuals for the spare rotor.

b. Shortening of OHM and Annual Inspection process

Work items during planned outages, such as OHM and annual inspections, are determined based on the results of daily operations and routine inspections. At Olkaria geothermal power station, the past calibration records and centering records were missing, and O&M data was not stored in the designated location and was not shared. Therefore, the JICA expert team gave a lecture on the concept of data-based maintenance planning, the importance of data recording, etc., and discussed this with Core members. The JICA expert team lectured and held discussions with Core members on the following topics. The JICA expert team also gave a lecture to Core members on the concept of critical path, which is the basis of work process management. Core members then reflected on their own work and discussed the possibility of reviewing the work

procedures for the critical path in the annual inspection and shortening the annual inspection period by introducing more efficient tools. After the lecture, the JICA expert team conducted a comprehension test to confirm that Core members had gained basic knowledge of the critical path concept. The JICA expert team discussed the critical path in the Annual Inspection with Core members, and the cleaning work of the cooling tower basin was identified as the critical path for each power station. In October 2023, Core members introduced a vacuum suction truck to clean the cooling tower Basin at Olkaria V-2, based on a Japanese case study, and the standard process for Annual Inspection was reduced by one day from 8 to 7 days. This good practice was horizontally deployed in December 2023 in Olkaria IV-2, April 2024 in Olkaria V-1 and II-3, and May 2024 in Olkaria IV-1, improving the cleaning work process of cooling tower basins using vacuum suction trucks.

The critical path for annual inspections changes as the work progresses, so it is necessary to understand the entire process and respond promptly when delays occur in critical work. Core members and other engineers understand the progress and challenges of the process through morning meetings and daily reports during annual inspection. It is important to continue sharing this information thoroughly and to be mindful of quickly identifying the cause and taking measures when problems occur.

③ Optimization of inspection interval

a. Condition Based Maintenance (CBM) and Time Based Maintenance (TBM) concept application

Core members understood the concept of CBM and TBM in maintenance planning, but they were unable to compare them due to missing historical maintenance data, so the JICA expert team explained to Core members the importance of recording and storing data for comparison purposes in the execution of CBM. The JICA expert team also explained that when data is stored in a designated location, information can be shared among members, and that properly timed maintenance based on CBM can extend the life of equipment and reduce costs compared to maintenance when a machine is found to be malfunctioning. In order to incorporate the CBM concept into their own work, Core members decided to collect baseline data on equipment at the Annual Inspection, implement improvement measures, and confirm their effectiveness.

b. Extension of Annual Inspection interval

In Japan, a minor inspection, equivalent to KenGen's Annual Inspection, is usually conducted every two years. On the other hand, KenGen conducts annual inspections according to OEM recommendations. In order to improve plant availability, the JICA expert team and Core members checked the maintenance status for each Annual Inspection and assessed the risk of extending the annual inspection interval. When formulating the action plan, Core members set priorities according to risk. For high-priority items, the condition before implementing measures as baseline data was recorded during the annual inspection, and the measures were implemented during the annual inspection. The effectiveness of the measures was then evaluated one year later.

In September 2023, the JICA expert team visited the Olkaria Power station for the Annual Inspection of Olkaria I-AU4 to obtain baseline data for the interval extension in cooperation with Core members. For the zinc anodes in the generator cooler, the remaining weight of the anodes removed in September 2023 was approximately 570 g, and the average monthly consumption based on the operating period of 10.1 months was approximately 1,600 g/month. In the cooling tower, the JICA expert team and Core members visually confirmed the condition of the fill packs removed from the cooling tower and the clogged condition of the water spray nozzles. Other visual checks were made on the condition of the steam turbine nozzle, the amount of accumulation in the cooling tower basin, and the condenser fill packs, and these were used as baseline data.

Core members and plant chemists have improved pH management since September 2023. As a result, at the annual inspection of Olkaria I-AU5, the zinc anode consumption of the generator cooler improved significantly, with the remaining amount being approximately 7,270g. The average monthly consumption based on the operation period of 14.2 months was approximately 670g/month. This represents a 2.4 times improvement compared to the average monthly consumption at Olkaria I-AU4 in 2023. The JICA expert team and Olkaria I-AU engineers reviewed these baseline data and the improvement status of each facility at the 2024 Annual Inspection and discussed how to proceed with interval extension.

At next annual inspection of Olkaria I-AU4, the engineers will measure the zinc anodes remaining amount of the generator cooler and compare it with these baseline data to consider extension of inspection interval.

Core members of the TS team inspect the pressure transmitter contacts annually because they change due to ambient vibration. In September 2023, the JICA expert team provided Core members with technology transfer on how to apply nail polish to the contacts as implemented in Japan to prevent them from changing. Core members plan to inspect the condition of the contacts with nail polish attached during the annual inspection of Olkaria I-AU4 at next annual inspection, and to confirm the impact of vibration on the contacts. If the effectiveness of the nail polish is confirmed, Core members plan to apply nail polish to areas where the contacts are loose.

④ Maintaining performance

a. Predictive trouble management and Performance management with IoT system

The Predictive Trouble Management System and the Performance Management System have been implemented in the UNIDO IoT system, which enables the corrective management of operational status and performance data of each Power station. The training contents, results and issues for Core members are described in Chapters 2.2.2 and 2.2.3.

b. Skills for maintenance of OHM/AI and routine program

Initially, the JICA expert team planned to conduct OJT for OHM in Olkaria during the project period, but a review of Olkaria's maintenance plan revealed that OHM was not planned. Therefore, the JICA expert team discussed this situation with KenGen, and The JICA expert

team traveled to Olkaria in September 2023 to coincide with the implementation of the Annual Inspection of Olkaria I-AU4 and conducted the following technology transfer.
Since this OJT was training for actual work, the technicians who were not subject to this project evaluation were provided with technology transfer, and the management procedures related to maintenance work were transferred to Core members. Since the skills of the technicians varied at the time of OJT, and the OJT period and manpower of the JICA expert team were limited, OJT was conducted mainly with technicians who had a certain level of skills and were highly motivated to learn. The electrical system group consisted of four (4) technicians, and the mechanical group consisted of two (2) technicians.

(a) Olkaria IV vacuum pump centering work

During OHM, centering work is a critical process, and improving the efficiency of centering work leads to a shorter annual inspection period. However, OHM was not planned, so OJT for centering work on a vacuum pump was conducted in the Power station. The JICA expert team first gave a lecture to the technicians on centering of the turbine rotor and checked the maintenance status of the vacuum pump. Although the vacuum pumps of Olkaria I-AU have been running smoothly since commissioning, and there are no problems, there was a possibility that they would conflict with other work of the Annual Inspection of Olkaria I-AU4. On the other hand, all four vacuum pumps of Olkaria IV were in a long-term shutdown state with high vibration, although there was no working problem, so OJT was conducted using the Unit2-B vacuum pumps at Olkaria IV. OJT included preparation of instruments and materials for centering work, how to read the instruments, calculation method for alignment adjustment, equipment adjustment work procedures, record entry procedures, and confirmation of criteria. Based on this on-the-job training, the technicians prepared a Personal note summarizing the key points of the work to maintain their skills. After the completion of the Olkaria IV Unit-2-B vacuum pump centering work, a test run of that pump was conducted, but was interrupted due to high vibration. Since it was presumed that the bearing was damaged during past operation, the JICA expert team asked KenGen to replace the bearing of the pump and then perform the centering and commissioning again. In January 2024, KenGen conducted centering operations with an Olkaria IV2-A vacuum pump, which is now running smoothly, so the technology transfer was successful.
In October 2024, the JICA expert team evaluated the technicians' skills in centering the vacuum pump at Olkaria IV. As a result, the technicians performed the centering work using the correct procedures and were able to accurately read dial gauges and gap gauges. On the other hand, there were cases where they could not determine whether the measurement data was correct, and we provided additional explanations on the importance of evaluating the measured data based on an understanding of the equipment's condition and theoretical values. It was confirmed that two technicians had a certain level of ability in centering (centering skill and instructing others) through the skill evaluation.

In the future, KenGen needs to hold classroom learning sessions to ensure that the technology is firmly established, and expand the technology to other technicians.

(b) Calibration work for Key Instruments in Olkaria I - AU4

Since past calibration records had not been stored at the Olkaria geothermal Power station and the calibration process is unknown, lectures were given to Core members and technicians on the importance of record keeping, including the necessity for past calibration records, work procedures, and reviewing record formats. In September 2023, OJT was conducted mainly with technicians for the Olkaria II hot well level meter (displacement type) and the Olkaria I-AU4 differential pressure type level transmitter, which had been postponed when the OJT was conducted in February 2023. OJT was also conducted for the calibration of a steam flowmeter transmitter and a thermometer, both of which are typical types of instruments for which pressure and temperature corrections are calculated on the transmitter side. The OJT included preparation of materials and equipment, confirmation of test procedures, record keeping, and adjustment procedures based on the evaluation of test results.

Table 2.2-6 List of Key Instruments

No	Key Instruments
1	Generator Output Transducer
2	Main Steam Flow Transmitter
3	Turbine Inlet Pressure Transmitter
4	Steam Chamber Pressure Transmitter
5	Turbine Exhaust Temperature Transmitter
6	Wet Bulb Temperature Thermometer
7	Cooling Tower Outlet Circulating Temperature Transmitter
8	Condenser Outlet Circulating Temperature Transmitter
9	Condenser Vacuum Transmitter (Absolute Pressure Type)

[Source: Prepared by Expert Team]

In September 2023, after the steam flow meter of Olkaria I-AU4 was calibrated, the steam flow rate tended to increase, and the power output per steam flow rate decreased before and after the meter calibration. The JICA expert team received the operational data and analyzed the cause by FTA. As a result, it is possible that the calibration was conducted with the module measurement range of the calibration meter larger than that of the transmitter, resulting in a larger meter error and a larger steam flow rate value.
In October 2024, the annual inspection of Olkaria geothermal power station was changed from Olkaria I-AU4 to I-AU5, so the JICA expert team conducted a technical evaluation using AU5 instruments. Through the technical evaluation of the technicians, the calibration procedures for the main steam flowmeter were confirmed at Olkaria I-AU5, and KenGen

members plan to calibrate the steam flowmeter of Olkaria I-AU4 at next annual inspection based on the correct manner according to the calibration procedures of the JICA expert team.

KenGen members performed Key Instrument calibrations at Olkaria V-1 in October 2023 and Olkaria IV-1 in April 2024. Since some of the calibration records had been conducted using different procedures from the OJT in September 2023, The JICA expert team held online lectures for Core members and technicians to confirm the work procedures and review the recording procedures in September 2024, and held in person lecture at Olkaria I-AU in October 2024.

In the future, the engineers including Core members need to review the work procedures to ensure that all technicians perform accurate calibration using the correct recording forms, and to plan regular maintenance based on data under Core member management to maintain instrument reliability.

(c) Countermeasures for leak of main steam pipe

Regarding the main steam piping leak, one of the major troubles at the Olkaria geothermal power stations, the JICA expert team confirmed the impact on the plant of stopping the cooling water injection in the steam pipe with the OEM company of the main machine. As a result, it was found that the calculated impact was small and negligible, and that the low pH cooling water injection could cause corrosion and piping erosion, and that pipe corrosion could lead to iron contamination of the main steam, which could promote silica scale adhesion on the steam turbine blades. The JICA expert team lectured Core members on the importance of pH control management and its impact on plant facilities, and proposed guidelines for stopping the injection of cooling water in the main steam pipe. The JICA expert team requested Core members to monitor the steam turbine operational data in accordance with the guidelines in the future.

(d) Automatic start-up routine test of emergency diesel generator

In the past, during blackouts at the Olkaria geothermal Power station, the emergency diesel generator did not start and the steam turbine bearings burned out. The JICA expert team reviewed with Core members the regular automatic start-up test procedures to ensure the equipment integrity of the emergency diesel generator and discussed remedial measures with Core members. The JICA expert team discussed improvement measures with Core members.

As a result, the JICA expert team proposed that the routine test sheet for emergency diesel generators include a column for test results and items to be noted (presence of abnormal noise, smells, visual conditions, etc.), and that this information be shared within KenGen for preventive maintenance.

(e) DC & Battery system maintenance policy

In the past, during blackouts at the Olkaria geothermal power station, the DC power supply did not function during a blackout due to the deterioration of the storage batteries. The

JICA expert team decided to discuss the implementation of technology transfer related to the maintenance of DC power supply. The JICA expert team checked the charging facilities of each station with KenGen members and confirmed that the combination of storage batteries and charging facilities were not matched, which would affect the lifespan of the storage batteries. The JICA expert team transferred technology to Core members on storage battery management methods and system configuration. At Olkaria II geothermal power station, vented batteries are installed even though the chargers do not have an equalizing charge function. As the storage batteries are deteriorating, periodic monitoring and future system configuration should be considered. In order to consider the maintenance policy of the storage battery system, during the training in Japan, Core members received lectures from a lecturer from a storage battery manufacturer on topics such as the approach to storage battery design items and procedures for determining the lifespan of storage batteries, and also participated in a question-and-answer session. Core members were able to improve their technical knowledge of storage battery systems and in October 2024, the JICA expert team and Core members discussed the maintenance policy of storage batteries. As a result, it was decided to implement the routine work procedure of equalizing charge for Olkaria IV and I-AU. For Olkaria II, Core members are currently checking with OEM of charge system whether it is possible to add an equalizing charge function to the Olkaria II actual charger.

2.2.5. Activity 1-5 Training on records, storage, analysis and maintenance planning

(1) Improve maintenance planning by introducing the PDCA cycle using the UNIDO IoT system

As an O&M challenge, the Olkaria geothermal Power station did not adequately collect and organize basic data on operations in real time, manage performance, and manage trends during maintenance work. In addition, there was no accumulated data on past trouble analysis or performance management, it was difficult to implement preventive maintenance or develop efficient, economical maintenance plans. To resolve this situation, an IoT system was installed at the Olkaria geothermal Power station in June 2022 with the cooperation of UNIDO and handed over to KenGen for the purpose of acquiring skills for proper data collection, analysis, and utilization at the Olkaria power station. In addition to the performance and predictive trouble management system, the UNIDO IoT system has the function of an operations management system (OPMS), which is effective for efficient maintenance planning and steady implementation of inspection and diagnosis by digitizing daily operation logs and information on maintenance measures. The OPMS has the following two main functions

Logbook: View, create, and maintain a log of events that occur during operations as a daily operations log.

Work Order: View, create, and manage work orders for future maintenance planning.

The Olkaria Power station had not established a system to keep records related to operation and maintenance and to develop a maintenance plan based on the data. Therefore, the JICA expert team decided to utilize the UNIDO IoT system and incorporate the PDCA cycle into the core members' work as a method for continuous operational improvement.

a. Development of an OPMS manual based on workflow

The JICA expert team discussed with Core members the current workflow and the workflow when the UNIDO IoT system was to be introduced, in order to utilize the above two functions of the OPMS and incorporate the PDCA cycle as technology transfer into Core members' own work. KenGen had previously used the existing SAP-PM system to issue work instructions for repair work and other such tasks, but when introducing the UNIDO IoT system, it was discovered that some SAP-PM functions overlapped with the UNIDO IoT system. In addition, the two systems were not integrated on KenGen's internal network, and Core members and operations staff commented that there was a sense of duplication in data entry tasks. The JICA expert team developed a draft workflow and a draft OPMS manual, and confirmed the steps of the PDCA cycle using the UNIDO IoT system and the operating procedures. When checking the workflow using the UNIDO IoT system based on the draft manual, it was found that the Shift in charge and Senior technician were in charge of issuing work instructions. Therefore, in addition to lectures and training for Core members, the JICA expert team decided to give a lecture on the purpose of the PDCA cycle to some of operators including Shift in charge and some of Senior technicians at each Power station, and to demonstrate the operation procedures of the UNIDO IoT system. Although it was difficult to give a lecture on the PDCA cycle using the UNIDO IoT system to all the Shift in charge and Senior technicians at all the Olkaria Power station due to time constraints, some Shift in charge and Senior technicians were given a lecture. The JICA expert team sent the OPMS operation manual and the operation video, which were modified through the demonstration, to the lecture participants and asked them to share them with other members of the team.

b. The UNIDO IoT system and SAP-PM system

The JICA expert team explained to KenGen members that the integration of the UNIDO IoT system and the SAP-PM system was outside the scope of this project. The JICA expert team then proposed to support the non-physical aspects of the project, such as the implementation of the PDCA cycle using the UNIDO IoT system and the development of work procedures. In the future, Through the actual operation of SAP-PM and UNIDO IoT systems, KenGen will identify issues with both systems and consider the necessary for integration from the perspectives of work efficiency and cost.

c. Customization of the UNIDO IoT System

Based on the proposed workflow, the JICA expert team conducted a trial with Core members using the UNIDO IoT system. The OPMS system was factory-configured with a generic workflow, which needed to be customized for the Power station's workflow. As a result, the screen display of the OPMS system needed to be customized. The ICT team and the system supplier attempted to modify the screen display but were unable to do so due to a lack of information in the system supplier's user manual. The ICT team will request additional information from the system supplier in the future.

d. The UNIDO IoT System Maintenance Policy

The ICT team requested JICA to support training on the UNIDO IoT system, considering the need for capacity building to improve the maintenance technology of the UNIDO IoT system and to integrate it with SAP-PM, but JICA replied that it could not support additional training due to budget constraints. Currently, KenGen is considering conducting training on the UNIDO IoT system on his own. After the expiration of the warranty period in June 2024, KenGen is currently discussing its maintenance policy for the UNIDO IoT system.

e. The PDCA cycle and the Action plan

The JICA expert team discussed with Core members the implementation of the PDCA cycle using the UNIDO IoT system to ensure efficient operation and continuous improvement of the facilities at the Olkaria geothermal Power station. Core members understood the purpose and importance of the PDCA cycle and developed the Action plan with a view to maximizing the amount of electricity generated. First, Core members identified the operation and repair status of each facility during the Annual Inspection of Olkaria II-3 and discussed potential risks with the JICA expert team. The measures to be implemented during the Annual Inspection were prioritized according to their impact on plant availability and set as a PLAN for the Action plan. Core members of each power station then discussed with the JICA expert team based on the Action plan of Olkaria II-3 and developed the Action plan for each power station in February 2023.

The JICA expert team and Core members held online meetings or the Action plan follow-up meetings at the Olkaria geothermal power station to share the maintenance plans and inspection results for each plant's Annual Inspection with Core members, and good improvement practices to be applied in the next Annual Inspection were horizontally developed.

The PDCA cycle for the Action plan is a mechanism for promoting the maintenance plan and achieving results through the PDCA (Plan→Do→Check→Act) cycle for improvement.

The PDCA cycle is expected to have the following effects

- Allows for planned and continuous improvement rather than incidental problem solving
- Clarifies goals and the Action plans for better results
- Sets clear goals with numerical indicators, which makes it easier to take concrete measures to achieve goals and solve problems.

After the IoT project is completed, KenGen Managers and Assistant Managers are expected to continue operation of the PDCA cycle and make O&M management improvement an integral part of their work throughout the organization. KenGen Managers and Assistant Managers will be expected to ensure that O&M management improvements become an integral part of their work throughout the organization.

f. Impact on training due to data quality issues in the UNIDO IoT system

The UNIDO IoT system improved in communication and data collection since the last inspection by the system supplier in early June 2024, but some data was missing due to lack of field instrument maintenance. KenGen was working on replacing necessary spare parts of the calibration instruments, but some instruments were affected by delays in procuring spare parts, and

some measurement data was missing. The JICA expert team prepared the missing data to provide TS Core members. TS Core members reflected on the Action plan to check the missing data and planned the calibration of key instruments in the UNIDO IoT system to maintain data accuracy during annual inspections. The system supplier also checked the communication status, corrected the data configuration, and performed a data quality analysis. The data time lag between the DCS and the UNIDO IoT system was resolved by synchronizing the Olkaria II client PC with the plant server. Data quality values were reported to KenGen in a final report issued by the system supplier. For the well data, the system supplier updated the flow ranges for all production wells according to the reservoir team's specifications, and the communication status between the steam wells and the remote system was also checked by the reservoir team. In January 2025, the well data of the UNIDO IoT system was only partially collected due to power supply issue and DCS of Olkaria IV issue

(2) Challenges and responses after the introduction of the UNIDO IoT system
The UNIDO IoT system, which has data center capabilities, was planned to collect and analyze operational data from the Olkaria geothermal power station in order to enhance performance analysis and improve maintenance planning for each Power station. However, the impact of COVID-19, system malfunctions, low data quality, and various other problems caused delays in the progress of technology transfer and led to a revision of some training content.

a. Trouble Timeline and Response

(a) Delayed system introduction (2021-2022)
The installation of the UNIDO IoT system was delayed due to COVID-19, and the originally planned schedule for conducting the OJT was changed.

(b) System failures and data quality issues (2022-2023)
Server down and data storage issues: A software malfunction resulted in insufficient operational data being stored and available for OJT. The system supplier resolved the problem by updating the software, but the OJT schedule was delayed. Missing and inaccurate data: Some data was missing or inaccurate, affecting the quality of OJT. Lack of spare parts and uncalibrated equipment also brought problems.

Communication failures and data time lags: Data quality was degraded due to wireless communication and optical cable failures and data discrepancies with the DCS.

(c) Problem Solving Initiatives (2023-2024)
Investigation and response by the system supplier: The system supplier investigated the cause of the problems, updated software and adjusted equipment.
Measures taken by KenGen: KenGen took steps to procure spare parts, calibrate equipment, and improve data quality.
Involvement of the MoEP: The MoEP was concerned about project delays and urged KenGen to resolve the issue.

b. Major troubleshooting situations

Table2.2-7 Major troubleshooting of UNIDO IoT system

Challenges	Root cause	Countermeasures
Schedule delays	Installation delays due to COVID-19	Revise of OJT schedule
System failure	Software issues, Hardware failure etc.	Software update, configuration
Low data quality	data missing, configuration error, Occurrence of time lag for data sampling	The system supplier conducted data configuration and settings reviews, improvement of communication systems, synchronize data time stamps with the Power station server. KenGen conducted instruments calibration to improve data quality and improved the network environment, including repairing existing fiber optic cables.
Spare parts procurement	Delays in procurement of solar panels, batteries, flow meters, etc.	Faulty instruments due to delays in procurement of spare parts
A lack of communication	Lack of coordination between the system supplier, KenGen and the JICA expert team	It is necessary to hold regular meetings and share information through reports, etc.

[Source: Prepared by Expert Team]

c. Remaining issues

Maintenance of data quality: Some predictive trouble management data is missing due to delayed maintenance of field equipment.

Undecided maintenance policy: The warranty period with the system supplier has expired and the future maintenance policy is undecided.

d. Potential root cause of the challenges

(a) Delayed system installation

Impact of COVID-19: The global pandemic severely limited the resources and environment necessary for project execution, including restrictions on the movement of human resources and supply chain disruptions.

(b) System failure and low data quality

Lack of preventive maintenance: Periodic instrument inspections and parts replacement are not performed.

Insufficient record management: Maintenance history, abnormality history, etc. are not properly recorded and managed.

Insufficient skills of personnel: Maintenance is performed by personnel who do not understand the structure of the system or how the software works due to lack of training.

Communication environment constraints: The communication environment and power supply at the installation site were unstable, causing problems with data transmission.

Complexity of data integration: problems were encountered in configuring interfaces because of the necessary to link, connect, and coordinate with existing systems.

(c) Lack of spare parts for instruments, etc.

Delayed procurement plans: Procurement plans for spare parts such as batteries and instruments were delayed, affecting data collection.

(d) Lack of communication

Lack of information sharing and gaps in problem recognition: Insufficient information sharing between the system supplier and KenGen staff regarding the system's operational status and the situation when problems occurred may have prevented an accurate understanding of the nature of the problems and made it difficult to take appropriate countermeasures.

(e) Importance of reflecting KenGen's opinions in the system design phase

Mismatch with KenGen's existing system: If the opinions of KenGen, who actually operates the system at power plants, were not reflected in the system, the system may not meet on-site needs, or conflicts between systems' functions and operations may result in poor usability and reduced operational efficiency.

Unclear responsibility: The system supplier delivered the system as designed, but UNIDO IoT system specifications did not meet KenGen's needs as a user, which might have led to unclear responsibility and delayed problem resolution.

Unexpected troubles: If KenGen's experience-based knowledge and site-specific constraints were not reflected in the design, unexpected troubles were likely to occur.

e. Recommendations for the success of future the UNIDO IoT projects

KenGen Participation from the Requirements Definition Phase: KenGen input during the system design phase is critical to the success of the system. By listening carefully to KenGen’s opinions and reflecting them in the design, system mismatches and problems can be prevented, and a more efficient and stable system can be built. This will help to prevent system mismatches and problems, and to build a more efficient and stable system.

Enhance communication: Implement effective communication channels, including regular meetings with system suppliers and information sharing.

Thorough quality control: From the system design stage, place emphasis on quality control and repeated testing to reduce the occurrence of bugs.

Proper management of spare parts: Ensure that necessary spare parts are secured in advance and inspected regularly.

Appropriate budget allocation and Human Resource Development: KenGen will implement training programs to acquire the skills and knowledge to operate and maintain the UNIDO IoT system and will allocate the necessary budget for maintenance.

f. Summary

The UNIDO IoT system faced several challenges, including delays in system implementation, system failures, and low data quality. In response to these issues, all parties concerned have played their roles and worked to solve the problems. However, some issues remain unresolved, and continuous improvement is needed to ensure stable and accurate data accumulation over the long term.

2.3. Reservoir management Activities and Results

(1) Background

In the first term, OJT in Kenya was postponed, as was the case with the Power station Operation and Maintenance. Instead, lecture materials and video materials were produced related to reservoir management, including apportion method of steam/water flow rate of each production well, reservoir modeling, chemical analysis for water (including support for new tracer studies), and countermeasures for scale, corrosion, and bacteria issues related to chemical management, and technology transfer was carried out remotely from Japan. In addition, based on the results of analysis of geothermal fluid samples shipped from KenGen to Japan, opinions were exchanged with core members. In the second term, specific technology transfer activities were carried out for activities 2-1 to 2-5 through four times of OJT in Kenya and twice of training in Japan. In addition, a high-performance liquid chromatograph (HPLC) was provided as equipment.

(2) Current status and issues of reservoir management at Olkaria Geothermal Power station

Olkaria Geothermal Power station currently has a power generation capacity of 533.4 MW, but there are plans to expand by 479 MW in the future. The total production volume is currently just under 6,000 t/h, while the total reinjection volume is just over 3,000 t/h, raising concerns about insufficient recharge. The total discharge volume is expected to increase to around 7,000 t/h with future expansion (JICA, 2019). The implementation items of Activity 2 agreed in the RD are: 1) Review the current status and issues of reservoir management, 2) Conduct training on analysis of physical characteristics of the well, 3) Conduct chemical analysis training including analysis with new tracer(s), 4) Conduct training on reservoir modeling using continuous pressure monitoring and gravity monitoring, and 5) Conduct training on geochemistry for preventing scaling, corrosion, and sulfur/bacteria deposition. The current situation and challenges in reservoir management at Olkaria Geothermal Power station are shown below.

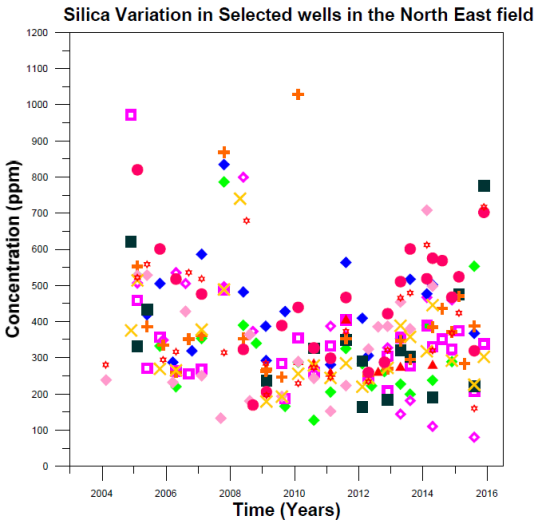
a. Evaluation technology for steam/water flow rate regarding production well
At Olkaria Geothermal power station, steam and brine volumes in production wells are measured four times a year using the TFT method, so continuous changes have not been evaluated. Therefore, it is necessary to support the study of estimating and allocating the steam/water volume of the collective separator from the continuously measured steam/water volume and geochemical data, as well as to support the improvement of technology for utilizing such data.

b. Reservoir modeling technology
This section targets the improvement of numerical modeling technology, but in order to conduct such training, it is necessary to review the conceptual models that KenGen has constructed so far from the expert perspectives of geology, geochemistry, and geophysical exploration.

c. Selection of new tracer reagents and analysis and evaluation techniques for geochemical data
Geochemical data is very useful for reservoir management because it contains a lot of information about reservoir fluids. However, as shown in Figure 2.3-1, there is currently a

large variability, and it seems that accurate analytical techniques have not yet been developed. In addition, there are few types of tracer reagents to grasp the state of reduced hot water flow, so evaluations are not performed frequently. Therefore, it is necessary to select new tracers that can be applied to the Olkaria geothermal reservoir and to provide technical training to improve chemical analysis techniques, including tracer analysis.

d. Chemical treatment technology for wells and Power station facilities
At the Olkaria Geothermal Power station, problems have arisen regarding neutralization of cooling tower overflow water, deposition of sulfur and bacteria at the cooling tower outlet, and scaling of calcium carbonate in the reinjection well, which are hindering operation (see Figure 2.3-2). In this project, we will work with the counterparts to investigate the causes of these problems and consider countermeasures and provide training on these technologies.



[Source：Prepared by Expert Team（2019）]

Figure 2.3-1 Changes in silica concentration over time in brine from production wells at Olkaria I Power Station

[Source：Prepared by Expert Team (2019）)

Figure 2.3-2 Corroded cold injection wellhead

2.3.1. Activity 2-1 Review the current status and issues of reservoir management.

JICA Expert Team reviewed the status of KenGen's reservoir monitoring and well testing including pressure monitoring, wellhead pressure and flow rate of production wells, geochemical monitoring of production fluid, tracer test, and reservoir modeling. The JICA expert team also reviewed the geothermal conceptual model of Olkaria field from the viewpoint of geology, geochemistry, and geophysics.

2.3.2. Activity 2-2 Conduct training on analysis of physical characteristics of the well (such as wellhead pressure and flow rate from tracer flow testing and IoT)

JICA Expert Team explained the objective of the reservoir management, actual example of the monitoring items, causes of declining capacity of production and reinjection wells and the example analysis. The JICA expert team and KenGen members discussed the current status and the issues of reservoir monitoring in Olkaria field to understand the importance of reservoir

management. Since the mass flow data of each production well in Olkaria are obtained periodically applying TFT (Tracer Flow Test) method, the session to discuss the interpretation of reservoir fluid behavior based on TFT data was held. As for the reservoir tracer test, The JICA expert team made lectures on the data analysis and interpretation. KenGen members have deepened their understanding of interpretation of output (deliverability) curve for the mass flow and enthalpy, apportion method of steam/water flow rate of each production well, and reservoir management by using monitoring data through the discussion.

2.3.3. Activity2-3 Chemical analysis training including analysis with new tracer(s)

(1) Training for the new tracer analysis

The JICA Expert Team transported brine from Olkaria production well to Japan and conducted laboratory tests in which a mixture of several new tracers was reacted at high temperature and pressure (April 2021). As a result, it was determined that four types of 1,5-NDS(Naphthalenedisulfonic Acid Disodium Salt), 1,6-NDS, 2,6-NDS, and 2,7-NDS were suitable as tracer for Olkaria reservoir, and a High Performance Liquid Chromatograph for analysis was provided to KenGen (May 2022, Figure 2.3.3.-1). After that, chemical analysis and interpretation training was conducted in three tracer tests (November 2022, August 2023, February 2024). In the August 2023 tracer test, tests and training were also conducted in which two different types of tracers were injected into the same reinjection well to analyze the reheating temperature.

[Source：Prepared by Expert Team]

Figure 2.3-3 High Performance Liquid Chromatograph (HPLC) installed in the KenGen laboratory

(2) Training on chemical analysis of brine from production wells

Training was provided on sample collection, chemical analysis, laboratory management, etc., so that appropriate geochemical monitoring could be performed using the chemical analysis values of KenGen's production well brine. When the same production well hot water samples from Olkaria were analyzed and compared between Japan and KenGen for 12 chemical components,

including major cations and major ions, the analytical values did not match at all the first two times and no trends were observed between the chemical components or samples because the pretreatment methods, analytical equipment, and analytical methods used were different even for the same chemical components. However, after training in Japan (September-October 2022 and May 2023) on fluid sampling and analysis at Japanese geothermal Power stations and laboratories, KenGen proposed that another laboratory in Olkaria also participate in ILC (Inter-Laboratory Comparison), and as a result, the differences in analytical values between Japan and KenGen were significantly improved.

2.3.4. Activity 2-4 Conduct training on reservoir modeling using continuous pressure monitoring and gravity monitoring

(1) Activity 2-4 Conduct training on reservoir modeling using continuous pressure monitoring and gravity monitoring.

The JICA expert team created the explanation materials which describing the actual examples of the reservoir modelling/reservoir management from journals of Japanese geothermal Power station and the format of input/output file of reservoir simulator iTOUGH2. The format is required when building the numerical model. Based on these materials, The JICA expert team explained to KenGen (May 2022). After acquiring the knowledge of numerical modelling, many practices were conducted using the simple sample problems, a little bit complicated problems of the fictional geothermal field and actual Olkaria numerical model which KenGen possesses (May 2022, November 2022, August 2023). These practices included the contents of building of numerical model, the calibration process and the forecasting study (case study). Matching data of practices were the continuous pressure monitoring, the gravity monitoring, the enthalpy changes of production wells and temperature/pressure profiles. At the training of case study, not only reservoir simulator but also wellbore simulator was used for practices. Also, the training of inversion analysis was conducted (February 2024). This inversion analysis has the possibility to make calibration process more efficient. During the training in Japan in September 2022 and May 2023, we visited to Hatchobaru, Yamagawa and Takigami Power station as the field trip. The JICA expert team explained about items of reservoir management with looking real things. Also, the calibration training was done. Through the above trainings, the technical capability of KenGen Core members for the reservoir numerical modelling was improved.

(2) Training on wellbore simulation of production well

The practices using wellbore simulator were conducted (November 2022). The wellbore simulator was using at the training of case study. At practices, the targets to analysis and reproduce were the characteristic curve and wellbore temperature/pressure profile during production which acquired by production tests. Wellbore simulator WellSim was used for this training. These data to reproduce were ones The JICA expert team prepared and the actual test results in Olkaria field. Through the above training, the technical capability of KenGen Core members for the wellbore simulation was improved.

2.3.5. Activity 2-5 Conduct training on geochemistry for preventing scaling, corrosion, and sulfur/bacteria deposition

(1) Training on calcium carbonate scale prevention

In discussions with KenGen members, The JICA expert team identified that the calcium carbonate scale in the low-temperature injection well was deposited inside the well when it was previously used as a production well. And the JICA expert team gave a lecture on general prevention measures for calcium carbonate scale in production wells (chemical injection) and acid stimulation.

(2) Training on neutralizing acid water of cooling water (corrosion prevention)

Ruptured steam piping

Corroded injection piping

Bacteria deposition on fill packs

Abandoned dosing pumps

[Source：Prepared by Expert Team]

Fig.2.3-4 Problems of ground equipment

a. Training on the mechanism of pH decrease in cooling tower water and its countermeasures

The corrosion of ground equipment is caused by the strong acidity of the cooling water. Core members were repeatedly instructed and trained in on-the-job training on acidic mechanisms, countermeasures, maintenance and management of instruments and equipment, and caustic soda as a neutralizer. A lecture was given on chemical management of geothermal Power station.

b. Training on equipment inspection during plant shut down

Core members were trained on the point of inspections of equipment and evaluation ways of scales analysis data during plant shut down. In the second training in Japan, a demonstration was conducted using Kyushu Electric Power's analyzer: XRF, XRD, EPMA, ICP, LC and AAS.

c. Training for developing their Action plan

The JICA expert team helped KenGen's miscellaneous and passive Action plan develop to positive ones for resolving our tasks by giving specific examples.

(3) Training to prevent sulfur and bacteria deposition in cooling towers

To prevent corrosion in the cooling tower circuit and cold injection wells, as well as to reduce the precipitation of sulfur in the cooling tower fill packs and piping it is important to maintain the pH at a neutral level of 7 or slightly higher. The positive effect of the pH control will be that biocides against biological contaminations will function more effectively. In addition, explanations and discussions were held with Power station managers to ensure that appropriate budgetary measures for chemicals, etc. were taken.

2.4. Overall Project activities

2.4.1. History of PDM Modification

A total of five JCC meetings were held for this project to discuss and approve project implementation policies and report on implementation details. Note that the first JCC was held as a remote meeting due to COVID-19. PDM and PO that were subsequently formulated differed significantly from the originally envisioned situation due to the impact of the spread of COVID-19 and the revision of the maintenance plan for the Olkaria geothermal Power station, etc. Therefore, the planned activities became difficult and were revised as follows.

(1) 1st JCC

As the 1st JCC was delayed due to the impact of COVID-19, it was decided to extend the project schedule until 24th August 2023. Regarding the plan for 2020, the JICA expert team proposed to postpone the travel and invitation for the first phase of the originally planned work until March 2021, taking into account the impact of COVID-19, and to conduct the technology transfer online, which was approved by the project members.

(2) 2nd JCC

Since it is difficult to conduct a quantitative evaluation based solely on the attendance rate of reservoirs in training, the "Objectively Verifiable Indicator" under "Outputs" was changed from a quantitative evaluation to "acquisition of analytical skills to be achieved through training". In the Means of Verification section, the evaluation sheet attached to the monitoring sheet was used as a reference to evaluate the competence of the trained staff and Managers.

a. Objectively Verifiable Indicators and Means of Verification of Output2, indicated in PDM

Table2.4-1 Revision of Objectively Verifiable Indicators and Means of Verification in Outout2

Before:

Objectively Verifiable Indicators	Means of Verification
<Output 2> 2-1 Review reports on current status and issues of reservoir management are prepared 2-2 x% of core members receive training on analysis of physical characteristics of the well 2-3 x% of core members receive training on chemical analysis including new tracer. 2-4 x% of core members receive training on reservoir modeling. 2-5 x% of core members receive training on geochemistry	2-1 Review reports 2-2 to 2-5 Capacity assessment of staff and managers that received training

After:

Objectively Verifiable Indicators	Means of Verification
<Output 2> 2-1 Review reports on current status and issues of reservoir management are prepared 2-2 Core members acquired the target skill levels through training on analysis of physical characteristics of the well 2-3 Core members acquired the target skill levels through training on chemical analysis including new tracer 2-4 Core members acquired the target skill levels through training on reservoir modeling 2-5 Core members acquired the target skill levels through training on geochemistry	2-1 Review reports 2-2 to 2-5 Capacity assessment of staff and managers that received training, in reference to the Evaluation Sheet attached to Monitoring Sheet

Note: Underlines indicate the amendment(s).

[Source：Prepared by Expert Team]

(3) 3rd JCC

Due to the review of the maintenance plan and the delay in the installation of equipment, a review of the following indicators was proposed to the JCC members and agreed upon.

a. Duration of the Project

Installation of equipment for the cooling tower and main steam pipe temperature monitoring system was scheduled for July 2023, and the end date of the project was subsequently extended from June 2024 to September 2024 to include one year for operational data accumulation and technology transfer.

Before:

25 August 2020 to 30 June 2024

(Minutes of Meeting, (hereinafter referred to as M/M) signed on 25 August 2022)

After:

25 August 2020 to 30 September 2024

b. Objectively Verifiable Indicators and Means of Verification of Overall Goal, indicated in PDM

The Project Team proposed some changes of the objectively verifiable indicators for the Output, Project Purpose and Overall Goal in the PDM to clearly state the target goals which should be

pursued by the Project Team. The JCC members seconded the Project Team's proposal including specified target values in objectively verifiable indicators.
JICA and KenGen recognized that one of the key elements to the success of this project was the acquisition of quality data in the UNIDO IoT system, and that KenGen would work to ensure data quality.

Table2.4-2 Revision of Objectively Verifiable Indicators and Means of Verification in Overall Goal

Before:

Objectively Verifiable Indicators	Means of Verification
In comparison to the indicators at the time of the baseline survey, 1. Increase in capacity availability rate* of each geothermal power station 2. Breakdown time of power plants decrease. 3. Durations of annual inspections and overhauls are reduced. *Definition of capacity availability rate (%): as agreed upon in the power purchase agreement	1, 2. and 3. KenGen's statistical data and reports

After:

Objectively Verifiable Indicators	Means of Verification
1. Increase of capacity availability 1-1 Increase of 1.31% capacity availability in OHM year as maintenance period is shortened by 4 days after Installation of spare rotor among other interventions 1-2 Increase of 0.65% capacity availability from OHM year to next OHM year due to reduction of Annual Inspection from 5 times to 3 times. 2. Increase of 5.07% capacity availability due to 443h 44m reduction of breakdown hours for the last five years. 3. Implementation of continuous technology transfer regarding power plant O&M and reservoir management.	1. KenGen's statistical data and reports 2. KenGen's statistical data and reports 3. Training program and Training actual results

Note: Underlines indicate the amendment(s).

[Source：Prepared by Expert Team]

c. Objectively Verifiable Indicators and Means of Verification of Project Purpose indicated in PDM

During the project period, it was found that OHM had not been planned, and the project team proposed to the JCC members that the OJT be changed from OHM to Annual Inspection, and that the indicators for generation facility management and reservoir management be changed to be more specific.

Table2.4-3 Revision of Objectively Verifiable Indicators and Means of Verification in Project Purpose

Before:

Objectively Verifiable Indicators	Means of Verification
1. x units** out of nine units (Olkaria I units 4 and 5; Olkaria II units 1, 2, and 3; Olkaria IV units 1 and 2; and Olkaria V units 1 and 2) in the KenGen 's Olkaria geothermal power stations apply the O&M knowledge acquired from the Project to their work for improvement. 2. Changes in reservoir characteristics can be appropriately detected. **Specific target numbers are to be determined after baseline survey.	1. Technical reports of KenGen's Olkaria geothermal power stations 2. Technical reports of 2.KenGen's Olkaria geothermal power stations

After:

Objectively Verifiable Indicators	Means of Verification
1-1 The introduction and management technology of spare rotor is developed and integrated into KenGen's OHM procedure 1-2 Spare rotor implementation plan is in place within the project period. 1-3 Acquired O&M knowledge for improvement through OJT of Annual Inspection is developed to their work.	1-1, 1-2 and 1-3 Newly created and approved action plan to achieve the Overall Goal in Olkaria
2. Technology transfer is implemented to reduce major troubles (4 items) that have occurred in the last five years.	2. Technical reports of 2.KenGen's Olkaria geothermal power stations
3. Major occurrence is recorded and stored in KenGen	3. UNIDO IoT system of KenGen's Olkaria geothermal power stations and other internal records
4. Acquire new operation technology which is applied in an organized manner in O&M by KenGen .	4. Monthly Report
5. Changes in reservoir characteristics are detected and the causes and countermeasures for those changes are appropriately examined.	5."Steam and reservoir status reports" and

6. Training programs are drawn based on the contents of O&M knowledge acquired and are incorporated in the KenGen's training program.	"Monthly power plant geochemistry report" of KenGen Olkaria geothermal power stations 6. training program and actual training results

Note: Underlines indicate the amendment(s).

[Source：Prepared by Expert Team]

d. Objectively Verifiable Indicators and Means of Verification of Output 1 indicated in PDM

The project team proposed to the JCC members that quantitative evaluation be set as Overall Goal and revised Output 1.

Table2.4-4 Revision of Objectively Verifiable Indicators and Means of Verification in Output1

Before:

Objectively Verifiable Indicators	Means of Verification
<Output 1> 1-1 Technical manuals for O&M are developed.	1-1 O&M manuals
<Operations> 1-2 x% of core members understand the basics of predictive trouble management and are able to apply it to their work	<Operations> 1-2 Capacity assessment of staff and managers that received training
1-3 x% of core members understand the basics of performance management and are able to apply it to their work	1-3 Capacity assessment of staff and managers that received training
<Maintenance>. 1-4 x% of core members understand the basics of data analysis of repair data and are able to apply it to their work	<Maintenance>. 1-4 Capacity assessment of staff and managers that received training
1-5 x% of core members understand the fault tree analysis for trouble-shooting and are able to apply it to their work.	1-5 Capacity assessment of staff and managers that received training
1-6 x% of core members understand the basics of overhaul maintenance and are able to apply it to their work	1-6 Capacity assessment of staff and managers that received training
1-7 Technical manuals for O&M are revised	1-7 Revised O&M manuals

After:

Objectively Verifiable Indicators	Means of Verification
1-1 Technical manuals for O&M are developed and revised. 1-2 The teaching materials used in the training are developed for education. 1-3 Core members acquire the target skill levels through training on basics of predictive trouble management and are able to apply it to their work. 1-4 Core members acquire the target skill levels through training on basics of performance management and are able to apply it to their work. 1-5 Core members acquire the target skill levels through training on fault tree analysis of trouble-shooting and are able to apply it to their work. 1-6 Core members acquire the target skill levels through training on basics of data analysis of repair data and are able to apply it to their work. 1-7 Core members acquire the target skill levels through training on the basics of Annual Inspection and are able to apply it to their work.	1-1 and 1-2 O&M manuals and lecture materials for KenGen in house training <Operations> 1-3 to 1-5 Capacity assessment of staff and managers that received training, in reference to the Evaluation Sheet attached to Monitoring Sheet <Maintenance> 1-5 to 1-7 Capacity assessment of staff and managers that received training, in reference to the Evaluation Sheet attached to Monitoring Sheet

Note: Underlines indicate the amendment(s).
[Source：Prepared by Expert Team]

e. Objectively Verifiable Indicators and Means of Verification of Output 2 indicated in PDM

The project team proposed to the JCC members that development of training materials be added to Output 2.

Table2.4-5 Revision of Objectively Verifiable Indicators and Means of Verification in Output 2

Before:

Objectively Verifiable Indicators	Means of Verification
<Output 2> 2-1 Review reports on current status and issues of reservoir management are prepared 2-2 Core members acquire the target skill levels through training on analysis of physical characteristics of the well 2-3 Core members acquire the target skill levels through training on chemical analysis including new tracer 2-4 Core members acquire the target skill levels through	2-1 Review reports 2-2 to 2-5 Capacity assessment of staff and managers that received training, in reference to the Evaluation Sheet attached to Monitoring Sheet

training on reservoir modeling 2-5 Core members acquire the target skill levels through training on geochemistry	

After:

Objectively Verifiable Indicators	Means of Verification
<Output 2> 2-1 Review reports on current status and issues of reservoir management are prepared. 2-2 Core members acquire the target skill levels through training on analysis of physical characteristics of the well. 2-3 Core members acquire the target skill levels through training on chemical analysis including new tracer. 2-4 Core members acquire the target skill levels through training on reservoir modeling. 2-5 Core members acquire the target skill levels through training on geochemistry. 2-6 <u>The teaching materials used in the training are developed for education.</u>	2-1 Review reports 2-2 to 2-5 Capacity assessment of staff and managers that received training, in reference to the Evaluation Sheet attached to Monitoring Sheet <u>2-6 Lecture materials for KenGen in house training</u>

Note: Underlines indicate the amendment(s).

[Source：Prepared by Expert Team]

f. Activities indicated in PDM

The project team proposed to the JCC members that the Olkaria V Power station be added to the PDM.

Table2.4-6 Revision of Activities

Before:

Activities
Activities 1-1 Review and analyze the current status and issues of O&M of Olkaria I (Units 4 and 5), Olkaria II (Units 1, 2 and 3), and Olkaria IV (Units 1 and 2).

After:

Activities
Activities 1-1 Review and analyze the current status and issues of O&M of Olkaria I (Units 4 and 5), Olkaria II (Units 1, 2 and 3), Olkaria IV (Units 1 and 2) and Olkaria V (Units 1 and 2).

Note: Underlines indicate the amendment(s).
[Source：Prepared by Expert Team]

(4) 4th JCC

The project team proposed to postpone the project end date be extended, etc. as follows. The JCC members seconded the project team's proposal.

a. Duration of the Project

The end date of the project was postponed from September 2024 to January 2025 due to a review of the maintenance plan of the Olkaria geothermal power station to consider the timing of the installation of the cooling tower and main steam pipe temperature monitoring equipment and the implementation of technology transfer based on its operational data and the submission of the project completion report.

Before:

25 August 2020 to 30 September 2024
(M/M signed on 1 December 2023)

After:

25 August 2020 to 31 January 2025

b. Objectively Verifiable Indicators and Means of Verification of Overall Goal, indicated in PDM

In the Means of Verification of project goal, the Action plan had already been introduced as a means of monitoring the progress of Power station operations and management, and was added to both the power generation side and the reservoir side. In addition, the evaluation target for the maintenance of power generation side, which had previously been Core members, was changed to each power station, since maintenance management is planned and carried out at each Power station, regardless of individual capabilities. Although ensuring data quality using the UNIDO IoT system was not within the scope of this project, it was added to the Important assumptions under Outputs because it was highly relevant to achieving the project goals.

Table2.4-7 Revision of Objectively Verifiable Indicators and Means of Verification in Overall Goal

Before:

Objectively Verifiable Indicators	Means of Verification
1.Increase of capacity availability 1-1 Increase of 1.31% capacity availability in OHM year as maintenance period is shortened by 4 days after installation of spare rotor among other interventions 1-1 1-2 Increase of 0.65% capacity availability from OHM year to next OHM year due to reduction of Annual Inspection from 5 times to 3 times. 2. Increase of 5.07% capacity availability due to 443h 44m reduction of breakdown hour for the last five years. 3.Implementation of continuous technology transfer regarding power plant O&M and reservoir management.	1. KenGen's statistical data and reports 2.KenGen's statistical data and reports 3. Training program and Training actual results

After:

Objectively Verifiable Indicators	Means of Verification
1.Increase of capacity availability 1-1 Increase of 1.31% capacity availability in OHM year as maintenance period is shortened by 4 days after installation of spare rotor among other interventions. 1-2 Increase of 1.12% capacity availability due to reduction of Annual Inspection from 2 times to 1 time. 2. Increase of 5.07% annual capacity availability due to 443h 44m/year reduction of breakdown hours for the last five years. 3.Implementation of continuous technology transfer by incorporating in-house training into an annual training program based on the annually updated trainee lists of Power plant O&M and Reservoir management.	1.KenGen's statistical data and reports 2.KenGen's statistical data and reports 3. Training program and Training actual results

Note: Underlines indicate the amendment(s).

[Source：Prepared by Expert Team]

c. Means of Verification of Project Purpose, indicated in the PDM

Table2.4-8 Revision of Objectively Verifiable Indicators and Means of Verification in Project purpose

Before:

Objectively Verifiable Indicators	Means of Verification
1-1 The introduction and management technology of spare rotor is developed and integrated into KenGen's OHM procedure 1-2 Spare rotor implementation plan is in place within the project period. 1-3 Acquired O&M knowledge for improvement through OJT of Annual Inspection is developed to their work	1-1, 1-2 and 1-3. Newly created and approved action plan to achieve the Overall Goal in Olkaria
2. Technology transfer is implemented to reduce major troubles (4 items) that have occurred in the last five years.	2.Technical reports of KenGen's Olkaria geothermal power stations
3. Major occurrence is recorded and stored in KenGen.	3. UNIDO IoT system of KenGen's Olkaria geothermal power stations and other internal records
4. Acquire new operation technology which is applied in an organized manner in O&M by KenGen .	4. Monthly Report
5. Changes in reservoir characteristics are detected and the causes and countermeasures for those changes are appropriately examined.	5. "Steam and reservoir status reports" and "Monthly power plant geochemistry report" of KenGen Olkaria geothermal power stations
6. Training programs are drawn based on the contents of O&M knowledge acquired and are incorporated in the KenGen's training program.	6. Training program and Training actual results

After:

Objectively Verifiable Indicators	Means of Verification
1-1 The introduction and management technology of spare rotor is developed and integrated into KenGen's OHM procedure 1-2 Spare rotor implementation plan is in place within the project period. 1-3 Acquired O&M knowledge for improvement through OJT of Annual Inspection is developed to their work	1-1,1-2 and 1-3. Newly created and approved action plan to achieve the Overall Goal in Olkaria
2. Technology transfer is implemented to reduce major troubles (4 items) that have occurred in the last five years.	2.Action plan and Monthly report of KenGen's Olkaria geothermal power stations
3.Major occurrence is recorded and stored in KenGen.	3. UNIDO IoT system of KenGen's Olkaria geothermal power stations and other internal records
4.Acquire new operation technology which is applied in an organized manner in O&M by KenGen .	4. Monthly Report
5. Changes in reservoir characteristics are detected and the causes and countermeasures for those changes are appropriately examined.	5.Steam and reservoir status report, Monthly power plant geochemistry report and Action plan of KenGen Olkaria geothermal power stations
6.Training programs are drawn based on the contents of O&M knowledge acquired and are incorporated in the KenGen's training program.	6. Training program and Training actual results

[Source：Prepared by Expert Team]

Note: Underlines indicate the amendment(s).

d. Important Assumption of Inputs, indicated in Outputs on PDM

Newly added:

Important Assumption
UNIDO IoT system steadily collects accurate and reliable data.

Note: Underlines indicate the amendment.

2.4.2. History of PO Modification

At the beginning of this project, the project duration was scheduled as follows, but due to a significant delay in the installation work of the cooling tower and main steam pipe temperature monitoring system in Olkaria II-3, the project duration was extended as follows after discussions at the 2nd and 4th JCC, considering the technology transfer period and the preparation period of the project completion report.

- The beginning of the project
  September 2021 - August 2023
- After discussion at the 2nd JCC
  September 2021 - September 2024
- After discussion at the 4th JCC
  September 2021 - January 2025
- After R/D amendment in January 2025 due to revision of Olkaria maintenance schedule
  September 2021 - March 2025

The duration of the activity was consequently extended by 19 months, from 24 to 43 months.

2.5. Technical Training in Japan

2.5.1. 1st Technical Training

a. Purpose

In order to achieve the expected effects of the project to enhance the operation and maintenance management capacity of the Olkaria geothermal Power station using IoT technology, which are to "Enhance the operation and maintenance management capacity of the Power station" and "Enhance the reservoir management capacity," counterpart members were invited to Japan to learn management and operations through observation, lectures, and On-the-job training in conjunction with overhaul inspection of the geothermal Power station of Kyushu Electric Power. Through participation in the technical training in Japan, Core members would acquire knowledge that would contribute to improve the operation and maintenance management of geothermal Power station, including their operation, maintenance management, and reservoir management, and the aim was to raise awareness of how to incorporate the skills learned into their own work and improve operations. Then as a final purpose, Core members would use this acquired knowledge to strengthen the operational capacity of the Olkaria geothermal Power station. Regarding senior management training in Japan, in order to increase the effectiveness of technology transfer in this project, technical training including a site visit to a geothermal Power plant management in Japan, was conducted for the C/P's management level. Opinions were exchanged with Electric power companies regarding operation and maintenance management from the management perspective. Opinions were also exchanged with Japanese experts and the JICA expert team to apply the training results to the Olkaria geothermal Power stations.

b. Participants

Participants in the first technical training are shown in Table 2.5-1.

Table 2.5-1 Participants in the first technical training

Overhaul maintenance (1st)

	Name	Post
1	Harrison Keter	Asst. Operations Manager, Geothermal - Team Leader
2	Grace Kamunge	Electrical Plant Engineer/Other
3	Lameck Makori	Operations Engineer/Operation
4	George Maingi	O&M Engineer/O&M
5	David Imaidi	Operations Engineer-Mech/Operation
6	Winnie Apiyo	PIC Engineer/Other

Reservoir (1st)

	Name	Post
1	Vincent Koech	Chief Eng. Reservoir Management
2	Maureen Ambunya	Reservoir Scientist

Geochemistry (1st)

	Name	Post
1	Ruth Wamalwa	Reservoir Geochemist
2	Catherine Leech	Geochemist
3	Samuel Mwangi	Geochemist
4	Joseph Gitau	Analytical Chemistry Super

5	Jane Chege	Analytical Chemistry Technician
6	Benedict Otieno	Analytical Chemistry Technician

Executive invitation program

	Name	Post
1	Francis Makabwa	Operation Manager-Geothermal
2	Samson Kimani	Power Generation Optimization Manager
3	Clety Kwambai	Ag. Reservoir & Steam Field Manager
4	Beatric Kandie	Human Resources Manager
5	Patric Gikunju	Asst. Manager Quality & Safety
6	Dr.Daniel Kemei	ICT Manager

[Source：Prepared by Expert Team]

c. Schedule

The first technical training was conducted according to the schedule in Table 2.5-2.

Table 2.5-2 First technical training schedule

Overhaul Maintenance Training (21 September - 4 October 2022)

Date	Training Contents	Location
21 September	Travel (Tokyo → Kitakyushu City)	
22 September	Briefing Training	JICA Kyushu
23 September	Power station entry safety training, Power station inspection	Hatchoubaru Geothermal Power station
	Power station Inspection	Otake Geothermal Power station
	Inspection of Power station production and reinjection wells	
24 September	Observation of Power station overhaul inspection work	Otake Geothermal Power station
	Safety management training, budget management training, inspection tour of Power station	Hatchoubaru Geothermal Power station
25 September	Quality Control Training	Hatchoubaru Geothermal Power station
	Observation and practice of Power station Overhaul inspection work	Otake Geothermal Power station
26 September	Observation of periodic inspection activities, observation of Overhaul inspection work	Otake Geothermal Power station
	Observation of daily routine work at Power station	Hatchoubaru Geothermal Power station
27 September	Schedule Management Training	Hatchoubaru Geothermal Power station
	Observation of overhaul inspection work	Otake Geothermal Power station
28 September	Substitute day off	
29 September	Travel (Kitakyushu City→Kagoshima City)	
30 September	Power station Inspection	Yamagawa Geothermal

		Power station Yamagawa Binary Power station
1,2 October	Day off	
3 October	The Action plan training, performance management data and equipment calibration training	Kyuden International
4 October	Travel (Fukuoka City→Tokyo)	

Geochemistry Training (22 September 2022 – 7 October 2022)

Date	Training Contents	Location
22 September	Travel to Japan	
23~25 September	Day off	
26 September	Briefing	JICA Kyushu
	Plant chemistry, hydrothermal extraction, chemical analysis, numerical modeling training	Geothermal Department, West Japan Engineering Consultants(WJEC)
27 September	Power station inspection, geothermal fluid sampling practice 1	Hatchoubaru Geothermal Power station
	On-site analysis laboratory inspection	Hatchoubaru Plant, Kyuden Sangyo Co.
28 September	Power station visit, geothermal fluid sampling practice 2	Otake Geothermal Power station
	On-site analysis laboratory inspection	Kyuden Sangyo Analysis Laboratory at Hatchoubaru Plant,
29 September	Power station inspection,	Yamagawa Geothermal Power station
	Inspection of Power station wellhead	Yamagawa Binary Power station
	Geothermal fluid sampling, field analysis, and instrument calibration practice 1	Kyuden Sangyo Analysis Laboratory
30 September	Geothermal fluid sampling, field analysis, and instrument calibration practice 2	Kyuden Sangyo Analysis Laboratory
	Field Trip Training Summary	Geothermal Department, WJEC
1,2 October	Day off	
3 October	Chemical analysis laboratory inspection, geothermal hydrothermal analysis practice	Environmental Department, Kyuden Sangyo
4 October	Tracer analysis, sample management, and quality control practice	Environmental Department, Kyuden Sangyo

5 October	Tracer test analysis training, Production well geochemical monitoring data analysis training, Scale measure training	Environmental Department, Kyuden Sangyo
6 October	Training summary, exchange of opinions	Environmental Department, Kyuden Sangyo.
7 October	Travel (Fukuoka City→Tokyo)	

Reservoir Modeling Training (22 September 2022 – 7 October 2022)

Date	Training Contents	Location
22 September	Travel to Japan	
23~25 September	Day off	
26 September	Briefing	JICA Kyushu
	Plant chemistry, hydrothermal extraction, chemical analysis, numerical modeling training	Geothermal Department,WJEC.
27 September	Power station inspection, geothermal fluid sampling practice 1	Hatchoubaru Geothermal Power station
	Inspection of geothermal Power station wellhead	Otake Geothermal Power station
28 September	Power station Inspection	Otake Geothermal Power station
	Geothermal fluid sampling practice 2, inspection of geothermal Power station well pad	Hatchoubaru Geothermal Power station
29 September	Inspection of Power station, inspection of Power station well pad	Yamagawa Geothermal Power station
	Field trip of Binary Power station	Yamagawa Binary Power station
	Inspection Training Summary	Geothermal Department,WJEC
30 September	Reservoir Modeling Practice	Geothermal Department,WJEC
1,2 October	Day off	
3 October	Reservoir Modeling Practice	Geothermal Department,WJEC.
4 October	Reservoir Modeling Practice	Geothermal Department,WJEC
5 October	Reservoir Modeling Practice	Geothermal Department,WJEC
6 October	Training summary discussion, exchange of opinions	Geothermal Department,WJEC.

7 October	Travel (Fukuoka City→Tokyo)	

Executive invitation program (24 October 2022 – 28 October 2022)

Date	Training Contents	Location
24 October	Travel to Japan	
25 October	Briefing, Power plant management training	JICA Kyushu
26 October	Power station Inspection	Otake Geothermal Power station
	Inspection tour of Power station, training on facility maintenance, stable operation, and storage tank management	Hatchoubaru Geothermal Power station
27 October	Discussion of fiber optic cooling tower temperature monitoring and observation of Power station operations Training in environmental conservation and social contribution, and inspection of well pad at Power station	Hatchoubaru Geothermal Power station
28 October	Kyushu Electric Power's education system training, summary discussion	Kyuden International

[Source：Prepared by Expert Team]

d. Training Overview and Results

(a) Overhaul maintenance training

- Site/Field trip
  - Power generation facilities: Hatchoubaru Power Station, Otake Power Station, Installation of internal temperature monitoring equipment in cooling tower
  - Turbine Disassembly: Chamber, turbine, diaphragm, steam stop valve, balance bellow
  - Inspection of auxiliary equipment: Preparation of outdoor auxiliary equipment and turbine honing
  - Morning meetings: radio calisthenics, safety morning meeting, hazard prediction activities
  - Electrical system inspection work: ASS (Automatic Synchronous System) and AVR (Automatic Voltage Regulator) function check, storage batteries
  - Routine work: Switching and cleaning of hot water pump shaft seal water strainer
  - Isolation work: Auxiliary equipment power-off work
  - Safety patrols: work area curing, tool management, slinging work, etc.
- Practical training
  - FRP piping repair
- Classroom learning and discussions
  - Schedule Control
  - Quality Control
  - Safety Management
  - Budget Management
- Visit to Yamagawa Power station and Yamagawa Binary Power station

- The Action plan creation, Wrap-up meeting

(b) Geochemical training

- Site/Field trip
  - Power generation facilities: Hatchoubaru Power station, Otake Power station, Yamagawa Power station& Yamagawa Binary Power stations
  - Well pad: Hatchoubaru Retaining tankbasin & 2H-13 well pad, Otake O-22 well pad, Yamagawa C&F well pad
  - Chemical Analysis Laboratory (Yamagawa Analysis Laboratory, Environmental Department, Kyuden Sangyo Co.)
- Actual practice
  - Geothermal fluid sampling: Hatchoubaru Reservoir & 2H-13 well pad, Yamagawa C&F well pad
  - On-site analysis and calibration of measuring instruments
  - Geothermal hydrothermal analysis: cations, anions, silica
  - Tracer analysis : NDS, Fluorescent
- Classroom learning
  - Overview of training content
  - Summary of Site Visits
  - Sample management and quality control
  - Tracer test analysis
  - Production Well Chemical Monitoring Data Analysis
  - Scale measures
- The Action plan creation, wrap-up meeting

(c) Reservoir modeling training

- Site/Field trip
  - Power generation facilities: Hatchoubaru Power station, Otake Power station, Yamagawa Power station & Yamagawa Binary Power station
  - Well Base: Hatchoubaru Reservoir & 2H-13 well pad, Otake O-22 well pad, Yamagawa C well pad
- Practice
  - Reservoir modeling: history matching using a model of the Olkaria region
  - Geothermal fluid sampling: Hatchoubaru Reservoir & 2H-13 Pad
- Classroom learning
  - Overview of training content
  - Summary of Site Visits
- The Action plan creation, wrap-up meeting

(d) Executive training

- Site/Field trip
  - Visits to Hatchoubaru Power Station, Otake Power Station, and 2H-13 pad

- Morning meetings: radio calisthenics, safety morning meeting, hazard prediction activities
- Routine work: Automatic start-up test of TOP, AOP, and EOP

➢ Classroom learning and discussions

- Risk Management
- Power plant management from a Finance Perspective
- Equipment Maintenance
- Maintaining stable operation
- Reservoir Management
- Economic evaluation using a cooling tower monitoring system
- Environmental preservation, regional symbiosis
- Education System

2.5.2. 2nd technical training (Reservoir modeling/Geochemistry)

a. Purpose

In order to achieve the expected effect of the project, that is "Strengthening Reservoir Management Capacity" of the Olkaria Geothermal Power station Operation and Maintenance Capacity Enhancement Project using IoT technology, training was conducted with the aim of providing trainees with "geochemical technology" or "reservoir modeling technology".

b. Participants

Participants in the second reservoir modeling and geochemical technology training are shown in Table 2.5-3.

Table 2.5-3 Participants in the second technical training

Reservoir (2nd)

	Name	Post
1	Urbanus Mbithi	Reservoir Engineer
2	Eric Rop	Reservoir Engineer

Geochemistry (2nd)

	Name	Post
1	Erique Nyawir	Reservoir Geochemist
2	Melissa Nkapiani	Geochemist
3	Eunice Bonyo	Geochemist
4	Kenneth Koech	Geochemist/ Analytical Chemistry Technician
5	Martin Opiyo	Analytical Chemistry Technician/ Power station Chemistry
6	Perpetua Kamau	Reservoir Technician II

[Source：Prepared by Expert Team]

c. Schedule

The second technical training was conducted according to the schedule in Table 2.5-4.

Table 2.5-4 Second technical training schedule

Geochemistry Training (21 May – 3 June 2023)

Date	Training Contents	Location
21 May	Travel to Japan	
22 May	Briefing	JICA Kyushu
	Plant chemistry, hydrothermal extraction, chemical analysis, numerical modeling training	Geothermal Department, WJEC.
23 May	Power station Equipment Training	Otake Geothermal Power station
	Training on Power station facilities and reinjection well pad, sampling practice of retention tank	Hatchoubaru Geothermal Power station
24 May	Inspection of Power station facilities	Takigami Power station
	Inspection of Power station facilities and production well pad	Takigami Binary Power station
	Inspection and training of Power station production well pad and chemical injection equipment	Otake Geothermal Power station
	Inspection of Power station production well pad, training on monitoring equipment, and inspection of surface geothermal indication	Hatchoubaru Geothermal Power station Areas around the Power station
25 May	Geothermal fluid sampling and analysis training and hands-on training	Hatchoubaru Geothermal Power station
26 May	Analytical instrument training, geothermal hydrothermal analysis practice	Kyushu Electric Power General Research Institute
27,28 May	Day off	
29 May	Practical training in analytical instrumentation and geothermal hydrothermal analysis	Environmental Department, Kyuden Sangyo
30 May	Practical training in geothermal hydrothermal analysis, sample management and quality control	Environmental Department, Kyuden Sangyo
31 May	Practical training in geothermal hydrothermal analysis, tracer analysis and tracer testing	Environmental Department, Kyuden Sangyo
1 June	Conceptual modeling and new production well chemistry analysis training, reservoir management training, tracer test analysis, scale measures, and hot spring monitoring training	Geothermal Department, WJEC
2 June	Training Summary Discussion	Geothermal Department, WJEC
3 June	Travel	

Reservoir Modeling Training (21 May – 3 June 2023)

Date	Training Contents	Location
21 May	Travel to Japan	
22 May	Briefing	JICA Kyushu
	Plant chemistry, hydrothermal extraction, chemical analysis, numerical modeling training	Geothermal Department, WJEC
23 May	Power station Equipment Training	Otake Geothermal Power station
	Training on Power station facilities and	Hatchoubaru Geothermal

	reinjection well pad, sampling practice of retention tank	Power station
24 May	Inspection of Power station facilities	Takigami Power station
	Field trip of Power station facilities and production bases	Takigami Binary Power station
	Field trip and training of Power station production base and chemical injection equipment	Otake Geothermal Power station
	Field trip of Power station production well pad training on monitoring equipment, and field trip of surface geothermal indication	Hatchoubaru Geothermal Power station Areas around the Power station
25 May	Geothermal fluid sampling and analysis training and hands-on training	Hatchoubaru Geothermal Power station
	Field Trip Summary Training	Geothermal Department, WJEC.
26 May	Reservoir Modeling Practice	Geothermal Department, WJEC.
27,28 May	Day off	
29 May	Reservoir Modeling Practice	Geothermal Department, WJEC.
30 May	Reservoir Modeling Practice	Geothermal Department, WJEC.
31 May	Reservoir Modeling Practice	Geothermal Department, WJEC.
1 June	Conceptual model building training, reservoir modeling practice	Geothermal Department, WJEC.
2 June	Training summary discussion and the Action plan presentation	Geothermal Department, WJEC.
	closing ceremony	JICA Kyushu
3 June	Travel	

[Source：Prepared by the JICA expert team]

d. Training Outline

(a) Geochemical training

① On-site lecture/Field trip

- Power generation facilities: Hatchoubaru Power station, Otake Power station, Takigami Binary Power station
- Well Base : Hatchoubaru retaining Tank & HR-19 well pad & 2H-13 well pad, Otake O-22 well pad
- Chemical Analysis Laboratory (Kyuden Sangyo Co. Inc, Ltd. Environmental Department: Mainly solution sample analysis)
- Chemical Analysis Laboratory (Kyushu Electric Power, General Research Laboratory: mainly solid sample analysis)

② Practical training/exercises

- Geothermal fluid sampling: Hatchoubaru Reservoir & H-19 well pad
- On-site analysis: On-site measurement of hot water, gas sampling and measurement, on-site titration, etc.
- Geothermal hydrothermal analysis: cations (Fe), anions (Cl, SO4)

- Tracer analysis : NDS, Fluorescent

③ Field trip of analytical instruments

- Field trip and analysis equipment: X-ray fluorescence analyzer, X-ray diffractometer, electron microprobe analyzer, microscope, etc.
- Field trip contents: Analysis principles, analysis methods (pretreatment, analysis), examples of analysis data, examples of analysis cases at electric power companies, maintenance of analysis equipment

④ Classroom learning

- Overview of training content
- Preliminary lecture on site visit
- Summary of Site Visits
- Sample management and quality control
- Tracer test analysis
- On the construction of the conceptual model
- Reservoir management (e.g., production well chemical monitoring data analysis)
- Scale measures

⑤ The Action plan development, Wrap-up meeting

(b) Reservoir modeling training

① On-site lecture/observation

- Power generation facilities: Hatchoubaru Power station, Otake Power station, Takigami Binary Power station
- Well pad: Hatchoubaru retaining tank & HR-19 well pad & 2H-13 well pad, Otake O-22 well pad

②Practice

- Reservoir modeling: discussion on natural state and history matching and gravity monitoring using a model of the Olkaria region
- Geothermal fluid sampling: Hatchoubaru retaining tank & H-19 well pad

③ Desk lectures

- Overview of training content
- Preliminary lecture on site visit
- Summary of Site Visits
- Establishment of the conceptual model

④ The Action plan development, wrap-up meeting

2.5.3. 3rd Technical Training

a. Purpose

In order to achieve the expected effect of the project to enhance the operation and maintenance management capacity of the Olkaria geothermal Power station through the use of IoT technology, the counterpart members were invited to Japan for field trip, classroom training, and on-the-job training in conjunction with the Power station's Overhaul inspection of Kyushu Electric Power.

The objective was for the trainees to deepen their understanding of the technologies they had learned at the Olkaria Power station and in the online lectures by checking the status of work in Japan with their own eyes and through discussions with engineers in Japan. After returning to Kenya, the trainees organized how they would incorporate the technologies they had learned into their own work, and held a presentation of the acquired technologies to other

members in the plants, with the aim of horizontally deploying the technologies to enhance the operational capacity of the Olkaria geothermal Power station.

b. Participants

Participants in the third technical training are shown in Table 2.5-5.

Table 2.5-5 Participants in the third technical training

Overhaul (2nd)

	Name	Post
1	Wesley Koros	Assistant Manager
2	Victor Ouma	Principal Engineer
3	Levine Onyari	Senior instrumentation and Control Engineer
4	Gideon Kemboi	Senior Engineer
5	Kennedy Tarus	Mechanical Engineer
6	Nathaniel Mugo	Senior instrumentation and Control Engineer

[Source: Prepared by Expert Team]

c. Schedule

The third technical training was conducted according to Table 2.5-6.

