A BRIEF HISTORY OF THE WAIRAKEI GEOTHERMAL POWER PROJECT

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INTRODUCTION

November 15, 1998 marks the 40th anniversary of the commissioning of the first generator at Wairakei geothermal power station, in New Zealand. At that time it was only the second geothermal plant in the world to begin commercial operation and the first to exploit a wet geothermal resource. This paper briefly traces the development and operational history of this pioneering development and in particular the efforts made to keep the plant supplied with steam.

THE LARDARELLO INFLUENCE ON THE DEVELOPMENT

The impetus for the development of Wairakei came in 1947 from severe electricity shortages following two dry years which restricted hydro generation and a desire by the Government for the New Zealand electricity supply to be independent of imported fuel.

During World War II government scientists arranged for New Zealand army engineers serving with the British 8th Army, in the Italian campaign, to visit, inspect and report on the Lardarello geothermal power development in Tuscany. Unfortunately when the army engineers got to the plant in June 1944 it had been totally destroyed.

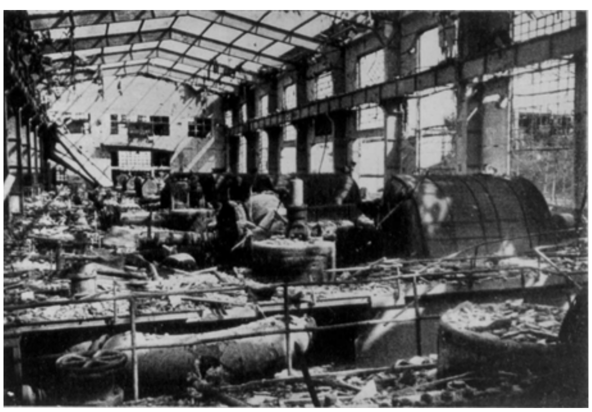

Figure 1. Destroyed Lardarello No 2 Station Turbine Hall.

In 1948 visits were again made by New Zealand engineers to Lardarello. This time they found rebuilt power plants producing over 140MW and the Lardarello No III station (142MW) in an advanced stage of construction.

While observations at Lardarello were important in providing the New Zealand engineers with an understanding of the overall approach to harnessing geothermal power, the dry steam resource was so different from the wet geothermal resource at Wairakei that its development would have to depend on exploiting technology designed in New Zealand.

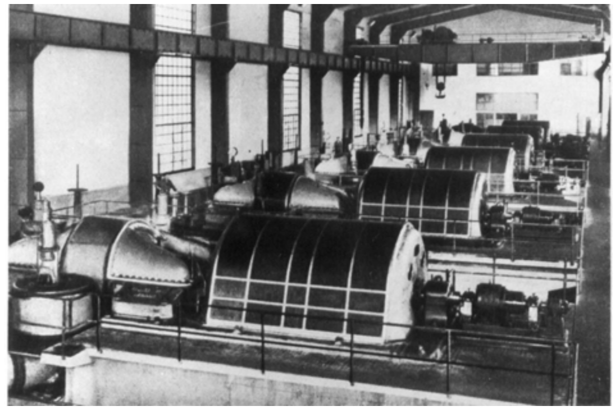

Figure 2. Rebuilt Lardarello No2 Station Turbine Hall.

Perhaps Lardarello`s most important contribution to the Wairakei development was its success and the enthusiasm the Italian engineers displayed for this type of power plant, because there is no doubt that these factors strongly influenced the New Zealand decision to proceed with a geothermal power development at Wairakei.

INVESTIGATION AND PROJECT DEVELOPMENT (1949 to 1958)

In 1949, a project development team was established and drilling together with scientific investigations proceeded rapidly so that by late 1952 steam capable of producing 20MW of electric power had been proven by shallow drilling (300m). Prospect of greater output from deeper drilling was also confidently predicted and larger drilling rigs were ordered. Important metallurgical research, into the corrosion effects of the Wairakei geothermal brine, were also completed about this time and these showed that mild steel could be used for the geothermal above ground systems without suffering any major corrosion effects. . Mishaps during this early development period were few, but when they did occur, it helped if one had a good turn of speed.

