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THE HEBER DOUBLE FLASH GEOTHERMAL POWER PLANT

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ABSTRACT

The 52 MW Heber geothermal power plant was completed in August, 1985 in Imperial Valley, California and has been successfully operating since then.
This power plant is not only the first large capacity hot water type geothermal power plant in U.S.A. but also the first double flash cycle geothermal power plant in U.S.A..

The mixed pressure turbine, air cooled generator and high efficiency steam gathering equipments were designed and manufactured by Mitsubishi reflecting the experience in the Hatchobaru 55MW double flash geothermal power plant in Japan, which is the first double flash geothermal power plant in the world.

Successively, the second 17MW double flash geothermal power plant started commercial operation in December, 1985 in Beowawe, Nevada.
This power plant had been completed in 14 months including engineering, manufacturing, construction and trial operation.
For this short completion a large capacity module turbine called MODULAR-25 was adopted for the first time.

INTRODUCTION

The Heber geothermal power plant is located in southeast of the community of Heber, Imperial Valley, of which view is shown on Figure 1.

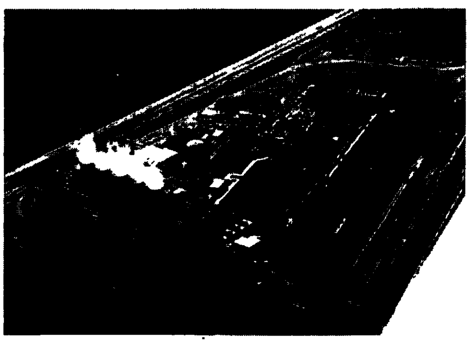

Fig. 1 VIEW OF HEBER GEOTHERMAL POWER PLANT

The geothermal brine is supplied by the Chevron Geothermal Company through a two-phase flow transmission pipe line from the production island.
The production wells produce approximately 8,200,000 lbs/hr brine with a downhole enthalpy of 332 Btu/lb at 360°F to generate 52,000kW gross /47,000kW net power and this geothermal brine contains 15,000 ppm TDS and 9,000 ppm chloride.

The double flash cycle combined with two-phase flow transmission system was adopted because of its economical higher efficiency at low temperature brine condition.

The steam gathering equipments are installed in front of the turbine pedestal and producing the primary and secondary steam. They are constructed as two trains of 50% each capacity.

A 52,000kW mixed pressure geothermal turbine and an 61,176kVA air cooled generator are installed on the foundation pedestal.
The plant was planned as outdoor installation, and then the turbine and generator were so designed. Design specification of the turbine and generator is shown on Table 1.

Table 1. DESIGN SPECIFICATION OF HEBER #1 AND BEOWAWE #1

Unit Name				HEBER #1	BEOWAWE #1
Turbine	Type			Double Pressure Double flow, Impulse-reaction	Double Pressure Single flow, Impulse-reaction
	Rated output		kW	52,000	16,660
	Max. capability		kW	52,000	17,010
	Speed		rpm	3,600	3,600
	Steam condition at MSV	press.	psig	40.4/1.0	49.1/1.42
		temp.	°F	(Sat.) 287/215	(Sat.) 294/210
		gas content	% (by weight)	0.005	0.01
	Exhaust pressure	exhaust hood	inHg abs.	3.5	1.31
		condenser	inHg abs.	3.5	1.25
	Steam consumption		lbs/hr	636,250/571,870	177,250/97,220
	No. of stages		-	5 x 2 flow	5 x 1 flow
	Last blade length		inch	25	25
Generator	Type			Rotating field	Rotating field
	Capability		kVA	61,176	18,900
	Voltage		kV	13.8	4.16
	Cooling			Air-cooled	Air-cooled

This paper describes features of the Heber double flash geothermal power plant and its major equipments and, at the same time, introduces a large capacity turbine module adopted to the Beowawe double flash geothermal power plant.

DOUBLE FLASH CYCLE SYSTEM

In single flash cycle system, a steam-hot water mixture from well is led to a separator, and the separated steam is led to a steam turbine while the remaining hot water is discharged as a waste.
In double flash cycle system, the remaining hot water goes to a low pressure flasher to produce secondary steam through flashing.
This steam is admitted to an intermediate stage of the turbine.

The double flash cycle was adopted to the 55MW Hatchobaru geothermal power plant for the first time in the world, and it has been operating since June, 1977.
Then, it was determined to apply the double flash cycle to the Heber geothermal power plant based on the successful operating record in the Hatchobaru power plant, of which availability factor is higher than 98%.

Figure 2 shows the general conception of double flash cycle and single flash cycle system.

