The 30 MW Rotokawa I geothermal project five years of operation

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Abstract

The 30 MW Rotokawa geothermal project was the first geothermal project developed in New Zealand by private sector interests following the deregulation of the electricity industry. The project is unique in its structure and technology: In its structure it is a joint venture between the Tauhara North No 2 Trust, the indigenous land-owner and the state-owned generator, Mighty River Power and in its technology as it uses high pressure steam of above 25 bar as its resource. The project has two production wells of around 2000 metres depth producing two-phase fluid and three reinjection wells of 500 metres depth. Steam is separated from the brine at ~25 bar and both the steam and the brine are used for electricity generation. The condensate is pumped up to the brine pressure, combined with the high-pressure brine, and reinjected with no further pumping. A 14 MW backpressure turbine is utilised to drop the steam pressure to ~ 1.5 bar. This steam is condensed in two binary units of 5 MW output each. This configuration, called by ORMAT a Geothermal Combined Cycle Unit, has the advantage of the low capital cost of a simple backpressure turbine and of condensing the steam in a shell and tube heat exchanger where steam wetness is not a problem. There is a third 5 MW binary unit, utilising the hot brine flow. Analysing the 5-year performance of the plant it can be stated that the Rotokawa plant is probably the most efficient operating geothermal plant in the world. A summary of the plant performances is presented and analysed.

Keywords: *geothermal, high temperature resource, environmental impact.*

1 Introduction

The 30 MW Rotokawa geothermal project is one of a number of geothermal projects developed in New Zealand by private sector interests following the deregulation of the electricity industry. What makes the project unique are the ownership structure, which is a joint venture between the Maori (indigenous people) landowners and a power company, and the technology, which allows economic development of the high-pressure resource.

Table 1: New Zealand's Geothermal Generating Plants.

Station	Location	Geothermal Field	Net Capacity MW	Output GWh	Year Commissioned
Wairakei	Taupo	Wairakei	156	1,300	1959-63
Tasman Paper	Kawerau	Kawerau	39	190	1959
TG1	Kawerau	Kawerau	2.2	18	1989
TG2	Kawerau	Kawerau	3.8	31	1993
Ohaaki	Reporoa	Broadlands	108	320	1989
McLachlan	Taupo	Wairakei	25	120	1997
Rotokawa	Taupo	Rotokawa	27	235	1997
Mokai	Taupo	Mokai	54	450	1998
Rotokawa Ext.	Taupo	Rotokawa	6.3	52	2002
Totals			**421.3**	**2,716**	

New Zealand lies on the South-west corner of the Pacific “ring of fire”; the chain of volcanic activity which extends up through the Pacific Islands, Indonesia, the Philippines, Japan, Alaska, the West coast of the US, and down to the tip of South America. The main geothermal area is centred on the towns of Taupo and Rotorua and the geothermal activity is of volcanic origin, with some of the volcanoes still active.

2 The Rotokawa geothermal resource

The Rotokawa geothermal field is a deep high temperature field covering 25 sq km and located approximately 12 km northeast of Taupo. (See Figure 1.) The boundary of the field has been established by resistivity surveys which show that about 40% of the field area is on the north bank of the Waikato River and the remainder on the south side, but field exploration to date shows the useful resource to lie to the south of the river. A pine plantation mainly covers the northern field area while the southern area is mainly farmland with some new pine plantings.

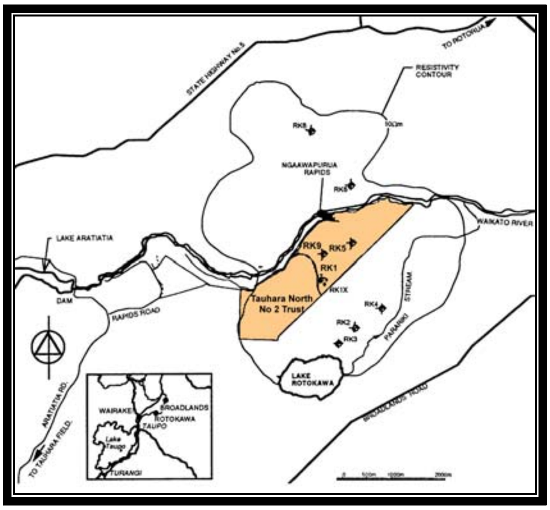

Figure 1: Rotokawa Geothermal Field.