The initial project at Wairakei was conceived as a combined power station and a heavy water plant. This was to be a joint venture between the New Zealand Government and the United Kingdom Atomic Energy Authority (UKAEA). Conceptual designs were progressed and in late 1954 funding was approved to build a plant capable of producing 47MW of electric power and 6 tonnes per year of heavy water. However, principally because of major cost increases in the cost of the heavy water plant the UKAEA pulled out of the project in January 1956. As contracts for the turbine generators had been let in mid-1955 and their fabrication well advanced, it was

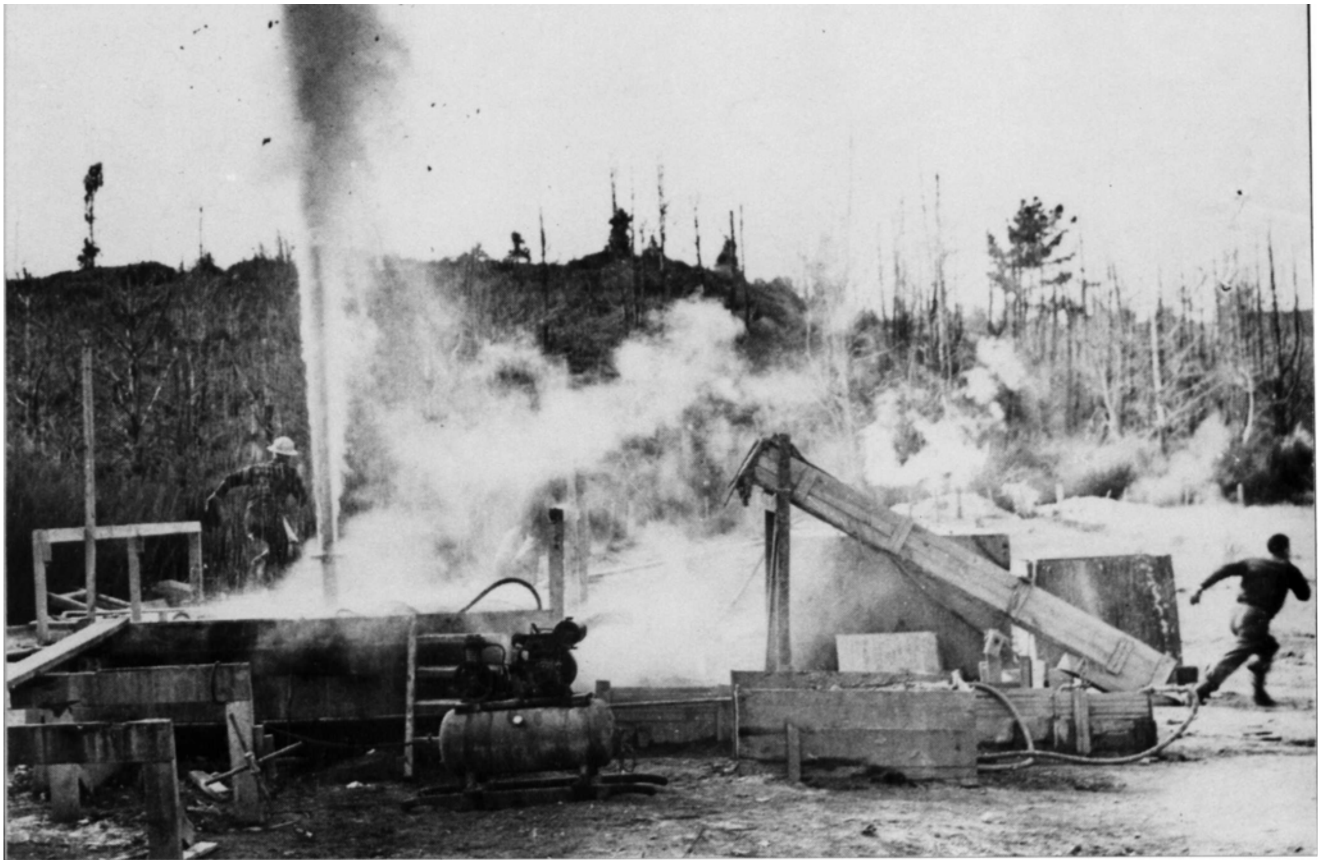

Figure 3. Techniques and safety standards have improved significantly since the early 1950`s but still present is the pioneering element exemplified by this early Wairakei photograph.

decided to proceed with the existing power plant design and to incorporate two intermediate pressure (IP) 11MW turbines generators in place of the heavy water plant. The Wairakei "A" station project initially was to consisted of two high pressure(HP)6.5 MW units; two intermediate pressure (IP) 11.2 MW units; and three low pressure (LP) condensing 11.2MW units giving an installed capacity of 69MW. The inlet pressure on the LP units was just above atmospheric pressure.

Meanwhile on the steamfield the larger drilling rigs had been very successful in winning more high pressure fluid at the greater depth. A two pressure system was evolved to tap the field; high pressure (HP) which produced flashed steam at the well head of around 13.5 barg (196 psig) and intermediate pressure IP producing flashed steam at 4.5 barg (65 psig). As a result of the greater output two HP 11 MW units and an additional LP 11 MW condensing unit were added to complete the Wairakei "A" Station (Stage I) development. This enhanced Stage I design also incorporated a pilot hot water flash plant which was sited adjacent to the power plant building and was fed with separated water from five HP wells and two IP wells. The very successful tangential entry bottom outlet steam separator was developed. (Wairakei Separator).

