FORTY YEARS OF SUCCESSFUL GENERATION AT WAIRAKEI: A SUCCESSFUL MATCH AND MARRIAGE

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SUMMARY - 40 years of generation at Wairakei. Power generation commenced on 15 November 1958 when Assistant Superintendent C D Elvines loaded the 6.5 MW high pressure turbine generator, G2, to 1.7 MW. Forty years of a successful match and a very successful marriage between the Wairakei geothermal field and the Wairakei geothermal power station have ensued.

In, 'Wairakei – The First Twenty Years', Ian Thain wrote "Wairakei, it is hoped, will be like grandfather's axe – four new shafts, two new heads, but still the same axe". There have been new shafts and new heads but Wairakei is Wairakei, is Wairakei, is Wairakei, is Wairakei ..... There is no hoping after forty years, it is reality. This is a remarkable achievement from a plant that is now a consistent and reliable electricity generation facility. But it wasn't always like this.

1.0 THE ENGAGEMENT

The beginning of this remarkable marriage started with an engagement where the matching process was anything but certain.

There were many questions that rapidly emerged and were difficult to answer:
What is the size of this resource?
How do we drill these wells and how big are the holes to be?
What size power station is to be installed ?

The plant was to be 20 MW. Then it was to be a combined power plant and heavy water production facility with a generating capacity of 46.6 MW and a 6 tonne per year heavy water production capacity (Figure 1). The UKAEA pulled out of the heavy water distillation facility and extra power turbines were installed to take the capacity to 69 MW.
How deep are the holes to be drilled ?

The pilot hot water scheme using water produced from a group of wells in the eastern borefield was proposed. Another 11.2 MW low pressure turbine was installed as Stage 1A to utilise steam produced from this scheme (Figure 2). This was to take the installed capacity to 80.2 MWe.

The design and procurement for 'A' station were progressing. In parallel, the steam winning was continuing so satisfactorily that extensions to the power station were proposed in 1956. Two more 11.2 MW high pressure (HP) turbines were to be installed in the 'A' station and a new 'B' station was to be constructed with three 30 MW mixed pressure (MP) sets (Figure 3). This was to take the installed capacity to 192.6 MWe.

2.0 BUILDING THE SUCCESSFUL MARRIAGE

Just like any successful marriage, there were issues that needed to be worked through. Working through these issues has put Wairakei on a sound footing.

In the early years the plant was temperamental, in modern idiom it was a "dog". The plant was vulnerable to minor fluctuations in the steamfield pressures causing machine instability. The rotary gas exhausters were unstable and unreliable. In fact such was Wairakei's reputation that the Minister of Electricity was to be personally informed of machine trips as soon as they occurred, as long as the house was sitting of course.

