The Ohaaki Geothermal Development

by
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Abstract

This paper discusses the design of Ohaaki Power Station recently commissioned on the Broadlands geothermal field in New Zealand. The author presents a brief history of the prolonged development of the resource and describes the systems and equipment installed, and the integrated nature of the steam field and power station. The environmental and cultural impacts of the project are also discussed.

Introduction

The recent commissioning of Ohaaki Geothermal Power Station at Broadlands, New Zealand, sees the first major geothermal power development in the country since the pioneering development at Wairakei. The new power station, Figure 1, which will be operated as a satellite of Wairakei 28 km away, incorporates a number of new features reflecting the development of geothermal technology since the late 1950s and the increasing concern for the environment.

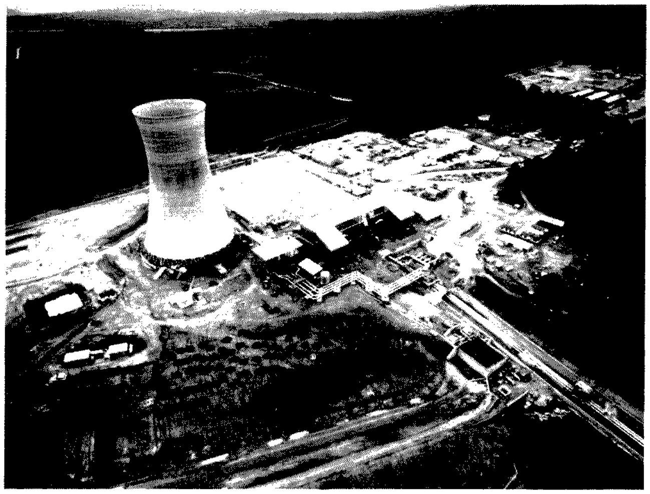

Figure 1.
Aerial view of Ohaaki Power Station

DesignPower and its sister company, PowerBuild, have been responsible for the overall design, construction and commissioning of the plant for Electricorp Production. All three organisations are either subsidiaries or business units of the Electricity Corporation of New Zealand, the national electricity utility.

This paper describes the development of the project both in terms of the history of the geothermal field and the plant ultimately installed.

History

Development of the Broadlands/Ohaaki resource, situated on both banks of the Waikato River, Figure 2, has spanned a number of decades with the first well being drilled in 1965. This prolonged development is not the most economic way to develop a geothermal resource but external forces, largely political in nature, were prevalent in New Zealand development prior to 1984.

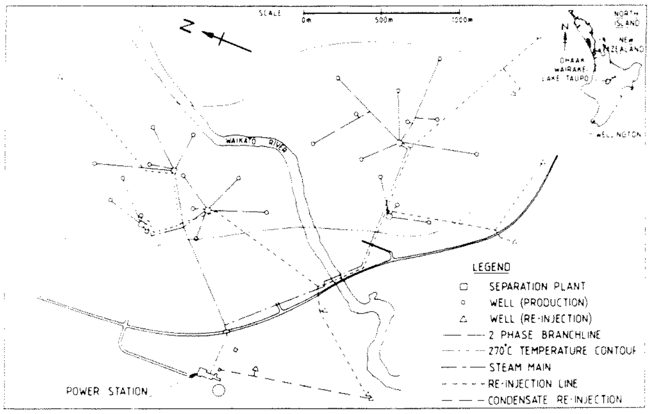

Figure 2. Field Layout

Initial investigation was reasonably rapid with 18 wells drilled by the end of 1970. Further investigations were influenced by a number of external factors such as changing electricity demand forecasts, the discovery of significant natural gas resources and the two oil shocks but provided a wealth of information. Broadlands has therefore become one of the most studied geothermal fields in the world.

Government approval to construct in 1982 was followed by further delays before the first turbine was commissioned in late 1988.

Key Reservoir Characteristics

The reservoir contains hot water, close to boiling conditions at a temperature of around 270° C at depths of 1100 m. The separated water has approximately 1500 ppm chlorides and has a silica saturation temperature of approximately 150° C.