Construction of Stage I was not that far advanced when proposals for additional generating capacity were approved because even more steam than expected had been found. This resulted in the development of the Wairakei "B" Station which consisted of three mixed pressure (MP) condensing 30 MW generating units. The steam supply to the MP units consisted of 3.5 barg (50 psig) at inlet with pass in steam at slightly above atmospheric pressure (2 psig) to the machines LP cylinder. This brought the total installed capacity of the Wairakei development to 192.6MW.

A further extension of the "B" Station was allowed for in the design which would have consisted of two more 30 MW mixed pressure units.

The Power Station is located adjacent to the Waikato River from which it draws once through water for the direct contact condensers. The centre of steam production is approximately 3.5 km (2.2 miles) from the power station and steam is transmitted to the station via three 760mm (30 inch) and five 508mm (20 inch) diameter pipelines.

On 15 November 1958 the first set in the "A" Station was synchronized to the national grid. The remaining machines and plant of the "A" and "B" developments proceeded at regular intervals, the last machine being synchronized to the grid in October 1963.

SETTING THE PLANT TO WORK AND DEVELOPMENT SHORTFALLS (1958 to 1968)

The setting to work of the power plant caused unexpected draw down and a rapid pressure decline of steamfield output. Secondly, the pilot hot water scheme had to be abandoned, for whilst it had operated successfully for a short period, the wells which were connected to it change to become dry steam producers and the plant became starved of separated water. At this time no consideration was given to connecting additional wells to it as it was thought that they in turn would change with time to become dry steam producers.

With the commissioning of the “B” Station 30MW units it became necessary to drill more production wells to make up for the rapid drop in well output. Production drilling continued through the early and mid 1960`s and the peak power of 173 MW was achieved in 1965, some 19 MW short of the installed capacity. However, this drilling was ended shortly afterwards when it was realized that the effort was yielding ever diminishing returns.

From 1958 to 1968 the “at depth” reservoir pressure of the Wairakei field dropped from 58.6 bar g (850 psig) to 40 bar g (580 psig). [The reservoir “at depth” pressure being obtained from a selection of wells measured at a depth of 275 m (900ft) below sea level.]