Table 2.5-6 Third technical training schedule

Overhaul Maintenance Training (6-21 November 2023)

Date	Training Contents	Location
6 November	Travel to Japan	
7 November	Explanation of the objectives and contents of the third technical training session	JICA Kyushu
8 November	Overview of Hatchoubaru Power station and OHM details and process progress training	Hatchoubaru Power station
9 November	Operational monitoring (including site visits)	Hatchoubaru Power station
		Takigami Power station
10 November	Field trip of Power station, equipment inspection training, process management training	Hatchoubaru Power station
		Sugawara Binary
11 November	Storage battery inspection training, site visit, organization and role-sharing system training	Hatchoubaru Power station
12 November	Day off	
13 November	pH control/cooling tower monitoring system training, Power station on-site training	Hatchoubaru Power station
	Power station on-site training	Otake Power station
14 November	Safety management training, On-the-job training, flow meter training	Hatchoubaru Power station
15 November	Generator and exciter protection relay training (including on-site briefing)	Hatchoubaru Power station
16 November	Training on considerations when calibrating transmitters, training on transducers	Hatchoubaru Power station
17 November	Field trip of employee training center	Kyushu Electric Power

18,19 November	Day off	
20 November	Presentation of training results, Q&A session	JICA Kyushu
21 November	Travel	

[Source: Prepared by Expert Team]

d. Training Outline

(1) Results of the 2nd Overhaul Maintenance Training

- Site/Field Trip
  - Power generation facilities: Hatchoubaru Power station, Hatchoubaru retention tank, 2H-13 well pad
  - Turbine assembly: Chamber, turbine, diaphragm, steam stop valve, and centering work
  - Auxiliary equipment inspection work: hot water pump LCV installation work, cooling tower fan centering work
  - Morning meetings: radio calisthenics, safety morning meeting, hazard prediction activities
  - Safety patrols: work area management, tool management, slinging, foreign object control, safety equipment, etc.
  - Electric system inspection work: Turbine/generator protection relays, storage batteries and DC power supply equipment, precautions when calibrating transmitters, calibration of flow meters, and electricity meter
  - Routine work: Shaft cooling water pump switchover (Unit A) to (Unit B)
  - Operation monitoring: Monitoring methods and alarm response procedures for unattended operation, and daily inspection procedures.
  - Maintenance System: Introduction of Kyuden Thermal Power Department System
  - Material Management: Storage status and classification of materials in the archives

- Classroom learning and discussions
  - Schedule control: Trouble cases introduction and process adjustment
  - Lubricant control: Control purpose and analysis items, cleaning work procedures, and improvement of work efficiency by using cleaners.
  - Operation monitoring: Unattended operation monitoring system, monitoring system, and Organizational daily inspection items
  - Structure: Kyushu Electric Power operation and maintenance structure, roles of each department, and communication methods
  - Centering work: Work procedures, instrument features and reading methods, adjustment and shim volume calculations.
  - pH control: Mechanisms and countermeasures for corrosion and silica scale formation due to low pH
  - Protection relay: Mechanism and principle of operation of each protection relay, and maintenance procedures
  - Storage Battery: Storage Battery Mechanism and Features, Concept of Composition, Maintenance Notes
  - DC power supply: Mechanism and configuration of the device

- Field trip of Otake Power station, Takigami Power station, and Sugawara Binary Power station

- Monitoring status of the cooling tower temperature monitoring system at the Otake Power station

- Takigami Power station Field trip
- Field trip of Kyusyu electric power training center: Coal fired thermal Power station simulator training, facilities in the training building, educational system lecture
- Personal note preparation, Wrap-up meeting

3. Project Objectives and Outcomes

3.1. Evaluation of Project Outcome Achievement

3.1.1. Achievement of Output 1

Output 1 1. O&M capacity of power stations is strengthened

Objectively Verifiable Indicator 1-1 Technical manuals for O&M are developed and revised

This indicator has been partially achieved. In November 2021, the JICA expert team visited the site and found that many experienced KenGen members would be needed to implement OHM at Olkaria geothermal power station, and there were issues with quality control. Therefore, the JICA expert team created an OHM manual and gave it to KenGen. OHM had not been planned at that time and OJT using this manual had not been conducted so the JICA expert team was not able to revise the manual to suit the actual OHM work of KenGen during the project period. In the future, KenGen plans to use the manual when implementing OHM at the Olkaria geothermal power station. The challenge for KenGen is to ensure that KenGen engineers revise the manual.

Objectively Verifiable Indicator 1-2 The teaching materials used in the training are developed for education 2

This indicator has been achieved. The JICA expert team prepared operation and maintenance training materials for KenGen's in-house training and provided it to KenGen.
The JICA expert team conducted a technical evaluation of Core members, selected potential trainers, and recommended them to KenGen. From now on, to establish the technology transferred by the JICA expert team, KenGen's trainers are tasked with using these training materials to conduct in-house training based on the training calendar and trainee list that is updated annually.

Objectively Verifiable Indicator 1-3 Core members acquire the target skill levels through training on basics of predictive trouble management and are able to apply it to their work Objectively Verifiable Indicator 1-4 Core members acquire the target skill levels through training on basics of performance management and are able to apply it to their work.

These indicators have been partially achieved. The JICA expert team conducted a technical evaluation of Core members on predictive trouble management and performance management. As a result, 12 out of 17 Core members achieved Level 4 targets, and 5 of these12 (one of whom had conditions excluding FTA) reached Level 5, and they acquired skills to be able to teach other KenGen members using in-house training materials prepared by the JICA expert team.

The UNIDO IoT system operational data for Olkaria V now has data reliability. The JICA expert team conducted technology transfer using the operational data of Olkaria V, while some data of the UNIDO IoT system were missing for other Power stations and Core members were not able to incorporate predictive trouble management and performance management into their work. However, Core members have acquired skills to analyze operational data for performance and predictive trouble management using Excel through the JICA expert team's OJT training and Core members can incorporate it into their work using Excel.
From now on, it is important to ensure high data quality based on factors such as accuracy, completeness, consistency and reliability in the UNIDO IoT system. KenGen members, including Core members should perform appropriate maintenance based on the Action plan. Once the data quality of each power station is improved, by utilizing the UNIDO IoT system, Core members will be able to efficiently and easily incorporate the predictive trouble management and performance management skills they have acquired into their own work. Therefore, KenGen's task is to ensure that the UNIDO IoT system operates normally and then incorporate predictive trouble management and performance management based on the data from the system into its own work.

Objectively Verifiable Indicator 1-5 Core members acquire the target skill levels through training on fault tree analysis of trouble-shooting and are able to apply it to their work.

This indicator has been partially achieved. KenGen engineers had been implementing FTA on a daily basis, but it was not being implemented effectively. Therefore, the JICA expert team provided FTA training to Core members using actual troubles at the Olkaria geothermal power station as a case study, and conducted a technical evaluation on FTA. As a result, 12 out of 17 Core members achieved the target level 4, and of those 12, 5 (one of whom had conditions excluding FTA) reached level 5, possessing the skills to teach other KenGen members. The JICA expert team proposed to Core members that FTA should be conducted when a decrease in Power station output and/or performance has occurred. In February 2023, Core members conducted FTAs for shaft vibration of the steam turbine of Olkaria II-3 and held discussions with the JICA expert team. Then, in August 2024, Olkaria II Core members gathered electrical and instrument and mechanical members to conduct the FTA regarding the high bearing temperature event that occurred in the steam turbine of Unit 3. Therefore, FTA is becoming established at least at Olkaria II.

Objectively Verifiable Indicator 1-6 Core members acquire the target skill levels through training on basics of data analysis of repair data and are able to apply it to their work.

This indicator has been achieved. JICA expert team trained Core members on the basic concept of data-based maintenance management, introduction of the PDCA cycle using the UNIDO IoT system, data recording procedures, etc. As a result of the technical evaluation in maintenance management, The Action plans are regularly updated at each Power station and Core members

share information at follow-up meetings. As a result, Core members identified that the cleaning work of the cooling tower basin is critical work in the annual inspection, and conducted the following measures to shorten the Annual Inspection period.
In October 2023, Core members improved the efficiency of the cleaning work of the cooling tower basin by using a vacuum suction truck during the annual inspection of Olkaria V-2. The Annual Inspection was then reduced by one day from the usual eight (8) days to seven (7) days. Core members of Olkaria IV-2 also used a vacuum suction truck to clean the cooling tower basin as a good practice, and the Annual Inspection was completed in seven (7) days, one day shorter than the normal annual inspection period.
Vacuum suction trucks were also used at Olkaria II and Olkaria I-AU for cleaning work of the cooling tower basin, contributing to improved work efficiency. This good practice was horizontally deployed at the Olkaria geothermal power stations. In addition, a major contribution to this project was made by the JICA expert team holding monthly online follow up meetings with core members to check progress. To continue to improve the maintenance plan, it is important that the Manager, Assistant Manager and engineers at Olkaria power station continually update the Action plan and implement the PDCA cycle. The challenge for KenGen is for assistant managers and managers to demonstrate leadership and lead the entire organization, focusing on Core members, to achieve the project goals.

Objectively Verifiable Indicator 1-7 Core members acquire the target skill levels through training on the basics of Annual Inspection and are able to apply it to their work.

This indicator has been achieved. The JICA expert team provided technology transfer to Core members to extend the interval of the annual inspection, including basic concepts on maintenance planning, pH control, and baseline data collection procedures etc. OJT was also provided to the technicians on Olkaria IV vacuum pump centering procedure and instrument calibration procedure during the annual inspection of Olkaria I-AU4 in September 2023. Core members and power plant chemist reviewed pH management and improved power plant water quality.
In January 2024, KenGen members performed and completed centering work on the Olkaria IV vacuum pumps. The vacuum pumps are still in operation and equipment reliability has been improved. On the other hand, the TS team conducted instrument calibration of Key Instruments in Olkaria IV-1 and V-1. The JICA expert team checked the instrument calibration records and, as the data recording procedure was different from the OJT conducted in 2023, the JICA expert team held online meetings with TS Core members on the correct recording procedure in September 2024. In addition, the JICA expert team gave a lecture on the correct recording procedure to Core members and technicians at Olkaria I-AU in October 2024.
As a result of the technical evaluation of maintenance management, Core members conducted a risk assessment of each Annual Inspection task, and identified critical tasks for extending the interval of the annual inspection. In October 2024, through a technical evaluation of maintenance management, Core members discussed the critical path based on each task during the annual inspection of Olkaria I-AU5. After completion of Olkaria I-AU5 annual inspection,

the JICA expert team and AU engineers discussed the review of critical tasks and measures to extend the interval between annual inspections and discussed countermeasures with the JICA expert team. During the annual inspection of Olkaria I-AU5, silica scale deposition occurred in all four main steam pressure control valves, which became a critical path. Olkaria AU engineers worked with Steam Field engineers to quickly carry out the maintenance work and completed the work within 8 days as planned. The JICA expert team and Olkaria AU engineers discussed countermeasures such as stocking spare parts to extend the annual inspection interval. In October 2024, the JICA expert team and Olkaria AU engineers collected baseline data for Olkaria I-AU5 and compared it with the baseline data for Olkaria I-AU4 collected in September 2023, and confirmed the effectiveness of the pH management. Olkaria AU engineers then evaluated the extension of the annual inspection in November 2024, considering the baseline results of the Olkaria I-AU4 annual inspection and the countermeasures for the main steam pressure control valve.

The JICA expert team also evaluated the technicians' skills in centering the vacuum pump and calibrating the instruments. As a result, the technicians performed the centering work using the correct procedures and were able to accurately read dial gauges and gap gauges. On the other hand, there were cases where they could not determine whether the measurement data was correct, and we provided additional explanations on the importance of evaluating the measured data based on an understanding of the equipment's condition and theoretical values. It was confirmed that two technicians had a certain level of ability in centering (centering skill and instructing others) through the skill evaluation. Regarding instrument calibration work, some technicians had acquired the skills to follow the calibration procedures of the instruments, but some did not understand how to adjust zero and span using the communicator. Improving the technical capabilities of technicians is essential to improving the performance of Olkaria geothermal power station. As mentioned above, technicians' skills vary from one another and are not at a sufficient level. The JICA expert team repeatedly requested KenGen to share centering work procedure and instruments calibration work procedure from some of the technicians to all of the technicians, but as a result, the procedures have not been shared to all of the technicians. KenGen's task is to systematically organize practical lectures on the procedures for all technicians.

3.1.2. Achievement of Output 2

Output 2 Reservoir management capacity is strengthened.

Objectively Verifiable Indicator 2-1 Review reports on current status and issues of reservoir management are prepared.

This indicator has been achieved. The JICA expert team has received the Steam status report of 2020, 2021, 2022 and 2023 from the core member. The JICA expert team received the draft of Steam status report of 2022 and 2023 in February 2024 which was the last OJT time and the

revised one in August 2024, but explained to Core member that it's important to discuss their reservoir monitoring data with other experts well for the better reservoir management.

Objectively Verifiable Indicator 2-2 Core members acquire the target skill levels through training on analysis of physical characteristics of the well.

This indicator has been achieved. The JICA expert team provided technology transfer to Core members regarding interpretation of output (deliverability) curve for the mass flow and enthalpy, apportion method of steam/water flow rate of each production well and reservoir management by using monitoring data. Core members understood them gradually by repeatedly conducted the JICA expert team's training such as online training, OJT in Kenya and training in Japan. Then the average skill level exceeds the target level of four.

Objectively Verifiable Indicator 2-3 Core members acquire the target skill levels through training on chemical analysis including new tracer.

This indicator has been achieved. The JICA expert team provided technology transfer to Core members regarding analyzing chemical components and their management, sampling of geothermal fluid from the well, and accurate analysis of new tracers by using donated equipment of HPLC. Core members understood them gradually by repeatedly conducted the JICA expert team's training. Then the average skill level exceeds the target level of four.

Objectively Verifiable Indicator 2-4 Core members acquire the target skill levels through training on reservoir modeling.

This indicator has been achieved. The JICA expert team provided technology transfer to Core members regarding the knowledge about numerical simulation, numerical simulation code, numerical model construction, natural state calibration and the case study. Core members understood them gradually by repeatedly conducted the JICA expert team's training. Then the average skill level exceeds the target level of four.

Objectively Verifiable Indicator 2-5 Core members acquire the target skill levels through training on geochemistry.

This indicator has been achieved. The JICA expert team provided technology transfer to Core members regarding the calcite scaling at cold injection well, corrosion at cold injection line, sulfur/bacteria deposition at the cooling tower. Core members understood them gradually by repeatedly conducted JICA's training. Then the average skill level exceeds the target level of four.

Objectively Verifiable Indicator 2-6 The teaching materials used in the training are developed for education.

This indicator has been achieved. JICA explained the training program and text contents for KenGen internal education for the activity 2 respectively to Core members and discussed with them then completed them.

3.2. Project purpose and achievement evaluation

The achievement evaluation of the project purpose is shown in table 3.2-1 below.

Table 3.2-1 Project purpose and achievement evaluation

Project Purpose	Objectively Verifiable Indicators	Achievement evaluation and prospect
Technical management of KenGen's Olkaria geothermal power stations is improved.	1-1 The introduction and management technology of spare rotor is developed and integrated into KenGen's OHM procedure	**【Achieved】** The spare rotor introduction plan for OHM was created and stored in the KenGen's sharing data folder.
	1-2 Spare rotor implementation plan is in place within the project period.	**【Achieved】** KenGen understood the importance of a spare rotor and applied to MoEP for budgeting for Olkaria II spare rotor in 2024/2025, but due to government budgetary constraints, the budget for 2024-2025 was postponed.
	1-3 Acquired O&M knowledge for improvement through OJT of Annual Inspection is developed to their work	**【Achieved】** Core members' maintenance management skills and the skills of some technicians have improved compared to last year. Technician skills vary from person to person, so classroom learning is required to improve the overall skills of technicians.
	2.Technology transfer is implemented to reduce major troubles (4 items) that have occurred in the last five years.	【Partially achieved】 After technology transfer, Olkaria geothermal power stations availability improved except for Olkaria II, which appeared to be affected by issues with aging equipment. After the technology transfer from March 2023 to September 2024, the average annual shut down hours in total Olkaria geothermal power stations due to the four (4) major troubles were 116 hours and 40 minutes, an improvement of 327 hours per year compared to before the technology transfer. The loss of annual availability was 1.33% after the

		technology transfer, and the loss of annual availability improved by 3.73% compared to before the technology transfer. Core members understood FTA as a method for analyzing the causes of problems. FTA is becoming established at Olkaria II, but it has not been implemented at other power plants. To accelerate the spread of FTA, The challenge for KenGen is to management recognize the importance of FTA and build a company-wide promotion system.
	3.Major occurrence is recorded and stored in KenGen.	【Partially achieved】 Core members understood the guidelines for creating the Monthly Report Attachment and created the September 2024 edition under the guidance of the JICA expert team. The challenge for KenGen is for Core members to continue creating the Attachment and sharing information.
	4.Acquire new operation technology which is applied in an organized manner in O&M by KenGen .	【Partially achieved】 Through the creation of the Monthly Report Attachment, Core members attempted to incorporate performance management and predictive trouble management as new operating techniques into their own work under the guidance of the JICA expert team. The challenge for KenGen is for Core members to continue creating the Attachment and sharing information.
	5.Changes in reservoir characteristics are detected and the causes and countermeasures for those changes are appropriately examined.	【Inadequate】 Discussion regarding changes in reservoir pressure and temperature, well characteristic test, tracer tests, and geochemical monitoring data at production well that affect steam production, and countermeasure for the change is necessary. Regarding

		this matter, as a follow-up to the technical evaluation, KenGen members (reservoir management and geochemistry) and the JICA expert team discussed appropriate reservoir management while looking at the current monitoring data in January 2025.
	6.Training programs are drawn based on the contents of O&M knowledge acquired and are incorporated in the KenGen's training program.	【Partially achieved】 JICA expert team has already submitted training programs, texts, a trainer-candidate list and a trainee list to KenGen. However, KenGen hasn't incorporated the programs into KenGen's training calendar yet. The challenge for KenGen is to apply them to the calendar and conduct training. KenGen has to available funds to conduct in-house training within the project period and consider to conduct OJT as well.

[Source: Prepared by Expert Team]

4. Results of Joint Review

4.1. Results of Review based on DAC Evaluation Criteria

4.1.1. Relevance

This project is considered to be highly relevant for the following reasons.

（1） Relevance with development policy

The MoEP of Kenya is moving forward with plans to increase geothermal development to 5,000 MW by 2030 as part of its "Kenya Vision 2030," the country's development plan for the period 2008-2030, and the Ministry's "10-Year Development Plan for the Power Sector (2014-2024)" also includes the development of the Olkaria geothermal field as an essential project for achieving the above plan. In addition, the "10-Year Development Plan for the Electricity Sector (2014-2024)" also positions the development of the Olkaria geothermal field, including JICA yen loan support, as an essential project to achieve the above plan. Therefore, the project is considered to be in line with the policies being promoted by the Kenyan government and is determined to have high policy relevance.

Japan's Country Development Cooperation Policy for Kenya aims to support sustainable economic growth and equitable social development in Kenya through the development of quality infrastructure. Specifically, the policy includes the development of Northern East Africa areas and strengthening of connectivity, appropriate development of major cities, and improved access to electricity. As reported above, the project will contribute to Kenya's economic growth by establishing an infrastructure base that will serve as a key economic and logistics hub for the entire region, and will also support the entry of Japanese companies into the region, thereby contributing to the improvement of the local economic environment.

This project will support geothermal development in Kenya from the aspect of power station operation and management, and is consistent with the Japanese government's aid policy, as it will contribute significantly to Kenya's socioeconomic development and the achievement of the Sustainable Development Goals (SDGs). Therefore, the project is considered to be in line with the Japanese government's aid policy, and is therefore considered to have high policy relevance.

（2） Relevance with development needs

The Project confirms a certain consistency with the needs of the beneficiaries from their perspective. The direct beneficiaries of the project are mainly geothermal engineers at KenGen. In addition, electricity consumers in Kenya are considered to be indirect beneficiaries who will benefit from the improved performance of geothermal power operation and maintenance. Geothermal engineers can improve efficiency and obtain higher levels of operation and maintenance which they perform as part of their daily work, and they can directly receive the benefits of this. In addition, it is expected that indirect beneficiaries, electricity consumers, will be able to obtain cheaper electricity service due to the improved efficiency of the power generation facilities. Therefore, as this Project can meet the needs of electricity consumers, its relevance is also recognized from the perspective of indirect beneficiaries.

（3） Appropriateness of project plans, approaches

The original plan was to conduct OJT for this IoT project during OHM, but due to a review of the KenGen's maintenance plan, OHM was not conducted on the expected schedule and time frame during the project period. Therefore, KenGen and the JICA expert team discussed and revised the OJT to be conducted at the annual inspection instead of OHM. The basic concepts of maintenance planning and management are common to OHM and annual inspection. In addition, the JICA expert team transferred the technologies of instrument calibration and centering work, which are basic equipment maintenance tasks, to technicians, and these technologies can also be applied to OHM. Due to the review of the maintenance plan, the installation work of the cooling tower and main steam pipe temperature monitoring system was delayed, and the technology transfer based on accumulated monitoring system data was postponed. The annual inspection of Olkaria I-AU4 in 2024 was also reviewed, and the project period was extended. KenGen and the JICA expert team held discussions at each meeting, considered alternative measures such as changing the annual inspection power station, and minimized the impact of delays.

The UNIDO IoT system was planned to collect and analyze operational data from the Olkaria geothermal power station in order to enhance performance analysis and improve maintenance planning for each power station. However, the impact of COVID-19, system malfunctions, low data quality, communication failure and various other challenges caused delays in the progress of technology transfer and led to a revision of some training content.

Regarding technology transfer of power plant management using the UNIDO IoT system, the quality of other plant data was low except for Olkaria V, so the JICA expert team conducted OJT using Olkaria V data. When the UNIDO IoT system is not available due to a malfunction, Core members can directly obtain operational data from the DCS and use the acquired skills to conduct performance management on their own PCs. In addition, regarding the PDCA cycle using the UNIDO IoT system, the JICA expert team created manuals and videos, gave lectures and conducted demonstrations using the system at each power station to KenGen members including Core members. However, Core members had never used the UNIDO IoT system. Based on KenGen's workflow and roles, to create a wide understanding of the benefits of the UNIDO IoT system among KenGen members and expedite its use, the JICA expert team also conducted lectures and demonstrations of the PDCA cycle using the UNIDO IoT system for some of the senior technicians and shift-in-charges at each power station. On the other hand, KenGen also uses an existing SAP-PM system, and some of its functions overlap with the UNIDO IoT system, so the priority for using the UNIDO IoT system is low. In addition, the UNIDO IoT system is separate from the KenGen network, and Core members cannot directly use UNIDO IoT data on their own PCs, so KenGen members are not actively using it.

Regarding the technology transfer of reservoir management using the UNIDO IoT system, well data could not be obtained in the UNIDO IoT system, so reservoir management training was conducted using temporary data. Core members can directly collect steam well data on the fields and use the acquired technology to conduct reservoir management on their own PCs.

4.1.2. Coherence

The project is considered to be highly coherent for the following reasons

(1) Internal coherence

a. Consistency within the organization
Consistency with KenGen's Vision: KenGen has identified the development of the Olkaria Geothermal zone as a key objective of its "Kenya Vision 2030," and this project is a concrete initiative to achieve this vision, which is consistent with KenGen's organizational goals.

b. Coherence with the Power Sector 10-Year Development Plan
The project is consistent with the objectives of the Plan, which focuses on the development of the Olkaria geothermal area, and is aligned with KenGen's long-term strategy.

c. Cooperation with JICA
JICA supports infrastructure development and human resource development in Kenya, and since this project will be implemented under JICA's cooperation, it is also consistent with JICA's aid policy.

(2) Coherence with international norms and standards

a. Sustainable Development Goals (SDGs)
This project contributes to SDG 7 (Make energy clean for everyone) and SDG 9 (Create a foundation for industrial and technological innovation) and contributes to the achievement of the Sustainable Development Goals.

b. Climate change measures
Geothermal power generation is a renewable energy source and is consistent with international climate change agreements in that it contributes to climate protection.

(3) External coherence

a. Cooperation with other donors
The UNIDO IoT system is providing support to KenGen for the improvement of O&M management. The project team shared responsibilities with UNIDO and worked together to improve O&M management skills.

b. Coherence with Kenyan government policy
The Kenyan government has set the stabilization of electricity supply and the introduction of renewable energy as policy goals, and this project contributes to these policy goals.

c. Coherence with other development projects in the region
The project is expected to contribute to energy development in the East African region and contribute to sustainable development in the region.

4.1.3. Effectiveness

The project is considered to be moderately effective for the following reasons.

(1) Achievement of Project Purpose

Regarding power plant management, through the activities of the JICA expert team, the core members' maintenance management capabilities, data management and analysis capabilities, etc. has been strengthened through these activities, leading to the following good practices and contributing

to the achievement of the project purpose. In addition, the technology was successfully transferred to Core members and technicians, and some technologies are becoming established in Olkaria geothermal power stations.

On the other hand, performance and predictive trouble management using the UNIDO IoT system and the PDCA cycle were only partially achieved because the Monthly Report Attachment was not created by Core members until September 2024 and the effect was not realized in the Objectively Verifiable Indicators. The JICA expert team thought that the explanation of the creation procedure was insufficient, so in October 2024, the core members confirmed and created the work procedures for the Monthly Report Attachment at each power plant under the guidance of the JICA expert team.

In the future, KenGen is expected to maintain and horizontally deploy the transferred technology by continuing to create the Monthly Report Attachment in an organized manner, and further improve the maintenance plan.

[Good Practice]

- Improved efficiency of cleaning work for cooling tower basin using exhaust vacuum trucks
- Improved cooling water quality by improving pH management.
- Prevention of leakage from main steam pipes by stopping De-SH water injection
- Restoration of Olkaria IV vacuum pumps through technology transfer of centering work
- Acquisition of instrument calibration procedures and correct recording methods
- Toolbox meetings have been held every morning at Olkaria II with the participation of operation and maintenance members.
- FTA was carried out twice at Olkaria II

Regarding Reservoir management, the analytical skills of engineers, including Core members, improved, but the engineers did not discuss relevant departments or consider countermeasures based on the data, and these were not reflected in the reservoir status reports. Regarding this matter, as a follow-up to the technical evaluation, KenGen members (reservoir and geochemistry) and the JICA expert team discussed appropriate reservoir management while looking at the current monitoring data in January 2025.

(2) Contribution to the project purpose through achievement of results

Regarding some of the Outputs related to power plant management, good practices were realized as mentioned above, and contributed to the achievement of the Project Purpose.

On the other hand, for the results related to Reservoir management, it is necessary to utilize the skills acquired by the engineers and deepen the discussion by involving the relevant departments. In order to break down the barriers between the departments related to reservoir management and promote lively discussion, the JICA expert team believes that it is possible to encourage lively discussion and draw out new knowledge and ideas by holding regular information sharing meetings.

(3) Were the planned results produced?

12 out of 17 core members of Power plant management achieved the target level 4, and 5 of those 12 (one of whom was conditional, excluding FTA) reached level 5, which means they have the skills to teach other KenGen members using the materials of the JICA expert team.

On average, Core members of reservoir management achieved the target level 4, and all of them reached the level to teach other KenGen members using the materials of the JICA expert team.

4.1.4. Efficiency

The efficiency of this project can be considered somewhat low for the following reasons.
It is regarded that the project was able to achieve a certain degree of success despite the impact of COVID-19. However, with travel restrictions due to COVID-19, online training has become the main focus, and the cost of labor for domestic work in Japan increased, delaying the timing of dispatching the JICA expert team. In addition, the number of Olkaria site visits decreased, and the impact on OJT regarding maintenance management was particularly large.

（1） Was the project cost used efficiently?

The project cost increased due to the input of additional equipment. However, the following issues occurred that affected the project plan, but they did not affect the budget.

- **Additional input equipment for the cooling tower and main steam pipe temperature monitoring system**.
  In August 2022, JICA, MoEP and KenGen agreed on the R/D Amendment, which provided additional input equipment, including technology transfer for the system using optical fibers for the cooling tower and main steam pipe to improve the efficiency of the cooling tower and monitor steam leakage from the main steam pipe at the Olkaria II-3, and the project budget was increased. The temperature monitoring system was installed during the annual inspection of Olkaria II-3 in May 2024, and after operational data has been accumulated, technology transfer conducted in October 2024. The project period was extended until March 2025.

- **Training constraints associated with low data quality in the UNIDO IoT system**.
  In June 2022, the UNIDO IoT system was installed in the Olkaria geothermal power station and handed over from UNIDO to KenGen. Since then, some operational data on the UNIDO IoT system appears to be missing or unreliable. As a result, the JICA expert team had to limit the technology transfer to Core members relating to performance management and predictive trouble management. The JICA expert team conducted the training using highly reliable operational data from Olkaria V, but the quality of data from other Power stations was poor, so other Core members except for Olkaria V were unable to incorporate performance management and predictive trouble management into their own work.
  Despite the training constraints encountered, once the operational data quality of the UNIDO IoT system improves, Core members will be able to use the skills acquired to perform performance management and predictive trouble management at each power station.

- **Additional training to promote the use of the UNIDO IoT system.**

Regarding the PDCA cycle using the UNIDO IoT system, the JICA expert team conducted lectures and demonstrations of the PDCA cycle using the UNIDO IoT system not only for Core members but also for some senior technicians and shift-in charge staff at each power station based on the KenGen workflow and roles. Initially, the JICA expert team planned to conduct lectures and demonstrations only for Core members, but in order to create a wide understanding of the benefits of the UNIDO IoT system among KenGen members and encourage its use, the senior technicians and shift-in charge staff were also included as targets of the technology transfer. The JICA expert team took advantage of travel opportunities such as JCC and conducted lectures and demonstrations in Olkaria.

- **Leaving from project of long-term expert during the project period**
  Communication between the JICA expert team and KenGen members became difficult due to long-term expert's contract expiration in March 2024. The scheduling of online meetings such as the Action Plan Follow-up Meeting were often delayed, and there were few meeting participants. In addition, it was discovered just before the trip to Olkaria that Core members would be absent for the duration of the site visit due to their attendance at other training, and some of the JICA expert members had to cancel their trip and postponed the OJT in Olkaria. As a result, although the OJT content was followed up with Core members through online meetings, practical OJT was not possible. This made it difficult for the JICA expert team to obtain information on the availability of the KenGen members and operation status of Olkaria geothermal power stations, which affected JICA expert team's activities.

（2） Was the project schedule appropriate?
In June 2023, during the circulating water pipe replacement work at Olkaria II-1, it was found that the piping material was defective, and the scheduled circulating water pipe replacement work at Olkaria II-2 and II-3 was subsequently rescheduled. Therefore, the installation work of the cooling tower and main steam pipe temperature monitoring system on Olkaria II-3, which had been planned to coincide with the replacement of the circulating water pipes, was also postponed. As a result, the temperature monitoring equipment was installed at the Annual Inspection of Olkaria II-3 in May 2024, and the technology was transferred in October 2024 after the monitoring system data had been accumulated. The project period was then extended until March 2025.

4.1.5. Impact

The impact of this project can be considered high for the following reasons.

（1） Prospects for achieving overall goal.
Currently, the plant availability has improved by 0.31% for Olkaria V-2 in October 2023, 0.36% for Olkaria IV -2 in December 2023, and 0.66% for Olkaria IV-1 in April 2024. On the other hand, the annual inspections of Olkaria II-1, 3 in 2024 and Olkaria I-AU5 in October 2024 implemented some good practices, but other works became critical paths, and were carried out in eight days almost as planned.
After the project is completed, it is expected that the acquired skills will at least be maintained if the trainee list is updated annually and in-house training is continuously implemented using training materials based on the training of the JICA expert team according to the Next 3 years Plan

of Operation such as training in performance and predictive trouble management, creation of Monthly Report Attachment, implementation of the PDCA cycle for action plans based on the basic concepts of O&M management, and reservoir management techniques transferred from the JICA expert team. To achieve Overall Goal, further reduction in breakdown hours and improvement of the plant availability of the Olkaria geothermal power stations, it is expected that the KenGen members, mainly the Core members, will continue to carry out FTA, use the action plans to identify potential root causes and implement countermeasures, which will be the effect of the project. The implementation of FTA is currently becoming established at Olkaria Ⅱ power station, and KenGen needs to make organizational efforts to expand the implementation of FTA.
On the other hand, possession of a spare rotor is expected to improve operation rates if the government approves the budget.

（2） Causal relationship
Currently, good practices based on O&M technical management have come out at the Olkaria geothermal power stations, and the overall goal has been partially achieved, so the relationship between the Overall Goal and the Project Purpose is clear.

（3） Ripple effect
KenGen managers are considering this IoT project as a pilot project and are considering deploying the management technology to KenGen's hydroelectric stations and thermal power stations, which is expected to have a ripple effect. KenGen is also considering introducing the UNIDO IoT system to Olkaria I-AU6.

4.1.6. Sustainability

The sustainability of this project can be judged somewhat low for the following reasons

（1） Policy
The development of geothermal resources is an important part of government policy, and geothermal power generation is also an important power generation method for KenGen as an inexpensive base load power source. In addition to the performance improvement of Olkaria geothermal power stations is expected to continue to be an important management issue.

（2） Organizational/Institutional
KenGen's organizational structure for geothermal Power station operation and maintenance is already established, and the necessary engineers and technicians will continue to be assigned to the Power station. After the completion of the project, it is important for KenGen management to lead Core members to continuously follow up on the Action plan and work improvement.

（3） Technical side
Although there are Core members who have reached a certain skill level and are trainer candidates, in-house training conducted by other KenGen members using training materials provided by the JICA expert team has not been registered in the KenGen’s training calendar for 2025. This in-house training is planned to be registered annually in the KenGen training calendar based on the trainee list, which is updated annually. This infrastructure is effective, and it is expected that skills will be

transferred to new employees assigned from other power stations, but at this time, it is unclear whether this in-house training will be continuously implemented to trainees, and sustainability is not ensured.

It is also important for sustaining the improvement of operation and maintenance management that the UNIDO IoT system steadily collects accurate and reliable data for data-based operation and maintenance management. Some data for predictive trouble management is missing, but Core members plan to follow up on the Action plan. The JICA expert team believes that sustainability can be ensured if inspections of instruments related to the UNIDO IoT system and maintenance of the system are carried out appropriately.

(4) Financial aspects

Resource support in terms of budgeting, staffing, etc. is extremely important for the implementation of this project and for sustaining its results. In the past, Power plant management had been based on the revenue from electricity sales to distribute the necessary budget and strengthen management to avoid outages. If performance improves in this project, the project team expects KenGen to receive more revenue from electricity sales than before, which will ensure the recurring costs for operation and maintenance. Therefore, it is believed that the recurring costs for operation and maintenance will be secured.

The prospect for the possession of a spare rotor for Olkaria II is expected to be included in the Olkaria II rehabilitation works, while the spare rotor for Olkaria V is uncertain as it depends on government budget approval. On the other hand, after the completion of the Olkaria I-AU, IV uprate project, the used rotor will be removed for maintenance, and KenGen plans to use it as a spare rotor for Olkaria I-AU and IV.

4.2. Key Factors Affecting Implementation and Outcomes

4.2.1. Operational issues and measures

During the project implementation period, the following operational challenges were faced, and the following measures were implemented.

Table 4.2-1 Issues and countermeasures during project complementation

Activity	Issue	Countermeasure
General	Initial survey on site and OJT could not be conducted due to COVID-19 in a timely manner.	During the travel restrictions, online technical meetings were held for Power plant management and reservoir management, and the JICA expert team conducted a preliminary survey based on emails and questionnaires. After the travel restrictions were relaxed, the initial survey was conducted by further investigating through

		interviews.
	Smooth communication and information exchange became extremely difficult between the JICA expert team and KenGen after the long-term expert departed in April 2024.	The JICA expert team coordinated an online meeting schedule with KenGen in advance and repeated reminders. SNS and cell phones were also used to coordinate dates. However, the JICA expert team were unable to obtain information about the Olkaria geothermal power stations, and some experts canceled their site visit trips. In addition, the online meetings were postponed multiple times, limiting the number of participants and the project team was unable to hold deep discussions.
Activities 1-2-1-5 and 2-2-2-5 through online meetings	It was difficult for Core members to actually learn practical skills through online training, and it was less effective than OJT. In addition, online training lacks non-verbal communication such as facial expressions and gestures, making it difficult to accurately grasp the level of understanding and interest of trainees.	Video materials were prepared for online training prior to the on-site trip and combined with face-to-face training to enhance training effectiveness.
Activity 1-2 and Activity 1-3 Conduct training on predictive trouble management and training on performance management based on IoT data analysis, including cooling tower and main steam pipe temperature monitoring system.	The accuracy of the data collected was low and there was a lack of data, except for Olkaria V. The JICA expert team was not able to conduct training on performance management and predictive trouble management using data from Power stations other than Olkaria V.	Using the highly accurate and reliable operational data of Olkaria V, the technology was transferred to Core members. Core members acquired the skills for performance and predictive trouble management. They are now able to extract operational data from the DCS and

		manage performance using Excel on their own PCs. However, Core members have not yet incorporated performance management and predictive trouble management into their own work, and organizational efforts are needed to utilize IoT systems.
	The installation work of the cooling tower and main steam pipe temperature monitoring system was delayed due to changes in the maintenance plan and training constraints occurred	The project end date was extended, and operational data of the cooling tower and main steam pipe temperature monitoring system could be accumulated for about four months. The JICA expert team used that data to transfer technology.
	The technology transfer for the cooling tower and main steam pipe temperature monitoring system was completed, but it was not possible to confirm that the transferred technology had been established during the project period.	Olkaria Ⅱ engineers learned the basic mechanism of the temperature monitoring system, as well as monitoring and maintenance procedures. Three engineers, including one core member, have a level of understanding that allows them to lecture other KenGen members, and the JICA expert team expects that they become trainers and pass on their skills to other KenGen members through in-house training.
1-2 Conduct training on predictive trouble management based on IoT data analysis, including cooling tower and main steam pipe temperature monitoring system.	Based on the history of problems in past years, there is concern that there may be a risk of similar troubles during the project period. However, the reason why no predictive events were identified is thought to be that the	Core members have acquired predictive management technology. In the future, if the reliability of the operational data can be ensured, Core members will be able to incorporate the predictive trouble

	reliability of data has not been ensured due to missing operational data, etc.	management into their own work.
	Although it is possible to detect steam leaks from the main steam pipes, no trouble has occurred after installation of the monitoring system. The cooling tower temperature monitoring system at Olkaria II-3 is able to properly display the status of each cooling tower, providing good monitoring conditions and contributing to proper operation.	By artificially simulating abnormal temperatures caused by hot water at multiple locations, the JICA expert team confirmed that it was possible to detect abnormalities at those locations in the central control room.
1-3 Conduct training on performance management based on IoT data analysis, including cooling tower and main steam pipe temperature monitoring system.	As with Activity 1-2, there were reliability issues such as missing operational data, and performance degradation could not be fully evaluated using actual data at each Power station except for Olkaria V.	The JICA expert team confirmed that cooling tower performance degradation can be evaluated using Excel with Olkaria V, which has relatively reliable data, and shared the evaluation and analysis method with Core members. Core members have a high level of understanding of performance management technology, and if the reliability of the operational data can be ensured, they will be able to use the performance management system in their own work.
	Although the cooling tower temperature monitoring system is performing well, there have been issues affecting cooling tower performance, such as water balance problems at Olkaria Ⅱ. The impact on the	Core members have a high level of understanding of performance management technology. If the reliability of Olkaria II's atmospheric wet bulb temperature and other data can be ensured, Core members will be able to

	efficiency of Olkaria Ⅱ Power station could not be evaluated due to issues with the reliability of Olkaria II's atmospheric wet bulb temperature data.	incorporate cooling tower performance management into their own work.
Activity 1-4 Conduct training on appropriate repair skills and effective maintenance planning.	OJT could not be conducted through OHM due to changes in the maintenance plan.	Since the basic concept of maintenance management and basic work procedures are the same for OHM and AI, the JICA expert team conducted OJT during the Annual Inspection.
	Since maintenance management is performed not only by core members but also by Power station members such as technicians and assistant managers in cooperation with each other, it was difficult to evaluate only by technical evaluation of core members.	At the 4th JCC, the project team proposed changing the target of technical evaluation on maintenance management from Core members to each Power station, which was approved.
	As past maintenance data was not available, it was difficult to develop an effective preventive maintenance plan based on past maintenance history and data.	The JICA expert team discussed with Core members the importance of data-based maintenance plans. The JICA expert team also instructed the Core members to collect baseline data during annual inspections and compare it with data after countermeasures were implemented. Core members developed action plans to improve the maintenance plan and planned to address the data quality issues through the action plan.
1-5 Conduct training on recording, storing, analyzing, and maintenance planning.	The UNIDO IoT system with data server functionality is an independent system and is not	The JICA expert team has requested the KenGen ICT team to distribute the USBs to

	connected to the KenGen network. To save data in the UNIDO IoT system, Core members must use USBs.	each power station, but as of now, the Core members of each power station have not received them.
2-2 Conduct training on analysis of physical characteristics of the well (such as wellhead pressure and flow rate from tracer flow testing and IoT).	The UNIDO IoT system was not functioning well.	The lecture was completed using limited available data.
2-3 Conduct chemical analysis training including analysis with new tracer(s).	There were some difficulties for KenGen to handle maintenance and procurement of spare parts of HPLC with the service company.	The JICA expert team assisted the communication between KenGen and the service company in South Africa through the Japanese maker.
2-4 Conduct training on reservoir modeling using continuous pressure monitoring (procured by UNIDO) and gravity monitoring.	KenGen didn't possess the tool of the numerical modeling (pre-processor) which all core members can use.	The JICA expert team provided their own program for KenGen's internal use only.
2-5 Conduct training on geochemistry for preventing scaling, corrosion, and sulfur/bacteria deposition.	Core members understood technical issues regarding corrosion, and sulfur/bacteria deposition. But facilities and chemicals for its countermeasure were not prepared by KenGen.	The JICA expert team involved plant management at the meeting to improve their mind regarding appropriate cooling tower water management.

[Source: Prepared by Expert Team]

4.2.2. Evaluation on the results of the Project Risk Management

(1) Results of Project Risk Management

After December 2022, the UNIDO IoT system encountered communication problems between the server and client PCs data, time lag events between the DCS and the UNIDO IoT system, and data discrepancies. Additionally, poor data quality continued due to failures in measuring instruments and DCS tag number errors, constraining the performance and predictive management and reservoir management training. After installation of the UNIDO IoT system at Olkaria geothermal power stations in June 2022, the system supplier checked the UNIDO IoT system at Olkaria every six months and summarized the preliminary findings in the minutes and submitted them to KenGen. KenGen assigned staff to address the problems noted in the minutes and tried to resolve the issues by June 2024, when the warranty period with the supplier ended.

At the 3rd JCC in March 2023, both JICA and KenGen confirmed that securing data quality was one of the keys for the success of JICA IoT project based on full utilization of UNIDO IoT system. KenGen recognized this and expressed their continuous efforts to keep good condition of their own existing data collection and transmission facilities for monitoring power plant operation and geothermal wells' condition, recovering some instrument and system errors.

The MoEP was also concerned about the situation of the UNIDO IoT system, so the Ministry issued a letter to KenGen in late November 2023 to request them to expedite all processes that might negatively impact the outcomes of the project, including the IoT system which had not fully functioned.

KenGen worked to rectify trouble in field instruments by replacing required spare parts despite procurement delay, and continuously conducted calibration of Key instruments of the UNIDO IoT system to maintain data accuracy every annual inspection. The system supplier also checked the communication status, corrected the data configuration, and performed a data quality analysis. The data time lag between the DCS and the UNIDO IoT system was resolved by synchronizing the Olkaria II client PC with the plant server. Regarding well data, the system supplier updated the flow range of all production wells according to the reservoir team specifications.

At the final JCC on January 28, 2025, the JICA expert team explained JICA's comments on the 4th JCC as follows, and JCC members discussed challenges as a joint review to be resolved within the project period, such as data quality issues in the UNIDO IoT system, creation of Monthly Report Attachment, implementation of in-house training, and discussion between the reservoir management team and the geochemistry team.

a. Project Sustainability for the achievement of the Overall Goal
   In the 4th JCC, JICA requested KenGen to consider the IoT content, knowledge and skills to be made critical part of training offered at the newly established KenGen's Centre of Excellence in order to achieve the Overall Goal.
   To achieve Overall Goal, KenGen formulated the action plan for next 3 years plan of operation to implement the plan of operation. Additionally, KenGen committed capture cost savings and revenue gains arising from the project and developed a budget line to ensure project continuity.
b. Current situation of UNIDO IoT system
   Some of the Predictive trouble data and the well field data were missing due to communication issue. KenGen was working to resolve the communication issue for UNIDO IoT system. KenGen proceeds to have the framework contract with Yokogawa and Analytical Solutions who are the OEMs by the end of the project period.
c. KenGen's ownership for project completion
   In the 4th JCC, JICA requested that KenGen take a lead in the project towards project completion. JICA also requested that KenGen implement this project with strong ownership. KenGen committed to undertaking training based on the O&M knowledge through a cross-sector and regional capacity building program at the Geothermal Center of Excellence. Additionally, KenGen submits the Monthly Report Attachment to JICA expert team for the next two months before the project completion date in line project objectively verifiable indicator number three.

JICA requested the project team to report on the status of the above challenges by the end of the project. Based on the results, JICA issued a letter to KenGen to take immediate action in February 2025.

4.2.3. Lessons Learned from this Project

(1) Efforts to change the mindset of counterparts

To improve the O&M management of Olkaria geothermal power station, it is essential to change the mindset of the entire KenGen organization.

- **Sharing information and training over the entire organization:** The technology transferred to core members needs to be shared throughout the organization. It is important to thoroughly inform all employees of O&M knowledge and skills through OJT and classroom learning etc. It is necessary to explain to engineers and technicians the importance of O&M management and how their work contributes to the stable operation of the power stations in detail to increase their motivation.
- **Setting goals and progress management:** The project team set specific improvement goals that can be shared across the organization and regularly shared progress status on acquired skills to promote a change in awareness. It is important to visualize efforts toward achieving the goals and give each employee a sense of contribution to achieving the goals.
- **Introducing action plans**: The JICA expert team discussed with Core members and created the issues to be addressed and the methods to address them in the action plans. By incorporating the issues reported by the power station members into this action plans and continuing the efforts, KenGen will be able to continuously implement improvement and reform activities based on the perspective of the field.

(2) Mutual understanding and building a relationship of trust among project teams is important.

- **Deep understanding of counterparts by JICA expert team:** The JICA expert team was required to cooperate with not only Core members but also with related persons and related departments throughout the organization and to deeply understand the organizational structure and culture. Cooperation with assistant managers at each power station was important in promoting improvements in the field work. The JICA expert team needs to build mutual understanding with its counterparts, and the project will proceed more smoothly if all counterparts, from management to technicians, build a common understanding of the importance of improving technical management and build a cooperative relationship.
- **Introduction of Japanese culture and customs through training in Japan**: The JICA expert team took advantage of opportunities such as training in Japan to actively explain Japanese culture and customs to their counterparts and worked to create mutual understanding.
- **Expertise alone is not enough:** JICA expert teams need to employ not only advanced experts, but also acquire language skills, and management techniques for conveying knowledge and know-how, including the development of teaching methods and teaching materials.

(3) Long-term expert support for the entire duration of the project

The JICA expert team was required to adjust the schedule and the items to be discussed with the project stakeholders under a tight schedule in the final stage of the project. Any delay in

adjustment or revision of the content of the discussions would have had a significant impact on the entire project progress, and the support of a long-term expert from the field was indispensable.

5. For the Achievement of Overall Goals after the Project Completion

5.1. Prospects to achieve Overall Goal

Regarding the Overall Goal of Objectively Verifiable Indicators 1-1, KenGen understood the importance of the spare rotor and is considering a budget application for the Olkaria V spare rotor in 2025-2026 CY.

It is expected that Core members will continuously create the Monthly Report Attachment including FTA to achieve Objectively Verifiable Indicators 1-2 and 2.

KenGen also plans to conduct in-house training from FY2025-2026.

Table 5.1-1 Achievement evaluation and prospect of Overall Goal

Overall Goal	Objectively Verifiable Indicators	Achievement evaluation and prospect
Performance of KenGen's Olkaria geothermal power stations is improved.	Increase of capacity availability 1-1 Increase of 1.31% capacity availability in OHM year as maintenance period is shortened by 4 days after installation of spare rotor among other interventions. Installation of spare rotor among other interventions.	**[Prospect: Under consideration]** It is difficult to budget in 2024/2025 CY. KenGen is currently reviewing budget applications for the Olkaria V spare rotor for 2025-2026.
	1-2 Increase of 1.12% capacity availability due to reduction of Annual Inspection from 2 times to 1 time.	**[Partially achieved]** Olkaria Ⅴ-2: Approx. 27 hours reduced during annual inspection in October 2023, Annual plant availability improved by 0.31%. OlkariaⅣ-2: Approx. 30 hours reduced during annual inspection in December 2023, Annual plant availability improved by 0.36%. OlkariaⅣ-1: Approx. 57 hours reduced during annual inspection in April 2024, Annual plant availability improved by 0.66%.
	2 Increase of 5.07% annual capacity availability due to 443h 44m/year reduction of breakdown hours for the last five years.	**[Prospect: Medium]** After the technology transfer, from March 2023 to the end of September 2024, the average annual shutdown hours due to major troubles was 116 hours and 40 minutes, an improvement of 327 hours. The loss of annual availability improved by 3.73%.

	3 Implementation of continuous technology transfer by incorporating in-house training into an annual training program based on the annually updated trainee lists of Power station O&M and Reservoir management.	**[Prospect: Medium]** KenGen will incorporate JICA expert team's inhouse training in the training calendar in 2025/2026 with the trainee list.

[Source: Prepared by Expert Team]

5.1.1. Average annual shut down hours and loss of annual availability related to the four (4) major troubles before and after technology transfer

The JICA expert team analyzed the average annual shut down hours and loss of annual availability for each power plant related to the four (4) major troubles before and after technology transfer.

After the technology transfer from March 2023 to September 2024, the average annual shut down hours in the total of Olkaria geothermal power stations due to the four (4) major troubles were 116 hours and 40 minutes, an improvement of 327 hours per year compared to before the technology transfer. The loss of annual availability was 1.33% after the technology transfer, and the loss of annual availability improved by 3.73% compared to before the technology transfer.

Table 5.1-2 Average annual shut down hours and loss of annual availability related to the four (4) major troubles before and after technology transfer

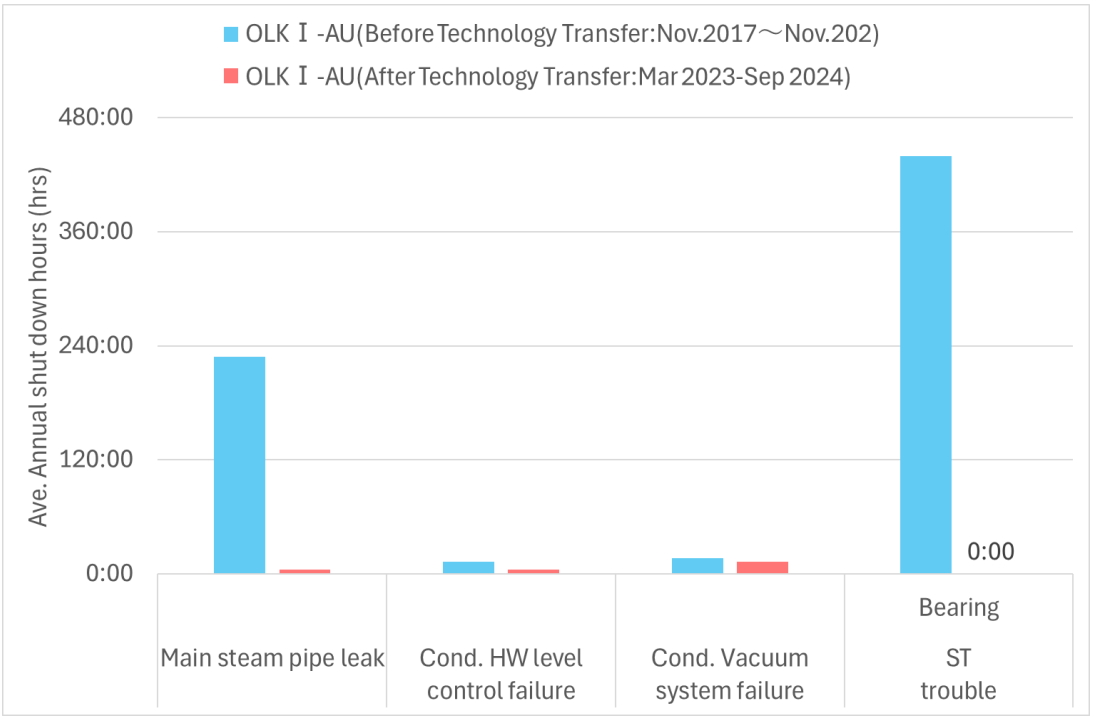
	The four (4) major troubles	Average annual shut down hours		Loss of annual availability	
		Before technology transfer (November 2017～November 2022)	After technology transfer (March 2023～September 2024)	Before technology transfer (November 2017～November 2022)	After technology transfer (March 2023～September 2024※)
(a)	Main steam piping leakage issue	90h44m30s/year	45h56m31s/year	1.036%	0.524%
(b)	Condenser HW level control failure including HW pump trouble	21h21m43s/year	61h39m46s/year	0.244%	0.704%
(c)	Condenser vacuum system failure	7h12m29S/year	9h3m58s/year	0.082%	0.103%
(d)	ST trouble (bearing issue, blade damage)	324h25m18s/year	-	3.703%	-
Total		**443h44m/year (Base)**	**116h40m/year (▲327h/year)**	**5.065% (Base)**	**1.332% (▲3.73%)**

※ Olkaria Ⅴ data is available up to February 2024.

[Source: Prepared by Expert Team]

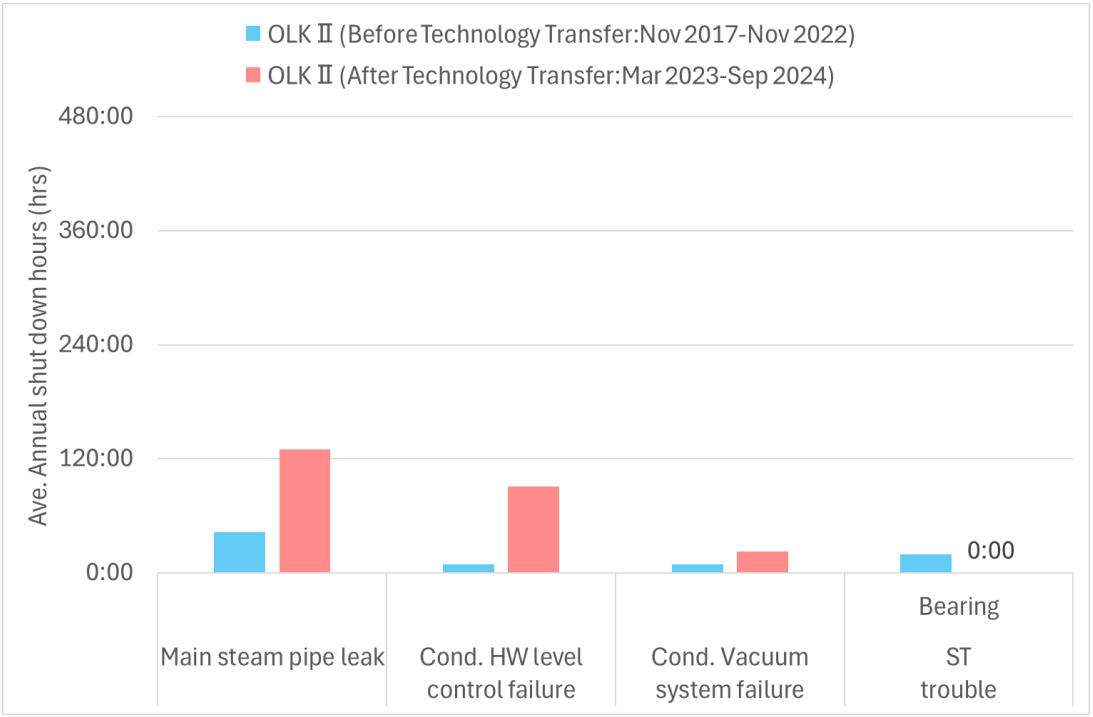
The figures below show a comparison of the four (4) main troubles at each power station before and after the technology transfer. After the technology transfer, the average annual shut down hours due to the four (4) main troubles decreased at all power stations except for Olkaria II, and

the loss of annual availability improved. However, At Olkaria II, no improvements were seen after the technology transfer due to the occurrences of steam leak in the main steam piping and malfunctions in the condenser LCV, etc. The JICA expert team thinks that the above mentioned troubles may have occurred due to the deterioration of the equipment caused by aging.



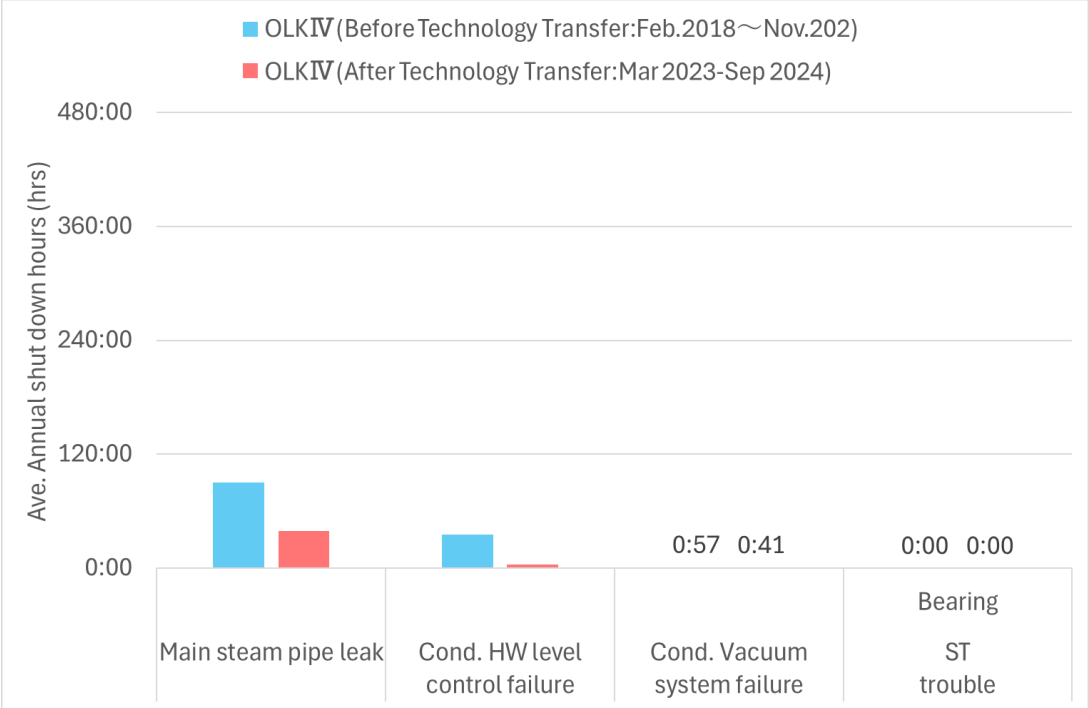
[Source: Prepared by Expert Team]

Fig. 5.1-1 Average annual shut down hours before and after technology transfer at Olkaria I-AU



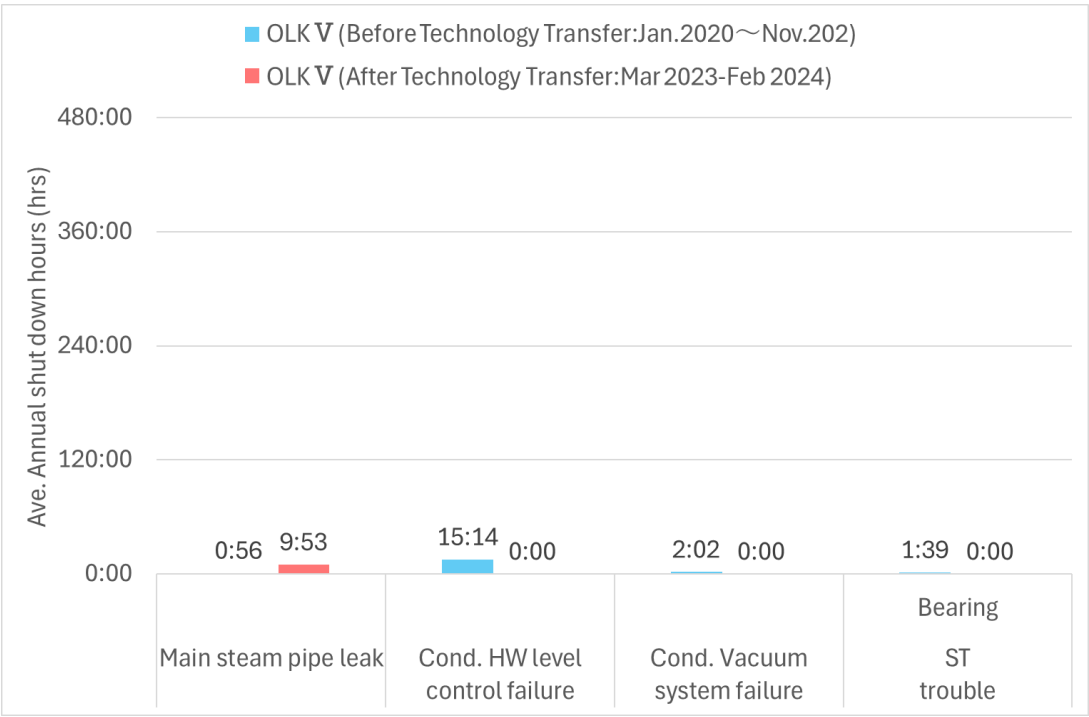
[Source: Prepared by Expert Team]

Fig. 5.1-2 Average annual shut down hours before and after technology transfer at Olkaria Ⅱ



[Source: Prepared by Expert Team]

Fig. 5.1-3 Average annual shut down hours before and after technology transfer at OlkariaⅣ



[Source: Prepared by Expert Team]

Fig. 5.1-4 Average annual shut down hours before and after technology transfer at Olkaria Ⅴ

5.2. Planned future activities expected of KenGen to achieve overall goal

In January 2025, the project team discussed with Core members the specific activities of the Next 3 years Plan of Operation and formulated an action plan based on the plan of operation. At the final JCC held on 28th January 2025, the implementation structure and monitoring plan based on the Next 3 years Plan of Operation from April 2025 onwards and the action plan were discussed in order to achieve the Overall Goal of the project.

As a result, KenGen General Manager, Operations will submit a report on the progress of the Next 3 years Plan of Operation to MoEP and the JICA Kenya Office every July from July 2025 to July 2028. The report format drafted by the JICA expert team based on the JICA monitoring sheet format.

Table 5.2-1 Next 3 years Plan of Operation as Future Action Plan by KenGen to Achieve Overall Goal

Activities		Implementation Bodies	1st year				2nd year				3rd year			
			I	II	III	IV	I	II	III	IV	I	II	III	IV
Power Plant management	Action Plan follow up meeting	Assistant Mgr., Engineers	■	■	■	■	■	■	■	■	■	■	■	■
	Creation of Monthly Report Attachment	Engineers	■	■	■	■	■	■	■	■	■	■	■	■
	Monitoring and Analysis of Performance/Predictive management system	Engineers	■	■	■	■	■	■	■	■	■	■	■	■
	Monitoring and Analysis of CT & MSP temp. monitoring system	OLKII & Civil Engineers	■	■	■	■	■	■	■	■	■	■	■	■
	Practical training for Technicians	Technicians	■	■	■	■	■	■	■	■	■	■	■	■
	Monitoring of UNIDO IoT system	TS Team, ICT Team, Reservoir /Steam field Team	■	■	■	■	■	■	■	■	■	■	■	■
	In-house training for Power plant management	Engineers, Technicians				■				■				■
	Annual Report	Engineers				■				■				■
Reservoir management	Review of Olkaria Development plan	Reservoir & Steam field	■	■			■	■			■	■		
	Review of Olkaria reservoir management plan	Reservoir & Steam field			■				■				■	
	Reservoir monitoring management meeting	All related sections				■				■				■
	- Steam/brine flow rate monitoring	Reservoir & Steam field			■				■				■	
	- Wellbore PT monitoring	Reservoir & Steam field			■				■				■	
	- Geochemical monitoring for production well	Geochemistry			■				■				■	
	- Tracer test	Reservoir chemistry												
	- Gravity monitoring	Geophysics			■				■				■	
	Emergency measure	All related sections	Whenever a big change occurs in the reservoir.											

[Source: Prepared by Expert Team]

5.3. Recommendations

5.3.1. Recommendations from JICA expert team to KenGen

(1) Active use of the UNIDO IoT system

To use the UNIDO IoT system more effectively, the JICA Expert Team makes the following recommendations to KenGen.

a. Improving data quality

Monitoring of data quality: Engineers, including core members, need to regularly check the predictive trouble management data and check the instruments and communication status for data indicated as Uncertain and Bad.

Calibration of key instruments: During annual inspections of each power plant, KenGen members should calibrate the instruments, considering the priority of key instruments.

The results of the work are created into the Monthly Report Attachment and shared with the assistant manager, manager, engineers, and technicians.

b. Stabilizing the system

Periodic maintenance of the UNIDO IoT system: KenGen needs to carry out regular maintenance to ensure stable operation of the system and consider entering into long-term maintenance contracts with system suppliers.

Ensuring power supply for the steam well remote monitoring device: KenGen needs to install a power supply system as soon as possible so that steam well data can be collected stably.

c. Linkage with KenGen's existing system

Consideration of system linkage: KenGen needs to consider building linkage and interface between the UNIDO IoT system and the existing SAP-PM system.

d. Training for members

Training implementation: Based on the training materials of the JICA expert team, KenGen needs to provide training to all relevant parties. In addition, KenGen needs to plan training on system maintenance for ICT members.

e. Organizational efforts

Active involvement of management: KenGen management must recognize the importance of the UNIDO IoT system and the cooling tower and main steam pipe temperature monitoring system on Olkaria II-3 are essential for improving power generation efficiency and stable operation, and consequently contribute to the profits of the Olkaria geothermal power stations, and must promote Core members and engineers to actively use of these systems.

Specifically, it is important for KenGen management to strengthen guidance and support for Core members and engineers to incorporate these systems into their daily own works, and demonstrate leadership. In addition, to enhance in-house education, it is necessary to implement continuous training programs by trainers and secure the necessary budget for the systems maintenance. The JICA expert team presented KenGen with a format for sharing the operational status of the UNIDO IoT system within KenGen as the Monthly Report Attachment and strongly requested KenGen to create it. The challenge for KenGen is to create the Monthly Report Attachment reliably.

(2) Utilization of Olkaria II-3 cooling tower and main steam pipe temperature monitoring system

The cooling tower and main steam pipe temperature monitoring system can check he degree of deterioration of the cooling tower and there are no abnormalities in the main steam pipe during normal operation. Olkaria II-3 engineers need to regularly monitor the cooling tower and main steam pipe temperature monitoring system to detect main steam pipe leaks early and know where to replace fill pack and clean nozzles before the annual inspection begins, which is expected to improve maintenance planning. This system is very effective in improving the efficiency of cooling tower O&M and ensuring safety.

(3) Establishment and deployment of FTA technology

KenGen needs to pass on the FTA to pawer plant members technology through in-house training and implement FTA when a critical event* occurs.

FTA technology not only cultivates logical thinking and trouble shooting skills, but also leads to improved communication skills. By visualizing the causes of failures in a complex system in a tree-like format, team members can work on solving problems efficiently while sharing a common understanding. In addition, through analysis, team members can gain a deeper understanding of the system's structure and the role of each component, and acquire expertise. These skills, if expanded to other power plants, will contribute to improving the quality of the entire organization.

To establish FTA skills, it is important to actively share experiences through OJT and present good practices with KenGen members, thereby fostering a culture in which the importance of FTA is recognized throughout the organization. The JICA expert team presented KenGen with a format for sharing the results of FTA implementation within KenGen as a Monthly Report Attachment and strongly requested them to create it. The challenge for KenGen is to create the Monthly Report Attachment reliably.

* A critical event is an event that affects the output or/and affects the efficiency of the power plant.

(4) Recording and storage of O&M data

KenGen recognizes the importance of preventive maintenance to improve technical management, and there is an urgent need to formulate and execute inspection and maintenance plans based on O&M data. KenGen needs to aggregate operation and maintenance data in a designated location and provide an environment where all related parties can access it, enabling more efficient and effective maintenance plans to be developed. In addition to recording and storing maintenance data, the UNIDO IoT system enables data sharing between power stations. The challenge for KenGen is to actively utilize the system to improve maintenance plans based on O&M data.

(5) Improving the overall skills of technicians

Technicians' skills vary from person to person. To improve the skills of all technicians, KenGen needs to regularly hold practical training sessions to share the technology transferred by the JICA expert team. The challenge for KenGen managers is to demonstrate leadership and plan and implement the training for technicians.

(6) Continuous implementation of the action plan and organizational efforts

Engineers, including Core members, need to regularly update the action plan with new challenges and countermeasures, and discuss them with other members. Good practices can be shared with each power plant or reservoir management team, leading to improvements at the Olkaria geothermal power station.

To continuously implement the action plan, it is necessary to incorporate it into the work of Core members. The challenge for KenGen assistant managers and managers is actively involved in following up on the action plans and ensure that measures are implemented through discussion.

(7) Creation of Monthly Report Attachment

The JICA expert team created the issues and countermeasures identified by Core members into an action plan. KenGen Engineers, including the core members, need to regularly update the action plan with newly occurred issues and countermeasures, and discuss them with other members. Good practices can be shared with each power station and the reservoir management team, leading to improvements at the entire Olkaria geothermal power station.

It is important to incorporate the action plan into the work of Core members in order to ensure its continuous implementation. Therefore, the challenge for the assistant manager and manager is to be actively involved in the follow-up of the action plan and ensure that the countermeasures are implemented through discussions with Core members.

(8) Implementation of in-house training using the JICA IoT project training materials

The JICA expert team prepared a KenGen in-house training program, training materials, lists of trainer candidates, and lists of trainees, and provided them to KenGen so that the basic concepts of the transferred technology would be continuously passed on within KenGen. The challenge for KenGen is to register these in KenGen's training calendar and implement training in a planned manner.

5.3.2. Recommendations from JICA expert team to JICA

After the long-term expert left in April 2024, communication and information sharing between the JICA expert team and KenGen members became extremely difficult, which led to delays and changes in plans. To ensure smooth project implementation, JICA should consider assigning the long-term expert until the end of the project. In particular, JICA needs to build an effective support system for the JICA expert team by observing their on-site activities to grasp the progress of projects in real time and quickly identify any issues.

5.3.3. Recommendations from JICA expert team to MoEP and JICA

The JICA expert team recommends MoEP and JICA to regularly monitor and provide feedback on the progress of KenGen's activities based on the Table 5.2-1 Next 3 years Plan of Operation as Future Action Plan by KenGen to achieve the Overall Goal.

By regularly sharing and discussing the progress and challenges through the monitoring, it is expected that the project's effectiveness will be enhanced and sustained.

5.3.4. Recommendations from KenGen to MoEP

KenGen commented to the MoEP on the need for legislation regarding the implementation of OHM. At the Olkaria Geothermal Power Plant, applications are made to the load dispatching center for planned shutdowns, but there are cases where planned shutdowns were not permitted due to supply and demand circumstances. If the timing of OHM implementation were legally regulated and OHM could be carried out regularly, the reliability of the facilities would improve.

KenGen also requested support from the Kenyan government for budgets related to spare rotors and capacity building.

Attached lists

ANNEX 1: Results of the Project

(List of Dispatched Experts, List of Counterparts, List of Trainings, Revised Plan of Operation, Pictures (Operation and maintenance, Reservoir） etc.)