There is also a relatively high gas content in the separated steam (5-8 percent or 15 times greater than at Wairakei) which is mainly CO_2 (98 percent) and H_2S (1 percent).

Development Constraints

A number of key constraints affected the development of the field. Environmental considerations played a major part in the development philosophy for the resource for power generation. Whilst New Zealand legislation is not advanced in the areas of environmental constraint as that of the U.S. it was recognised that for discharges into the environment requirements would become more stringent. Steam discharge is therefore restricted by allowing the steam pressures at the turbine inlet to float over a small range removing the need to vent if small quantities of surplus steam are available.

Noncondensable gas discharge is mixed with the cooling tower plume to ensure greater dispersion. Permitted ground level concentrations of H_2S of 0.05 parts per million were set with contigency plans made to allow the later installations of gas clean-up technology (e.g. Stretford process) if necessary. This target is lower than that presently experienced in local tourist areas where widespread geothermal district heating is used.

Reinjection of separated water and condensate was also required to avoid contamination of ground water. Cultural sensitivity was also a major consideration. Part of the field and the power station site itself are located on Maori owned land. In addition to the question of traditioal Maori land values and the special affinity the Maori holds for the land, there are a number of local features with special significance to the local tribe. These include the Ohaaki Pool, a major hot spring, and a rock with fertility powers. Provision was made for a lease, with the land reverting to the tribe after the power developments life. Care was also taken to involve the tribe's trustees in a number of decisions pertaining to the project including landscaping of the steamfield to reduce the impact of noise on the local marae (meeting house).

The economics of manning a base-load station located only a few kilometres from an existing geothermal power station were also unattractive and therefore Ohaaki was designed as an unmanned satellite of Wairakei. Local start-up of the plant items is required, but synchronisation, load changing and trip facilities were to be provided at Wairakei along with the basic operational information from the plant. This operating philosophy has had a significant effect on the Ohaaki plant design as automatic response is required for any operational abnormality; a situation which is achieved by tripping or reverting to a safe condition until staff is available to attend to the problem.

Overall Power Station Design

The wealth of information gathered during the protracted investigation allowed the development of an extensive resevoir model which has been used to predict the performance of the resource.

Separation pressure optimisation procedures suggested a long term power station operating pressure of 4 barg with higher pressures (13 barg) being available for up to 10 years without damage to the field. Pressure rundown at Wairakei Power Station had made the original HP backpressure turbines redundant and it was therefore decided to utilise the available pressure by moving the two 12.5 barg inlet (3.5 barg outlet) 11.2 MW sets to Ohaaki as topping sets.

The use of the ex-Wairakei sets and the forecast availability of a sustainable steam extraction rate of 700 tonnes/hr, resulted in the adoption of a two pressure system incorporating two new IP condensing sets each rated at 47 MW. Provision is made in the initial design for the larger derating to a single pressure system. Figure 3 is a simplified flow diagram for the project.

Steamfield

Twenty production wells produce fluid at nominal pressures of either 18 barg (HP) or 8 barg (IP). Each production wellhead, in addition to the master isolation valve, has a motorised two phase branchline isolation valve and a wellhead dump valve with associated atmospheric discharge silencer. The silencer is provided for commissioning and testing purposes only. Five of the largest HP wells are fitted with remote controlled throttling valves to allow well output and hence steam flow to be controlled.

Separation of two phase fluid from groups of wells is carried out in one of five two-stage separation plants (Figure 4). Horizontal offset is used for thermal expansion in two phase lines to avoid problems associated with stress corrosion and/or silica deposition in compensators.

HP ad IP inlet manifolds are provided at each separation plant to allow simpler derating (HP to IP) of individual wells at a later date. Cyclone separators with separate water vessels are used with automatic water vessel level control provided by the motorised flash valve, for the HP, and the reinjection system pumps and dump valves for the IP.