The dominant surface manifestation is Lake Rotokawa, a hot acidic lake that contains considerable deposits of elemental sulphur. The area around the lake has been considerably modified by sulphur mining, but still contains a number of important geothermal ecosystems which have established on the hydro thermally altered ground. There are also a number of small hot springs, steaming ground, steam vents and numerous hydrothermal explosion craters.

The potential of the Rotokawa field was recognised in the early 1950’s and it was gazetted as a Geothermal Steam Area in 1953. Eight wells were drilled during the period 1966-86 as part of the Government’s programme to assess the region’s geothermal resources. Most of these have since been capped and abandoned, either because they were not commercial producers or because of casing corrosion.

3 The project structure

The project is unique in its structure and technology; in its structure, which brings the indigenous Maori people into the development as a joint venture partner with the state-owned power company Mighty River Power; and in its technology which allows effective use of the high-pressure steam from this resource.

The indigenous landowner, the Tauhara North No 2 Trust, owns the land over the middle of the geothermal field, including the land around the well RK5, the best of the Rotokawa wells drilled by the Government, and RK1. The Trust has also lodged a claim with the Waitangi Tribunal for ownership of the geothermal resource under the provisions of the Treaty of Waitangi; the founding treaty, signed in 1840, between the British Crown and the Maori people. Utilising their position as landowner, the Trust purchased the existing wells RK5 and RK1 from the Government and has made these wells available to the project. This is the first geothermal development undertaken by the Tauhara North No. 2 Trust.

The plant configuration selected was ORMAT's Geothermal Combined Cycle technology, which uses a steam turbine and binary plant to capture the best features of each technology. The turnkey contractor and supplier of the equipment for the 24 MW net output plant was the ORMAT Group of Companies. The generated electricity is sold under a long term contract to Tauranga based Trust Power, New Zealand's fourth largest electricity retailer.

4 Project design

The project has two production wells of around 2000 metres depth producing two-phase fluid, which is piped to a separator at the station. Steam is separated from the brine at 23 bar and both the steam and the brine are used for electricity generation. The condensed steam is pumped up to the brine pressure, combined with the high-pressure brine, and reinjected with no further pumping. There are three reinjection wells of around 500-metre depth, one of which is one of the original field exploratory wells. To maximise the benefits of the high steam pressure a General Electric backpressure turbine of 14 MW output is utilised to drop the steam pressure to approximately 1.5 bar. This low-pressure steam is condensed in two binary units of 5 MW output each.

5 Station parameters

	Design	Actual
Steam turbine output	14 MW	
Binary unit output	3 x 5 MW	
Net output	24 MW	27.5 MW
Annual energy output	189 GWh	235 GWh
	Design	Actual
Steam flow rate	130 t/hr	140 t/hr
NCG flow rate	3.1 t/hr	
Steam wetness ex separator	99.98%	
Steam pressure separator outlet	23.2 bara	25.5 bara
Steam temperature separator outlet	219.4ºC	226ºC
Brine flow rate	303 t/hr	
Brine inlet temperature	217.5ºC	225ºC
Brine outlet temperature	150ºC	
Design ambient air temperature	12ºC	

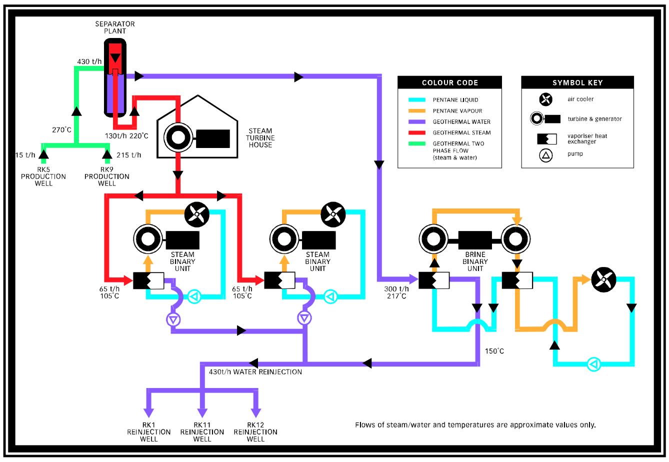

Figure 2: Process Diagram.

6 Main equipment description

The steam turbine is a backpressure multi-stage reaction-type turbine. The turbine housing, shaft assembly and nozzle ring were designed to ORMAT's specification for operation with geothermal steam.

