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TOSHIBA'S EXPERIENCES OF GEOTHERMAL POWER PLANT AND THEIR FEATURES

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ABSTRACT

Toshiba has supplied and experienced long operations of several thousand kW to 110-120MW plants, thus we have now share of approx. 30% in total capacity of geothermal plants all over the world.
The amount of total capacity of Toshiba's geothermal steam turbines has reached approx. 248MW with 7 units for Japanese domestic plants and more than 2556MW with 45 units for overseas plants.

The recent Japanese domestic geothermal plants are represented by Uenotai plant(28.8MW) which is the first unit of a totally rationalized plant, Yanaizu-Nishiyama plant (65MW) applying parallel operation of gas extraction system by compressors and steam ejectors for high gas content, and Kakkonda No.2 plant (30MW) first applying a dry-wet cooling tower in Japan in order to prevent visual white exhaust moisture and icing of surrounding trees.

1.INTRODUCTION

The geothermal energy is clean energy with low CO_2 emission and has little impact on the environment.
Geothermal power generations have been introduced in many countries, and Toshiba has supplied many geothermal plants.
Toshiba has been developing and applying various new technologies to improve plant efficiency, increase power plant capacity and rationalize power units in response to the issues of natural resources and the global environment.
This paper describes Toshiba's technology and experiences of geothermal power generation and the features of the recent Japanese domestic representative plants.

2.THE HISTORY OF TOSHIBA'S GEOTHERMAL POWER GENERATION TECHNOLOGY AND EXPERIENCES

Toshiba's representative geothermal power generation technology and experiences are shown in Table 1.
In 1965 Toshiba manufactured, for the first time, a 22MW turbine-generator for the Matsukawa geothermal power plant in Japan. Since then, we have delivered a large number of geothermal power plants in USA, Mexico, the Philippines, Japan etc.. These geothermal turbines have almost all established records in output power, performance, turbine type, etc.. Geysers 124MW×2units in USA have largest capacity, Cerro Prieto 110MW×4units in Mexico are largest capacity double flash steam turbines in the world. Yanaizu-Nishiyama 65MW unit is largest capacity in Japan.

Toshiba was awarded a prize by the Japan Society of Mechanical Engineers for the design of Geysers Power Plant 110MW geothermal turbine in 1976 and a prize by Prime Minister of Japan for design, manufacturing and construction of Kakkonda power plant in 1979.

Toshiba has experienced many kinds of fluid, for example, direct steam application, separated hot water and steam application and binary cycle etc.. We participated in national project called the "Sunshine Project", and manufactured binary cycle power generating equipment which uses hot water. From the view point of capacity, we have supplied and experienced long operations of several thousand kW to 110-120MW plants, thus we have now share of approx. 30% in total capacity of geothermal plants all over the world.
The history of the amount of total capacity of Toshiba's geothermal steam turbines is shown in Figure 1.

3.THE FEATURES OF THE RECENT DOMESTIC REPRESENTATIVE PLANTS

The recent domestic geothermal plants are represented by Uenotai plant (28.8MW), Yanaizu-Nishiyama plant (65MW) and Kakkonda No.2 plant (30MW) of Tohoku Electric Power Company .
The features and key construction schedules of the resent japanese domestic representative 3 plants is shown in Table 2.

3.1 The features of Uenotai geothermal plant

Uenotai geothermal plant is located in Akita prefecture in Japan.
This plant is reflected to experiences of other plants operation and is rationalized to the utmost with keeping the high reliability.
Main stop valves, main steam control valves, gas ejectors of condenser, cooling water pumps, and circulate water pumps are altered to single series. These equipment omit spare equipment and eliminated the number owing to the high reliable experiences.
And also equipment of extremely low frequency of use and the equipment which are substituted by the other equipment are omitted. The turning oil pump which is used at steam turbine start and stop is omitted and is substituted by the auxiliary oil pump. The oil-water separator is omitted. All the air control valves are changed to the motor driven valves, then the control-air compressor system is omitted.
The steam turbine is arranged at the first floor and the condenser is arranged outside to reduce the turbine generator building. The compact, multi-cell cooling tower is applied to use the plant space effectively (Figure 2).