Unlike the two phase lines, steam branchlines and mains carrying steam to the power station make use of vertical loops and compensators for expansion purposes

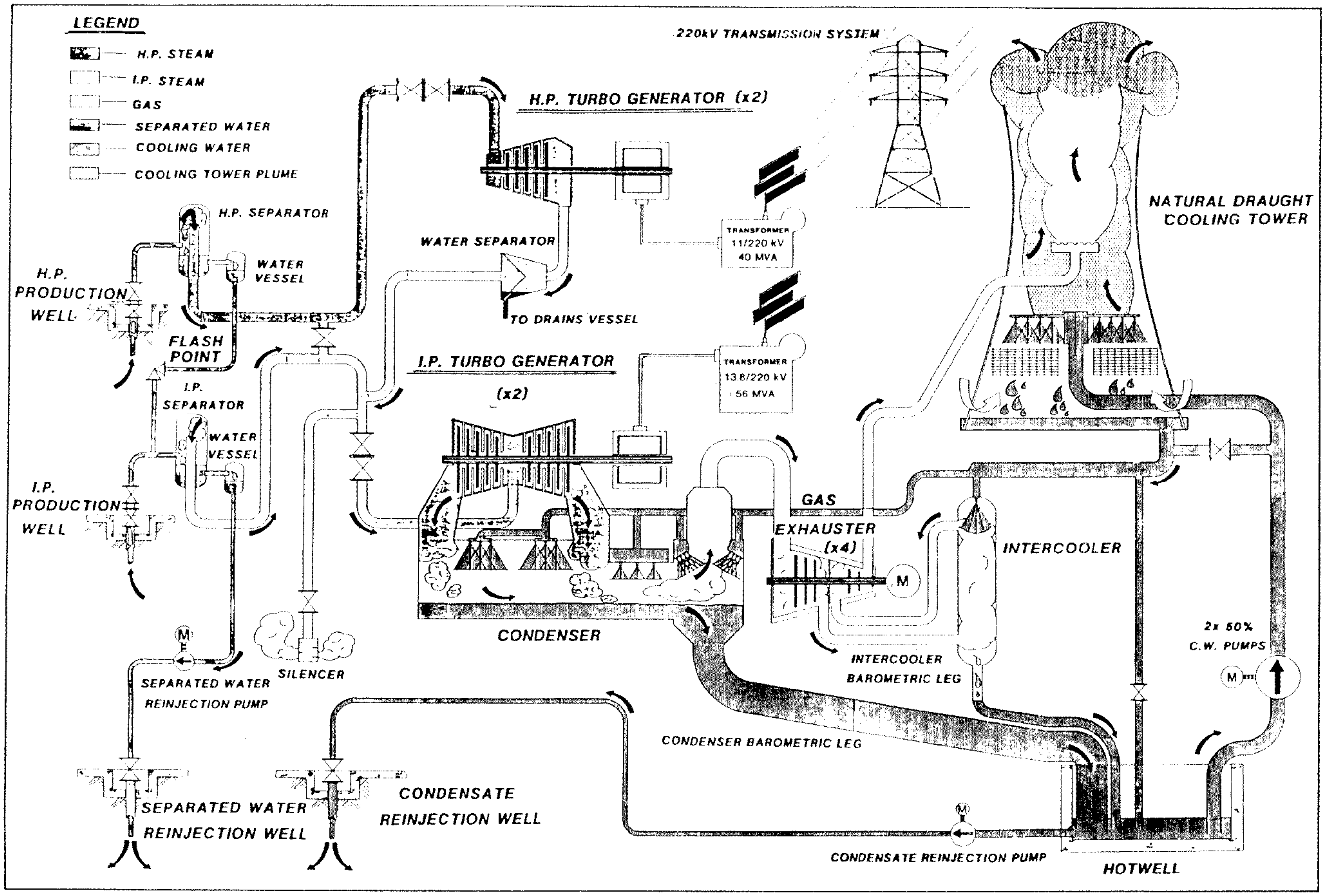

Figure 3. Simplified Flow Diagram

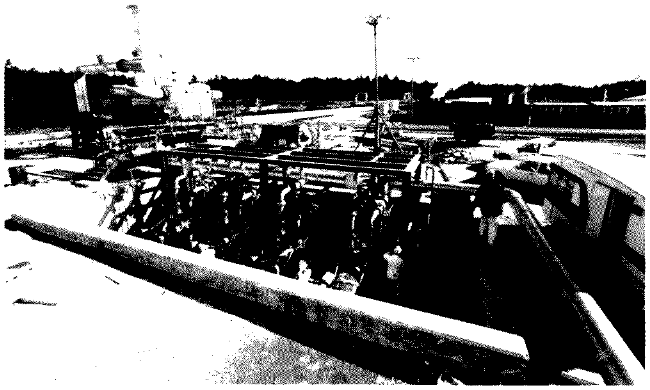

Figure 4. Separation plant showing separator, water vessels and reinjection pumps.

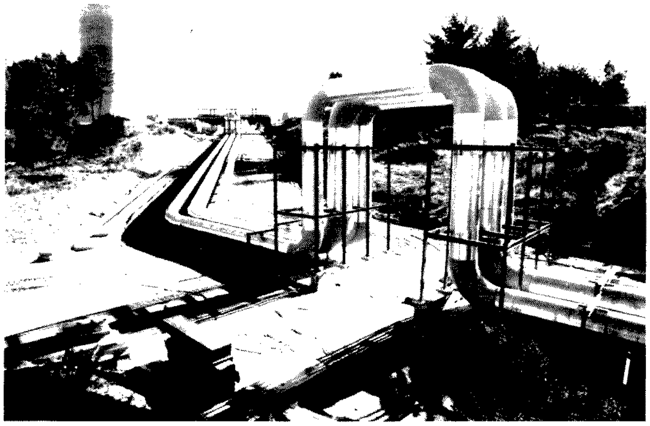

Figure 5. Steam mains showing expansion loops.

(Figure 5). One HP steam main leads to the power station from each side of the river, a pressure balancing connection only being provided. The IP mains from each side of the river join before reaching the power station. Overpressure protection is provided by safety valves installed on the steam branchlines.

Peripheral reinjection, using a pumped system, is required to meet environmental constraints. Particular care was taken to ensure that maximum flexibility was provided in the system to take account of the varying water quantities and pressures resulting from the exploitation of the field. The final design is a system using standardised, single stage pumps, with suction inducer, driven by variable speed a.c. inverter drives discharging into a common system linking all separation plants and the eight reinjection wells. Three duty and one standby are installed at each separation plant. Each set of variable speed pumps is cascade controlled in unison by the water level in the IP water vessel and the water flow leaving the separation plant. Low suction head availability requires that a set of reinjection pumps are installed in a pit adjacent to the IP water vessel at each separation plant (Figure 4).

