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FLASH CYCLE FOR LOW TEMPERATURE GEOTHERMAL RESOURCES VERY LOW PRESSURE (VLP) FLASH CYCLE

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ABSTRACT

The most common usage of the geothermal resources for the power generation is the flash cycle with the steam turbines, however the temperature of the geothermal resources utilized for the flash cycle has been rather high. For the low temperature resources, the binary cycle has been employed. It would be beneficial that the flash cycle can be used also for low temperature geothermal resources because the binary cycle requires the working fluid which is normally hazardous.

This paper introduces the very low pressure (VLP) flash cycle for the low temperature geothermal resources and its features.

1. INTRODUCTION

Total installed capacity in the world of the geothermal power generation units is about 8,000 MW as of 1999, and the most of the plants utilizes the flash cycle. If the resource temperature is not high enough for generating the steam well above the atmospheric pressure, the binary cycle has been utilized. However the very low pressure steam still can drive the steam turbines as we can see in the expansion lines of the ordinary geothermal steam turbines. Even there are some issues to employ the steam turbines to the low inlet steam pressure with the flash cycle, those would not be essential.

Although the binary cycle presents the most beneficial feature that the system never emit the non-condensable gases including the hydrogen sulphide gas to the atmosphere, it uses working fluids other than water which makes the system operation and maintenance difficult, sensitive and costly compared to the flash cycle.

Since the flash cycle offers very simple operation and easy maintenance, it should be utilized even for the low temperature geothermal resources.

2. ISSUES OF LOW PRESSURE FLASH

To utilize low temperature geothermal resources, flash pressure should be very low and the turbines should be condensing type to generate as much electric power as possible from the limited energy.

Even employing the condensing turbines, there are some issues to be discussed because the flash pressure has to be very low compared to the conventional flash cycle plants.

2.1 Gland Sealing

The flash pressure is usually optimized to get the largest output. The Fig. 1 is a sample of the optimization for the 130 deg. C saturated hot water. As shown on the Fig. 1, the maximum output can be achieved around at 0.65 bar abs of the flash pressure for this example.

The condensing turbine shaft is normally sealed with the sealing steam to avoid entering the ambient air. If 0.65 bar is selected as the design conditions based on the curve, this steam cannot be used as the sealing steam because the pressure is less than the atmosphere.

There can be two considerations for the gland sealing issue. One idea is to select the flash pressure at which maximum output can be taken, regardless of pressure. The air leaking into the turbine will flow to the condenser, and finally be extracted by the gas removal system. Gas removal system capacity has to be enlarged considering this amount of the air. The second idea is to install a small flasher for the purpose of generating the required sealing steam flashed at about 1.1 bar. Fig.2 shows a rough idea of this system. Even though the system requires additional flasher probably with additional controls, this idea would be superior to the former one in terms of corrosion protection. The air should not be admitted into the turbine during the operation.

2.2 Gas Extraction

If the low temperature geothermal resources come from the high pressure separators, it will not contain much non-condensable gases. If this is the case, we do not think about the gas extraction system much. Since the steam pressure is too low to employ the steam jet ejectors, the liquid ring vacuum pump should be used.

If the resources directly come from the production wells, the resources may contain lots of non-condensable gases. In this case , either vacuum pump or water jet pump system whichever more favorable from the point of view of saving the parasitic load will be used for gas extraction because there is no steam of which pressure is high enough to drive a set of steam jet ejectors.

2.3 Large Volume Flow

Because the inlet steam pressure is very low, the volume flow of the inlet steam is very large, which makes the turbine inlet valves very large. Fig.3 shows the relation between the turbine inlet pressure and the diameter of the inlet valves when the inlet steam flow is 100 t/h. The diameter shown on Fig. 3 is based on dual inlets to the turbine. Inlet valves larger than 1,000 mm will not be feasible.

