ROTOKAWA: STEAMFIELD TECHNICAL OVERVIEW

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KEYWORDS

Rotokawa steamfield, production, reinjection, Tauhara North 2 Power Station, New Zealand.

ABSTRACT

It is proposed to develop an 18 MWe geothermal power project using the Rotokawa Geothermal Resource.

The critical factors in the design of the steamfield were:

- limited output (18 MWe approx)
- limited local electricity market
- to be commercially viable at the NZ wholesale electricity rates of US$0.026 per kWhr
- high silica saturation temperature
- use of a high enthalpy and temperature resource
- desire to use simple practical design solutions

The final selection of the separation pressure (19 bara) was dominated by the silica deposition restraints and the desire to minimise the installed cost of generation per MWe output.

1 INTRODUCTION

The Rotokawa geothermal field is located 12kms north of Taupo in the Taupo Volcanic Zone. The first well was drilled in 1966 and investigation drilling continued until 1986. The field has an estimated capacity between 100 - 400 MWe.

Development approval (Bloomer 1995) has been obtained on the basis of a small first stage project which is not expected to have a significant impact on the reservoir. The project has been designed to use three existing investigation wells and a new production and reinjection well.

The project has been named as Tauhara North 2 Power Station in recognition of the land owner Tauhara North No 2 Trust. The steamfield will be developed by the Tauhara North No 2 Joint Venture comprising Tauhara North No 2 Trust (the Land Owner) Taupo Electricity Ltd (the local electricity supply company) and WORKS Civil Construction Ltd (whose subsidiary WORKS Geothermal Ltd is the local geothermal development company). The power station will be developed by Taupo Electricity Ltd.

2 SCHEMATIC FLOW DIAGRAM

Figure 1 shows the schematic flow diagram for the proposed project Production fluid will be supplied froin RK5 and an additional new production well (RK9).

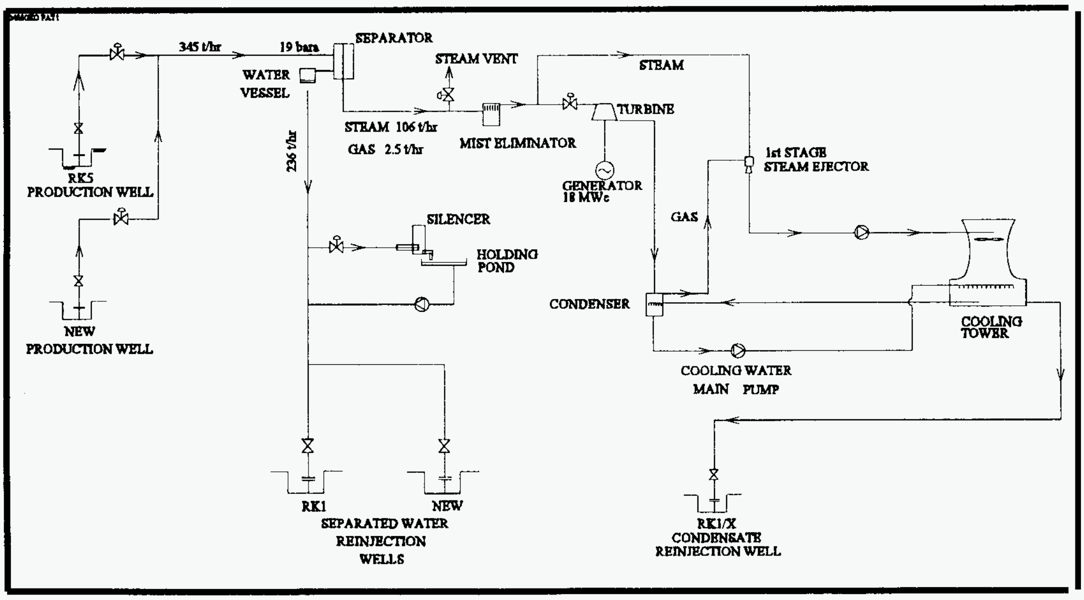

Figure 1
Schematic Flow Diagram

Two phase pipelines carry the fluid to a separation plant where the steam is separated for supply to the power station. The waste geothermal water will be gravity reinjected into RKI and an additional new reinjection well. Water will be discharged to a holding pond during startup and in the event of a reinjection malfunction. Water from the holding pond will be pumped back into the reinjection system. **A** steam vent has been included for control of overpressure.