Excepting these rationalization measures, high reliable technology is applied in this plant. The turbine water injection system that prevents scale for turbine is applied.

3.2 The features of Yanaizu-Nishiyama geothermal plant

Yanaizu-Nishiyama geothermal plant is located in Fukushima prefecture. The residential area is close to the site.
The generator output is 65MW of the largest capacity in Japan and the gas content is 6.88wt% of high concentration.
The double flow configuration steam turbine is applied due to the largest generator output in Japan. By applying double flow turbine to decrease the bucket height, the bucket centrifugal force is eased and the 23 inch last stage blade is applied that have many application experiences.
The cooling towers are 9 cell gathering type in order to diffuse exhaust air effectively.

For the high gas content, gas-compressors are used with steam-ejectors in the gas extraction system. There is an experience of applying a gas-compressor to Mori geothermal plant(50MW) of Hokkaido Electric Power Company but it is the first time to apply the parallel operation of the gas extraction system by the gas compressors and the steam ejectors with different characteristics. The outline of flow diagram is shown in Figure 3.
For the gas extraction system, the parallel operation by the gas compressors and steam ejectors is the important technical point. The optimum equipment capacity is selected and the equipment control method was examined by performing simulations of various operation patterns.

3.3 The features of Kakkonda No.2 geothermal plant

Kakkonda geothermal plant is located in Iwate prefecture.
Since this plant is in a national park, the dry-wet cooling tower is applied in order to prevent icing of surrounding trees. The dry-wet cooling tower is shown in Figure 4.
The dry-wet cooling tower has a fin tube heat exchanger at the upper part. The exhaust moisture is reduced by mixing exhaust air and warm air heated by hot water at dry cooling section. This cooling tower is effective for preventing visual white exhaust moisture.

A brush less exciter with the compact control panel is applied to the generator and a digital AVR with improved function is applied.

4.CONCLUSION

Geothermal power generation gives little impact on the environment with low CO_2 emission. However, it is necessary to increase power plant capacity since the current capacity per unit is not large. And the construction cost needs to be lower.
For the issue of increasing power plant capacity, lengthening the last-stage blades is important.
For the issue of lower construction cost, the rationalization of equipment with keeping the high reliability is necessary. Altering to single series of equipment, applying remote monitoring and control system and omitting control-air compressor system through use motor driven valves instead of air control valves etc. contribute to the rationalization.
Toshiba would continue to make an effort to develop the technologies of geothermal power generation.

Table 1 Toshiba's representative geothermal power generation technology and experiences

YEAR	PLANT, TOPICS	COUNTRY	FEATURE AND APPLYING TECHNOLOGY
1996	・Matsukawa 20MW	Japan	・First geothermal plant of Japan
1967	・Geysers 55MW× 3 units	USA	・First exported geothermal turbine and generator
1970	・Geysers 110MW× 2 units	USA	・Tandem compound 4 flow, 2 casing turbine
1974	・Tiwi 55MW× 4 units ・Start R&D program of binary cycle power plant under Agency of Industrial Science and Technology, the Ministry of International Trade and Industry ,Japan.	Philippines Japan	・Double flash type (FTK) ・Participating in the R&D
1975	・Tiwi 1.3MW unit	Philippines	・For supplying electric power during construction and at black out start of the geothermal plant
1976	・Awarded a prize by the Japanese Society of Mechanical Engineers (JSME) for the design of 110MW geothermal turbine	Japan	・Design of large capacity steam turbine
1977	・Geysers 124MW× 2 units	USA	・Largest capacity geothermal plant
1978	・Succeed in operation of 1 MW binary cycle plant in Nigorikawa, Japan	Japan	・Largest plant of geothermal binary cycle
1979	・Awarded Prize by Prime Minister of Japan for design ,manufacturing and construction of Kakkonda geothermal plant ・Mori 50MW unit	Japan Japan	・Large capacity steam turbine for separated hot water and steam application ・Gas-compressor that is directly connected with steam turbine
1980	・Cerro Prieto 110MW× 4 units	Mexico	・Largest capacity double flash steam turbines
1981	・Santa Fe 48.5MW× 2 units	USA	・Dual rating machine
1984	・IIE 5 MW unit	Mexico	・Portable well head type
1991	・Miravalles 55MW unit	Costa Rica	・First geothermal plant in Costa Rica
1993	・Yanaizu-Nishiyama 65MW unit	Japan	・Largest capacity geothermal plant in Japan