2.4 Turbine Last Stage Blades

Fig.4 shows the relation between the turbine inlet steam pressure and the adiabatic heat drop through the turbine at 0.1 bar exhaust pressure.

As shown above, heat drop of the low pressure flash case is one half to one third of the conventional geothermal units. When the standardized low pressure blades are used and the inlet pressure is very low, the steam will be admitted just before the sets of the low pressure stages (normally 2 or 3 stages) because of the low inlet steam pressure. In this case, the flash pressure will be selected based on the characteristics of the standardized low pressure stages.

3. EXAMPLE

As shown above, there are some issues for planning the flash cycle with the low temperature geothermal resources, however there are no technically critical issues.

In this section, one example is introduced.

3.1 Basis

The following basis are used for this example.

Hot water temperature	130 degC saturated water
Hot water flow	1,000 t/h
Wet bulb temperature	20 degC

The hot water is assumed to be taken from the high pressure separator drain, which contains no non-condensable gases.

3.2 Features

Fig. 5 shows an example heat and mass balance diagram of this system. Although the maximum output would be achieved at 0.65 bar abs based on Fig. 1, the flash pressure of 0.7 bar abs is selected since the steam flow at 0.65 bar abs exceeds the maximum steam admission of the selected turbine model for this example. The selected turbine model is single flow skid mounted type with 467 mm last stage blades. Fig. 6 shows the sectional view of the turbine. As shown on Fig. 6, turbine is quite conventional geothermal steam turbine except that the number of stages is only three.

A liquid ring vacuum pump is considered to extract small quantity of leaked air and accompanying steam.

Parasitic loads of this example are, Hotwell Pump (110 kW), Auxiliary Cooling Water Pump (5.5 kW), Cooling Tower Fans (110 kW), Vacuum Pump (15 kW) and power for the control system (Ca. 10 kW) such as an air compressor, making approximately 250 kW which is roughly 7% of the gross output.

4. CONCLUSIONS

There may be a variety of cases other than the example described in the previous section. If geothermal hot water contains some percentage of steam, the turbine inlet pressure can be raised to, for example 0.9 bar abs, and the gross output will be considerably increased although more power must be consumed for the gas extraction, because in such a case usually some non-condensable gases are contained in steam. The condenser pressure plays a very important role in determining the output since the heat drop across the VLP turbine is quite low compared to the ordinary geothermal turbine. For the VLP flash system it is more effective than ordinary geothermal power generation to lower the design condenser pressure to increase the output under the same brine consumption.

Nature of geothermal resources varies area to area, and the site conditions also differ. What is important is to select the most suitable system under the given conditions. The VLP flash cycle will contribute to widen a range of the selection for geothermal power generation with low temperature resources.

REFERENCES

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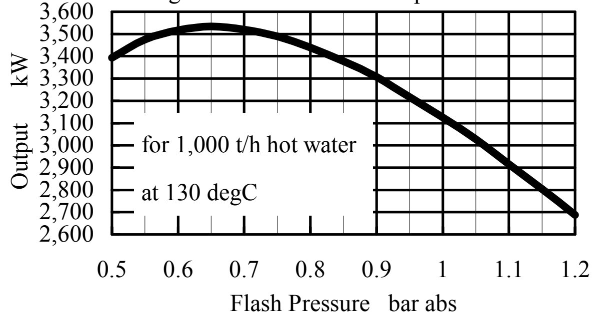
Fig.1 Flash Pressure vs Output