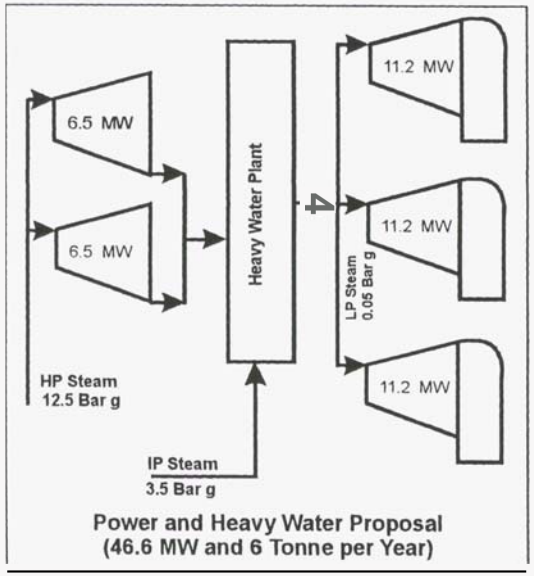

Figure 1. Power and Heavy Water Plant

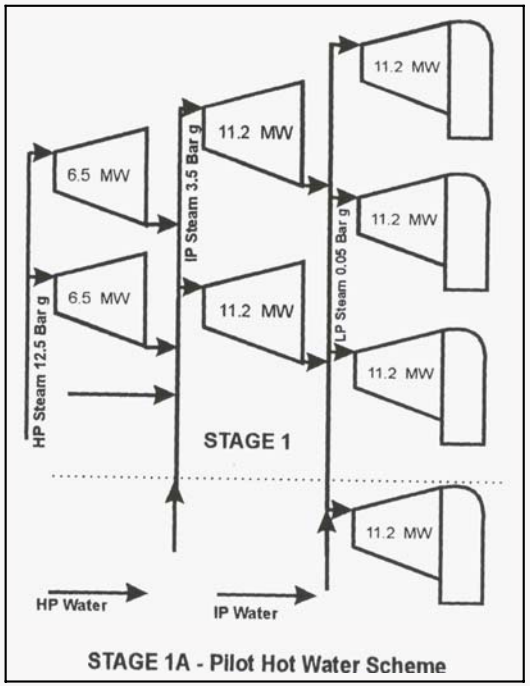

Figure 2. Stage 1 and 1A

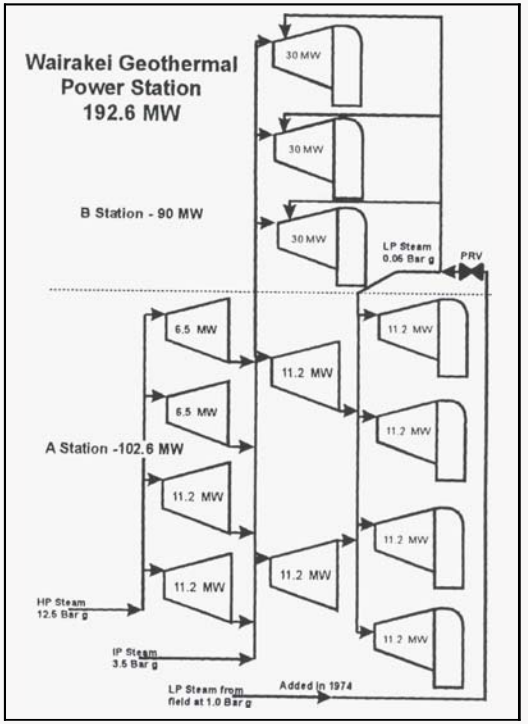

Figure 3. A and B Stations

As more wells were connected into the steamfield system so the stability improved. The gas exhauster problems were solved by scrapping this equipment and installing steam jet ejectors on the 'A' station LP condensing turbines. The last of the rotary gas exhausters was replaced in 1970. The 30 MW 'B' station sets came supplied with steam jet ejectors.

Corrosion was a problem in some areas. Electrical equipment was vulnerable but so was the pipework leading to the gas stacks which corroded rapidly until resistant materials were sourced.

The focus of the work was to improve the reliability of the power plant and to improve its consistency in energy production. High load factors and low forced outage rates were also objectives. These objectives started to be achieved from the mid 1960's. From then on Wairakei has gone from strength to strength in achieving an enviable record of power plant performance.

3.0 ENRICHING A SUCCESSFUL MARRIAGE

Wairakei was a cornerstone of electricity production in the North Island in its earlier years. This was in the days before 1965 when the North and South Islands grids were joined with the commissioning of the Cook Strait cables. Over the Christmas period of the early 1960s Wairakei supplied 50% of the total electrical load of the North Island. The contribution to the electrical energy supply in the North Island and New Zealand on an annual basis is shown in figure 4. In 1966 Wairakei supplied about 19% of the North Island's total electrical energy consumption.

Initially the Wairakei development was a two pressure steam system with steam supplied at HP and IP pressures (Turbine Inlet pressures of 12.5 (HP) and 3.5 bar g (IP).). 500mm (20") diameter HP and IP pipelines carried steam from the steamfield to the power station. Three larger 750mm (30") diameter steam lines were installed as part of the 'B' station development. The reservoir fluid was separated at individual wellhead separators, with the steam transmitted to the power station and the water discharged to the drainage system.

Optimisation and more efficient utilisation of the geothermal energy and water have contributed to the success of the Wairakei development.

It was recognised that additional steam could be produced from the discharged water. The pilot hot water scheme was one of the early efficiency projects. The scheme was designed to collect water from seven eastern borefield wells, transmit it to the power station and produce additional IP and LP steam. The scheme was installed but as the enthalpy of the eastern borefield wells rose once production commenced, the amount of water available for processing decreased significantly and the scheme never functioned properly. In April 1964 after about a year of operation the system was decommissioned.

