Geothermal Energy Utilization Technology of Nippon Steel Engineering Co., Ltd. ~Wasabizawa Geothermal Power Station~ *1

1. Introduction

The Japanese government regards geothermal energy as clean energy and includes it in the baseload power sources based on its various characteristics; for example, geothermal energy does not release greenhouse gases, the quantity of the resources occurring in Japan is large, and geothermal energy can generate electric power stably.

In addition, the Japanese government has been implementing measures to increase geothermal power generation. It has been supporting "Research and Development of Geothermal Energy Generation and Renewable Heat Technologies" and "the Project to Investigate Geothermal Resources and Promote Understanding of Geothermal Power Generation." The government has also been reviewing regulations and systems. Capacity of geothermal power in Japan was 566 MW in 2019, but is expected to increase to 1550 MW by 2030.

2. Geothermal Energy Utilization Technology of Nippon Steel Engineering Co., Ltd.

(1) Supply records in the geothermal power generation field

We started working on steamfield above ground systems (hereinafter SAGS) in the 1980s of the geothermal development in Japan. We have been dealing with basic plans, basic design, detailed design, and construction of many geothermal power stations. We have delivered SAGS to approximately half of the large-scale geothermal power stations in Japan. **Table 1** shows our supply records of Geothermal Power Stations in Japan.

Table 1 Supply record of Geothermal Power Stations in Japan

No	Project Name	Authorized Output (kW)	Operation start
1	MORI Geothermal Power Station	25000	Nov, 1982
2	UENOTAI Geothermal Power Station	28800	Mar, 1994
3	YAMAGAWA Geothermal Power Station	30000	Mar, 1995
4	SUMIKAWA Geothermal Power Station	50000	Mar, 1995
5	Yanaizu-Nishiyama Geothermal Power Station	30000	May, 1995
6	KAKKONDA Geothermal Power Station No2	30000	Mar, 1996
7	OGIRI Geothermal Power Station	25800	Mar, 1996
8	TAKIGAMI Geothermal Power Station	27500	Nov, 1996
9	HACHIJOJIMA Geothermal Power Station	3300	Mar, 1999
10	WASABIZAWAGeothermal Power Station	46199	May, 2019

(2) Our technologies for effective use of geothermal steam and heat

In geothermal development, SAGS needs to be optimized based on various characteristics: (a) fluid conditions (flow rate, the steam-water ratio, temperature, pressure), (b) fluid properties (pH, corrosive components, scale components, the presence/absence of solid compositions), (c) installation conditions (distance, altitude difference, ups and downs between the facility and geothermal well, the necessity of authorization), and (d) estimated gradual decrease in the geothermal well performance.

We have systematically accumulated knowledge on SAGS plans with two-phase-flow transfer as the cores, design of high-performance steam separators, and equipment plans that prevent pipe & equipment walls from thinning and scale from adhering. Accordingly, we can offer highly-reliable, highly-economical, optimum SAGS that matches the conditions of various sites.

3. Outline of the Wasabizawa Geothermal Power Station

Yuzawa Geothermal Power Generation Corporation started commercial operation of the Wasabizawa Geothermal Power Station on May 20, 2019. This is the first newly developed large-scale geothermal power station in Japan in 23 years. The station is the fourth-largest geothermal power station in Japan and produces 46199 kW of output. The station site is approximately 150000 m^2 and this site includes large difference in altitude. Between 620 m and 930 m above sea level, there are three production bases, one power station, and two reinjection bases.

The construction site is located in a mountainous region in the southern part of Akita Prefecture and the region is contiguous with Yamagata and Miyagi Prefectures. In this extremely cold region, which is designated as a special area of heavy snowfall, the minimum temperature drops to near −20°C in winter and snow falls to a depth of 4 m to 5 m.

At the Wasabizawa Geothermal Power Station, geothermal fluid that was taken out from the production bases is separated into steam and hot water by steam separators. They are supplied to the power station and after use, geothermal fluid is reinjected into the ground via the reinjection bases.

We managed the design, production, and construction of the production bases, steam separator, pipelines that connect the bases, and reinjection bases for the Wasabizawa Geothermal Power Station. **Figure 1** shows the system flow at the geothermal power station.