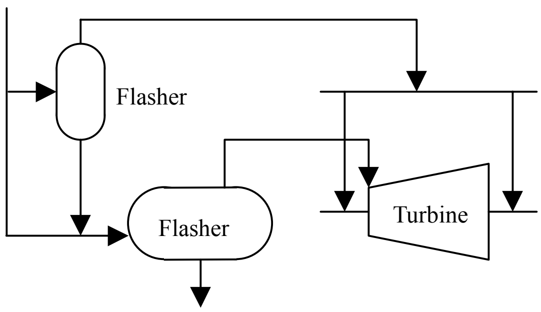


Fig.2 Flasher for Sealing Steam

Fig.3 Diameter of Inlet Valves

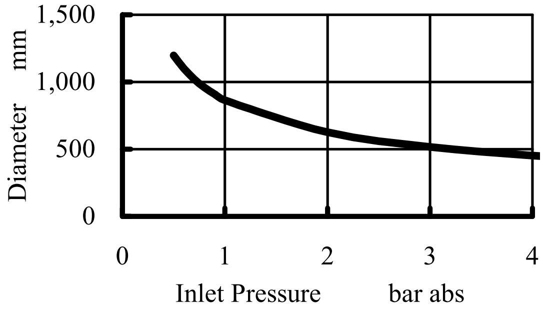
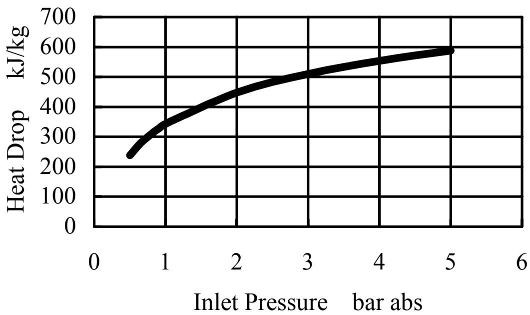


