Proceedings World Geothermal Congress 2005
Antalya, Turkey, 24-29 April 2005

Scaling Protection Technology for Hachijyo-Jima Geothermal Power Plant

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Keywords: Hachijyo-Jima, Scaling

ABSTRACT

Hachijyo-jima geothermal Power Plant, the first geothermal power plant to be built on a remote island in Japan, was constructed in the Nakanogo district of Hachijyo-Jima. Hachijyo-jima is an island located approximately 400km south of the Tokyo metropolitan area, and has a circumference of 58.9km and area of 65.9 km^2. This island is gourd-shaped, and has two volcanic mountains, Miharayama (or Eastern Mountain, located in the south eastern part of the island) and Hachijyo Fuji (or Western Mountain, located in the northwestern part).

In 1989, the New Energy and Industrial Technology Development Organization (NEDO) selected the island as a site to survey for the promotion of geothermal development, and exploratory drilling confirmed the existence of promising geothermal resources in the southern part of the Eastern Mountain.

In 1992, the Tokyo Electric Power Company began geothermal development work on site and performed production well drilling, blow-off tests, an environmental survey, and the basic planning and design for a power generation plant. After having completed various pre-construction procedures, The Tokyo Electric Power Company stated construction of the Hachijyo-jima Geothermal Power Plant in June 1998. This plant was put into commercial operation on March 25,1999.

1. INTRODUCTION

After the start of commercial operation, the turbine became unable to produce sufficient power to meet net demand due to decreasing condenser vacuum. An investigation identified the cause as scaling products which had adhered to the steam ejector nozzle and caused a narrowing of the area through which motive steam passes, and consequently, a reduction in performance.

Meanwhile, the turbine chest pressure had been increasing gradually. It seemed that scales had formed on the steam turbine blades and steam ejector nozzles.

It is thought that scaling occurs when scaling products dissolved in the geothermal steam precipitate and adhere to the surface of metals during the transition when saturated steam changes to dry steam due to throttling.

2. OVERVIEW OF THE POWER PLANT

Fig. 1 shows an external view of Hachijyo-Jima geothermal power plant. Fuji received the order for this plant as a turn-key project from The Tokyo Electric Power Company.

Figure 1: Hachijyo-jima geothermal power plant

Table 1 lists specifications of major equipment for the Hachijyo-Jima geothermal power plant.

Table 1: Specifications of major equipment

Name of Equipment	Specification
Date of commercial operation	1999-3-25
Rated power	3,300kW
Inlet steam pressure/ temp.	0.69MPag / 187□
Steam turbine Type Speed Quantity	Single-cylinder, single flow, top exhaust condensing high-speed turbine 7,266 rpm One (1)

Generator	
Type	Horizontal air cooled
Capacity	3,660 kVA
Voltage	6,900V
Speed	1,500rpm
Excitation	Brushless
Frequency	50Hz
Quantity	1(one)
Condenser	
Type	Spray type direct contact
Pressure	880 hPa
Cooling water flow	1,032 t/h
Quantity	1(one)
Separator	Vertical, cyclone type
Steam scrubbing system	Venturi tube□mist separator
H_2S abatement system	Oxidation furnace□Absorber □Magnesium sulfate□
Gas removal system	
Type	2stages-2X100%steam ejector
Capacity	1,181kg/h
Quantity	1 set (1:back up)
Cooling tower	
Type	Induced draft counter flow
Capacity	1,262 t/h
Quantity	1(one)
Electrical and instrumentation	Control panels, high voltage cubicles are installed in the pre-fabricated type electrical and control room
Control monitoring	All necessary monitoring and control of the voltage or load are performed by ITV at the remote central control room for the diesel power station located about 12km from this plant

3. SCALING CONDITION

Scaling conditions after the start of commercial operation are described below.

3.1 One-half year of operation

Heavy scaling was observed on the surface of turbine blades or turbine casing when a turbine was disassembled for temporary inspection.

The heavy black scaling found on the convex side of the 1st stage stationary blades consisted mainly of magnetite (Fe_3O_4), iron sulfides (FeS, FeS_2) and a trace of silica (SiO_2)(Fig.2). Scaling was not found on the concave side.

It is suspected that drain or mist carry-over from the separator may have occurred occasionally and brought impurities into the steam turbine, thereby causing the scaling problem.