3 FLUID

Table 1 shows the significant properties of the Rotokawa fluid.

Table 1
Typical Fluid Properties

Typical feed depth	2200 m
Enthalpy	1500 kJ/kg
NCG in total fluid	0.7%
Downhole Temperature	310°C
Silica Saturation Temperature	210°C
Maximum Discharge Pressure	67 bara

Well output is restricted by formation permeability and well output is relatively constant at lower wellhead pressures. Figure 2 shows the estimated combined well flow characteristic for this development and the steam and water flows assuming a separation pressure which is 3 bars lower than the wellhead pressure.

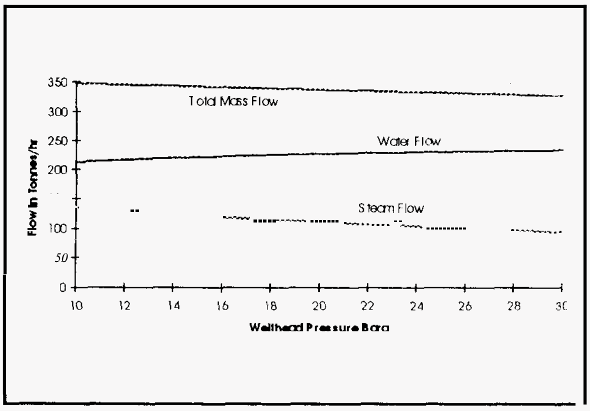

Figure 2
Rotokawa Well Output Curve

Chemical analysis of the geothermal fluid at Rotokawa has shown that a unity silica saturation index occurs at a separation pressure of 19 bara. At this separation pressure the concentration of silica will he 1052 g/t.

4 SEPARATION PRESSURE

The critical parameters that were considered in the selection of the separation pressure were

- silica saturation temperature
- potential electrical output of wells
- power plant cost
- reservoir pressure drawdown

Although the final selection of separation pressure was dominated by the high silica saturation temperature, the other parameters were considered in order to gain an insight into the relationshp between separation pressure and plant output.

All analysis assumed that the wellhead pressure was 3 bars higher than the separation pressure and the turbine inlet pressure 1 bar lower than the separation pressure.

The Rotokawa Resource Consents were obtained on the condition that the discharge geothermal water would be reinjected. The silica saturation temperature at Rotokawa is 210°C which corresponds to a separation pressure of 19 bara. Extensive investigation (Barnett and Garcia 1993) has been carried out by the geothermal industry on the relationship between silica deposition and silica saturation temperature and in a number of places in the world geothermal water is successfully reinjected at a temperature less than the silica saturation temperature. However this has not been achieved without extensive field trials with the actual fluid. Limited experimental work has been completed at Rotokawa to measure silica deposition rates with respect to temperature and while the results support reinjecting the water at the saturation temperature, further investigations would be required if the water was reinjected at a temperature less than the saturation temperature. In order to keep the geothermal fluid in an undersaturated state with repect to silica a separation pressure greater than or equal to 19 bara was preferred unless further experimental work was undertaken.

Figure 3 which was developed from the fluid flows shown in Figure 2 shows the potential electrical energy of the fluid in the geothermal steam (assuming a single flash and condensing at 45°C) and in the geothermal water assuming it is cooled through a binary plant from the flash temperature to 90°C. The optimum separation pressure from consideration of the steam fraction only is approximately 11 hara. At this pressure the potential output **is** approximately 4% greater than the output at the proposed separation pressure of 19 bara.