Further schemes were developed to utilise the separated geothermal water. A steamfield optimisation *study* was undertaken by J P F Robinson in 1970. The design and construction that followed was undertaken by the Ministry of Works and included 'G' line, a 1.2m (48") diameter low pressure steam pipeline. Flash plants were installed as part of the steamfield optimisation to flash additional steam fi-om the geothermal water. 'G' line was installed to bring this low pressure steam from the field down to the power station. It operated at a pressure of about 1 bar gauge at the power station where the steam was passed through pressure reducing valves before being admitted to the low pressure steam system in the power station. This equipment was commissioned in 1974. A *three* pressure steam system was in operation in the Wairakei steamfield at this time with steam being supplied to the power station at HP, IP and LP conditions from the steam field.

From the time that the power plant was fully commissioned in 1963 up until the early 1980's several wells in the western borefield were connected up into the steamfield pipe network. These were wells which had been drilled as part of the initial drilling but they had not been connected up to the steamfield pipe network.

The high pressure turbine inlet pressure was progressively reduced between 1963 and 1982 to enable more energy to be extracted from the available wells to partly compensate for the decline in reservoir pressure. On the 30 November 1982 the HP steam system was

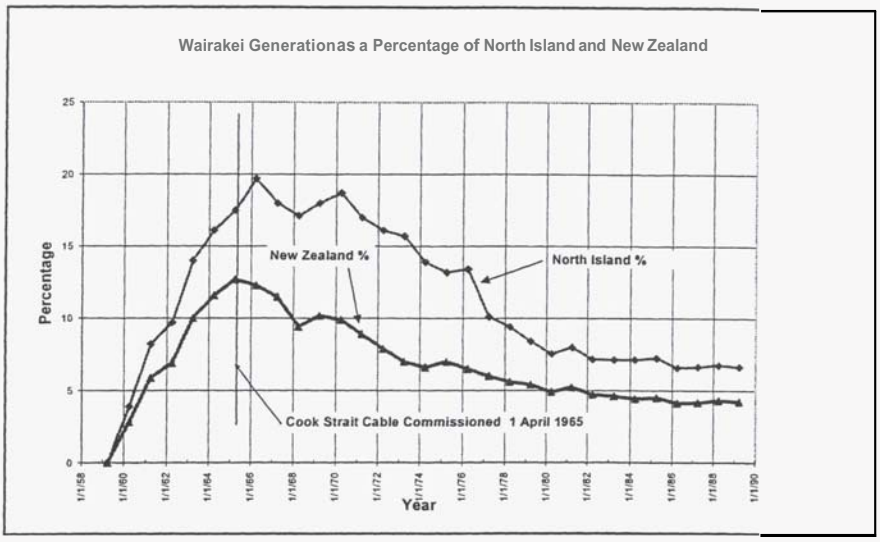

Figure 4. Wairaki Generation Statistics

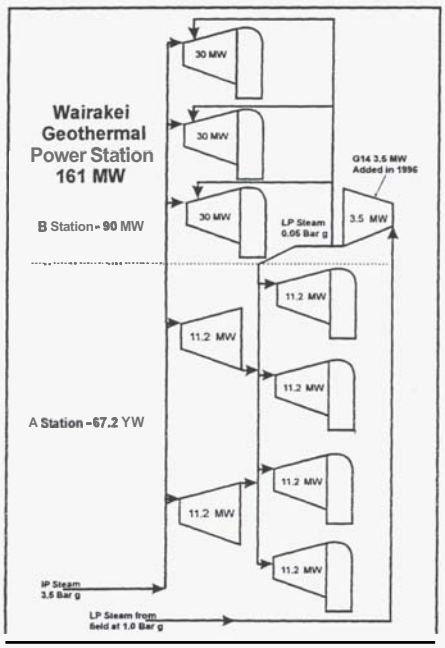

Figure 5. Power Plant 1996-1998

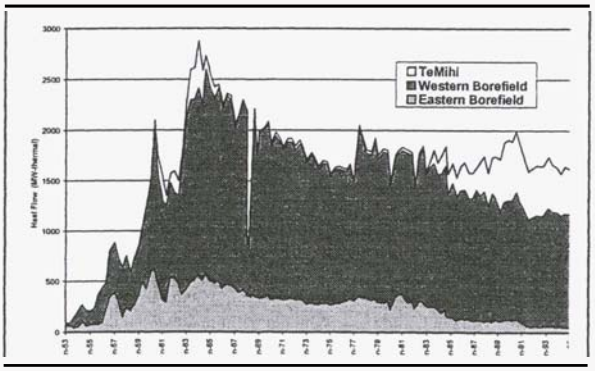

Figure 6. Field Energy Production with Time

decommissioned (Morris p78). The HP pipeline system was converted to IP and the 4 HP turbines (G2, G3, G5, G6) decommissioned. The installed capacity of the plant became 157.2 MW. The steamfield was now a two pressure system supplying IP and LP steam to the power station.

