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Rotokawa geothermal combined-cycle power plant

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ABSTRACT

During the first week of October **1998,** the **24** MW geothermal power plant at Rotokawa, New Zealand, completed its first operational year. The project was developed following the deregulation of the electricity market in New Zealand by a New Zealand electricity company and was built, supplied and erected by the Ormat Group of Companies on a turnkey basis. Operating at an average output of approximately **25.5** MW and at a yearly availability of over **96%,** the plant bas achieved an unexpectedly high annual output of over **215** GWh, at an operating cost of under 0.3 US ¢/kWh.

KEYWORDS

Geothermal power plant, combined-cycle, sustainable energy, Maoris

Introduction

During the first week of October **1998,** the **24** MW geothermal power plant at Rotokawa, New Zealand, completed its first operational year. The project was developed following the deregulation of the electricity market in New Zealand by a New Zealand electricity company and was built, supplied and erected by the Ormat Group of Companies on a turnkey basis. Operating at an average output **of** approximately **25.5** MW and at a yearly availability of over **96%,** the plant has achieved an unexpectedly high annual output of over **215** GWh, at an operating cost **of** under 0.3 US ¢/kWh.

The Rotorua-Taupo geothermal region

Most of the geothermal activity in New Zealand is of tectonic origin and the heat flows and temperatures are not sufficient for commercial power generation. The major geothermal fields of the Rotorua-Taupo **area** are identified in figure **1.** The Wairakei, Rotokawa, Kawerau and Ohaaki fields have been developed for commercial power production **as** detailed in Table **1,** and the Mokai field is currently being developed by a 60 MW plant.

The Rotokawa geothermal field is a deep high temperature field covering 25 sq. km and located approximately 12 km north-east of Taupo (figure 2).

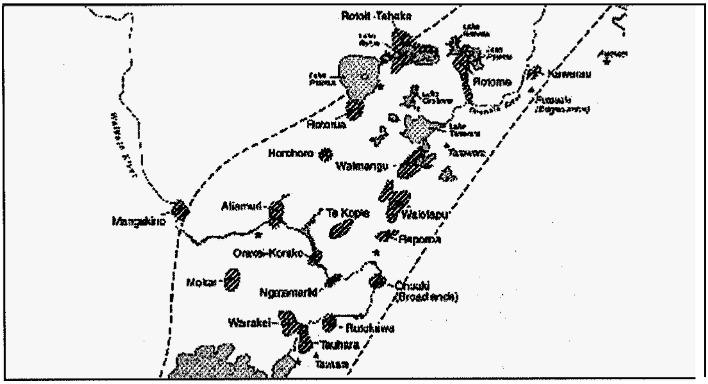

Figure 1: Rotorua-Taupo geothermal region

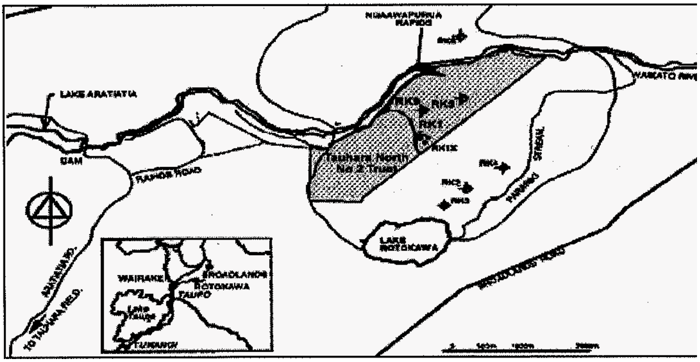

Figure 2: Rotokawa geothermalfield.

Several previous attempts to develop by different groups a geothermal project at Rotokawa by using a conventional condensing steam turbine have failed. On becoming a partner in the project Power New Zealand undertook a thorough review of the plant configuration and the technology options, and decided to select the more flexible and modular Geothermal Combined Cycle configurations proposed by Ormat using the steam and brine components of the geothermal fluid.

This plant configuration uses a back pressure steam turbine and air cooled 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 were the Ormat Group of Companies.

Project design

The project bas two production wells of around 2000 meters depth producing two **phase** fluid which is piped to a separator at the station. Steam is separated from the brine at 23 bar while both the steam and the brine are used for electricity generation. The condensed steam is pumped up to the brine pressure, mixed with the high-pressure brine, and reinjected at gravity pressure. There are three reinjection wells of around 500 meter depth, one of which is one of the original field exploratory wells.

To maximize the benefits of the available high pressure steam, a back pressure turbine of 14 MW output is utilized to drop the steam pressure to approximately 1.5 bar. This low pressure steam is condensed in two air cooled binary units of 5 MW output each. Ormat's air cooled Geothermal Combined Cycle Unit configuration, bas the advantage of the low capital cost and the simplicity of the back pressure turbine while condensing the steam takes place in **the** tube and shell beat vaporizers of the OEC units where steam wetness in the turbines last stage is not a problem.

A third 5 MW binary unit, utilizes the hot brine flow released from the separator while cooling it from 219°C to 150°C. The plant configuration is shown in figure 3.