The field management strategy adopted in the late 1960`s was to:

- hold mass output from the field at the current production level of around 50 million tonnes per year;

- to sacrifice HP machine output by progressively reducing HP well head pressure in order to maintain fluid flow and thus ensure that the IP, MP, and LP machines were fully supplied with steam at design pressure;

- to implement measures which would make more efficient use of the total energy discharged from the field and improving the reliability of the generating plant.

PERIOD OF CONSOLIDATION (1969 to 1982)

The use of flashed steam from separated HP borewater was not abandoned with the demise of the pilot hot water scheme. The process was instead moved to the steamfield where double flash units were installed adjacent to HP wells. These units were initially designed to be portable so that they could be moved in the event of the wells changing to become dry producers as had happened with the pilot hot water scheme. The well head double flash process was very successful and in 1974 the scheme was extended to triple flashing so as to extract intermediate low pressure, 1.7bar g (25 psig) (ILP) steam by flashing separated IP borewater at steamfield located central flash plants. A major part of this project was the construction of an ILP steam pipe, of 1.22 m (48 inch) diameter to carry the 1.7 bar g steam to the power station. There the ILP steam was passed through pressure reducing valves to reduce the pressure to 0.05 bar g (2 psig) to make suitable for passing into the A Station LP machines and as pass in steam to the B Station MP Machines.

Over the next few years a policy of connecting previously unused wells and piping additional water to the flash plants to maximize the use of the flash plants and the new ILP steam transmission line was pursued. When Wairakei was commissioned only 4.5 percent of the total energy above 0 deg C was converted to electrical energy, with the optimizing of the triple flash system in the late 1970`s this conversion factor had been increased to over 8.5 percent.

By 1981 the HP had been progressively reduced to about 7 bar g (100 psig) and the shortfall in IP and LP machine generation had fallen below what was being generated by the HP machines. Studies showed that a net gain in generation would be achieved by completely decommissioning the HP system and derating all HP wells to IP conditions.

Derating the HP system was carried out in November 1982 and this involved both wellhead and major flash plant modifications plus the installation of flow balancing crossovers on the steam transmission lines. This exercise resulted in the installed capacity of the plant being reduced to 157.2 MW (Gross)

The main reactions of the Wairakei reservoir to exploitation up to this point in time had been:

- after an initial very rapid fall, the “at depth” pressure of the field had now become relatively stable, which indicates that the mass withdrawal from the field was being balanced by a similar amount of natural recharge;

- despite the near stabilization of the “at depth” pressure and mass withdrawal the apparent enthalpy of the fluid continued to decrease slowly, reflected by annual decline in fluid temperature of around 0.5 deg. C per year; indication the system was being slowly mined of its heat by the production process.

- the water level in the reservoir had been drawn down approximately 200m (650 ft)

After decommissioning the HP system it became field management policy to once again tap the field in order to sustain full load on the remaining installed plant.

FIELD MANAGEMENT AND STEAM WINNING (1982 to 1997)

In 1983 three additional existing wells, drilled in the mid 1960`s for a proposed new power development on the north western sector of the field known as the Te Mihi area, were connected into the Wairakei steam transmission system This required extending the steam collection system by a further 3 km (approx. 2 miles) further from the power station. The output from these three wells were expected to keep the Wairakei plant fully loaded until 1987/88. This however did not materialize due to the resultant increase in pressure drop within the extended steam transmission system pushing up production wellhead pressures. This caused the output of all production wells to decline marginally. As a result the net increase in steam supply to the station was only 50% of what had been expected.

In consequence by 1884, Wairakei was once again facing a steam shortage.

Faced with further steam winning, attention turned to the utilization of a dry steam reservoir trapped at shallow depth beneath an impermeable cap in the Te Mihi area of the field. The presence of a shallow vapor dominated reservoir in this area was initially inferred from precise gravity changes and from the direct measurement of steam pressures in the existing Te Mihi wells. This steam resource having formed as a result of the exploitation of the liquid resource and the resultant draw down in the fluid level by approximately 200m. The reduction in reservoir pressure causing boiling of the fluid.