Utilising wells drilled as part of the 200 series investigation programme commenced in the early 1980's. The commissioning of pipeline extensions into the Te Mihi area occurred on 15 June 1983. These extensions included flash plants 9 and 10 to enable wells 206, 207 and 215 to be utilised. These three wells had been drilled in 1960 and 1961 as part of the 200 series investigation program but had not been connected into the power station pipe network.

Production drilling at Wairakei recommenced in 1985 some 30 years after the 200 series investigation well drilling programme had concluded. A shallow steam well WK 228 was drilled in October 1985 to utilise the high pressure Te Mihi steam zone. Additional drilling to delineate the north western extent of the Te Mihi high pressure steam zone was undertaken in early 1987. Three wells WK 230,231 and 232 were drilled.

Additional steam production wells were drilled between August and December 1987. WK 233 and 234 intercepted the steam zone. Limited permeability was encountered in WK 235 over the steam zone interval and this well was drilled deeper to 1400m as a liquid producing well. Connecting these wells into the steamfield network involved the installation of 1m diameter steam main from WK234, near trig A, down to the anchor 10 pipeline junction in the western borefield. This steam main was commissioned on 30 August 1988 with steam supplied fiom WK233. WK234 was commissioned on 8 September 1988. WK 235 was commissioned during August 1989 with geothermal fluid being supplied to flash plant 9.

An additional intermediate pressure steam pipeline running parallel to the existing steam mains was installed fiom anchor 10 in the western borefield down to the power station. This 1.2m (48") diameter pipeline was commissioned on 12 December 1992.

Further efficiency gains have been achieved by replacing the pressure reducing valves in the low pressure steam system that were installed as part of the 1970's steamfield optimisation work with a turbine generator (Figure 5). A refurbished turbine and induction generator (G14) capable of producing about 3.5 MW were connected to the national grid on the 5 May 1996. The installed capacity of the plant increased to 161 MW.

Additional steam and liquid wells in the Te Mihi area have been drilled and connected into the power station steam supply system since the end of 1995. The changing location of fluid production through the years is shown in figure 6. This figure shows the decline of the eastern borefield area, changes in the western borefield and the increasing production of energy from the Te Mihi area since the mid 1980's.

The recent work during 1998 has fully loaded the power plant enabling it to produce up to 164 MW for the grid.

4.0 POURING COLD WATER ONTO THE MARRIAGE

This is technically known by geothermal specialists as injection or reinjection.

Scientific investigation and testing of injection of separated geothermal water has been undertaken at Wairakei since about 1978. Initial work was focused on seeking to understand fluid flow in the reservoir. Tracer testing undertaken by the DSIR using isotopes of iodine was used to assist in determining flow paths and patterns.

From 1980 to 1984 six trial injection tests were undertaken. The first injection investigation well WK301 was completed in 1984.

Consents for a larger injection test were applied for in 1986 and granted in 1988. This test involved injection of about 15% of the separated geothermal water into WK 62 in the eastern borefield. The test was undertaken from April 1988 to May 1989.

A further three injection investigation wells were drilled in 1989 / 1990.

Discharge consents were applied for under the Resource Management Act for injection of up to 60,000 tomes per day of geothermal water