Station parameters

	Predicted performance	Average of first operation year
Steam turbine output	14 MW	14,5 MW
Binary unit output	3x4 MW	3x4,5 MW
Net output (average)	24 MW	25,5 MW
Annual energy output	189 GWh	215 GWh

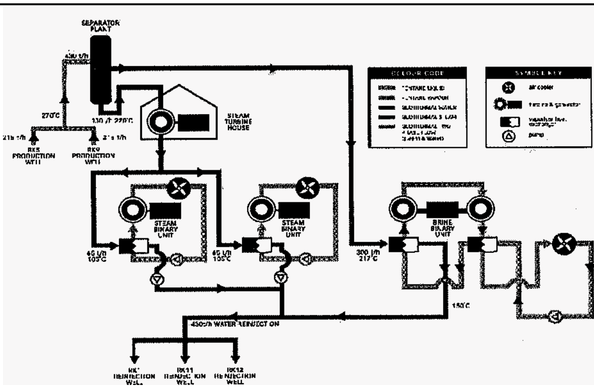

Figure 3: Process diagram

Heat and mass balance

The geothermal steam and brine partial flows have the following design point conditions:

Steam flow rate	t/hr	130
NCG flow rate	t/hr	3.1
Steam wetness ex separator	%	99.98
Steam pressure separator outlet	bara	23.2
Steam temperature separator outlet	°C	219.4
Brine flow rate	t/hr	303
Brine inlet temperature	°C	217.5
Brine outlet temperature	°C	150
Design ambient air temperature	°C	12
Steam rate	t/hr/MW	5.15

Main equipment description

The steam turbine is a back pressure multi-stage reaction-type turbine. The turbine housing, **shaft** assembly and nozzle ring were redesigned 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
Steam outlet pressure	1.5 bara
Speed	3000 rpm
Construction	Horizontal split casing
Generator rated **output**	15 MW
Voltage	11kV, **3** phase, 50 Hz
Power factor	**0.85** (lagging)
Efficiency	***91.5%***
Level II Ormat Energy Converter	
Organic vapor 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
- 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 protested. This reduces construction time and speeds commissioning on site. The overall station control is from a control room attached to the steam turbine building. The station control is by computer utilizing software and graphics developed by Ormat.

Construction programme

The modular nature of this plant has allowed a very short construction period on site. All the binary turbines were mounted on simple, low level foundations. As the steam turbine has no attached condenser it too is mounted on a low-level foundation, allowing a simple turbine building of modest size. The binary plant components were designed to be shipped in packages of standard container size and within days of the shipment arriving the main components were bolted down and the air cooled condenser erection was under way.

The overall program for the plant development was as follows:

Decision to proceed	July 1995
Contract award	December 1995
Notice to proceed	March 1996
Delivery of main equipment	April 1997
Commercial operation	November 1997

Environmental impact

The station was designed to have virtually no environmental impact. Under normal operating conditions the geothermal fluid is completely contained from production to reinjection with the only emissions being negligible quantities of steam emitted by the steam traps, and the non-condensable gases emitted above the air coolers. The plant has a small footprint, and an extreme low profile when compared with a conventional condensing steam turbine with underslung condenser. The air cooler structures are also of much lower profile than wet cooling towers, and have the advantage of never producing a visible plume. In addition to its low profile, the plant has no water or chemicals consumption and no blowdown of contaminated cooling tower water. All used fluids are re-injected into dedicated reinjection wells drilled for this purpose. 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. This development was carefully planed to avoid any adverse effect on the resource.

The potential of this field was estimated to be between 100 and 200MW so that this development started with just a 24 MW station to unable monitoring of the field before any further development will be carried out. We at Ormat believe that the greatest achievement of this project is not the speed of its development, nor even its innovative technology. The true significance of this project is that it is New Zealand's first power project to involve local Maori landowners as a full partner. And as such, it serves as a model for the development of the country's natural resources. Because the development is small relative to the ultimate capacity of the very deep resource, it is expected that there will be no impact on the surface features. A comprehensive baseline monitoring program was undertaken prior to project operation and an ongoing program is monitoring any changes against this baseline.

Operation and maintenance

During the frst year of operation of the station, the operation was contracted to Power New Zealand Contracting who supplied six operators to provide 24 hour cover on a 12-hour shift basis. Two operators were on duty during the day shift and a single operator at night. Operators were required to undertake in addition to the operations duties, minor routine and emergency maintenance work as well. The station is supervised by an operations manager.

All maintenance work was contracted in fiom selected contractors available in the area. Apart fiom the operators, some of whom are qualified trades people, there is no permanent maintenance staff. The analysis of the costs of the first operational year shows that a significantly reduced operating costs has been achieved without having any negative impact on the generated MWh. Operating at an average output of approximately 25.5 MW and at a yearly availability of over 96%, the plant has achieved an unexpectedly high annual output of over 215 GWh, at an operating cost of under 0.3 US ¢/kWh.

Summary

We believe that this project **is** a model of best practice in this geothermal field. In engineering terms, Ormat have erected a sophisticated power station, featuring the latest in geothermal technology. In fact, this is only the third power station of this configuration anywhere in the world. A similar power plant with a generation capacity of 60 MW is presently erected at Mokai, New Zealand.