ANNEX 2: List of Products (Report, Manuals, Handbooks, etc.) Produced by the Project

ANNEX 3: PDM (All versions of PDM)

ANNEX 4: R/D, M/M, Minutes of JCC (copy) *

ANNEX 5: Monitoring Sheet (copy) *

ANNEX 6: Trouble history analysis of Olkaria geothermal power plant *

(Remarks: ANNEX 4, 5 and 6 are internal reference only)

ANNEX 1

Annex1

Dispatch Experts

Name Position title	Planned Actual	Phase 2-1 P/M In Kenya	 In Japan	Phase 2-2 P/M In Kenya	 In Japan
NAKANISHI Makoto Chief advisor	Planned	0	1.05	2.9	0.9
	Actual	0	1.05	5.53	1.1
KAWAZOE Seiki Power Plant Management	Planned	0	3.20	3.97	4.5
	Actual	0	3.70	3.93	4.54
HATANAKA Hideki Reservoir Management	Planned	0	2.05	2.77	1.25
	Actual	0	2.25	2.6	1.15
KATSUKI Shintaro Power Plant Management	Planned	0	1.35	2.13	1.6
	Actual	0	1.35	1.07	1.4
TSUKIMOTO Kiyotaka Power Plant Management	Planned	0	0.50	3.67	1.1
	Actual	0	0.50	2.47	0.9
KEMONOSONO Sohei Power Plant Management	Planned	0	0.50	1.06	0.95
	Actual	0	0.50	1.53	0.95
SHIBATA Masaya Mainatenance Management	Planned	0	0.00	2.07	0.65
	Actual	0	0.00	2.03	0.73
ICHINOMIYA Tadaomi Maintenance Management	Planned	0	1.55	2.6	1.48
	Actual	0	1.55	2.4	1.48
TOYOMOTO Hiroshi Maintenance Management	Planned	0	1.75	3.13	1.35
	Actual	0	1.93	3.03	1.35
TANAKA Tetsuji Repair work/ Quality control	Planned	0	2.45	1.53	1.15
	Actual	0	2.45	1.33	1.15
NAGAMOTO Mitsufumi Repair work/ Quality control	Planned	0	2.45	1.53	1.05
	Actual	0	2.45	1.33	1.05
FUKUDA Norihiro Performance facilityA	Planned	0	0.00	0	0.35
	Actual	0	0.00	0	0.25
IDEGUCHI Junya Performance facilityB	Planned	0	0.00	0	0.35
	Actual	0	0.00	0	0.45
Mcgrory Peter Cooling tower and main steam pipe temperature monitoring	Planned	0	0.00	2.03	0.25
	Actual	0	0.00	1.57	0.35
ISOBE Momoka Cooling tower and main steam pipe temperature monitoring	Planned	0	0.00	2.03	0.25
	Actual	0	0.00	1.57	0.45
Manish Kamal Kishore Dhanuka Cooling tower and main steam pipe temperature monitoring	Planned	0	0.00	1.1	0.25
	Actual	0	0.00	0.83	0.25
Naveenkumar Kitthnakeri Harishkumar Cooling tower and main steam pipe temperature monitoring	Planned	0	0.00	0.83	0.25
	Actual	0	0.00	0.93	0.25
UCHIYAMA Noriaki Geochemistry	Planned	0	2.25	2.93	1.75
	Actual	0	2.25	3.07	2.3
OSHIMA Shogo Geochemistry	Planned	0	0.55	0	0
	Actual	0	0.25	0	0
INOUE Naho Laboratory Chemistry	Planned	0	1.85	2.9	0.95
	Actual	0	1.85	3.07	0.95
SAKURADA Toshio Power Plant Chemistry	Planned	0	1.90	1.43	0.6
	Actual	0	1.90	1.43	0.6
IKEDA Mari Laboratory Chemistry	Planned	0	0.35	0	0.7
	Actual	0	0.35	0	0.7
Paul, Reulen Power Plant Chemistry	Planned	0	0.20	0.7	0.35
	Actual	0	0.20	0.7	0.35
MAEDA Norihide Numerical modeling	Planned	0	1.30	2.73	1.7
	Actual	0	1.10	2.6	1.7
SAITO Hiroki Geophysics	Planned	0	0.45	0	0
	Actual	0	0.15	0	0
INAGAKI Haruhiro Geophysics	Planned	0	0.10	0	0.05
	Actual	0	0.10	0	0.05
SOEDA Yoshio Geology	Planned	0	0.40	0	0
	Actual	0	0.33	0	0
Tri Wulaningsih Geology	Planned	0	0.10	0	0.1
	Actual	0	0.10	0	0.1
IDE Tomonori Cooling tower and main steam pipe temperature monitoring	Planned	0	0.00	0	0
	Actual	0	0.00	0.97	0
LIMA ISOMURA Enrique Yuki Video Material Supervision	Planned	0	3.90	1.1	1.2
	Actual	0	3.90	1.1	1.2
Total	Planned	0	30.2	45.14	25.08
	Actual	0	30.2	45.09	25.75

List of Counterparts

Core members		Designation	Department/Division
Act1.1～1.7	Margaret Kamau	Senior Engineer-Olkaria 2&1	Operation , Geothermal
	David Imaidi	Principal Engineer , Olk 2	Operation , Geothermal
	Lameck Makori(*)	Engineer - Olkaria 4	Operation , Geothermal
	Sarah Gichonge	Engineer , Olkaria 5	Operation , Geothermal
	Leonard Langat	Assistant Manager, Olkaria 4	Operation , Geothermal
	George Ngomi	Assistant Manager, Olkaria 2	Operation , Geothermal
	Gideon Kemboi	Senior Prijects Auditor	System and Process Audit
	Victor Ouma	Principal Engineer-Olk 4	Operation , Geothermal
	Moses Letina	Engineer, Olkaria 5	Operation , Geothermal
	Martin Mwangi	Assistant Manager for dispatch	Operation , Geothermal
	Kennedy Tarus	Engineer I Well Head	Operation , Geothermal
	George Maingi	Principal Engineer, Well Head	Operation , Geothermal
	Grace Kamunge	Electrical Engineer	Business Development division
	Alex Wanjohi	Senior Engineer	Technical Services
	Levin Onyari	Senior Engineer, PIC	Technical Services
	Winnie Apiyo	Senior Engineer, PIC	Technical Services
	Nathaniel Mugo	Senior Engineer, PIC	Technical Services

* Studied in Japan (Kyushu University) from August 2023 to December 2023

Core members		Designation	Department/Division
Act.2-2 Act.2-4	Mr. Vincent Koech	Reservoir Engineer	Reservoir & Steamfield
	Ms. Maureen Ambunya	Reservoir Scientist	Reservoir & Steamfield
	Mr. Urbanus Mbithi	Reservoir Engineer	Reservoir & Steamfield
	Mr. Eric Rop	Reservoir Engineer	Reservoir & Steamfield
Act.2-3	Ms. Ruth Wamalwa	Reservoir Geochemist	Reservoir & Steamfield
	Mr. Erique Nyawir	Reservoir Geochemist	Reservoir & Steamfield
Act.2-3 Act.2-5	Ms. Melissa Nkapiani	Geochemist	Geothermal Operations
	Mr. Edwin W. Wafula*	Geochemist	Resource Development
	Ms. Catherine L. Ndinda	Geochemist	Resource Development
	Mr. Samuel Muraguri Mwangi	Geochemist	Resource Development
	Ms. Eunice Bonyo	Geochemist	Resource Development

Labo technicians		Designation	Department/Division
Act.2-3	Ms. Perpetua Muthoni	Geochemist Technician	Reservoir & Steamfield
	Mr. Joseph Gitau	Reservoir Chemistry Technician	Reservoir & Steamfield
	Ms. Jane Chege	Reservoir Chemistry Technician	Reservoir & Steamfield
	Mr. Kenneth Koech	Analytical Chemistry Technician	Reservoir & Steamfield
Act.2-5	Mr. Martin Odhiambo	Geochemist Technician	Geothermal Operations
	Mr. Benedict Ouma	Geochemist Technician	Geothermal Operations

* Studied in Japan (Kyushu University) from September 2021 to October 2024

List of Trainings (Power plant management)

	Name of the course	From	To	Trainee
1st	Overhaul Maintenance Training	21-Sep-22	4-Oct-22	6
1st	Senior Management invitation program	24-Oct-22	28-Oct-22	6
2nd	Overhaul Maintenance Training	6-Nov-23	21-Nov-23	6

	Name of the course	From	To	Trainee
1st	Reservoir Modeling Training	22-Sep-22	7-Oct-22	2
1st	Geochemistry Training	22-Sep-22	7-Oct-22	6
2nd	Reservoir Modeling Training	21-May-23	3-Jun-23	2
2nd	Geochemistry Training	21-May-23	3-Jun-23	6

Plan of Operation

Version 7.0
Dated 14 January, 2025

Project Title: The Project for Strengthening Operation and Maintenance Capacity of Olkaria Geothermal Power Stations Using IoT Technology

Monitoring

Inputs	Remarks	Issue	Solution
Expert			
Chief advisor			
Power Plant Management			
Operation management			
Maintenance management			
Repair work/Quality control			
Reservoir Management			
Numerical modeling			
Geochemistry			
Geophysics			
Geology			
Video Material Supervision			
Cooling tower and main steam pipe temperature monitoring			
Geothermal Human Resource Development Coordinator			
Equipment			
High performance liquid chromatography			
Interactive whiteboards			
Cooling tower and main steam pipe temperature monitoring system			
Training in Japan (TBD)			
Training on overhaul maintenance			
Reservoir modeling			
Geochemical training (chemical analysis, tracer test, scaling, corrosion)			
Invitation program			
In-country/Third country Training			

Activities / Sub-Activities	Responsible Organization: Japan	Responsible Organization: GOK	Achievements	Issue & Countermeasures
Output 1: O&M capacity of power stations is strengthened.				
1-1 Review and analyze the current status and issues of O&M of Olkaria I (Units 4 and 5), Olkaria II (Units 1, 2 and 3), Olkaria IV (Units 1 and 2) and Olkaria Ⅴ (Units 1 and 2).	JICA	KenGen		
1.2 Conduct training on predictive trouble management based on IoT data analysis, including cooling tower and main steam pipe temperature monitoring system.	JICA	KenGen		
1.3 Conduct training on performance management based on IoT data analysis including cooling tower and main steam pipe temperature monitoring system.	JICA	KenGen		
1.4 Conduct training on appropriate repair skills and effective maintenance planning.	JICA	KenGen		
(1) Develop a maintenance manual based on analysis of repair history.	JICA	KenGen		
(2) Conduct on-the-job training during overhaul maintenances based on the manual.	JICA	KenGen		
(3) Revise the maintenance manual and make improvements to the business process.	JICA	KenGen		
1.5 Conduct training on recording, storing, analyzing, and maintenance planning.	JICA	KenGen		
(1) Record and store repair records of each equipment in the IoT system.	JICA	KenGen		
(2) Prepare a maintenance plan based on the repair data of each equipment recorded and stored in the IoT system.	JICA	KenGen		
Output 2:2. Reservoir management capacity is strengthened.				
2.1 Review the current status and issues of reservoir management.	JICA	KenGen		
2.2 Conduct training on analysis of physical characteristics of the well (such as wellhead pressure and flow rate from tracer flow testing and IoT).	JICA	KenGen		
2.3 Conduct chemical analysis training including analysis with new tracer(s).	JICA	KenGen		
2.4 Conduct training on reservoir modeling using continuous pressure monitoring (procured by UNIDO) and gravity monitoring.	JICA	KenGen		
2.5 Conduct training on geochemistry for preventing scaling, corrosion, and sulfur/bacteria deposition.	JICA	KenGen		
Duration / Phasing				

Monitoring Plan	Remarks	Issue	Solution
Monitoring			
Joint Coordinating Committee			
Set-up the Detailed Plan of Operation			
Submission of Monitoring Sheet			
Monitoring Mission from Japan			
Joint Monitoring			
Post Monitoring			
Reports/Documents			
Training Materials			
Project Completion Report			
Public Relations			

Photo (Power plant management)

Records at the time of the second site visit (May-June 2022)

Kick-off meeting

Discussion on how to remove bolts in the field

Explanation of the benefits of introducing spare rotor

Exercise on FTA

Discussion on cause of main steam piping leak

Wrap-up meeting

First Overhaul Maintenance Training in Japan (September-October 2022)

Practical training on repairing FRP piping

Site visit of turbine sandblasting work

Field trip of storage batteries

Participation in morning meeting at power plant site

Commemorative photo after overhaul maintenance training

Awarding ceremony of training certificates

Executive training in Japan (October 2022)

Lecture on power plant management for finance perspective

Field trip of steam turbine at Hatchobaru Power Plant

Lecture on Hatchobaru Power Plant operation management

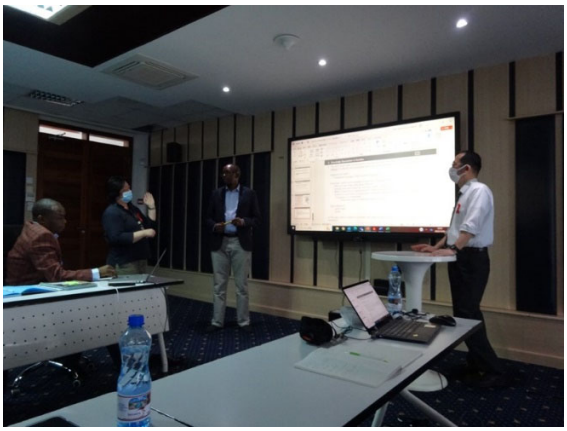
Field trip of worker safety meeting at Hatchobaru Power Plant

Field trip of routine test at Hatchobaru Power Plant

Awarding ceremony of training certificates

Records at the time of the third site visit (November-December 2023)

Meeting with human resource of Geothermal training center



Wrap up meeting

Courtesy call at KenGen HQ

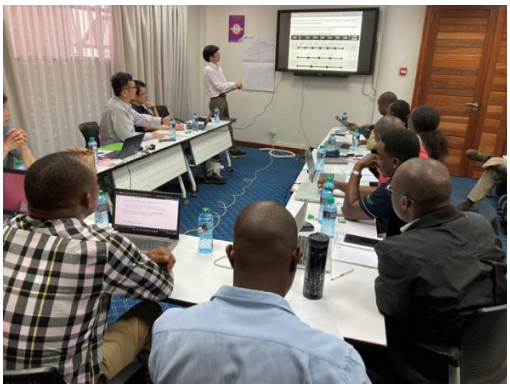
Courtesy call at embassy of Japan in Kenya

Courtesy call at Geothermal division of MoEP

Courtesy call of Human resource development division of MoEP

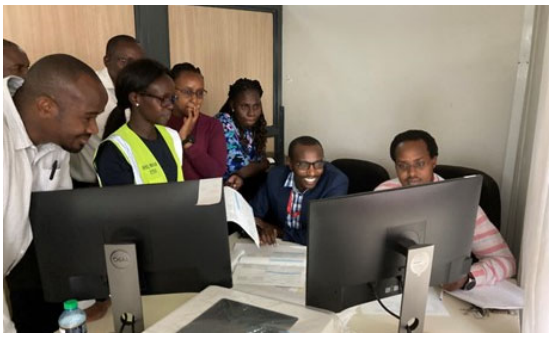
Records at the time of the fourth site visit (February-March 2023)

Kick off meeting



Lecture on optimization of OHM/AI process

Root cause analysis for ST bearing damage



Training of Performance management

OJT for Transmitter calibration

Development of Action Plan

Site survey at Olkaria II UPS

3rd JCC at MoEP

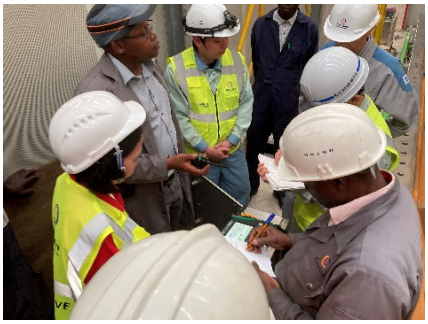
Records at the time of the fifth site visit (August-September 2023)

Lecture on centering work

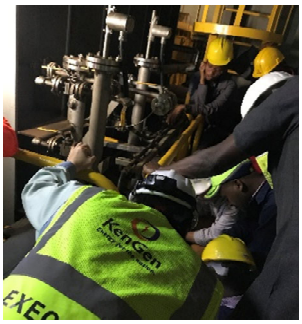
Lecture on UNIDO IoT system

OJT for centering work

OJT for centering work

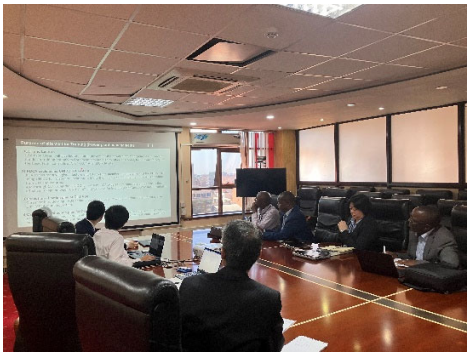


OJT for turbine exhaust temperature calibration



OJT for condenser HW level transmitter calibration

Wrap up meeting



Activity report to KenGen HQ

Second overhaul maintenance training in Japan (November,2023)

Classroom leaning for O&M Organization Structure in KIC

Classroom leaning for centering work

Field trip for the centering work of Hatchobaru Unit 1

Calculation practice for centering work

Protection relay device inspection

Discussion of operation monitoring procedures for unmanned

Discussion of cooling tower temperature monitoring system in Otake Power plant

Participation of the NPC morning meeting

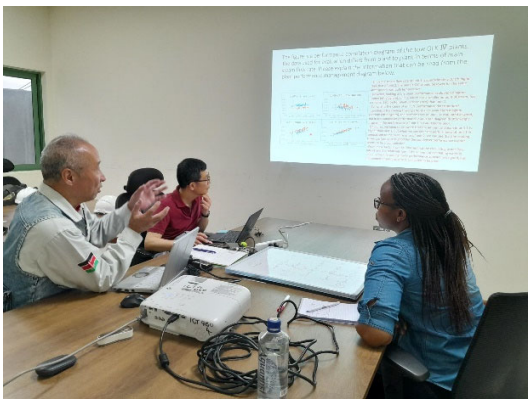
Inspection of main steam shutoff valve

Facility visit at Kyuden Training centert

Closing ceremony

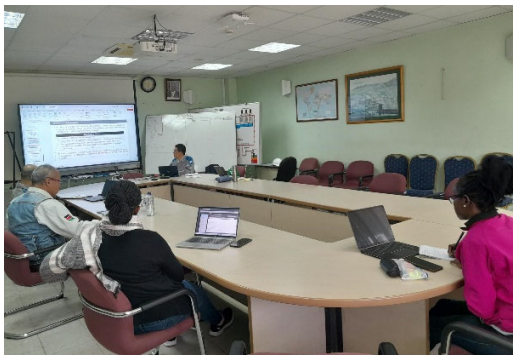
Records at the time of the sixth site visit (February-March 2024)

Lecture on OPMS procedure at Olkaria IV

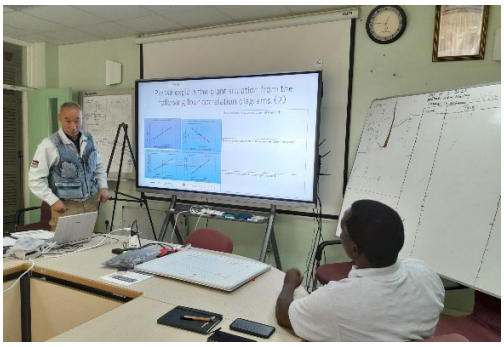


Performance management skill evaluation for core members

Lecture on OPMS procedure at Olkaria V

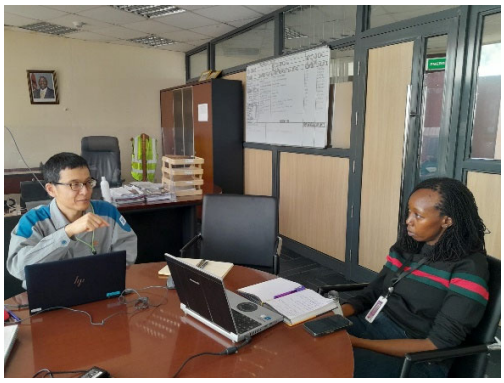


Discussion of data quality issue with TS team



Performance management skill evaluation for core members

Action Plan follow up meeting



Discussion of UNIDO system issue with ICT team

Activity report to KenGen HQ

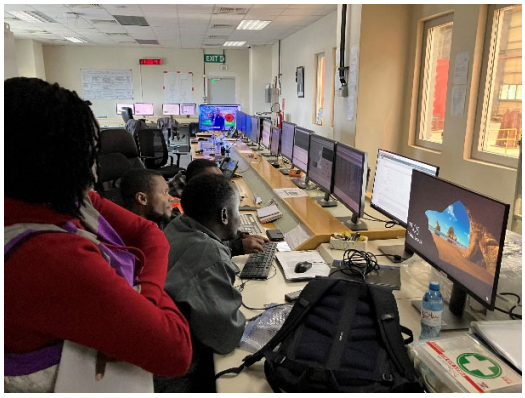
Records at the time of the seventh site visit (April-May 2024)

Lecture on cooling tower and main steam pipe temperature monitoring system at Olkaria II

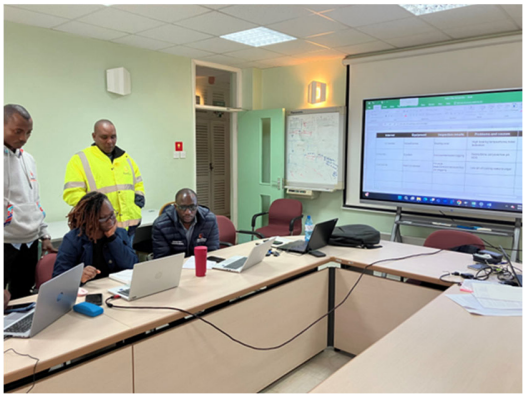
Records at the time of the eighth site visit (June-July 2024)

Prior explanation of JCC discussion at MoEP

4th JCC at MoEP



Lectures and demonstrations on how to use OPMS at Olkaria IV

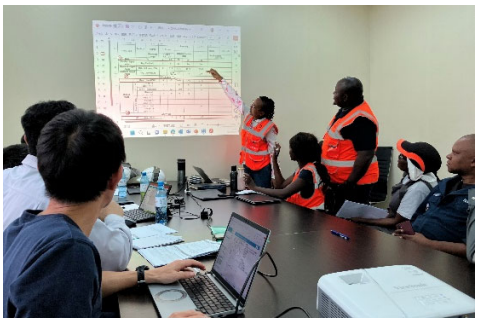


Lecture on maintenance management concept for new engineers

Records at the time of the ninth site visit (October-November 2024)

Lecture on centering work

OJT of centering work at Olkaria IV



Discussion of calibration record

Equalizing charge at Olkaria I-AU

Interview with Olkaria II Assistant manager

Meeting with the KenGen HQ Human Resources division

Wrap up meeting

Interview with KenGen manager

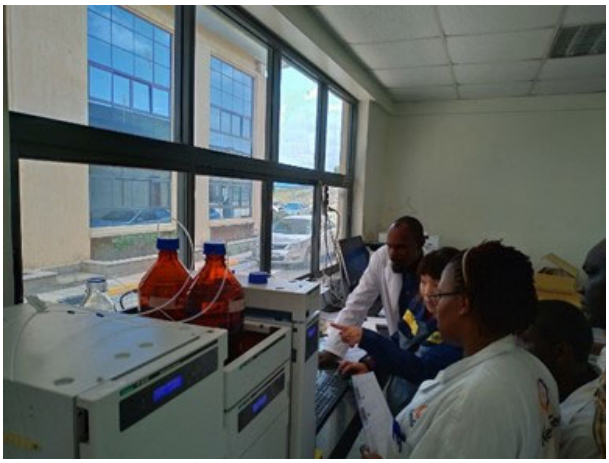
Photo (Reservoir management)

Records at the time of the first site visit (May-June 2022)

Confirmation of current status of equipment around observation wells

Confirmation and guidance of two-phase flow sampling method for production wells

Confirmation and guidance on power plant cooling tower status



Guidance on new tracer analysis method by HPLC

Discussion on conceptual model

Wrap-up meeting

Records at the time of the 1st training in Japan (September-October 2022)

Field trip of facilities at Hatchobaru Power Plant

Field trip of production base at Otake Power Plant

Field trip of facilities at Yamakawa Power Plant

Collection of effluent during geochemical training

Action plan presentation

Commemorative photo after the closing ceremony

Records at the time of the second site visit (November-December 2022)

Confirmation and guidance on the method of collecting hot water from production well blowouts

Confirmation and guidance on the status of chemical injection at the power plant

Instruction on well simulator

Discussion with Power plant, Plant chemistry team

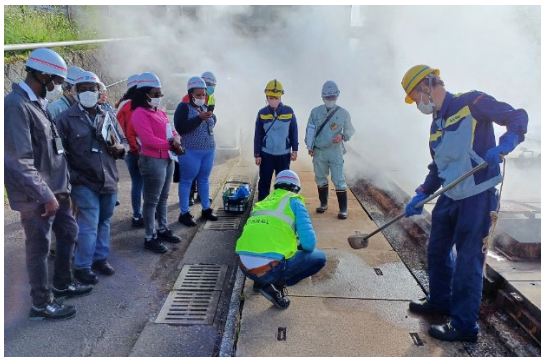
Action plan presentation in KenGen

Wrap-up meeting

Second reservoir management training in Japan (May, 2023)

Chemical analysis training

Group photo at Hatchobaru

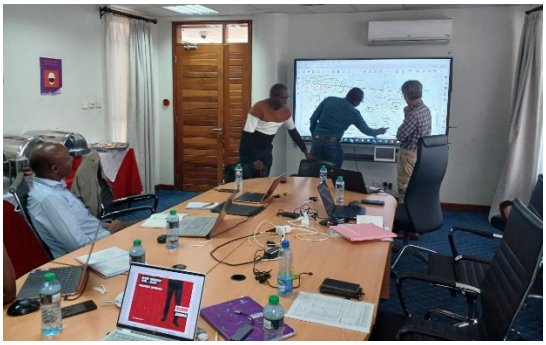


Fluid sampling training at Hatchobaru

Action Plan presentation at West JEC

OJT at Olkaria (August, 2023)

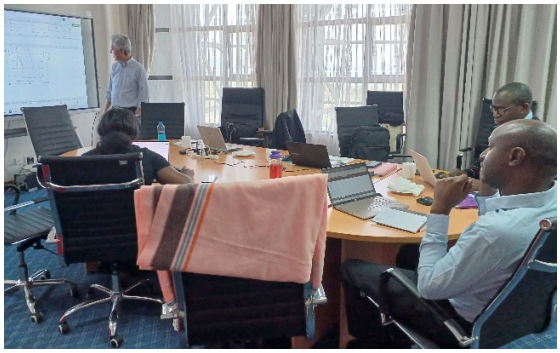
Fluid sampling training at Olkaria



Discussion on reservoir management

OJT at Olkaria (February, 2024)

Fluid sampling



Discussion on reservoir management

Certification Award Ceremony (January 2025)

Certification Award Ceremony

Achievement Presentation

Final JCC (January 2025)

ANNEX 2

Project for Strengthening Operation and Maintenance
Capacity of Olkaria Geothermal Power Stations
Using IoT Technology

Geothermal Power Plant Operation Manual

March 2021

Japan International Cooperation Agency (JICA)

JICA Experts

（Kyushu Electric Power Co. Inc.,

West Japan Engineering Consultants, Inc.）

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Annex

Annex 1: Repair procedure manual (Mechanical)
Annex 2: Repair procedure manual (Electrical)

1 Basics of plant engineering

1.1 Gauge pressure and absolute pressure

Usually, the pressure used in the field instruments of power plants and operation data for operation management often refers to the *gauge* pressure. However, when performing heat balance and performance calculation, *absolute* pressure is used as in steam tables and equations of state. The gauge pressure is based on atmospheric pressure, and the standard atmospheric pressure is set to 0 "zero", which is expressed in MPa (gauge).

On the other hand, the absolute pressure is based on the absolute vacuum state, and the difference between gauge pressure and absolute pressure is expressed as follows: absolute pressure = gauge pressure + atmospheric pressure.

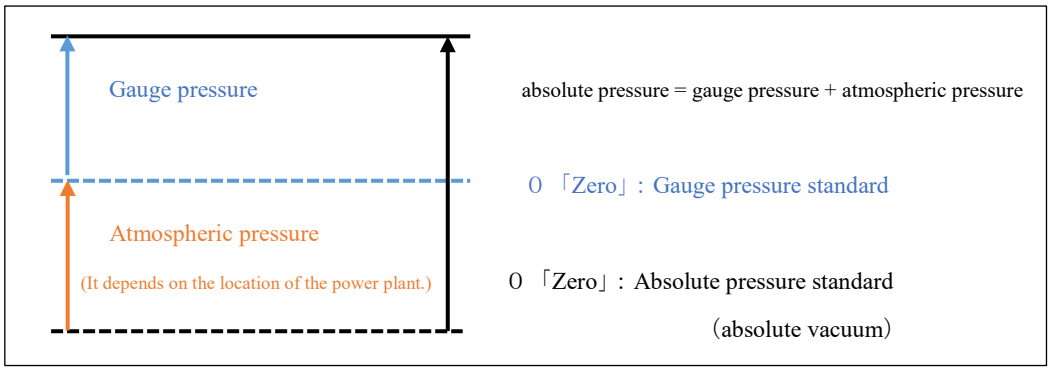


Figure 1-1 Relationship between gauge pressure and absolute pressure

The standard atmospheric pressure is equal to the pressure of 760 mm of mercury (Hg) at 0 ° C at the place of standard gravity. That is, 1 (one) standard atmospheric pressure (1 atm) = 101.325 kPa = 1013.25 hPa. However, in general, the standard atmospheric pressure is different at each point where the power plant is located. In a power plant, the pressure inside the condenser, which is lower than the atmospheric pressure and is close to an absolute vacuum, may be expressed as an absolute pressure, or the degree of vacuum may be expressed as "-90 kPa" by adding a minus sign with the atmospheric pressure as zero.

Table 1-1 Conversion of various pressures

MPa	at(kgf/cm2)	mmHg	atm
1	10.19	—	9.86
0.098	1	735.6	0.96
0.133	1.36	1000	1.31
0.101	1.033	760	1
0.007	0.07	51.71	0.068

1.2 Specific enthalpy (h)- Specific entropy (s) diagram, dryness (wetness)

When water is heated under constant pressure, the temperature of the water gradually rises, and when it reaches a certain temperature, the rise in the water temperature stops, and the additional thermal energy is consumed for evaporation of the water. For example, when water is heated at a standard

atmospheric pressure of 1,013 hPa (760 mmHg), the temperature of the water rises to 100 ° C and stops. This temperature is called the *saturation temperature* at the standard atmospheric pressure, water at the saturation temperature is called *saturated water*, and steam at the saturation temperature is called *saturated steam*. There is a certain relationship between the temperature and the pressure of saturated water and saturated steam, the pressure when temperature is given is called the *saturation pressure* at that temperature. When saturated water is further heated, the heat is consumed to convert the water into steam, but the temperature remains at saturation temperature. In this state, water and steam coexist, so it is called wet steam, and the mass fraction of saturated water in the wet steam (saturated water content ratio) is called *wetness*. The mass fraction of saturated steam in wet steam is called *dryness*, and the sum of wetness and dryness is 1 (one). When saturated water gradually turns into steam, its volume increases significantly. The steam in which all the saturated water has evaporated is called *dry saturated steam*. The wetness of dry saturated steam is 0 (zero).
Further heating of the dry saturated steam causes the temperature to rise above the saturation temperature. Steam heated above this saturation temperature is called *superheated steam*.

Figure 1-2 shows the state of steam with the horizontal axis as the *specific entropy* and the vertical axis as the *specific enthalpy*, which is called (h-s diagram) in the steam diagram. A-K is called a saturated water line, B-K is called a saturated steam line, and both are collectively called a *saturated line*.
The state on the left side of the A-K line is water, the state on the upper right side of B-K is called superheated steam, and the state below the A-K line and the B-K line is wet steam that is a mixture of saturated water and saturated steam. Explaining the wetness on the isobar of 0.1MPa shown by the green line (C-D) in Figure 1-2, when x (kg) dry saturated steam and (1-x) kg of saturated water are contained in 1 kg of wet steam, x is called dryness and (1-x) is called wetness, and the dryness indicated by the green line in this figure is 0.7 on the corresponding broken line.

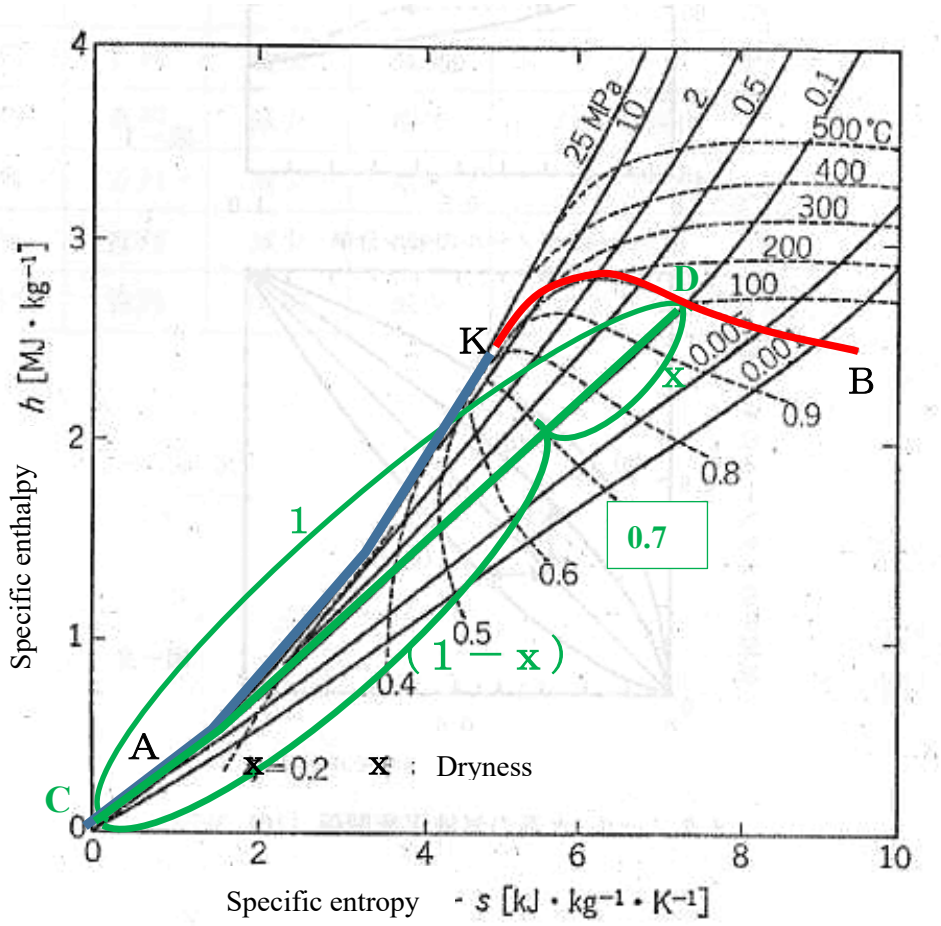


Figure 1-2 h-s diagram of water (1)

The specific enthalpy h and the specific entropy s of the wet steam with dryness of x are calculated by the following equations.

Specific enthalpy: $h = h_c + x\,(h_d - h_c) = h_c + x\,r$

Specific entropy: $s = s_c + x\,(s_d - s_c)$

However, it is as shown in the table below.

Table 1-2 Specific enthalpy, Specific entropy, Heat of vaporization

	Unit	Saturated water	Dry saturated steam
Specific enthalpy: h	k J/ kg	**h_c**	**h_d**
Specific entropy: s	k J/ (kg*K)	**S_c**	**S_d**
Heat of vaporization (Enthalpy of vaporization): r	k J/ kg	**$h_d - h_c$**	

1.3 Isentropic heat drop

In a steam turbine, the thermal energy of steam is converted into velocity energy to rotate the axle. The difference between the specific enthalpy of the inlet steam and the specific enthalpy of the outlet steam in the steam turbine is called the heat drop, which is the basic state quantity for estimating the output of the steam turbine. In particular, the heat drop when there is an isentropic change (an adiabatic change) is called the isentropic heat drop, and it is a numerical value that shows how much energy can be extracted by expanding steam.

The h-s diagram is a graphic, with specific enthalpy (h) on vertical axis and specific entropy (s) on horizontal axis, is used for calculating the steam state in a power generation facility and the workload of the steam turbine. The advantage of h-s diagram is that the throttle expansion (isenthalpic change) is indicated by a horizontal line while the adiabatic change (isentropic change) is indicated by a vertical line.

In Figure 1-3 and Figure 1-4, assuming that the state of the geothermal fluid in the reservoir ① is 5MPa abs, the state changes to become wet steam via isenthalpic change from the reservoir to the outlet of the steam separator ② (assumed to be 0.6MPa abs.) via the production well. After the wet steam is unmixed by the steam separator, into the steam at the turbine inlet as saturated steam ③, and the separated hot water as saturated hot water ⑤. In the state of ③, the steam at the turbine inlet adiabatically expands to the pressure inside the condenser (0.01MPa abs.) while working in the turbine (isentropic change), and becomes the state of ④. Therefore, the change of state from ③ to ④ converts the thermal energy of steam into velocity energy to rotate the axle of the turbine.

When changing from ③ to ④, there is a pressure loss in the turbine, which increases the specific entropy of steam. Therefore, in reality, about 80% to 90% of the isentropic heat drop becomes the rotational force of the turbine, so it becomes ④'.

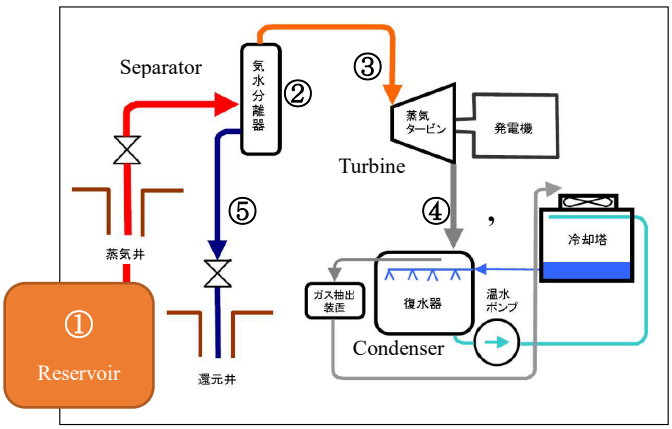


Figure 1-3 Single flash (condensate) power generation conceptual diagram

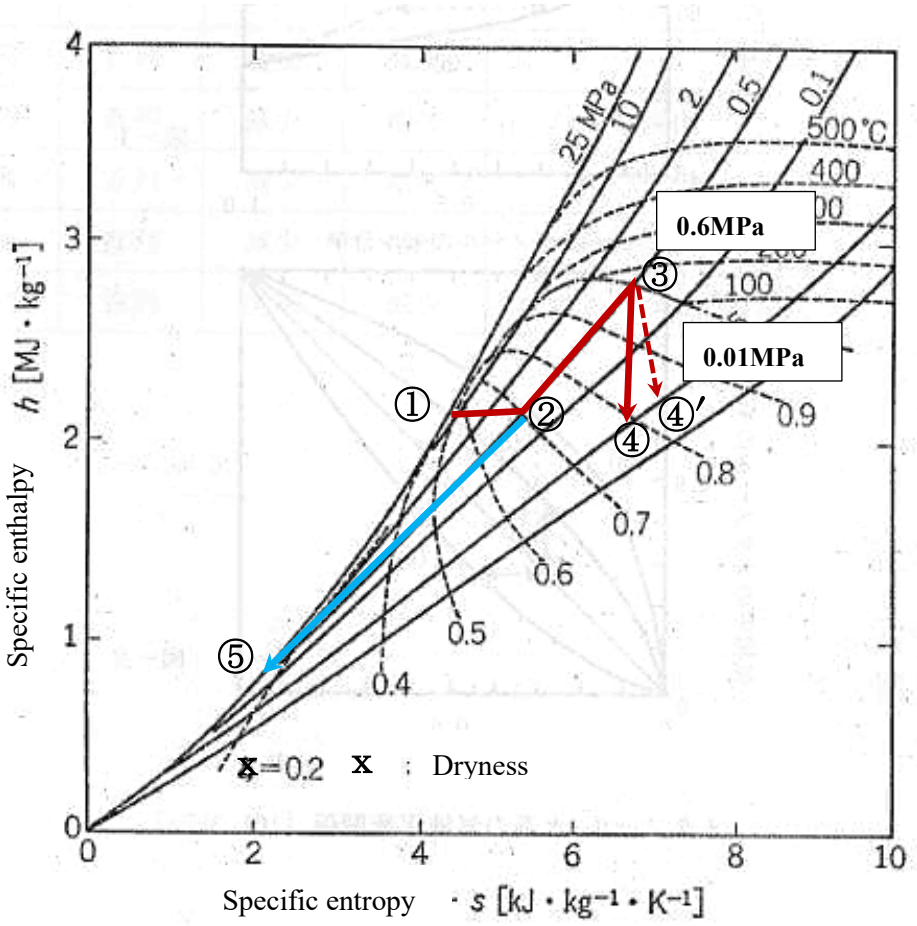


Figure 1-4 h-s diagram of water (2)

1.4 Power generation output calculated from the isentropic heat drop

In the previous section 1.3, theoretically, the isentropic heat drop is taken out as turbine power, but it is understood that due to the pressure loss in real-world turbine about 80% to 90% of the isentropic heat drop is converted to rotational force.

Based on that understanding, we will calculate what will happen to the power plant output if the turbine inlet pressure and turbine outlet pressure (condenser pressure) are given.

Also, the change of the power generation output caused by the change of the turbine inlet pressure is calculated for the given turbine outlet pressure.

As shown in Figure 1-5, the calculation is performed in two cases where the turbine inlet pressure is 0.8 MPa and 0.6 MPa under the same conditions as the turbine outlet pressure of 0.01 MPa. In the calculation, the efficiency in consideration of the loss generated while the steam works in the turbine is 85%, and the efficiency in the generator is 90%.

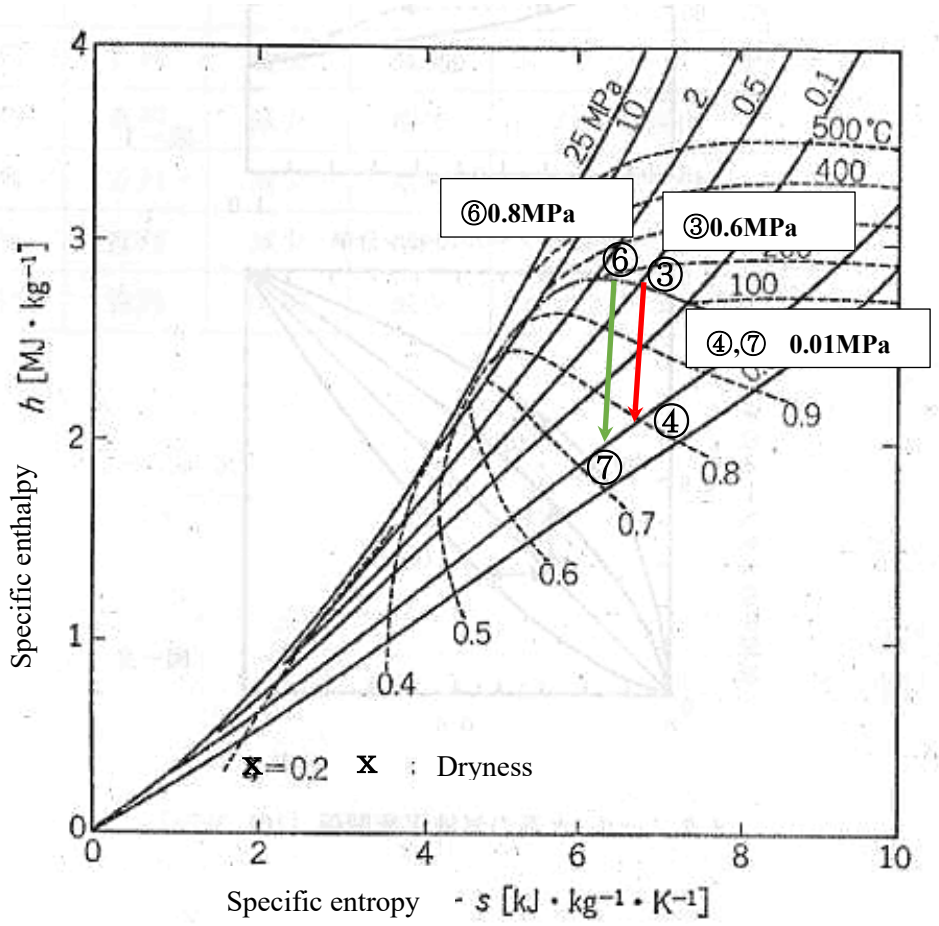


Figure 1-5 h-s diagram of water (3)

【Steam table】

Pressure MPa.abs	Temperature ℃	Specific enthalpy kJ/kg		
		Saturated water (h_c)	Dry saturated steam (h_d)	heat of vaporization (r)
0.01	45.81	191.81	2,583.89	2,392.08
0.5	151.83	640.19	2,748.11	2,107.92
0.6	158.83	670.50	2,756.14	2,085.64
0.7	164.95	697.14	2.762.75	2,065.61
0.8	170.41	721.02	2,768.30	2,047.28
0.9	175.36	742.72	2,773.04	2,030.32

【Calculate the actual workload on the turbine】

① Specific enthalpy at turbine inlet pressure (saturated steam)

Extract the saturated steam pressure from the steam table. The specific enthalpies of the two cases 0.8MPa and 0.6MPa are 2,768.30 kJ / kg and 2,756.14 kJ / kg, respectively.

② Specific enthalpy of turbine outlet pressure (condenser pressure)

As shown in Figure 1-5, the saturated steam of the turbine inlet pressure undergoes an isentropic change (decreases vertically in the figure) and moves to a wet region at the turbine outlet. Therefore, the specific enthalpy of steam at the turbine outlet is expressed by the following equation, where x is the dryness, as explained in "1.2 Specific enthalpy (h) -specific entropy (s) diagram, dryness (wetness)".

$$\text{Specific enthalpy}: h = h_c + x\,(h_d - h_c)$$

Calculate the specific enthalpy at the turbine outlet pressure (condenser pressure) 0.01MPa in the case of 0.8MPa. From Figure 1-5, the dryness X when changing from 0.8MPa to 0.01Mpa with isentropic is 0.80, so the specific enthalpy h to be obtained is expressed by the following equation.

Specific enthalpy：h＝ 191.81 + 0.80 (2,583.89 – 191.81) = 2,105.47 kJ/kg ・・・a

Enthalpy of saturated steam at 0.01 MPa: 2,583.89 kJ/kg

Enthalpy of saturated water at 0.01MPa: 191.81 kJ/kg

Similarly, in the case of 0.6MPa, the dryness x is 0.81, and the specific enthalpy of the turbine outlet steam in this case is expressed by the following equation.

Specific enthalpy：h＝ 191.81 + 0.81 (2,583.89 – 191.81) = 2,129.39kJ/kg ・・・b

③ Turbine enthalpy amount that can be used for power generation

The isentropic heat drop, which is the difference between the specific enthalpy of saturated steam and the specific enthalpy at the turbine outlet (condenser) pressure, is expressed by the difference between the value of ① and the value calculated in ②. The isentropic heat drop in each case of turbine inlet steam pressure 0.8MPa and 0.6MPa is as follows.

Isentropic heat drop of 0.8MPa case：2,768.3kJ/kg－2,105.5 kJ/kg＝662.8 kJ/kg・・c

Isentropic heat drop of 0.6MPa case：2,756.1kJ/kg－2,129.4 kJ/kg＝626.7 kJ/kg・・d

Considering that the turbine efficiency is 85%, the amount of enthalpy available for the rotational force of the turbine in each case of 0.8MPa and 0.6MPa is as follows per 1 kg of steam.

Enthalpy amount of 0.8MPa case：662.8 kJ/kg×85%＝563.4 kJ/kg・・e

Enthalpy amount of 0.6MPa case：626.7 kJ/kg×85%＝532.7 kJ/kg・・f

④ Power generation

Once the steam pressure, temperature, steam amount and turbine exhaust pressure at the inlet of the steam turbine are known, the turbine output considering the loss in the turbine and generator can be calculated by the following equation.

$$Pa = \frac{G \times (h1 - h2) \times \eta T \times \eta g}{3{,}600} \quad (kW)$$

Pa ＝ Generator output (kW)
G ＝ Turbine inlet steam amount (kg/h)
h1 ＝ Specific enthalpy at turbine inlet (saturated steam) pressure（kJ/kg）
h2 ＝ Specific enthalpy at turbine exhaust pressure（kJ/kg）
ηT ＝ Turbine efficiency
η g ＝ Generator efficiency

Here, assuming that the steam amount at the turbine inlet is 200 t / h and the generator efficiency is 90%, the power generation is as follows.
Turbine efficiency has already been calculated from "③ Turbine enthalpy amount that can be used for power generation".

Power generation of 0.8MPa case：

（200t/h×563.4kJ/kg×1000×90%）／3,600＝28,170kW・・・g

Power generation of 0.6MPa case：

（200t/h×532.7 kJ/kg×1000×90%）／3,600＝26,635kW・・・h

The above calculation results are summarized in Table 1-3 and Table 1-4.

Table 1-3 Turbine inlet pressure and isentropic heat drop

Turbine inlet pressure	Turbine inlet enthalpy	Turbine outlet (condenser) pressure	Turbine outlet dryness	Turbine outlet enthalpy	Isentropic heat drop
0.8 MPa.abs.	2,768.3kJ/kg	0.01MPa abs	0.80	2,105.5kJ/kg	662.8 kJ/kg
0.6 MPa.abs.	2,756.1kJ/kg	0.01MPa abs	0.81	2,153.5kJ/kg	626.7 kJ/kg

Table 1-4 Turbine inlet pressure and generator output

Turbine inlet pressure	Isentropic heat drop	Turbine efficiency	Energy to convert to turbine rotational force	Main steam flow rate	Generator efficiency	Generator output
0.8 MPa.abs.	662.8 kJ/kg	85%	563.4 kJ/kg	200t/h	90%	28,170kW
0.6 MPa.abs.	626.7kJ/kg	85%	532.7 kJ/kg	200t/h	90%	26,635kW

Comparing the two cases of 0.8 MPa and 0.6 MPa in Table 1-4, 0.8 MPa improves the power generation output by about 5% [1- (28,170kW / 26,635kW) = 0.054] than 0.6 MPa with the same steam amount.
From this calculation result, the specific enthalpies at the turbine inlets are almost the same with the difference of 1% or less, but the power generation output has a difference of about 5%. Explaining this difference in power generation output, in Figure 1-5, there is no big difference in the value of the specific enthalpy due to the difference in the turbine inlet pressure on the saturated steam line in the h-s diagram, but the constant-pressure line intersecting the saturated steam line rises to the right, the isentropic heat drop decreases as the turbine inlet pressure decreases.

As shown in Table 1-4, when the steam flow is the same under the same conditions, the heat drop becomes larger when the turbine inlet pressure is higher, and the amount of energy converted into the rotational force of the turbine (⇒ generator output) also becomes larger.

Therefore, as shown in Table 1-3, as the turbine inlet pressure increases, the heat drop increases and the generator output also increases. On the other hand, generally, looking at the characteristics of the production well, when the turbine inlet pressure (which is almost equal to the pressure inside the steam separator) increases, the amount of steam flow usually decreases, so the amount of steam flowing into the turbine also decreases. As shown in equation ④, the turbine output (⇒ generator output) is proportional to the product of the heat drop between the turbine inlet and outlet and the steam flow rate flowing through the turbine. Therefore it is possible to set the turbine inlet pressure at which the theoretical maximum output can be obtained under constant geothermal fluid conditions by calculating the product of steam flow and heat drop as shown in Figure 1-6.

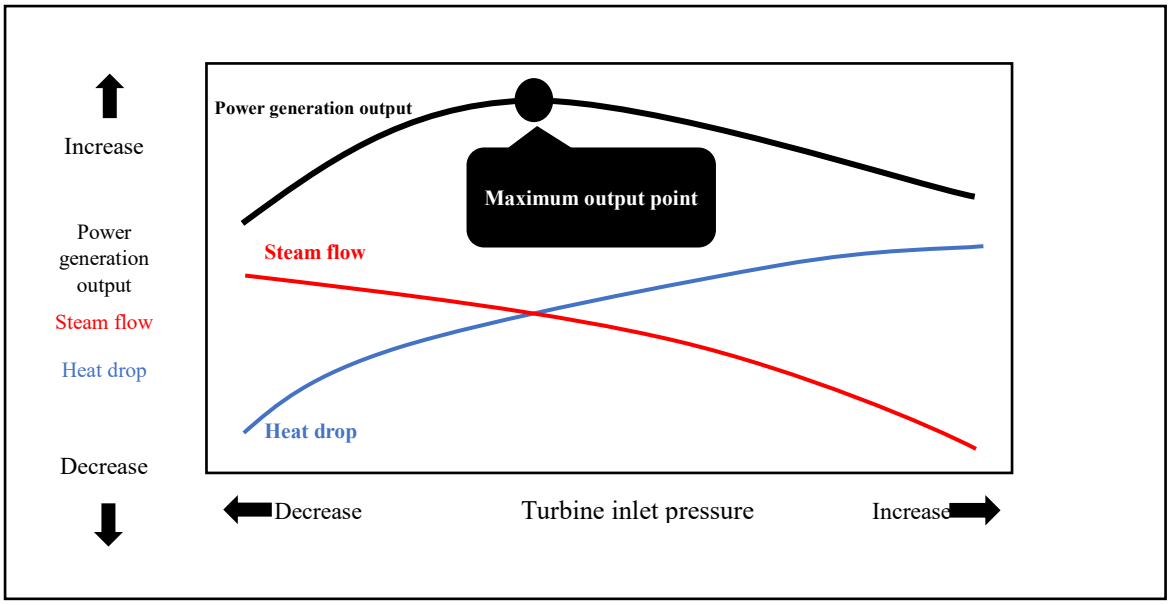


Figure 1-6 Turbine inlet pressure-steam flow rate-generator output relationship

2 Predictive trouble management

2.1 Definition and significance of predictive trouble management

Predictive trouble management is defined as a management method aimed at avoiding unit trips and load suppression by detecting at an early stage the situation where the equipment seems to be performing as designed but continues to operate in a different state from the design. By performing predictive trouble management, it is possible to avoid unit trips and load suppression, and improve the availability factor and utilization factor.

2.2 Operation data to be managed

The management of the target devices and the systems is organized according to the following ideas. Use trend charts and correlation charts as a way to see the predictive signs before the problems such as unit trips and load suppression become apparent.

(1) Operation data required for daily operation management in each facility and system
- "Confirmation of unchanged operating data" even if operating conditions change.
  Ground steam pressure / flow rate, turbine oil system pressure, generator voltage, etc.
- "Confirmation of changing operating data" according to operating conditions.
  Generator output due to fluctuations in atmospheric wet-bulb temperature, steam pressure, and flow rate, etc.

(2) Operation data associated with power plant-specific events
- Operation data of equipment / systems that require special attention (examined from the history of unit trips, etc.)

(3) Comparison with design values and past results, operation data for reference
- Design values and operation data related to performance
- Trend history of MSV / GOV during stem-free test, etc.

2.3 Management method

2.3.1 "Confirmation of unchanged operation data" even if operating conditions change

Under normal operating conditions, confirm that the operation data that should not change has not changed. If the operation data that should not change has changed, there is some reason. If the reason cannot be figured out, it is necessary to suspect an abnormality.
For "confirmation of unchanged operation data", the operation data collected in one hour cycle during normal operation is confirmed, and if an abnormal sign appears, the operation data collected in one second cycle of the relevant part is analysed for further detail. Here is to introduce the method for further analysis.

Following trend chart, Figure 2-1 shows the main steam pressure, the ejector steam flow rate, and the steam chamber pressure that do not change under normal operating conditions. In the figure, the steam chamber pressure fluctuates from 0.14 to 0.15 Mpag, but this is evaluated as a normal state because fluctuation is caused by the situation that the main steam pressure is adjusted by GOV. On the other hand, looking at the operating conditions at 8:59 on August 22, 2020, it is evaluated that some kind of abnormality has occurred because the amount of ejector steam has risen sharply even though the main steam pressure has not fluctuated.

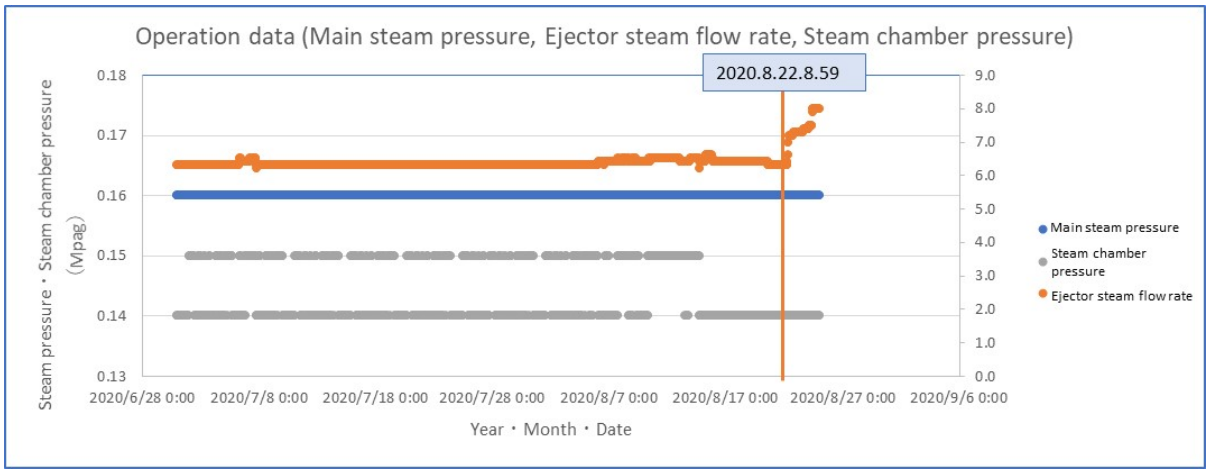


Figure 2-1 One hour cycle operating data during normal operation
(Main steam pressure, ejector steam flow rate, steam chamber pressure)

The trend chart of operation data (Figure 2-2) collected in the one second cycle around 8:59 on August 22, 2020 will be transferred from the trend chart in Figure 2-1. In the example shown in Figure 2-2, it is assumed that there are operation data of A and B related to the ejector steam flow rate. The operation data of A changes after the change of the ejector steam flow rate, and it is unlikely that the cause is a secondary event accompanying the change of the ejector steam flow rate. On the other hand, the operation data of B changes before the ejector steam flow rate changes, which can be evaluated that it may be the cause of the change in the ejector steam flow rate. However, it should be noted that the order in which the abnormalities are observed does not always match the order in which the events occur. This is because, depending on the equipment, there is a time lag until the steam flow travels through the piping and it leads to the pressure fluctuation of the container. It is necessary to identify the causal relationship by referring to the materials and checking the site.

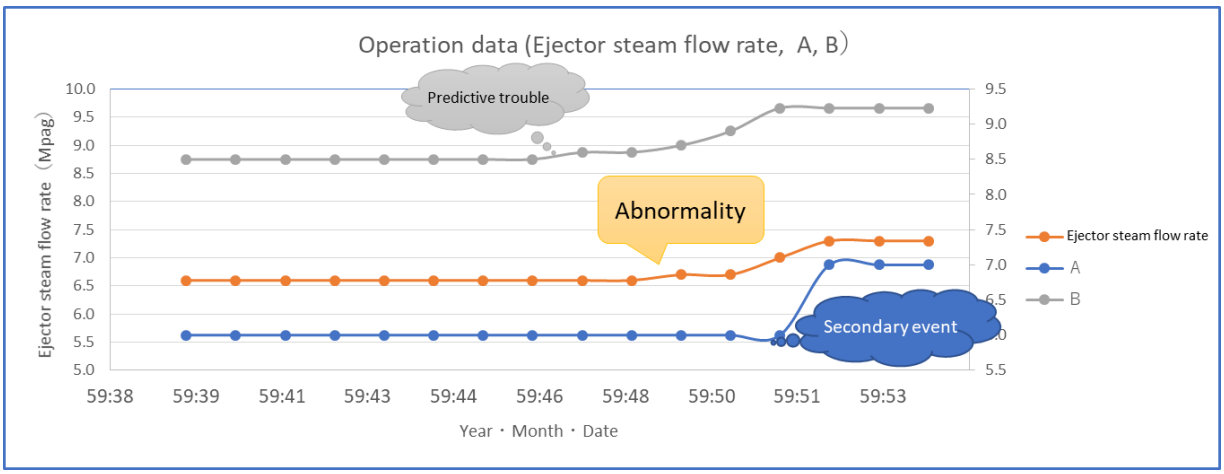


Figure 2-2 One second cycle operating data during normal operation
(Main steam pressure, ejector steam flow rate, steam chamber pressure)

2.3.2 "Confirmation of changing operation data" according to operating conditions

Confirm that the operation data that should change according to the operating conditions has changed. If the operation data that should change has not changed, there is some reason. If the reason cannot be figured out, it is necessary to suspect an abnormality. Also, if the change is different from the expected

change, suspect an abnormality. As explained in 2.3.1 "Confirmation of unchanged operation data" even if operating conditions change, when an abnormality is suspected, evaluate by looking at one second cycle operating data.

Figure 2-3 shows a trend chart of the circulating water temperature at the inlet of the condenser (left axis), which must change according to the change in the atmospheric wet-bulb temperature (right axis) under normal operating conditions. In the figure, the temperature of the circulating water at the inlet of the condenser changes in accordance with the change in the atmospheric wet-bulb temperature, which is normal movement.
Even if a normal trend is expressed as shown in this figure, it does not necessarily mean that the performance is maintained. Comprehensive and quantitative judgment is required in consideration of external conditions and the condition of related equipment.

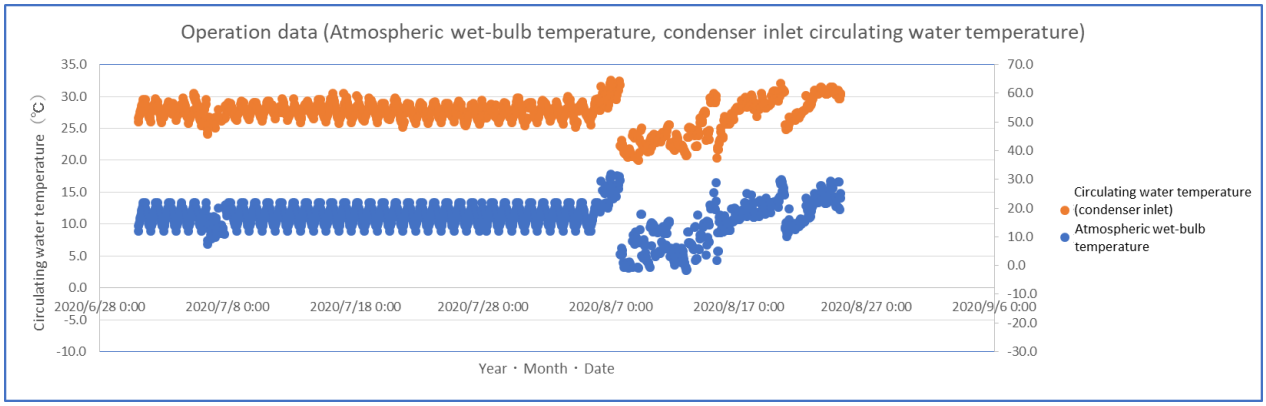


Figure 2-3 One hour cycle operating data during normal operation
(Atmospheric wet-bulb temperature, condenser inlet circulating water temperature)

2.3.3 Operation data associated with power plant-specific events

For example, suppose that the power plant has been shut down multiple times due to "condenser water level high" from the past trouble history. In that case, consider a method of catching signs so that the power plant will not be shut down. Considering that the fluctuation of the condenser water level is a secondary event, there may be a problem in adjusting the outlet valve of the circulating water pump. Therefore, it can be considered as a method to monitor the movement of the trend chart of the circulating water pump outlet valve opening.
The circulating water pump outlet valve controls the water level of the condenser. When the condenser water level rises, the opening is increased, and when the water level is low, the opening is decreased.
As shown in Figure 2-4, when the adjustment is made in a range larger than the normal valve opening adjustment, a problem in the control system is pointed out. In this case, the following methods are conceivable. One is to detect an abnormality by comparing the actual data at the time of normal adjustment with the operation data indicating the current adjustment status. And another is to issue an alarm by setting the upper and lower limits of the valve adjustment range based on the actual data.
In the case where the unit trip occurs in such a short time, it is necessary to manage with the operating data collected in one second cycle.

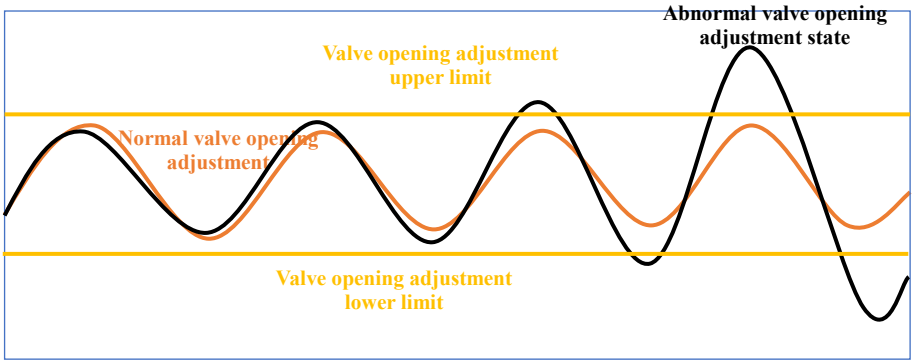


Figure 2-4 Abnormal trend chart of circulating water pump outlet valve
(The case where the opening adjustment range is larger than the normal state)

Also, what happens when the outlet valve of the circulating water pump is mechanically restricted by foreign matter in the opening direction as shown in Figure 2-5. As shown in Figure 2-4, even if the upper limit is set, abnormality cannot be detected.

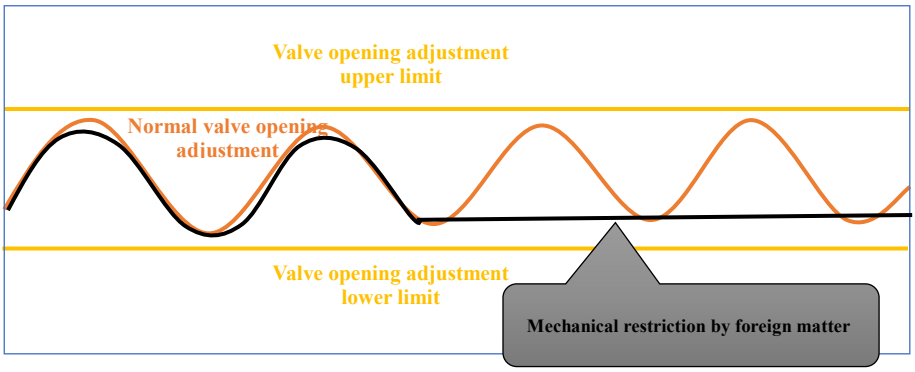


Figure 2-5 Abnormal trend chart of circulating water pump outlet valve
(The case where the outlet valve is mechanically restricted by foreign matter in the opening direction)

In the case of Figure 2-5, the deviation indicating the abnormal state may be visually grasped, but it is also conceivable to set the calculated value to detect the sign more easily and quickly.
As based on the average value of the valve opening for a certain period at the normal time, a state showing a value deviating from the average value at the normal time can be detected.
As shown in Figure 2-6 trend chart, the average value can be grasped as a sign at an early stage by comparing with the "simple moving average".

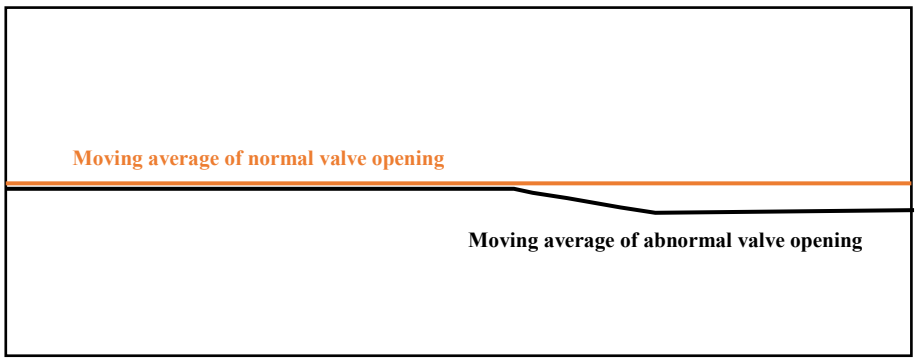


Figure 2-6 Detecting signs of circulating water volume control valve opening abnormality by comparing with the average valve opening value in the normal state (image)

2.3.4 Comparison of past operation data and design values with current operation values

Abnormal operation data collected in power generation equipment may not be recognized in a short period. The operating condition of the power generation equipment may gradually change (deteriorate) over a period of days, months or years, such as the accumulation of scale. It is effective for power plant monitoring to check the changes over time by comparing the past results and the current values on the same trend chart.

Figure 2-7 shows the circulating water flow rate on a trend chart under normal operating conditions, comparing and displaying data for any 13 days of November and December. In this trend chart, the data in November has maintained a constant flow rate, while the circulating water flow rate in December has started to decrease from the 11th day, and the amount of decrease has gradually increased. In other words, it can be determined that an abnormality has occurred by looking at the trend of decreasing flow rate.

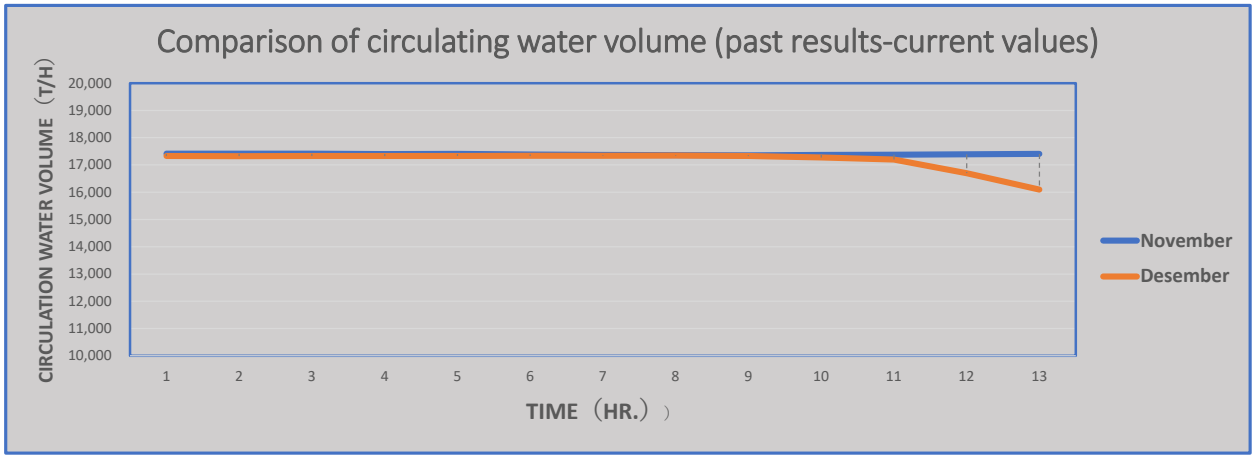


Figure 2-7 Circulating water flow rate data during normal operation

Although the situation of abnormal occurrence can be grasped in the example of Figure 2-7, there is another way of expressing it.

It is a method to show the deviation as a calculated value based on the normal data and the design value. Figure 2-8 shows an example of displaying the calculated deviation of the December data with respect to the design value.

The value obtained by dividing the measured value in December by the design value is shown by the green line, and the green line is downside and the downside width is large.

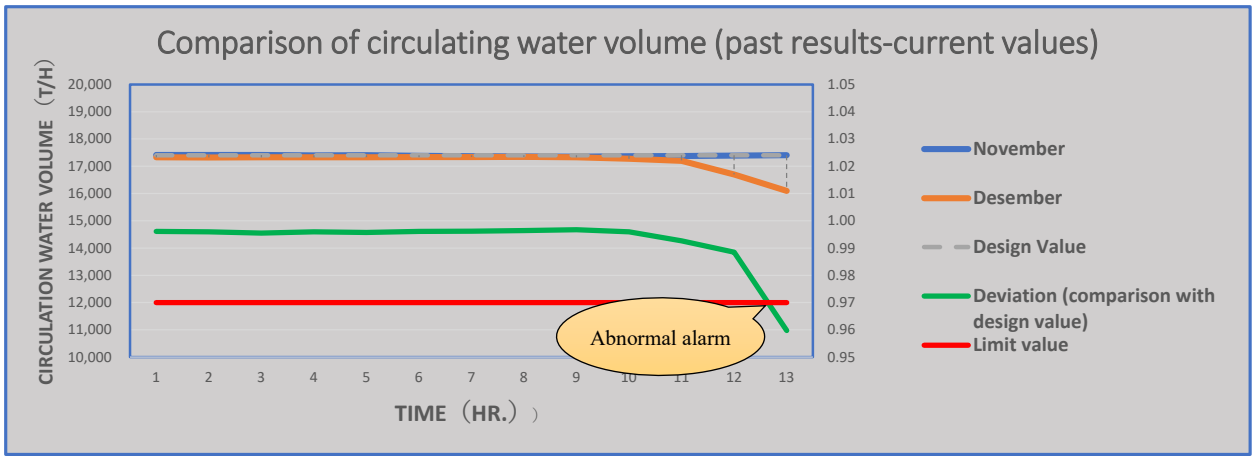


Figure 2-8 One hour cycle operating data during normal operation
(Measured value, design value)

Furthermore, from a management perspective, in order to grasp the deviation more objectively, if a lower limit value corresponding to the deviation can be set and an alarm can be issued, it is possible to respond without time delay. In the figure, the lower limit value (alarm value) is indicated by the red line.

2.3.5 Operation data when referring to past performance

Figure 2-9 show examples of using the trend chart based on the normal operation history of MSV / GOV during the stem-free test.
It is possible to confirm whether the current operation is appropriate while looking at the past performance trends at the stem-free test. Especially inexperienced young generation can use it as a reference for operations.
In addition, if the operation data is different from the past normal operation state even though the operation is properly performed, it is possible to confirm the defect in the relevant part.

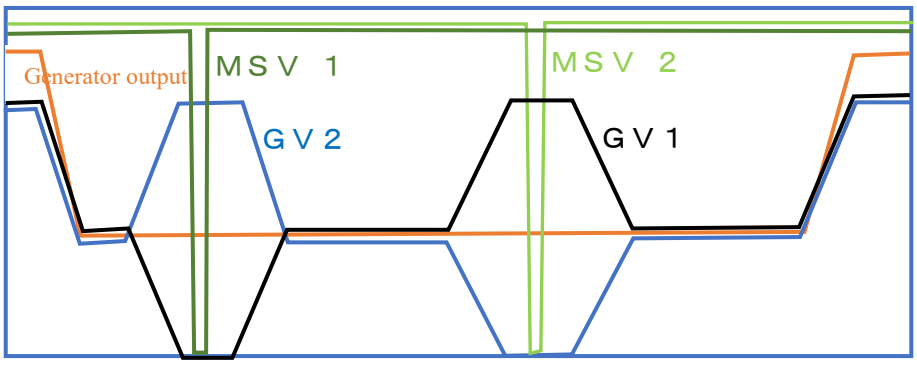


Figure 2-9 Comparison, evaluation with past proper operation by trend chart
(Stem free test　image)

Focusing on GV1 based on Figure 2-10, the deviation between the actual valve movement (normal state) shown by the black solid line and the valve operation during the test shown by the broken line are confirmed. From this difference (deviation), it can be detected that the GV1 is not moving well at

a low opening degree. If it is left as it is and deteriorates further, there is a concern that it will have a serious effect on the emergency response.