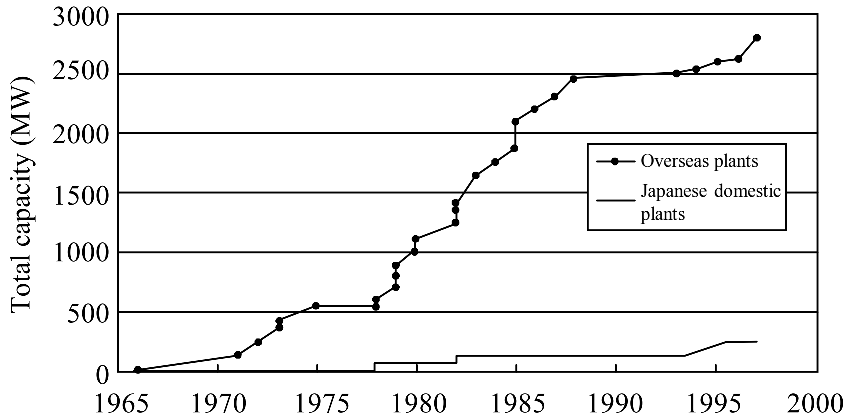

Figure 1 The history of the amount of total capacity of Toshiba's geotherhat steam turbines

Table 2 Features and key construction schedules of the resent Japanese domestic representative 3 plants

Plant		Uenotai	Yanaizu-Nishiyama	Kakkonda No.2
Location		Akita prefecture	Fukushima prefecture	Iwate prefecture
Rating (kW)		28,800	65,000	30,000
Construction schedule	Construction work starting	92/4	93/6	94/4
	Initial power receiving	93/9	94/12	95/10
	Commencement of commercial operation	94/3	95/5	96/3
Gas content in steam (wt%)		0.47	6.88	0.06
Main steam pressure (kg/cm^2g)		5.5	6.5	3.5
Type of steam turbine		SCSF-23"	SCDF-23"	SCSF-23"
Features		・Compact multi-cell cooling tower 12cel ・Main feed water line and equipment were altered to single series. ・Arranging steam turbine at the first floor and condenser outside ・First practical use of the turbine water injection system.	・Largest capacity in Japan ・Double flow steam turbine ・Gathering type cooling tower 9 cell ・High gas content in steam ・Parallel operation of gas extraction system by compressor and steam ejector	・In a national park ・Neighboring with Kakkonda No.1 ・Main feed water line and equipment were altered to single series. ・Dry-wet cooling tower ・Arranging steam turbine at the first floor