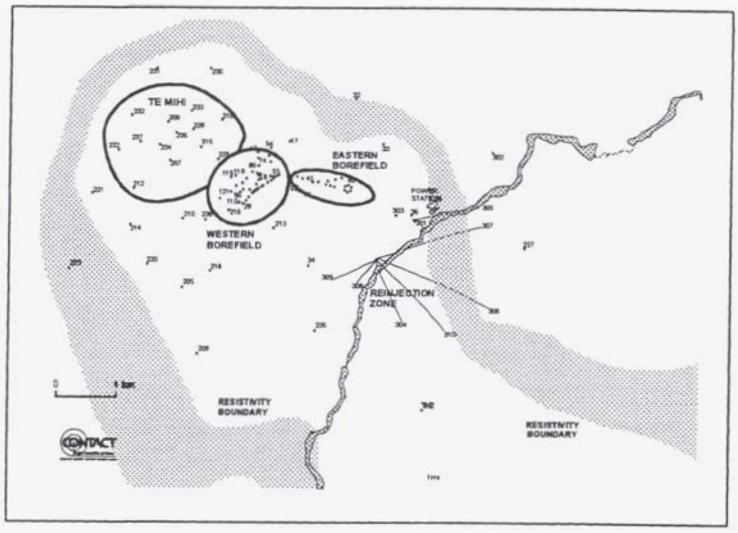

Figure 7. Wairaki Field

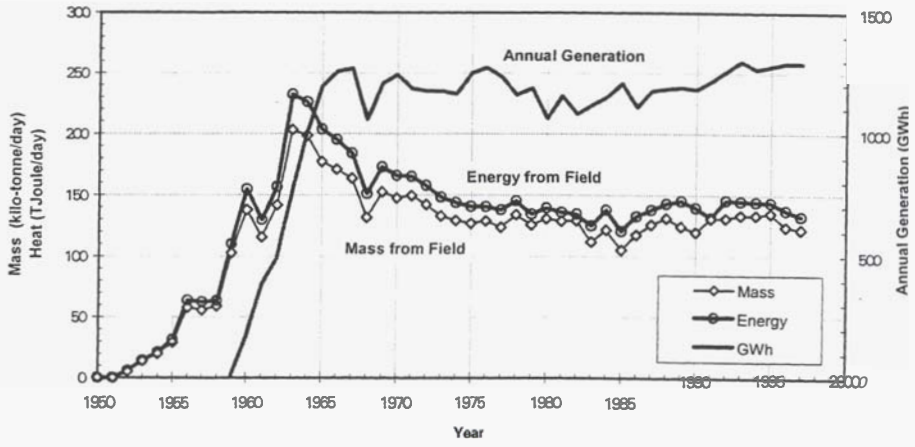

Figure 8. Generation and Field Data

in January 1992. These consents were issued in August 1996. Additional injection well drilling was undertaken in 1995. Construction was undertaken and injection under the consents is progressing. The water is being injected to the east of the production area. (Figure 7)

5.0 FAITHFUL, CONSISTENT AND RELIABLE

Wairakei has been a consistent and reliable producer of electrical energy. Load factors greater than 90% have frequently been achieved. The annual energy production from the plant is plotted in figure 8. The generation peaked at 173 megawatts in 1965 and in that year Wairakei generated 1202 GWH some 12% of New Zealand's electricity.
Focus on steam supply availability and plant reliability resulted in the maximum annual energy production of 1298 GWH in 1993.

During 1998 the plant produced a half hourly peak power readings of over 164 MW for the grid. Previously this level of generation has only been exceeded between 1965 to 1969.
The plant consistently produces about 1250 GWH per year with Wairakei now contributing about 3.5 % of the electricity produced in New Zealand.

6.0 PLANNING FOR THE FUTURE OF THE MARRIAGE

More handles, more heads but the same grandfather's axe. The future at Wairakei is promising. The field and the power plant are well matched for a long partnership.

More drilling will likely be undertaken to makeup for production decline. Both steam and liquid wells will be drilled. The Te Mihi area is likely to be the focus of this activity.

The drive for improving efficiency will continue. The use of an Organic Rankine Cycle heat recovery system (Binary Plant) is possible at Wairakei. Planning to install a 14 MW Binary Plant to utilise the geothermal water is currently being progressed.

The management of injection is expected to be an important element and a key to ensuing a lasting partnership between the power plant and the resource.

Throughout the past 40 years changes to the steamfield have been made. Changes will continue in order to more effectively utilise the geothermal resource. As in other areas economics are the overriding driver for any plant modifications.
And now, maybe, Contact Energy is a Bride awaiting a new suitor. The government is investigating selling Contact Energy including the Wairakei Power Plant.

7.0 COMMITMENT – TILL DEATH DO US PART

Lasting marriages are based on commitment and a willingness to work through what at times appear to be insurmountable issues.
Commitment is a feature of the people who have worked at Wairakei. They have committed themselves to producing the very best. They have faced difficult and what at times seem like insurmountable issues and have produced the outstanding achievement that is Wairakei.

8.0 REFERENCES

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