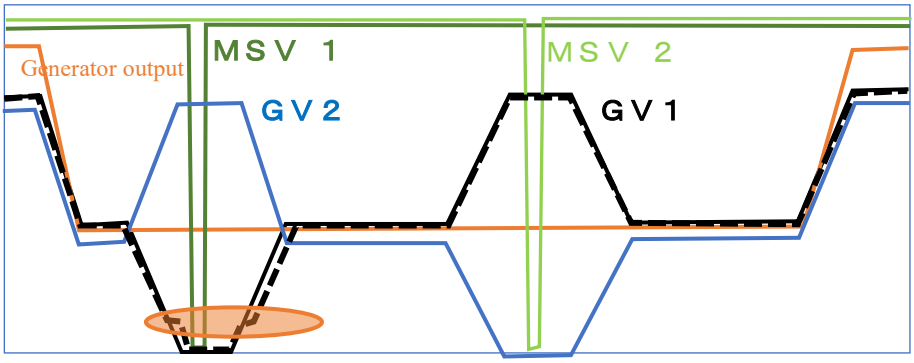


Figure 2-10 Detecting signs of abnormal circulating water volume using a correlation diagram (image)

[Reference] Abnormality detection example using a correlation diagram

There is also a plant monitoring method using a correlation diagram. Since the amount of circulating water correlates with the condenser vacuum level, when a correlation diagram is created from those operation data, points indicating the operation state are plotted at places deviating from the normal operation state as shown in Figure 2-11. As a result, it is possible to detect that the amount of circulating water is abnormal (decreased). Such correlations may be obtained from operation data, but it is possible to consider the correlations without data by interpreting based on knowledge (domain knowledge) regarding the mechanism of equipment and plant equipment configuration.

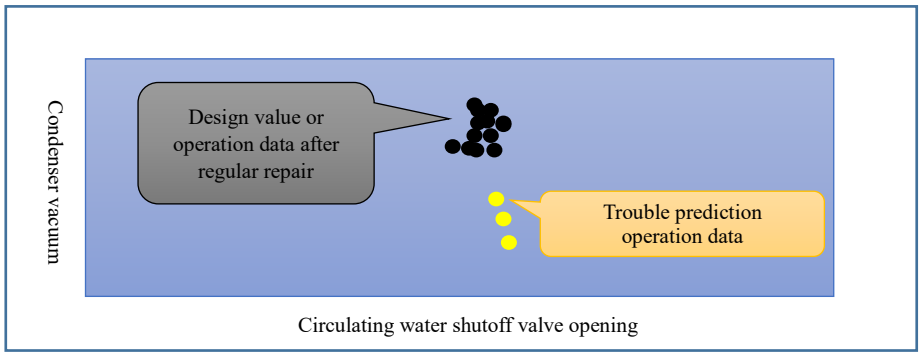


Figure 2-11 Detecting signs of abnormal circulating water volume using a correlation diagram (image)

3 Performance management

3.1 Correlation analysis

3.1.1 What is correlation analysis?

Correlation analysis is a method of evaluating whether or not there is a relationship between two variables. Here, when evaluating that there is a correlation, it means that the value of Y increases or decreases as the value of X increases in the two variables X and Y, and the strength of the correlation is expressed by a correlation coefficient.
When the value of Y increases as the value of X increases, it is said that there is a positive correlation, and it is evaluated that the positive correlation becomes stronger as it approaches 1 between 0 and 1. When the value of Y decreases as the value of X increases, it is said that there is a negative correlation, and it is evaluated that the negative correlation is stronger as it approaches -1 between 0 and -1. This correlation coefficient is generally evaluated as having a certain correlation when the absolute value is 0.5 to 0.6 or more, and is used for various evaluations.
As an example, the correlation will be explained in the following figures.

(1) Steam flow rate and power generation output → There is a positive correlation (correlation coefficient: 0.95)

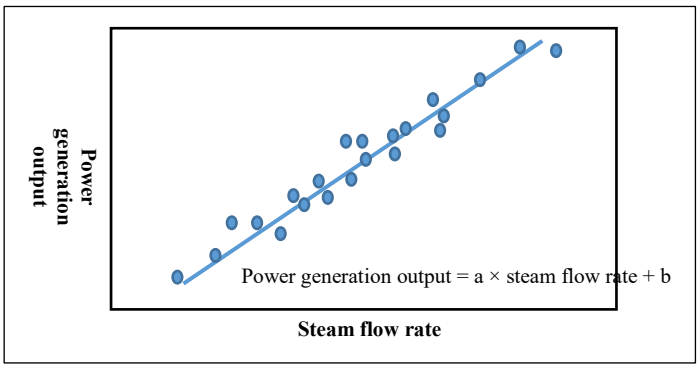


Figure 3-1 Positive correlation diagram (e.g., steam flow rate - power generation output)

(2) Steam-water separation pressure and production steam flow rate → There is a negative correlation (correlation coefficient: -0.95)

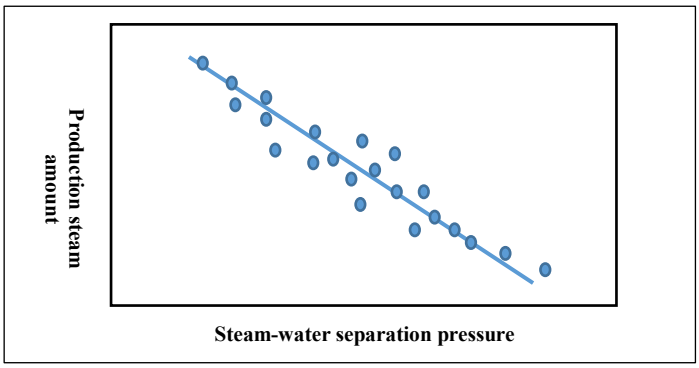


Figure 3-2 Negative correlation diagram (e.g., steam-water separation pressure - steam flow)

(3) Number of days off for power plant staff and power generation output → No correlation (correlation coefficient: 0.01)

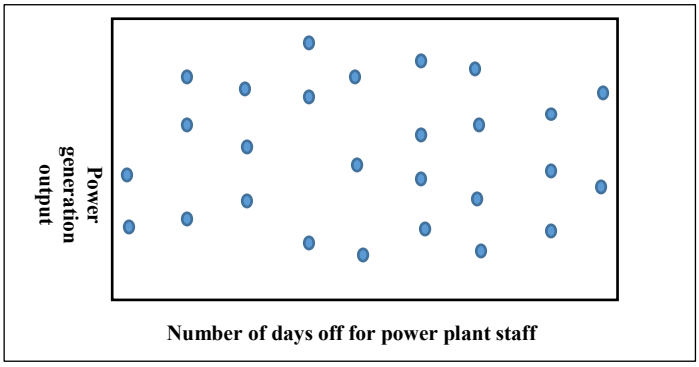


Figure 3-3 No correlation diagram (e.g., number of days off for power plant staff - power generation output)

As shown in the positive correlation diagram of Figure 3-1, when there is a correlation between the two data, if the data of X is known, the data of the other Y can be inferred. The method is called regression analysis.

Regression analysis expresses the relationship between the explanatory variable (X) that is the cause and the result (Y) that is the objective variable by one relational formula. When the value of X is determined, the value of Y is also determined. The relational formula between the case of the linear formula and the case of the quadratic formula is shown below.

$$Y = aX + b \text{ (linear formula)}, \quad Y = aX^2 + bX + c \text{ (quadratic formula)}$$

For example, if there is a correlation between the steam flow rate and the power generation output in Figure 3-1 and the steam flow rate is X using this formula, the power generation output Y is uniquely calculated by the relational expression "power generation output = a x steam flow rate + b".

3.1.2 Basic utilization of correlation diagram

If there are two variables with strong correlation and there is a point outside the point cloud that forms the correlation diagram, that point can be judged to be abnormal.

As shown in Figure 3-4, there is a strong correlation between the main steam flow rate and the generator output.

When point A is plotted there, it can be inferred as follows; "it indicates that the generator output is higher than the normal state at the same main steam flow rate. Since this is a realistically impossible state, there is something wrong with the instrument that measures the main steam flow rate or generator output." Also, when point B is plotted, it can be inferred as follows; "it indicates that the generator output is lower than the normal state at the same main steam flow rate, which may be due to a bad instrument measuring the main steam flow rate or generator output but the performance of the power plant has deteriorated.

Further, as described above, the generator output Y can be estimated with the main steam flow rate as X.

When there is a strong correlation between the main steam flow rate and the generator output (correlation coefficient: 0.95) in Figure 3-4, the relationship between the main steam flow rate and the

generator output is expressed by Equation 3-1 as shown in the figure. If the main steam flow rate is 100t / h, inputting 100t / h to the main steam flow rate in Equation 3-1 will lead to a generator output of 13,600kW.
In geothermal power plants, there is a strong correlation between the main steam flow rate and the generator output under the same conditions.

Generator output=125×main steam flow rate+1,100 ------ Equation 3-1

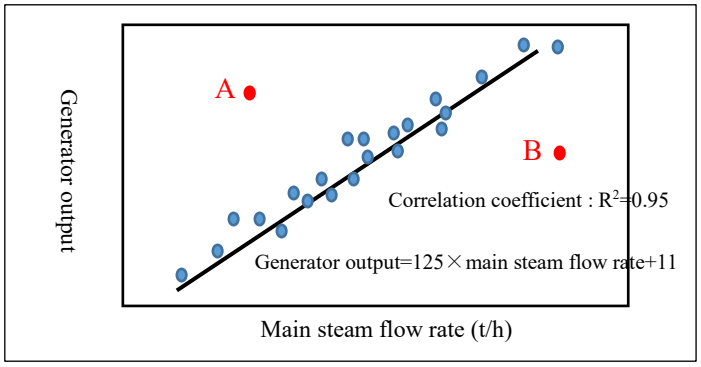


Figure 3-4 Positive correlation diagram (e.g., main steam flow rate - generator output)
* Correlation formula and correlation coefficient are not calculated but images

3.2 Definition and significance of performance management

Performance management is defined as a management method that aims to detect a state that affects the power generation output at an early stage and restore it to a normal state in a situation where the equipment cannot perform its intended function and continues to operate.
As described above, performance management enables the power generation output to recover, or enables the utilization factor to improve by preventing the power generation output in advance.

3.3 Management target

The management target is mainly SSC (Specific steam consumption) defined as "the amount of steam required to generate 1kWh", and when an abnormality is detected in SSC, the turbine, condenser, and cooling tower that make up the power plant are the target.

3.4 Management method and application example to geothermal power plant

The evaluation method using the correlation diagram is mainly used to evaluate the performance deterioration with the deviation between the data defined the normal value as shown below.

(1) Comparison between design values and plant performance test data conducted at the time of PPA and current operation data
(2) Comparison of performance test operation data at the commencement of operation, operation data just before and after regular repair, and current operation data
(3) Comparison of correlated current operation data

3.4.1 Atmospheric wet - bulb temperature - SSC

The SSC correlates with the atmospheric wet-bulb temperature when the turbine inlet pressure and the steam flow rate are under the same condition.
The reference value such as the design value and the operation data just after the overhaul maintenance is compared with the operation data to be evaluated under the same conditions (steam pressure and steam flow rate are almost the same). When there is a significant deviation between the mutual operation data, it can be evaluated that the performance of the plant has deteriorated and the instrument has malfunctioned.

Figure 3-5 shows a correlation diagram between atmospheric wet-bulb temperature and SSC.
As the atmospheric wet-bulb temperature rises, the steam flow rate required to generate 1kWh increases, and due to this relationship, it remains within a certain range as shown in the figure.
If the correlation breaks down and deviates upward from a certain range, it can be evaluated that there is an abnormality in some system or equipment, and if it deviates downward, a malfunction of the measuring instrument is suspected.

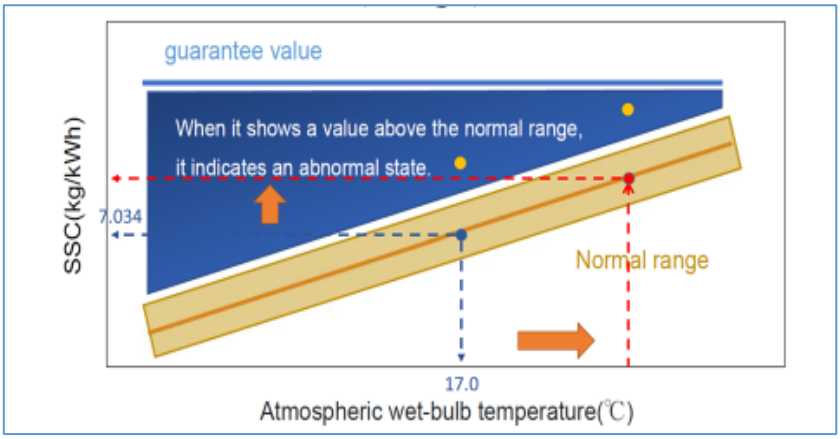


Figure 3-5 Correlation diagram between atmospheric wet-bulb temperature and SSC (image)

3.4.2 Evaluation of each state of cooling tower - condenser - turbine

If an abnormality is found in the correlation diagram between the atmospheric wet-bulb temperature and SSC in Figure 3-5, it is necessary to evaluate which system the abnormality is occurring in. Therefore, the data collected in the same period as the data in Figure 3-5 is divided into three systems for evaluation.
Each system is related, and in Figure 3-6, it is possible to grasp whether the state, "(starting point) atmospheric wet-bulb temperature → cooling tower outlet circulating water temperature → condenser vacuum level → generator output (end point)", is normal by looking at it with the following order, starting from the atmospheric wet-bulb temperature as shown by the blue line.

<The order to look at the figures>
Lower left figure (cooling tower performance: correlation diagram between atmospheric wet bulb temperature and cooling tower outlet circulating water temperature) → **Lower right figure** (condenser performance: correlation diagram between cooling tower outlet circulating water temperature and condenser vacuum level) → **Upper right figure** (turbine performance: correlation

diagram between condenser vacuum level and generator output)

If the operating point is plotted at the different point as the one in the normal state in each correlation diagram, it can be evaluated that there is an event that the performance deteriorates in the system (cooling tower or condenser or turbine) related to the correlation diagram.
The case of Figure 3-6 shows a situation in which the performance of the cooling tower has deteriorated. As shown by the broken line in red, the current operating point is plotted on the normal operation data in the lower right figure showing the performance of the condenser and the upper right figure showing the performance of the turbine. However, in the lower left figure showing the performance of the cooling tower, the current operating point is plotted at the point higher than the normal condenser inlet temperature at the same atmospheric wet-bulb temperature. It indicates that the performance of the cooling tower deteriorates.

[Evaluation procedure]
(1) Set the same conditions (steam pressure and flow rate in a certain range)
(2) Create three correlation diagrams with operation data for a certain period in the normal state
(3) Expand the operation data which needs to be evaluated on the correlation diagrams of (2) (The operation data under the same conditions as (2))
(4) Evaluate whether there is a significant deviation between the operation data in the normal state and the operation data which needs to be evaluated
(5) If there is a significant deviation, it is judged that performance deterioration has occurred in one of the applicable systems (cooling tower, condenser or turbine) or multiple places
(6) Investigate the cause and consider countermeasures by troubleshooting

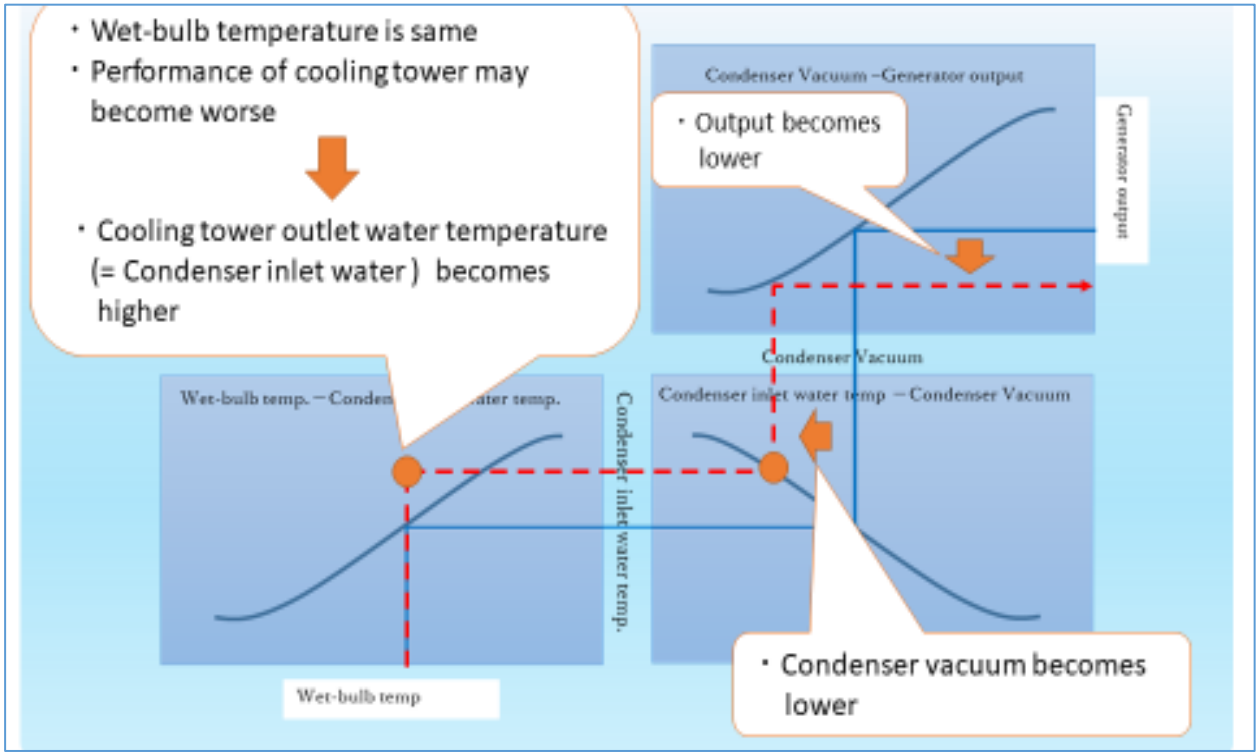


Figure 3-6 Correlation diagram for evaluation of each state of cooling tower - condenser-turbine (image)

3.5 Case study

In Figure 3-7, the relationship between the atmospheric wet-bulb temperature on the upper left and the SSC is shown. Comparing the design value (7.23t / h / Mwh) for the atmospheric wet-bulb temperature of 14.3 ° C and the current operating value (7.56t), the plant performance is degraded by about 4.6%.
The 4.6% performance degradation is equivalent to about 1.6 MW in power generation output, and it is necessary to take immediate action.
Organize the conditions as shown in Figure 3-7, create a correlation diagram for each and monitor the performance of the entire power plant in ① as shown in the figure below. If an abnormality is found as shown in ① below, it is possible to understand where the cause is and how much the generator output drops in this abnormal state by looking at the figures ② to ④. The correlation diagram is organized as follows; the upper left figure①: the main evaluation diagram of the entire plant, the lower left figure②: cooling tower performance evaluation diagram, the lower right figure③: condenser performance evaluation diagram, and the upper right figure④: turbine performance evaluation diagram.

Table 3-1 Olkaria-II No.3 unit Operation data for performance evaluation (comparison between design value and current value)

Olkaria-Ⅱ No.3unit	Generation output (MW)		Wet Bulb Temperature (℃)	Main steam flow rate (t/h)	Main steam pressure (bar.abs)	Steam chamber flow rate (t/h)	Steam chamber pressure (bar.abs)	Condenser pressure (bar.abs)	Cooling tower outlet temperature (℃)	Cooling tower inlet temperature (℃)	Cooling tower inlet / outlet temperature difference (℃)	SSC (t/h/Mwh)
Heat and Mass balance	100%	35.326	8.0	260.144t/h	5.00	253.904	4.80	0.072	18.0	34.2	16.2	7.19
	100%	35.140	14.3	260.114t/h	5.00	253.904	4.80	0.075	21.3	37.3	16.0	7.23
	80%	28.489	14.3	217.185t/h	5.00	210.850	4.80	0.069	20.7	34.4	13.7	7.40
270t/h : Current Operating Parameters as of 08/08/2020	100%	35.7	15.0	276t/h	5.74	270	5.16	0.12	29.1	49.0	19.9	7.56

Assumed value

(Main steam flow rate)-6t/h(for Ejector)

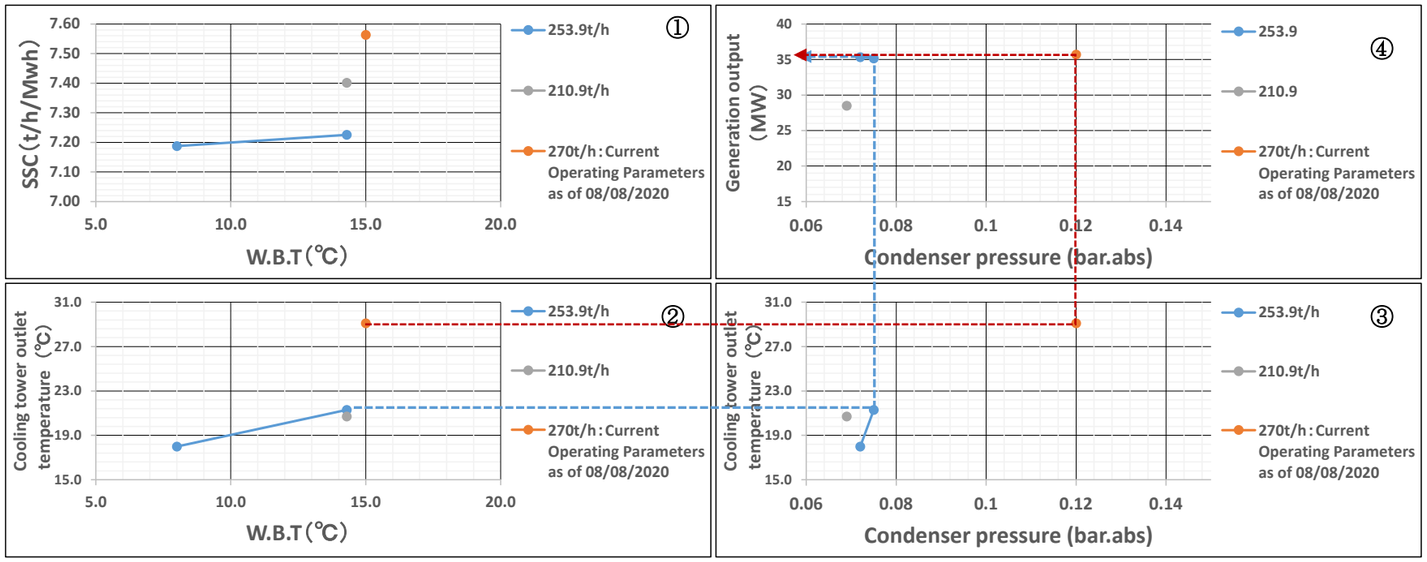


Figure 3-7 Correlation diagram for plant performance management

4 Troubleshooting using FTA (Fault Tree Analysis)

4.1 Troubleshooting and its significance

Troubleshooting is generally defined as "solving a problem. and repairing a failed machine."
When a problem occurs while operating a power plant, it is understood as troubleshooting to identify the equipment or system where the problem occurred, investigate the cause of the problem, and consider solutions and alternatives.

However, the question remains whether this is right.
Have you ever had the following experience at work?

(1) The cause was found and countermeasures were taken, but the same trouble reoccurred at the same location.
(2) The same trouble occurred at another power plant.
(3) It is doubtful whether it is a measure to solve the cause of the trouble.
(4) Even if similar troubles occurred, the same examination was carried out from the beginning.

If you have the above experience, what is wrong with the troubleshooting you have done?
In (1), it is "insufficient prevention of reoccurrence". It is necessary to consider not only the solution of the trouble in front of us, but also the mechanism to prevent the same trouble from occurring.
In (2), there is a “lack of information sharing” with other power plants where similar troubles may occur. The same trouble can be avoided by sharing the mechanism up to the prevention measures to the power plant.
In (3), the arrangement of all the events related to the trouble and the investigation of the possible causes are insufficient, which is "insufficient arrangement of the events and investigation of the cause". It is understood that investigating the cause is an important factor that leads to countermeasures, but it is important how far the cause has been investigated, and "calling attention to the person in charge of business" is not sufficient. Recognizing that "trouble may occur even if people pay attention", it is important to consider a "mechanism" that does not cause trouble even if people neglect to pay attention.
In (4), the cause is that the troubleshooting carried out by some people is only the knowledge and experience of a specific individual, and is not saved or shared due to the transfer or retirement of a specific person. For troubleshooting, it is necessary to consider with related persons including young engineers and experienced engineers. And it is necessary to save the result of the examination and to have a mechanism that allows us to search immediately when similar troubles occur in the future.

This section is to understand the basic thinking flow of troubleshooting using FTA (Fault tree analysis), while recognizing the above points.

4.2 FTA

In troubleshooting, a method of analyzing systematically using FTA (Fault Tree Analysis) is often used for the examination, and the examination by FTA will be explained here.
FTA organizes the current situation related to the trouble that has occurred, and targets the facts that are the gap between the ideal state and the current situation, and is required to grasp the problems in order and without omission. Ultimately, this is a study method that leads to not only temporary measures but also measures that can be stopped.
Furthermore, FTA study is expected to have the effect of not only dealing with the root cause of the

problem and preventing reoccurrence, but also learning the reasoning of things, gaining new awareness, and fostering a sense of unity in the workplace through analysis.
FTA referred to here may be understood as RCA (Root Cause Analysis).

In FTA, it is necessary to understand the following eight points, and ④, ⑤, and ⑥ are especially important.

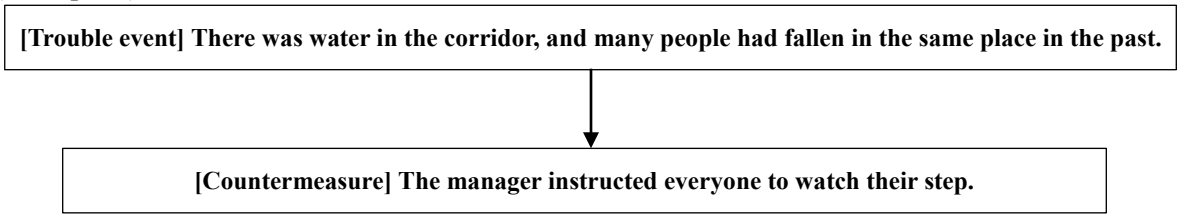
① The leader does not rely solely on the experience and thoughts of himself or a specific person, but proceeds so that all participants give their opinions. (Technology inheritance)
② In FTA, use concise expressions.
③ When examining the cause, if there is no gap in the "current situation" compared to the "function and performance that the device originally has", the examination of the cause is completed as "OK". Similarly, if the countermeasures cannot be dealt with in terms of operation, the examination will be completed with "OK".
④ There is not only one cause and countermeasure. (Prevention measures)
⑤ Repeat "why" and pursue "concrete actions" to solve the problem. (Prevention measures)
⑥ Provide information to the people involved in other plants that have similar equipment where the trouble occurred. (Information sharing)
⑦ Save the created FTA diagram in the database and refer to it if a similar event occurs.
⑧ If the cause cannot be identified due to a trouble case, it is necessary to think about making a hypothesis and verifying it.

4.3 FTA use cases

Here are some examples that considers eight points to be understood in FTA mentioned above.

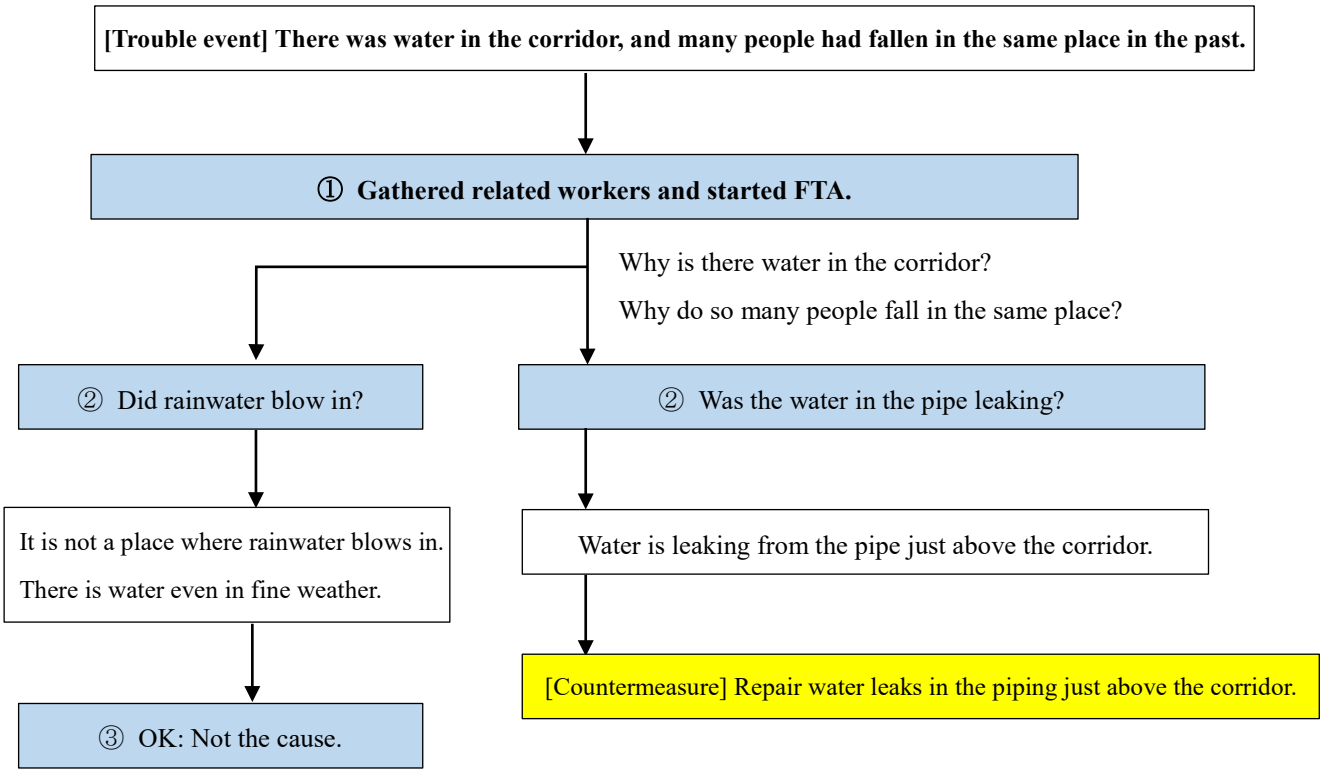
An example of FTA implementation is shown in Example 1, but it is insufficient consideration. Where is the problem?

(Example 1)



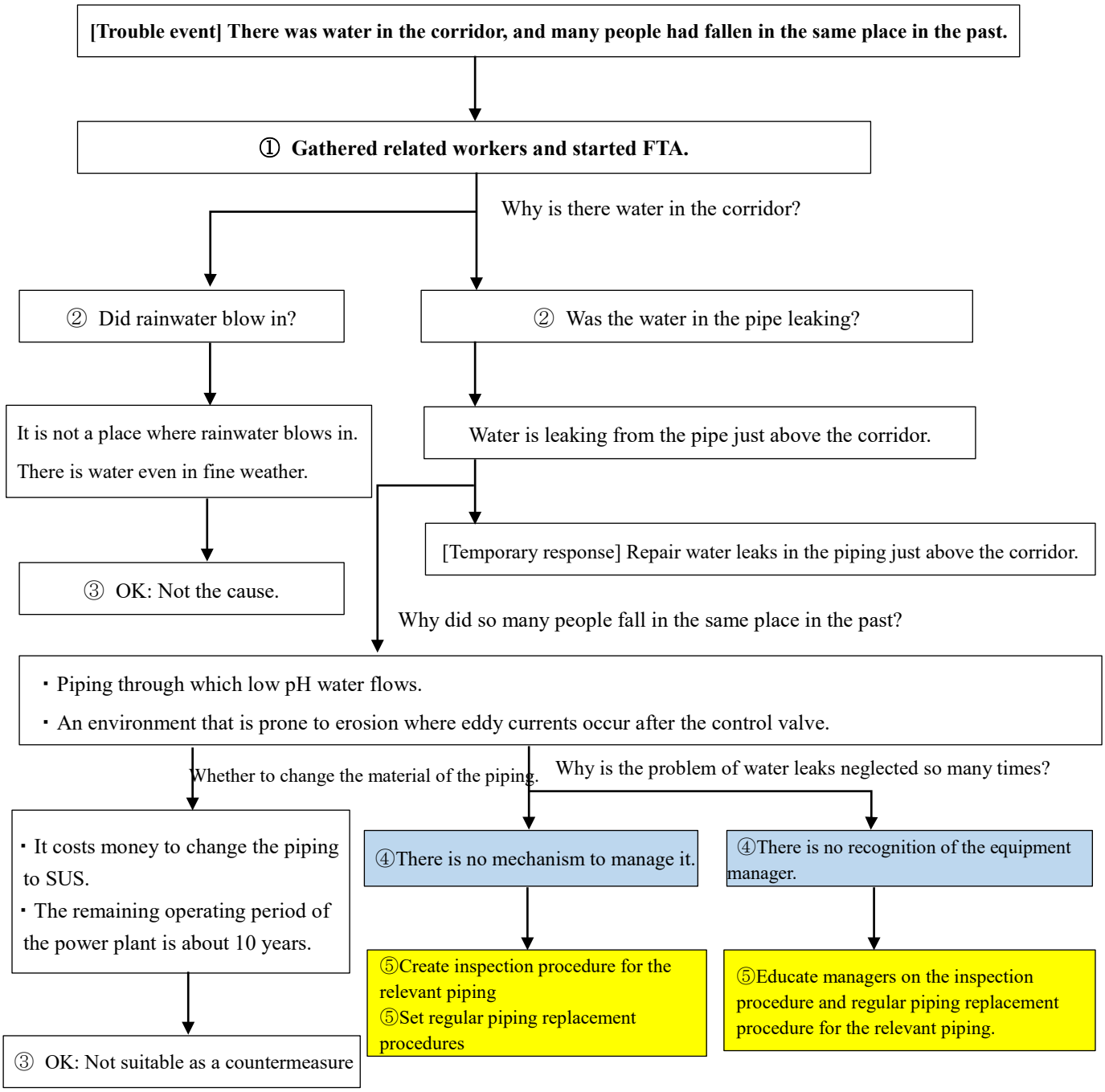
[Problem]
The countermeasure doesn’t meet most of the eight points mentioned above.

(Example 2)



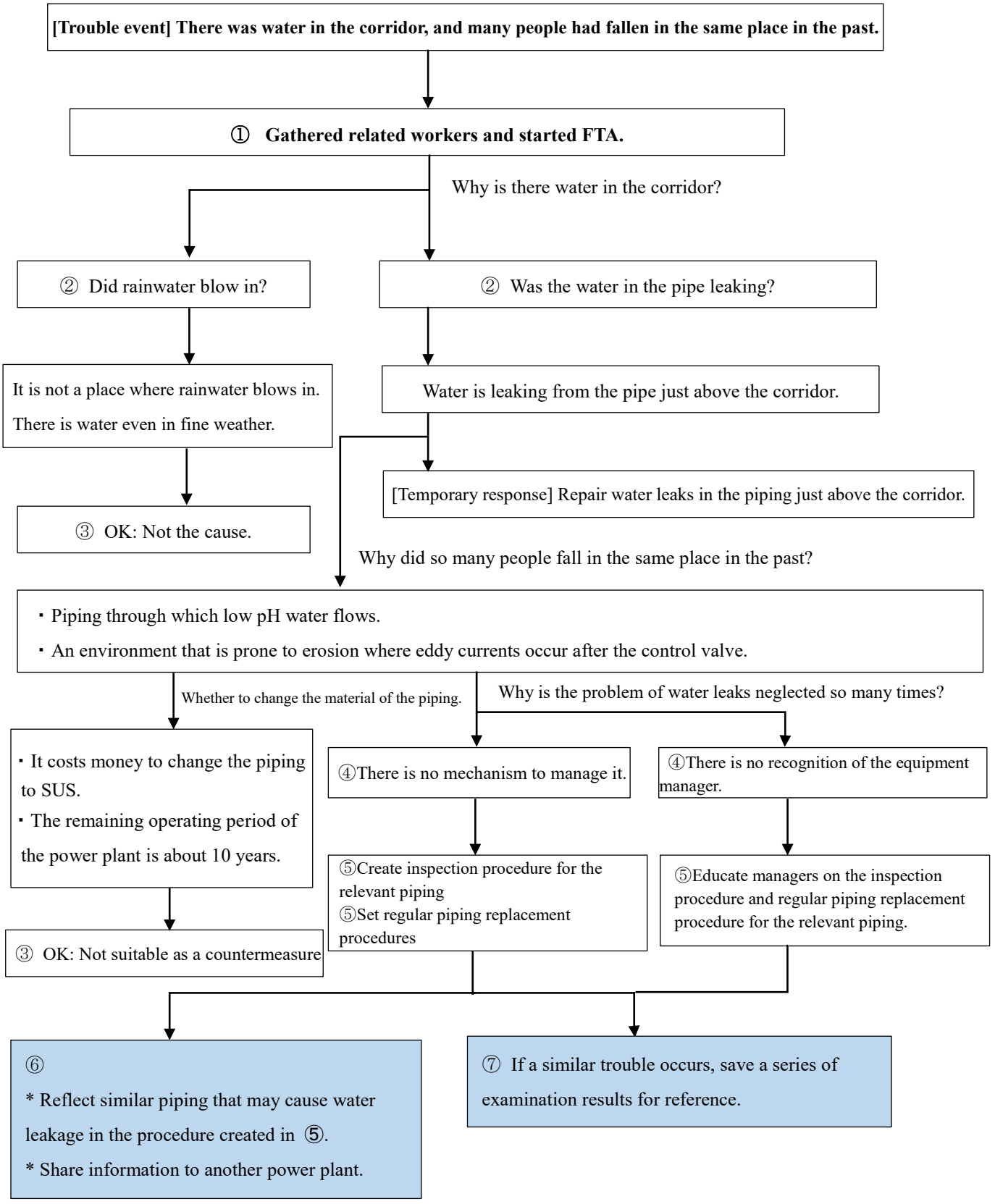
By the way, is FTA completed in Example 2? In Example 2, ① to ③ of the eight points are fulfilled, but ④ to ⑧ are not fulfilled. In particular, just taking the countermeasure "repair water leaks in the pipe just above the corridor" may cause some people to fall for the same reason. It is necessary to consider until it becomes a countermeasure when the same trouble reoccurs.

(Example 3)



By the way, is FTA completed in Example 3? In Example 3, ① to ⑤ of the eight points are fulfilled, but ⑥ to ⑧ are not fulfilled. If there are other pipes that may cause water leakage, it is necessary to consider making similar pipes subject to inspection or regular replacement. It is also necessary to share information when there is a possibility of similar troubles at another power plant.

(Example 4)


[Trouble event] There was water in the corridor, and many people had fallen in the same place in the past.
① Gathered related workers and started FTA.
Why is there water in the corridor?
② Did rainwater blow in?
② Was the water in the pipe leaking?
It is not a place where rainwater blows in.
There is water even in fine weather.
Water is leaking from the pipe just above the corridor.
[Temporary response] Repair water leaks in the piping just above the corridor.
③ OK: Not the cause.
Why did so many people fall in the same place in the past?
・Piping through which low pH water flows.
・An environment that is prone to erosion where eddy currents occur after the control valve.
Whether to change the material of the piping.
Why is the problem of water leaks neglected so many times?
・It costs money to change the piping to SUS.
・The remaining operating period of the power plant is about 10 years.
④There is no mechanism to manage it.
④There is no recognition of the equipment manager.
⑤Create inspection procedure for the relevant piping
⑤Set regular piping replacement procedures
⑤Educate managers on the inspection procedure and regular piping replacement procedure for the relevant piping.
③ OK: Not suitable as a countermeasure
⑥
* Reflect similar piping that may cause water leakage in the procedure created in ⑤.
* Share information to another power plant.
⑦ If a similar trouble occurs, save a series of examination results for reference.

Through the above examination, a series of FTA is completed.
It should also be recognized that "⑧ If the cause cannot be identified due to a trouble case, it is necessary to think about making a hypothesis and verifying it."

5 Maintenance process flow

5.1 Significance of maintenance

High credibility of equipment at power plant has been accomplished because of handling a various trouble experiences so far and a pile of proper processing.

Also, thanks to sophisticated preventive maintenance and equipment diagnosis, power plant can realize the extension of equipment lifetime and efficient operation and cost reduction.

In addition, accumulating and applying to these skills greatly contribute not only engineer's training but also improving their skills and ability.

Through aging the equipment, it is surely essential to take the skills over successors leading in the next generation in order to keep high credibility of equipment.

5.2 Preventive maintenance

5.2.1 Purpose of preventive maintenance

To do stable power supply and cost reduction at the same time by securing equipment safety and power security by preventing unplanned plant outage.

Maintenance is divided into preventive maintenance and breakdown maintenance.

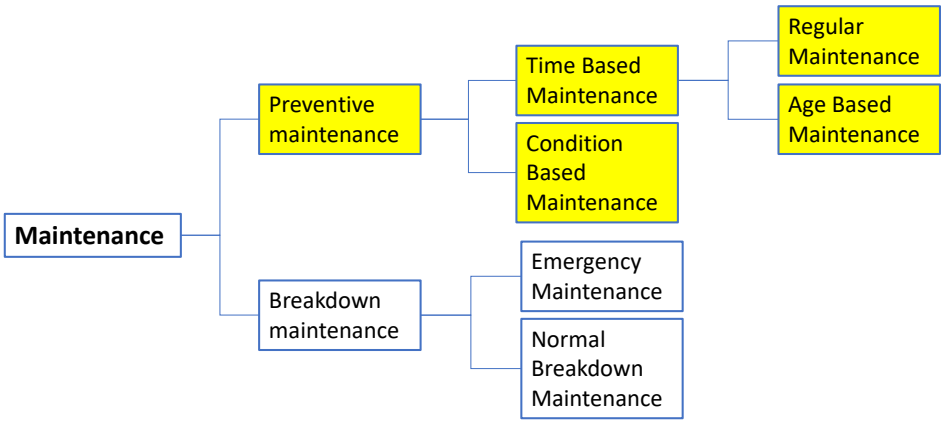


Figure 5-1 Maintenance

Maintenance is divided into preventive maintenance and breakdown maintenance.

There are two types in preventive maintenance, the one is TBM (Time Based Maintenance: to conduct the maintenance by planning a time schedule based on operation time) and the other one is CBM (Condition Based Maintenance: to conduct the maintenance based on the result of equipment diagnosis;).

Each maintenance method is to be considered the importance of facilities, progress of deterioration, the possibility to cause troubles and the impact by occurring the troubles, and the expense for the maintenance measure. After that, the appropriate method will be selected corresponding the characteristic in each equipment.

5.2.2 Preventive maintenance

To keep generating electricity extremely it needs to make an effort to minimize power plant outage.

Basically, the equipment works in good condition by replacing when recommended by manufacturer, but the equipment may break down lightly while operating. On this situation, maintenance group need to consider whether repairment can be done without unit shutdown or the equipment can keep operation until the next regular maintenance without repairing.

Maintenance group must judge the appropriate timing and the duration of repairing accurately considering the experience of malfunction while operating normally in order to repair surely.

Based on the result of repairing conducted in normal operating, a cycle of inspection or replacement recommended by manufacturer and a diagnosis of the rest of lifetime, the repairing plan will be formulated that enables units to minimize power plant outage, the equipment keeps working in good condition for long period.

5.2.3 Formulating the appropriate maintenance planning

There are some pending issues to consider in the overhaul maintenance, which are the equipment repaired temporarily while operating and the leaving matter on the previous regular maintenance should be repaired. All the pending issues should resolve certainly in the overhaul or regular maintenance, the repairment should carry out along with the critical working because the period of maintenance becomes longer and capacity availability rate may lower.

5.3 Maintenance process flow

5.3.1 Maintenance process flow

To keep power plants generating power at the highest level, it is essential for us to maximize the equipment's efficiency and to minimize outage frequency. Therefore, maintenance group are required to manage performances of the equipment appropriately. We are working on detecting defection as early as possible, and making and executing appropriate maintenance plans based on the accumulated data.

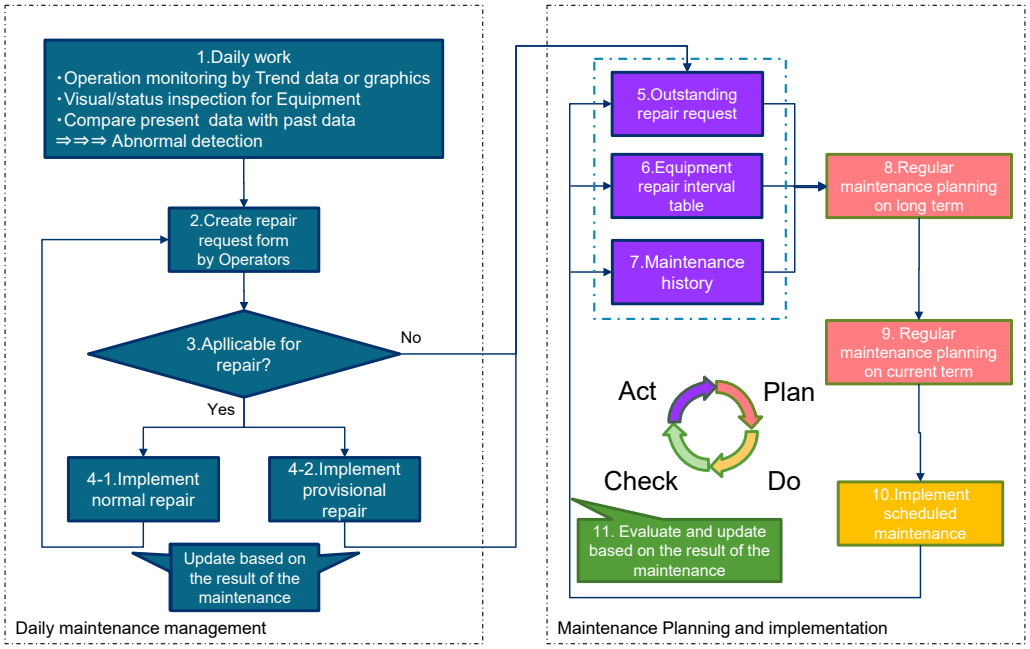


Figure 5-2 Maintenance process flow

<Maintenance process flow>

1 “Daily work”

In daily work, operator monitor the unit condition through trend data or graphics from point of equipment performance management and predictive management.

Operator and maintenance engineer inspect if there is some defection on performances of equipment.

2 “Create repair request form by Operator”

According to the inspection, when they find the defection and it needs repairing, operator creates a maintenance request form and applies for maintenance group.

3 “Applicable for repair?”

Receiving the maintenance request form, the members in maintenance group judge whether they can repair while operating units.

If the defection point can’t be repaired which operation or does not need to be repaired, they keep a record as an incomplete cases of maintenance request Box number 5.

4 “Repair”

4.1 “Implement normal repair”

If the maintenance group judges repair is possible, operator isolates and the maintenance members start the repair after they receive a permit to work from operator.

4.2 “Implement provisional repair”

To complete the repair, they carry out a temporary repair so as not to get the current state worse until next regular maintenance if the unit needs plant outage.

When the temporary repair is carried out, they keep a record as the pending work in the repair request Box number 5.

5 “Outstanding repair request” is issue which may be a large impact on the power plant operation in the pending issues.

6 “Equipment replace interval table” is interval table which is planned based on the track records and manufacturer’s recommendation.

7 “Maintenance history” is that the track records or pending issues at the past regular inspection.

8 “Regular maintenance planning on long term”

Maintenance engineer reflect three items which are box number 5,6 and 7 in the maintenance plan of annual and overhaul, and complete maintenance planning for medium- long term

9 “Regular maintenance planning on current term”

Maintenance engineer put together the regular repair contents on the current term of maintenance plan box number 8 which has been formulated.

10 “Implement scheduled maintenance”

They carry out annual or overhaul maintenance based on the contents in the regular maintenance of current term.

11 “Evaluate and Update based on the result of the maintenance”

We deal with the pending items in repair requests and close it.

We reflect the actual results in the equipment interval table and sort the maintenance history by complete items or pending items. Finally, we finish the update.

5.3.2 PDCA cycle method

The PDCA cycle is a method of continuously improving managements such as production control and quality control by repeating Plan, Do, Check, and Action. Just as a circle has no end, the PDCA cycle should be repeated again and again for continuous improvement.

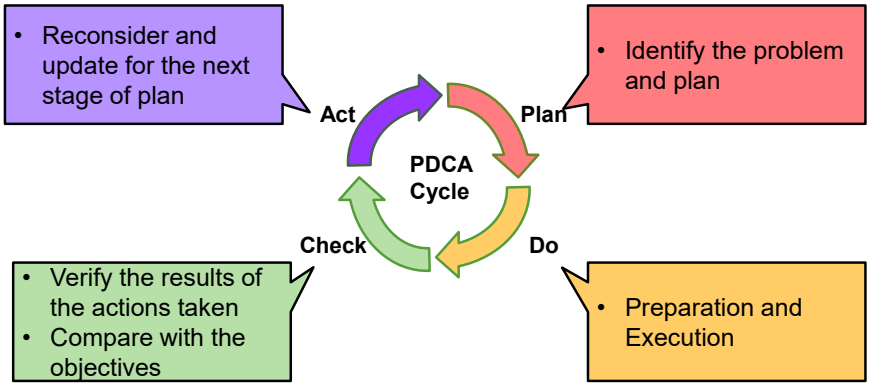


Figure 5-3 PDCA cycle

Plan : Stage of creating a business plan. First, you collect the problems and pending issues, come up with solutions, and make a plan.

Do : Stage of executing the Plan which is made at the P of PDCA.

Check: Stage of evaluating the result of the D of PDCA.

Act : Stage of reconstructing the maintenance materials based on the result of C of PDCA.

Annex 1

Project for Strengthening Operation and Maintenance
Capacity of Olkaria Geothermal Power Stations
Using IoT Technology

Repair Procedure Manual

（Mechanical）

March 2021

Japan International Cooperation Agency (JICA)

JICA Experts

（Kyushu Electric Power Co. Inc.,

West Japan Engineering Consultants, Inc.）

Steam turbine

Plant/Unit	KenGen Olkaria Geothermal Power Plant *xx* Unit *xx*	How to fill in 1 In the HP (hold point) classification column, when "Items for which confirmation is completed and proceed to the next process", enter ○. 2 Enter B1 to B3 (designated 1st to 3rd) for special danger work and Q for quality control work in the HP classification column. 3 In the Record Required column, enter ◎ for inspection / test and ○ for collection of records to be submitted. 4 In the Chief engineer Witness column, enter ○ in the witness schedule. 5 Enter ○ for pass, × for fail in the criteria column.
Equipment	Steam turbine	
Work Items	（1） Owned parts inspection, Test （2） Establish work area （3） Establish managed work zone （4） Removal of outer garment and heat insulation	

Plan			Work Unit	Check Item (Describe required place, model, material, qualification, recording style, etc. after *)	Quality Standard (Including criteria)	Confirmation Record				
HP Classification	Record Required	Chief engineer Witness				Criteria	Chief engineer		Engineer	
						○ ×	Date	Name	Date	Name
			(1) Owned parts inspection, Test			—				
○	◎		a Introducing inspection of own parts		No mistakes the number and specification				—	
				*Check inspection day in a list		—	—	—	—	—
○		○	b Inspecting equipment and devices		No abnormality					
						—	—	—		
						—	—	—		
						—	—	—		
						—	—	—	—	—
			(2) Establish work area			—	—	—	—	—
○		○	a Indicate the work area by every block		Appropriate area					
			・Set staff-only notification			—	—	—		
			・Secure the passage for safety			—	—	—		
						—	—	—	—	—
			(3) Establish managed work zone			—	—	—	—	—
○		○	a Indicate primary operation zone		Appropriate area					
○		○	b Indicate secondary operation zone		Appropriate area					
			・Secure a safe passage ways in the work area			—	—	—	—	—
○	○		※Set up the managed work zone following safety management				—	—		
			area and parts allocated map			—	—	—	—	—
			・ After setting the work zone, fill in the "Tools Bring-in Sheet"			—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
			(4) Removal of outer garment and heat insulation			—	—	—	—	—
			a Remove the Governor side garment			—	—	—		
			b Remove the central part of turbine garment			—	—	—		
			c Remove the heat insulation in the central part of the upper casing			—	—	—		
			d Remove the Generator side garment			—	—	—		
			・Isolate the connection and extinguishing piping			—	—	—	—	—
			・Check if the lifting tools and lifting position are correct			—	—	—	—	—
			・Check that the instrument does not come into contact with the			—	—	—	—	—
			instrument when lifting			—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—

Plant/Unit	KenGen Olkaria Geothermal Power Plant *xx* Unit *xx*	How to fill in 1 In the HP (hold point) classification column, when "Items for which confirmation is completed and proceed to the next process", enter ○. 2 Enter B1 to B3 (designated 1st to 3rd) for special danger work and Q for quality control work in the HP classification column. 3 In the Record Required column, enter ◎ for inspection / test and ○ for collection of records to be submitted. 4 In the Chief engineer Witness column, enter ○ in the witness schedule. 5 Enter ○ for pass, × for fail in the criteria column.
Equipment	Steam turbine	
Work Items	（５） Removal and inspection of Turning gear device （６） Bearing opening and disassembly （７） Separation of coupling	

Plan			Work Unit	Check Item (Describe required place, model, material, qualification, recording style, etc. after *)	Quality Standard (Including criteria)	Confirmation Record				
HP Classification	Record Required	Chief engineer Witness				Criteria	Chief engineer		Engineer	
						○ ×	Date	Name	Date	Name
			(5) Removal and inspection of Turning gear device			—	—	—	—	—
			a Turning device disassembly and maitenance			—	—	—		
○	○		b Measurement and inspection of each part		Within criteria of manufacturer		—	—		
			・Take measures to prevent loss of disassembled parts			—	—	—		
			・Store disassembled parts in designated storage spaces			—	—	—		
○		○	・Cure openings to prevent foreign objects from entering		Equipment internal control standards		—		—	
			・Check for abnomal gear contact, wear and damages			—	—	—		
			・Check for any clogs in the lubrication line			—	—	—		
						—	—	—		
						—	—	—		
						—	—	—	—	—
						—	—	—	—	—
			(6) Bearing opening and disassembly			—	—	—	—	—
○			a Remove the upper bearing #1		No abnormality at White metal		—	—		
○			b Remove the upper bearing #2		No abnormality at White metal		—	—		
○			c Remove the thrust bearing (Drive end side)		No abnormality at White metal		—	—		
○			d Lift the thrust bearing (Non-drive end side)		No abnormality at White metal		—	—		
			e Remove thrust liner			—	—	—		
			・Work carefully because it is easy to slip			—	—	—	—	—
			・Check the contact width of the bearing pressure receiving surface and check for damage			—	—	—	—	—
			・Check for carbon adhering to the lower half-axis cutting comb teeth			—	—	—	—	—
			・Cover bearing box not to have foreign objects and clean			—	—	—	—	—
			・Use a string to prevent forgetting to remove the oil pipe so			—	—	—	—	—
			that foreign matter does not get into the opening.			—	—	—	—	—
			・Cover by rubber sheet not to have flaws on rotor journal			—	—	—	—	—
			and thrust color part			—	—	—	—	—
			・Pay attention to handle with thermocouple			—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
			(7) Separation of coupling			—	—	—	—	—
○			a Loose and remove coupling bolts between turbine and MOP		No abnormality such as damages		—	—		
			b Separate coupling between turbine and MOP			—	—	—		
○			c Loose and remove coupling bolts between turbine and MOP		No abnormality such as damages		—	—		
			d Separate the coupling between the turbine and Gen.			—	—	—		
			・Work carefully because of slipping easily by oil			—	—	—	—	—
			・Cover bearing box not to have foreign objects and clean			—	—	—	—	—
			・Use a string to prevent forgetting to remove the oil pipe so			—	—	—	—	—
			that foreign matter does not get into the opening.			—	—	—	—	—
			・Be careful not to damage instrumentation			—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—

Plant/Unit	KenGen Olkaria Geothermal Power Plant *xx* Unit *xx*
Equipment	Steam turbine
Work Items	（８） Unbolting and remove the casing （９） Upper diaphragm removal （10） turbine rotor removal

How to fill in
1 In the HP (hold point) classification column, when "Items for which confirmation is completed and proceed to the next process", enter ○.
2 Enter B1 to B3 (designated 1st to 3rd) for special danger work and Q for quality control work in the HP classification column.
3 In the Record Required column, enter ◎ for inspection / test and ○ for collection of records to be submitted.
4 In the Chief engineer Witness column, enter ○ in the witness schedule.
5 Enter ○ for pass, × for fail in the criteria column.

Plan			Work Unit	Check Item (Describe required place, model, material, qualification, recording style, etc. after *)	Quality Standard (Including criteria)	Confirmation Record				
						Criteria	Chief engineer		Engineer	
HP Classification	Record Required	Chief engineer Witness				○ ×	Date	Name	Date	Name
			(8) Unbolting and remove the casing			—	—	—	—	—
			a Remove heat insulation of the upper casing			—	—	—		
			b Disassemble gland box			—	—	—		
			c Unbolt and remove the upper casing bolts			—	—	—		
B1			d Remove the upper casing			—	—	—		
			・Protect not removed heat insulation not to damage		・解体しない保温は破損防止養生をおこなう。	—	—	—		
			・Work carefully because of slipping easily by oil			—	—	—		
			・Cover bearing box not to have foreign objects and clean			—	—	—		
			・Use a string to prevent forgetting to remove the oil pipe so			—	—	—		
			that foreign matter does not get into the opening.			—	—	—		
			・Be careful not to damage instrumentation			—	—	—		
			・Be careful of wire position when lifting upper casing				—		—	
			and cover at the corner part where wire hits			—	—	—		
			・Place lubricated guide rods when lifting the upper casi			—	—	—		
						—	—	—		
						—	—	—		
						—	—	—		
						—	—	—		
						—	—	—		
						—	—	—		
			(9) Upper diaphragm removal			—				
B1			a Invert upper casing			—				
			b Remove upper diaphragm			—				
			・Check scale deposition				—		—	
			・Nozzle damage, horizontal joint surface erosion, presence or absence of defect indication pattern			—	—	—		
			・Check the erosion of the key and the upper part of the keyway			—	—	—		
			・Check erosion,abrasion and bentness at labyrinth, and corrosionbny steam			—	—	—		
			・Confirmation of packing gap measurement record			—	—	—	—	—
			（Check for wear and reduced turbine efficiency）			—	—	—		
			・Erosion of the static blade and horizontal joint surface, and the			—	—	—		
			presence or absence of defect indication patterns			—	—	—		
						—				
						—				
						—	—	—		
			(10) turbine rotor removal			—	—	—	—	—
			a Check the rotor level			—	—	—		
B1			b Remove the rotor			—	—	—		
			・Check lifting position of instrument			—	—	—		
			・Check cracks, erosion			—	—	—		
			・Allocate observers at four direction because it is a narr			—	—	—		
			between turbine rotor and casing			—	—	—		
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—

Plant/Unit	KenGen Olkaria Geothermal Power Plant *xx* Unit *xx*	How to fill in 1 In the HP (hold point) classification column, when "Items for which confirmation is completed and proceed to the next process", enter ○. 2 Enter B1 to B3 (designated 1st to 3rd) for special danger work and Q for quality control work in the HP classification column. 3 In the Record Required column, enter ◎ for inspection / test and ○ for collection of records to be submitted. 4 In the Chief engineer Witness column, enter ○ in the witness schedule. 5 Enter ○ for pass, × for fail in the criteria column.
Equipment	Steam turbine	
Work Items	（11） Removal of lower diaphragm and bearing （12） Parts care, measurement, PT inspection （13） Insert lower diaphragm and bearing	

Plan			Work Unit	Check Item (Describe required place, model, material, qualification, recording style, etc. after *)	Quality Standard (Including criteria)	Confirmation Record				
HP Classification	Record Required	Chief engineer Witness				Criteria	Chief engineer		Engineer	
						○ ×	Date	Name	Date	Name
			(11) Removal of lower diaphragm and bearing			—	—	—		
			a Remove the lower diaphragm			—	—	—		
○			b Remove #1 lower bearing		No abnormality at White metal		—	—		
○			c Remove #2 lower bearing		No abnormality at White metal		—	—		
			・Cover bearing metal by rubber sheets not to damage it				—		—	
			・Cover bearing box not to have foreign objects and clean				—		—	
			・Metal damage, check the contact width of the bearing pressure receiving surface			—	—	—		
			・Work carefully because of slipping easily by oil			—	—	—		
			・Check erosion, defection and corrosion of each part, and Weld drain cut			—	—	—		
						—	—	—		
						—	—	—		
						—	—	—		
						—	—	—	—	—
			(12) Parts care, measurement, PT inspection			—	—	—		
			a Care each part			—	—	—		
○	○	○	b Measure each part		Within criteria of manufacturer		—		—	
○	◎	○	c Penetrant Test (PT) of each part		No defection		—		—	
			・Show the sort of parts and have member management not to lose parts			—	—	—		
			・Use calibration device after checking base point whether it is calibrated			—	—	—		
			・Care elaboratively each parts, and clean and organaize the workplace			—	—	—		
						—	—	—		
						—	—	—		
						—	—	—		
						—	—	—		
						—	—	—		
						—	—	—		
						—	—	—	—	—
			(13) Insert lower diaphragm and bearing			—	—	—	—	—
			a Apply mold release coating to the diaphragm			—	—	—		
			b Insert lower diaphragm			—	—	—		
○			c Insert #1 lower bearing		No abnormality		—	—		
○			d Insert #2 lower bearing		No abnormality		—	—		
			・Cover bearing metal by rubber sheets not to damage it				—		—	
			・Cover bearing box not to have foreign objects and clean			—	—	—		
			・Be careful of the fitting of parts and work carefully			—	—	—		
			・Work carefully because of slipping easily by oil			—	—	—		
			・Check that the partition plate key is fitted, and check that the gap between the holding bolt threads is not large.			—	—	—	—	—
						—	—	—		
						—	—	—		
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—

Plant/Unit	KenGen Olkaria Geothermal Power Plant *xx* Unit *xx*	How to fill in 1 In the HP (hold point) classification column, when "Items for which confirmation is completed and proceed to the next process", enter ○. 2 Enter B1 to B3 (designated 1st to 3rd) for special danger work and Q for quality control work in the HP classification column. 3 In the Record Required column, enter ◎ for inspection / test and ○ for collection of records to be submitted. 4 In the Chief engineer Witness column, enter ○ in the witness schedule. 5 Enter ○ for pass, × for fail in the criteria column.
Equipment	Steam turbine	
Work Items	（14） Insert the turbine rotor （15） Insert upper diaphragm （16） Insert the upper casing and bolting	

Plan			Work Unit	Check Item (Describe required place, model, material, qualification, recording style, etc. after *)	Quality Standard (Including criteria)	Confirmation Record				
HP Classification	Record Required	Chief engineer Witness				Criteria	Chief engineer		Engineer	
						○ ×	Date	Name	Date	Name
B1			**(14) Insert the turbine rotor**			—	—	—	—	—
			a Check the rotor level			—	—	—		
Q			b Insert the turbine rotor		Do not hurt rotor by touching somewhere		—	—		
			・Check lifting position of instrument			—	—	—		
			・Define the role of each engineer and lift in with instruction from			—	—	—		
			director			—	—	—		
			・Allocate observers at four direction because it is a narrow space				—		—	
			between turbine rotor and casing			—	—	—		
			・Check covers left and foreign objects inside			—	—	—	—	—
			(15) Insert upper diaphragm			—	—	—		
B1			a Turn back upper casing			—	—	—		
			b Apply mold release coating to the diaphragm			—	—	—		
			c Insert upper diaphragm			—	—	—		
			・When turn back upper casing, move out the people around casing and				—		—	
			cover the part where the sling hits stuffs			—	—	—		
			・Check that the partition plate key is fitted, and check			—	—	—		
			that the gap between the holding bolt threads is not large.			—	—	—		
						—	—	—		
						—	—	—		
						—	—	—		
						—	—	—	—	—
B1			**(16) Insert the upper casing and bolting**			—	—	—	—	—
Q			a Insert the upper casing		No contamination inside of casing		—	—		
			b Tighten flat bolt to the upper casing			—	—	—		
			c Assemle the gland box			—	—	—		
			d Restore heat insulation of the upper casing			—	—	—		
			・Define the role of each engineer and lift in with instruction from			—	—	—		
			director			—	—	—		
			・Allocate observers at four direction because it is a narrow space			—	—	—		
			between turbine rotor and casing			—	—	—		
			・Check foreign objects on the bottom horizontal surface of the casing			—	—	—		
							—		—	
						—	—	—		

Plant/Unit	KenGen Olkaria Geothermal Power Plant *xx* Unit *xx*	How to fill in 1 In the HP (hold point) classification column, when "Items for which confirmation is completed and proceed to the next process", enter ○. 2 Enter B1 to B3 (designated 1st to 3rd) for special danger work and Q for quality control work in the HP classification column. 3 In the Record Required column, enter ◎ for inspection / test and ○ for collection of records to be submitted. 4 In the Chief engineer Witness column, enter ○ in the witness schedule. 5 Enter ○ for pass, × for fail in the criteria column.
Equipment	Steam turbine	
Work Items	（17） Bearing assembly （18） Assembly and restoring turning device （19） Centering, coupling combining	

Plan			Work Unit	Check Item (Describe required place, model, material, qualification, recording style, etc. after *)	Quality Standard (Including criteria)	Confirmation Record				
HP Classification	Record Required	Chief engineer Witness				Criteria	Chief engineer		Engineer	
						○ ×	Date	Name	Date	Name
			（17）Bearing assembly			—	—	—	—	—
○			a Insert #1 upper bearing		No abnormality such as damages		—	—		
○			b Insert #2 upper bearing		No abnormality such as damages		—	—		
○			c Insert the thrust bearing （Drive end side)		No abnormality such as damages		—	—		
○			d Insert the thrust bearing （Non-drive end side)		No abnormality such as damages		—	—		
			e Install the thrust liner			—	—	—		
			・Work carefully because of slipping easily by oil			—	—	—		
			・Cover bearing box not to have foreign objects and clean				—		—	
			・Check the cover left			—	—	—		
						—	—	—		
						—	—	—		
						—	—	—		
						—	—	—		
						—	—	—		
						—	—	—	—	—
			（18）Assembly and restoring turning device			—	—	—	—	—
			a Assemble turning device			—	—	—		
○	◎	○	b Restore turning device		Within criteria of manufacturer		—		—	
			・Check the cover left			—	—	—		
			・Pay attention to the fit of the gear and hang it			—	—	—		
						—	—	—		
						—	—	—		
							—		—	
						—	—	—		
						—	—	—		
						—	—	—		
						—	—	—		
						—	—	—	—	—
			（19）Centering, coupling combining			—	—	—	—	—
○	○	○	a Perform centering between turbine and MOP		Within criteria		—		—	
			b Connect the coupling between tubine and MOP			—	—	—		
			c Tighen coupling bolts between turbine and MOP			—	—	—		
○	○	○	d Perform centering between turbine and GEN		Within criteria		—		—	
			e Connect the coupling between tubine and GEN			—	—	—		
			f Tighen coupling bolts between turbine and GEN			—	—	—		
			・Work carefully because of slipping easily by oil			—	—	—		
			・Cover bearing box not to have foreign objects and clean			—	—	—		
			・Work with mutual communication so as not to cause accident			—	—	—		
			（The rotor is rotated by the crane when measuring the centering)			—	—	—	—	—
			・Coupling bolts In-low The fitting part is easy to bite, so check for burrs when cleaning.			—	—	—	—	—
						—	—	—	—	—
						—	—	—		
						—	—	—		
						—	—	—		
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—

Plant/Unit	KenGen Olkaria Geothermal Power Plant *xx* Unit *xx*	How to fill in 1 In the HP (hold point) classification column, when "Items for which confirmation is completed and proceed to the next process", enter ○. 2 Enter B1 to B3 (designated 1st to 3rd) for special danger work and Q for quality control work in the HP classification column. 3 In the Record Required column, enter ◎ for inspection / test and ○ for collection of records to be submitted. 4 In the Chief engineer Witness column, enter ○ in the witness schedule. 5 Enter ○ for pass, × for fail in the criteria column.
Equipment	Steam turbine	
Work Items	（20） Restore outer garment and heat insulation、and coating （21） Opening, inspection, cleaning and restoring of oil conditioner (22) Opening, inspection, cleaning and restoring of oil tank	

Plan			Work Unit	Check Item (Describe required place, model, material, qualification, recording style, etc. after *)	Quality Standard (Including criteria)	Confirmation Record				
HP Classification	Record Required	Chief engineer Witness				Criteria	Chief engineer		Engineer	
						○ ×	Date	Name	Date	Name
			(20) Restore outer garment and heat insulation、and coating			—	—	—	—	—
			a Restore GOV side garment			—	—	—		
			b Restore the heat insulation in the central part of the upper casing			—	—	—		
			c Restore the central part of turbine garment			—	—	—		
			d Restore GEN side garment			—	—	—		
			e Have maintanance painting of each part			—	—	—		
			・Pay attention not to bump equipment during mounting			—	—	—		
			・Pay attention to the fitting part			—	—	—		
			・Be careful of step and the opening			—	—	—		
						—	—	—		
						—	—	—	—	—
B1			**(21) Opening, inspection, cleaning and restoring of oil conditioner**			—	—	—	—	—
			a Opening, inner inspection, care and cleaning of oil conditioner			—	—	—	—	—
			b Inspect and care of oil separator			—	—	—		
○			c Replace oil filter		Conpleting all replacement		—	—		
		○	d Restore oil conditioner			—				
			・Work carefully because of slipping easily by oil			—	—	—		
			・Cover oil conditioner not to have foreign objects and clean				—	—		
						—	—	—	—	—
							—		—	
						—	—	—		
						—	—	—		
						—	—	—		
						—	—	—		
						—	—	—	—	—
B1			**(22) Opening, inspection, cleaning and restoring of oil tank**			—	—	—	—	—
			a Open main oil tank			—	—	—		
			b Inspect and clean inside of main oil tank			—	—	—		
○			c Inspect and clean lubricating oil system and strainer of each part		No abnormality such as damages		—	—		
			d Inspect of each joint for lubricating oil system			—	—	—		
		○	e Restore main oil tank			—				
			・Work carefully because of slipping easily by oil				—	—		
			・Cover main oil tank not to have foreign objects and clean			—	—	—		
						—	—	—		
						—	—	—		
						—	—	—		
						—	—	—		
						—	—	—		
						—	—	—		
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—

Plant/Unit	KenGen Olkaria Geothermal Power Plant *xx* Unit *xx*	How to fill in 1 In the HP (hold point) classification column, when "Items for which confirmation is completed and proceed to the next process", enter ○. 2 Enter B1 to B3 (designated 1st to 3rd) for special danger work and Q for quality control work in the HP classification column. 3 In the Record Required column, enter ◎ for inspection / test and ○ for collection of records to be submitted. 4 In the Chief engineer Witness column, enter ○ in the witness schedule. 5 Enter ○ for pass, × for fail in the criteria column.
Equipment	Steam turbine	
Work Items	(23) Disassemly, inspection and restoring oil pumps	

Plan			Work Unit	Check Item (Describe required place, model, material, qualification, recording style, etc. after *)	Quality Standard (Including criteria)	Confirmation Record				
HP Classification	Record Required	Chief engineer Witness				Criteria	Chief engineer		Engineer	
						○ ×	Date	Name	Date	Name
			(23) Disassemly, inspection and restoring oil pumps			—	—	—	—	—
			a Overhaul inspection of auxiliary oil pump			—	—	—		
			1) Disassemble the pump			—	—	—		
○	○	○	2) Inspect, care and measure each part		Within criteria of manufacturer		—		—	
○	◎	○	3) Penetrant Test (PT) of each part		No defection		—		—	
			4) Assemble the pump			—	—	—		
○	◎	○	5) Install the pump and have centering		Within criteria		—		—	
						—	—	—	—	—
			b Overhaul inspection of turning gear oil pump			—	—	—	—	—
			1) Disassemble the pump			—	—	—		
○	○	○	2) Inspect, care and measure each part		Within criteria of manufacturer		—		—	
○	◎	○	3) Penetrant Test (PT) of each part		No defection		—		—	
			4) Assemble the pump			—	—	—		
○	◎	○	5) Install the pump and have centering		Within criteria		—		—	
						—	—	—	—	—
			c Overhaul inspection of emergency oil pump			—	—	—	—	—
			1) Disassemble the pump			—	—	—		
○	○	○	2) Inspect, care and measure each part		Within criteria of manufacturer		—		—	
○	◎	○	3) Penetrant Test (PT) of each part		No defection		—		—	
			4) Assemble the pump			—	—	—		
○	◎	○	5) Install the pump and have centering		Within criteria		—		—	
						—	—	—	—	—
			d Overhaul inspection of inlet and outlet pumps for oil conditioner filter			—	—	—	—	—
			1) Disassemble the pump			—	—	—		
○	○	○	2) Inspect, care and measure each part		Within criteria of manufacturer		—		—	
○	◎	○	3) Penetrant Test (PT) of each part		No defection		—		—	
			4) Assemble the pump			—	—	—		
○	◎	○	5) Install the pump and have centering		Within criteria		—		—	
						—	—	—	—	—
			e Overhaul inspection of dirty oil transfer pumps by			—	—	—	—	—
			1) Disassemble the pump			—	—	—		
○	○	○	2) Inspect, care and measure each part		Within criteria of manufacturer		—		—	
○	◎	○	3) Penetrant Test (PT) of each part		No defection		—		—	
			4) Assemble the pump			—				
○	◎	○	5) Install the pump and have centering		Within criteria		—		—	
						—				
			f Overhaul inspection of dirty oil transfer pumps by DC			—	—	—	—	—
			1) Disassemble the pump			—	—	—		
○	○	○	2) Inspect, care and measure each part		Within criteria of manufacturer		—		—	
○	◎	○	3) Penetrant Test (PT) of each part		No defection		—		—	
			4) Assemble the pump			—				
○	◎	○	5) Install the pump and have centering		Within criteria		—		—	
						—				
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—

Plant/Unit	KenGen Olkaria Geothermal Power Plant *xx* Unit *xx*	How to fill in 1 In the HP (hold point) classification column, when "Items for which confirmation is completed and proceed to the next process", enter ○. 2 Enter B1 to B3 (designated 1st to 3rd) for special danger work and Q for quality control work in the HP classification column. 3 In the Record Required column, enter ◎ for inspection / test and ○ for collection of records to be submitted. 4 In the Chief engineer Witness column, enter ○ in the witness schedule. 5 Enter ○ for pass, × for fail in the criteria column.
Equipment	Steam turbine	
Work Items	(24) Inspection, care of #B oil cooler	

Plan			Work Unit	Check Item (Describe required place, model, material, qualification, recording style, etc. after *)	Quality Standard (Including criteria)	Confirmation Record				
HP Classification	Record Required	Chief engineer Witness				Criteria ○ ×	Chief engineer Date	Chief engineer Name	Engineer Date	Engineer Name
			g Overhaul oil conditionor gas extractor			—	—	—	—	—
			1) Disassemble the pump			—	—	—		
○	○	○	2) Inspect, care and measure each part		Within criteria of manufacturer		—		—	
○	◎	○	3) Penetrant Test (PT) of each part		No defection		—		—	
			4) Assemble the pump			—	—	—	—	
○	◎	○	5) Install the pump and have centering		Within criteria		—		—	
						—	—	—	—	—
			h Overhaul main oil tank gas extractor			—	—	—	—	—
			1) Disassemble the pump			—	—	—		
○	○	○	2) Inspect, care and measure each part		Within criteria of manufacturer		—		—	
○	◎	○	3) Penetrant Test (PT) of each part		No defection		—		—	
			4) Assemble the pump			—	—	—	—	
○	◎	○	5) Install the pump and have centering		Within criteria		—		—	
						—	—	—	—	—
			・Prepare all the replacement parts before disassembly			—	—	—		
			・Work carefully because of slipping easily by oil			—	—	—		
			・Cover the opening not to have foreign objects and clean			—	—	—		
						—	—	—		
						—	—	—		
							—		—	
						—	—	—		
						—	—	—		
						—	—	—		
						—	—	—		
						—	—	—		
						—	—	—	—	—
			(24) Inspection, care of #B oil cooler			—	—	—	—	—
			a Open water room cover			—	—	—		
○			b Inspection, care and cleaning of tube and each part		No abnormality such as leakage		—		—	
		○	c Restore water room cover			—				
			d Inspect and care oil pressure control valve			—	—	—		
○		○	w Leak test		No leaking					
			・Prepare all the replacement parts before disassembly			—	—	—		
			・Cover the opening not to have foreign objects and clean			—	—	—		
							—		—	
						—	—	—		
						—	—	—		
						—	—	—		
						—	—	—		
						—	—	—	—	—
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						—	—	—	—	—
						—	—	—	—	—

Plant/Unit	KenGen Olkaria Geothermal Power Plant *xx* Unit *xx*
Equipment	Steam turbine
Work Items	（25） Release managed work zone （26) Commissioning （27） Final inspection （28） Cleaning

How to fill in
1 In the HP (hold point) classification column, when "Items for which confirmation is completed and proceed to the next process", enter ○.
2 Enter B1 to B3 (designated 1st to 3rd) for special danger work and Q for quality control work in the HP classification column.
3 In the Record Required column, enter ◎ for inspection / test and ○ for collection of records to be submitted.
4 In the Chief engineer Witness column, enter ○ in the witness schedule.
5 Enter ○ for pass, × for fail in the criteria column.