Figure 2: Scale on 1st stage stationary blade

3.2 1st year of operation

Black scales consisting of iron sulfides (FeS, FeS_2), magnetite (Fe_3O_4) and the like were found on the convex side of the 1st stage stationary blades. The amount of scaling was slightly less than that after one-half year of operation.

3.3 2nd year of operation

Gray-white scales were deposited on the convex side of the 1st stage stationary blades (Fig.3).

Although iron sulfides (FeS, FeS_2) were not detected in ample quantity, silica scale (SiO_2) and calcium compounds ($CaCO_3$) were found in significant quantities compared to levels after the 1st year of operation. Countermeasures described in the latter part of this paper, however, have been implemented to decrease the quantity of these scales.

Figure 3: 1st □4th Stationary blade row

3rd year of operation

Gray-white scales were deposited on the convex side of the 1st stage stationary blades, but the amount of scaling was much less than that after the 2nd year of operation. (Fig.4)

Figure 4: 1st □5th Stationary blade rows

3.4 4th year of operation

The amount of scaling was quite small compared to that after the 2nd and 3rd years of operation. (Fig.5)

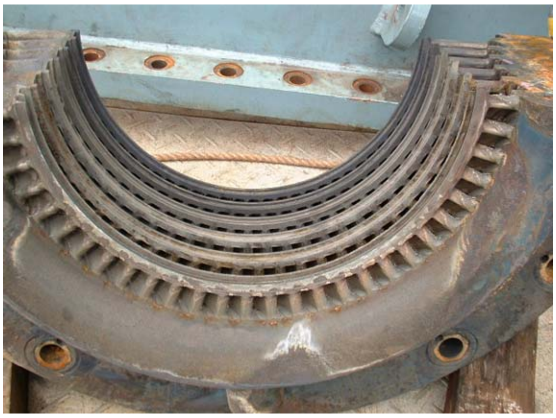

Figure 5: 1st □5th Stationary blade rows

4. CONTERMEASURES TO REDUCE SCALING ON THE TURBINE

The following countermeasures were carried out for this plant.

4.1 Improvement of the drainage

In order to prevent drain carry-over from reaching the steam turbine, several drain traps were installed along the main steam pipe between the cyclone separator outlet and the inlets to the steam turbine and steam ejector.

These drain traps (2” Dia.) were installed at the bottom of a down pipe from a cyclone separator, before the venturi tube and behind a mist separator.

Figure 6: Drain traps installed along the main steam pipe

4.2 Installation of mesh type demister

A mesh type demister, which consists of a wire mesh element (first element) and demister element (second element), was installed on the rising pipe before the steam ejector nozzle.

Most of the mist contained in the steam was collected and formed into large water particles by the wire mesh element, and these water droplets were then eliminated by the demister element installed behind the wire mesh. (Fig.7,8)

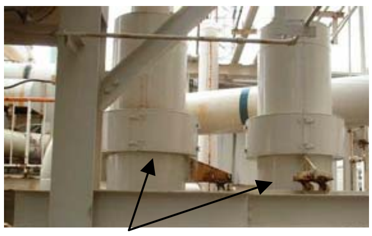

Figure 7: General view of the mesh demister

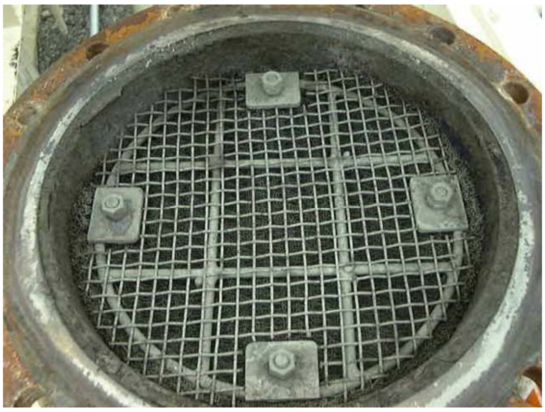

Figure 8: Mesh demister element

4.3 Turbine blade washing system

A turbine blade washing system was adopted to prevent the gradual increase in turbine chest pressure caused by scaling on the turbine blades. This system consists of a blade injection pump, a flow meter and a needle valve for adjusting the flow. (Fig.9)

The purpose of the turbine blade washing system is to prevent superheating of the steam at the outlet near the 1st stationary blade, and to wash away scale that has been deposited on the turbine blade surface.

Demineralized hot water up to approximately 2% of the total steam flow is injected into the main steam piping by a spray nozzle while the turbine is at normal operation. The use of demineralized water as the injection water enabled the water quality which been worse than of the steam, to be improved by a scrubbing system.