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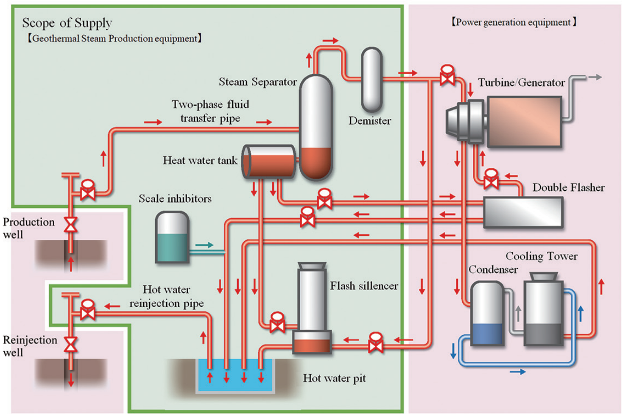

Fig. 1 System flow

4. Technologies Utilized for the Wasabizawa Geothermal Power Station

(1) Two-phase-flow technology

Geothermal fluid that is taken out from the three production bases of the Wasabizawa Geothermal Power Station is two-phase fluid mixed with steam and hot water. Therefore, the project adopted the two-phase-flow transfer technology of us; two-phase-flow pipelines were used to send geothermal fluid taken out at the production bases toward the power generation equipment and put together the separator near the station for steam separation. By integrating the steam-water separation process, we reduced the separator, related equipment and pipelines at each production bases, making the facility more rational and efficient.

(2) Steam separation technology

Steam separators of geothermal power stations need to supply dry, good-quality steam to allow the power stations to continue operating stably and highly efficiently. Accordingly, we evaluated the conditions and properties of the fluid at the Wasabizawa Geothermal Power Station and designed top-outlet type steam separators by our knowledge on steam separator designing. As a result, the top-outlet type steam separator at the Wasabizawa Power Generation Station achieved a steam separation efficiency of more than 99.9% and has been supplying good-quality steam to the power station.

Regarding the top-outlet type separator, the steam outlet is located on top of the cylinder. Accordingly, the separator does not have structures inside the cylinder and at the end plate section in the lower section and thereby the structure is rather simple compared to general lower-outlet type steam separators. This characteristic makes it possible to efficiently discharge deposits from the inside of the cylinder via the drain valve during inspections. Furthermore, this characteristic also makes it easier to install scaffolding inside the cylinder as well as clean, inspect, and repair the inside. Thus, this type is also superior from the viewpoint of maintenance and management. In addition, the external size is smaller than the conventional type, which allows the site to be used in an effective way. **Figure 2** shows the top-outlet type separator.

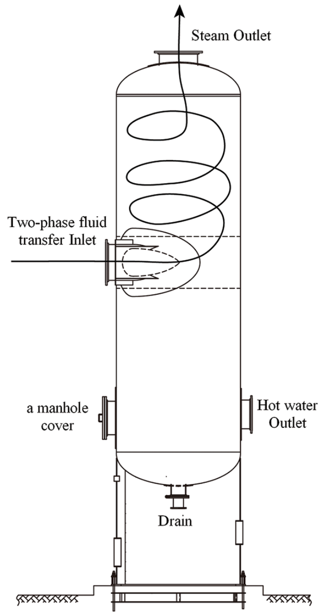

Fig. 2 Top outlet type separator

(3) Construction work

Because the Wasabizawa Geothermal Power Station site is located in a heavy snowfall area, construction work was assumed to be impossible for five months in winter and thereby the construction was demanded to be completed in a short period of time. In addition, because the site is located in the designated protected forest, there were strict restrictions on tree trimming and changes to the morphological characteristics, and the premises also needed to be minimized. Furthermore, the protection of the natural environment with attention to rare wildlife in the vicinity was required. The geographic features were complicated involving a steep slope and soft ground, which are typical characteristics of construction works in mountainous areas. There were various restrictions originating in a narrow access road for transporting construction materials and equipment and limited spaces for storing such. We also had to submit many applications to obtain authorization. Many factors including those listed above made the construction difficult.

Accordingly, we closely investigated the geographic features and the nature of the soil and thoroughly discussed construction methods in advance. We selected optimum construction equipment and methods based on the geographic features; we developed the land with the rock climbing construction method and built a bridge, propulsion tunnels, and cut-and-cover culverts.