Plan			Work Unit	Check Item (Describe required place, model, material, qualification, recording style, etc. after *)	Quality Standard (Including criteria)	Confirmation Record				
HP Classification	Record Required	Chief engineer Witness				Criteria	Chief engineer		Engineer	
						○ ×	Date	Name	Date	Name
			（25） Release managed work zone			—	—	—	—	—
			a Release designated manged work zone			—	—	—		
						—	—	—		
						—	—	—		
						—	—	—		
						—	—	—		
						—	—	—		
						—	—	—	—	—
			（26) Commissioning			—	—	—	—	—
○		○	a Witness commissioning		No abnormality					
	○		b Record the result of each masurement		Within criteria		—		—	
			・Keep away from rotating equipment not to get involved			—	—	—		
						—	—	—		
						—	—	—		
						—	—	—		
						—	—	—		
			（27）Final inspection			—	—	—	—	—
○	◎		・Implement visual inspection at maintenance points		No abnormality		—	—		
○	◎		・All works completed as planned schedule without any problems		Completed		—	—		
○	◎		・All the required record are kept		Checked final record		—	—		
○		○	・Chief engineer completed checking		No neccesary to point out					
						—	—	—		
			（28）Cleaning			—	—	—	—	—
○			・There's no materials left in work area				—	—		
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—

Turbine main valve

Plant/Unit	KenGen Olkaria Geothermal Power Plant *xx* Unit *xx*
Equipment	Turbine main valve
Work Items	（１） Owned parts inspection, test （２） Establish work area （３） Establish managed work zone

How to fill in
1 In the HP (hold point) classification column, when "Items for which confirmation is completed and proceed to the next process", enter ○.
2 Enter B1 to B3 (designated 1st to 3rd) for special danger work and Q for quality control work in the HP classification column.
3 In the Record Required column, enter ◎ for inspection / test and ○ for collection of records to be submitted.
4 In the Chief engineer Witness column, enter ○ in the witness schedule.
5 Enter ○ for pass, × for fail in the criteria column.

Plan			Work Unit	Check Item (Describe required place, model, material, qualification, recording style, etc. after *)	Quality Standard (Including criteria)	Confirmation Record				
HP Classification	Record Required	Chief engineer Witness				Criteria	Chief engineer		Engineer	
						○ ×	Date	Name	Date	Name
			(1) Owned parts inspection, test			—				
○	◎		a Introducing inspection of own parts		No mistakes the number and specification				—	
				*Check inspection day in a list		—	—	—	—	—
○		○	b Inspecting equipment and devices		No abnormality					
				・in-stock the items of specification		—	—	—		
				・Do not put the product on the floor directly		—	—	—		
						—	—	—		
						—	—	—	—	—
			(2) Establish work area			—	—	—	—	—
○		○	a Indicate the work area by every block		Appropriate area					
				・Set staff-only notification		—	—	—		
				・Secure the passage for safety		—	—	—		
						—	—	—	—	—
						—	—	—	—	—
			(3) Establish managed work zone			—	—	—	—	—
○		○	a Indicate primary operation zone		Appropriate area					
○		○	b Indicate secondary operation zone		Appropriate area					
				・Secure a safe passage ways in the work area		—	—	—	—	—
				・Report when a disaster occurs		—	—	—	—	—
				・ When a trouble happens, suspend it once and discuss with Chief engineer		—	—	—	—	—
				・Contact Chief engineer before working		—	—	—	—	—
○	○			・Set up the managed work zone and manage brought tools			—	—		
				※Set up the managed work zone following safety management		—	—	—	—	—
				area and parts allocated map		—	—	—	—	—
				・ After setting the work zone, fill in the "Tools Bring-in Sheet"		—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—

Plant/Unit	KenGen Olkaria Geothermal Power Plant *xx* Unit *xx*	How to fill in 1 In the HP (hold point) classification column, when "Items for which confirmation is completed and proceed to the next process", enter ○. 2 Enter B1 to B3 (designated 1st to 3rd) for special danger work and Q for quality control work in the HP classification column. 3 In the Record Required column, enter ◎ for inspection / test and ○ for collection of records to be submitted. 4 In the Chief engineer Witness column, enter ○ in the witness schedule. 5 Enter ○ for pass, × for fail in the criteria column.
Equipment	Turbine main valve	
Work Items	（４） Lifting out turbine main steam valve （５） Disassembly, care, assembly of first main steam stop valve (L)	

Plan			Work Unit	Check Item (Describe required place, model, material, qualification, recording style, etc. after *)	Quality Standard (Including criteria)	Confirmation Record				
HP Classification	Record Required	Chief engineer Witness				Criteria	Chief engineer		Engineer	
						○ ×	Date	Name	Date	Name
			(4) Lifting out turbine main steam valve			—	—	—	—	—
			a Remove heat insulation from the valve			—	—	—		
			b Lifting out the first main steam valve (L)			—	—	—		
			1) Remove main steam control valve			—	—	—		
			2) Remove main steam stop valve			—	—	—		
			3) Remove oil hydraulic device of each valve			—	—	—		
			4) Remove pipings around each valve			—	—	—		
			c Lifting out the first main steam valve (R)			—	—	—		
			1) Remove main steam control valve			—	—	—		
			2) Remove main steam stop valve			—	—	—		
			3) Remove oil hydraulic device of each valve			—	—	—		
			4) Remove pipings around each valve			—	—	—		
			d Lifting out the second main steam valve (L)			—	—	—		
			1) Remove main steam control valve			—	—	—		
			2) Remove main steam stop valve			—	—	—		
			3) Remove oil hydraulic device of each valve			—	—	—		
			4) Remove pipings around each valve			—	—	—		
			e Lifting out the second main steam valve (R)			—	—	—		
			1) Remove main steam control valve			—	—	—		
			2) Remove main steam stop valve			—	—	—		
			3) Remove oil hydraulic device of each valve			—	—	—		
			4) Remove pipings around each valve			—	—	—		
			・Cover by cloth not to scatter the left oil to a floor during removing oil piping			—	—	—		
			・Check completion of instruments removal			—	—	—		
			・Make sure to cover the opening part after removing the parts to prevent it from foreign material			—	—	—		
							—		—	
						—	—	—		
						—	—	—		
						—	—	—		
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
			(5) Disassembly, care, assembly of first main steam stop valve (L)			—	—	—	—	—
			a Disassembly, care, assembly			—	—	—		
	○		b Measure each part			—	—	—		
○	◎	○	c Penetrant Test (PT)		Within criteria		—		—	
			・Cover by cloth not to scatter the left oil to a floor during removing oil piping			—	—	—		
			・Check any cracks, corrosion, abrasion and erosion on valve body and valve seat				—	—		
						—	—	—		
			・Measure the valve stem and bush sliding surface and check flaw and abrasion of them				—		—	
						—	—	—		
			・Check the deformation and crack of valve stem and key groove			—	—	—		
						—	—	—		
						—	—	—		

Plant/Unit	KenGen Olkaria Geothermal Power Plant *xx* Unit *xx*
Equipment	Turbine main valve
Work Items	（6） Disassembly, care, assembly of second main steam stop valve (L) （7） Disassembly, care, assembly of first main steam stop valve (R) （8） Disassembly, care, assembly of second main steam stop valve (R) （9） Disassembly, care, assembly of first main steam control valve (L)

How to fill in
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3 In the Record Required column, enter ◎ for inspection / test and ○ for collection of records to be submitted.
4 In the Chief engineer Witness column, enter ○ in the witness schedule.
5 Enter ○ for pass, × for fail in the criteria column.

Plan			Work Unit	Check Item (Describe required place, model, material, qualification, recording style, etc. after *)	Quality Standard (Including criteria)	Confirmation Record				
HP Classification	Record Required	Chief engineer Witness				Criteria	Chief engineer		Engineer	
						○ ×	Date	Name	Date	Name
			(6) Disassembly, care, assembly of second main steam stop valve (L)			—	—	—	—	—
			a Disassembly, care, assembly			—	—	—		
	○		b Measure each part			—	—	—		
○	◎	○	c Penetrant Test (PT)		Within criteria		—		—	
				・Cover by cloth not to scatter the left oil to a floor during removing oil piping		—	—	—		
				・Check any cracks, corrosion, abrasion and erosion on valve body and valve seat		—	—		—	
							—		—	
				・Measure the valve stem and bush sliding surface and check flaw and abrasion of them		—	—	—		
						—	—	—		
				・Check the deformation and crack of valve stem and key groove		—	—	—	—	—
						—	—	—		
						—	—	—		
			(7) Disassembly, care, assembly of first main steam stop valve (R)			—	—	—	—	—
			a Disassembly, care, assembly			—	—	—		
	○		b Measure each part			—	—	—		
○	◎	○	c Penetrant Test (PT)		Within criteria		—		—	
				・Cover by cloth not to scatter the left oil to a floor during removing oil piping		—	—	—		
				・Check any cracks, corrosion, abrasion and erosion on valve body and valve seat			—	—		
							—		—	
				・Measure the valve stem and bush sliding surface and check flaw and abrasion of them		—	—	—		
						—	—	—		
				・Check the deformation and crack of valve stem and key groove		—	—	—		
						—	—	—		
						—	—	—	—	—
			(8) Disassembly, care, assembly of second main steam stop valve (R)			—	—	—	—	—
			a Disassembly, care, assembly			—	—	—		
	○		b Measure each part			—	—	—		
○	◎	○	c Penetrant Test (PT)		Within criteria		—		—	
				・Cover by cloth not to scatter the left oil to a floor during removing oil piping		—	—	—		
				・Check any cracks, corrosion, abrasion and erosion on		—	—	—		
				valve body and valve seat		—	—	—		
				・Measure the valve stem and bush sliding surface and check flaw and abrasion of them			—		—	
						—	—	—		
				・Check the deformation and crack of valve stem and key groove		—	—	—		
						—	—	—		
						—	—	—	—	—
			(9) Disassembly, care, assembly of first main steam control valve (L)			—	—	—	—	—
			a Disassembly, care, assembly			—	—	—		
	○		b Measure each part			—	—	—		
○	◎	○	c Penetrant Test (PT)		Within criteria		—		—	
				・Cover by cloth not to scatter the left oil to a floor during removing oil piping		—	—	—		
				・Check any cracks, corrosion, abrasion and erosion on		—	—	—		
				valve body and valve seat		—	—	—		
				・Measure the valve stem and bush sliding surface and check flaw and abrasion of them			—		—	
						—	—	—		
				・Check the deformation and crack of valve stem and key groove		—	—	—		
				・Check the abnormality such as clogging of grease hole amd oil trench		—	—	—		
						—	—	—		

Plant/Unit	KenGen Olkaria Geothermal Power Plant *xx* Unit *xx*
Equipment	Turbine main valve
Work Items	（１０）Disassembly, care, assembly of second main steam stop valve (L) （１１）Disassembly, care, assembly of first main steam control valve (R) （１２）Disassembly, care, assembly of second main steam control valve (R)

How to fill in
1 In the HP (hold point) classification column, when "Items for which confirmation is completed and proceed to the next process", enter ○.
2 Enter B1 to B3 (designated 1st to 3rd) for special danger work and Q for quality control work in the HP classification column.
3 In the Record Required column, enter ◎ for inspection / test and ○ for collection of records to be submitted.
4 In the Chief engineer Witness column, enter ○ in the witness schedule.
5 Enter ○ for pass, × for fail in the criteria column.

Plan			Work Unit	Check Item (Describe required place, model, material, qualification, recording style, etc. after *)	Quality Standard (Including criteria)	Confirmation Record				
HP Classification	Record Required	Chief engineer Witness				Criteria	Chief engineer		Engineer	
						○ ×	Date	Name	Date	Name
			(10) Disassembly, care, assembly of second main steam stop valve (L)			—	—	—	—	—
			a Disassembly, care, assembly			—	—	—		
	○		b Measure each part			—	—	—		
○	◎	○	c Penetrant Test (PT)		Within criteria		—		—	
				・Cover by cloth not to scatter the left oil to a floor during removing oil piping		—	—	—		
				・Check any cracks, corrosion, abrasion and erosion on valve body and valve seat			—	—		
						—	—	—		
				・Measure the valve stem and bush sliding surface and check flaw and abrasion of them			—		—	
						—	—	—		
				・Check the deformation and crack of valve stem and key groove		—	—	—		
				・Check the abnormality such as clogging of grease hole amd oil trench		—	—	—		
						—	—	—		
						—	—	—	—	—
			(11) Disassembly, care, assembly of first main steam control valve (R)			—	—	—	—	—
			a Disassembly, care, assembly			—	—	—		
	○		b Measure each part			—	—	—	—	
○	◎	○	c Penetrant Test (PT)		Within criteria	—	—	—		
				・Cover by cloth not to scatter the left oil to a floor during removing oil piping		—	—	—		
				・Check any cracks, corrosion, abrasion and erosion on valve body and valve seat			—	—		
						—	—	—		
				・Measure the valve stem and bush sliding surface and check flaw and abrasion of them			—		—	
						—	—	—		
				・Check the deformation and crack of valve stem and key groove		—	—	—		
				・Check the abnormality such as clogging of grease hole amd oil trench		—	—	—		
						—	—	—		
						—	—	—	—	—
			(12) Disassembly, care, assembly of second main steam control valve (R)			—	—	—	—	—
			a Disassembly, care, assembly			—	—	—		
	○		b Measure each part			—	—	—	—	
○	◎	○	c Penetrant Test (PT)		Within criteria		—		—	
				・Cover by cloth not to scatter the left oil to a floor during removing oil piping		—	—	—		
				・Check any cracks, corrosion, abrasion and erosion on valve body and valve seat			—	—		
						—	—	—		
				・Measure the valve stem and bush sliding surface and check flaw and abrasion of them			—		—	
						—	—	—		
				・Check the deformation and crack of valve stem and key groove		—	—	—		
				・Check the abnormality such as clogging of grease hole amd oil trench		—	—	—		
						—	—	—		
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—

Plant/Unit	KenGen Olkaria Geothermal Power Plant *xx* Unit *xx*
Equipment	Turbine main valve
Work Items	（13） Mounting Turbine main steam valve

How to fill in
1 In the HP (hold point) classification column, when "Items for which confirmation is completed and proceed to the next process", enter ○.
2 Enter B1 to B3 (designated 1st to 3rd) for special danger work and Q for quality control work in the HP classification column.
3 In the Record Required column, enter ◎ for inspection / test and ○ for collection of records to be submitted.
4 In the Chief engineer Witness column, enter ○ in the witness schedule.
5 Enter ○ for pass, × for fail in the criteria column.

Plan			Work Unit	Check Item (Describe required place, model, material, qualification, recording style, etc. after *)	Quality Standard (Including criteria)	Confirmation Record				
HP Classification	Record Required	Chief engineer Witness				Criteria	Chief engineer		Engineer	
						○ ×	Date	Name	Date	Name
			(13) Mounting Turbine main steam valve			—	—	—	—	—
			a Mounting first main steam valve (L)			—	—	—		
			1) Mount main steam control valve			—	—	—		
			2) Mount main steam stop valve			—	—	—		
			3) Mount oil hydraulic device of each valve			—	—	—		
			4) Mount pipings around each valve			—	—	—		
			b Mounting first main steam valve (R)			—	—	—		
			1) Mount main steam control valve			—	—	—		
			2) Mount main steam stop valve			—	—	—		
			3) Mount oil hydraulic device of each valve			—	—	—		
			4) Mount pipings around each valve			—	—	—		
			c Mounting second main steam valve (L)			—	—	—		
			1) Mount main steam control valve			—	—	—		
			2) Mount main steam stop valve			—	—	—		
			3) Mount oil hydraulic device of each valve			—	—	—		
			4) Mount pipings around each valve			—	—	—		
			d Mounting second main steam valve (R)			—	—	—		
			1) Mount main steam control valve			—	—	—		
			2) Mount main steam stop valve			—	—	—		
			3) Mount oil hydraulic device of each valve			—	—	—		
			4) Mount pipings around each valve			—	—	—		
			・Make sure to take covering away from oil piping			—	—	—		
			・Check there is no foreign material inside of steam pipe			—	—	—		
			・Work carefully not to crush screw thread duaring connecting union			—	—	—		
			・Position gascket carefully			—	—	—		
						—	—	—		
						—	—	—		
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Plant/Unit	KenGen Olkaria Geothermal Power Plant *xx* Unit *xx*
Equipment	Turbine main valve
Work Items	（14） Heat insulation and coating repairing （15） Release managed work zone （16） Commissioning （17） Final inspection （18） Cleaning

How to fill in
1 In the HP (hold point) classification column, when "Items for which confirmation is completed and proceed to the next process", enter ○.
2 Enter B1 to B3 (designated 1st to 3rd) for special danger work and Q for quality control work in the HP classification column.
3 In the Record Required column, enter ◎ for inspection / test and ○ for collection of records to be submitted.
4 In the Chief engineer Witness column, enter ○ in the witness schedule.
5 Enter ○ for pass, × for fail in the criteria column.

Plan			Work Unit	Check Item (Describe required place, model, material, qualification, recording style, etc. after *)	Quality Standard (Including criteria)	Confirmation Record				
HP Classification	Record Required	Chief engineer Witness				Criteria	Chief engineer		Engineer	
						○ ×	Date	Name	Date	Name
			(14) Heat insulation and coating repairing			—	—	—	—	—
			a Restore heat insulation			—	—	—		
			b Restore coating			—	—	—		
			・Use appropriate instrument			—	—	—		
			・Use appropriate protective instrument			—	—	—		
			・Work with an appropriate working position			—	—	—		
			・Report when disaster occurs soon			—	—	—		
			・Use Harness surely at the higher location			—	—	—		
			・Report, Communicate, discuss with Chief engineer			—	—	—		
			・Suspend working and report to Chief engineer when a trouble happens			—	—	—		
			and have a measurement			—	—	—		
			・Check around not to damage divices nearby			—	—	—		
			・Have double-check not to leave painting			—	—	—		
						—	—	—	—	—
			(15) Release managed work zone			—	—	—	—	—
○			a Release designated managed work zone			—	—	—		
			・Set staff-only notification			—	—	—		
						—	—	—	—	—
			(16) Commissioning			—	—	—	—	—
○		○	a Witness commissioning			—				
	○		b Record the result of each masurement		Within criteria		—		—	
			・Pay enough attention to the rotating parts			—	—	—		
			・Clear communication and work signal between workers			—	—	—		
			・Report when a disaster occurs			—	—	—		
			・ When a trouble happens, suspend working once and discuss with Chief eng			—	—	—		
			・Contact to the Chief engineer before working			—	—	—		
						—	—	—		
			(17) Final inspection			—	—	—	—	—
○	◎		・Implement visual inspection at maintenance points		No abnormality		—	—		
○	◎		・All works completed as planned schedule without any problems		Completed		—	—		
○	◎		・All the required record are kept		Checked final record		—	—		
		○	・Chief engineer completed checking		No neccesary to point out					
						—	—	—	—	—
			(18) Cleaning			—	—	—	—	—
○			・There's no materials left in work area				—	—		
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	Inspection Chief engineer	
						—	—	—		
						—	—	—		
						—	—	—		
						—	—	—		
						—	—	—		

Condenser, Circuration water pipe

Plant/Unit	KenGen Olkaria Geothermal Power Plant *xx* Unit *xx*	How to fill in 1 In the HP (hold point) classification column, when "Items for which confirmation is completed and proceed to the next process", enter ○. 2 Enter B1 to B3 (designated 1st to 3rd) for special danger work and Q for quality control work in the HP classification column. 3 In the Record Required column, enter ◎ for inspection / test and ○ for collection of records to be submitted. 4 In the Chief engineer Witness column, enter ○ in the witness schedule. 5 Enter ○ for pass, × for fail in the criteria column.
Equipment	Condenser, Circuration water pipe	
Work Items	（１） Owned parts inspection, test （２） Establish work area （３） Cleaning condenser waterbox	

Plan			Work Unit	Check Item (Describe required place, model, material, qualification, recording style, etc. after *)	Quality Standard (Including criteria)	Confirmation Record				
HP Classification	Record Required	Chief engineer Witness				Criteria	Chief engineer		Engineer	
						○ ×	Date	Name	Date	Name
			(1) Owned parts inspection, test			—	—	—	—	—
○	◎		a Introducing inspection of own parts		No mistakes a number and specifcation				—	
			*Check inspection day in a list			—	—	—	—	—
○		○	b Inspecting equipment and devices		No abnormality					
			・in-stock the items of specification			—	—	—		
			・Do not put the product on the floor directly			—	—	—		
						—	—	—		
						—	—	—	—	—
			(2) Establish work area			—	—	—	—	—
○		○	a Indicate the work area by every block		appopriate area					
			・Set staff-only notification			—	—	—		
			・Secure the passage for safety			—	—	—		
						—	—	—	—	—
						—	—	—	—	—
B1			**(3) Cleaning condenser waterbox**			—	—	—	—	—
			a Remove manhole cover			—	—	—		
			b Build temporary scaffold			—	—	—		
			c Clean inside of waterbox			—	—	—		
			d Inspect and clear watering nozzles			—	—	—		
○			e Remove deposition of waterbox and clean inside		No materials left inside		—	—		
			f Dismantle temporary scaffold			—	—	—		
		○	g Close manhole cover tightly			—				
			h Inspect expansion joint			—	—	—		
			・Check crack on welding of Rectifying plate				—	—		
			・Check corrosion and crack on watering nozzle piping support and welding of reinforcing plate			—	—	—		
			・Check corrosion and crack on welding of splay nozzle			—	—	—		
			・Check sludge deposition and Anti-corrosion paint peeling			—	—	—		
			・Check corrosion of Bottom plate, support and piping			—	—	—		
						—	—	—		
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Plant/Unit	KenGen Olkaria Geothermal Power Plant *xx* Unit *xx*	How to fill in 1 In the HP (hold point) classification column, when "Items for which confirmation is completed and proceed to the next process", enter ○. 2 Enter B1 to B3 (designated 1st to 3rd) for special danger work and Q for quality control work in the HP classification column. 3 In the Record Required column, enter ◎ for inspection / test and ○ for collection of records to be submitted. 4 In the Chief engineer Witness column, enter ○ in the witness schedule. 5 Enter ○ for pass, × for fail in the criteria column.
Equipment	Condenser, Circuration water pipe	
Work Items	(4)Disassembly, inspection, care of sealing water strainer	

Plan			Work Unit	Check Item (Describe required place, model, material, qualification, recording style, etc. after *)	Quality Standard (Including criteria)	Confirmation Record				
HP Classification	Record Required	Chief engineer Witness				Criteria	Chief engineer		Engineer	
						○ ×	Date	Name	Date	Name
			(4)Disassembly, inspection, care of sealing water strainer			—	—	—	—	—
			a ＃A Inspection of sealing water strainer			—	—	—	—	—
			1) Remove strainer cover			—	—	—		
○			2) Inspection and cleaning of inside of strainer		No abnormality		—	—		
			3) Insert strainer and attach cover			—	—	—		
			b ＃A Inspection of sealing water strainer (by-pass)			—	—	—	—	—
			1) Remove strainer cover			—	—	—		
○			2) Inspection and cleaning of inside of strainer		No abnormality		—	—		
			3) Insert strainer and attach cover			—	—	—		
			c ＃B Inspection of sealing water strainer			—	—	—	—	—
			1) Remove strainer cover			—	—	—		
○			2) Inspection and cleaning of inside of strainer		No abnormality		—	—		
			3) Insert strainer and attach cover			—	—	—		
			d ＃B Inspection of sealing water strainer (by-pass)			—	—	—	—	—
			1) Remove strainer cover			—	—	—		
○			2) Inspection and cleaning of inside of strainer		No abnormality		—	—		
			3) Insert strainer and attach cover			—	—	—		
			・Remove instruments and check no pressure in piping before working			—	—	—		
			・Fill match mark before piping disassembly			—	—	—		
			・Cover the opening part and make sure to remove it when assembly			—	—	—		
						—	—	—		
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Plant/Unit	KenGen Olkaria Geothermal Power Plant *xx* Unit *xx*	How to fill in 1 In the HP (hold point) classification column, when "Items for which confirmation is completed and proceed to the next process", enter ○. 2 Enter B1 to B3 (designated 1st to 3rd) for special danger work and Q for quality control work in the HP classification column. 3 In the Record Required column, enter ◎ for inspection / test and ○ for collection of records to be submitted. 4 In the Chief engineer Witness column, enter ○ in the witness schedule. 5 Enter ○ for pass, × for fail in the criteria column.
Equipment	Condenser, Circuration water pipe	
Work Items	（５） Disassembly, inspection, assembly of gland steam ejector （６） Opening, inspection, assembly of NaOH injection device	

Plan			Work Unit	Check Item (Describe required place, model, material, qualification, recording style, etc. after *)	Quality Standard (Including criteria)	Confirmation Record				
HP Classification	Record Required	Chief engineer Witness				Criteria	Chief engineer		Engineer	
						○ ×	Date	Name	Date	Name
			(5) Disassembly, inspection, assembly of gland steam ejector			—	—	—	—	—
			a Disassemble, inspect and care of jet nozzle and throat			—	—	—		
			b Disassemble, inspect and care of auxiliary valves			—	—	—		
			1) Steam inlet valve			—	—	—		
			2) Gland steam inlet valve			—	—	—		
			c Assemble each part			—	—	—		
			・Check corrosion or stress corrosion cracking of Gas suction port			—	—	—		
			・Check erosion and corrosion of nozzle and diffuser			—	—	—		
						—	—	—		
						—	—	—		
						—	—	—		
							—		—	
						—	—	—	—	—
						—	—	—	—	—
			(6) Opening, inspection, assembly of NaOH injection device			—	—	—	—	—
			a Dispose left chemicals			—	—	—		
B1			b Inspect and cleaning for inside of tank			—	—	—		
			c Inspect and care mixer			—	—	—		
			・Make sure of completion of turn off and isolation before working				—	—		
			・Clean satisfactorily not to get damaged by left chemicals			—	—	—		
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Plant/Unit	KenGen Olkaria Geothermal Power Plant *xx* Unit *xx*	How to fill in 1 In the HP (hold point) classification column, when "Items for which confirmation is completed and proceed to the next process", enter ○. 2 Enter B1 to B3 (designated 1st to 3rd) for special danger work and Q for quality control work in the HP classification column. 3 In the Record Required column, enter ◎ for inspection / test and ○ for collection of records to be submitted. 4 In the Chief engineer Witness column, enter ○ in the witness schedule. 5 Enter ○ for pass, × for fail in the criteria column.
Equipment	Condenser, Circuration water pipe	
Work Items	（７） Inspection, care of valves on hotwell system （８） Disassembly, inspection, care of valves on re-circulating water system	

Plan			Work Unit	Check Item (Describe required place, model, material, qualification, recording style, etc. after *)	Quality Standard (Including criteria)	Confirmation Record				
HP Classification	Record Required	Chief engineer Witness				Criteria	Chief engineer		Engineer	
						○ ×	Date	Name	Date	Name
			(7) Inspection, care of valves on hotwell system			—	—	—	—	—
			a ＃A Inspect hotwell pump inlet valve			—	—	—		
			b ＃B Inspect hotwell pump inlet valve			—	—	—		
			c ＃A Inspect hotwell pump outlet valve			—	—	—		
			d ＃B Inspect hotwell pump outlet valve			—	—	—		
			e ＃A Inspect and care hotwell pump outlet check valve			—	—	—		
			f ＃B Inspect and care hotwell pump outlet check valve			—	—	—		
			g ＃A Inspect and care hotwell pump bypass valve of outlet check valve			—	—	—		
			h ＃B Inspect and care hotwell pump bypass valve of outlet check valve			—	—	—		
			I Disassemble, inspect and care cooling tower inlet hotwell distribution valve			—	—	—		
			・Check any damages and flaws on valve sheet			—	—	—		
			・Check adherence scales on moving parts			—	—	—		
			・Check no gap of gasket correct position during restoring			—	—	—		
			・Check deposition inside of valves			—	—	—		
						—	—	—		
							—		—	
						—	—	—		
						—	—	—		
						—	—	—		
						—	—	—	—	—
			(8) Disassembly, inspection, care of valves on re-circulating water system			—	—	—	-	-
			a Disassemble, inspect and care reinjection valve			—	—	—		
			b Disassemble, inspect and care before and after reinjection valve			—	—	—		
			c Disassemble, inspect and care reinjection bypass valve			—	—	—		
			e Disassemble, inspect and care condenser initial filling valve			—	—	—		
			・Check any damages and flaws on valve sheet			—	—	—		
			・Check adherence scales on moving parts			—	—	—		
			・Check no gap of gasket correct position during restoring			—	—	—		
			・Check deposition inside of valves			—	—	—		
						—	—	—		
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Plant/Unit	KenGen Olkaria Geothermal Power Plant *xx* Unit *xx*	How to fill in 1 In the HP (hold point) classification column, when "Items for which confirmation is completed and proceed to the next process", enter ○. 2 Enter B1 to B3 (designated 1st to 3rd) for special danger work and Q for quality control work in the HP classification column. 3 In the Record Required column, enter ◎ for inspection / test and ○ for collection of records to be submitted. 4 In the Chief engineer Witness column, enter ○ in the witness schedule. 5 Enter ○ for pass, × for fail in the criteria column.
Equipment	Condenser, Circuration water pipe	
Work Items	（９） Disassembly, inspection, care of valve on condenser cooling water system （１０） Inspection, care of piping for circulating water system and aux. cooling water system	

Plan			Work Unit	Check Item (Describe required place, model, material, qualification, recording style, etc. after *)	Quality Standard (Including criteria)	Confirmation Record				
HP Classification	Record Required	Chief engineer Witness				Criteria	Chief engineer		Engineer	
						○ ×	Date	Name	Date	Name
			(9) Disassembly, inspection, care of valve on condenser cooling water system			—	—	—	—	—
			a Inspect cooling water shutoff valve			—	—	—		
			b Inspect siphone braker valve			—	—	—	—	—
			1. Inspect siphone braker valve			—	—	—		
			2. Inspect siphone braker minimum flow valve			—	—	—		
			3. Inspect front valve of siphone braker valve			—	—	—		
			4. Inspect front valve of siphone braker minimum flow valve			—	—	—		
			c Disassemble, inspect and care cooling tower level control valve			—	—	—	—	—
			1. Inspect front valve of cooling tower level control valve			—	—	—		
			2. Inspect rear valve of cooling tower level control valve			—	—	—		
			3. Inspect cooling tower level control valve bypass valve			—	—	—		
			・Check any damages and flaws on valve sheet			—	—	—		
			・Check adherence scales on moving parts				—		—	
			・Check no gap of gasket correct position during restoring			—	—	—		
			・Check deposition inside of valves			—	—	—		
						—	—	—	—	—
			(10) Inspection, care of piping for circulating water system and aux. cooling water system			—	—	—	—	—
B1			a Inspection of piping for circulating water system			—	—	—	—	—
			1) Open manhole cover			—	—	—		
○			2) Inspect inside of piping		No abnormality inside		—	—		
			3) Repair lining piping			—	—	—		
			4) Restore manhole cover			—	—	—		
B1			b Inspection of cooling water piping			—	—	—	—	—
			1) Open manhole cover			—	—	—		
○			2) Inspect inside of piping		No abnormality inside		—	—		
			3) Repair lining piping			—	—	—		
			4) Restore manhole cover			—	—	—		
			c Inspection of hotwell pump inlet/outlet expansion			—	—	—		
			1) #A Inspect pump inlet expansion			—	—	—		
			2) #A Inspect pump outlet expansion			—	—	—		
			3) #B Inspect pump inlet expansion			—	—	—		
			4) #B Inspect pump outlet expansion			—	—	—		
			・Check diposition inside piping			—	—	—		
			・Check any damages lining piping				—	—		
			・Check surface treatment before lining piping repair			—	—	—		
			・Check no gap of gasket correct position during restoring				—		—	
						—	—	—		
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Plant/Unit	KenGen Olkaria Geothermal Power Plant *xx* Unit *xx*	How to fill in 1 In the HP (hold point) classification column, when "Items for which confirmation is completed and proceed to the next process", enter ○. 2 Enter B1 to B3 (designated 1st to 3rd) for special danger work and Q for quality control work in the HP classification column. 3 In the Record Required column, enter ◎ for inspection / test and ○ for collection of records to be submitted. 4 In the Chief engineer Witness column, enter ○ in the witness schedule. 5 Enter ○ for pass, × for fail in the criteria column.
Equipment	Condenser, Circuration water pipe	
Work Items	(1 1) Inspection, care of valves for aux. cooling water system	

Plan			Work Unit	Check Item (Describe required place, model, material, qualification, recording style, etc. after *)	Quality Standard (Including criteria)	Confirmation Record				
HP Classification	Record Required	Chief engineer Witness				Criteria	Chief engineer		Engineer	
						○ ×	Date	Name	Date	Name
			(11) Inspection, care of valves for aux. cooling water system			—	—	—	—	—
			a Inspection of valves before and after standpipe level control valve			—	—	—	—	—
			1) Disassemble valves			—	—	—		
○			2) Inspect and care each part		No abnormality		—	—		
			3) Assemble the valves			—	—	—		
			b Inspection of standpipe level control bypass valve			—	—	—	—	—
			1) Disassemble valve			—	—	—		
○			2) Inspect and care each part		No abnormality		—	—		
			3) Assemble the valve			—	—	—		
			c Cleaning standpipe level control valve outlet strainer			—	—	—		
			d Inspection of valve before and after turbine oil cooler control valve			—	—	—	—	—
			1) Disassemble valve			—	—	—		
○			2) Inspect and care each part		No abnormality		—	—		
			3) Assemble the valve			—	—	—		
			e Inspection of turbine oil cooler control bypass valve			—	—	—	—	—
			1) Disassemble valve			—	—	—		
○			2) Inspect and care each part		No abnormality		—	—		
			3) Assemble the valve			—	—	—		
			f Inspection of Generator cooler inlet and outlet valves			—	—	—	—	—
			1) Disassemble valves			—	—	—		
○			2) Inspect and care each part		No abnormality		—	—		
			3) Assemble the valves			—	—	—		
			g Inspection of seal oil cooling water inlet and outlet valves			—	—	—	—	—
			1) Disassemble valve			—	—	—		
○			2) Inspect and care each part		No abnormality		—	—		
			3) Assemble the valve			—	—	—		
			h Inspection og Exciter cooler inlet and outlet valves			—	—	—	—	—
			1) Disassemble valves			—	—	—		
○			2) Inspect and care each part		No abnormality		—	—		
			3) Assemble the valves			—	—	—		
			i Inspcetion of oil cooler for blower inlet and outlet valves			—	—	—	—	—
			1) Disassemble valves			—	—	—		
○			2) Inspect and care each part		No abnormality		—	—		
			3) Assemble the valves			—	—	—		
			・Check any damages and flaws on valve sheet			—	—	—		
			・Check adherence scales on moving parts				—		—	
			・Check no gap of gasket correct position during restoring			—	—	—		
			・Check deposition inside of valves			—	—	—		
						—	—	—		
						—	—	—	—	—
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Plant/Unit	KenGen Olkaria Geothermal Power Plant *xx* Unit *xx*	How to fill in 1 In the HP (hold point) classification column, when "Items for which confirmation is completed and proceed to the next process", enter ○. 2 Enter B1 to B3 (designated 1st to 3rd) for special danger work and Q for quality control work in the HP classification column. 3 In the Record Required column, enter ◎ for inspection / test and ○ for collection of records to be submitted. 4 In the Chief engineer Witness column, enter ○ in the witness schedule. 5 Enter ○ for pass, × for fail in the criteria column.
Equipment	Condenser, Circuration water pipe	
Work Items	（１２） Inspection and care of cooling water cooler （１３） Valves inspection, maintanance	

Plan			Work Unit	Check Item (Describe required place, model, material, qualification, recording style, etc. after *)	Quality Standard (Including criteria)	Confirmation Record				
HP Classification	Record Required	Chief engineer Witness				Criteria	Chief engineer		Engineer	
						○ ×	Date	Name	Date	Name
			(12) **Inspection and care of cooling water cooler**			—	—	—	—	—
			a Open water room cover			—	—	—		
			b Clean and care for tube and water room			—	—	—		
			c Inspect tube leak			—	—	—		
			d Restore water room cover			—	—	—		
			e Check leaking after filling water			—	—	—		
			f Replace air vent valve			—	—	—		
			・Be careful when wash tube by washing machine			—	—	—		
			・Be careful of washing inside of water room cover (rubber lining)			—	—	—		
			・Work with cooler guide when lifting cooler out and in			—	—	—		
			(the water flow from the cooling tower to the cooling water pipe is fast)			—	—	—		
						—	—	—		
						—	—	—	—	—
			(13) **Valves inspection, maintanance**			—	—	—	—	—
			a Replace defective valves			—	—	—		
			b Have maintanance of blow valves and other parts			—	—	—		
			・Make sure the specification of the defective valves before replace			—	—	—		
			・Check the clogging before and after piping			—	—	—		
						—	—	—		
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Plant/Unit	KenGen Olkaria Geothermal Power Plant *xx* Unit *xx*	How to fill in 1 In the HP (hold point) classification column, when "Items for which confirmation is completed and proceed to the next process", enter ○. 2 Enter B1 to B3 (designated 1st to 3rd) for special danger work and Q for quality control work in the HP classification column. 3 In the Record Required column, enter ◎ for inspection / test and ○ for collection of records to be submitted. 4 In the Chief engineer Witness column, enter ○ in the witness schedule. 5 Enter ○ for pass, × for fail in the criteria column.
Equipment	Condenser, Circuration water pipe	
Work Items	（１４）Disassembly, inspection, assembly of rotary screen	

Plan			Work Unit	Check Item (Describe required place, model, material, qualification, recording style, etc. after *)	Quality Standard (Including criteria)	Confirmation Record				
HP Classification	Record Required	Chief engineer Witness				Criteria	Chief engineer		Engineer	
						○ ×	Date	Name	Date	Name
			(14) Disassembly, inspection, assembly of rotary screen			—	—	—	—	—
			a ＃A Disassembling rotary screen			—	—	—	—	—
			1.Inspect and clean net			—	—	—		
			2.Disassembly, inspection and care of top and bottom sprockets			—	—	—		
			3. Replace chain			—	—	—		
			4. Inspect and care shaft and torque tube			—	—	—		
			5. Inspect and care spray pipe and nozzle			—	—	—		
			6. Replace defactive parts			—	—	—		
			7. Clean, assemble, and restore each part			—	—	—		
			8. Adjust tension			—	—	—		
			9.Cleaning, inspection and care of Dust remover			—	—	—		
			a ＃B Disassembling rotary screen			—	—	—	—	—
			1.Inspect and clean net			—	—	—		
			2.Disassembly, inspection and care of top and bottom sprockets			—	—	—		
			3. Replace chain			—	—	—		
			4. Inspect and care shaft and torque tube			—	—	—		
			5. Inspect and care spray pipe and nozzle			—	—	—		
			6. Replace defactive parts			—	—	—		
			7. Clean, assemble, and restore each part			—	—	—		
			8. Adjust tension			—	—	—		
			9.Cleaning, inspection and care of Dust remover			—	—	—		
			・Check any damage of volts, chain, net and sprockets			—	—	—		
			・Check clogging and damages of spray piping and nozzle			—	—	—		
						—	—	—		
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Plant/Unit	KenGen Olkaria Geothermal Power Plant *xx* Unit *xx*	How to fill in 1 In the HP (hold point) classification column, when "Items for which confirmation is completed and proceed to the next process", enter ○. 2 Enter B1 to B3 (designated 1st to 3rd) for special danger work and Q for quality control work in the HP classification column. 3 In the Record Required column, enter ◎ for inspection / test and ○ for collection of records to be submitted. 4 In the Chief engineer Witness column, enter ○ in the witness schedule. 5 Enter ○ for pass, × for fail in the criteria column.
Equipment	Condenser, Circuration water pipe	
Work Items	（１５）Disassembly, inspection, assembly of rotary screen washing pump	

Plan			Work Unit	Check Item (Describe required place, model, material, qualification, recording style, etc. after *)	Quality Standard (Including criteria)	Confirmation Record				
HP Classification	Record Required	Chief engineer Witness				Criteria	Chief engineer		Engineer	
						○ ×	Date	Name	Date	Name
			(15) Disassembly, inspection, assembly of rotary screen washing pump			—	—	—	—	—
			a Lift up pump			—	—	—		
			b Disassemble pump			—	—	—		
			c Inspect and care seal ring			—	—	—		
			d Inspect and care impeller			—	—	—		
			e Disassemble, inspect and care main shaft and bearing			—	—	—		
			f Measure axle runout and gap			—	—	—		
			g Clean, assemble and restore each part			—	—	—		
			h Replace defective parts			—	—	—		
			i Clean, assemble and restore strainer			—	—	—		
			j Have centering			—	—	—		
			・Make sure of isolation before disassembling			—	—	—		
			・Prepare replacement parts before disassembling			—	—	—		
			・Check deposition at pump suction			—	—	—		
						—	—	—		
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Plant/Unit	KenGen Olkaria Geothermal Power Plant *xx* Unit *xx*	How to fill in 1 In the HP (hold point) classification column, when "Items for which confirmation is completed and proceed to the next process", enter ○. 2 Enter B1 to B3 (designated 1st to 3rd) for special danger work and Q for quality control work in the HP classification column. 3 In the Record Required column, enter ◎ for inspection / test and ○ for collection of records to be submitted. 4 In the Chief engineer Witness column, enter ○ in the witness schedule. 5 Enter ○ for pass, × for fail in the criteria column.
Equipment	Condenser, Circuration water pipe	
Work Items	（１６）Final inspection （１７）Cleaning	

Plan			Work Unit	Check Item (Describe required place, model, material, qualification, recording style, etc. after *)	Quality Standard (Including criteria)	Confirmation Record				
HP Classification	Record Required	Chief engineer Witness				Criteria	Chief engineer		Engineer	
						○ ×	Date	Name	Date	Name
			(16) Final inspection			—	—	—	—	—
○	◎			・Implement visual inspection at maintenance points	No abnormality		—	—		
○	◎			・All works completed as planned schedule without any problems	Completed		—	—		
○	◎			・All the required record are kept	Checked final record		—	—		
		○		・Engineer completed checking	No neccesary to point out					
						—	—	—	—	—
			(17) Cleaning			—	—	—	—	—
○				・There's no materials left in work area			—	—		
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—

Auxiliary pump

Plant/Unit	KenGen Olkaria Geothermal Power Plant *xx* Unit *xx*	How to fill in 1 In the HP (hold point) classification column, when "Items for which confirmation is completed and proceed to the next process", enter ○. 2 Enter B1 to B3 (designated 1st to 3rd) for special danger work and Q for quality control work in the HP classification column. 3 In the Record Required column, enter ◎ for inspection / test and ○ for collection of records to be submitted. 4 In the Chief engineer Witness column, enter ○ in the witness schedule. 5 Enter ○ for pass, × for fail in the criteria column.
Equipment	Auxiliary pump	
Work Items	（１） Owned parts inspection, test （２） Establish work area	

Plan			Work Unit	Check Item (Describe required place, model, material, qualification, recording style, etc. after *)	Quality Standard (Including criteria)	Confirmation Record				
HP Classification	Record Required	Chief engineer Witness				Criteria	Chief engineer		Engineer	
						○ ×	Date	Name	Date	Name
			(1) Owned parts inspection, test			—	—	—	—	—
○	◎		a Introducing inspection of own parts		No mistakes a number and specifcation				—	
			*Check inspection day in a list			—	—	—	—	—
○		○	b Inspecting equipment and devices		No abnormality					
			・in-stock the items of specification			—	—	—		
			・Do not put the product on the floor directly			—	—	—		
						—	—	—		
			(2) Establish work area			—	—	—	—	—
		○	a Indicate the work area by every block		appopriate area					
			・Set staff-only notification			—	—	—		
			・Secure the passage for safety			—	—	—		
						—	—	—		
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—

Plant/Unit	KenGen Olkaria Geothermal Power Plant *xx* Unit *xx*	How to fill in 1 In the HP (hold point) classification column, when "Items for which confirmation is completed and proceed to the next process", enter ○. 2 Enter B1 to B3 (designated 1st to 3rd) for special danger work and Q for quality control work in the HP classification column. 3 In the Record Required column, enter ◎ for inspection / test and ○ for collection of records to be submitted. 4 In the Chief engineer Witness column, enter ○ in the witness schedule. 5 Enter ○ for pass, × for fail in the criteria column.
Equipment	Auxiliary pump	
Work Items	（３） Disassembly, inspection, assembly of hotwell pump	

Plan			Work Unit	Check Item (Describe required place, model, material, qualification, recording style, etc. after *)	Quality Standard (Including criteria)	Confirmation Record				
HP Classification	Record Required	Chief engineer Witness				Criteria	Chief engineer		Engineer	
						○ ×	Date	Name	Date	Name
			(3) Disassembly, inspection, assembly of hotwell pump			—	—	—	—	—
			a #A Disassembly, inspection, assembly of hotwell pump			—	—	—	—	—
			1) Lift up Auxiliary pump and disassembly			—	—	—		
			2) Ship shaft and impeller to factory			—	—	—		
			3) Take care of Auxiliary pump			—	—	—		
○	○		4) Measure and replace each part of pump		Within criteria of manufacturer		—		—	
○	◎	○	5) PT inspection of each part		No defection		—		—	
			5) Receive shaft and impeller				—		—	
			5) Carry Auxiliary pump and assembly			—	—	—		
○	◎	○	6) Installtion and centering		Within criteria		—		—	
○	○	○	7) Supporting for commissioning		No abnormality		—		—	
			b #B Disassembly, inspection, assembly of hotwell pump			—	—	—	—	—
			1) Suspend, disassembly and carry hotwell pump			—	—	—		
			2) Take care of hotwell pump			—	—	—		
○	○		3) Measure and replace each part of pump		Within criteria of manufacturer		—		—	
○	◎	○	4) PT inspection of each part		No defection		—		—	
			5) Carry hotwell pump and assembly			—	—	—		
○	◎	○	6) Installation and centering		Within criteria		—		—	
○	○	○	7) Supporting for commissioning		No abnormality		—		—	
			・Make sure of the status of an isolation for power supply before working			—	—	—		
			・Make sure to complete the removal of the lubricating water pipe and instrument piping			—	—	—		
			・Check abrasion of gland sleeve and any damage			—	—	—		
			・Check impeller abrasion, casing abrasion, defection and erosion			—	—	—		
			・Check casing damage, shaftcrack, and deformation of key groove			—	—	—		
			・Check clogging of lubricant piping			—	—	—		
			・Check lucricant oil not to mix with water during extracting			—	—	—		
			・Make sure to cover not to damage bearing journal			—	—	—		
			・Be careful of handling metal for slipping by oil				—		—	
						—	—	—		
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Plant/Unit	KenGen Olkaria Geothermal Power Plant *xx* Unit *xx*	How to fill in 1 In the HP (hold point) classification column, when "Items for which confirmation is completed and proceed to the next process", enter ○. 2 Enter B1 to B3 (designated 1st to 3rd) for special danger work and Q for quality control work in the HP classification column. 3 In the Record Required column, enter ◎ for inspection / test and ○ for collection of records to be submitted. 4 In the Chief engineer Witness column, enter ○ in the witness schedule. 5 Enter ○ for pass, × for fail in the criteria column.
Equipment	Auxiliary pump	
Work Items	（４） Disassembly, inspection, care of sealing water pump （５） Disassembly, inspection, care of sealing pump strainer	

Plan			Work Unit	Check Item (Describe required place, model, material, qualification, recording style, etc. after *)	Quality Standard (Including criteria)	Confirmation Record				
HP Classification	Record Required	Chief engineer Witness				Criteria	Chief engineer		Engineer	
						○ ×	Date	Name	Date	Name
			(4) Disassembly, inspection, care of sealing water pump			—	—	—	—	—
			a Disassembly, inspection, assembly of sealing water pump			—	—	—		
			1) Disassemble sealing water pump			—	—	—		
			2) Take care of each part			—	—	—		
○	○		3) Measure and replace each part of pump		Within criteria of manufacturer		—		—	
○	◎	○	4) PT inspection of each part		No defection		—		—	
			5) Assemble the pump			—	—	—		
○	◎	○	6) Installation and centering		Within criteria		—		—	
○	○	○	7) Supporting for commissioning		No abnormality		—		—	
			・Make sure of the status of an isolation before disassembly			—	—	—		
			・Check all the consumables and replacing parts before disassembly			—	—	—		
			・Check deposition and blockage inside of piping and pump			—	—	—		
			・Take care thoroughly of installing pedestal for pump and motor			—	—	—		
			（for Stabilization of measured values during centering）			—	—	—		
						—	—	—		
						—	—	—	—	—
			(5) Disassembly, inspection, care of sealing pump strainer			—	—	—	—	—
			a #A Inspection of sealing pump strainer			—	—	—		
			1) Remove strainer cover			—	—	—		
○			2) Inner inspection and cleaning of strainer		No abnormality		—	—		
			3) Insert strainer and attach cover			—	—	—		
			b #A Inspection of sealing pump strainer (for by-pass)			—	—	—		
			1) Remove strainer cover			—	—	—		
○			2) Inner inspection and cleaning of strainer		No abnormality		—	—		
			3) Insert strainer and attach cover			—	—	—		
			c #B Inspection of sealing pump strainer			—	—	—		
			1) Removing strainer cover			—	—	—		
○			2) Inner inspection and cleaning of strainer		No abnormality		—	—		
			3) Insert strainer and attach cover			—	—	—		
			d #B Inspection of sealing pump strainer (by-pass)			—	—	—		
			1) Remove strainer cover			—	—	—		
○			2) Inner inspection and cleaning of strainer		No abnormality		—	—		
			3) Insert strainer and attach cover			—	—	—		
			・Make sure of the status of an isolation before working			—	—	—		
			・Check deposition and blockage inside of starainer			—	—	—		
			・Check any damage on strainer			—	—	—		
			・Check any damage on attachment part of strainer			—	—	—		
			・Check corrosion and erosion of flange sheet			—	—	—		
			・Make sure not to have foreign matter when assembly				—		—	
						—	—	—		
						—	—	—		
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						—	—	—	—	—
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Plant/Unit	KenGen Olkaria Geothermal Power Plant *xx* Unit *xx*	How to fill in 1 In the HP (hold point) classification column, when "Items for which confirmation is completed and proceed to the next process", enter ○. 2 Enter B1 to B3 (designated 1st to 3rd) for special danger work and Q for quality control work in the HP classification column. 3 In the Record Required column, enter ◎ for inspection / test and ○ for collection of records to be submitted. 4 In the Chief engineer Witness column, enter ○ in the witness schedule. 5 Enter ○ for pass, × for fail in the criteria column.
Equipment	Auxiliary pump	
Work Items	（６） Disassembly, inspection, care of NaOH injection pump （７） Disassembly, inspection, assembly of aux. cooling water pumps	

Plan			Work Unit	Check Item (Describe required place, model, material, qualification, recording style, etc. after *)	Quality Standard (Including criteria)	Confirmation Record				
HP Classification	Record Required	Chief engineer Witness				Criteria	Chief engineer		Engineer	
						○ ×	Date	Name	Date	Name
			(6) Disassembly, inspection, care of NaOH injection pump			—	—	—	—	—
			1) Disassemble NaOH injection pump			—	—	—		
			2) Take care of each part			—	—	—		
○	○		3) Measure and replace each part of pump		Within criteria of manufacturer		—	—		
○	◎	○	4) PT inspection of each part		No defection		—		—	
			5) Assemble the pump			—	—	—		
○	○	○	6) Supporting for commissioning		No abnormality		—	—		
			・Make sure of the status of an isolation before disassembly			—	—	—		
			・Check the left liquid of a chemical carefully			—	—	—		
			・Be careful not to damage small caliber piping			—	—	—		
			・Be careful of handling the part of oil seal lip because it's fragile			—	—	—		
			・Check inserting O-ring at connection part of piping			—	—	—		
			・Don't adjust stroke for diaphragm pump forcely				—		—	
			because it's easy to be torn			—	—	—		
			・To vent air before commissioning			—	—	—		
						—	—	—		
						—	—	—	—	—
			(7) Disassembly, inspection, assembly of aux. cooling water pumps			—	—	—	—	—
			a ＃A Disassembly, inspection, assembly of aux. cooling water pump			—	—	—	—	—
			1) Disassemble the pump			—	—	—		
			2) Take care of each part			—	—	—		
○	○		3) Measure each part, and replace parts		Within criteria of manufacturer		—		—	
○	◎	○	4) PT inspection of each part		No defection		—		—	
			5) Assemle the pump			—	—	—		
○	◎	○	6) Installation and centering		Within criteria		—		—	
○	○	○	7) Supporting for commissioning		No abnormality		—		—	
			b #B Disassembly, inspection, assembly of aux. cooling water pump			—	—	—	—	—
			1) Disassemble the pump			—	—	—		
			2) Take care of each part			—	—	—		
○	○		3) Measure each part, and replace parts		Within criteria of manufacturer		—		—	
○	◎	○	4) PT inspection of each part		No defection		—		—	
			5) Assemle the pump			—	—	—		
○	◎	○	6) Installation and centering		Within criteria		—		—	
○	○	○	7) Supporting for commissioning		No abnormality		—		—	
			・Make sure of the status of an isolation before disassembly			—	—	—		
			・Check all the consumables and replacing parts before disassembly			—	—	—		
			・Check any damage and erosion of of impeller and casing when disassembly			—	—	—		
			・Check deposition and blockage			—	—	—		
			・Check a condition of abrasion of gland sleeve			—	—	—		
			・Check clogging the sealing water piping			—	—	—		
			・Check water pouring into bearing			—	—	—		
			・Check corrosion on the inside of shaft sleeve				—		—	
			・Check clogging and deposition of drain piping			—	—	—		
						—	—	—		
						—	—	—		

Plant/Unit	KenGen Olkaria Geothermal Power Plant *xx* Unit *xx*	How to fill in 1 In the HP (hold point) classification column, when "Items for which confirmation is completed and proceed to the next process", enter ○. 2 Enter B1 to B3 (designated 1st to 3rd) for special danger work and Q for quality control work in the HP classification column. 3 In the Record Required column, enter ◎ for inspection / test and ○ for collection of records to be submitted. 4 In the Chief engineer Witness column, enter ○ in the witness schedule. 5 Enter ○ for pass, × for fail in the criteria column.
Equipment	Auxiliary pump	
Work Items	（８） Disassembly, inspection, assembly Intercooler cooling water pump	

Plan			Work Unit	Check Item (Describe required place, model, material, qualification, recording style, etc. after *)	Quality Standard (Including criteria)	Confirmation Record				
HP Classification	Record Required	Chief engineer Witness				Criteria	Chief engineer		Engineer	
						○ ×	Date	Name	Date	Name
			(8) Disassembly, inspection, assembly Intercooler cooling water pump			—	—	—	—	—
			a #A Disassembly, inspection, assembly Intercooler cooling water pump			—	—	—		
			1) Disassemble Intercooler cooling water pump			—	—	—		
			2) Take care of each part			—	—	—		
○	○		3) Measure and replace each part of pump		Within criteria of manufacturer		—		—	
○	◎	○	4) PT inspection of each part		No defection		—		—	
			5) Assemle the pump			—	—	—		
○	◎	○	6) Installation and centering		Within criteria		—		—	
○	○	○	7) Supporting for commissioning		No abnormality		—		—	
						—	—	—	—	—
			b #B Disassembly, inspection, assembly Intercooler cooling water pump			—	—	—	—	—
			1) Disassemble Intercooler cooling water pump			—	—	—		
			2) Take care of each part			—	—	—		
○	○		3) Measure and replace each part of pump		Within criteria of manufacturer		—		—	
○	◎	○	4) PT inspection of each part		No defection		—		—	
			5) Assemle the pump			—	—	—		
○	◎	○	6) Installation and centering		Within criteria		—		—	
○	○	○	7) Supporting for commissioning		No abnormality		—		—	
			・Make sure of the status of an isolation before disassembly			—	—	—		
			・Check all the consumables and replacing parts before disassembly			—	—	—		
			・Check any damage and erosion of of impeller and casing when disassembly			—	—	—		
			・Check deposition and blockage			—	—	—		
			・Check a condition of abrasion of gland sleeve			—	—	—		
			・Check clogging the sealing water piping			—	—	—		
			・Check water pouring into bearing				—		—	
			・Check corrosion on the inside of shaft sleeve			—	—	—		
			・Check clogging and deposition of drain piping			—	—	—		
						—	—	—		
						—	—	—		
						—	—	—	—	—

Plant/Unit	KenGen Olkaria Geothermal Power Plant *xx* Unit *xx*	How to fill in 1 In the HP (hold point) classification column, when "Items for which confirmation is completed and proceed to the next process", enter ○. 2 Enter B1 to B3 (designated 1st to 3rd) for special danger work and Q for quality control work in the HP classification column. 3 In the Record Required column, enter ◎ for inspection / test and ○ for collection of records to be submitted. 4 In the Chief engineer Witness column, enter ○ in the witness schedule. 5 Enter ○ for pass, × for fail in the criteria column.
Equipment	Auxiliary pump	
Work Items	（１０） Disassembly, inspection, assembly of fire fighting pump （１１） Disassembly, inspection, assembly of service water pump	

Plan			Work Unit	Check Item (Describe required place, model, material, qualification, recording style, etc. after *)	Quality Standard (Including criteria)	Confirmation Record				
HP Classification	Record Required	Chief engineer Witness				Criteria	Chief engineer		Engineer	
						○ ×	Date	Name	Date	Name
			(10) **Disassembly, inspection, assembly of fire fighting pump**			—	—	—	—	—
			a Disassembly, inspection, assembly of fire fighting pump			—	—	—	—	—
			1) Disassemble fire fighting pump			—	—	—		
			2) Take care of each part			—	—	—		
○	○		3) Measure and replace each part of pump		Within criteria of manufacturer		—		—	
○	◎	○	4) PT inspection of each part		No defection		—		—	
			5) Assemble the pump			—	—	—		
			・Make sure of the status of an isolation before disassembly			—	—	—		
			・Check all the consumables and replacing parts before disassembly			—	—	—		
			・Check any damage and erosion of of impeller and casing when disassembly			—	—	—		
			・Check deposition and blockage				—		—	
			・Check a condition of abrasion of gland sleeve			—	—	—		
			・Check clogging the sealing water piping			—	—	—		
			・Check water pouring into bearing			—	—	—		
			・Check corrosion on the inside of shaft sleeve			—	—	—		
			・Check clogging and deposition of drain piping			—	—	—	—	—
			(11) **Disassembly, inspection, assembly of service water pump**			—	—	—	—	—
			a #A Disassembly, inspection, assembly of service water pump			—	—	—		
			1) #A Disassemble service water pump			—	—	—		
			2) #A Take care of each part			—	—	—		
○	○		3) Measure and replace each part of pump		Within criteria of manufacturer		—		—	
○	◎	○	4) PT inspection of each part		No defection		—		—	
			5) #A Assemble the pump			—	—	—		
○	◎	○	6) Installation and centering		Within criteria		—		—	
○	○	○	7) Supporting for commissioning		No abnormality		—		—	
			b #B Disassembly, inspection, assembly of service water pump			—	—	—	—	—
			1) #B Disassemble the pump			—	—	—		
			2) #B Take care of each part			—	—	—		
○	○		3) Measure and replace each part of pump		Within criteria of manufacturer		—		—	
○	◎	○	4) PT inspection of each part		No defection		—		—	
			5) #B Assemble the pump			—	—	—		
○	◎	○	6) Installation and centering		Within criteria		—		—	
○	○	○	7) Supporting for commissioning		No abnormality		—		—	
			・Make sure of the status of an isolation before disassembly			—	—	—		
			・Check all the consumables and replacing parts before disassembly			—	—	—		
			・Check any damage and erosion of of impeller and casing when disassembly			—	—	—		
			・Check deposition and blockage			—	—	—		
			・Check a condition of abrasion of gland sleeve			—	—	—		
			・Check clogging the sealing water piping			—	—	—		
			・Check water pouring into bearing			—	—	—		
			・Check corrosion on the inside of shaft sleeve				—		—	
			・Check clogging and deposition of drain piping			—	—	—		
						—	—	—		
						—	—	—		
						—	—	—	—	—

Plant/Unit	KenGen Olkaria Geothermal Power Plant *xx* Unit *xx*
Equipment	Auxiliary pump
Work Items	（１２） Final inspection （１３） Cleaning

How to fill in
1 In the HP (hold point) classification column, when "Items for which confirmation is completed and proceed to the next process", enter ○.
2 Enter B1 to B3 (designated 1st to 3rd) for special danger work and Q for quality control work in the HP classification column.
3 In the Record Required column, enter ◎ for inspection / test and ○ for collection of records to be submitted.
4 In the Chief engineer Witness column, enter ○ in the witness schedule.
5 Enter ○ for pass, × for fail in the criteria column.

Plan			Work Unit	Check Item (Describe required place, model, material, qualification, recording style, etc. after *)	Quality Standard (Including criteria)	Confirmation Record				
HP Classification	Record Required	Chief engineer Witness				Criteria	Chief engineer		Engineer	
						○ ×	Date	Name	Date	Name
			(12) **Final inspection**			—	—	—	—	—
○	◎			・Implement visual inspection at maintenance points	No abnormality		—	—		
○	◎			・All works completed as planned schedule without any problems	Completed		—	—		
○	◎			・All the required record are kept	Checked final record		—	—		
		○		・Chief engineer completed checking	No neccesary to point out					
						—	—	—	—	—
			(13) **Cleaning**			—	—	—	—	—
○				・There's no materials left in work area			—	—		
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—

Equipment internal management check sheet

mounting position	Mounter	mount date	Remover	removal date	confirmer	Remarks

Managed work zone time in / out check sheet

Date	Name	Time in	Time out	Department	Remarks
/		:	:		
/		:	:		
/		:	:		
/		:	:		
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Bringing in / out tools check sheet (Internal work zone)

Chief engineer

Tools	quantity	Bring-in date	Bring-out date	Remarks
		/	/	
		/	/	
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Annex 2

Project for Strengthening Operation and Maintenance
Capacity of Olkaria Geothermal Power Stations
Using IoT Technology

Repair Procedure Manual

（Electrical）

March 2021

Japan International Cooperation Agency (JICA)

JICA Experts

（Kyushu Electric Power Co. Inc.,

West Japan Engineering Consultants, Inc.）

Power Generator

Plant/Unit	KenGen Olkaria Geothermal Power Plant *xx* Unit *xx*	How to fill in
Equipment	Power Generator	1 In the HP (hold point) classification column, when "Items for which confirmation is completed and proceed to the next process", enter ○.
Work Items	• Purchase goods, Owned parts inspection, Test • Setting work area • Preparation • Items to check before starting work • Insulation resistance measurement • Foreign matter management area setting	2 Enter B1 to B3 (designated 1st to 3rd) for special danger work and Q for quality control work in the HP classification column. 3 In the Record Required column, enter ◎ for inspection / test and ○ for collection of records to be submitted. 4 In the Chief Engineer Witness column, enter ○ in the witness schedule. 5 Enter ○ for pass, × for fail in the criteria column.

Plan			Work Unit / Check Item (Describe required place, model, material, qualification, recording style, etc. after *)	Quality Standard (Including criteria)	Confirmation Record				
HP Classification	Record Required	Chief Engineer Witness			Criteria ○ ×	Chief Engineer Date	Chief Engineer Name	Engineer Date	Engineer Name
			(1) Purchase goods, Owned parts inspection, Test		—	—	—	—	—
○	◎		a Conduct acceptance inspection of purchased goods	Make sure of the quantity and the specifications		—	—		
○	◎		b Conduct acceptance inspection of owned parts	Make sure of the quantity and the specifications		—	—		
			* Check the inspection date on the list		—	—	—	—	—
○		○	c Inspect equipment and devices	Make sure that there is no abnormality					
			・Conduct temporary storage section display		—	—	—		
			・Arrival of items with purchase specifications		—	—	—		
			・Do not place the product directly		—	—	—		
					—	—	—	—	—
			(2) Control area setting		—	—	—	—	—
		○	a Display the range of the controlled area	Make sure that it is an appropriate area					
			・Be sure to secure a safety passage		—	—	—		
			* Set the controlled area according to the safety		—	—	—	—	—
			control area and parts layout diagram.		—	—	—	—	—
					—	—	—	—	—
			(3) Preparation		—	—	—	—	—
		○	a Meeting with the chief engineer		—				
			b Meeting with related engineers		—	—	—		
			c Preparation of jigs and tools		—	—	—		
			・Closely discuss safety measures and construction		—	—	—		
			procedures with the chief engineer / manufacturer		—	—	—	—	—
			・Closely hold meetings with related engineers regarding		—	—	—		
			construction procedures and specific dangerous work		—	—	—	—	—
					—	—	—	—	—
			(4) Items to check before starting work		—	—	—	—	—
○			a Confirmation of power "off"		—	—	—		
			・Check with the chief engineer to turn off the powe		—	—	—		
○			b Request for valve operation		—	—	—		
			・Confirm the implementation of the isolation operation		—	—	—		
			with the chief engineer		—	—	—	—	—
					—	—	—	—	—
			(5) Insulation resistance measurement		—	—	—	—	—
○	◎	○	a Insulation resistance measurement of stator coil on NGR board	Criteria: Refer to the regular repair data					
			・Check, isolate, and detect circuit before measurement	(management instruction value)	—	—	—		
			・Be sure to discharge after measurement		—	—	—		
		○	b Grounding work		—				
			・After grounding, display the grounding on the board		—	—	—		
					—	—	—	—	—
					—	—	—	—	—
			(6) Second control area setting		—	—	—	—	—
○			a Second control area setting		—	—	—		
			・Enclose and display the controlled area		—	—	—		
			so as to be recognized		—	—	—	—	—
			・Manage with a tool carry-in / take-out check sheet		—	—	—		
					—	—	—	—	—
					—	—	—	—	—
					—	—	—	—	—

Plant/Unit	KenGen Olkaria Geothermal Power Plant *xx* Unit *xx*	How to fill in
Equipment	Power Generator	1 In the HP (hold point) classification column, when "Items for which confirmation is completed and proceed to the next process", enter ○.
Work Items	• Exciter housing removal • Wind tunnel cover removal • Measurement of each part, cable disconnection • Exciter coupling disconnection • Exciter bearing disassembly	2 Enter B1 to B3 (designated 1st to 3rd) for special danger work and Q for quality control work in the HP classification column. 3 In the Record Required column, enter ◎ for inspection / test and ○ for collection of records to be submitted. 4 In the Chief Engineer Witness column, enter ○ in the witness schedule. 5 Enter ○ for pass, × for fail in the criteria column.

Plan			Work Unit	Check Item (Describe required place, model, material, qualification, recording style, etc. after *)	Quality Standard (Including criteria)	Confirmation Record				
						Criteria	Chief Engineer		Engineer	
HP Classification	Record Required	Chief Engineer Witness				○ ×	Date	Name	Date	Name
			(7) Exciter housing removal			—	—	—	—	—
			a End cover removal			—	—	—		
			b Air cooler water pipe removal			—	—	—		
○			c Housing hanging			—	—	—		
				• At the time of separation, check for widespread curing		—	—	—		
				and isolation		—	—	—		
				• Check the match mark		—	—	—		
				• Handle with care so as not to damage the insulation plate		—	—	—		
				• Make sure to cure the pipe so that foreign matter does not		—	—	—	—	—
				get inside the pipe.		—	—	—		
				• When hanging the housing, work carefully so that there		—	—	—	—	—
				are no contact points.		—	—	—		
				• Ensuring proper staffing		—	—	—	—	—
			(8) Wind tunnel cover removal			—	—	—	—	—
			a Wind tunnel cover removal			—	—	—		
				• Since it is half-split, fill in the matching mark and		—	—	—		
				remove it.		—	—	—	—	—
						—	—	—	—	—
			(9) Measurement of each part, cable disconnection			—	—	—	—	—
	○		a Air gap measurement of PMG and ACG		Criteria: Refer to the regular repair data		—	—		
			b Cable disconnection		(management instruction value)	—	—	—		
				• Double check not to misread the measured value		—	—	—		
				• Check the power "off" and carry out voltage detection		—	—	—	—	—
				• Record the connection status in a notebook		—	—	—		
				before disconnecting		—	—	—		
						—	—	—	—	—
			(10) Exciter coupling disconnection			—	—	—	—	—
			a Radial lead removal			—	—	—		
			b Rotor support mounting			—	—	—		
			c Coupling disconnection			—	—	—		
				• Securely store parts so as not to lose them		—	—	—		
				• Use proper tools when loosening bolts		—	—	—		
				• When loosening the bolt, do not apply excessive		—	—	—		
				force so as not to damage the screw part.		—	—	—	—	—
						—	—	—	—	—
			(11) Exciter bearing disassembly			—	—	—		
	○		a Oil stop ring gap measurement, removal			—	—	—		
	○		b Metal back gap measurement, removal			—	—	—		
	◎		c Oil clearance measurement		Criteria: Refer to the regular repair data		—	—		
			d Upper half metal removal		(management instruction value)	—	—	—		
			e Lower half metal removal			—	—	—		
				• Double check not to misread the measured value		—	—	—		
				• When removing the oil stop ring, handle it		—	—	—	—	—
				carefully so as not to damage the labyrinth.		—	—	—		
				• When handling metal, handle it carefully		—	—	—	—	—
				so as not to damage the white metal part.		—	—	—		
						—	—	—	—	—

Plant/Unit	KenGen Olkaria Geothermal Power Plant *xx* Unit *xx*	How to fill in
Equipment	Power Generator	1 In the HP (hold point) classification column, when "Items for which confirmation is completed and proceed to the next process", enter ○.
Work Items	• Opening manhole • Oil stop ring removal • Bearing insulation washer disassembly • Upper half bearing disassembly and measurement • Lower half bearing disassembly and measurement	2 Enter B1 to B3 (designated 1st to 3rd) for special danger work and Q for quality control work in the HP classification column. 3 In the Record Required column, enter ◎ for inspection / test and ○ for collection of records to be submitted. 4 In the Chief Engineer Witness column, enter ○ in the witness schedule. 5 Enter ○ for pass, × for fail in the criteria column.