Shaft sealing is another critical area when pumping silica-ladened water. Mechanical seals were the only proven choice. Double seals, with separated water injection from the pump discharge into the stuffing box with clean river water as a barrier fluid between the seals, were eventually selected as this system reduces stagnation and hence silica deposition in the stuffing box area.

Reinjection wellhead pressures are typically 25 barg although fixed speed booster pumps are installed on the pipeline leading to selected wells to take advantage of improved reinjection capacity at 35 barg.

Automatic controlled dumping will occur if there is a reinjection system failure. Two hydraulically operated globe valves are fitted to each HP and IP water vessel, one to control and the other to act in the event of an emergency trip.

Power Station

Adjacent to the power station, automatic pressure control valves are available to bypass HP steam to the IP system in the event of the HP turbines nonavailability due to maintenance requirements or a trip (Figure 6).

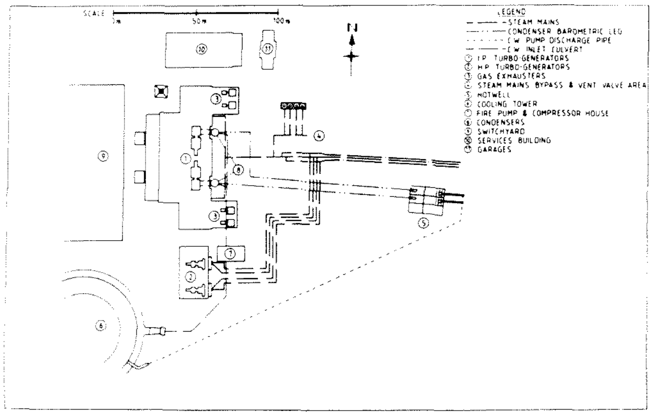

Figure 6. Power Station Layout

IP vent valves are also installed in this area. These hydraulically operated valves are designed either to control the IP steam pressure (3.5 barg) by venting directly to atmosphere or to act as the power station IP safety valves. Power station HP safety valves are not installed, reliance being placed on the steam field safety valves.