This steam zone was found to have pressures of around 25 bar g (360 psig). Beneath the steam cap fluid at up to 260 deg. C temperature was found. This liquid being some 30 to 40 deg. C hotter than liquid found in the main production area of the field. Given the good production potential the first new production well to be drilled at Wairakei since 1967 was drilled into this steam cap in 1985. At a depth of only 390 m (1270 ft) excellent dry steam production was encountered.

Following the success of this dry steam well efforts over the next three years were devoted to defining the extent and production potential of the Te Mihi vapor reservoir. The most important parameter was to determine its size and to determine this a number of exploratory wells were drilled to probe the perimeter of the resource. From the data obtained it was estimated that the resource could sustain a production of around 500 tonnes per hour for many years. Based on these estimates a development plan was prepared.

This development plan entailed drilling a further three 330 mm diameter (13") wells and the construction of a 1 m diameter (40") steam transmission line approximately 2.5 km long (1.5 miles) to connect the new production area with the existing Wairakei steam transmission system. This project was completed in September 1988. Two of the wells encountered excellent production from the shallow dry steam resource; however, the third failed to find permeable conditions at the dry steam horizon and this was successfully deepened into the liquid zone. These new wells provided a steam surplus and were able to keep the plant fully loaded until 1994.

However, the dry steam production was not without problems. The gas content of this steam was significantly higher than flashed steam. The net result of this increase was to increase the content of the steam delivered to the power plant from 0.4 % to just under 1%. The steam driven gas ejectors on the four A Station LP machines were inadequate to handle this increase and the condenser vacuum deteriorated, resulting in a decline in output of around 10 to 12%. The B Station plant ejectors whilst able to maintain design vacuum conditions, it was achieved at the expense of an increase in ejector steam supply from 27 to 88 tonnes/hour. These problems were overcome by redesigning the ejectors and improving the cooling efficiency of the ejector inter cooler.

The second problem encountered with the dry steam wells was that they spasmodically discharged significant quantities of sub micron sized particles of quartz. This quartz generally appears when the wells are being returned to service following a shutdown. Whilst contained within the steam phase the quartz very effectively removed silica scale deposits from within the turbine steam path and the magnetite coatings from the steam lines causing blockage of the turbine casing drains. However serious damage resulted when the quartz mixes with steam condensate. This mixture cuts out and destroys condensate drain valves in a matter of days. As the quartz is so fine it is not possible to remove from the system by normal debris collection methods. This problem is being partly overcome by carrying out a sustained vertical discharge of the well before it is returned to service.

The last major steam winning project to be carried out at Wairakei entailed tackling the steamline pressure drop problem which was overcome by constructing a new 1 m diameter (40") pipeline from the power station to the steamfield. This effectively reduced the wellhead pressure on all the production wells causing the output of each to be marginally increased. This project was completed in 1995.

Ways of making more efficient use of the energy withdrawn from the Wairakei field has always had a high priority and this was further enhanced in 1996 when the pressure reducing valves which reduce the ILP steam to LP conditions were replaced by a steam turbine which produces approximately 4 MW of additional output.

This year further wells were drilled to tap the Te Mihi dry steam resource and these have been successful in keeping the plant once again fully loaded

Perhaps the biggest challenge facing Wairakei in the near future will be the renewal of its resource consents before 2001. Up until now Wairakei has operated under "existing use" consents which were issued in 1968. With the passing of the Resource Management Act in 1991 all "existing use" resource consent holders had until a certain date to seek renewal of their consents in accordance with the requirements of the new legislation

SUMMARY

Wairakei has been one of the most reliable generating facilities within the New Zealand electricity supply system. Since decommissioning the HP plant in 1982 the station has operated consistently with an annual load factor of over 90%. Maintaining this output has been achieved by on-going steam winning initiatives and it is likely that with careful management of the resource Wairakei will continue to operate well into the new millennium.