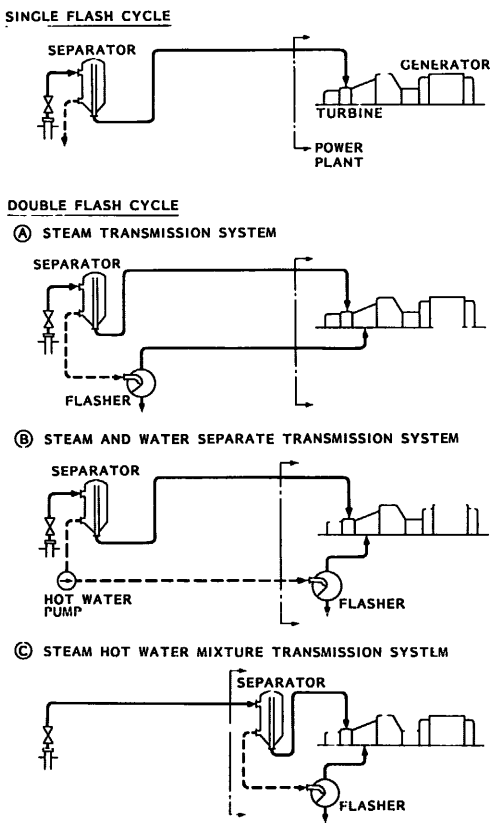

Fig. 2 SCHEMATIC DIAGRAMS OF SINGLE AND DOUBLE FLASH CYCLES

The advantages of double flash cycle system are as follows:

- About 50 % more power can be produced with the same geothermal brine supply than in single flash cycle system.
- Although the total investment cost of the plant is, about 5% higher than that of single flash cycle system, the net cost per kilowatt hour is about 25 to 30 % lower.

TWO-PHASE FLOW TRANSMISSION

Two-phase fluid, steam-hot water mixture, is transmitted from the production wells to the power plant through two 36 inch diameter pipes.

Adoption of two-phase flow transmission system to the double flash cycle further improves plant efficiency becuase pressure loss of two-phase flow transmission does not cause a power loss like a steam transmission.
The steam-hot water mixture transmission system was adopted to the Hatchobaru geothermal power plant in Japan for the first time in the world based on the cumulative field test results, and now this system has become a proven system in a hot water type geothermal power plant.

The most important thing to design this system is to adopt the piping arrangement which can maintain a stable two-phase flow at any plant operating condition.

STEAM GATHERING SYSTEM

Steam gathering system in the Heber power plant consists of auxiliary flash tank, high pressure flash tank (steam separator), hot water collecting tank, low pressure flash tank (flasher) and brine return surge tank as shown on the schematic system diagram Figure 3.
Design condition of the steam gathering system is shown on Table 2.

Table 2. DESIGN CONDITION OF STEAM GATHERING EQUIPMENTS

BRINE/STEAM SUPPLY		
	FLOW RATE	8,200,000 LB/HR
	PRESSURE	60 PSIA
	TEMPERATURE	SAT.
	NONCONDENSABLE GAS CONTENT (MAXIMUM)	0.005%
HIGH PRESSURE STEAM		
	FLOW RATE	640,000 LB/HR
	RPESSURE	55 PSIA
	TEMPERATURE	SAT.
LOW PRESSURE STEAM		
	FLOW RATE	580,000 LB/HR
	PRESSURE	16 PSIA
	TEMPERATURE	SAT.