Plan			Work Unit	Check Item (Describe required place, model, material, qualification, recording style, etc. after *)	Quality Standard (Including criteria)	Confirmation Record				
HP Classification	Record Required	Chief Engineer Witness				Criteria ○ ×	Chief Engineer Date	Chief Engineer Name	Engineer Date	Engineer Name
			(12) Opening manhole			—	—	—	—	—
			a Turbine side manhole open			—	—	—		
			b Exciter side manhole open			—	—	—		
				• After opening, be sure to cure to prevent foreign matter from entering.		—	—	—		
				• Confirmation of internal pressure 0 MPa before opening		—	—	—	—	—
			(13) Oil stop ring removal			—	—	—	—	—
	○		a Turbine side oil stop ring gap measurement, removal		Criteria: Refer to the regular repair data (management instruction value)		—	—		
	○		b Exciter side oil stop ring gap measurement, removal		Criteria: Refer to the regular repair data (management instruction value)		—	—		
				• Check the match mark		—	—	—		
				• Handle with care not to damage the insulation tube		—	—	—		
				• Securely attach the closing plate to prevent objects from falling into the bracket oil drain pipe.		—	—	—	—	—
						—	—	—	—	—
			(14) Bearing insulation washer disassembly			—	—	—	—	—
			a Turbine side removal		The vibration detector has been removed		—	—		
			b Exciter side removal		The vibration detector has been removed		—	—		
				• Make sure to cure the bolts so as not to drop them.		—	—	—		
				• Check the match mark		—	—	—		
						—	—	—	—	—
			(15) Upper half bearing disassembly and measurement			—	—	—	—	—
	◎		a Turbine side oil clearance measurement		Criteria: Refer to the regular repair data		—	—		
			b Turbine side upper half metal removal		(management instruction value)	—	—	—		
	◎		c Exciter side oil clearance measurement		Criteria: Refer to the regular repair data		—	—		
			d Exciter side upper half metal removal		(management instruction value)	—	—	—		
				• Perform a pre-use inspection of the jig		—	—	—		
				• Be sure to cure, after removing the metal.		—	—	—		
						—	—	—	—	—
			(16) Lower half bearing disassembly and measurement			—	—	—	—	—
	○		a Turbine side lower half metal removal		Criteria: Refer to the regular repair data (management instruction value)		—	—		
	○		b Exciter side lower half metal removal		Criteria: Refer to the regular repair data (management instruction value)		—	—		
				• Double check to avoid measurement mistakes		—	—	—		
				• When reversing metal, communicate verbally between workers so as not to pinch their fingers.		—	—	—		
				• Put a pad to prevent rotation		—	—	—	—	—
						—	—	—		
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
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						—	—	—	—	—
						—	—	—	—	—

Plant/Unit	KenGen Olkaria Geothermal Power Plant *xx* Unit *xx*	How to fill in
Equipment	Power Generator	1 In the HP (hold point) classification column, when "Items for which confirmation is completed and proceed to the next process", enter ○.
Work Items	• Inspection of each part and maintenance of disassembled par • Lower half bearing assembly and adjustment • Exciter lower half bearing assembly and adjustment • Comprehensive leak test • Final confirmation, manhole closure	2 Enter B1 to B3 (designated 1st to 3rd) for special danger work and Q for quality control work in the HP classification column. 3 In the Record Required column, enter ◎ for inspection / test and ○ for collection of records to be submitted. 4 In the Chief Engineer Witness column, enter ○ in the witness schedule. 5 Enter ○ for pass, × for fail in the criteria column.

Plan			Work Unit	Check Item (Describe required place, model, material, qualification, recording style, etc. after *)	Quality Standard (Including criteria)	Confirmation Record				
HP Classification	Record Required	Chief Engineer Witness				Criteria ○ ×	Chief Engineer Date	Chief Engineer Name	Engineer Date	Engineer Name
			(17) Inspection of each part and maintenance of disassembled parts			—	—	—	—	—
○			a	Check for abnormalities by visual inspection of each part	Make sure that there is no abnormality		—	—		
○	◎	○	b	Visual inspection and PT inspection of bearing metal	Criteria: Refer to the regular repair data (management instruction value)		—	—		
			c	Inspection and cleaning of the lead conductor	Make sure that there is no abnormality		—	—		
			d	Inspection and cleaning inside the PT / SA panel		—	—	—		
○	◎	○	e	Insulation resistance measurement of each part	Criteria: Refer to the regular repair data (management instruction value)		—	—		
			f	Inspection and cleaning		—	—	—		
				• If any abnormalities occur, promptly contact the chief engineer		—	—	—		
				and ask for instructions.		—	—	—	—	—
				• PT inspection is carried out by qualified personnel		—	—	—		
				• Check if there is anything left behind in the panel,		—	—	—		
				after the inspection.		—	—	—		
				• Be sure to discharge after insulation measurement		—	—	—		
				• Check the number of tools so that there are no lost items,		—	—	—	—	—
				and make a final check of the inside.		—	—	—	—	—
			(18) Lower half bearing assembly and adjustment			—	—	—	—	—
	○		a	Turbine side lower half metal assembly and adjustment	Criteria: Refer to the regular repair data (management instruction value)		—	—		
	○		b	Exciter side lower half metal assembly and adjustment	Criteria: Refer to the regular repair data (management instruction value)		—	—		
				• Double check to avoid measurement mistakes		—	—	—		
						—	—	—	—	—
			(19) Exciter lower half bearing assembly and adjustmen			—	—	—	—	—
	○		a	Lower half metal assembly and adjustment	Criteria: Refer to the regular repair data (management instruction value)		—	—		
				• Check the match mark		—	—	—		
						—	—	—	—	—
			(20) Comprehensive leak test			—	—	—	—	—
○		○	a	Comprehensive leak test	No leaks		—	—		
				• Keep in close contact with the chief engineer and		—	—	—		
				promptly contact if there is any abnormalities		—	—	—	—	—
				• Make sure that the workers related to turbines and		—	—	—		
				condensers are informed.		—	—	—	—	—
						—	—	—	—	—
			(21) Final confirmation, manhole closure			—	—	—	—	—
○	◎	○	a	Final confirmation	Criteria: No foreign matter		—	—		
				• Make sure there are no foreign objects inside		—	—	—		
			b	Turbine side manhole closed		—	—	—		
			c	Exciter side manhole closed		—	—	—		
				• Check if the packing is misaligned		—	—	—		
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—

Plant/Unit	KenGen Olkaria Geothermal Power Plant *xx* Unit *xx*	How to fill in
Equipment	Power Generator	1 In the HP (hold point) classification column, when "Items for which confirmation is completed and proceed to the next process", enter ○. 2 Enter B1 to B3 (designated 1st to 3rd) for special danger work and Q for quality control work in the HP classification column. 3 In the Record Required column, enter ◎ for inspection / test and ○ for collection of records to be submitted. 4 In the Chief Engineer Witness column, enter ○ in the witness schedule. 5 Enter ○ for pass, × for fail in the criteria column.
Work Items	• Centering between T and G • Centering between G and E • G-E coupling, swing test • Upper half bearing assembly	

Plan			Work Unit / Check Item (Describe required place, model, material, qualification, recording style, etc. after *)	Quality Standard (Including criteria)	Confirmation Record				
HP Classification	Record Required	Chief Engineer Witness			Criteria ○ ×	Chief Engineer Date	Chief Engineer Name	Engineer Date	Engineer Name
			(22) Centering between T and G		—	—	—	—	—
			a Preparation of tools and jigs		—	—	—		
			b Generator casing cover removal		—	—	—		
○	◎	○	c Surface and circumference runout measurement	Criteria: Refer to the regular repair data (management instruction value)		—	—		
			d Liner adjustment		—	—	—		
			e Generator casing cover installation		—	—	—		
			• Make sure to perform a pre-use inspection of the jig		—	—	—		
			• Keep in close contact with the engineer who is in charge		—	—	—		
			of the turbine when the turbine rotor is rotating		—	—	—	—	—
			• Double check to avoid misreading the measured value		—	—	—		
			• When inserting the liner, insert it not to overlap,		—	—	—		
			and insert it so that the bolts do not get caught.		—	—	—	—	—
					—	—	—	—	—
					—	—	—	—	—
			(23) Centering between G and E		—	—	—	—	—
○	◎	○	a Surface and circumference runout measurement	Criteria: Refer to the regular repair data (management instruction value)		—	—		
			b Liner adjustment		—	—	—		
			• Contact with the engineer who is in charge of the turbine		—	—	—		
			to confirm safety when the generator rotor is rotating		—	—	—	—	—
			• Double check to avoid measurement mistakes		—	—	—		
			• When inserting the liner, insert it not to overlap,		—	—	—		
			and insert it so that the bolts do not get caught.		—	—	—	—	—
					—	—	—	—	—
			(24) G-E coupling, swing test		—	—	—	—	—
			a Coupling		—	—	—		
	○		b Runout measurement and adjustment	Criteria: Refer to the regular repair data (management instruction value)		—	—		
	○		c Swing test	Criteria: Refer to the regular repair data (management instruction value)		—	—		
			• Check the match mark		—	—	—		
			• Double check to avoid misreading the numbers		—	—	—		
			• Do not get closer than necessary to avoid getting caught		—	—	—		
			in the rotating part		—	—	—	—	—
			• When coupling, the bolts are thin screws, so tighten		—	—	—		
			them carefully.		—	—	—	—	—
			• Avoid damaging the threads		—	—	—		
					—	—	—	—	—
			(25) Upper half bearing assembly		—	—	—	—	—
	◎		a Turbine side oil clearance measurement	Criteria: Refer to the regular repair data (management instruction value)		—	—		
			b Turbine side upper half metal assembly		—	—	—		
	◎		c Exciter side oil clearance measurement	Criteria: Refer to the regular repair data (management instruction value)		—	—		
			d Exciter side upper half metal assembly		—	—	—		
			• Make sure to perform a pre-use inspection of the jig		—	—	—		
			• Check the inside to prevent foreign matter from entering		—	—	—		
					—	—	—	—	—
					—	—	—	—	—
					—	—	—	—	—
					—	—	—	—	—

Plant/Unit	KenGen Olkaria Geothermal Power Plant *xx* Unit *xx*	How to fill in
Equipment	Exciter	1 In the HP (hold point) classification column, when "Items for which confirmation is completed and proceed to the next process", enter ○.
Work Items	• Bearing insulation washer assembly and adjustment • Oil stop ring assembly and adjustment • Exciter upper half bearing assembly • Foreign matter control area release • Exciter assembly	2 Enter B1 to B3 (designated 1st to 3rd) for special danger work and Q for quality control work in the HP classification column. 3 In the Record Required column, enter ◎ for inspection / test and ○ for collection of records to be submitted. 4 In the Chief Engineer Witness column, enter ○ in the witness schedule. 5 Enter ○ for pass, × for fail in the criteria column.

Plan			Work Unit	Check Item (Describe required place, model, material, qualification, recording style, etc. after *)	Quality Standard (Including criteria)	Confirmation Record				
HP Classification	Record Required	Chief Engineer Witness				Criteria ○ ×	Chief Engineer Date	Chief Engineer Name	Engineer Date	Engineer Name
			(26) Bearing insulation washer assembly and adjustment			—	—	—	—	—
	○		a	Turbine side mounting and adjustment	Criteria: Refer to the regular repair data (management instruction value)		—	—		
	○		b	Exciter side mounting and adjustment	Criteria: Refer to the regular repair data (management instruction value)		—	—		
				• Make sure to cure the bolts so as not to drop them.		—	—	—		
				• Check the match mark		—	—	—		
						—	—	—	—	—
			(27) Oil stop ring assembly and adjustment			—	—	—	—	—
	○		a	Turbine side oil stop ring installation, gap adjustment	Criteria: Refer to the regular repair data (management instruction value)		—	—		
			b	Exciter side oil stop ring installation, gap adjustment		—	—	—		
				• Handle with care to avoid damaging the labyrinth		—	—	—		
				• Check the match mark		—	—	—		
				• Handle with care to avoid damaging the insulation tube		—	—	—		
				• When refueling or draining oil, reconfirm before restoration so that you do not forget to take the curing.		—	—	—	—	—
						—	—	—	—	—
			(28) Exciter upper half bearing assembly			—	—	—	—	—
	○		a	Upper half metal assembly, measurement	Criteria: Refer to the regular repair data (management instruction value)		—	—		
	○		b	Oil stop ring installation, gap adjustment	Criteria: Refer to the regular repair data (management instruction value)		—	—		
			c	Restoration of each part		—	—	—		
				• Double check so that the torque value is not mistaken		—	—	—		
				• Handle with care to avoid damaging the labyrinth		—	—	—		
				• Make a final check so as not to forget restoration		—	—	—		
						—	—	—	—	—
			(29) Release of the second controlled area			—	—	—	—	—
			a	Release of the second controlled area		—	—	—		
				• When the control area is released, make a final check so as not to forget restoration		—	—	—	—	—
						—	—	—	—	—
			(30) Exciter assembly			—	—	—	—	—
	○		a	Fan guide assembly and adjustment	Criteria: Refer to the regular repair data (management instruction value)		—	—		
	○		b	PMG assembly and measurement	Criteria: Refer to the regular repair data (management instruction value)		—	—		
	○		c	ACG gap measurement	Criteria: Refer to the regular repair data (management instruction value)		—	—		
			d	Restoration of each part, connection		—	—	—		
				• Double check to avoid misreading the measured value		—	—	—		
				• Double check to avoid measurement mistakes		—	—	—		
				• Double check to avoid wiring mistakes		—	—	—		
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—

Plant/Unit	KenGen Olkaria Geothermal Power Plant *xx* Unit *xx*
Equipment	Exciter, Gas cooler
Work Items	• Wind tunnel cover assembly • Exciter housing assembly • Gas cooler inspection

How to fill in

1 In the HP (hold point) classification column, when "Items for which confirmation is completed and proceed to the next process", enter ○.
2 Enter B1 to B3 (designated 1st to 3rd) for special danger work and Q for quality control work in the HP classification column.
3 In the Record Required column, enter ◎ for inspection / test and ○ for collection of records to be submitted.
4 In the Chief Engineer Witness column, enter ○ in the witness schedule.
5 Enter ○ for pass, × for fail in the criteria column.

Plan			Work Unit	Check Item (Describe required place, model, material, qualification, recording style, etc. after *)	Quality Standard (Including criteria)	Confirmation Record				
HP Classification	Record Required	Chief Engineer Witness				Criteria ○ ×	Chief Engineer Date	Chief Engineer Name	Engineer Date	Engineer Name
			(31) Wind tunnel cover assembly			—	—	—	—	—
			a Wind tunnel cover assembly			—	—	—		
				• Since it is half-split, check the matching mark and		—	—	—		
				assemble.		—	—	—	—	—
						—	—	—	—	—
			(32) Exciter housing assembly			—	—	—	—	—
			a Housing installation			—	—	—		
			b Air cooler water pipe installation			—	—	—		
			c End cover mounting			—	—	—		
				• When installing the housing, work carefully so that there		—	—	—		
				are no contact points.		—	—	—	—	—
				• Check the matching mark when installing		—	—	—		
				• Handle with care so that the insulation plate does not crack		—	—	—		
				• Reconfirm before restoration so that you do not forget to		—	—	—		
				take the curing in the piping		—	—	—	—	—
						—	—	—	—	—
			(33) Gas cooler inspection			—	—	—	—	—
			a Confirmation of valve "closed"			—	—	—		
			b Separation of cooling water piping			—	—	—		
			c Remove the water chamber lid, clean the thin tube,			—	—	—		
			and replace the zinc rod (if there is a decrease)			—	—	—		
	◎	○	d Internal check after cleaning		No foreign matter inside					
			e Water chamber assembly			—	—	—		
○	○	○	f Leak test			—				
				* 0.4MPa for 2 hours or more		—	—	—	—	—
			g Air cooler installation			—	—	—		
			h Cooling water pipe installation			—	—	—		
			i Water flow test			—	—	—		
				• Make sure to cure the pipe so that foreign matter does not		—	—	—		
				get inside the pipe.		—	—	—	—	—
				• Make sure there are no foreign objects inside		—	—	—		
				• Check the number of sponges in order not to forget them		—	—	—		
				in the thin tube.		—	—	—	—	—
				• Tighten to the specified torque when assembling		—	—	—		
				the water chamber		—	—	—	—	—
				• Double check in order not to forget to insert the packing		—	—	—		
				• Work with well cordination with the chief engineer		—	—	—		
				during water flowing		—	—	—	—	—
				• Make sure there are no leaks when water flows		—	—	—		
				• Tighten evenly while looking at the packing in order not		—	—	—		
				to become one-sided.		—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—

Plant/Unit	KenGen Olkaria Geothermal Power Plant *xx* Unit *xx*	How to fill in
Equipment	Circuit breaker for generator	1 In the HP (hold point) classification column, when "Items for which confirmation is completed and proceed to the next process", enter ○.
Work Items	• Circuit breaker panel inspection for generator • Inspection of cooling device for generator breaker	2 Enter B1 to B3 (designated 1st to 3rd) for special danger work and Q for quality control work in the HP classification column. 3 In the Record Required column, enter ◎ for inspection / test and ○ for collection of records to be submitted. 4 In the Chief Engineer Witness column, enter ○ in the witness schedule. 5 Enter ○ for pass, × for fail in the criteria column.

Plan			Work Unit	Check Item (Describe required place, model, material, qualification, recording style, etc. after *)	Quality Standard (Including criteria)	Confirmation Record				
						Criteria	Chief Engineer		Engineer	
HP Classification	Record Required	Chief Engineer Witness				○ ×	Date	Name	Date	Name
			(34) Circuit breaker panel inspection for generator			—	—	—	—	—
			a Support insulator inspection, cleaning			—	—	—		
			b Inspection of connections, tightening of bolts			—	—	—		
			c Cleaning inside the panel			—	—	—		
				• If necessary, cure the insulator so as not to damage it.		—	—	—		
				• Check the connection for arc marks		—	—	—		
				• When you clean the inside of the panel, mainly use a vacuum cleaner and try to prevent dust from scattering.		—	—	—	—	—
				• Make sure to cure the open areas to prevent foreign matter from entering.		—	—	—	—	—
				• Carefully inspect each part so as not to overlook.		—	—	—		
						—	—	—	—	—
						—	—	—	—	—
			(35) Inspection of cooling device for generator breaker			—	—	—	—	—
			a Drain piping inspection			—	—	—		
		○	b Check temperature setting			—				
		○	c Unit test (cold air pressure, cold air confirmation)			—				
				• Make sure the pipes are not clogged		—	—	—		
				• Check with the chief engineer to set the temperature		—	—	—		
				• The test is conducted in contact with the chief engineer.		—	—	—		
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—

Plant/Unit	KenGen Olkaria Geothermal Power Plant *xx* Unit *xx*	How to fill in
Equipment	Hydrogen gas sealing oil device, hydrogen gas device	1 In the HP (hold point) classification column, when "Items for which confirmation is completed and proceed to the next process", enter ○.
Work Items	• Sealing oil device inspection and maintenance • Hydrogen gas device inspection and maintenance	2 Enter B1 to B3 (designated 1st to 3rd) for special danger work and Q for quality control work in the HP classification column. 3 In the Record Required column, enter ◎ for inspection / test and ○ for collection of records to be submitted. 4 In the Chief Engineer Witness column, enter ○ in the witness schedule. 5 Enter ○ for pass, × for fail in the criteria column.

Plan			Work Unit	Check Item (Describe required place, model, material, qualification, recording style, etc. after *)	Quality Standard (Including criteria)	Confirmation Record				
HP Classification	Record Required	Chief Engineer Witness				Criteria ○ ×	Chief Engineer Date	Chief Engineer Name	Engineer Date	Engineer Name
			(36) Sealing oil device inspection and maintenance			—	—	—	—	—
			a	Draining oil in the device		—	—	—		
			b	Loop seal tank inspection cleaning		—	—	—		
			c	Control valve inspection and maintenance		—	—	—		
			d	Overhaul of each pump motor		—	—	—		
			e	Adding oil in the device		—	—	—		
		○	f	Safety device test and seal oil amount measurement		—				
		○	g	Sealing oil device oil flushing		—				
		○	h	Sealed oil heater device inspection, operation test		—				
			i	Sealed oil heater inspection and cleaning		—	—	—		
			j	Leak test		—	—	—		
			k	Instrument inspection and calibration		—	—	—		
			l	Inspection and cleaning inside the control panel		—	—	—		
		○	m	Test run		—				
				• Make sure to cure the floor so as not to spill the oil.		—	—	—		
				• Use a sponge when cleaning the inside of the tank		—	—	—		
				• Be sure to fill in the matching mark when disassembling the control valve		—	—	—		
				• Make sure there are no foreign objects inside before assembling		—	—	—		
				• Use appropriate tools during overhaul so as not to damage parts, etc.		—	—	—		
				• Make sure there are no foreign objects when installing the strainer		—	—	—	—	—
				• Work carefully to avoid damaging the equipment		—	—	—		
				• Check the pseudo input value in advance when calibrating		—	—	—		
				• Cure the charging part to prevent electric shock at the charging part		—	—	—		
				• Work closely with the engineer during each test and test run		—	—	—		
			(37) Hydrogen gas device inspection and maintenance			—	—	—	—	—
		○	a	Hydrogen gas replacement		—				
			b	Hydrogen gas dryer overhaul, desiccant replacement, heater check		—	—	—		
			c	Inspection of gas pressure regulator, piping, valves		—	—	—		
			d	Security equipment test, inspection and maintenance		—	—	—		
		○	e	Leak test		—				
			f	Instrument inspection and calibration		—	—	—		
			g	Inspection and cleaning inside the control panel		—	—	—		
		○	h	Test run		—				
				• Work with contacting the chief engineer when replacing hydrogen gas		—	—	—		
				• Make sure there are no foreign objects inside before restoration		—	—	—		
				• Work carefully to avoid damaging the equipment		—	—	—		
				• Check the pseudo input value in advance when calibrati		—	—	—		
				• Cure the charging part to prevent electric shock at the charging part		—	—	—		

Plant/Unit	KenGen Olkaria Geothermal Power Plant *xx* Unit *xx*
Equipment	Nitrogen gas filling device, 11kV bus duct, neutral grounding device
Work Items	• Nitrogen gas filling device inspection and maintenance (manufacturer inspection assistance) • 11kV bus duct inspection / cleaning (manufacturer inspection assistance) • Neutral grounding device inspection and maintenance (manufacturer inspection assistance)

How to fill in

1 In the HP (hold point) classification column, when "Items for which confirmation is completed and proceed to the next process", enter ○.
2 Enter B1 to B3 (designated 1st to 3rd) for special danger work and Q for quality control work in the HP classification column.
3 In the Record Required column, enter ◎ for inspection / test and ○ for collection of records to be submitted.
4 In the Chief Engineer Witness column, enter ○ in the witness schedule.
5 Enter ○ for pass, × for fail in the criteria column.

Plan			Work Unit	Check Item (Describe required place, model, material, qualification, recording style, etc. after *)	Quality Standard (Including criteria)	Confirmation Record				
HP Classification	Record Required	Chief Engineer Witness				Criteria ○ ×	Chief Engineer Date	Chief Engineer Name	Engineer Date	Engineer Name
			(38) Nitrogen gas filling device inspection and maintenance (manufacturer inspection assistance)			—	—	—	—	—
			a	Gas pressure control valve, piping, valve inspection		—	—	—		
			b	Inspection of nitrogen-filled shutoff valve		—	—	—		
		○	c	Leak test		—				
			d	Instrument inspection and calibration		—	—	—		
				• Work carefully to avoid damaging the equipment		—	—	—		
				• Make sure there are no foreign objects inside before assembling		—	—	—		
			(39) 11kV bus duct inspection / cleaning (manufacturer inspection assistance)			—	—	—	—	—
				(Including GEN-NGR and HTr-NGR lines)		—	—	—	—	—
			a	Inspection of conductor connections		—	—	—		
			b	Inspection and cleaning of conductors and support insulators	Visual confirmation that there is no foreign matter		—	—		
			c	Check for condensation and rainwater intrusion inside		—	—	—		
				the bus duct		—	—	—		
				• Perform visual inspection carefully so as not to overlook		—	—	—		
				• If any abnormalities are found as a result of the inspection,		—	—	—		
				promptly contact the chief engineer and ask for instructions.		—	—	—	—	—
				• Insulators are cured as needed		—	—	—		
				• When inspecting the inside of the bus duct, clean the		—	—	—		
				shoes well before performing the inspection work.		—	—	—	—	—
						—	—	—	—	—
			(40) Neutral grounding device inspection and maintenance (manufacturer inspection assistance)			—	—	—	—	—
			a	Appearance inspection and maintenance of transformers,		—	—	—		
				reactors and resistors		—	—	—		
			b	Appearance inspection and cleaning of insulators		—	—	—		
			c	Inspection and maintenance of conductor connections		—	—	—		
			d	Inspection and maintenance of disconnector contact and		—	—	—		
				mechanical parts		—	—	—		
			e	Measurement of resistance value		—	—	—		
			f	Inspection and cleaning inside the cubicle board		—	—	—		
				• Perform visual inspection carefully so as not to overlook		—	—	—		
				• Insulators are cured as needed		—	—	—		
				• Work carefully to avoid damaging the cable		—	—	—		
				• Check the resistance value with the chief engineer and		—	—	—		
				the manufacturer worker		—	—	—	—	—
				• When working inside the board, check the work		—	—	—		
				surroundings so as not to damage the peripheral		—	—	—	—	—
				equipment.		—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—

Plant/Unit	KenGen Olkaria Geothermal Power Plant *xx* Unit *xx*	How to fill in
Equipment	PT, Surge absorber	1 In the HP (hold point) classification column, when "Items for which confirmation is completed and proceed to the next process", enter ○.
Work Items	• PT and surge absorber inspection and maintenance (manufacturer inspection assistance) • Test run • Clean up • Final inspection	2 Enter B1 to B3 (designated 1st to 3rd) for special danger work and Q for quality control work in the HP classification column. 3 In the Record Required column, enter ◎ for inspection / test and ○ for collection of records to be submitted. 4 In the Chief Engineer Witness column, enter ○ in the witness schedule. 5 Enter ○ for pass, × for fail in the criteria column.

Plan			Work Unit	Check Item (Describe required place, model, material, qualification, recording style, etc. after *)	Quality Standard (Including criteria)	Confirmation Record				
HP Classification	Record Required	Chief Engineer Witness				Criteria ○ ×	Chief Engineer Date	Chief Engineer Name	Engineer Date	Engineer Name
			(41) PT and surge absorber inspection and maintenance (manufacturer inspection assistance)			—	—	—	—	—
			a Inspection and maintenance of connections and porcelain pipes			—	—	—		
			b Tightening and inspection of conductor connections			—	—	—		
			c Appearance inspection and cleaning of lightning arresters and electrolytic capacitors			—	—	—		
			d Inspection and cleaning inside the cubicle board			—	—	—		
			e Fuse inspection and replacement			—	—	—		
			• Perform visual inspection carefully so as not to overlook			—	—	—		
			• Work carefully to avoid damaging the cable			—	—	—		
			• When working inside the board, check the work surroundings so as not to damage the peripheral equipment.			—	—	—	—	—
			• Use proper tools when replacing fuses			—	—	—		
						—	—	—	—	—
			(42) Test run			—	—	—	—	—
			a Prior confirmation			—	—	—		
○		○	b Turning		Make sure that there is no abnormality					
○		○	c Test run			—				
			• Check the inspection points before turning and make sure that there are no abnormalities or forgetfulness.			—	—	—	—	—
			• Check if there is any abnormal noise such as contact inside the machine or inside the exciter.			—	—	—	—	—
			• Do not get too close to the rotating part so as not to get caught in it			—	—	—	—	—
			• Check the temperature and vibration of the stator and rotor			—	—	—	—	—
			(43) Clean up			—	—	—	—	—
			a Clean up			—	—	—		
			• Check the number of tools and equipment			—	—	—		
			• Check if there is any dust or residue left around			—	—	—		
						—	—	—	—	—
			(44) Final inspection			—	—	—	—	—
○	◎		• Perform a visual inspection of the repaired area		Make sure that there is no abnormality		—	—		
○	◎		• All specified activities have been completed without any problems		Completed		—	—		
○	◎		• The necessary records have been created and prepared		Creation of records, etc. has been confirmed		—	—		
		○	• Confirmation of the chief engineer has been completed		No matters to point out					
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	Inspection Chief Engineer	

Outdoor Switchyard and Main Transformer

Plant/Unit	KenGen Olkaria Geothermal Power Plant *xx* Unit *xx*	How to fill in
Equipment	Outdoor Switchyard and Main Transformer	1 In the HP (hold point) classification column, when "Items for which confirmation is completed and proceed to the next process", enter ○.
Work Items	• Purchase goods, Owned parts inspection, Test • Setting work area • Inspection of main transformer (house transformer in the facility) • Outdoor switchyard (GIS) inspection	2 Enter B1 to B3 (designated 1st to 3rd) for special danger work and Q for quality control work in the HP classification column. 3 In the Record Required column, enter ◎ for inspection / test and ○ for collection of records to be submitted. 4 In the Chief Engineer Witness column, enter ○ in the witness schedule. 5 Enter ○ for pass, × for fail in the criteria column.

Plan			Work Unit	Check Item (Describe required place, model, material, qualification, recording style, etc. after *)	Quality Standard (Including criteria)	Confirmation Record				
HP Classification	Record Required	Chief Engineer Witness				Criteria ○ ×	Chief Engineer Date	Chief Engineer Name	Engineer Date	Engineer Name
			(1) Purchase goods, Owned parts inspection, Test			—	—	—	—	—
○	◎		a	Conduct acceptance inspection of purchased goods	Make sure of the quantity and the specifications	—	—	—	—	—
○	◎		b	Conduct acceptance inspection of owned parts	Make sure of the quantity and the specifications	—	—	—	—	—
				* Check the inspection date on the list		—	—	—	—	—
○		○	c	Inspect equipment and devices	Make sure that there is no abnormality		—	—		
				• Conduct temporary storage section display		—	—	—		
				• Arrival of items with purchase specifications		—	—	—		
				• Do not place the product directly		—	—	—		
						—	—	—	—	—
			(2) Setting work area			—	—	—	—	—
		○	a	Display the work area		—				
				• Display authorized personnel only		—	—	—		
				• Be sure to secure a safety passage		—	—	—		
						—	—	—	—	—
			(3) Inspection of main transformer (house transformer in the facility)			—	—	—	—	—
			a	Inspection and maintenance of the main body and accessories		—	—	—		
			b	Inspection and maintenance of porcelain pipes		—	—	—		
			c	Inspection and maintenance of cooling fan and oil pump		—	—	—		
			d	Inspection and maintenance of lightning arrester		—	—	—		
			e	Control panel inspection and maintenance		—	—	—		
			f	Neutral grounding device inspection and maintenance		—	—	—		
		○	g	Various tests		—				
				• Insulators are cured as needed		—	—	—		
				• Work carefully so as not to damage the equipment inside the panel		—	—	—		
				• Work by having a meeting with the chief engineer		—	—	—		
				• Make sure to discharge after measuring the insulation resistance		—	—	—		
						—	—	—	—	—
			(4) Outdoor switchyard (GIS) inspection			—	—	—	—	—
			a	GIS inspection maintenance		—	—	—		
			b	Circuit breaker inspection		—	—	—		
			c	Disconnector and ground switch inspection		—	—	—		
			d	On-site control panel inspection		—	—	—		
				• Do not hold anything above your shoulders to avoid electric shock		—	—	—		
				• Work carefully so as not to damage the equipment inside the panel		—	—	—		
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—

Plant/Unit	KenGen Olkaria Geothermal Power Plant *xx* Unit *xx*	How to fill in
Equipment	Outdoor Switchyard and Main Transformer	1 In the HP (hold point) classification column, when "Items for which confirmation is completed and proceed to the next process", enter ○. 2 Enter B1 to B3 (designated 1st to 3rd) for special danger work and Q for quality control work in the HP classification column. 3 In the Record Required column, enter ◎ for inspection / test and ○ for collection of records to be submitted. 4 In the Chief Engineer Witness column, enter ○ in the witness schedule. 5 Enter ○ for pass, × for fail in the criteria column.
Work Items	• 110kV CLZE cable inspection and maintenance • Clean up • Final inspection	

Plan			Work Unit	Check Item (Describe required place, model, material, qualification, recording style, etc. after *)	Quality Standard (Including criteria)	Confirmation Record				
HP Classification	Record Required	Chief Engineer Witness				Criteria	Chief Engineer		Engineer	
						○ ×	Date	Name	Date	Name
			(5) 110kV CLZE cable inspection and maintenance			—	—	—	—	—
			a	Check the cable laying status		—	—	—		
			b	Appearance inspection of cable head		—	—	—		
			c	Surface inspection of cable terminal		—	—	—		
○	◎	○	d	Insulation resistance measurement	0.4MΩ or more (management instruction value)					
				• Perform visual inspection carefully so as not to overlook		—	—	—		
				• If any abnormalities are found as a result of the inspection, promptly contact the chief engineer and ask for instructions.		—	—	—	—	—
				• Do not touch the cable terminal with your bare hands		—	—	—		
				• Make sure to discharge after measuring the insulation resistance		—	—	—	—	—
						—	—	—	—	—
			(6) Clean up			—	—	—	—	—
			a	Clean up		—	—	—		
				• Check the number of tools and equipment		—	—	—		
				• Check if there is any dust or residue left around		—	—	—		
						—	—	—	—	—
			(7) Final inspection			—	—	—	—	—
○	◎			• Perform a visual inspection of the repaired area	Make sure that there is no abnormality		—	—		
○	◎			• All specified activities have been completed without any problems	Completed		—	—		
○	◎			• The necessary records have been created and prepared	Creation of records, etc. has been confirmed		—	—		
		○		• Confirmation of the chief engineer has been completed	No matters to point out					
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	Inspection Chief Engineer	
						—	—	—		
						—	—	—		
						—	—	—		
						—	—	—		
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—

Switchboard switchgear

Plant/Unit	KenGen Olkaria Geothermal Power Plant *xx* Unit *xx*	How to fill in
Equipment	Switchboard switchgear	1 In the HP (hold point) classification column, when "Items for which confirmation is completed and proceed to the next process", enter ○.
Work Items	・ Purchase goods, Owned parts inspection, Test ・ Setting work area ・ Board and cubicle inspection maintenance (manufacturer inspection assistance) ・ 3.3kV metal clad circuit breaker inspection (manufacturer inspection assistance)	2 Enter B1 to B3 (designated 1st to 3rd) for special danger work and Q for quality control work in the HP classification column. 3 In the Record Required column, enter ◎ for inspection / test and ○ for collection of records to be submitted. 4 In the Chief Engineer Witness column, enter ○ in the witness schedule. 5 Enter ○ for pass, × for fail in the criteria column.

Plan			Work Unit	Check Item (Describe required place, model, material, qualification, recording style, etc. after *)	Quality Standard (Including criteria)	Confirmation Record				
HP Classification	Record Required	Chief Engineer Witness				Criteria ○ ×	Chief Engineer Date	Chief Engineer Name	Engineer Date	Engineer Name
			(1) Purchase goods, Owned parts inspection, Test			—	—	—	—	—
○	◎		a	Conduct acceptance inspection of purchased goods	Make sure of the quantity and the specifications	—	—	—	—	—
○	◎		b	Conduct acceptance inspection of owned parts	Make sure of the quantity and the specifications	—	—	—	—	—
				* Check the inspection date on the list		—	—	—	—	—
○		○	c	Inspect equipment and devices	Make sure that there is no abnormality					
				・ Conduct temporary storage section display		—	—	—		
				・ Arrival of items with purchase specifications		—	—	—		
				・ Do not place the product directly		—	—	—		
						—	—	—	—	—
			(2) Setting work area			—	—	—	—	—
○		○	a	Display the work area		—	—	—		
○		○		・ Display authorized personnel only		—	—	—		
				・ Be sure to secure a safety passage		—	—	—		
						—	—	—	—	—
			(3) Board and cubicle inspection maintenance (manufacturer inspection assistance)			—	—	—	—	—
			a	3.3kV PT inspection and maintenance		—	—	—		
			b	MV Switchgear incoming panel inspection and maintenance		—	—	—		
B2			c	Motor control center incoming panel inspection and maintenance		—	—	—		
			d	Board instruments, calibration, external inspection		—	—	—		
				and maintenance		—	—	—		
			e	In-panel cable wire terminal inspection, tightening and cleaning		—	—	—		
○	◎	○	f	Insulation resistance measurement	0.4MΩ or more (management instruction value)		—	—		
			g	Fuse inspection and replacement		—	—	—		
				・ Peripheral equipment should be cured as needed		—	—	—		
				・ Make sure to discharge after measuring the		—	—	—	—	—
				insulation resistance		—	—	—	—	—
			(4) 3.3kV metal clad circuit breaker inspection (manufacturer inspection assistance)			—	—	—	—	—
			a	External inspection and maintenance of the drawer mechanism		—	—	—		
			b	Primary and secondary disconnection inspection, maintenance		—	—	—		
				and cleaning		—	—	—		
			c	Appearance inspection and maintenance of conductor		—	—	—		
				connections		—	—	—		
			d	Magnetic contactor, auxiliary switch inspection, maintenance		—	—	—		
			e	Control circuit interlock device inspection and maintenance		—	—	—		
			f	In-panel cable terminal inspection, tightening and cleaning		—	—	—		
○	◎		g	Insulation resistance measurement	0.4MΩ or more (management instruction value)		—	—		
			h	CT secondary circuit terminal tightening		—	—	—		
			i	Feeder cable disconnection / connection		—	—	—		
				・ Be sure to check the voltage before inspection		—	—	—		
				・ Use proper tools when tightening terminals		—	—	—		
				・ Be sure to discharge after measuring the insulation		—	—	—		
				resistance		—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—

Plant/Unit	KenGen Olkaria Geothermal Power Plant *xx* Unit *xx*	How to fill in
Equipment	Switchboard switchgear	1 In the HP (hold point) classification column, when "Items for which confirmation is completed and proceed to the next process", enter ○.
Work Items	• Motor control center panel inspection (manufacturer inspection assistance) • Bus-related (11kV, 3.3kV, 440V bus) (Manufacturer inspection assistance) • Test and measurement • Clean up • Final inspection	2 Enter B1 to B3 (designated 1st to 3rd) for special danger work and Q for quality control work in the HP classification column. 3 In the Record Required column, enter ◎ for inspection / test and ○ for collection of records to be submitted. 4 In the Chief Engineer Witness column, enter ○ in the witness schedule. 5 Enter ○ for pass, × for fail in the criteria column.

Plan			Work Unit / Check Item (Describe required place, model, material, qualification, recording style, etc. after *)	Quality Standard (Including criteria)	Confirmation Record				
					Criteria	Chief Engineer		Engineer	
HP Classification	Record Required	Chief Engineer Witness			○ ×	Date	Name	Date	Name
			(5) Control center panel inspection (manufacturer inspection assistance)		—	—	—	—	—
			a Main contactor, each auxiliary contactor inspection		—	—	—		
			and maintenance		—	—	—		
			b Inspection, tightening, cleaning of each part		—	—	—		
			c Cleaning the inside and outside of the panel		—	—	—		
			d Measurement of insulation resistance of load side circuit		—	—	—		
			・Be sure to check the voltage before inspection		—	—	—		
			・Use proper tools when tightening terminals		—	—	—		
			・Make sure to discharge after megaring		—	—	—		
			(6) Bus-related (11kV, 3.3kV, 440V bus)(Manufacturer inspection assistance)		—	—	—	—	—
			a Conductor connection tightening condition, overheat discoloration		—	—	—		
			and support insulator inspection, maintenance and cleaning		—	—	—	—	—
			b 440V bus tie cable connection terminal inspection		—	—	—		
			and tightening		—	—	—		
			・Use proper tools when tightening terminals		—	—	—		
			(7) Test and measurement		—	—	—	—	—
			a Interlock, sequence test		—	—	—		
			b Insulation resistance measurement		—	—	—		
			・Perform voltage detection during inspection		—	—	—		
			・Make sure to discharge after measuring the insulation		—	—	—		
			resistance		—	—	—	—	—
			(8) Clean up		—	—	—	—	—
			a Clean up		—	—	—		
			・Check the number of tools and equipment		—	—	—		
			・Check if there is any dust or residue left around		—	—	—		
					—	—	—	—	—
			(9) Final inspection		—	—	—	—	—
○	◎		・Perform a visual inspection of the repaired area	Make sure that there is no abnormality		—	—		
○	◎		・All specified activities have been completed without	Completed		—	—		
			any problems			—	—		
○	◎		・The necessary records have been created and prepared	Creation of records, etc. has been confirmed		—	—		
		○	・Confirmation of the chief engineer has been completed	No matters to point out					
					—	—	—	—	—
					—	—	—	—	—
					—	—	—	—	—
					—	—	—	Inspection Chief Engineer	
					—	—	—		
					—	—	—		
					—	—	—		
					—	—	—		
					—	—	—		
					—	—	—	—	—
					—	—	—	—	—
					—	—	—	—	—
					—	—	—	—	—
					—	—	—	—	—
					—	—	—	—	—

Auxiliary motor

Plant/Unit	KenGen Olkaria Geothermal Power Plant *xx* Unit *xx*	How to fill in
Equipment	Auxiliary motor	1 In the HP (hold point) classification column, when "Items for which confirmation is completed and proceed to the next process", enter ○.
Work Items	• Purchase goods, Owned parts inspection, Test • Setting work area • Motor removal • Preparation • Items to check before work • Cable disconnection • Centering check	2 Enter B1 to B3 (designated 1st to 3rd) for special danger work and Q for quality control work in the HP classification column. 3 In the Record Required column, enter ◎ for inspection / test and ○ for collection of records to be submitted. 4 In the Chief Engineer Witness column, enter ○ in the witness schedule. 5 Enter ○ for pass, × for fail in the criteria column.

Plan			Work Unit / Check Item (Describe required place, model, material, qualification, recording style, etc. after *)	Quality Standard (Including criteria)	Confirmation Record				
					Criteria	Chief Engineer		Engineer	
HP Classification	Record Required	Chief Engineer Witness			○ ×	Date	Name	Date	Name
			(1) Purchase goods, Owned parts inspection, Test		—	—	—	—	—
○	◎		a Conduct acceptance inspection of purchased goods	Make sure of the quantity and the specifications		—	—	—	—
○	◎		b Conduct acceptance inspection of owned parts	Make sure of the quantity and the specifications		—	—	—	—
			* Check the inspection date on the list		—	—	—	—	—
○		○	c Inspect equipment and devices	Make sure that there is no abnormality					
			・Conduct temporary storage section display		—	—	—		
			・Arrival of items with purchase specifications		—	—	—		
			・Do not place the product directly		—	—	—		
					—	—	—	—	—
			(2) Setting work area		—	—	—	—	—
○		○	a Display the work area		—	—	—		
○			・Display authorized personnel only		—	—	—		
			・Be sure to secure a safety passage		—	—	—		
					—	—	—	—	—
			(3) Preparation		—	—	—	—	—
			a Check tools, equipment and quantity	There is no damage and the required number is secured.		—	—		
			b Inspect power tools	The inspected sticker is affixed		—	—		
					—	—	—	—	—
			(4) Items to check before work		—	—	—	—	—
○			a Check the power supply "OFF"		—	—	—		
			・Check with the chief engineer to turn off the power.		—	—	—		
					—	—	—	—	—
			(5) Cable disconnection	* Check the inspection date and confirmers on the list	—	—	—	—	—
			a Power cable disconnection		—	—	—		
○	◎		b Measurement of power cable and motor insulation resistance	0.4MΩ or more (management instruction value)		—	—		
			・Be sure to check the voltage before disconnecting	There is no voltage		—	—		
			・Record the connection status on a tag etc. before disconnection	Record so that other workers can connect		—	—		
					—	—	—		
			・After measuring the insulation resistance, be sure to discharge and cure the cable terminal.		—	—	—		
					—	—	—	—	—
			(6) Centering check	* Check the inspection date and confirmers on the list	—	—	—	—	—
			a Coupling disconnection		—	—	—		
			b Centering check		—	—	—		
			・Check the match mark and the mounting position of the coupling bolt		—	—	—		
					—	—	—	—	—
			・Measure circles, planes and between planes, and compare with the previous record		—	—	—		
					—	—	—	—	—
					—	—	—	—	—
			(7) Motor removal	* Check the inspection date and confirmers on the list	—	—	—	—	—
			a Motor removal, movement, temporary storage		—	—	—		
			b Liner removal and storage		—	—	—		
			・Store separately for each base so as not to mix		—	—	—		
					—	—	—	—	—
					—	—	—	—	—
					—	—	—	—	—
					—	—	—	—	—
					—	—	—	—	—

Plant/Unit	KenGen Olkaria Geothermal Power Plant *xx* Unit *xx*	How to fill in
Equipment	Auxiliary motor	1 In the HP (hold point) classification column, when "Items for which confirmation is completed and proceed to the next process", enter ○.
Work Items	• Disassembly and measurement of each part • Rotor pulling out	2 Enter B1 to B3 (designated 1st to 3rd) for special danger work and Q for quality control work in the HP classification column. 3 In the Record Required column, enter ◎ for inspection / test and ○ for collection of records to be submitted. 4 In the Chief Engineer Witness column, enter ○ in the witness schedule. 5 Enter ○ for pass, × for fail in the criteria column.

Plan			Work Unit	Check Item (Describe required place, model, material, qualification, recording style, etc. after *)	Quality Standard (Including criteria)	Confirmation Record				
						Criteria	Chief Engineer		Engineer	
HP Classification	Record Required	Chief Engineer Witness				○ ×	Date	Name	Date	Name
			(8) Disassembly and measurement of each part		* Check the inspection date and confirmers on the list	—	—	—	—	—
			a Exterior cleaning			—	—	—		
			b Coupling runout measurement			—	—	—		
○			c Coupling removal			—	—	—		
			d Shaft runout measurement			—	—	—		
			e Fan cover, fan removal			—	—	—		
○			f Disassembly of outer bearing parts (load side, non-load side)			—	—	—		
○			g Bracket removal (load side, non-load side)			—	—	—		
			h Removal of bearings and other parts			—	—	—		
				• When opening the bracket, clean it so that foreign matter		—	—	—		
				does not get inside.		—	—	—	—	—
				• Reconfirm to avoid measurement errors		—	—	—		
				• Measure and record the coupling and the fan allowance		—	—	—		
				• Make sure that no excessive force is applied and remove it.	Check the removal of the set screw		—	—		
				• Measure the dimensions from the shaft end to each part		—	—	—		
				• Organize parts on the load side and non-load side in order		—	—	—		
				not to mix up.		—	—	—	—	—
				• Check the matching mark before disassembling		—	—	—		
				• Equalize the gap between the stator and bracket	Do not apply excessive force to the bracket		—	—		
				and remove		—	—	—		
				• Remove rust on shafts, paint, bulges, and grease on		—	—	—		
				bearings		—	—	—	—	—
				• Measure the dimension from the shaft end to the bearing	Make a note of the measured value		—	—		
			(9) Rotor pulling out		* Check the inspection date and confirmers on the list	—	—	—	—	—
			a Slinging, centering		Never hang wires on the end ring and		—	—		
○			b Rotor pulling out		the journal	—	—	—		
			c Temporarily placed on the rotor cradle			—	—	—		
				• When using a pipe, cure it so as not to damage the shaft.		—	—	—		
				• Always check the levelness and parallelism to secure		—	—	—		
				an air gap.		—	—	—	—	—
				• Perform internal monitoring to prevent damage on the		—	—	—		
				coil and stator			—	—		
				• Inspect the rotor pedestal before use	The plank is tied to the pedestal		—	—		
				• Check the stability after temporarily placing the rotor	Do not attach to the journal		—	—		
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—

Plant/Unit	KenGen Olkaria Geothermal Power Plant *xx* Unit *xx*	How to fill in
Equipment	Auxiliary motor	1 In the HP (hold point) classification column, when "Items for which confirmation is completed and proceed to the next process", enter ○.
Work Items	• Inspection, maintenance and measurement of disassembled parts • Rotor insertion • Assembly and measurement of each part	2 Enter B1 to B3 (designated 1st to 3rd) for special danger work and Q for quality control work in the HP classification column. 3 In the Record Required column, enter ◎ for inspection / test and ○ for collection of records to be submitted. 4 In the Chief Engineer Witness column, enter ○ in the witness schedule. 5 Enter ○ for pass, × for fail in the criteria column.

Plan			Work Unit	Check Item (Describe required place, model, material, qualification, recording style, etc. after *)	Quality Standard (Including criteria)	Confirmation Record				
HP Classification	Record Required	Chief Engineer Witness				Criteria ○ ×	Chief Engineer Date	Chief Engineer Name	Engineer Date	Engineer Name
			(10) Inspection, maintenance and measurement of disassembled parts		* Check the inspection date and confirmers on the list	—	—	—	—	—
			a Rotor and stator inspection			—	—	—		
			b Maintenance for disassembled parts			—	—	—		
	○		c Axle box and other measurements		Criteria: Described on the motor check sheet		—	—		
				• Handle with care not to damage the coil		—	—	—		
				• Sort by parts box in order not to mix up the disassembled parts		—	—	—		
				• Handle with care so as not to damage the measuring instrument		—	—	—		
						—	—	—	—	—
			(11) Rotor insertion		* Check the inspection date and confirmers on the list	—	—	—	—	—
○	◎	○	a Inside inspection		Criteria: No foreign matter					
			b Slinging, centering			—	—	—		
○			c Rotor insertion			—	—	—		
				• Make sure there are no foreign objects inside		—	—	—		
				• When using a pipe, cure it so as not to damage the shaft.		—	—	—		
				• Sufficient internal monitoring to avoid damaging the rotor and stator		—	—	—	—	—
				• Check the levelness and parallelism, and secure the air gap.		—	—	—		
						—	—	—	—	—
						—	—	—	—	—
			(12) Assembly and measurement of each part		* Check the inspection date and confirmers on the list	—	—	—	—	—
○			a Installation of bearings and other parts			—	—	—		
○			b Bracket mounting (load side, non-load side)			—	—	—		
○			c Installation of outer bearing parts (load side, non-load side)			—	—	—		
			d Shaft runout measurement			—	—	—		
○			e Fan, fan cover installation			—	—	—		
○			f Coupling installation			—	—	—		
			g Coupling runout measurement		Make sure the rotor turns smoothly	—	—	—		
				• Check for parts before installing bearings	Parts inside the bearing are installed		—	—		
				• Check the orientation of the bearing		—	—	—		
				• After mounting the bearing, measure the dimensions from the shaft end	Same as when disassembling		—	—		
							—	—		
				• Equalize the gap between the stator and bracket	Do not apply excessive force to the bracket		—	—		
				• Tighten the bolts diagonally		—	—	—		
				• When installing the outer bearing parts, measure the dimensions from the shaft end to each part.	Same as when disassembling	—	—	—	—	—
				• Check the match mark			—	—		
				• Measure and record the coupling and the fan allowance	Same as when disassembling		—	—		
				• Make sure that no excessive force is applied when installing the fan cover.	Tighten the set screw after the coupling has cooled.	—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—

Plant/Unit	KenGen Olkaria Geothermal Power Plant *xx* Unit *xx*	How to fill in
Equipment	Auxiliary motor	1 In the HP (hold point) classification column, when "Items for which confirmation is completed and proceed to the next process", enter ○.
Work Items	• Motor installation • Cable connection • Electric motor unit test run • Centering, coupling	2 Enter B1 to B3 (designated 1st to 3rd) for special danger work and Q for quality control work in the HP classification column. 3 In the Record Required column, enter ◎ for inspection / test and ○ for collection of records to be submitted. 4 In the Chief Engineer Witness column, enter ○ in the witness schedule. 5 Enter ○ for pass, × for fail in the criteria column.

Plan			Work Unit	Check Item (Describe required place, model, material, qualification, recording style, etc. after *)	Quality Standard (Including criteria)	Confirmation Record				
HP Classification	Record Required	Chief Engineer Witness				Criteria	Chief Engineer		Engineer	
						○ ×	Date	Name	Date	Name
			(13) Motor installation		* Check the inspection date and confirmers on the list	—	—	—	—	—
			a	Motor installation		—	—	—		
			b	Liner insertion		—	—	—		
				• Make sure there are no foreign objects between the base		—	—	—		
				and the base plate		—	—	—	—	—
			(14) Cable connection		* Check the inspection date and confirmers on the list	—	—	—	—	—
○	◎		a	Measurement of power cable and motor insulation resistance	0.4MΩ or more (management instruction value)		—	—		
			b	Power cable connection		—	—	—		
				• Always discharge after measuring insulation resistance		—	—	—		
				• Perform voltage detection before connecting	There is no voltage		—	—		
				• Check the connection status with a tag etc.	Record so that other workers can connect		—	—		
						—	—	—	—	—
			(15) Electric motor unit test run		* Check the inspection date and confirmers on the list	—	—	—	—	—
			a	Thermometer installation at the measurement points		—	—	—		
			b	Vibrometer, ammeter preparation		—	—	—		
			c	Recording paper preparation		—	—	—		
			d	Request to create test run condition		—	—	—		
			e	Rotor hand turning		—	—	—		
○	○	○	f	Instant start witness, check for abnormalities, current	Criteria: No abnormality					
				measurement, recording						
○	○	○	g	Continuous start witness, abnormality confirmation, current	Criteria: No abnormality					
				measurement, recording						
				• Communicate thoroughly with the chief engineer and		—	—	—		
				related engineers		—	—	—		
				• At the time of test run, partition and clear the people		—	—	—		
				out of the area		—	—	—		
				• If there is any abnormalities, promptly contact the chief		—	—	—		
				engineer.		—	—	—		
				• Check the direction of rotation		—	—	—		
○	◎		**(16) Centering, coupling**		* Check the inspection date and confirmers on the list	—	—	—	—	—
			a	Centering	Circle: Within 5 / 100mm		—	—		
			b	Coupling	Plane: Within 3/100 mm	—	—	—		
				• Measure circles, planes and between planes and adjust		—	—	—		
				within the reference value		—	—	—		
				• Check the match mark		—	—	—		
				• Check the position and tightening of the coupling bolt		—	—	—		
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—

Plant/Unit	KenGen Olkaria Geothermal Power Plant *xx* Unit *xx*	How to fill in
Equipment	Auxiliary motor	1 In the HP (hold point) classification column, when "Items for which confirmation is completed and proceed to the next process", enter ○.
Work Items	• Load test run • Clean up • Final inspection	2 Enter B1 to B3 (designated 1st to 3rd) for special danger work and Q for quality control work in the HP classification column. 3 In the Record Required column, enter ◎ for inspection / test and ○ for collection of records to be submitted. 4 In the Chief Engineer Witness column, enter ○ in the witness schedule. 5 Enter ○ for pass, × for fail in the criteria column.

Plan			Work Unit	Check Item (Describe required place, model, material, qualification, recording style, etc. after *)	Quality Standard (Including criteria)	Confirmation Record				
HP Classification	Record Required	Chief Engineer Witness				Criteria	Chief Engineer		Engineer	
						○ ×	Date	Name	Date	Name
			(17) Load test run		* Check the inspection date and confirmers on the list	—	—	—	—	—
			a	Thermometer installation at the measurement points		—	—	—		
			b	Vibrometer, ammeter preparation		—	—	—		
			c	Recording paper preparation		—	—	—		
			d	Request to create test run condition		—	—	—		
			e	Rotor hand turning		—	—	—		
○	○	○	f	Instant start witness, check for abnormalities, current	Criteria: No abnormality					
				measurement, recording						
○	○	○	g	Continuous start witness, abnormality confirmation, current	Criteria: No abnormality					
				measurement, recording		—	—	—		
				• Communicate thoroughly with the chief engineer and		—	—	—		
				related engineers		—	—	—		
				• At the time of test run, partition and clear the people		—	—	—		
				out of the area		—	—	—		
				• If there is any abnormalities, promptly contact the chief		—	—	—		
				engineer.		—	—	—		
				• Check the direction of rotation		—	—	—		
			(18) Clean up			—	—	—	—	—
			a	Repair painting		—	—	—		
			b	Unpartition, cleaning up materials and equipment		—	—	—		
			c	Workplace cleaning		—	—	—		
				• Cure the floor in order not to stain with the paint.		—	—	—		
				• Check the surroundings not to leave residual material		—	—	—		
				• Check if there is any dust or residue left around		—	—	—		
						—	—	—	—	—
			(19) Final inspection			—	—	—	—	—
○	◎			• Perform a visual inspection of the repaired area	Criteria: No abnormality		—	—		
○	◎			• All specified activities have been completed without	Completed		—	—		
				any problems						
○	◎			• The necessary records have been created and prepared	Creation of records, etc. has been confirmed		—	—		
		○		• Confirmation of the chief engineer has been completed	No matters to point out					
						—	—	—	—	—
						—	—	—	Inspection Chief Engineer	
						—	—	—		
						—	—	—		
						—	—	—		
						—	—	—		
						—	—	—		
						—	—	—	—	—
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						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—
						—	—	—	—	—

Work item confirmation table

Equipment \ Work Items		Confirmation of power "off"	Cable disconnection and insulation resistance measurement	Centering check	Motor removal	Motor disassembly / measurement	Rotor pulling out	Parts inspection / maintenance / measurement	Rotor insertion	Assembly / internal confirmation / measurement	Motor installation	Cable connection and insulation resistance measurement	Unit test run	Centering Coupling	Load test run
	Chief Engineer Witness	○								○		○	○	○	○
Turbine auxiliary oil pump	Date														
	Chief Engineer														
Turbine turning oil pump	Date														
	Chief Engineer														
Turbine emergency oil pump	Date														
	Chief Engineer														
Turbine main oil tank vapor fan	Date														
	Chief Engineer														
Turbine turning equipment	Date														
	Chief Engineer														
Turbine oil purifier inlet oil pump	Date														
	Chief Engineer														
Turbine oil purifier outlet oil pump	Date														
	Chief Engineer														
Turbine oil purifier vapor fan	Date														
	Chief Engineer														
A-Servomotor oil drain recovery pump	Date														
	Chief Engineer														
B-Servomotor oil drain recovery pump	Date														
	Chief Engineer														
Hot water pump shaft sealing pump	Date														
	Chief Engineer														
Turbine oil transfer pump	Date														
	Chief Engineer														
A-Hot water pump room ventilation fan	Date														
	Chief Engineer														
B-Hot water pump room ventilation fan	Date														
	Chief Engineer														
A-Intercooler Cooling water pump	Date														
	Chief Engineer														

Manual

Olkaria Geothermal Power Plant
Operation management
(Prediction and performance management/FTA)

Sep.2023

JICA Expert Team

(Kyuden Inter national and West Japan Engineering)

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1. Basic understanding of geothermal power plant operation

Geothermal power generation cannot be operated properly without understanding conditions of the steam and hot water in each part of the plant based on the respective heat mass balance.
This is because the reservoir will gradually change after the power plant starts operating, so it is necessary to optimize the operation according to the condition of the reservoir.
Scale precipitation and corrosion are problems in geothermal power generation. Therefore it is also necessary to understand these phenomena.

1. Basic understanding of geothermal power plant operation

(1) Basic knowledge (converting steam energy into electricity)

The generator output is determined by the amount of steam flowrate, the difference between the turbine inlet pressure and the condenser internal pressure.

It is easy to understand that the generator output increases as the amount of steam flow rate increases.

Here, the difference between the turbine inlet pressure and the condenser internal pressure is explained.

If the difference between the turbine inlet pressure and the condenser internal pressure is large, the amount of work in the turbine increases and the generator output also increases.

An example is shown in the Figure 1-1.

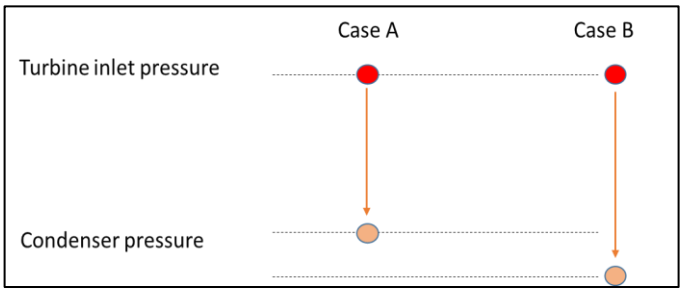


Figure 1-1 converting steam energy

The length of the arrows are meant to show that the pressure inside the condenser is lower in Case B than in Case A under the same turbine inlet pressure. As the arrow becomes longer, the turbine does more work and the generator produces more output.

Therefore, it is important to keep the internal pressure of the condenser as low as possible in order to keep the generator output high.

In the previous slide, it was explained that it is important to operate the condenser at a low pressure in order to maintain high generator output.
Here, it should also be understood that even if the condenser internal pressure remains the same, once the turbine inlet pressure increases, the generator output gets larger.
As indicated by the length of the arrow in the figure, under the same condenser internal pressure conditions, Case B has a higher turbine inlet pressure than Case A in the Figure 1-2, so the arrow becomes longer, the turbine does more work, and the generator produces more output.
Therefore, in order to increase the generator output, it is better to increase the turbine inlet pressure, but in that case, it is also necessary to understand the relationship between the turbine inlet pressure and the main steam mass flow rate. The relationship is further explained in the next slide.

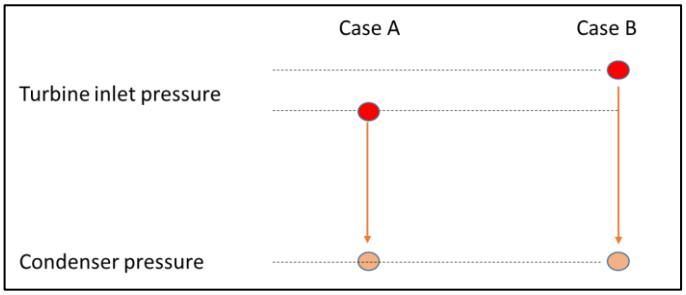


Figure 1-2 converting steam energy into electricity

(2) Relationship between the main steam mass flow rate and the generator output based on the turbine inlet pressure

Smaller the separator pressure, more the steam mass flow is available. On the other hand, heat drop (energy extractable by steam turbine) decreases as the turbine inlet pressure gets smaller. This relationship is depicted in the Figure 1-2 in terms of the turbine inlet pressure, the steam mass flowrate and the heat drop.
The red line in the Figure 1-3 indicates the steam mass flow rate, which increases as the steam/brine separation pressure is lower.
The blue line in the Figure 1-3 indicates the heat drop (kJ/kg), which increases as the turbine inlet pressure increases.
As shown in the Figure 1-3, trends of the turbine heat drop and the steam mass flow rate regarding the separator pressure behave in opposite ways.
Since the generator output is the product of the turbine heat drop and the steam mass flow rate, its profile will be similar to the black line shown in the Figure,

while the black point indicates the maximum output.

Two things need to be understood here.
①It should be understood that the optimum operating point will change in the current reservoir conditions.
②Moreover, if the steam is extracted more than the reservoir capacity, the steam production will decrease eventually in the long run, even if the system is set at the optimum operating point.

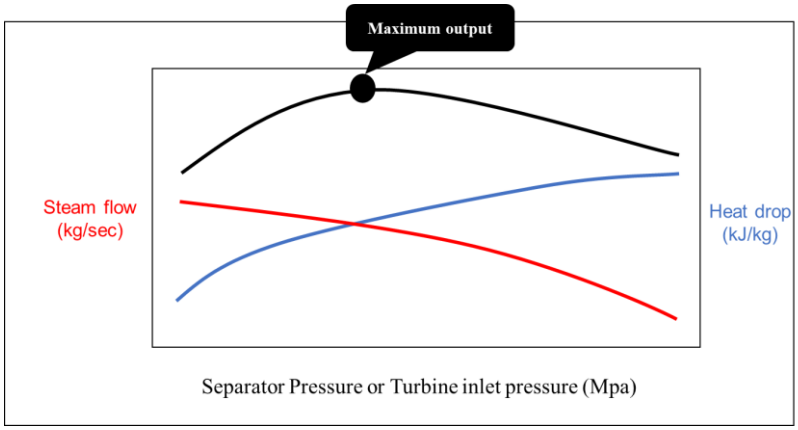


Figure 1-3 Relationship between the main steam flow rate and the generator output based on the turbine inlet pressure

2. Problems of the Olkaria Geothermal Power Plant from a Chemical Perspective

We will understand how the chemical composition in geothermal fluids (steam, gas, hot water) affects plant installations. (Countermeasures for these possible chemical problems require specialized diagnosis and examination, so it is not covered in this session.)

The Olkaria power plant has experienced performance deterioration caused by scale precipitation and frequent shutdowns of the plants caused by corrosion and erosion.
Overhaul maintenance and annual maintenance consist mostly of descaling, repair of corrosion and erosion, and ad hoc countermeasures for these problems. In order to achieve more stable operation of the plant, it is necessary to pursue more fundamental analysis and measures against these problems. This training

program is intended to help you tackling these problems.
In this session, we shall review the generation mechanisms of scale, corrosion, and erosion indicated below.

① Erosion/Corrosion at pipe line
② Silica scaling in a turbine
③ Corrosion at reinjection well head
④ Clogging fill pack at cooling tower
⑤ Collapse of concrete at vessel of cooling tower

(1) Erosion/Corrosion at main steam pipe line

Breakage of the main steam pipes have been reported elsewhere in the world. So what are the causes of frequent occurrences in Olkaria?

It is presumed that the cause is the injection of low-ph water which is used for de-superheating.

Although long section of pipe is required for the injected water to evaporate completely, the length of the pipe from the injection point to the elbow is too short to evaporate sufficiently.

Furthermore, at the places where the low-ph water caused the erosion, corrosion is also induced. The combination of two often results in hole breakage, especially at the elbows.

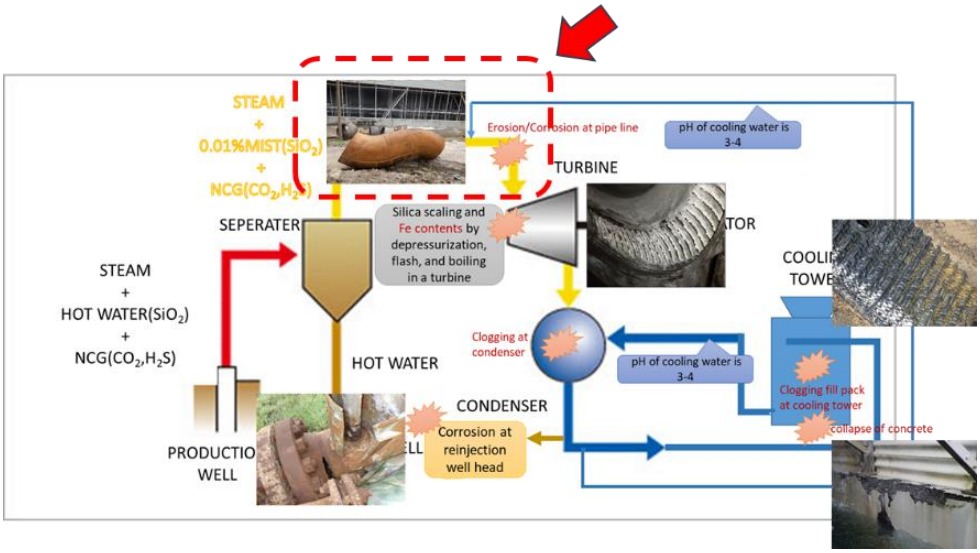


Figure 1-4 Problems of the Olkaria Geothermal Power Plant from a Chemical Perspective (Erosion/Corrosion at main steam pipe

(2) Silica scaling in a turbine

Turbine scaling is a problem for geothermal power plants everywhere.

A small amount of hot water is brought to the turbine along with the steam from the reservoir.

Silica (SiO2) is contained in the hot water and it is precipitated when the pressure is reduced after the governor, where the water evaporates.

Especially in Olkaria, low-ph water is injected for de-superheating, so it is presumed that the iron component is transported from the corroded steam pipe to the turbine which acts as catalyst to accelerate the precipitation process.

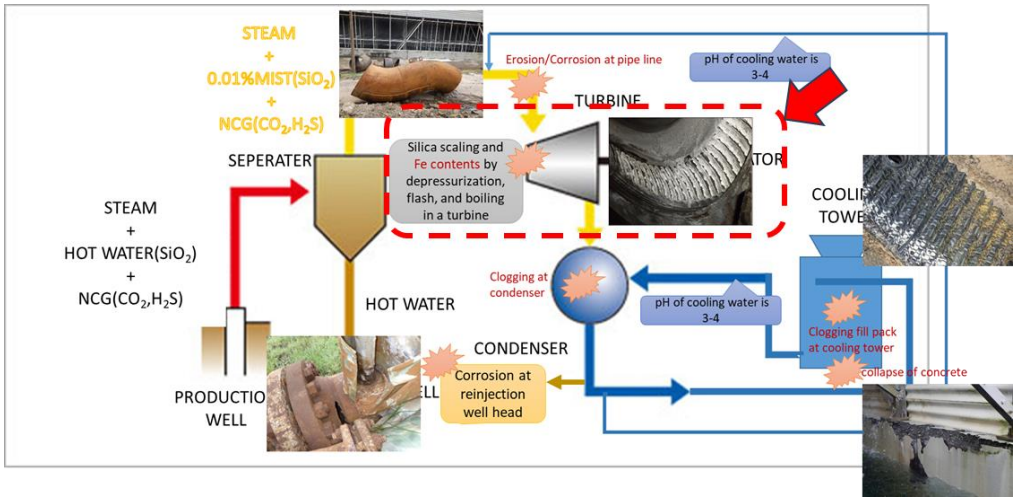


Figure 1-5 Problems of the Olkaria Geothermal Power Plant from a Chemical Perspective (Silica scaling in a turbine)

(3) Corrosion at reinjection well head

Corrosion of the reinjection wellhead equipment is a problem at Olkaria.

In geothermal power plants, hydrogen sulfide (H2S) in Non- Condensable Gas or NCG lowers the pH of circulating water, so alkali chemicals are injected to neutralize it.

Exhaust from the turbine contains NCG including Hydrogen sulfide. In the cooling tower, it reacts with oxygen(O2) in the air and produces sulfuric acid (H2SO4) , which lowers the pH of the circulating water.

And the low pH circulating water corrodes the reinjection wellhead made of carbon steel.

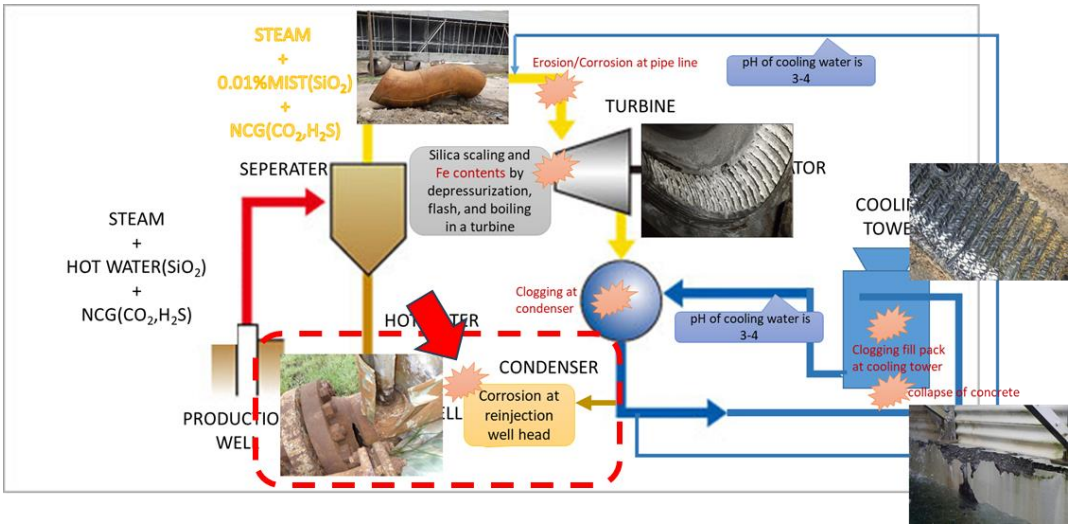


Figure 1-6 Problems of the Olkaria Geothermal Power Plant from a Chemical Perspective (Corrosion at reinjection well head)

(4) Collapse of concrete at vessel of cooling tower

Corrosion of the cooling water tank is another problem in Olkaria.

In the geothermal power plants, hydrogen sulfide (H2S) in NCG (Non-Condensable Gas) lowers the pH of circulating water, so alkali chemicals are injected to neutralize it.

And the low pH circulating water corrodes the concrete cooling water tank.

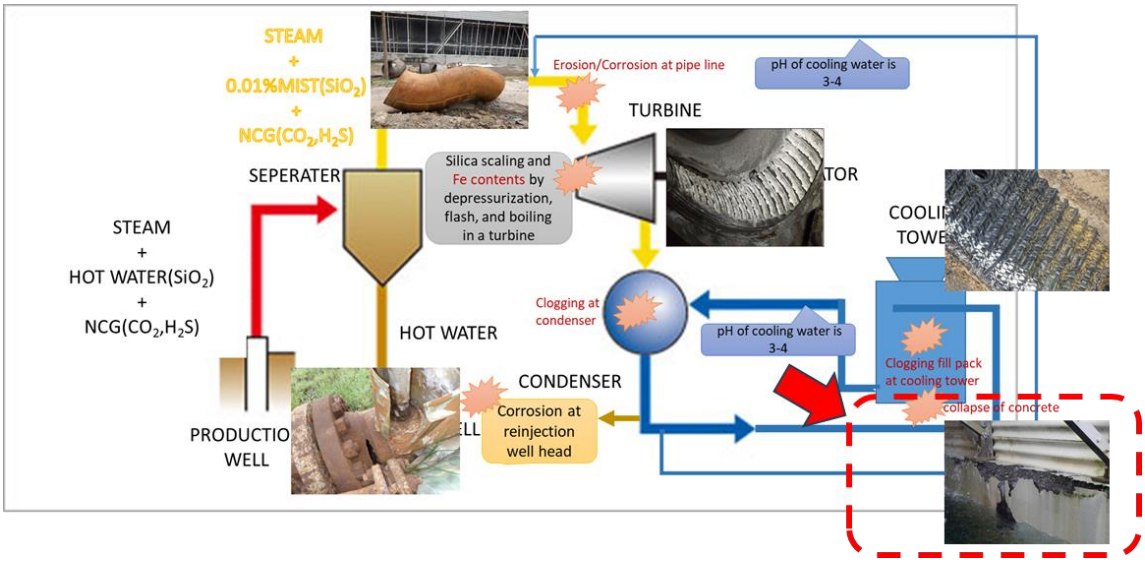


Figure 1-7 Problems of the Olkaria Geothermal Power Plant from a Chemical Perspective (Collapse of concrete at vessel of cooling tower)

(5) Clogging fill pack at cooling tower

Clogging of cooling tower packing with scale such as sulfides is a problem in Olkaria.