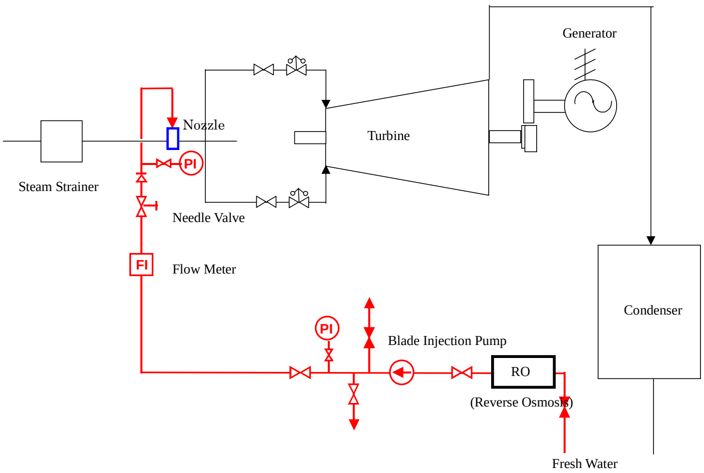

Figure 9: Turbine blade washing system

4.4 Scrubbing System

A scrubbing system, which is one of the most effective methods in an on-line cleaning system for eliminating steam impurities, was installed upstream of the steam turbine to improve the steam purity.

This system consists of a water injection pump, a venturi tube with four (4) spray nozzles and a mist separator. Mist contained in the steam runs into splash water injected from spray nozzles and is mixed there. After mixing, a two-phase flow is formed and conveyed to a mist separator, which separates steam and hot water by centrifugal force. Figs.11 and 12 shows exterior views of a venturi tube and a mist separator, respectively.

Major specifications of the scrubbing system are as follows.

Venturi tube

Steam flow: Max. 40 t/h
Number of nozzles: 4
Injection water flow: 3.7 t/h

Mist separator

Type: Vertical vane type
Capacity: Max. 40t/h
Design Pressure/Temp.: 0.97Mpag / 200□

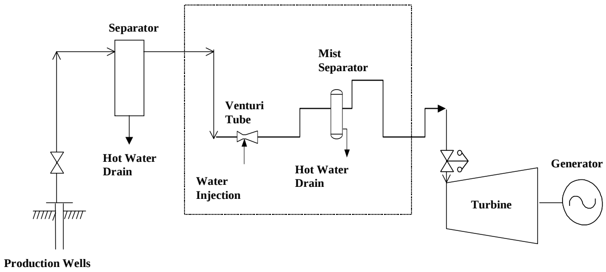

Figure 10: System configuration of scrubbing system

Figure 11: General view of the venturi tube

Figure 12: Mist separator

5. EFFECTIVENESS OF CONTERMEASURES

Several countermeasures were implemented to reduce scaling on the turbine blade and steam ejector nozzle.

Improvements to the drainage and mesh demister systems were not as effective as had been desired.

The turbine blade washing system was more effective in suppressing the increase in turbine chest pressure and maintaining continuous operation over the course of several year of operation without decreasing the condenser vacuum. Currently, since the increasing rate of turbine chest pressure has leveled off, turbine blade washing method is performed intermittently.

The scrubbing system also obtained good results and steam purity was improved by approximately 60%.

6. CONCLUSION

This paper introduced and described the effectiveness of several measures for preventing scaling problems.

We are convinced that the turbine washing system and scrubbing system are most effective in restraining scaling growth and improving steam purity

The authors will be grateful if the scaling protection technology described herein proves to be useful to the reader.

The combined effects of both a turbine washing system and a scrubbing system is effective suppressing scaling growth and improving steam purity at this plant.

The turbine washing system is operated periodically once per month.

The sudden change from wet to dry steam due to throttling is presumed to cause the precipitation of scaling products dissolved in the geothermal steam.

REFERENCES

Toshiaki Majima, Vol, 23, No.1 & 2, 36-49P, 1998, submitted to Japan Geothermal Energy Association

Toshiaki Majima, Vol, 35, No.4 (Ser. No.154), 1998, submitted to Japan Geothermal Energy Association

Takashi Murakami, Vol.47, No.4, 113-119P, 2001, submitted to Fuji Review

Takashi Murakami, 25^{th} Anniversary Natural Energy Forum and 2003 Annual Meeting, submitted to Geothermal Research Society of Japan.