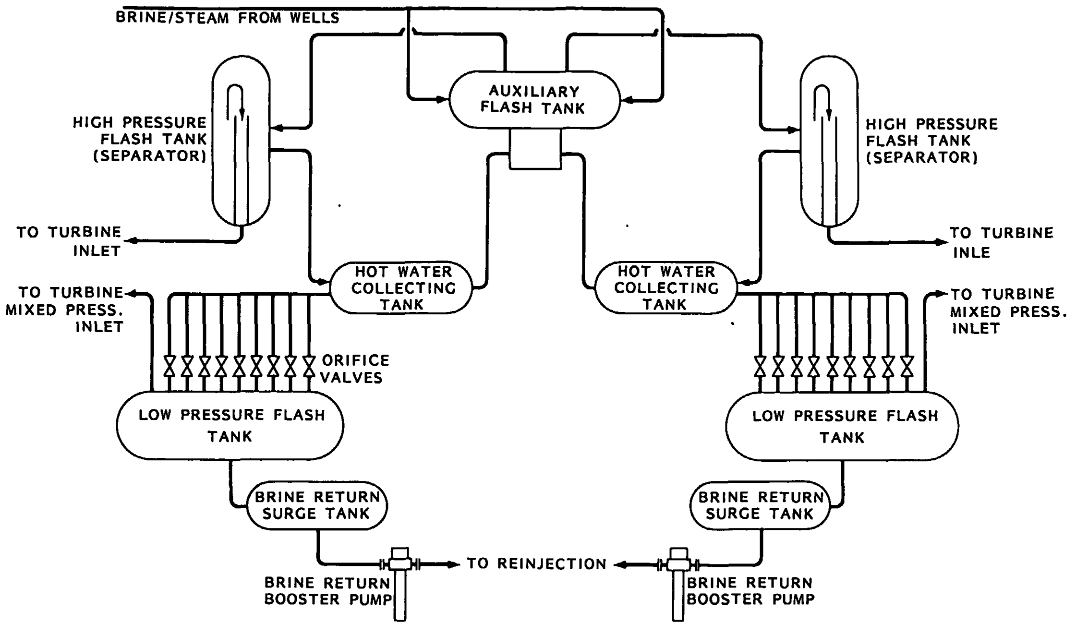

Fig. 3 SYSTEM DIAGRAM OF STEAM GATHERING

Geothermal steam-hot water mixture is transmitted to the power plant area by the two-phase flow transmission pipes and, at first, led to the auxiliary flash tank for pre-flashing. Steam flashed in the auxiliary flash tank is then led to the steam separators, where pre-flashed steam is further flashed to primary steam of higher purity.

The auxiliary flash tank is installed at lower level than the separator to maintain stability of two-phase flow by eliminating the up-grade pipe directly connected to the separator.
The discharged hot water from the auxiliary flash tank and separator is led to the hot water collecting tanks in which the water level is maintained.
This hot water is, in the next, led to the flasher to be flashed into low pressure steam, which is introduced into an intermediate stage of the turbine as secondary steam.

Two sets of 50% capacity separators and flashers are adopted because of excessive size of these tanks, and installed symmetrically to prevent unbalance flow.
The discharged hot water from the flashers is led to the hot water surge tank at once and reinjected by the pumps.

HIGH PRESSURE FLASH TANK (STEAM SEPARATOR)

Cyclone type high pressure flash tanks (steam separator) are installed to separate steam completely from the steam-hot water mixture and the separated high purity steam is led to the turbine as primary steam.

By adopting steam-hot water mixture transmission system, the number of steam separator is minimized and they are installed near turbine to maintain small steam pressure loss.

The internal view of high pressure flash tank is shown on Figure 4.

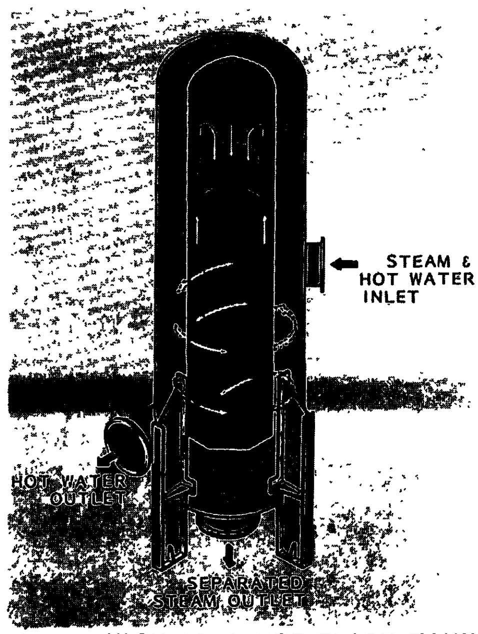

Fig. 4 HIGH PRESSURE FLASH TANK

The proportion of cyclone in the vessel is very important to keep high separation efficiency, and it was determined based on the design data obtained in the field model test.

This type of high pressure flash tank (steam separator) has been applied to every hot water type geothermal power plant supplied by us and showed successful operating experiences on reliability and performance.

LOW PRESSURE FLASH TANK (FLASHER)

The high pressure flash tank (steam separator) separates steam from steam-hot water mixture, while the low pressure flash tank (flasher) produces steam from hot water.
The type of flash tank, either steam separator or flasher shall be selected corresponding to steam-hot water ratio.

The internal view of flasher is shown on Figure 5.
The important requirement for flasher is to maintain higher separating efficiency and small pressure loss as well as the separator.

This flasher was developed based on the model tests at Otake in Japan and Cerro Prieto in Mexico, and its separating efficiency is high enough to obtain more than 99.9% purity.

Fig. 5 LOW PRESSURE FLASH TANK

DEMISTER

As steam purity is a key factor to maintain high reliability of the power plant, a corrugated plate type demister is provided in the separator and flasher to improve the steam purity further. The internal view of demister is shown on Figure 6.
The collecting efficiency of mist in the demister is analysed by flow pattern analysis and applied to design.