Fig.4 Heat Drop



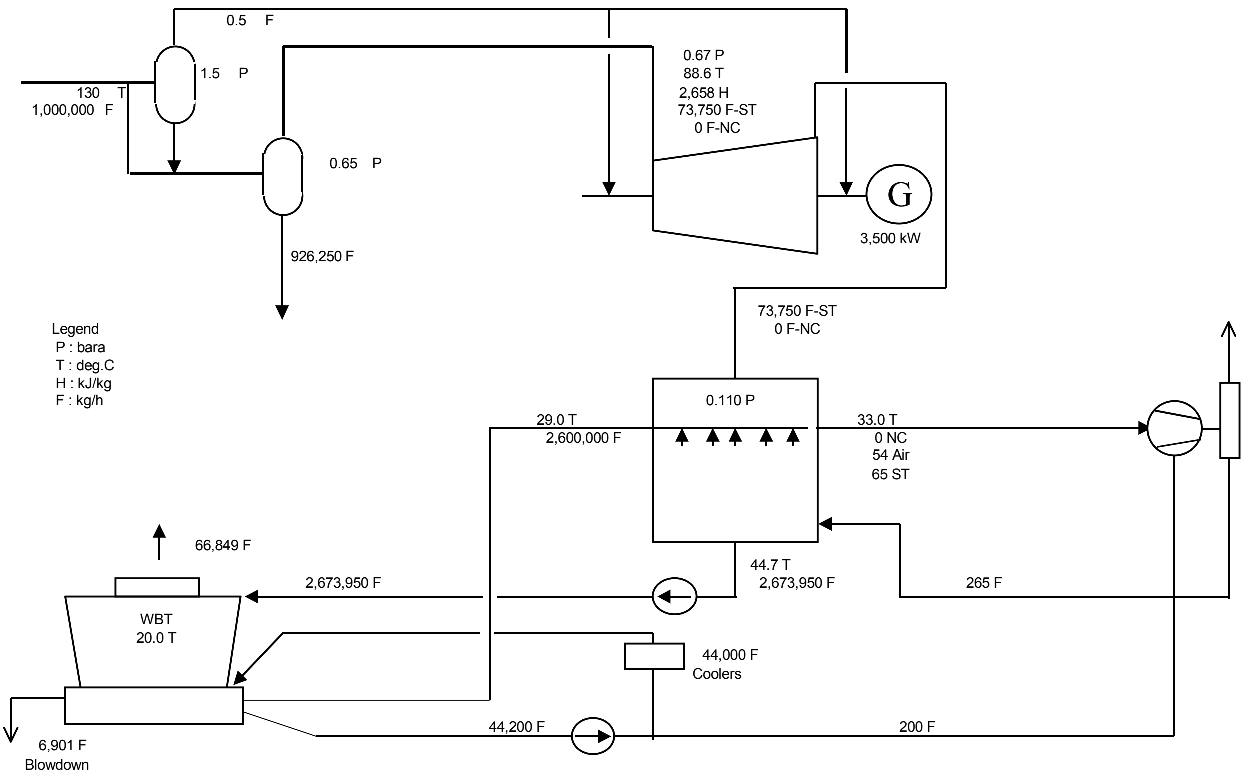


Fig. 5 Sample Heat and Mass Balance Diagram

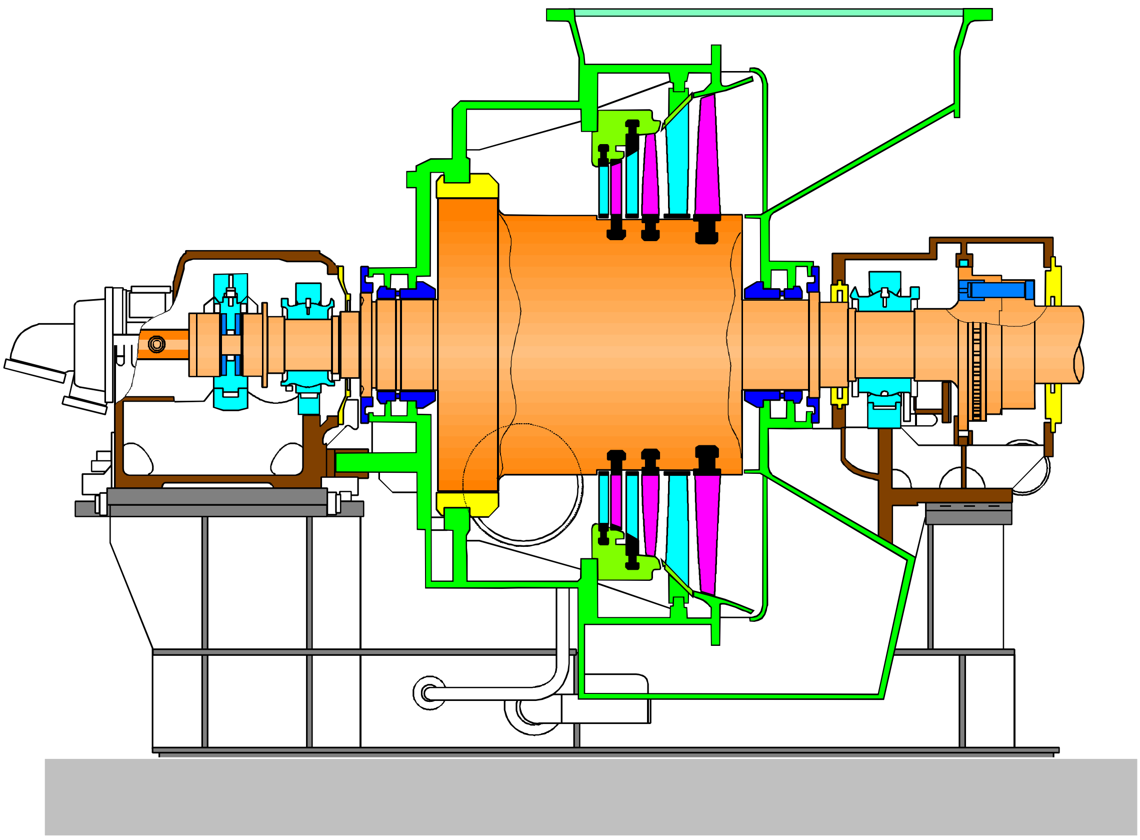


Fig. 6 Sectional View of the Turbine for Very Low Pressure