Hydrogen sulfide (H2S) in NCG (Non-Condensable Gas) discharged from the turbine reacts with bacteria present in the circulating water to form sulfide scale.

The sulfide scale then clogs the cooling tower packing.

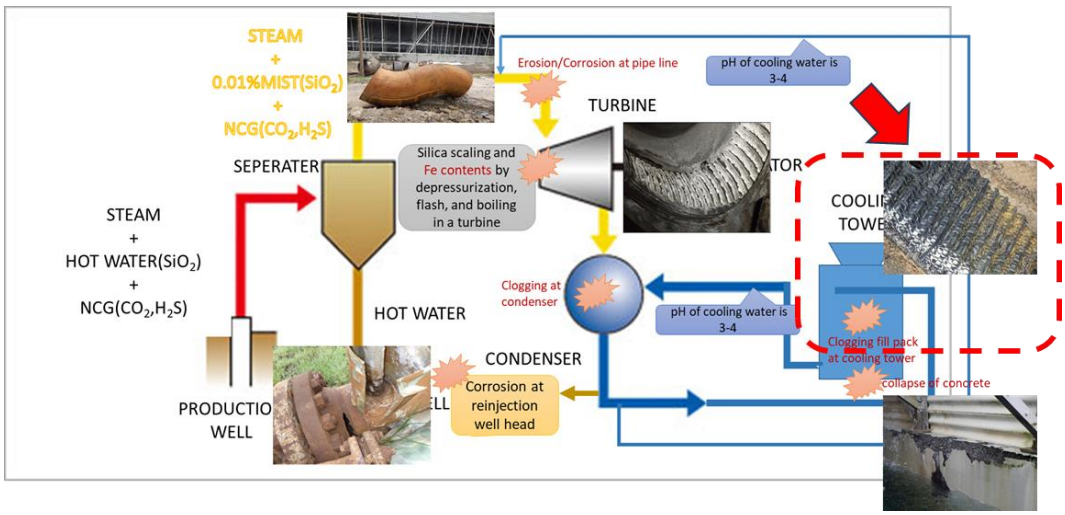


Figure 1-8 Problems of the Olkaria Geothermal Power Plant from a Chemical Perspective (Clogging fill pack at cooling tower)

2. Predictive trouble management

1. Predictive trouble management

Unit may stop because of the serious troubles which may occur to components of the equipment. When the causes of the troubles are analyzed, in many cases there are early signs before the symptoms get to the serious stage.

If we can detect these "signs" early and take proper countermeasures, we may be able to avoid the serious troubles such as unit stopping.

"Prediction management" is to constantly monitor the status of each facility and detect the signs of trouble.

(1) Prediction of future operating conditions from current operation data

In the Figure 2-1, failure symptoms initially occurs at the upper left point, and signs of failure gradually grows to more serious stages.

If this condition is left unchecked, it may develop serious problems such as unit shut-down in the worst case.

If you can detect the signs early, damage will be smaller. In the worst case, if the equipment stops, the power plant as a whole may stop and you may suffer a great loss.

In case of rotating equipment, for example, it is important to detect small changes of the equipment such as "abnormal bearing noise" and "temperature rise" as early signs.

Predictions can be detected through daily patrols and monitoring of operational data. In other words, you can reduce costs by detecting early signs of troubles and taking proper countermeasures.

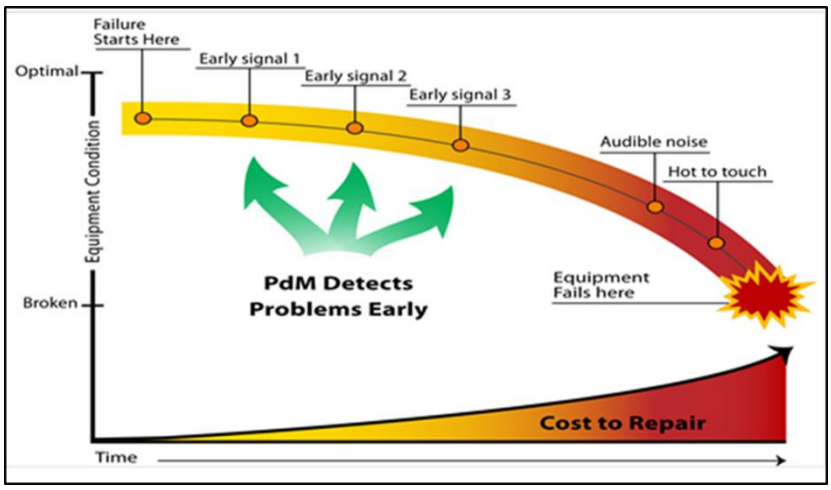


Figure 2-1 the concept of “predictive management”

【Example】

In the Figure 2-2, monthly trend of the temperature of the turbine bearing is shown.

By monitoring the bearing temperature on a regular interval such as daily, monthly and quarterly, you can predict when the bearing should be serviced.

First, in this Figure, the bearing temperature decreased from the 16th month.

How we evaluate cause of the change in the trend is important.

For example, if the temperature has decreased by greasing the bearings, the frequency of greasing should be shortened.

In other words, if it can be dealt with by daily maintenance, it is only necessary to deal with it.

However, if it's not a bearing grease problem, you'll need to disassemble it at some point.

Then you have to decide when to stop this machine and repair it.

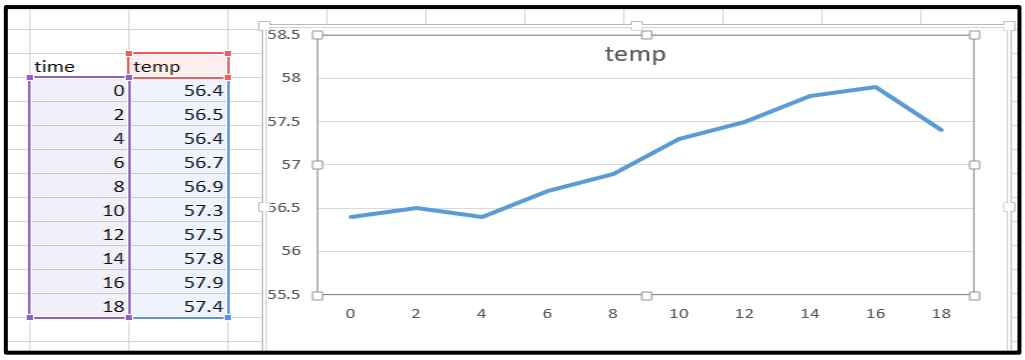


Figure 2-2 Example：monthly trend in turbine bearing temperature over time

The bearing eventually needs to be replaced at certain stage. Question is when we should do.

Two trends in the Figure 2-3, pessimistic and optimistic, can be drawn based on the actual temperature results for the past 18 months.

It is estimated that the limits of its life will reach between 25th and 38th month judging from the pessimistic and optimistic scenario.

If we take the pessimistic scenario, we will replace it during the annual maintenance which is scheduled on the 23rd month. If we take the optimistic scenario, we will replace it during the annual maintenance which is scheduled

on the 35th month. Which do you think the right choice?

It's up to you whether you select the safe side and replace it with the nearest annual maintenance schedule. Or accept risk and replace it during the later annual maintenance schedule.

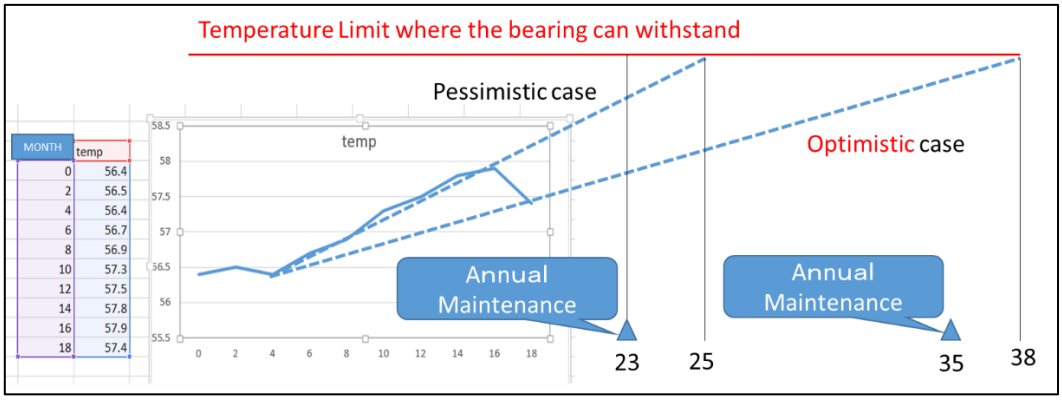


Figure 2-3 Example : monthly trend in turbine bearing temperature over time (Consideration future plan)

(2) "Confirmation of unchanged operating data" even if operating conditions change.

Operator must confirm the unchanged operating data even if operating conditions change. The operators should understand the values of the unchanged operating parameters.

【Example】

The turbine bearing lubricating oil pressure must be above a certain value regardless of the state of the plant, so it should be confirmed whether it stays within a limit in comparison with it under the Normal condition.

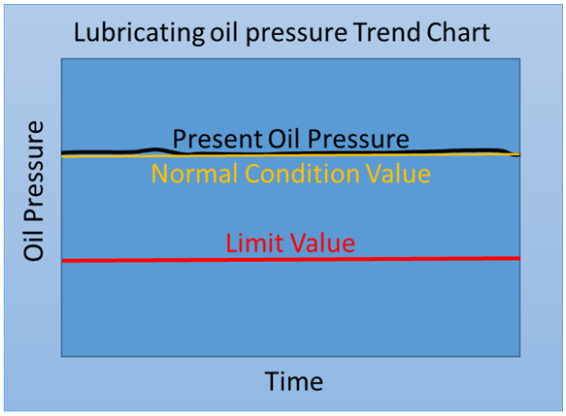


Figure 2-4 Example : Lubricating oil pressure is stable even if other unit value is moving

(3) "Confirmation of changing operating data" according to operating conditions.

Operator must confirm whether the operating data have changed as the operating conditions change. If possible, it is desirable that the operators understand the values of the parameters at each conditions.

【Example】

Generator output changes due to fluctuations in atmospheric wet-bulb temperature, so it should be confirmed that both value is moving at same ratio.

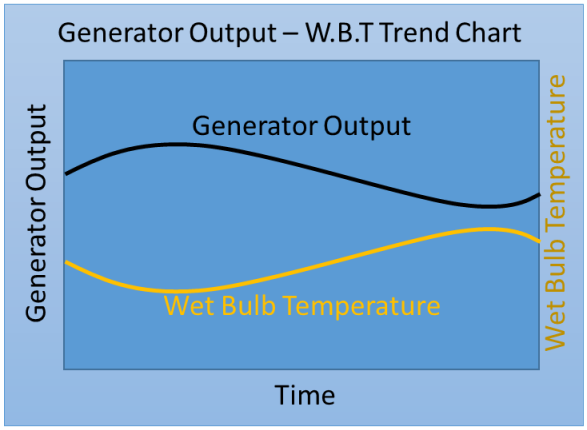


Figure 2-5 Example：Generator Output is change as Wet bulb Temperature

(4) State monitoring using correlation diagram

In the left figure in the Figure 2-6, the correlation between main steam mass flow rate and generator output of Olkaria V is shown.

Under the normal conditions, there is a strong linear positive correlation between these data.

In addition, you notice that the design values are also on the line.

In the right figure, it is shown the correlation diagram between the main steam mass flow rate and the generator output of Olkaria I-au (No.4). The data clouds that fall under a strong positive linear correlation which are evaluated as normal. In addition, there are data clouds which are located out of the main clouds line which indicate the generator output varies largely even though the main steam mass flow rate remains constant. They clearly indicate the equipment is operating in abnormal condition. Abnormal state of the turbine can be easily detected by comparing the normal state data with the abnormal state data by plotting them on the same correlation diagram.

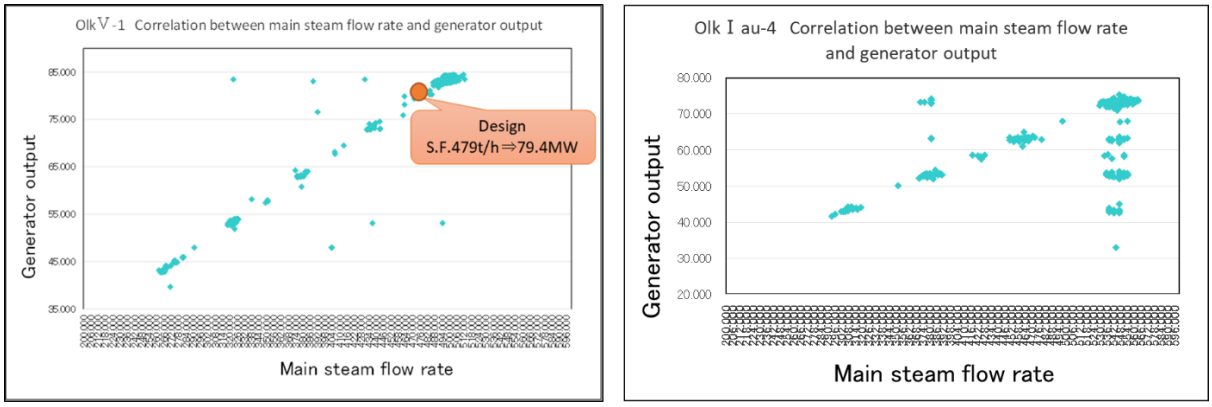


Figure 2-6 Abnormal value detection using correlation diagram between main steam mass flow rate and generator output

(5) Using metrics with formulas

Metrics are measures of quantitative assessment commonly used for assessing, comparing, and tracking performance or production.

Operating data can be used as an indicator of the state of each part of the plant by displaying it with a calculation formula with a purpose.

The indices used in geothermal power plants are shown below.

a. Simple evaluation method for condenser performance

In the figure2-7, the exhaust temperature of steam discharged from the turbine is **Hs**, the temperature of circulating water entering the condenser is $\mathbf{W_I}$, and the temperature of circulating water leaving the condenser is **Wo**.

⊿**T1** is the difference between "the exhaust temperature of the steam discharged from the turbine is **Hs**" and "the temperature of the circulating water entering the condenser is $\mathbf{W_I}$".

In addition, ⊿ **T2** is the difference between "the condenser outlet circulating water temperature **Wo**" and "the condenser inlet circulating water temperature $\mathbf{W_I}$".

The performance of the condenser depends on how much heat the inlet circulating water of the condenser can absorb from the turbine exhaust steam.

It can be calculated by dividing the

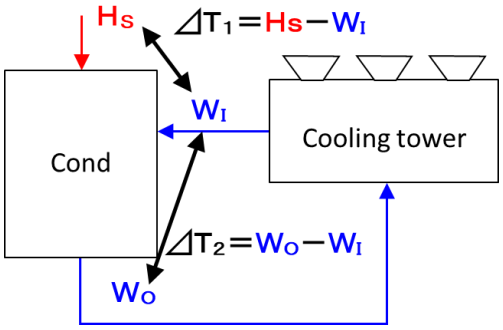


Figure 2-7 Defining operating data for condenser performance evaluation

"temperature difference between the circulating water at the condenser inlet and the outlet" by the "temperature difference between the steam and the circulating water at the condenser inlet" as follows.
If the formula gives smaller value, the performance of the condenser may be degraded.
Please understand that this value changes when the main steam volume or circulating water volume changes.

$$\frac{\text{(Condenser outlet circulating water temperature) } W_O - \text{(Condenser inlet circulating water temperature) } W_I}{\text{(Turbine exhaust temperature) } H_S - \text{(Condenser inlet circulating water temperature) } W_I} = \frac{\Delta T_2}{\Delta T_1}$$

b. Simple evaluation method for cooling tower (What is approach temperature?)
Generally, the temperature difference between the "atmospheric wet-bulb temperature" and the "cooling tower outlet circulating water temperature" is defined as “the approach temperature”. Smaller the temperature difference, better the performance of the cooling tower.
However, please note that this evaluation method is valid when the main steam flow rate and the circulating water flow rate are kept at constant.

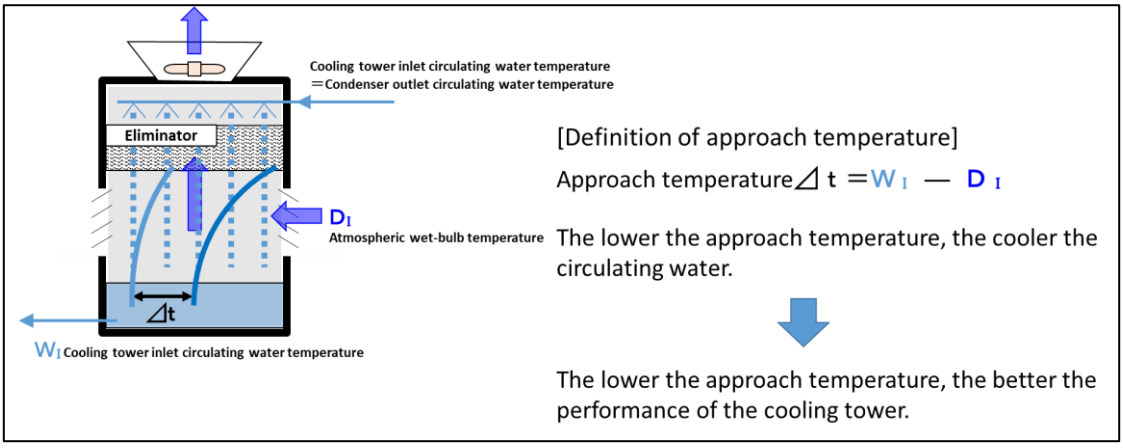


Figure 2-8 Defining Approach Temperature

c. Simple evaluation method for Turbine nozzle clogging

In the upper left figure in the Figure 2-9 an image diagram of steam pressure and steam flow rate near the turbine nozzle is depicted.

It can be imagined that if the pressure is constant, the steam flow rate is also constant assuming there is no external problems such as scale precipitation in the turbine nozzle.

On the other hand, in the lower left figure, where presence of scale deposits on the turbine nozzle is depicted, the flow path of the nozzle narrowed. In this situation, the relationship between the pressure and the steam flow rate at the turbine inlet is as follows.

Assuming the steam supply capacity from the production well is kept constant, when scale precipitates on the turbine nozzle, which made the steam flow path narrowed (in the figure, the width indicated as **g1** is narrower than **g0**), the steam pressure **P1** increases or the steam flow rate **F1** decreases.

In other words, regarding the formula, if there is no clogging in the turbine nozzle, the value will be "**1**", and if clogging is present, it will be less than "**1**". In this way, the formula would render quantitative evaluation.

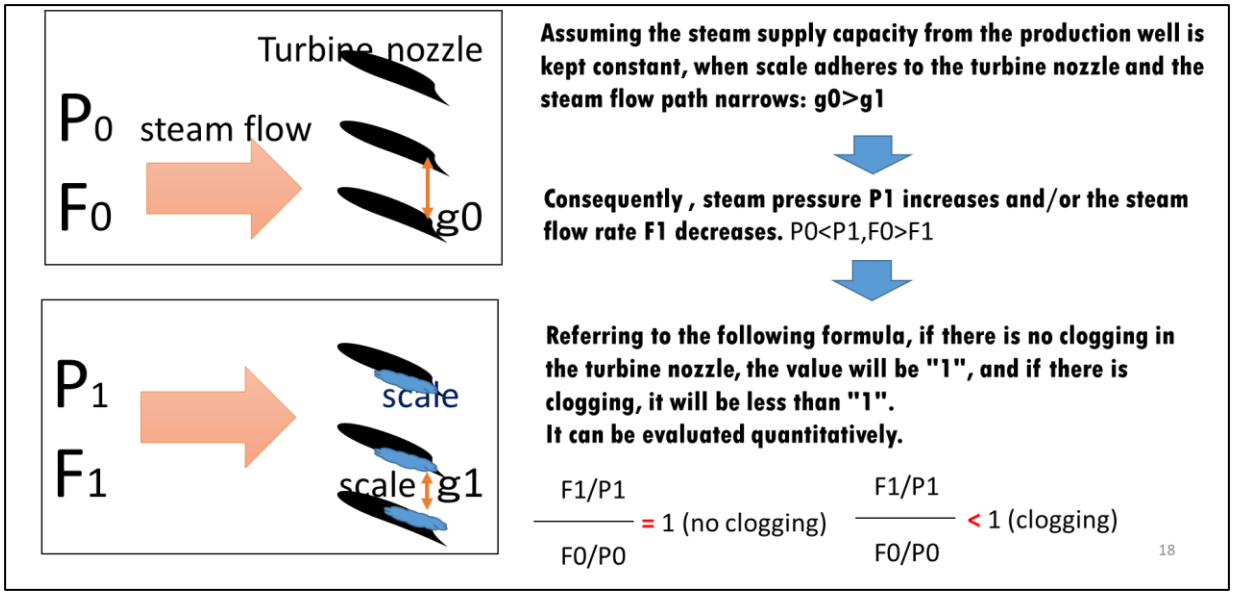


Figure 2-9 Defining Turbine Nozzle Clogging

3. Performance management

1. Basic concept of performance evaluation using correlation diagram

Correlation analysis is a method of creating a correlation diagram of a normal state using two correlating data, and judging whether the operating state is normal or abnormal by comparing the two plots of data.

If you plot the correlation data for the normal state and the corresponding data taken under abnormal states on the same diagram, you will notice difference between them. The method can be effectively used for power plant performance management.

(1) Basic utilization of correlation diagram

Shown here in the Figure 3-1 is an example of a positive correlation diagram, where the two data have strong correlation.

In the Figure 3-1, the horizontal axis is the main steam mass flow rate, and the vertical axis is the generator output, and there is a strong correlation between these two data.

The figure on the right also shows that there is a strong negative correlation between the steam separator pressure and the main steam mass flow rate.

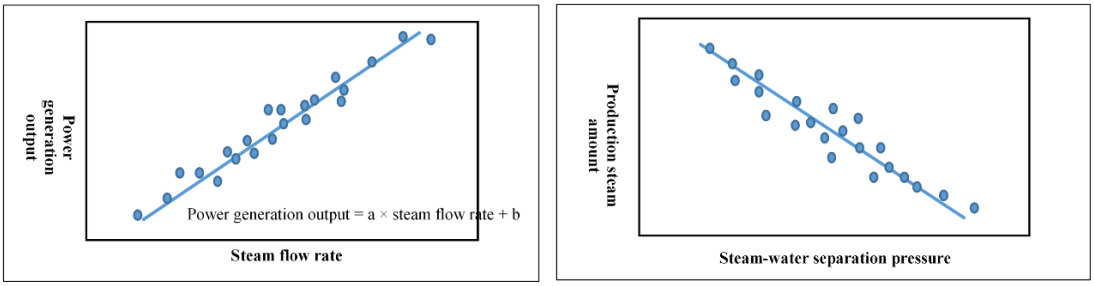


Figure 3-1 correlation diagrams

In the Figure 3-2, When the plot for the measured generation output and the steam flow rate falls on point A, it indicates that the generator output is higher than the one expected for the normal state at the same main steam mass flow rate. Since this situation is unrealistic, some malfunction is suspected on the instrument that measures the steam flow rate or generator output.

Also, when the plot falls on point B, it means “The generator output is lower than the normal state at the same steam mass flow rate” Other than the instrument malfunction, this situation can be caused by deterioration of the power plant performance.

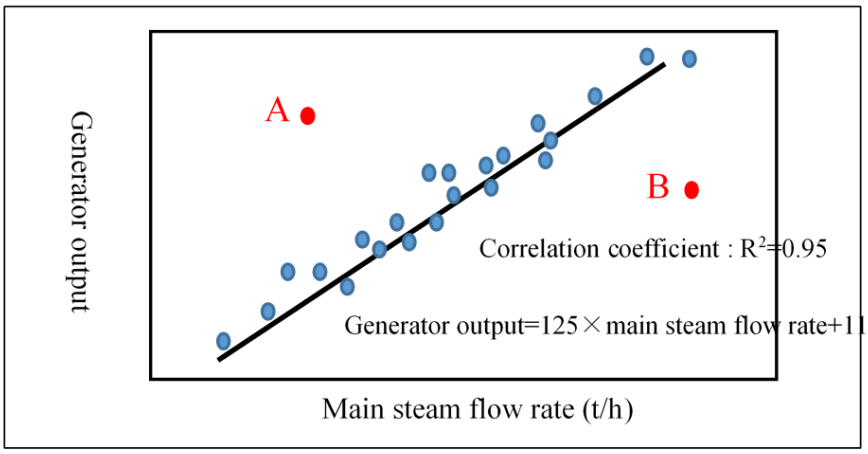


Figure 3-2 Basic utilization of correlation diagram

(2) Evaluation of each state of cooling tower, condenser and turbine (Normal Condition)

Geothermal power plant performance can be evaluated by the four diagrams for the relating parameters.

The Figure 3-3 explain the concept of the four correlation diagrams so that you can understand the condition settings for creating each correlation diagram.

In the upper left Figure, correlation between specific steam consumption or SSC and wet bulb temperature or W.B.T. is shown and this diagram is used to evaluate the plant condition.

In the lower left figure, correlation diagram between atmospheric wet bulb temperature and cooling tower outlet circulating water temperature is shown, from which cooling tower performance can be evaluated.

In the lower right figure, correlation diagram between cooling tower outlet circulating water temperature and condenser pressure is shown, from which condenser performance can be evaluated.

In the upper right figure, correlation diagram between condenser pressure and generator output is shown, from which turbine performance can be evaluated.

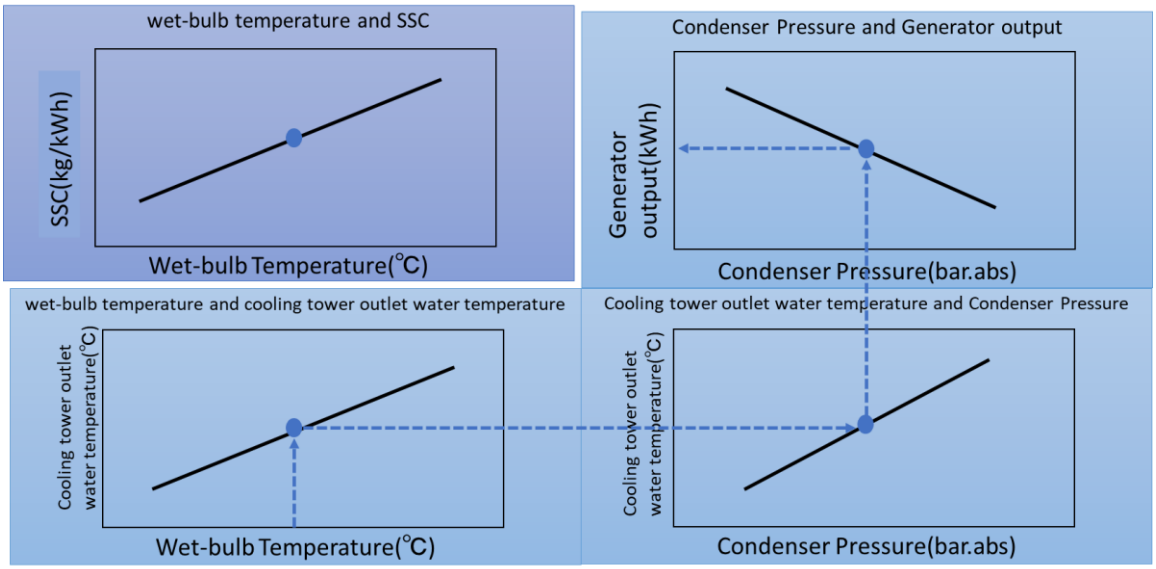


Figure 3-3 Evaluation of each state of cooling tower - condenser – turbine (Normal Condition)

(3) What is important when using correlation diagrams for plant performance management

In order to perform proper evaluation, data should be compared under similar external conditions. In this particular example, evaluation should be made while the main steam mass flow rate and the main steam pressure are at same values for the two cases.

When the main steam pressure changes, the specific enthalpy of the steam changes accordingly, so it is important to compare data under the same main steam pressure. However, an error of about 0.1 bar may be allowed.

Since the total enthalpy flow volume changes as the main steam mass flow rate changes, it is important to compare data under the same main steam mass flow rate. However, an error of about 1t/h may be allowed.

Now, let me explain how it is expressed on each correlation diagram in the Figure 3-4 when the main steam mass flow rate increases or decreases with respect to the reference flow rate.

In each diagram, the black line is the design correlation plots for the reference main steam mass flow rate.

Green lines shown in each diagram are the correlation diagrams where the

main steam mass flow rate is lower than the reference main steam mass flow rate. In addition, red lines shown in each diagram are the correlation diagrams where the main steam mass flow rate is larger than the reference main steam mass flow rate.

In other words, unless these correlation diagrams are created without matching the main steam mass flow rates as shown in this example, correct evaluation will not be possible.

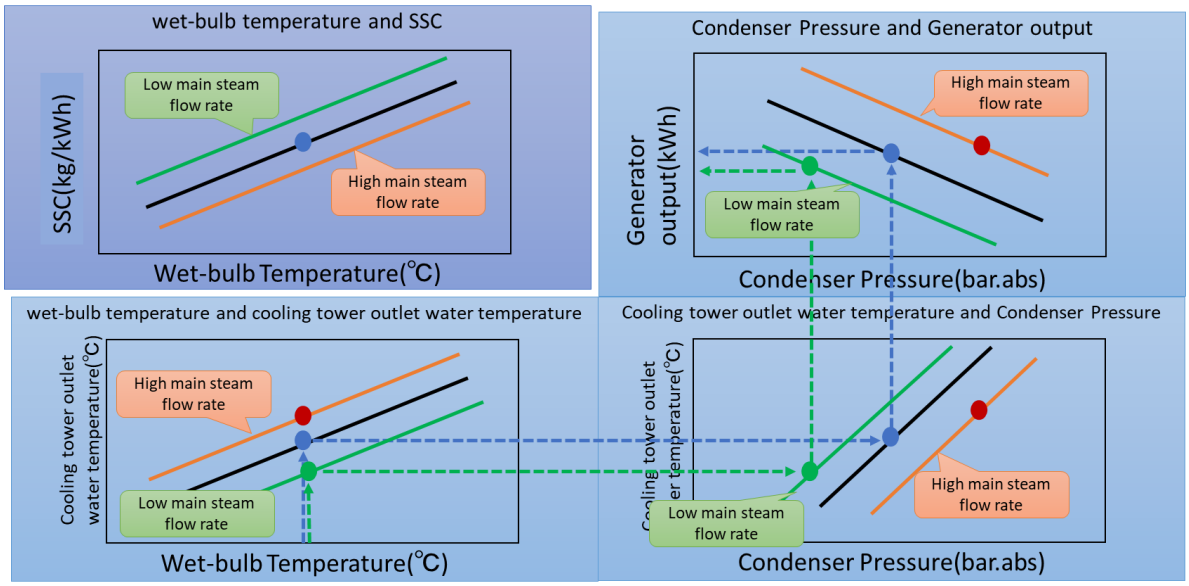


Figure 3-4 Correlation diagram when the main steam mass flow rate increases or decreases with respect to the reference flow rate

(4) Evaluation method using the correlation diagram

The method using the correlation diagram is mainly for evaluating performance deterioration of the target equipment, based on the deviation of the parameters from the data defined as the normal value, by the following process.

① The data must be compared while eliminating the other disturbances such as the main steam mass flow rate and main steam pressure conditions which should be set to the same conditions.

② Creating Diagrams

③ The normal condition data are either design values or ones taken Immediately after the overhaul maintenance. They are compared with the current operation data which you want to evaluate.

In addition, it can be applied for evaluation of the effectiveness of the regular maintenance by comparing the data between before and after the regular maintenance.

④ If there is difference in values between under the operating state to be evaluated and under the normal state, it is likely that the plant performance is deteriorating and the cause should be investigated through the FTA.

【Example】

In this example in the Figure3-5, a case of more complex correlation curves is explained. In the upper left diagram, correlation between the wet-bulb temperature and the specific steam consumption in a given steam flowrate is shown.

This correlation diagram is product of the three step correlation of the relating parameters.

1st step of the correlation is between the wet-bulb temperature and the cooling tower outlet water temperature.

2nd step of the correlation is between the cooling tower outlet water temperature and the condenser pressure.

Finally 3rd step of the correlation is between the condenser pressure and the generator output shown in the upper right diagram.

The performance of the three systems, steam turbine, condenser and cooling tower is all related. Therefore by comparing the measured operating state indicated by blue dots with the normal or design operating state indicated by the black lines, it is possible to evaluate whether the equipment is working as expected.

For example, if the measured operation data indicated by blue dots fall on the black lines, we can conclude the current operation status of the equipment is normal.

In this example, where each correlation diagram is connected, the operating status can be seen as follows.

starting point is atmospheric wet-bulb temperature → cooling tower outlet circulating water temperature → condenser pressure, finally generator output.

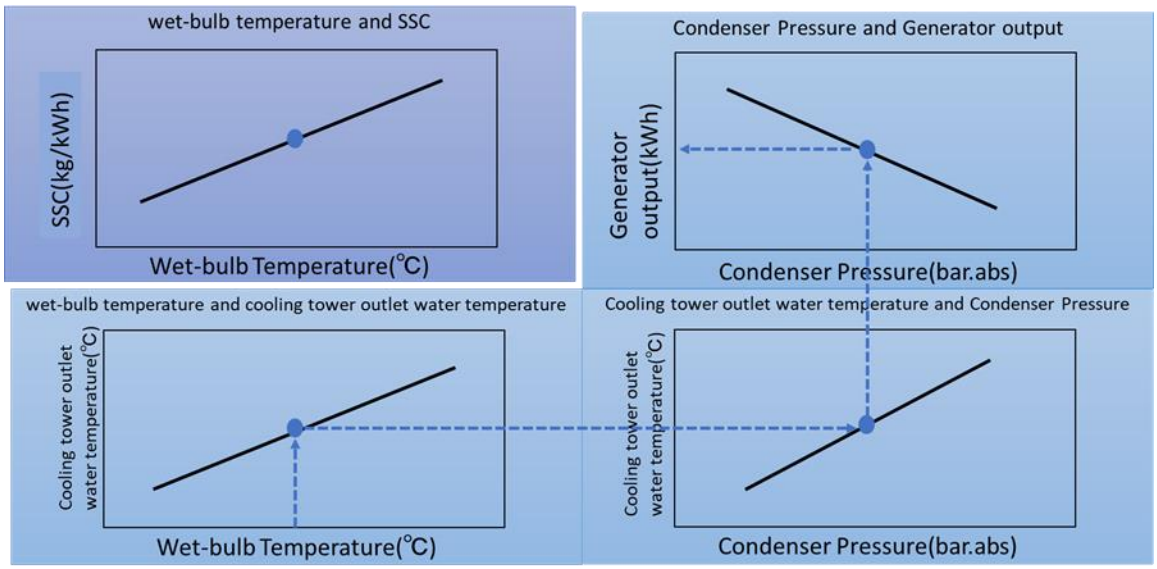


Figure 3-5 Evaluation of each state of cooling tower - condenser – turbine (Normal Condition)

(5) Confirmation of understanding using examples

① Example : Cooling tower performance deterioration

In the upper left diagram in the Figure3-6 , SSC indicated by Orange dot is plotted above the normal state line, which means the performance of the plant is deteriorating.

Let's see which part the performance has deteriorated.

First, looking at the performance evaluation diagram of the cooling tower at the lower left, we can see that the temperature of the circulating water at the outlet of the cooling tower indicated by orang dot is higher than the normal temperature at the same atmospheric wet-bulb.

Looking at the other two performance evaluation diagrams, the operating values indicated by orang dot are on the black line of the normal state, and there are normal condition with the performance of each.

In other words, from these figures, the cause of the deterioration in plant performance is diagnosed to the deterioration in cooling tower performance.

Furthermore, in the upper right figure showing the turbine performance evaluation, from the difference between the generator output in the normal state indicated by the blue dot and the current generator output

indicated by the orange dot, it can be deduced how much deterioration of the cooling tower performance reduces the generator output.

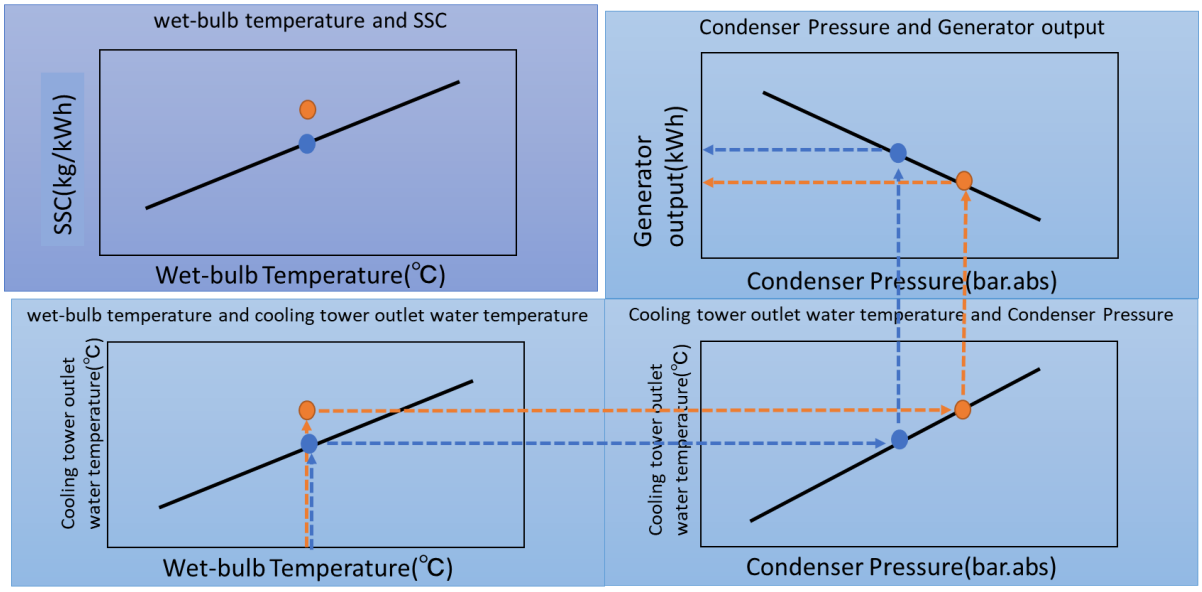


Figure 3-6 Evaluation of each state of cooling tower - condenser – turbine (Cooling tower performance deterioration)

② Example : Condenser performance deterioration

In the upper left diagram in the Figure3-7, SSC indicated by Orange dot is plotted above the normal state line, which means the performance of the plant is deteriorating.

Let's see which part the performance has deteriorated.

First, looking at the performance evaluation diagram of the condenser at the lower right, we can see that condenser pressure indicated by orang dot is higher than the normal pressure at the same cooling water temperature.

Looking at the other two performance evaluation diagrams, the operating values indicated by orang dot are on the black line of the normal state, and there are normal condition with the performance of each.

In other words, from these figures, the cause of the deterioration in plant performance is diagnosed to the deterioration in condenser performance.

Furthermore, in the upper right figure showing the turbine performance evaluation, from the difference between the generator output in the normal state indicated by the blue dot and the current generator output indicated by the orange dot, it can be deduced how much deterioration of the condenser performance reduces the generator output.

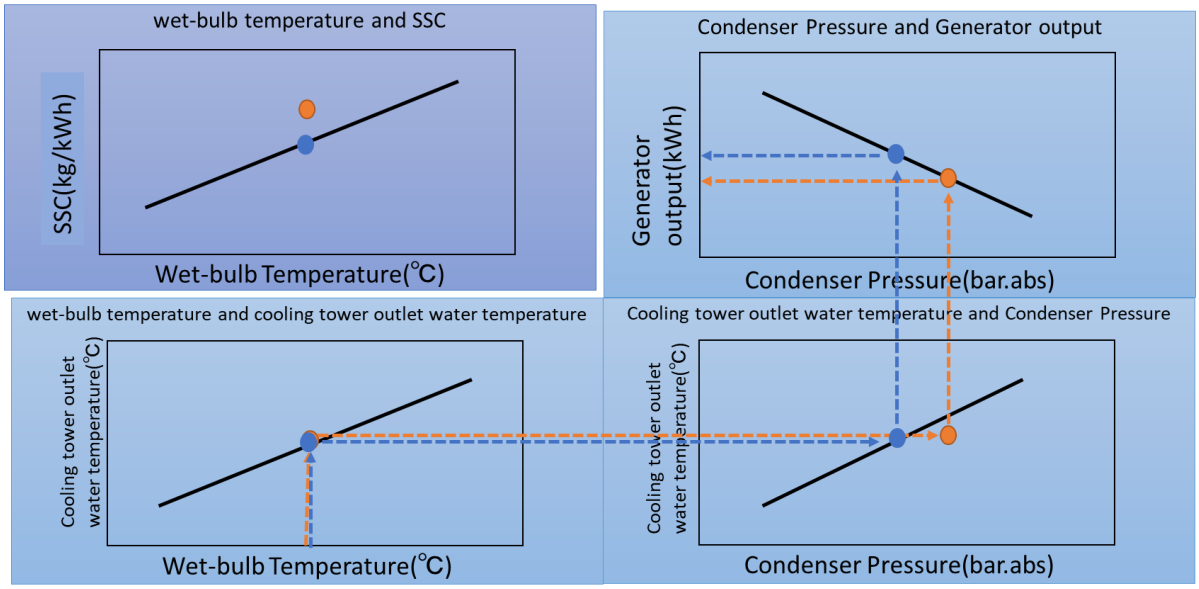


Figure 3-7 Evaluation of each state of cooling tower - condenser – turbine
(Condenser performance deterioration)

③Example：Faulty circulating water thermometer at the outlet of the cooling tower

In the upper left diagram in the Figure 3-8, the Orange dot is plotted on the normal state line, which indicates and the performance of the plant in terms of SSC is in normal condition.

First, looking at the performance evaluation diagram of the turbine at the upper right, the present status indicated by orange dot confirms it is in the normal state.

On the other hand, the orange dots in the performance evaluation diagram of the cooling tower fall on the worse side than those in the normal state, which suggests the equipment performance is declining.

It is contradictory that SSC and generator output are normal even though the performance of the cooling tower is deteriorating.

In other words, based on the information, "faulty circulating water thermometer at the outlet of the cooling tower" is suspected.

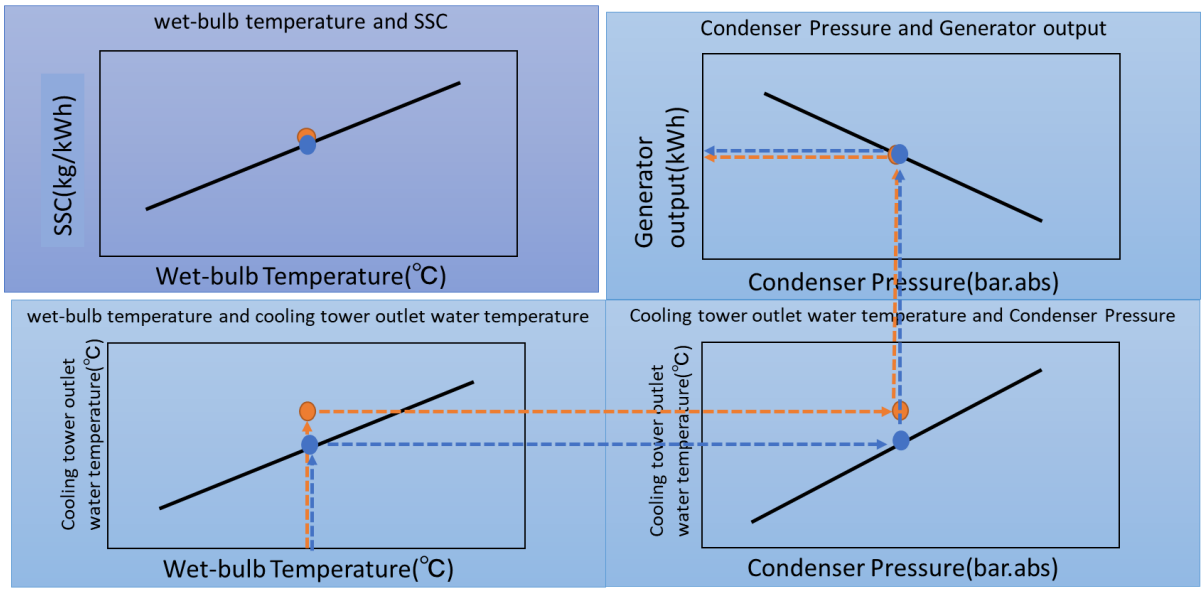


Figure 3-8 Evaluation of each state of cooling tower - condenser – turbine
(faulty circulating water thermometer at the outlet of the cooling tower)

④ Example : Faulty condenser pressure indicator

In the upper left diagram in the Figure3-9, the Orange dot is plotted on the normal state line, which indicates and the performance of the plant in terms of SSC is in normal condition.

First, looking at the performance evaluation diagram of the cooling tower at the lower left, the present status indicated by orange dot confirms it is in the normal state.

On the other hand, the orange dots in the performance evaluation diagram of condenser fall on the worse side than those in the normal state, which suggests the equipment performance is declining.

It is contradictory that SSC and generator output are normal even though condenser is deteriorating.

In other words, based on the information, "faulty condenser pressure indicator" is suspected.

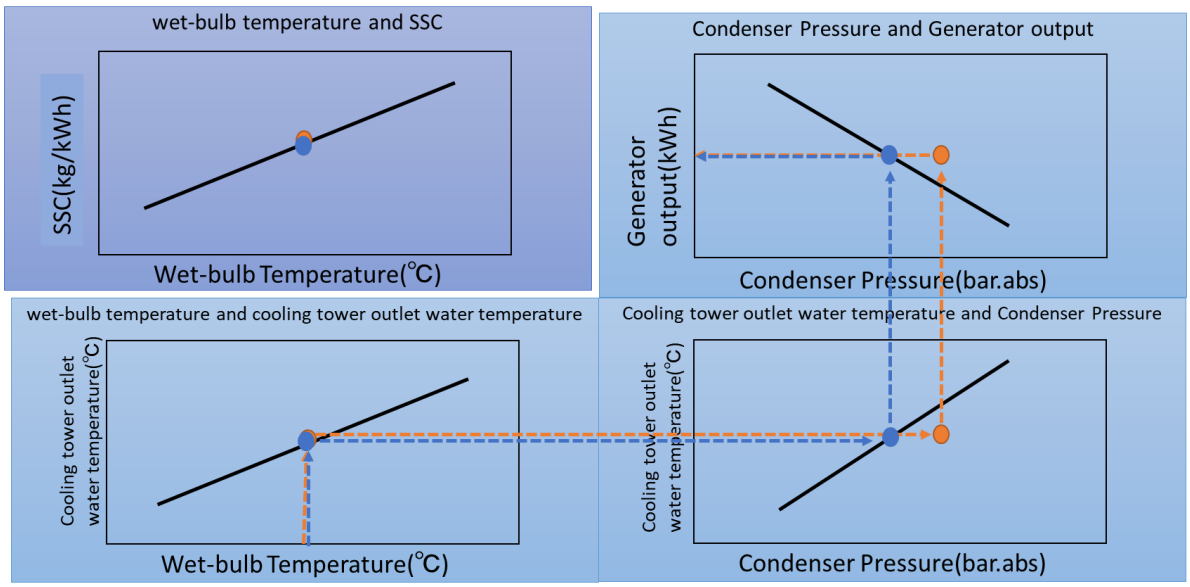


Figure 3-9 Evaluation of each state of cooling tower - condenser – turbine (faulty condenser pressure indicator)

2. Plant performance evaluation using actual data from the Olkaria power plant

Assess plant conditions using operational data from Olkaria V.

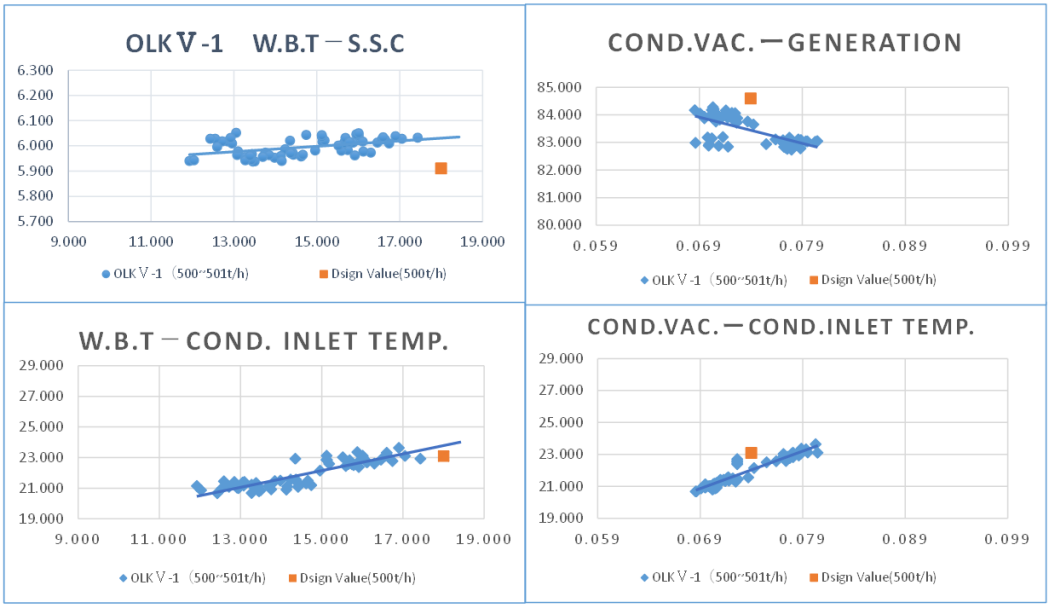
(1) OLK V-1 performance evaluation diagram

From the plant performance management diagram, each diagram has a certain correlation in the Fifure3-10.

Design value is also plotted on this diagram.

Looking at the upper left diagram, the performance of the entire plant has deteriorated compared to the design value, and from the other three diagrams, it is presumed that the performance deterioration of both the cooling tower and the condenser is the cause.

However, it is necessary to analyze the data in detail as to why the turbine performance is declining in the upper right figure.



OLK Ⅴ Plant performance comparison chart between Design value and UNIT1

(26.May.2022～21.Jun.2022)

Figure 3-10 OLK V-1 performance evaluation diagram

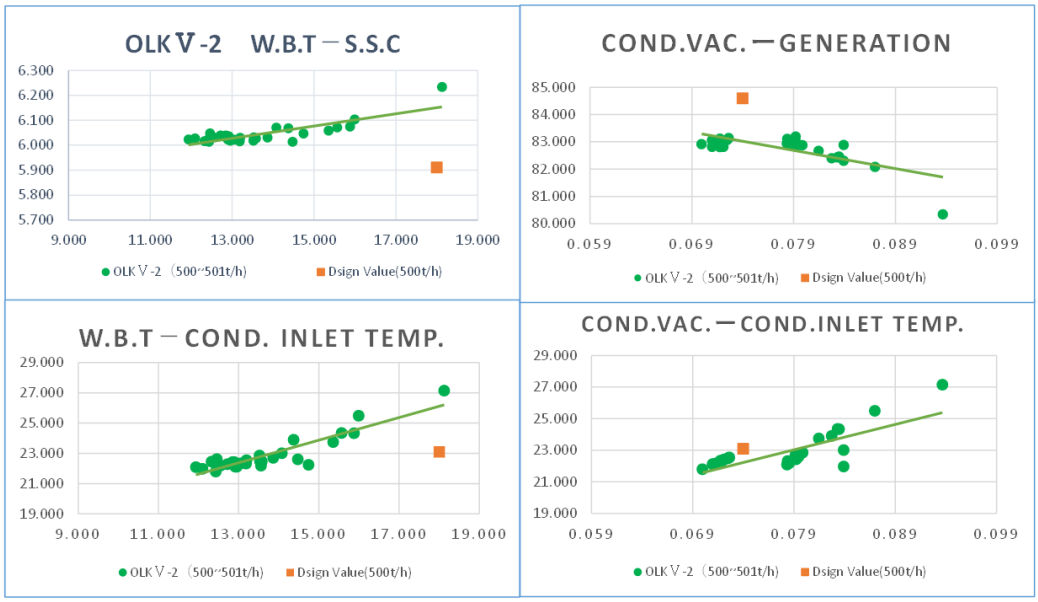
(2) OLK V-2 performance evaluation diagram

From the plant performance management diagram, each diagram has a certain correlation.

Design value is also plotted on this diagram.

Looking at the upper left diagram, the performance of the entire plant has deteriorated compared to the design value, and from the other three figures, it is presumed that the performance deterioration of the cooling tower is the cause.

However, it is necessary to analyze the data in detail as to why the turbine performance is declining in the upper right figure.



OLK V Plant performance comparison chart between Design value and UNIT2 (26.May.2022～21.Jun.2022)

Figure 3-11 OLK V-2 performance evaluation diagram

(3) OLK V-1 and OLK V-2 performance evaluation

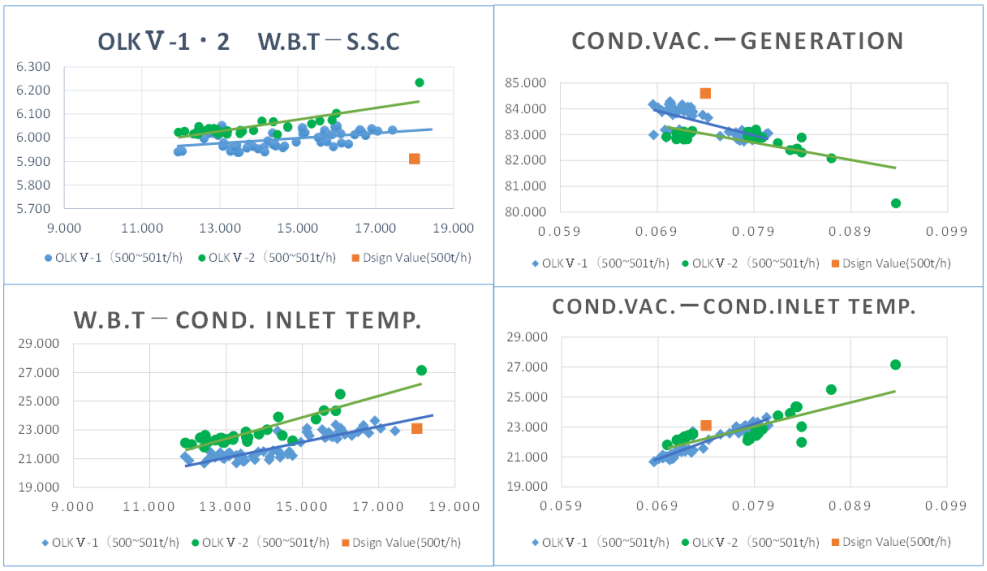
The results of comparing and evaluating OLK V No.1 and No.2 units are shown below.

①In the SSC-W.B.T correlation diagram (upper left), the SSC value of Unit 2 is larger than that of Unit 1 at the same W.B.T (around 14°C), indicating that the plant performance of Unit 2 is declining.

② Looking at the cooling tower outlet temperature - W.B.T correlation diagram (lower left), the cooling tower outlet temperature of Unit 2 is higher than Unit 1 at the same W.B.T (about 14°C), and the performance of Unit 2 cooling tower is declining.

③ There is no significant difference between Unit 1 and Unit 2 in the condenser inlet temperature-condenser internal pressure correlation diagram (lower right) and condenser internal pressure-generator output correlation diagram (upper right diagram). , it can be evaluated that there is no significant difference in the performance of the condenser and turbine between Units 1 and 2.

④Therefore, from these diagrams, it can be evaluated that it is necessary to investigate the cause of the performance deterioration of the Unit 2 cooling tower and to consider countermeasures



OLK V Plant performance comparison chart between UNIT1 and UNIT2
(26.May.2022～21.Jun.2022)

Figure 3-12 OLK V-1 and OLK V-2 performance evaluation on the same diagram

3. NCG (Non-Condensable Gas) exhaust system prediction/performance management method

A method of monitoring the NCG exhaust system is introduced as a method of performance management using actual operating data. This monitoring method detects troubles that actually occur at the power plant, and each engineer can consider managing other facilities using the same method.

Here, the example of the NCG exhaust system of Olkaria I-au (No.4) will be explained.

The Figure 3-13 shows the schematic diagram of the NCG exhaust system of Olkaria I-au (No.4).

There are three ejectors on each of the first and second stages, and two of the three ejectors are always in operation and one is on standby.

And there is an intercooler between the 1st and 2nd stage.

In addition, there are two vacuum pumps after the second stage ejector, one always in operation and an aftercooler downstream of the vacuum pump.

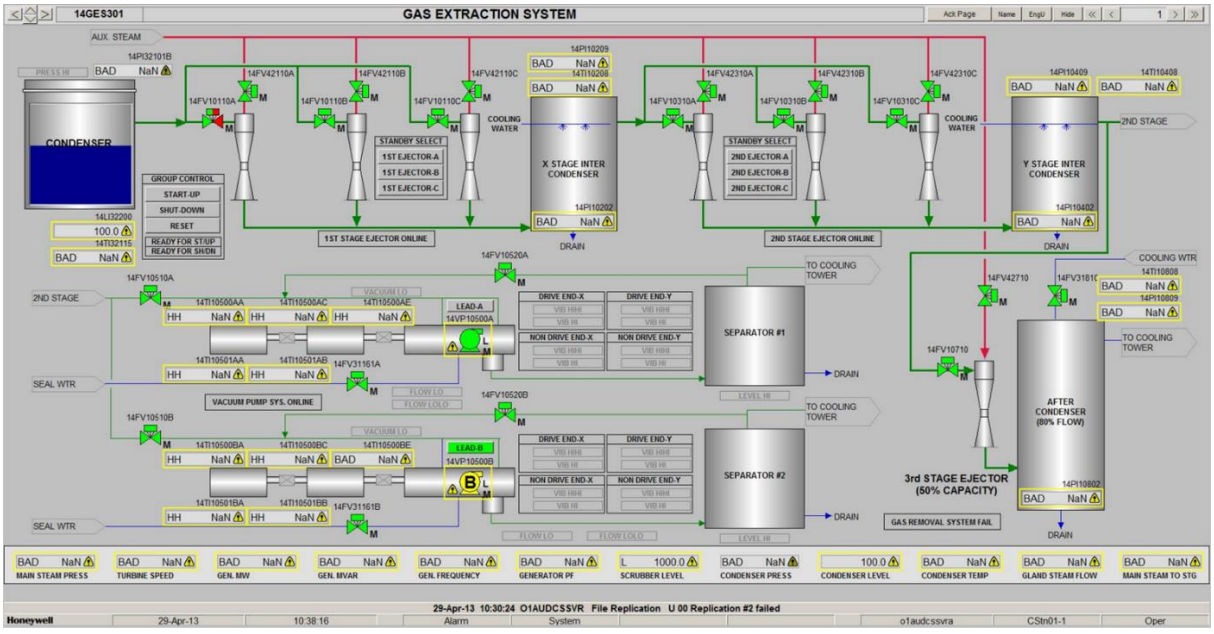


Figure 3-13 schematic diagram of NCG (Non Condensable Gas) exhaust

What kind of problems are you concerned about?

From the diagram of the NCG exhaust system, we extracted places of possible troubles which may occur.

【Possible Trouble】

① Decrease inter cooler performance
(Clogging of the filler in the cooler with scale)
② Decrease in the amount of cooling water
③ Steam leak from improper closing of spare ejector steam inlet valve
④ Malfunction of the ejector (clogging of the steam line)
⑤ Decrease steam flow from the ejector (clogging of ejector)

These troubles can be detected by creating and evaluating a correlation diagram of two data related to the NCG exhaust system.
Since it was confirmed that there is a strong correlation between “cooling water temperature" and "NCG exhaust temperature" in the 1st./2nd. Intercooler, abnormal state which might occur in either system can be detected using this correlation diagram.

【Result of detection of possible trouble using correlation diagram】

When there is an operating value above the normal state indicated by the set of blue dots in each correlation diagram (at the point indicated by A in the figure), the following troubles are presumed.

① Possibility of deterioration in cooling performance due to scale in the Inter Cooler.
② Possibility that the cooling water volume has decreased.
③ Possibility that steam is flowing into the Inter Condenser from the ejector on standby.

The following troubles are presumed when there is an operating value under the normal state indicated by the set of blue dots in each correlation diagram (at the point indicated by B in the figure).

④ There is a possibility that the ejector is clogged.
⑤ Decrease steam flow from the ejector (clogging of ejector)

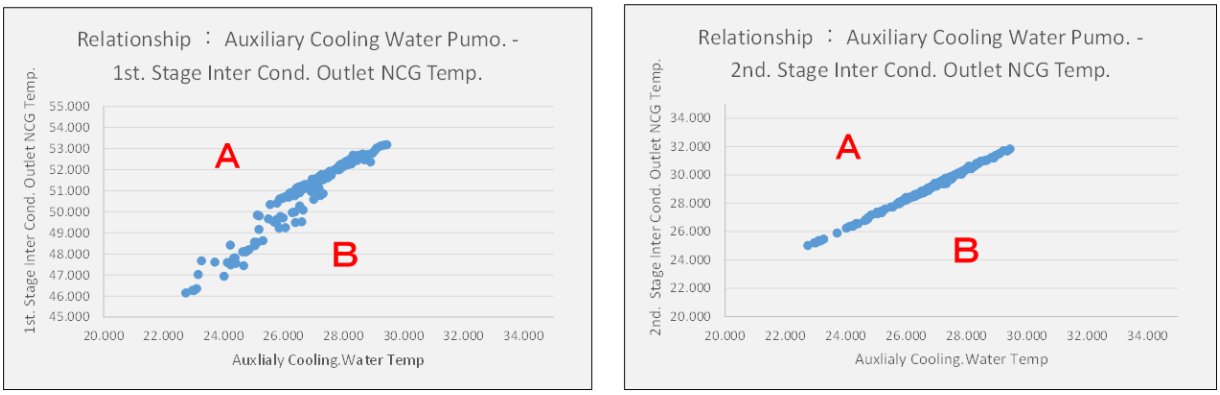


Figure 3-14 Correlation diagram between Auxiliary cooling water and 1st/2nd Stage inter condenser outlet N.C.G Temp.
(NCG exhaust system performance monitoring method)

4. FTA
(Fault Tree Analysis)

Here, basic concept of FTA and why we need it for smooth operation of the power plant are explained.

Next, the basic methodology of FTA is explained.

Then, we'll see some of the application samples in order to understand it better.

1. What is FTA and why do we need it?

At first , we will consider "What is FTA ?" and "Do we need FTA ?"

What is FTA ? Do we need FTA ?

- If your car stops working, you try to find out what caused it and take appropriate actions.
- You are carrying out it for whatever the machine you have on a daily basis.

When your car stops working, you'll try to find out what caused it and then take appropriate action.

For example, "Is there enough gasoline?", "Is the battery well charged?", "Are there problems with the engine?"

This process is FTA after all, and we conduct FTA for whatever machine you have on a daily basis.

In our daily life, there are various phenomena that requires analysis and appropriate measures, and we unconsciously enter into FTA in response to these problems.

【Why do we buy Toyota car?】

Consider a case where you plan to buy a Toyota car.

Why do you prefer Toyota for purchasing?

Good design, Good fuel economy, Cheap price, Fewer failures ・・・

So why do Toyota cars have good fuel economy and few breakdowns?

Let's pay attention to "Toyota's original culture".

Toyota has a unique FTA culture of "why-why analysis".

For example, In order to "minimize occurrence of failures", Toyota repeatedly analyze and implement countermeasures even for factors that cannot be

classified as those that may cause failures.
In addition, issues such as "How to work efficiently in a production plant?" and "How to improve fuel efficiency?“ are addressed as well.
Over the years, TOYOTA has built a unique culture where they strive to improve customer satisfaction by conducting "Why Why Analysis" (FTA).

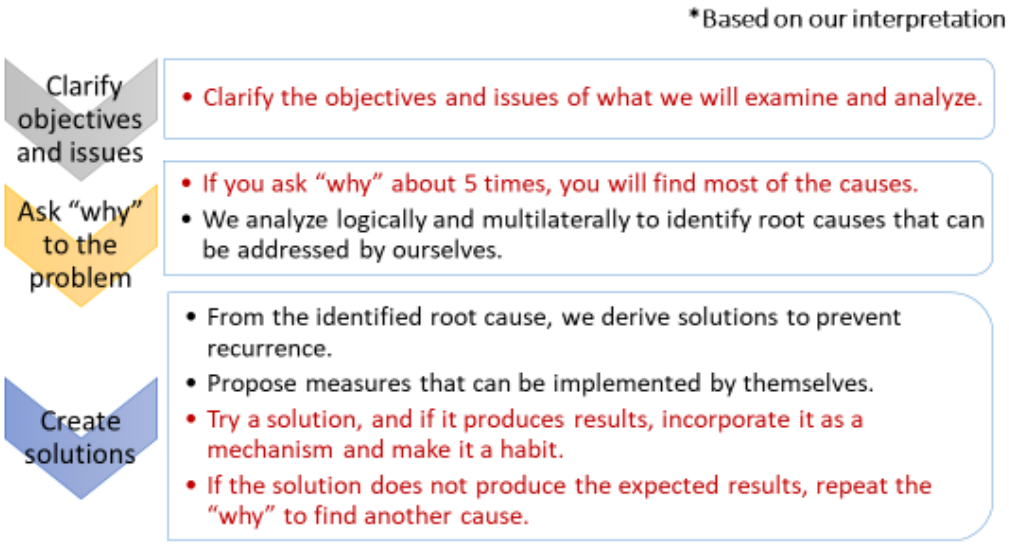


Figure 4-1 TOYOT's FTA activities

First of all, if the objectives and issues remain vague, the answer to "why" will also be vague. Therefore they must be clear to start with.
Next, At TOYOTA, empirically, they find the cause by repeating the “why” question about five times.
Lastly, based on the identified root cause, they generate solutions to prevent recurrence. These solutions should be implementable by themselves.
Try a solution, and if it produces results, incorporate it as a mechanism and make it a habit, and if the solution does not produce the expected results, repeat the “why” to find another cause.
Based on this basic idea, TOYOTA has repeatedly implemented FTA on many issues, which has made them highly evaluated around the world.

In the Figure 4-1, TOYOTA introduced, "Clarifying the purpose and issues of what to examine and analyze.“ An explanation of "Clarifying the purpose and issues of what to examine and analyze." is added on the next page using examples.

【Example：Figure 4-2】

Assume they were suffering a problem as “vehicles manufactured in-house have many breakdowns and sales volume is decreasing.” Direction of the FTA strategy changes greatly depending on how the issues are identified.

In the flow on the left, the task "What can the driver do to get it repaired sooner?" is set. And it leads to measures such as "methods that are easy for drivers to repair" and "increase the number of repair industries".

On the other hand, in the flow on the right, the question "What can we do to minimize car damage?" is set.

This leads to consideration of measures to halve the number of failures by extracting failures that occur frequently.

The flow on the left considers "easiness of repair" and responds quickly, while the flow on the right considers permanent countermeasures for "technological development that makes it difficult for failures to occur “.

If the FTA is completed only by considering the flow on the left, the failure frequency will not decrease, and the customer may switch to another automaker.

Also, the flow on the right lacks responsiveness, and customers may switch to another automaker just because of this countermeasure.

At the very least, both FTA are considered necessary to "prevent sales decline" set here.

It should be noted that this study flow example was created by the author based on TOYOTA's literature, and was not created by TOYOTA.

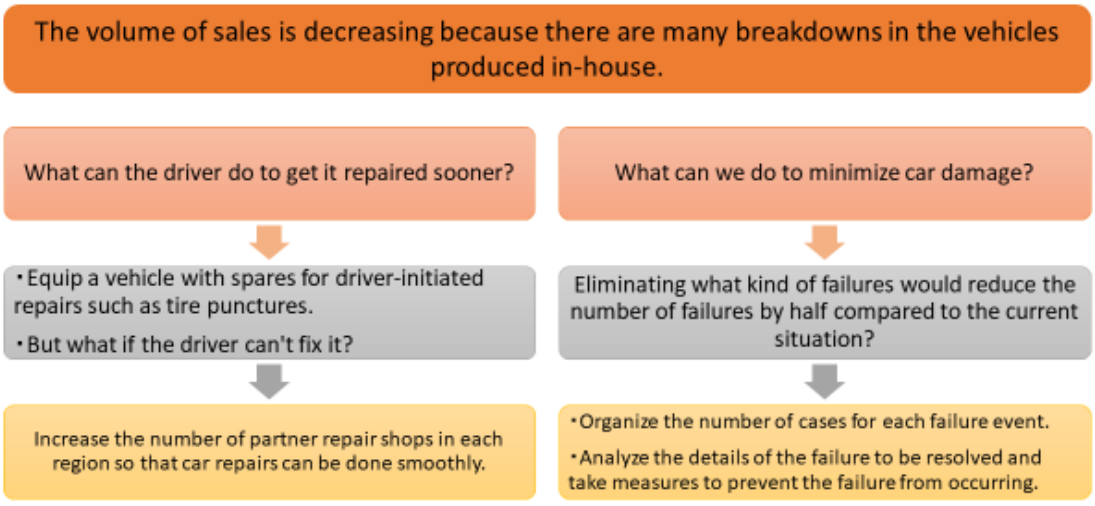


Figure 4-2 Content of analysis differs depending on perspective towards the issues (Importance of issue design)

2. Basic understanding of FTA

FTA (Fault Tree Analysis) is a method to identify and analyze the conditions and causes of abnormalities based on operational data and on-site information.

Some of the merits of FTA can be summarized as follows:

- The root cause of the abnormality can be identified, the maintenance efficiency will improve.
- The relationship between the troubles and the causes will be identified, which makes planning for the preventive measures easier.
- The process of analysis will be clearly documented in a diagram, so the concept can be shared with other staffs including the staffs in future.
- As the result, the skills and know-how will be accumulated in the organization as well as individual specialists.

(1) Procedure to prepare FTA diagram

Figure 4-3 shows the procedure to prepare FTA diagram.

①Make a list of possible direct (primary) causes of the trouble/abnormality. For example, power outage, leak from a pipeline, or motor immobility.

②Then, make a list of possible secondary (indirect) causes of each primary cause. Why the power shut off? What caused leakage, or Why the motor does not operate.

③By performing the analysis repeatedly, we arrive at the cause to be addressed.

④After the "elemental cause" is identified, a countermeasure shall be taken. It is not only "quick fix" but also permanent/radical countermeasure.

⑤ Prepare a trouble report describing the situation, analysis, and countermeasures for recordkeeping.

⑥If similar facility exists in other unit or system, the countermeasure may be applied as well.

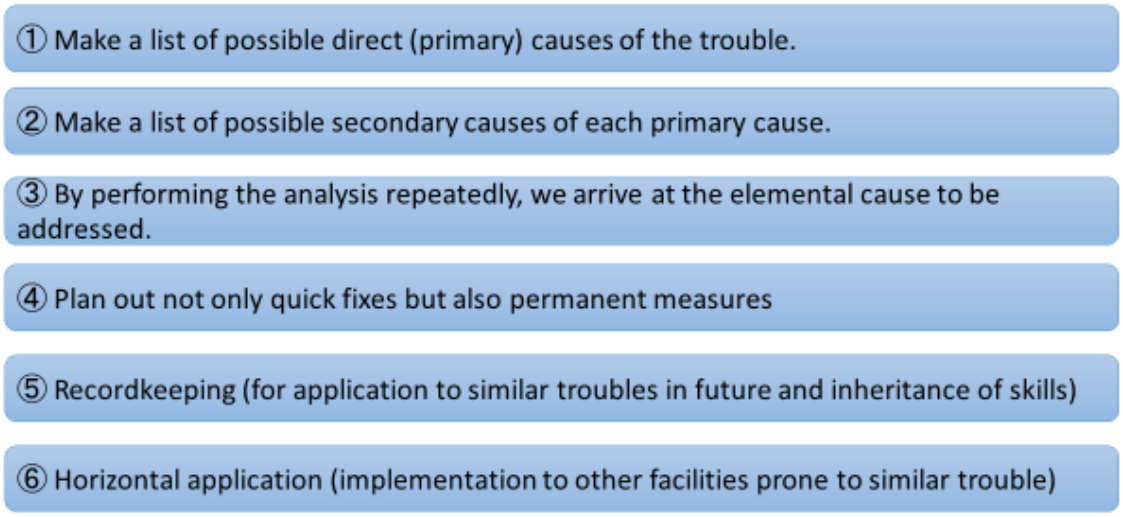


Figure 4-3 Procedure to prepare FT diagram

(2) Basic concept of FTA creation (Figure 4-4)

In an FTA, we extract the primary causes for the issues we want to solve. For each cause, when multiple factors occur at the same time, it is displayed as "AND", and when it occurs due to a single factor, it is displayed as "OR". Repeat the factor analysis to the point where the particular factor becomes “We can't examine it more deeply“, then it is classified as "Elemental Cause“. Once the “Elementary Causes” are found, their countermeasures will be sought.