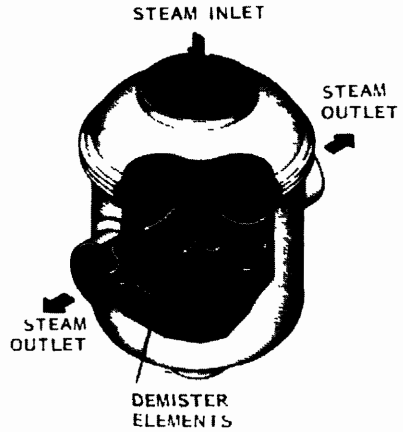

Fig. 6 DEMISTER

DOUBLE PRESSURE TURBINE

A steam turbine adopted to the Heber geothermal power plant is of a five stage double flow, mixed pressure, condensing turbine fitted with 25 inch last blades. The longitudinal section is shown on Figure 7.

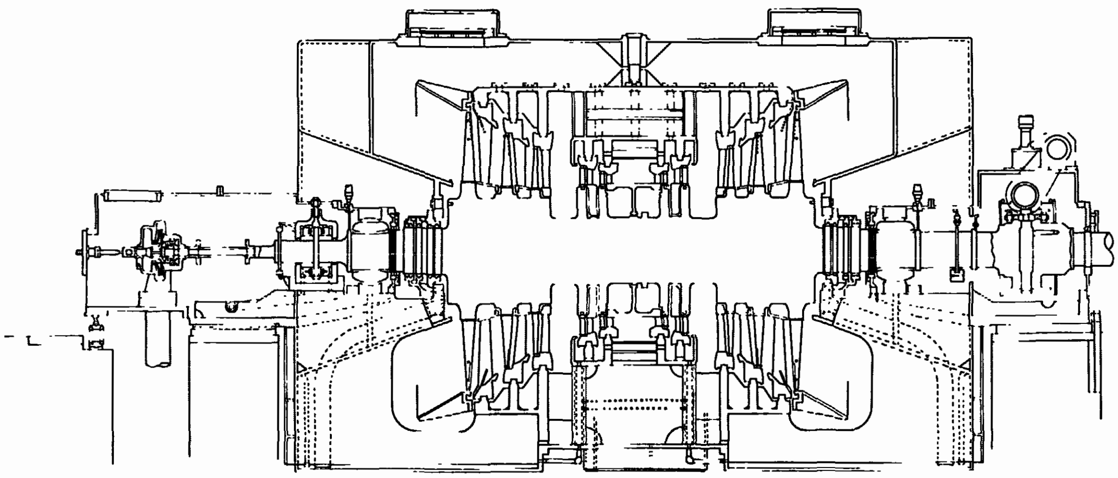

Fig. 7 LONGITUDINAL SECTION OF 52,000 kW MIXED PRESSURE TURBINE

The primary steam is admitted to the first stage and the secondary steam is admitted to the third stage inlet, at which it is mixed with the primary steam.
The location of this mixed pressure stage was selected to match the secondary steam pressure.
At each turbine inlet of the primary and secondary steam, swing check type main stop valve and butterfly type governing valve are mounted.

As the above valves for the secondary steam become very large like 40 inch nominal diameter due to a large amount of volumetric flow at low steam pressure, shock stress occurred in the main stop valve at turbine trip was analysed and its result was reflected to the design.

The control system of turbine includes not only speed control but also secondary steam pressure control to maintain it higher than atmosphere. The double casing design was applied to minimize a capacity of overhead maintenance crane to 30 metric tons.
The first two stages are impulse type and the last three stages are reaction type.
25 inch last blades, which are the longest blades for our geothermal turbine, were adopted because of higher efficiency due to smaller leaving loss at large exhaust flow rate. The exhausted steam is led to the surface condenser installed below the turbine.

OPERATION EXPERIENCE

Commercial operation of the Heber double flash geothermal power plant was started on August 1st, 1985.
The availability factor up to March in this year was 95.6%.

In April, 1986, the first overhaul inspection was carried out and it was confirmed that the turbine condition is satisfactory.
Thus seventeen days later, the unit went into two years of continuous operation upon recognition of its soundness.

THE BEOWAWE GEOTHERMAL POWER PLANT

The second double flash geothermal power plant in U.S.A. was completed in December, 1985 at the Beowawe, Nevada, which is well known as a potential hot water type geothermal resource.