The 30 year old HP turbo-generators have been refurbished and incorporate minor modifications to facilitate unmanned operation. The IP turbo-generators are new single casing, double flow condensing sets.

Large barometric leg type direct contact condensers, manufactured from carbon steel clad with 316 stainless steel for wetted parts are used for the IP sets. The condenser consists of four sections, co-current, cross current, counter current and gas cooler. Water flow to the gas cooler is controlled independently from flows to the other sections in order to allow control of water chemistry. This aspect of the design stems from pilot plant studies at Ohaaki and will initially be manual with provision being made for later automatic control.

Two 50 percent, intercooled, motor driven industrial type rotary gas exhausters are installed per turbine to draw the noncondensible gas from the gas cooler and discharge it via ducts in the natural draft cooling tower. An anti-surge system is fitted to each exhauster. A startup steam ejector is fitted for initial volume raising.

The circulating water (CW) system incorporates a natural draft cooling tower 105 m high and 70 m diameter. CW is aspirated into the condensers and intercoolers from the tower via a buried fibre reinforced plastic culvert running under the power station buildings. The barometric legs discharge to a hot well from which two 50 percent CW pumps return the water to the tower. The pumps are not unitised and it is possible to maintain partial load on both turbo-generators in the event of a single pump trip. Surplus condensate is directed back to the geothermal reservoir via a condensate reinjection system.

The River Water System, with an intake structure on the banks of the Waikato River, provides the power station with initial fill water for the main CW system and make-up if required plus some cooling water for refurbished plants.

The Auxiliary Cooling Water (ACW) system, connected to the main CW system, is used for IP turbine auxiliary cooling and makes use of geothermal condensate, complete with dosing chemicals. Return of the cooler discharge to the tower pond allows the system to continue to operate automatically and independently from the main CW system after turbine shutdown and CW system trip.

Control

A VDU/keyboard approach for local controls was not considered appropriate as the station was to be unmanned. Conventional panels with indicators, controllers and alarms are included for operation of the various items of the plant. Pumps and isolating valves are generally controlled via relay logic with more complex control carried out by programmable logic controllers. The analogue controllers are microprocessor based, with control configuration and variation of tuning parameters being carried out through a personal computer. A major supervisory, control and data acquisition system (SCADA) has been installed at Wairakei for remote logging of data. This SCADA system has the potential for expansion to control future geothermal power stations in the Wairakei area.

Communications between Ohaaki and Wairakei is via a high reliability digital microwave link.

A control annexe is located alongside the IP turbine house. This annexe houses the control panels and switchgear associated with the IP turbo-generators and associated power station systems (CW & ACW systems, Switchyard, etc). The environment within the control annexe is controlled to limit the risk of atmospheric H_2S corrosion of the electrical and control equipment contained within it. This is achieved by maintaining the building pressure at above atmospheric pressure and filtering both makeup and recirculated air with activated carbon filters.

Relocatable package substations are installed at each separation plant and the river water intake. These substations provide an atmospherically controlled environment for the switchgear and controls for the separation plant (or river water intake) and the associated steamfield (wellheads, steam mains, reinjection system, etc). The variable speed drives associated with the reinjection pumps, although physically installed within the substation make use of air drawn from outside the substation for cooling. This has arisen due to the prohibitive costs associated with removing large quantities of heat from within the substation. ☐

Acknowledgement

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Author's Note

Ohaaki Power Station is the keynote subject in the Eleventh New Zealand Geothermal Workshop, University of Auckland in November 1989. Interested parties are directed to the proceedings of that forum for further papers on the subject.