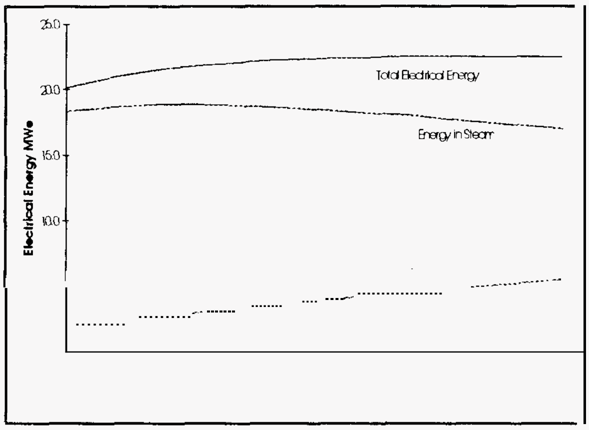

Figure 3
Electrical Output Vs Separation Pressure

Although it was not considered prudent to use the energy available in the separated water initially, the project has been designed to allow electrical energy to be extracted (eg by the installation of a packaged binary plant) once operating experience has been gained from the station. Silica deposition investigations will be undertaken as soon as the plant becomes operational and it is envisaged that methods to manage silica deposition will be developed to allow the installation of a binary plant following **2** years of operation. Therefore electrical output available from the separated water was considered in the selection of the separation pressure. The potential electrical generation increases with increasing separation pressure as both the quantity and temperature of water is proportional to the separation pressure. The absolute energy that can be extracted from the fluid will also depend on the allowable discharge temperature of the geothermal water. Although the economic discharge temperature is 80-90°C this may be increased because of silica deposition considerations.

The optimum separation pressure from consideration of the combined electrical potential of the steam and geothermal writer is approximately 21 bara although this is sensitive to the allowable discharge temperature of the geothermal water. The higher the discharge temperature the lower will be the optimum separation pressure.

An alternative consideration was the potential electrical output versus separation pressure for a constant flow of fluid at 1500 kJ/kg enthalpy. The trend is similar to that shown by Figure 3 except optimum electrical production occurs at a separation pressure of 13 bara.

Power plant will produce more electricity per unit mass of steam flow at higher steam inlet pressures. In addition the cost of geothermal power plant depends on both the electricity output and design steam flow. Typically therefore the capital cost of power plant per MWe will decrease with increasing turbine inlet pressure. This was particularly important for the Rotokawa development because of the tight financial constraints.

This analysis supported the selection of a relatively high steam inlet pressure. However there was some concern as to how this high steam inlet pressure may affect well deliverability in the long term. Reservoir modelling was completed as part of the resource consent application. The model indicated that there will be an initial rapid decline of about 12 hars in the reservoir over the first *3* years of production following which the pressures will stabilise. This pressure change was used to estimate steam flow rundown and confirmed the suitability of the proposed higher steam inlet pressure. In addition the effect of an increase in total production from the Rotokawa reservoir was also considered. This also showed a corresponding additional reduction in reservoir pressure.

The final selection of the separation pressure (19 bara) was dominated by the silica deposition restraints and the desire to minimise the installed cost of generation per MWe output. The future uncertainties associated with pressure decline were mitigated by specifying power plant that could be modified to accept lower steam inlet conditons whilst maintaining an efficient output characteristic.

The proposed power station will be constructed by Ansaldo GIE of Italy. The turbine **is** based on their standard 20MW Universale turbine, which has been previously developed in Italy to suit this criteria

5 REINJECTION

The Rotokawa Resource Consents were obtained **on** the condition that the geothermal water and condensate would be reinjected into the geothermal reservoir. Reinjection of this fluid is required to protect both the environment and local river from the additional discharge of geothermal fluid.

Gravity reinjection is proposed into an existing well RKI and one new well drilled to a depth of 500m. These wells are located in the centre of the production field and are approximately 1000m from the production wells (refer to Figure 4). The reinjection strategy relies on a minimum vertical separation of 1000m, poor vertical permeability and a horizontal separation of 1000m. The temperature of the receiving environment in the reinjection wells will not be less than the 210°C geothermal water.

The system has been designed for gravity reinjection in keeping with the principle of design simplicity. To assist with this approach the separation plant was located on higher ground midway between the production and reinjection zones in order to provide a greater head at the reinjection wells. This location was also the preferred site for the power station.

Condensate will be kept separate from geothermal water because of its corrosive nature, the mismatch of delivery pressures and the potential for increasing silica deposition due to the addition of aerated condensate. Disposal will be by gravity reinjection into an existing shallow pilot well RK1/X.