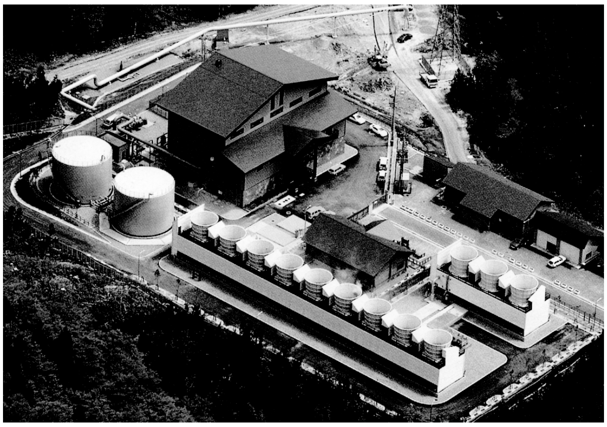

Figure 2 Uenotai geothermal plant

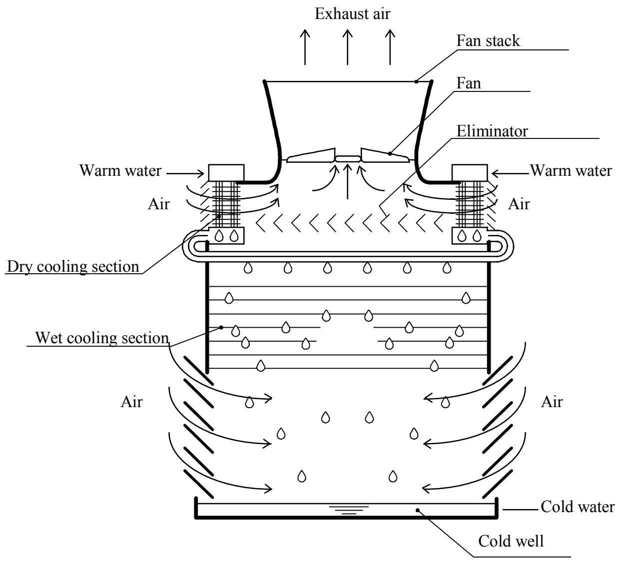

Figure 4 Dry-wet cooling tower

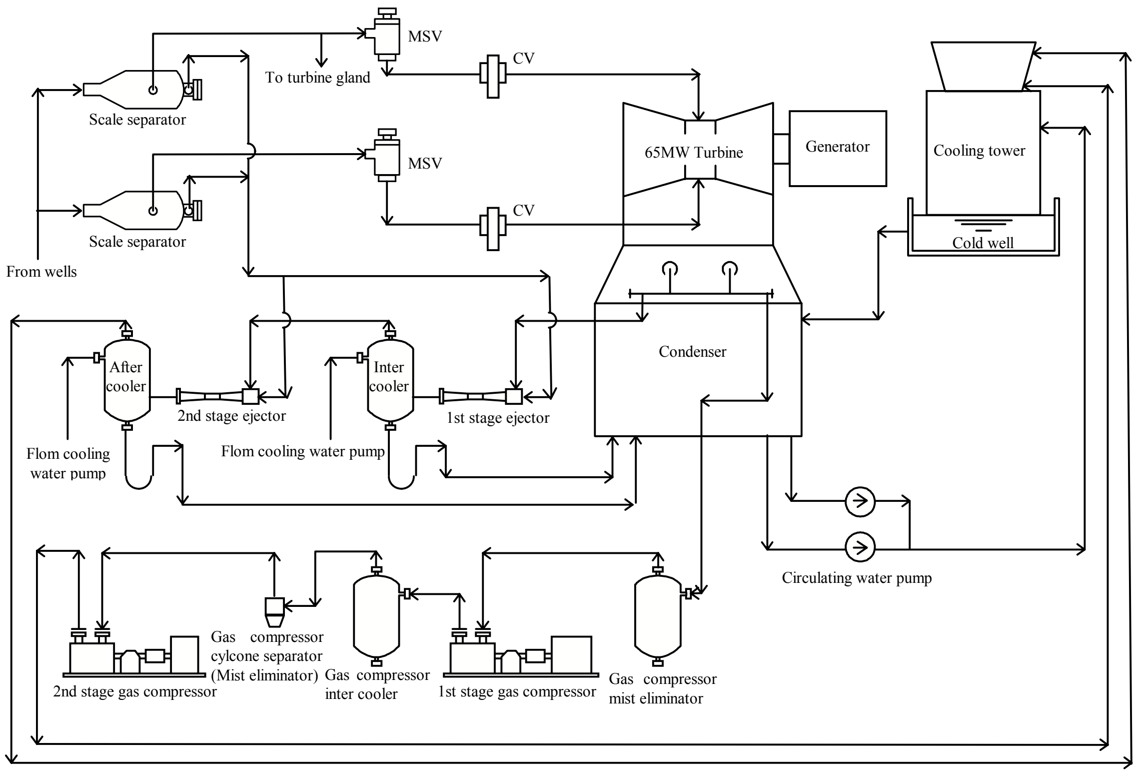

Figure 3 Flow diagram of Yanaizu-Nishiyama plant