This power plant aimed at short construction time and Mitsubishi took not only design and manufacturing of equipments but also engineering of whole power plant to minimize engineering time.
Optimization of power plant design parameters, such as main steam pressure and condenser vacuum, was performed based on the data of production wells and weather condition such that the plant site is especially located at cold district.

Design specification of the turbine and generator is shown on Table 1 in the previous page.

The feature of this power plant is adoption of equipment module to minimize the erection period. A large capacity module turbine called MODULAR-25 was adopted to this project. The outline of turbine and generator is shown on Figure 8.

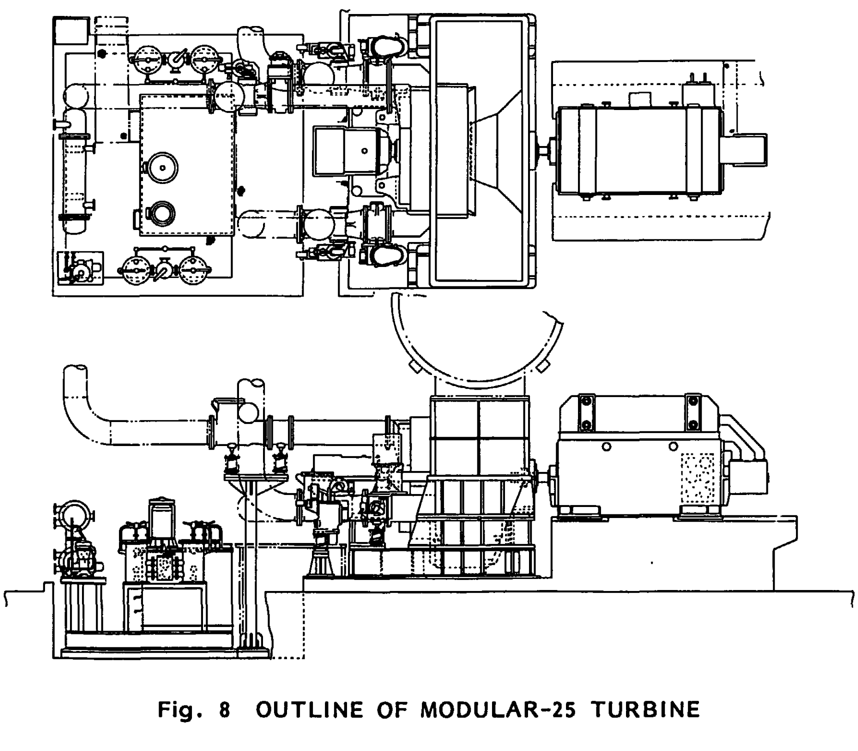

Fig. 8 OUTLINE OF MODULAR-25 TURBINE

This turbine module consists of two components, turbine package and oil unit console, and both of components are constructed and assembled on the steel skid respectively as shown on Figure 9.

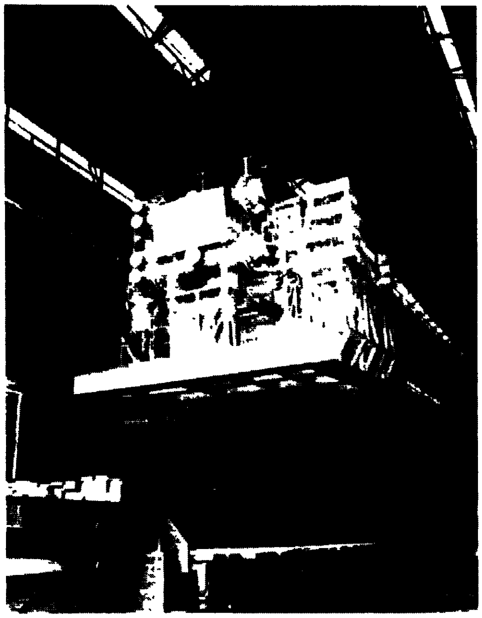

Fig. 9 LIFTED OIL UNIT CONSOLE

Required test and adjustment of control and lubricating oil system can be completed in a shop and eliminated at site.

The electrical and control equipments were assembled in a package house and delivered to the site after finishing test.
Other equipments were also designed as a package as much as possible. By this way, this power plant was completed in 14 months after being placed in order.

CONCLUSION

It is obvious that double flash cycle combined with two-phase flow transmission system has become popular now in case of hot water type geothermal power plant, as we can see in the Heber and the Beowawe.
It is no other reason than its economical higher efficiency and reliability.

Thus, it is very important to optimize operating condition and type of components for steam gathering system considering geothermal brine condition, such as temperature and chemical composition, in order to obtain its higher efficiency and reliability.

In the near future, we will be able to see more double flash geothermal power plants in the world in accordance with progress of development of hot water type geothermal resources.

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