6 STEAM PURITY

The steam supply system has been designed to minimise the solids carried with the steam into the steam turbine. This is achieved by using a high efficiency steam separator, a generously sized steam main, specially designed steam traps and a mist eliminator.

A single separator will be used to separate the steam from the geothermal fluid. The performance of these separators has been developed from plant used at Wairakei, Kawerau and Ohaaki. The separator will be sized to minimise the carryover of geothermal water with the geothermal steam.

A 140m long steam main will connect the separation plant to the power station. The steam main will be generously sized to assist condensate removal as this will reduce the solids loading as the impurities are normally dissolved in the condensate. Insulation will be specified to allow controlled condensation to occur which will also assist in scrubbing solids from the steam supply. The steam main length was chosen as a practical compromise between cost reduction (short as possible) and solids removal (as long as possible).

Two baffled deep steam traps will be located in the steam main. These have been developed to efficiently remove condensate from the steam main. Steam main layout and trap location will be considered to maximise each steam trap's effectiveness.

A mist eliminator will be installed immediately upstream of the steam turbine. This will act as a highly efficient steam trap and further reduce both the steam condensate and the solids. The friction losses in the complete system will be minimised to ensure that the mist eliminator does not cause superheating of the steam which would have an adverse effect on steam quality.

7 CONTROL SYSTEM

Pressure will be normally maintained by balancing the steam flow with the swallowing capacity of the steam turbine. This will be manually controlled by remotely operated flow control valves fitted to each production well. Overpressure will be controlled by an automatic steam vent. This vent will be designed to control steam pressure in the event of a turbine trip at full load. Final overpressure protection will be provided by safety valves complete with bursting discs.

No control will be required for the gravity reinjection system as this will be essentially a self modulating system. Water dump valves will be installed to discharge geothermal water to a holding pond in the event of a high water level in the water vessel.

All steamfield transmitters (flow and pressure) and controllers will be connected to a PC based monitoring and logging system. This will provide operators with graphical process information and log field operating variables. These data are required for steamfield operations and management as well as for compliance with the monitoring requirements of the Resource Consents.

8 OVERALL LAYOUT

The overall layout of the proposed project is shown on Figure 4. The power station has been located on the highest ground in the immediate area in order to assist with the dispersal of non condensible gases and the cooling tower plume.

The separation plant is located adjacent to the power station and connected to this by the 140m long steam main. The elevation of the separation plant will be *3* - 5m above the power station.

The proposed reinjection area is 10m higher than the proposed production area This potential problem for gravity reinjectinn has been avoided by locating the separation plant on a hill between the two areas.

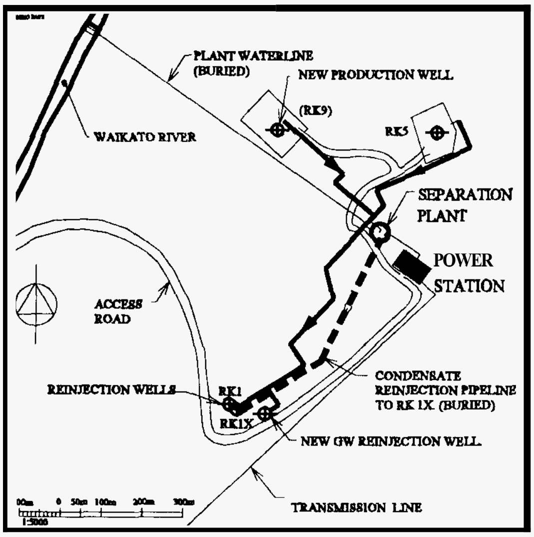

Figure 4
Steamfield Layout

9 CONCLUSION

The separation pressure of 19 bara was selected to avoid silica deposition problems. Investigations will be conducted once the plant becomes operational in order that the electrial energy can be extrated from the high temperature geothermal water.

Construction of the proposed Tauhara North 2 Power Station is planned to commence in 1995. The steamfield construction and well drilling contracts will be completed by WORKS Geothermal Ltd while the power station will be constructed by Ansaldo GIE of Italy.

The simple, practical steamfield design has assisted in making the project commercially viable.

10 ACKNOWLEDGEMENT

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