Level I Steam turbine & generator

Steam turbine type	Multi stage, single cylinder reaction
Steam inlet pressure	22.3 bara (design) 25.5 bara (actual)
Steam outlet pressure	1.5 bara
Speed	3000 rpm
Construction	Horizontal split casing
Generator rated output	14 MW
Voltage	11kV, 3 phase, 50 Hz
Power factor	0.85 (lagging)
Efficiency	97.5%

Level II ORMAT® energy converter (OEC)

Organic vapour turbine type	Impulse
Speed	1500 rpm
Construction	Horizontal (overhung) vertical split casing
Number of stages	2
Motive fluid	Pentane
Generator rated output	5 MW
Voltage	11kV 3 phase, 50 Hz
Speed	1500 rpm
Efficiency	97%

The power plant consists of the geothermal combined cycle unit, the brine driven OEC unit plus following main systems: Power plant geothermal fluid gathering system, Auxiliary systems, Electrical systems, Main station control, Fire fighting systems, and Auxiliary buildings

The generator circuit breaker, control and auxiliary electrical equipment for each binary unit is housed in a container, which is fully wired and pretested. This reduces construction time and speeds commissioning on site. The overall station control is from a control room attached to the steam turbine building. Station control is by computer utilising software and graphics developed by ORMAT and by GE Fanuc programmable logic controllers programmed by ORMAT.

Figure 3: Rotokawa power station.

7 Environmental impact

The station is designed to have minimal environmental impact. Under normal operating conditions the geothermal fluid is completely contained from production to reinjection with the only emissions being small quantities of steam emitted by the steam traps and the non-condensable gases emitted above the air coolers. Only during start-up and shut down and in emergencies is steam emitted from the rock muffler.

The power generation technology implemented at Rotokawa complies with the resource consents and is dedicated to the needs of a sustainable, environmentally benign and reliable geothermal power plant.

8 Operation and maintenance

Mighty River Powers executed the operation of the station, its operators providing 24-hour cover on a 12-hour shift basis. Two operators are on duty during the day shift and one at night. Operators are undertaking routine and emergency minor maintenance work as well as operations duties. An Operations Manager, who is also involved in other geothermal development work, supervises the station.

9 Operating experience

The Rotokawa field has been assessed as having a development potential of between 100 and 200 MW. Following the initial 5 years of operation of the power plant, an impressive summary of results and achievements can be presented:

a. The power plant has proven to be an extremely reliable and easy to operate system. It is operated as a base load plant and is serving as a back up plant for the electricity supply for Taupo.
b. The geothermal resource is operated at a higher temperature / pressure level than the initial design points

c. The power plant is operated at an output level, which is 10% higher than the initial design point
d. The power plant is operated at a significant higher availability level than expected achieving greater than 98% availability (including scheduled outages) in the last year of operation.
e. The power plant is generating on a yearly basis approximately 25% more electricity than expected at project approval.
f. The performance of the single components is more than satisfactory, including the high-pressure steam turbine.
g. The geothermal subsystems such as the production and reinjection wells and production and reinjection lines are performing without any malfunctioning. The wear and tear of these subsystems is significantly lower than the expected values despite the extremely high temperature and pressure of the production lines and the high silica content in the reinjection flow.
h. Following the undertaking of a detailed programme for environmental and reservoir monitoring it can be noted that no changes have been recorded and that the measured values are not exceeding the acceptable limits.
i. Following 4 years of operations and extensive monitoring of the resource and environment, the joint venture decided to utilize the spare capacity of the production and reinjection sub-systems. A contract for the supply of an additional 6 MW air-cooled OEC operating on steam and brine at 25.5 bar was awarded to ORMAT in December 2001. In a record time of manufacturing and installation the plant was fully commissioned in December 2002.

10 Summary

The Rotokawa Geothermal Project is a working example of the indigenous landowners developing their resources through a partnership with a power company.

In addition to the scientific resource modelling and resource behaviour projections there were two essential comfort factors, which were taken into consideration by the project developers:

A power generation technology that avoids the drainage of the geothermal resource and assures a long term maintenance of the fluid level and characteristics of the field, and

A power plant configuration, which maximises the use of the geothermal energy, minimises the risk factors for the equity owners and generates the highest possible income.