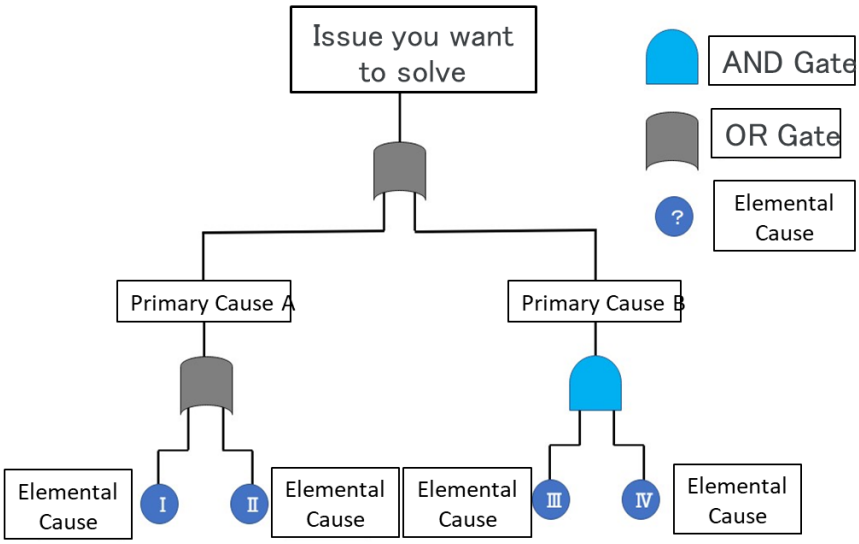


Figure 4-4 Procedure to prepare FTA

(3) [Example] Create an FTA diagram for when the motor does not operate.

Let's assume a case showing in the Figure 4-5 where "the motor does not operate". FTA diagram for this case can be made as follows:

There are two batteries and one switch.

The possible primary causes may be: motor malfunction, battery trouble, switch trouble.

Then, let's go into deeper analysis: "What is the cause of motor malfunction?" "Why battery does not operate?" "Why the switch breaks down."

The trouble (motor not operating) is put at the top.

Then, primary causes are shown in the second line.

The primary causes are "motor failure", "switch failure", and "battery wear".

Then analyze root causes for each of the primary causes.

Regarding the motor body failure, "winding short circuit" and "brush damage" are secondary causes, but for winding short circuit, it is a product quality problem and cannot be investigated further, so it is a "elemental cause."

Regarding the damage of the brush, we will dig deeper into "Why did it break?"

Brush failure may have two causes: Aged deterioration and Crush down

"Contact wear" is considered as a elemental cause for the switch failure.

In addition, it is also possible that "a foreign object came into contact with the product and damaged it."

Battery Fault may be run down. "AND gate" is applied since connected in parallel.

The chart shows the analysis to identify elemental cause only, but we need to explore countermeasures.

For example with internal short circuit, the countermeasures may be "use reliable motor" or "stock spare motor"

For example with the brush failure, the countermeasures may be "accumulated operation time management" against degradation; "do not use the motor fallen down" or "prevent fall-down of a motor" against the accidental causes.

For battery, install extra battery is considered as countermeasure.

In conclusion, choose best countermeasure in consideration of the frequency, the severity of trouble, and the cost.

Naturally, after examining the root causes and implementing permanent countermeasures, it is also necessary to create a record and use it as a reference for similar troubles in the future, and to share information with the plants where similar troubles are expected to occur.

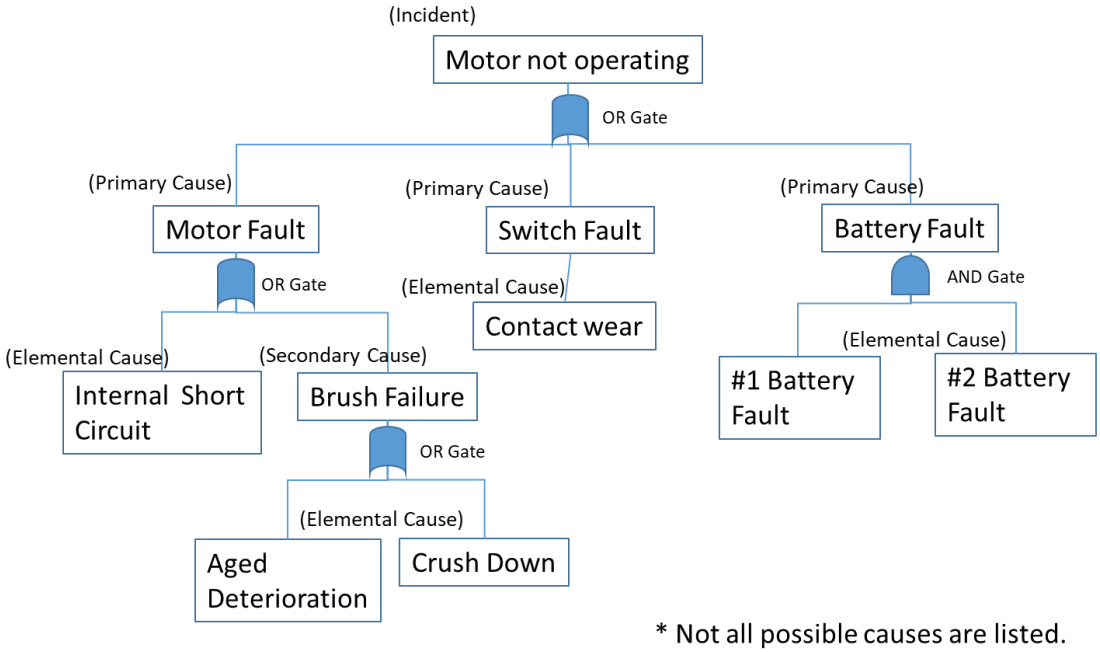


Figure 4-5 [Example] FTA diagram for when the motor does not operate

(4) Further consideration based on the understanding of FTA basics

(Deeper examination of Battery fault to identify element causes)

In the above item (2), if the battery is the cause of the motor stoppage, the countermeasure is to "replace with a spare battery".

Although this countermeasure is not wrong, it is insufficient as the proper FTA.

What do you think is lacking? This is one of the way for FTA process which Toyota is doing.

Based on the analysis in the Figure 4-5, let's assume that we ended the FTA task with the measure of "having a spare battery so that we can immediately respond even if the motor does not operate". In this case, occurrence of motor stalling because of the battery is not eliminated.

If this motor is an important device and the plant stops due to the motor stopping, it will be a big loss.

I introduced earlier page that "the analysis under this FTA is missing an important perspective."

I think the missing perspective is such as "What should be done to maintain the health of the motor?" or "What must our organization do to keep the motor going? "

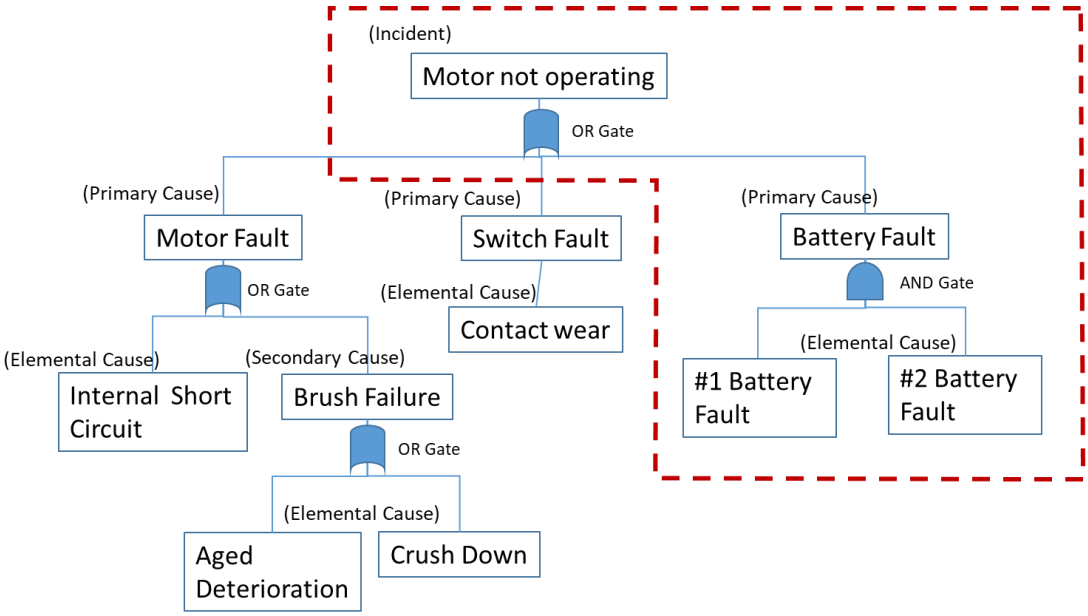


Figure 4-6 [Example] FT diagram for when the motor does not operate
(Deeper analysis about batteries)

Let's consider the TOYOTA-style FTA in the Figure 4-7.
Could it be that we didn't notice the degradation in performance before the battery failed?
In other words, if we can notice the deterioration in performance before the battery malfunctions, we can achieve our goal of ensuring the health of the motor.
So, what do you think next after "no one noticed the deterioration of battery performance"?

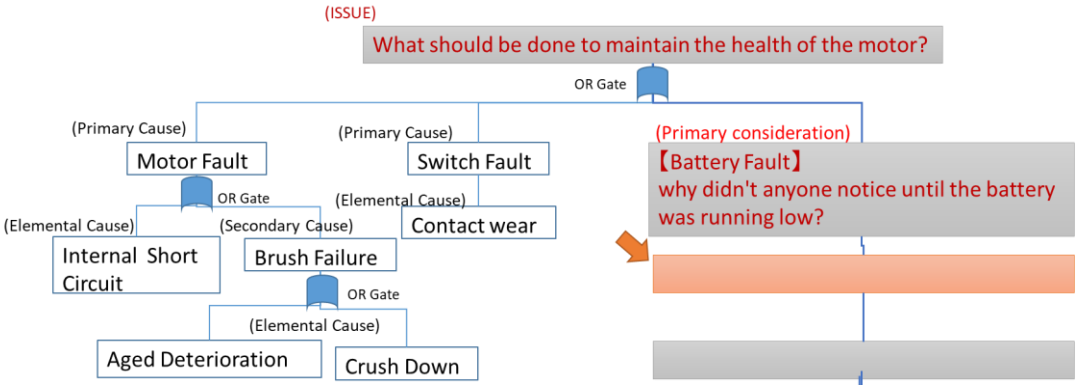


Figure 4-7 [Example] FT diagram for when the motor does not operate
(Based on TOYOTA “Why-Why Analysis”) （1）

The answer is assumed "What should we do to maintain battery health? “
So, what do you think next after receiving the question, "What should we do to maintain battery health?" in the Figure 4-8.

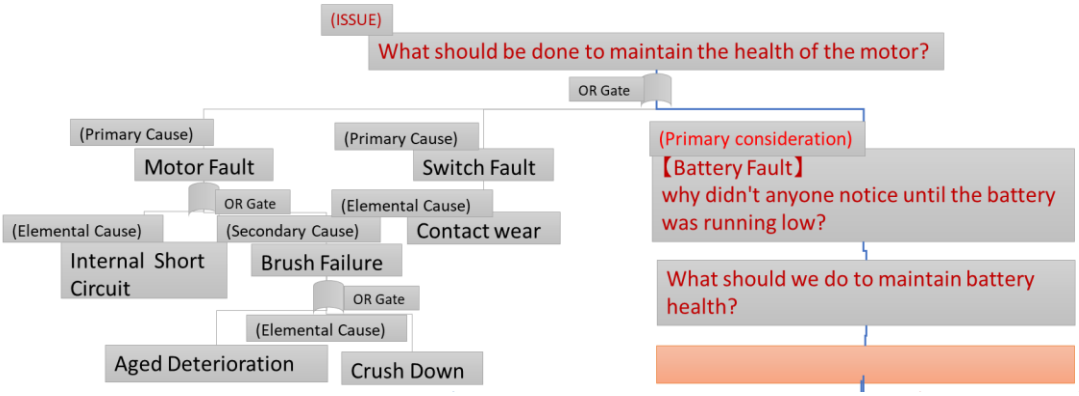


Figure 4-8 [Example] FT diagram for when the motor does not operate
(Based on TOYOTA “Why-Why Analysis”) (2)

The answer is assumed "Building necessary mechanism to maintain a healthy battery “.
Now, let's think about what is the “Necessary mechanism to maintain a healthy battery" in the Figure 4-9.

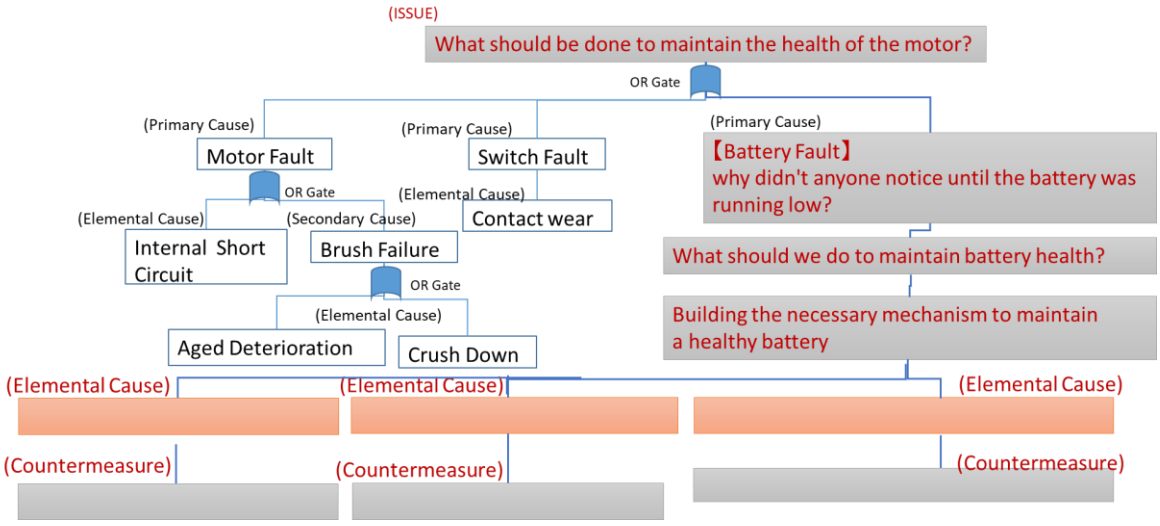


Figure 4-9 [Example] FT diagram for when the motor does not operate
(Based on TOYOTA “Why-Why Analysis”) (3)

Then, what can be specifically considered as "necessity mechanism to maintain a healthy battery? " in the Figure 4-9.

There are three things showed in the Figure 4-10.

First one is “No check sheet to manage the normal state of the battery ” .

Second one is “Routines do not reflect checking the health of the battery”.

Third one is “Inadequate technical knowledge of battery health check sheets”.

These three are the "element causes", and if we can analyze them up to this point, we should be able to take countermeasures against the "element causes".

In other words, if the countermeasures become vague, it means that the analysis has not been completed up to the "element cause".

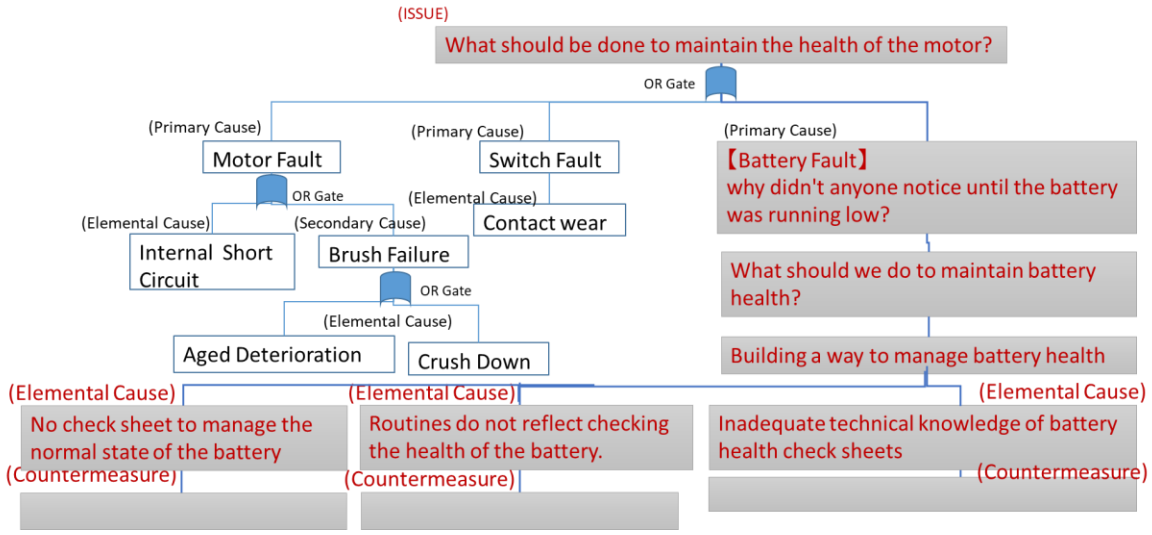


Figure 4-10 [Example] FT diagram for when the motor does not operate

(Based on TOYOTA “Why-Why Analysis”) (4)

Countermeasures are shown in the Figure 4-11.
Each of the countermeasures is to make it possible to do what is not possible described in "Element causes".

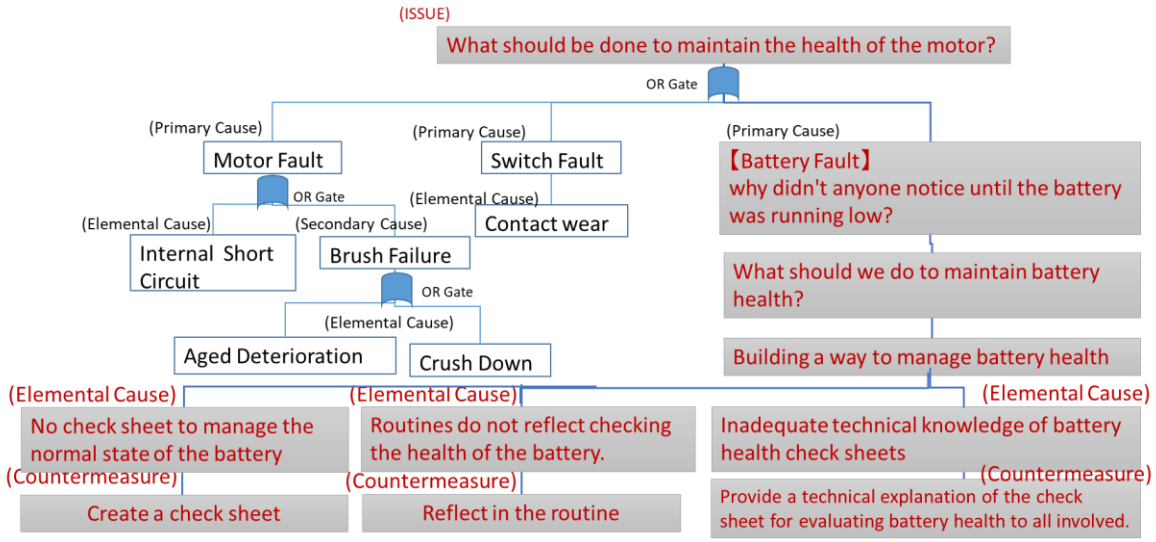


Figure 4-11 [Example] FT diagram for when the motor does not operate
(Based on TOYOTA "Why-Why Analysis") (5)

(5) Summary

You all engage in FTA to address various issues in your daily life.
In other words, FTA are also used for O&M of the power plants.
It is desirable for the manager to understand that the power plant is operated with the involvement of many people, and that what he or she can do alone is limited, and that many concerned parties should consider ways to solve problems.
If occurrence of the similar problems do not decrease even if the countermeasures have been implemented in accordance with the past FTA, the FTA process was not adequate nor sufficient. Ask yourself if the measures you take are permanent measures that will not cause the same problem.
" TOYOTA " keep reviewing the existing FTA results for further improvement, which I believe is one of the main reasons having made them supported by people all around the world.

Rev. 3 (February 2023)}2024)}2025)}2026)}2027)}2028)}2029)

Item			CY2021					CY2022												CY2023												CY2024												CY2025		
			8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
JCC						▲(Online) ▲(Online)													▲			▲								▲							▲										
PCU Meeting				▲						▲						▲						▲						▲					▲												
Support of Training in Japan																▲ ▲ ▲ ▲				▲	▲			▲						▲															
Overhaul / Annual Maintenance in Olkaria			II - 2 (rotor reblading)					II - 3			I - 5								II - 1							I-AU4						II - 3							I-AU5						
Monitoring Sheet						▲ ▲				▲					▲	▲				▲	▲					▲					▲	▲							▲	▲					
Report						▲ 2nd Work Plan ▲ 2nd Work Plan																																								Project Completion Report ▲		
Overall Management	00-1.	Preparation of the report				■													■																				■	■	■	■	■	■	■	
	00-2.	Set up for PDM Objectively Verifiable Indicators								■	■							■	■																										
	00-3.	Monitoring and Preparation, Update and Discussions of Monitoring Sheet			■	■				■	■	■			■	■		■	■	■		■					■	■					■	■						■	■					
	00-4.	Joint Coordination Committee (JCC) Meeting				■												■													■												■		
	00-5.	Training in Japan									■ (Management)			■ (Engineering) ■ (Engineering)				■ (Management)							■ (Engineering)						■ (Engineering)														
Output 1: O&M capacity of power stations is strengthened.																																												
Activities	1-0.	Selection of Core Member																																										
	1-1.	Review and analyze the current status and issues of O&M of Olkaria I (Units 4 and 5), Olkaria II (Units 1, 2 and 3), and Olkaria IV(Units 1, 2, and 3).		■	■	■																																						
	1-2.	Conduct training on predictive trouble management based on IoT data analysis				■					■	■	■	■	■	■	■	■	■	■		■	■	■	■	■	■	■	■	■	■	■		■	■	■	■	■	■	■	■	■	■	■	
	1-3.	Conduct training on performance management based on IoT data analysis				■					■	■	■	■	■	■	■	■	■	■		■	■	■	■	■	■	■	■	■	■	■		■	■	■	■	■	■	■	■	■	■	■	
	1-4.	Conduct training on appropriate repair skills and effective maintenance planning (a) Develop a maintenance manual based on analysis of repair history (b) Conduct OJT for daily maintenances based on the manual (c) Conduct OJT during periodical maintenances (annual as well as overhaul) based on the manual (d) Revise the maintenance manual and make improvements to the work procedure				■					■	■	■	■	■	■	■	■	■	■		■	■	■	■	■	■	■	■	■	■	■		■	■	■	■	■	■	■	■	■	■	■	
	1-5.	Conduct training on recording, storing, analyzing, and maintenance planning (a) Record and store repair records of each equipment in the IoT system (b) Prepare a maintenance plan based on the repair data of each equipment recorded and stored in the IoT system				■					■	■	■	■	■	■	■	■	■	■		■	■	■	■	■	■	■	■	■	■	■		■	■	■	■	■	■	■	■	■	■	■	
		Shoot videos				■					■	■																																	
		Installation of Cooling tower and Main steam pipe Temperature Measurement System		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■															■	■									
		Web Training									■	■										■	■	■	■	■	■	■	■	■	■	■		■	■	■	■	■	■	■	■	■	■	■	
		Training in Japan															■	■												■	■															
Output 2: Reservoir management capacity is strengthened.																																												
Activities	2-0.	Selection of Core Member																																										
	2-1.	Review the current status and issues of reservoir management.			■																																								
	2-2.	Conduct training on analysis of physical characteristics (such as wellhead pressure and flow rate) of the well		■	■					■	■						■	■				■	■					■	■					■	■					■	■				■	
	2-3.	Conduct trainings on chemical treatment activities by chemical analysis training and addition of new tracers		■	■					■	■			■	■			■	■			■	■					■	■					■	■					■	■				■	
	2-4.	Conduct training on reservoir modeling using continuous pressure monitoring (procured by UNIDO) and gravity monitoring		■	■					■	■						■	■				■	■					■	■					■	■					■	■				■	
	2-5.	Conduct training on plant facility maintenance such as scaling, corrosion, and sulfur/bacteria deposition		■	■					■	■			■	■			■	■			■	■					■	■					■	■					■	■				■	
		Shoot videos									■	■	■	■																															
		Procurement of the high performance liquid chromatograph (HPLC)		■	■					■																																		
		Web Training			<- Technical Online Meeting ->																																									
		Training in Japan															■	■												■	■															

Legend
- = Work in Japan
- = Work in Kenya
- = Work in Kenya (to be rescheduled)

KenGen in-house training texts

(a) Operation

- Basic Understanding of Geothermal Power Plant Operation
- Predictive Trouble Management
- Performance Management
- F.T.A(Fault Tree Analysis)
- Cooling tower and main steam pipe monitoring system analysis method

(b) Maintenance

- Optimization of Maintenance Process
- PDCA Cycle in Maintenance Activities

(c) Reservoir Management

- 1. Overview of Geothermal Reservoir Management
- 2. Well and Geothermal Reservoir Monitoring for Reservoir Management
- 3. Continuous Reservoir Pressure Monitoring for Reservoir Management
- 4. Reservoir Management Based on Monitoring Data in the Olkaria Field - 1) Interpretation of Reservoir Fluid Behavior based on TFT (Tracer Flow Testing) Data
- 4. Reservoir Management Based on Monitoring Data in the Olkaria Field - 2) Analyze and Interpretation of Tracer Test Results for Reservoir Management
- 4. Reservoir Management Based on Monitoring Data in the Olkaria Field - 3) Interpretation of output (deliverability) curve, Apportion method of steam/water flow rate, and Downhole pressure monitoring data

(d) Geochemistry

- 1. The role of geochemistry in the reservoir management
- 2. Sampling and chemical analysis - (1) Sampling (including preparation)
- 2. Sampling and chemical analysis - (2) Chemical Analysis
- 2. Sampling and chemical analysis - (3) Quality Control
- 3. Tracer test and analysis - (1)Test Plan / (2)Injection (how to inject) / (3)Sampling and sample preservation
- 3. Tracer test and analysis - (4)Chemical analysis (Fluorescein, NIDS) / (5)Interpretation
- 4.Geochemical monitoring (1)Brine from production well / (2)Influence from reinjection fluid to production reservoir
- Video material on reservoir management: Basics of JASCO LC-4000 HPLC system

(e) Numerical Modeling

1. A. Geothermal reservoir modeling - The outline and flow of numerical model / the introduction of WestJEC examples
2. B. Issues of reservoir modeling and reservoir evaluation method - (1) selection of

relative permeability curve

3. B. Issues of reservoir modeling and reservoir evaluation method - (2) The outline of wellbore simulator “WellSim”
4. B. Issues of reservoir modeling and reservoir evaluation method - (3) Analysis and evaluation of deliverability curve with WellSim
5. B. Issues of reservoir modeling and reservoir evaluation method - (4) Analysis and evaluation of production logging with WellSim (feed zone etc)
6. C. Reservoir simulation with iTOUGH2 - (1) iTOUGH2 Training No.1 (Forward run analysis, input/output file)
7. C. Reservoir simulation with iTOUGH2 - (2) iTOUGH2 Training No.2 (Inversion run analysis, input/output file)
8. C. Reservoir simulation with iTOUGH2 - (3) iTOUGH2 Training No.3 (commands of inversion run analysis/introduction of improved cases)
9. C. Reservoir simulation with iTOUGH2 - (4) Practice of inversion run analysis with iTOUGH2 (Basic)
10. C. Reservoir simulation with iTOUGH2 - (5) Practice of inversion run analysis with iTOUGH2 (Advance)
11. C. Reservoir simulation with iTOUGH2 - (6) Case study by the linkage of iTOUGH2 and WellSim (Basic)
12. C. Reservoir simulation with iTOUGH2 - (6) Case study by the linkage of iTOUGH2 and WellSim (Advance)
13. D. Reservoir model calibration - (1) Calibration examples of Olkaria numerical model
14. E. Reservoir modeling of fictional field - (1) Calibration practice of forward run analysis with PetraSim
14. E. Reservoir modeling of fictional field - (1) Calibration practice of forward run analysis with WestJEC processors
14. E. Reservoir modeling of fictional field - (1) Calibration practice of forward run analysis with WestJEC processors -2
15. E. Reservoir modeling of fictional field - (2) Practice of forecast calculation with PetraSim
16. E. Reservoir modeling of fictional field - (3) Practice of history calibration with the result of gravity monitoring data

(f) Power Plant Chemistry

1. Impact of pH on Performance of Cooling Water System
2. Basics of Corrosion, Scaling and Bio Fouling
3. Scales in Geothermal Power Plant
4. Biology and Biocides
5. Cooling Tower
6. Inspection during Plant Overhaul

ANNEX 3

Annex 2

Draft Project Design Matrix (PDM) (Ver. 1.0)

Project Title: The Project for Strengthening Operation and Maintenance Capacity of Olkaria Geothermal Power Stations Using IoT Technology
Project Term: March 2020 – February 2023 (Three Years)
Country: The Republic of Kenya
Target Area: KenGen's Olkaria Geothermal Power Stations
Target Group: KenGen (direct), Power consumers (indirect)

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumptions
Overall Goal Performance of KenGen's Olkaria geothermal power stations is improved.	In comparison to the indicators at the time of baseline survey, 1. Increase in capacity availability rate* of each geothermal power station 2. Breakdown time of power plants decrease. 3. Durations of annual inspection and overhaul are reduced. **Definition of capacity availability rate (%): as agreed upon in the power purchase agreement*	1., 2. and 3. KenGen's statistical data and reports	
Project Purpose Technical management of KenGen's Olkaria geothermal power stations is improved.	1. x units** out of nine units (Olkaria I units 4 and 5; Olkaria II units 1, 2, and 3; Olkaria IV units 1 and 2; and Olkaria V units 1 and 2) in the KenGen's Olkaria geothermal power stations apply the O&M knowledge acquired from the Project to their work for improvement. 2. Changes in reservoir characteristics can be appropriately detected. ***Specific target numbers are to be determined after baseline survey.*	1. Technical reports of KenGen's Olkaria geothermal power stations 2. Technical reports of KenGen's Olkaria geothermal power stations	KenGen continues commitment to the Project by continuing budget allocation as well as assignment of personnel for the post-Project activities.

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumptions
Outputs 1. O&M capacity of power stations is strengthened.	<Output 1> 1-1 Technical manuals for O&M are developed. <Operations> 1-2 x% of counterparts understand the basics of predictive trouble management and are able to apply it to their work 1-3 x% of counterparts understand the basics of performance management and are able to apply it to their work <Maintenance> 1-4 x% of counterparts understand the basics of data analysis of repair data and are able to apply it to their work 1-5 x% of counterparts understand the fault tree analysis for trouble-shooting and are able to apply it to their work. 1-6 x% of counterparts understand the basics of overhaul maintenance and are able to apply it to their work 1-7 Technical manuals for O&M are revised	1-1 O&M manuals <Operations> 1-2 Capacity assessment of staff and managers that received training 1-3 Capacity assessment of staff and managers that received training <Maintenance> 1-4 Capacity assessment of staff and managers that received training 1-5 Capacity assessment of staff and managers that received training 1-6 Capacity assessment of staff and managers that received training 1-7 Revised O&M manuals	
2. Reservoir management capacity is strengthened.	<Output 2> 2-1 Review reports on current status and issues of reservoir management are prepared 2-2 x% of counterparts receive training on analysis of physical characteristics of the well	2-1 Review reports 2-2 to 2-5 Capacity assessment of staff and managers that received training	

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumptions
	2-3 x% of counterparts receive training on chemical analysis including new tracer. 2-4 x% of counterparts receive training on reservoir modeling. 2-5 x% of counterparts receive training on geochemistry		
Activities 1-1 Review and analyze the current status and issues of O&M of Olkaria I (Units 4 and 5), Olkaria II (Units 1, 2 and 3), and Olkaria IV (Units 1 and 2). <Operations> 1-2 Conduct training on predictive trouble management based on IoT data analysis. 1-3 Conduct training on performance management based on IoT data analysis. <Maintenance> 1-4 Conduct training on appropriate repair skills and effective maintenance planning. (1) Develop a maintenance manual based on analysis of repair history. (2) Conduct on-the-job training during overhaul maintenances based on the manual. (3) Revise the maintenance manual and make improvements to the business process. 1-5 Conduct training on recording, storing, analyzing, and maintenance planning. (1) Record and store repair records of each equipment in the IoT system. (2) Prepare a maintenance plan based on the repair data of each equipment recorded and stored in the IoT system.	**Inputs** **(Japanese side)** 1. Dispatch of the Japanese experts -Chief Advisor <O&M> -Operation (performance management) -Operation (predictive trouble management) -Operation (data and history analysis) -Maintenance of main equipment (mechanical, electrical), - Maintenance of auxiliary equipment (mechanical, electrical) - Maintenance (data analysis and manual production) <Reservoir management> - Geochemist - Reservoir engineer - Geophysicist - Geologist 2. Training in Japan - Training on overhaul maintenance - Reservoir modeling - Geochemical training (chemical analysis, tracer test, scaling, corrosion)	**(Kenya side)** 1. Assignment of counterparts -Project Director (P/D) -Project Manager (P/M) -Engineers in charge of O&M -Planning officer -Others 2. Facilities and equipment -Project office space -Office equipment -Tracer chemicals and other consumables 3.Recurrent costs - counterparts' wages and allowances - counterparts' domestic travel expense	Precondition - KenGen to provide support for project implementation such as office space and to deploy necessary counterparts staff - UNIDO to install the IoT system

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumptions
2-1 Review the current status and issues of reservoir management. 2-2 Conduct training on analysis of physical characteristics of the well (such as wellhead pressure and flow rate from tracer flow testing and IoT). 2-3 Conduct chemical analysis training including analysis with new tracer(s). 2-4 Conduct training on reservoir modeling using continuous pressure monitoring (procured by UNIDO) and gravity monitoring. 2-5 Conduct training on geochemistry for preventing scaling, corrosion, and sulfur/bacteria deposition.	3. Equipment - High performance liquid chromatography		

Annex 2

Draft Project Design Matrix (PDM) (Ver. 1.5)

Project Title: The Project for Strengthening Operation and Maintenance Capacity of Olkaria Geothermal Power Stations Using IoT Technology
Project Term: March 2020 – February 2023 (Three Years)
Country: Republic of Kenya
Target Area: KenGen's Olkaria Geothermal Power Stations
Target Group: KenGen (direct), Power consumers (indirect)

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumptions
Overall Goal Performance of KenGen's Olkaria geothermal power stations is improved.	In comparison to the indicators at the time of baseline survey, 1. Increase in capacity availability rate* of each geothermal power station 2. Breakdown time of power plants decrease. 3. Durations of annual inspection and overhaul are reduced. **Definition of capacity availability rate (%): as agreed upon in the power purchase agreement*	1., 2. and 3. KenGen's statistical data and reports	
Project Purpose Technical management of KenGen's Olkaria geothermal power stations is improved.	1. x units** out of nine units (Olkaria I units 4 and 5; Olkaria II units 1, 2, and 3; Olkaria IV units 1 and 2; and Olkaria V units 1 and 2) in the KenGen's Olkaria geothermal power stations apply the O&M knowledge acquired from the Project to their work for improvement. 2. Changes in reservoir characteristics can be appropriately detected. ***Specific target numbers are to be determined after baseline survey.*	1. Technical reports of KenGen's Olkaria geothermal power stations 2. Technical reports of KenGen's Olkaria geothermal power stations	KenGen continues commitment to the Project by continuing budget allocation as well as assignment of personnel for the post-Project activities.

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumptions
Outputs 1. O&M capacity of power stations is strengthened.	<Output 1> 1-1 Technical manuals for O&M are developed. <Operations> 1-2 x% of counterparts understand the basics of predictive trouble management and are able to apply it to their work 1-3 x% of counterparts understand the basics of performance management and are able to apply it to their work <Maintenance> 1-4 x% of counterparts understand the basics of data analysis of repair data and are able to apply it to their work 1-5 x% of counterparts understand the fault tree analysis for trouble-shooting and are able to apply it to their work. 1-6 x% of counterparts understand the basics of overhaul maintenance and are able to apply it to their work 1-7 Technical manuals for O&M are revised	1-1 O&M manuals <Operations> 1-2 Capacity assessment of staff and managers that received training 1-3 Capacity assessment of staff and managers that received training <Maintenance> 1-4 Capacity assessment of staff and managers that received training 1-5 Capacity assessment of staff and managers that received training 1-6 Capacity assessment of staff and managers that received training 1-7 Revised O&M manuals	
2. Reservoir management capacity is strengthened.	<Output 2> 2-1 Review reports on current status and issues of reservoir management are prepared 2-2 x% of counterparts receive training on analysis of physical characteristics of the well 2-3 x% of counterparts receive training on chemical analysis including new tracer.	2-1 Review reports 2-2 to 2-5 Capacity assessment of staff and managers that received training	

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumptions
	2-4 x% of counterparts receive training on reservoir modeling. 2-5 x% of counterparts receive training on geochemistry		
Activities 1-1 Review and analyze the current status and issues of O&M of Olkaria I (Units 4 and 5), Olkaria II (Units 1, 2 and 3), and Olkaria IV (Units 1 and 2). <Operations> 1-2 Conduct training on predictive trouble management based on IoT data analysis. 1-3 Conduct training on performance management based on IoT data analysis. <Maintenance> 1-4 Conduct training on appropriate repair skills and effective maintenance planning. (1) Develop a maintenance manual based on analysis of repair history. (2) Conduct on-the-job training during overhaul maintenances based on the manual. (3) Revise the maintenance manual and make improvements to the business process. 1-5 Conduct training on recording, storing, analyzing, and maintenance planning. (1) Record and store repair records of each equipment in the IoT system. (2) Prepare a maintenance plan based on the repair data of each equipment recorded and stored in the IoT system. 2-1 Review the current status and issues of reservoir management.	**Inputs** **(Japanese side)** 1. Dispatch of the Japanese experts -Chief Advisor <O&M> -Operation (performance management) -Operation (predictive trouble management) -Operation (data and history analysis) -Maintenance of main equipment (mechanical, electrical), - Maintenance of auxiliary equipment (mechanical, electrical) - Maintenance (data analysis and manual production) <Reservoir management> - Geochemist - Reservoir engineer - Geophysicist - Geologist 2. Training in Japan - Training on overhaul maintenance - Reservoir modeling - Geochemical training (chemical analysis, tracer test, scaling, corrosion) 3. Equipment - High performance liquid chromatography	**(Kenya side)** 1. Assignment of counterparts -Project Director (P/D) -Project Manager (P/M) -Engineers in charge of O&M -Planning officer -Others 2. Facilities and equipment -Project office space -Office equipment -Tracer chemicals and other consumables 3.Recurrent costs - counterparts' wages and allowances - counterparts' domestic travel expense	Precondition - KenGen to provide support for project implementation such as office space and to deploy necessary counterparts staff - UNIDO to install the IoT system

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumptions
2-2 Conduct training on analysis of physical characteristics of the well (such as wellhead pressure and flow rate from tracer flow testing and IoT). 2-3 Conduct chemical analysis training including analysis with new tracer(s). 2-4 Conduct training on reservoir modeling using continuous pressure monitoring (procured by UNIDO) and gravity monitoring. 2-5 Conduct training on geochemistry for preventing scaling, corrosion, and sulfur/bacteria deposition.			

Project Design Matrix

Project Title: **The Project for Strengthening Operation and Maintenance Capacity of Olkaria Geothermal Power Stations Using IoT Technology**

Version 2.0

Dated March 16, 2021

Implementing Agency: Kenya Generating Power Company Plc. (KenGen)

Target Group: KenGen (direct), Power consumers (indirect)

Period of Project: August 2020 – August 2023 (Three Years)

Project Site: Nairobi, Olkaria **Model Site:** Olkaria Geothermal Power Station II, IV, I-AU, V

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumption	Achievement	Remarks
Overall Goal					
Performance of KenGen's Olkaria geothermal power stations is improved.	In comparison to the indicators at the time of baseline survey, 1. Increase in capacity availability rate* of each geothermal power station 2. Breakdown time of power plants decrease. 3. Durations of annual inspection and overhaul are reduced. *Definition of capacity availability rate (%): as agreed upon in the power purchase agreement	1., 2. and 3. KenGen's statistical data and reports			
Project Purpose					
Technical management of KenGen's Olkaria geothermal power stations is improved.	1. x units** out of nine units (Olkaria I units 4 and 5; Olkaria II units 1, 2, and 3; Olkaria IV units 1 and 2; and Olkaria V units 1 and 2) in the KenGen's Olkaria geothermal power stations apply the O&M knowledge acquired from the Project to their work for improvement. 2. Changes in reservoir characteristics can be appropriately detected. **Specific target numbers are to be determined after baseline survey.	1. Technical reports of KenGen's Olkaria geothermal power stations 2. Technical reports of KenGen's Olkaria geothermal power stations	KenGen continues commitment to the Project by continuing budget allocation as well as assignment of personnel for the post- Project activities.		

Outputs					
1. O&M capacity of power stations is strengthened.	<Output 1> 1-1 Technical manuals for O&M are developed. <Operations> 1-2 x% of core members understand the basics of predictive trouble management and are able to apply it to their work 1-3 x% of core members understand the basics of performance management and are able to apply it to their work <Maintenance> 1-4 x% of core members understand the basics of data analysis of repair data and are able to apply it to their work 1-5 x% of core members understand the fault tree analysis for trouble-shooting and are able to apply it to their work. 1-6 x% of core members understand the basics of overhaul maintenance and are able to apply it to their work 1-7 Technical manuals for O&M are revised	1-1 O&M manuals <Operations> 1-2 Capacity assessment of staff and managers that received training 1-3 Capacity assessment of staff and managers that received training <Maintenance> 1-4 Capacity assessment of staff and managers that received training 1-5 Capacity assessment of staff and managers that received training 1-6 Capacity assessment of staff and managers that received training 1-7 Revised O&M manuals			
2. Reservoir management capacity is strengthened.	<Output 2> 2-1 Review reports on current status and issues of reservoir management are prepared 2-2 x% of core members receive training on analysis of physical characteristics of the well 2-3 x% of core members receive training on chemical analysis including new tracer. 2-4 x% of core members receive training on reservoir modeling. 2-5 x% of core members receive training on geochemistry	2-1 Review reports 2-2 to 2-5 Capacity assessment of staff and managers that received training			

Activities	Inputs		Important Assumption
	The Japanese Side	The Kenyan Side	
Activities 1-1 Review and analyze the current status and issues of O&M of Olkaria I (Units 4 and 5), Olkaria II (Units 1, 2 and 3), and Olkaria IV (Units 1 and 2). <Operations> 1-2 Conduct training on predictive trouble management based on IoT data analysis. 1-3 Conduct training on performance management based on IoT data analysis. <Maintenance> 1-4 Conduct training on appropriate repair skills and effective maintenance planning. (1) Develop a maintenance manual based on analysis of repair history. (2) Conduct on-the-job training during overhaul maintenances based on the manual. (3) Revise the maintenance manual and make improvements to the business process. 1-5 Conduct training on recording, storing, analyzing, and maintenance planning. (1) Record and store repair records of each equipment in the IoT system. (2) Prepare a maintenance plan based on the repair data of each equipment recorded and stored in the IoT system. 2-1 Review the current status and issues of reservoir management. 2-2 Conduct training on analysis of physical characteristics of the well (such as wellhead pressure and flow rate from tracer flow testing and IoT). 2-3 Conduct chemical analysis training including analysis with new tracer(s). 2-4 Conduct training on reservoir modeling using continuous pressure monitoring (procured by UNIDO) and gravity monitoring. 2-5 Conduct training on geochemistry for preventing scaling, corrosion, and sulfur/bacteria deposition	1. Dispatch of the Japanese experts -Chief Advisor <O&M> - Power Plant Management - Operation management - Maintenance management - Repair work/Quality control <Reservoir management> - Reservoir Management - Numerical modeling - Geochemistry - Geophysics - Geology - Video Material Supervision - Geothermal Human Resource Development Coordinator 2. Training in Japan - Training on overhaul maintenance - Reservoir modeling - Geochemical training (chemical analysis, tracer test, scaling, corrosion) 3. Equipment - High performance liquid chromatography	1. Assignment of counterparts -Project Director (P/D) -Project Manager (P/M) - Core members (Main training target) -Planning officer -Others 2. Facilities and equipment -Project office space -Office equipment -Tracer chemicals and other consumables 3.Recurrent costs - counterparts' wages and allowances - counterparts' domestic travel expense	**Precondition** - KenGen to provide support for project implementation such as office space and to deploy necessary counterparts staff - UNIDO to install the IoT system **<Issues and countermeasures>**

Project Design Matrix

Project Title: **The Project for Strengthening Operation and Maintenance Capacity of Olkaria Geothermal Power Stations Using IoT Technology** **Version 3.0**

Implementing Agency: Kenya Generating Power Company Plc. (KenGen) **Dated February 16, 2022**

Target Group: KenGen (direct), Power consumers (indirect)

Period of Project: August 2020 – August 2023 (Three Years)

Project Site: Nairobi, Olkaria **Model Site:** Olkaria Geothermal Power Station II, IV, I-AU, V

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumption	Achievement	Remarks
Overall Goal					
Performance of KenGen's Olkaria geothermal power stations is improved.	In comparison to the indicators at the time of baseline survey, 1. Increase in capacity availability rate* of each geothermal power station 2. Breakdown time of power plants decrease. 3. Durations of annual inspection and overhaul are reduced. *Definition of capacity availability rate (%): as agreed upon in the power purchase agreement	1., 2. and 3. KenGen's statistical data and reports			
Project Purpose					
Technical management of KenGen's Olkaria geothermal power stations is improved.	1. x units** out of nine units (Olkaria I units 4 and 5; Olkaria II units 1, 2, and 3; Olkaria IV units 1 and 2; and Olkaria V units 1 and 2) in the KenGen's Olkaria geothermal power stations apply the O&M knowledge acquired from the Project to their work for improvement. 2. Changes in reservoir characteristics can be appropriately detected. **Specific target numbers are to be determined after baseline survey.	1. Technical reports of KenGen's Olkaria geothermal power stations 2. Technical reports of KenGen's Olkaria geothermal power stations	KenGen continues commitment to the Project by continuing budget allocation as well as assignment of personnel for the post-Project activities.		
Outputs					
1. O&M capacity of power stations is strengthened.	<Output 1> 1-1 Technical manuals for O&M are developed. <Operations> 1-2 x% of core members understand the basics of predictive trouble management and are able to apply it to their work 1-3 x% of core members understand the basics of performance management and are able to apply it to their work <Maintenance> 1-4 x% of core members understand the basics of data analysis of repair data and are able to apply it to their work 1-5 x% of core members understand the fault tree analysis for trouble-shooting and are able to apply it to their work. 1-6 x% of core members understand the basics of overhaul maintenance and are able to apply it to their work 1-7 Technical manuals for O&M are revised	1-1 O&M manuals <Operations> 1-2 Capacity assessment of staff and managers that received training 1-3 Capacity assessment of staff and managers that received training <Maintenance> 1-4 Capacity assessment of staff and managers that received training 1-5 Capacity assessment of staff and managers that received training 1-6 Capacity assessment of staff and managers that received training 1-7 Revised O&M manuals			
2. Reservoir management capacity is strengthened.	<Output 2> 2-1 Review reports on current status and issues of reservoir management are prepared 2-2 Core members acquire the target skill levels through training on analysis of physical characteristics of the well 2-3 Core members acquire the target skill levels through training on chemical analysis including new tracer 2-4 Core members acquire the target skill levels through training on reservoir modeling 2-5 Core members acquire the target skill levels	2-1 Review reports 2-2 to 2-5 Capacity assessment of staff and managers that received training, in reference to the Evaluation Sheet attached to Monitoring Sheet			

Activities	Inputs		Important Assumption
	The Japanese Side	The Kenyan Side	
Activities 1-1 Review and analyze the current status and issues of O&M of Olkaria I (Units 4 and 5), Olkaria II (Units 1, 2 and 3), and Olkaria IV (Units 1 and 2). <Operations> 1-2 Conduct training on predictive trouble management based on IoT data analysis. 1-3 Conduct training on performance management based on IoT data analysis. <Maintenance> 1-4 Conduct training on appropriate repair skills and effective maintenance planning. (1) Develop a maintenance manual based on analysis of repair history. (2) Conduct on-the-job training during overhaul maintenances based on the manual. (3) Revise the maintenance manual and make improvements to the business process. 1-5 Conduct training on recording, storing, analyzing, and maintenance planning. (1) Record and store repair records of each equipment in the IoT system. (2) Prepare a maintenance plan based on the repair data of each equipment recorded and stored in the IoT system. 2-1 Review the current status and issues of reservoir management. 2-2 Conduct training on analysis of physical characteristics of the well (such as wellhead pressure and flow rate from tracer flow testing and IoT). 2-3 Conduct chemical analysis training including analysis with new tracer(s). 2-4 Conduct training on reservoir modeling using continuous pressure monitoring (procured by UNIDO) and gravity monitoring. 2-5 Conduct training on geochemistry for preventing	1. Dispatch of the Japanese experts -Chief Advisor <O&M> - Power Plant Management - Operation management - Maintenance management - Repair work/Quality control <Reservoir management> - Reservoir Management - Numerical modeling - Geochemistry - Geophysics - Geology - Video Material Supervision - Geothermal Human Resource Development Coordinator 2. Training in Japan - Training on overhaul maintenance - Reservoir modeling - Geochemical training (chemical analysis, tracer test, scaling, corrosion) 3. Equipment - High performance liquid chromatography - Interactive whitebords	1. Assignment of counterparts -Project Director (P/D) -Project Manager (P/M) - Core members (Main training target) -Planning officer -Others 2. Facilities and equipment -Project office space -Office equipment -Tracer chemicals and other consumables 3.Recurrent costs - counterparts' wages and allowances - counterparts' domestic travel expense	**Precondition** - KenGen to provide support for project implementation such as office space and to deploy necessary counterparts staff - UNIDO to install the IoT system **<Issues and countermeasures>**

Project Design Matrix

Project Title: **The Project for Strengthening Operation and Maintenance Capacity of Olkaria Geothermal Power Stations Using IoT Technology**

Version 4.0

Dated August 25, 2022

Implementing Agency: Kenya Generating Power Company Plc. (KenGen)

Target Group: KenGen (direct), Power consumers (indirect)

Period of Project: August 2020 – June 2024

Project Site: Nairobi, Olkaria **Model Site:** Olkaria Geothermal Power Station II, IV, I-AU, V

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumption	Achievement	Remarks
Overall Goal					
Performance of KenGen's Olkaria geothermal power stations is improved.	In comparison to the indicators at the time of baseline survey, 1. Increase in capacity availability rate* of each geothermal power station 2. Breakdown time of power plants decrease. 3. Durations of annual inspection and overhaul are reduced. *Definition of capacity availability rate (%): as agreed upon in the power purchase agreement	1., 2. and 3. KenGen's statistical data and reports			
Project Purpose					
Technical management of KenGen's Olkaria geothermal power stations is improved.	1. x units** out of nine units (Olkaria I units 4 and 5; Olkaria II units 1, 2, and 3; Olkaria IV units 1 and 2; and Olkaria V units 1 and 2) in the KenGen's Olkaria geothermal power stations apply the O&M knowledge acquired from the Project to their work for improvement. 2. Changes in reservoir characteristics can be appropriately detected. **Specific target numbers are to be determined after baseline survey.	1. Technical reports of KenGen's Olkaria geothermal power stations 2. Technical reports of KenGen's Olkaria geothermal power stations	KenGen continues commitment to the Project by continuing budget allocation as well as assignment of personnel for the post- Project activities.		
Outputs					
1. O&M capacity of power stations is strengthened.	<Output 1> 1-1 Technical manuals for O&M are developed. <Operations> 1-2 x% of core members understand the basics of predictive trouble management and are able to apply it to their work 1-3 x% of core members understand the basics of performance management and are able to apply it to their work <Maintenance> 1-4 x% of core members understand the basics of data analysis of repair data and are able to apply it to their work 1-5 x% of core members understand the fault tree analysis for trouble-shooting and are able to apply it to their work. 1-6 x% of core members understand the basics of overhaul maintenance and are able to apply it to their work 1-7 Technical manuals for O&M are revised	1-1 O&M manuals <Operations> 1-2 Capacity assessment of staff and managers that received training 1-3 Capacity assessment of staff and managers that received training <Maintenance> 1-4 Capacity assessment of staff and managers that received training 1-5 Capacity assessment of staff and managers that received training 1-6 Capacity assessment of staff and managers that received training 1-7 Revised O&M manuals			
2. Reservoir management capacity is strengthened.	<Output 2> 2-1 Review reports on current status and issues of reservoir management are prepared 2-2 Core members acquire the target skill levels through training on analysis of physical characteristics of the well 2-3 Core members acquire the target skill levels through training on chemical analysis including new tracer 2-4 Core members acquire the target skill levels through training on reservoir modeling 2-5 Core members acquire the target skill levels	2-1 Review reports 2-2 to 2-5 Capacity assessment of staff and managers that received training, in reference to the Evaluation Sheet attached to Monitoring Sheet			

Activities	Inputs		Important Assumption
	The Japanese Side	**The Kenyan Side**	
Activities 1-1 Review and analyze the current status and issues of O&M of Olkaria I (Units 4 and 5), Olkaria II (Units 1, 2 and 3), and Olkaria IV (Units 1 and 2). <Operations> 1-2 Conduct training on predictive trouble management based on IoT data analysis, including cooling tower and main steam pipe temperature monitoring system. 1-3 Conduct training on performance management based on IoT data analysis, including cooling tower and main steam pipe temperature monitoring system. <Maintenance> 1-4 Conduct training on appropriate repair skills and effective maintenance planning. (1) Develop a maintenance manual based on analysis of repair history. (2) Conduct on-the-job training during overhaul maintenances based on the manual. (3) Revise the maintenance manual and make improvements to the business process. 1-5 Conduct training on recording, storing, analyzing, and maintenance planning. (1) Record and store repair records of each equipment in the IoT system. (2) Prepare a maintenance plan based on the repair data of each equipment recorded and stored in the IoT system. 2-1 Review the current status and issues of reservoir management. 2-2 Conduct training on analysis of physical characteristics of the well (such as wellhead pressure and flow rate from tracer flow testing and IoT). 2-3 Conduct chemical analysis training including analysis with new tracer(s). 2-4 Conduct training on reservoir modeling using continuous pressure monitoring (procured by UNIDO) and gravity monitoring	1. Dispatch of the Japanese experts -Chief Advisor <O&M> - Power Plant Management - Operation management - Maintenance management - Repair work/Quality control - Cooling tower and main steam pipe temperature monitoring <Reservoir management> - Reservoir Management - Numerical modeling - Geochemistry - Geophysics - Geology - Video Material Supervision - Geothermal Human Resource Development Coordinator 2. Training in Japan - Training on overhaul maintenance - Reservoir modeling - Geochemical training (chemical analysis, tracer test, scaling, corrosion) 3. Equipment - High performance liquid chromatography - Interactive whitebords - Cooling tower and main steam pipe temperature monitoring system	1. Assignment of counterparts -Project Director (P/D) -Project Manager (P/M) - Core members (Main training target) -Planning officer -Others 2. Facilities and equipment -Project office space -Office equipment -Tracer chemicals and other consumables 3.Recurrent costs - counterparts' wages and allowances - counterparts' domestic travel expense	**Precondition** - KenGen to provide support for project implementation such as office space and to deploy necessary counterparts staff - UNIDO to install the IoT system **<Issues and countermeasures>**

Project Design Matrix

Project Title: **The Project for Strengthening Operation and Maintenance Capacity of Olkaria Geothermal Power Stations Using IoT Technology**

Version 5.0

Dated 1st December, 2023

Implementing Agency: Kenya Generating Power Company Plc. (KenGen)

Target Group: KenGen (direct), Power consumers (indirect)

Period of Project: August 2020 – Sep 2024

Project Site: Nairobi, Olkaria **Model Site:** Olkaria Geothermal Power Station II, IV, I-AU, V

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumption	Achievement	Remarks
Overall Goal					
Performance of KenGen's Olkaria geothermal power stations is improved.	1. Increase of capacity availability 1-1 Increase of 1.31% capacity availability in OHM year as maintenance period is shortened by 4 days after installation of spare rotor among other interventions. 1-2 Increase of 0.65% capacity availability from OHM year to next OHM year due to reduction of Annual Inspection from 5 times to 3 times. 2. Increase of 5.07% capacity availability due to 443h 44m reduction of breakdown hours for the last five years. 3. Implementation of continuous technology transfer	1. KenGen's statistical data and reports 2. KenGen's statistical data and reports 3. Training program and Training			
Project Purpose					
Technical management of KenGen's Olkaria geothermal power stations is improved.	1-1 The introduction and management technology of spare rotor is developed and integrated into KenGen's OHM procedure 1-2 Spare rotor implementation plan is in place within the project period. 1-3 Acquired O&M knowledge for improvement through OJT of Annual Inspection is developed to their work. 2. Technology transfer is implemented to reduce major troubles (4 items) that have occurred in the last five years. 3. Major occurrence is recorded and stored in KenGen. 4. Acquire new operation technology which is applied in an organized manner in O&M by KenGen . 5. Changes in reservoir characteristics are detected and the causes and countermeasures for those changes are appropriately examined. 6. Training programs are drawn based on the contents of O&M knowledge acquired and are incorporated in the KenGen's training program.	1-1, 1-2 and 1-3. Newly created and approved action plan to achieve the Overall Goal in Olkaria 2. Technical reports of KenGen's Olkaria geothermal power stations 3. UNIDO system of KenGen's Olkaria geothermal power stations and other internal records 4. Monthly Report 5. "Steam and reservoir status reports" and "Monthly power plant geochemistry report" of KenGen Olkaria geothermal power stations 6. Training program and Training actual results	KenGen continues commitment to the Project by continuing budget allocation as well as assignment of personnel for the post- Project activities.		

Outputs					
1. O&M capacity of power stations is strengthened.	1-1 Technical manuals for O&M are developed and revised. 1-2 The teaching materials used in the training are developed for education. 1-3 Core members acquire the target skill levels through training on basics of predictive trouble management and are able to apply it to their work. 1-4 Core members acquire the target skill levels through training on basics of performance management and are able to apply it to their work. 1-5 Core members acquire the target skill levels through training on fault tree analysis of trouble-shooting and are able to apply it to their work. 1-6 Core members acquire the target skill levels through training on basics of data analysis of repair data and are able to apply it to their work. 1-7 Core members acquire the target skill levels through training on basics of Annual Inspection and are able to apply it to their work.	1-1 and 1-2 O&M manuals and lecture materials for KenGen in house training <Operations> 1-3 to 1-5 Capacity assessment of staff and managers that received training, in reference to the Evaluation Sheet attached to Monitoring Sheet <Maintenance> 1-5 to 1-7 Capacity assessment of staff and managers that received training, in reference to the Evaluation Sheet attached to Monitoring Sheet			
2. Reservoir management capacity is strengthened.	<Output 2> 2-1 Review reports on current status and issues of reservoir management are prepared. 2-2 Core members acquire the target skill levels through training on analysis of physical characteristics of the well. 2-3 Core members acquire the target skill levels through training on chemical analysis including new tracer. 2-4 Core members acquire the target skill levels through training on reservoir modeling. 2-5 Core members acquire the target skill levels through training on geochemistry. 2-6 The teaching materials used in the training are developed for education.	2-1 Review reports 2-2 to 2-5 Capacity assessment of staff and managers that received training, in reference to the Evaluation Sheet attached to Monitoring Sheet 2-6 Lecture materials for KenGen in house training			

Activities	Inputs		Important Assumption
	The Japanese Side	The Kenyan Side	
Activities <u>1-1 Review and analyze the current status and issues of O&M of Olkaria I (Units 4 and 5), Olkaria II (Units 1, 2 and 3), Olkaria IV (Units 1 and 2) and Olkaria V (Units 1 and 2).</u> <Operations> 1-2 Conduct training on predictive trouble management based on IoT data analysis, including cooling tower and main steam pipe temperature monitoring system. 1-3 Conduct training on performance management based on IoT data analysis, including cooling tower and main steam pipe temperature monitoring system. <Maintenance> 1-4 Conduct training on appropriate repair skills and effective maintenance planning. (1) Develop a maintenance manual based on analysis of repair history. (2) Conduct on-the-job training during overhaul maintenances based on the manual. (3) Revise the maintenance manual and make improvements to the business process. 1-5 Conduct training on recording, storing, analyzing, and maintenance planning. (1) Record and store repair records of each equipment in the IoT system. (2) Prepare a maintenance plan based on the repair data of each equipment recorded and stored in the IoT system. 2-1 Review the current status and issues of reservoir management. 2-2 Conduct training on analysis of physical characteristics of the well (such as wellhead pressure and flow rate from tracer flow testing and IoT). 2-3 Conduct chemical analysis training including analysis with new tracer(s). 2-4 Conduct training on reservoir modeling using continuous pressure monitoring (procured by UNIDO) and gravity monitoring. 2-5 Conduct training on geochemistry for preventing scaling, corrosion, and sulfur/bacteria deposition.	1. Dispatch of the Japanese experts -Chief Advisor <O&M> - Power Plant Management - Operation management - Maintenance management - Repair work/Quality control - Cooling tower and main steam pipe temperature monitoring <Reservoir management> - Reservoir Management - Numerical modeling - Geochemistry - Geophysics - Geology - Video Material Supervision - Geothermal Human Resource Development Coordinator 2. Training in Japan - Training on overhaul maintenance - Reservoir modeling - Geochemical training (chemical analysis, tracer test, scaling, corrosion) 3. Equipment - High performance liquid chromatography - Interactive whiteboards - Cooling tower and main steam pipe temperature monitoring system	1. Assignment of counterparts -Project Director (P/D) -Project Manager (P/M) - Core members (Main training target) -Planning officer -Others 2. Facilities and equipment -Project office space -Office equipment -Tracer chemicals and other consumables 3.Recurrent costs - counterparts' wages and allowances - counterparts' domestic travel expense	**Precondition** - KenGen to provide support for project implementation such as office space and to deploy necessary counterparts staff - UNIDO to install the IoT system **<Issues and countermeasures>**

Project Design Matrix

Project Title: **The Project for Strengthening Operation and Maintenance Capacity of Olkaria Geothermal Power Stations Using IoT Technology**

Version 6.0

Dated xx September, 2024

Implementing Agency: Kenya Generating Power Company Plc. (KenGen)

Target Group: KenGen (direct), Power consumers (indirect)

Period of Project: August 2020 – **January 2025**

Project Site: Nairobi, Olkaria **Model Site:** Olkaria Geothermal Power Station II, IV, I-AU, V

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumption	Achievement	Remarks
Overall Goal					
Performance of KenGen's Olkaria geothermal power stations is improved.	1. Increase of capacity availability 1-1 Increase of 1.31%(*1) capacity availability in OHM year(*2) as maintenance period is shortened by 4 days after installation of spare rotor(*3) among other interventions(*4). 1-2 Increase of 1.12%(*5) capacity availability due to reduction of Annual Inspection from 2 times to 1 time(*6). 2. Increase of 5.07% (*7)annual capacity availability due to 443h 44m/year(*8) reduction of breakdown hours for the last five years(*9). 3. Implementation of continuous technology transfer(*10) by incorporating in-house training into an annual training program based on the annually updated trainee lists of Power plant O&M and Reservoir management	1. KenGen's statistical data and reports 2. KenGen's statistical data and reports 3. Training program and Training actual results			
Project Purpose					
Technical management of KenGen's Olkaria geothermal power stations is improved.	1-1 The introduction and management technology (*11)of spare rotor is developed and integrated into KenGen's OHM procedure 1-2 Spare rotor implementation plan(*12) is in place within the project period. 1-3 Acquired O&M knowledge(*13) for improvement through OJT of Annual Inspection is developed to their work 2. Technology transfer is implemented to reduce major troubles (4 items) (*14)that have occurred in the last five years(*15). 3. Major occurrence(*16) is recorded and stored in KenGen. 4. Acquire new operation technology(*17) which is applied in an organized manner(*18) in O&M by KenGen . 5. Changes in reservoir characteristics (*19)are detected (*20)and the causes and countermeasures for those changes are appropriately examined(*21). 6. Training programs(*22) are drawn based on the contents of O&M knowledge acquired(*23) and are	1-1, 1-2 and 1-3. Newly created and approved action plan to achieve the Overall Goal in Olkaria 2. Action plan(*24) and Monthly report of KenGen's Olkaria geothermal power stations 3. UNIDO system of KenGen's Olkaria geothermal power stations and other internal records 4. Monthly Report 5. Steam and reservoir status report, Monthly power plant geochemistry report and Action plan(*25) of KenGen Olkaria geothermal power stations 6. Training program and Training actual results	KenGen continues commitment to the Project by continuing budget allocation as well as assignment of personnel for the post- Project activities.		

Outputs					
1. O&M capacity of power stations is strengthened.	1-1 Technical manuals for O&M are developed and revised. 1-2 The teaching materials used in the training are developed for education. 1-3 Core members acquire the target skill levels through training on basics of predictive trouble management and are able to apply it to their work. 1-4 Core members acquire the target skill levels through training on basics of performance management and are able to apply it to their work. 1-5 Core members acquire the target skill levels through training on fault tree analysis of trouble-shooting and are able to apply it to their work. 1-6 Core members acquire the target skill levels through training on basics of data analysis of repair data and are able to apply it to their work. 1-7 Core members acquire the target skill levels through training on basics of Annual Inspection and are able to apply it to their work.	1-1 and 1-2 O&M manuals and lecture materials for KenGen in house training <Operations> 1-3 to 1-5 Capacity assessment of staff and managers that received training, in reference to the Evaluation Sheet attached to Monitoring Sheet <Maintenance> 1-5 to 1-7 Capacity assessment of staff and managers that received training, in reference to the Evaluation Sheet attached to Monitoring Sheet	UNIDO IoT system steadily collects accurate and reliable data.		
2. Reservoir management capacity is strengthened.	<Output 2> 2-1 Review reports on current status and issues of reservoir management are prepared. 2-2 Core members acquire the target skill levels through training on analysis of physical characteristics of the well. 2-3 Core members acquire the target skill levels through training on chemical analysis including new tracer. 2-4 Core members acquire the target skill levels through training on reservoir modeling. 2-5 Core members acquire the target skill levels through training on geochemistry. 2-6 The teaching materials used in the training are developed for education.	2-1 Review reports 2-2 to 2-5 Capacity assessment of staff and managers that received training, in reference to the Evaluation Sheet attached to Monitoring Sheet 2-6 Lecture materials for KenGen in house training			

Activities	Inputs			Important Assumption
	The Japanese Side		**The Kenyan Side**	
Activities 1-1 Review and analyze the current status and issues of O&M of Olkaria I (Units 4 and 5), Olkaria II (Units 1, 2 and 3), Olkaria IV (Units 1 and 2) and Olkaria V (Units 1 and 2). <Operations> 1-2 Conduct training on predictive trouble management based on IoT data analysis, including cooling tower and main steam pipe temperature monitoring system. 1-3 Conduct training on performance management based on IoT data analysis, including cooling tower and main steam pipe temperature monitoring system. <Maintenance> 1-4 Conduct training on appropriate repair skills and effective maintenance planning. (1) Develop a maintenance manual based on analysis of repair history. (2) Conduct on-the-job training during overhaul maintenances based on the manual. (3) Revise the maintenance manual and make improvements to the business process. 1-5 Conduct training on recording, storing, analyzing, and maintenance planning. (1) Record and store repair records of each equipment in the IoT system. (2) Prepare a maintenance plan based on the repair data of each equipment recorded and stored in the IoT system. 2-1 Review the current status and issues of reservoir management. 2-2 Conduct training on analysis of physical characteristics of the well (such as wellhead pressure and flow rate from tracer flow testing and IoT). 2-3 Conduct chemical analysis training including analysis with new tracer(s). 2-4 Conduct training on reservoir modeling using continuous pressure monitoring (procured by UNIDO) and gravity monitoring. 2-5 Conduct training on geochemistry for preventing	1. Dispatch of the Japanese experts -Chief Advisor <O&M> - Power Plant Management - Operation management - Maintenance management - Repair work/Quality control - Cooling tower and main steam pipe temperature monitoring <Reservoir management> - Reservoir Management - Numerical modeling - Geochemistry - Geophysics - Geology - Video Material Supervision - Geothermal Human Resource Development Coordinator 2. Training in Japan - Training on overhaul maintenance - Reservoir modeling - Geochemical training (chemical analysis, tracer test, scaling, corrosion) 3. Equipment - High performance liquid chromatography - Interactive whiteboards - Cooling tower and main steam pipe temperature monitoring system		1. Assignment of counterparts -Project Director (P/D) -Project Manager (P/M) - Core members (Main training target) -Planning officer -Others 2. Facilities and equipment -Project office space -Office equipment -Tracer chemicals and other consumables 3.Recurrent costs - counterparts' wages and allowances - counterparts' domestic travel expense	**Precondition** - KenGen to provide support for project implementation such as office space and to deploy necessary counterparts staff - UNIDO to install the IoT system **<Issues and countermeasures>**

Note: Definisions

(*1)

Increase of **"1.31%"** means the result of calculation based on the formular of X% capacity availability

$$X\% = \left(\frac{365days - (Programmed\ Shutdown\ Days - Number\ of\ Shortned\ Days)}{365days - (Programmed\ Shutdown\ Days)}\right) \times 100$$

(*2)

"OHM year" means Programmed Overhaul Maintenance is planned for 60 day and its capacity availability is calculated for the relevant fiscal year.

$$X\% = \left(\frac{365days - (60days - 4days)}{365days - 60days}\right) \times 100 = 101.31\%$$

(*3)

"spare rotor" means a steam turbine rotor owned by KenGen as a spare parts to be determined on a budgetary basis.

(*4)

"among other interventions" means spare diagram and/or another spare parts for using overhaul maintenance.

(*14)

"major troubles (4 items)" means the following items listed in the table on page 5.

1) Main steam pipe leak
2) Condenser HW level control including HW pump trouble
3) Cond. Vacuum system failure
4) ST trouble(bearing issue, blade damage)

(*15)

"the last five years" means from Nov. 2017 to Nov. 2022

(*16)

"Major occurrence" means events that affects the power plant output and/or affects the plant efficiency in Olkaria.

(*17)

"Acquire new operation technology" means the Performance management and Prediction trouble management in UNIDO IoT system.

(*5) (*6)

Increase of **"1.12%"** means the result of calculation based on the formular of Y% capacity availability

$$Y\% = \left(\frac{2years \times 365days - Total\ number\ of\ Annual\ Inspection\ days\ for\ 2years}{2years \times 365days - Original\ Annual\ Inspection\ days \times 2years}\right) \times 100$$

Total number of Annual Inspection cays means ex-post evaluation is planned 2 years after completion of this IoT project. If KenGen implements corrective measures for critical items, the annual inspection interval would be extended.

If Annual inspection interval is extended from 1year to 1.5year, the number of Annual Inspection times are reduced from" 2 "times to "1" time for 2 years.

When Annual Inspection days are 8days, Original Annual Inspection days for 2 times are 16days and Total number of Annual Inspection days for 1 time are 8days. Accordingly,

$$Y\% = \left(\frac{2years \times 365days - 8days}{2years \times 365days - 16days}\right) \times 100 = 101.12\%$$

(*7) / (*8) / (*9)

Based on the Monthly Report history data from Nov. 2017 to Nov. 2022 as **"past five years"**, the following four(4) major trouble were identified.

"breakdown hour for past five years"|means shut down hours which is from starting of load reduction time to synchronized time is integrated for each four major trouble at the power plant. The averaged shut down hours and Annual availability are calculated based on the integrated shut down hours for each of the four major trouble.

"5.07%" means that a trouble equivalent to a breakdown hour**"443h44m"** occurs every year.

(*10)

"continuous technology transfer" means JICA expert team training program using the JICA expert team's training materials is incorporated into the annual KenGen's in-house training program based on the annually updated trainee lists of the power plant team and reservoir teams.

(*11)

"introduction and management technology" means KenGen members including Core members understand the effectiveness of owing a spare rotor in quickly recovering from rotor damage and other troubles in the unlikely event of an emergency, as well as shortening shout down hour during Overhaul maintenance.

(*12)

"implementation plan" means KenGen take an action based on action plan consicering "implementation policy" such as a budget for owing a spare rotor.

(*13)

"Acquired O&M knowledge" means Core members have acquired maintenance management such as critical path, CBM, TBM, etc. and they plan and conduct AI in accordance with Action plan.

【Part of Acquired O&M knowledge】

- FTA
- Performance/Predictive management
- pH control
- Ensure instruments reliability for data quality of UNIDO system
- Check pump/motor alignment
- Maintenance schedule optimization
- Acquisition of baseline data
- Quality assurance with updated procedure manuals and recording forms
- Technology sharing will be performed as horizontal deployment such as a classroom learning

etc.

(*18)

"organized manner " means Core members summarize Performance management and Prediction trouble management as Monthly Report Attachment and share the Performance/Predictive trouble information with KenGen management.

(*19)

"Changes in reservoir characteristics " means the changes in reservoir pressure and reservoir temperature that affect steam production, often accompanied by geochemical changes in the production fluid.

(*20)

"detect" means being recognized by core members and written in the relevant report about pressure monitoring (continuous and periodic), temperature monitoring (periodic), well characteristic test, geochemical monitoring, tracer test, and so on.

(*21)

"appropriately examined." means being discussed as a reservoir management team and written in the relevant report.

(*22)

"Training programs " means a program consisting of training materials provided by JICA experts team.

(*23)

"O&M knowledge acquired" means the following items

- FTA
- Performance/Predictive management
- pH control
- Ensure instruments reliability for data quality of UNIDO system
- Check pump/motor alignment
- Maintenance schedule optimization
- Acquisition of baseline data
- Quality assurance with updated procedure manuals and recording forms
- Technology sharing will be performed as horizontal deployment such as a classroom learning

etc.

(*24)

"Action plan" means the implementation status of the action plan created by the Core members of the power plant management in the IoT project and approved by Operations Manager-Geothermal.

(*25)

"Action plan" means the implementation status of the action plan created by the Core members of the reservoir management in the IoT project and approved by each affiliated organization.

Project Design Matrix

Project Title: **The Project for Strengthening Operation and Maintenance Capacity of Olkaria Geothermal Power Stations Using IoT Technology**

Version 7.0

Dated 14th January, 2025

Implementing Agency: Kenya Generating Power Company Plc. (KenGen)

Target Group: KenGen (direct), Power consumers (indirect)

Period of Project: August 2020 – **March 2025**

Project Site: Nairobi, Olkaria **Model Site:** Olkaria Geothermal Power Station II, IV, I-AU, V

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