In addition, during the construction work, while implementing environmental measures and ground improvement work with reliability, we quickly addressed issues actualized in the course of the construction one by one. Moreover, to resolve issues (restrictions) originating in the narrow access road and limited site, we flexibly reviewed the construction plan based on the progress of daily construction work; for example, we adjusted the schedule (processes) in line with other companies' construction works, we were adaptable as to the travel of construction vehicles of other companies at the time of entering and leaving the premises, and adjusted locations to which materials would be brought in. These successfully worked to complete the difficult construction work within the construction period. **Figure 3** shows a general view of the Wasabizawa Geothermal

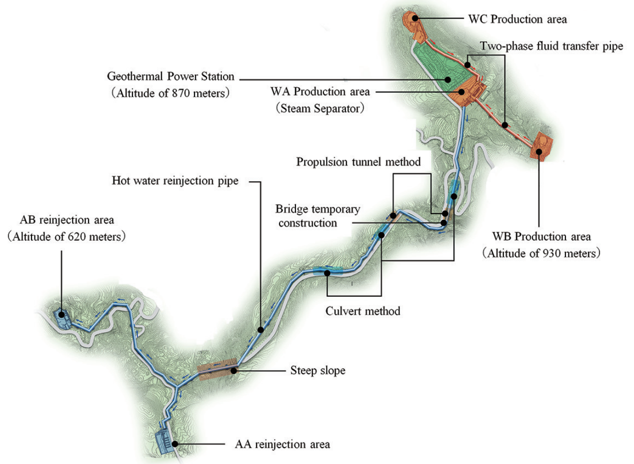

Fig. 3 WASABIZAWA Geothermal Power Station layout

Power Station.

(4) Pipeline construction work

In the vast Wasabizawa Geothermal Power Station site, the length of the pipeline for sending hot water to be reinjected (hereinafter, reinjection hot water) from the power station to the reinjection bases is as long as 2.9 km. We formulated a detailed plan for the route and layout of this large, long pipeline and constructed it so as to allow reinjection hot water to naturally flow to the reinjection bases via a steep slope, bridge, tunnels, and culverts. This plan enabling reinjection hot water to naturally flow down by gravity eliminated the need for hot water reinjection pits, pumps, and related facilities in the course of the pipeline, making the hot water reinjection equipment more rational and efficient.

To realize this plan, we conducted extremely difficult pipeline construction work on a steep slope where the maximum inclination is 45 degrees and the altitude difference is 100 m. In the construction work, the pipeline was constructed safely and efficiently by using an erection cable crane. **Figure 4** shows an outline of the pipeline construction using an erection cable crane.

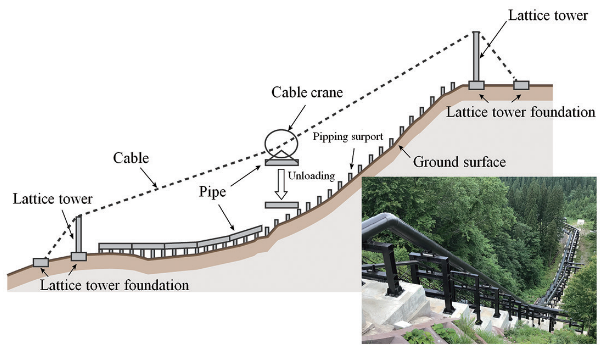

Fig. 4 Pipeline construction using erection cable crane

5. Future Work

As the awareness of the sustainable development goals (SDGs) is increasing around the world, the promotion and expansion of the effective use of clean geothermal energy matches one of the SDGs "Affordable and clean energy." The Japanese government also expects the development of geothermal power generation will greatly advance by 2030 in its policy.

We have developed various technologies that are essential for geothermal energy development: Two-phase-flow transfer technology, high-performance steam separator designing technology, equipment planning technology to prevent pipe & equipment walls from thinning and scale from adhering, and construction technologies. We will contribute to promoting and expanding the effective use of geothermal energy by offering these geothermal steam and heat utilization technologies to society and constructing highly-reliable, highly-economical SAGS.

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