Kawerau Direct Heat Use: Historical Patterns and Recent Developments

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Keywords: *Kawerau, direct heat.*

ABSTRACT

Ngati Tuwharetoa Geothermal Assets Limited (NTGAL) is the owner of the Kawerau steamfield that currently supplies about 300-t/h of raw geothermal steam and 20-t/h of clean steam to the adjacent mills. Mighty River Power (MRP) operates the steamfield on behalf of NTGAL.

Geothermal process steam has been supplied to the mills since 1957. The steam is used in the pulp and paper process, for timber drying and for co-generation. Some of the steam is used in heat exchangers to generate clean process steam. An innovative technique developed by Norske Skog Tasman (NST) uses stripped geothermal condensate as feedwater for the heat exchangers. Raw geothermal steam is used in kilns for timber drying.

The industrial direct use at Kawerau accounts for about 56% of all New Zealand's direct geothermal heat use and is the largest industrial use in the world.

Recently there has been renewed interest in the use of geothermal steam for industrial processes and NTGAL is working with existing and potential new users to provide geothermal energy in different forms.

NTGAL has recently constructed a purpose-designed heat plant to supply clean steam to SCA's tissue mill at Kawerau. This plant was designed to have very high reliability. It also uses the NST condensate stripping process to provide feedwater; the process has been further refined.

Design is progressing on pipelines to supply separated geothermal water (SGW) and steam to a binary power plant to be constructed by NST. The SGW that will be used is a by-product of the steam supply and some is currently being discharged to the Tarawera River without the heat being extracted.

There is increased interest in raw geothermal steam for timber drying, which is likely to result in an increase in the high-pressure steam capacity. One of the new SCA-supply heat plant separators can be used to supplement the existing supply.

This paper does not consider traditional or domestic uses such as bathing, space heating and cooking, which have been part of Kawerau for generations.

Figure 1: Kawerau Steamfield

The mills and the geothermal field are shown in Figure 1. The pulp, paper and tissue mills are to the left (south), the sawmill is near centre and Mighty River Power's KGL power station is to the right (north), marked by the vapour from the cooling tower. The NTGAL steamfield – production wells, reinjection wells and steamfield equipment – is generally located north of the mills, south of the MRP power station. It is marked by vapour discharges from silencers at separation plants SP19 and SP35 to the west, and SP21 to the east.

1. HISTORIC USE

1.1 Background

The Kawerau geothermal field assets owned by Ngati Tuwharetoa Geothermal Assets Limited (NTGAL) provide geothermal steam to the adjacent pulp, paper, timber and tissue mills. MRP is the steamfield manager and operator. The field has been providing geothermal steam since 1957. The steamfield equipment and practices reflect this early development.

The mill supply system was originally established as a dual pressure system with high-pressure (HP) steam supplied at about 14-bar gauge (b.g) (200-psi, or pounds per square inch, in the units used at the time) and low-pressure (LP) supplied at about 7-b g. (100-psi).

Unlike an electricity generating plant, the mill demand varies, so the steamfield has been designed and is operated to be load following. That is, the steam demand from the mill varies over a wide range as processes within the mill change. Consequently the steamfield must be able to rapidly reduce or increase the steam supply to the mill.

The industrial direct use at Kawerau accounts for about 56% of all New Zealand's geothermal direct heat use and the combined mills are the largest industrial user in the world. (Lund et al, 2010).

1.2 Production wells

Production well drilling commenced in 1952. The first wells were clustered around the geothermal manifestations north of the mill and were intended for production. After some of the early wells failed owing to inflows of cooler surface water, subsequent production wells were cased to greater depths. Although some wells were sited further out, the producing steamfield area remains relatively small at around one square kilometre. Plans are progressing to bring in wells from further out and to drill new production wells to the south of the mill.

A total of 18 wells were drilled up until 1993, of which 12 were useful producers. (Wigley, Stevens, 1993).

Production wells at Kawerau have long lives: for example, KA19 has been producing more than 70 tonnes per hour (t/h) of steam since 1972. It has produced something like 15 million tonnes of steam over that time. New production wells have generally been drilled to increase the steam supply, rather than just to maintain it. However, calcite formation within the formation has caused a decline in some wells. Pressure and enthalpy declines have been small but have contributed to steam output decline.

1.3 Geothermal Steam Production

The steamfield provides about 300-t/h of raw geothermal steam, primarily as LP steam at about 7-b.g. HP steam is also provided at about 9-b.g. A recent development is supply of about 20-t/h of "clean" steam at 16 b.g. "Clean" steam is steam that has had the geothermal gases stripped out. This clean steam system is similar to that used by NST within the mill. Refer to section 1.6 below.

300-t/h of steam is approximately equivalent to 40 MW of power production, although most of the steam is used for process heat. Some is used in a backpressure steam turbine to generate electricity, with the exhaust steam being further used as process heat.

The steam supplied to the mills increased at an average of about 60,000-t/year from 1957 to the late 1980s, with a slower rate of increase since then. 2.3-Mt of steam was provided in the 2010-11 year compared to about 2.0-Mt in 1987. Peak supply was just over 2.6-Mt in the 2004-05 year. Annual steam output is illustrated in Figure 2. The dates when the current production wells were drilled, along with their approximate, original, maximum mass outputs, have been superimposed on that figure.

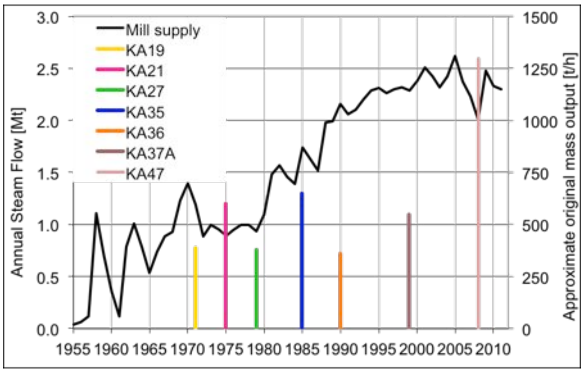

Figure 2: Annual steam supply and when wells were drilled

1.4 Pulp and Paper Use

About 25 % of the pulp and paper mills' process steam is provided by geothermal; the majority of the process steam is generated within the process, either by burning "black liquor" or wood waste. (Hotson 1995, 2000).

The geothermal steam is used in five heat exchangers to generate clean process steam, or directly in the process or in boiler feedwater heaters. A significant fraction is also used in a turbine to generate power: this is used to balance steam loads, with the mill demand generally taking precedence over power generation. The exhaust steam from the turbine is used in a liquor pre-evaporator, water heater and condensate stripper. (Hotson 2000).

1.5 Timber Drying

Carter Holt Harvey Wood Products (CHHWP) operates a large sawmill at Kawerau. Since the 1970s some of the sawn timber output has been kiln dried. The kilns are heated with high-pressure (HP) geothermal steam.

Additional kilns were constructed in the 1980s with the geothermal steam supply to them being extended at the same time.

The steam is supplied at about 10-b.g. or 185°C, which produces kiln temperatures of up to 150°C. The actual kiln temperature can range between 80 and 140°C, depending on the required drying regime. The steam runs through pipe heat exchangers within the kilns, with air being forced around the kilns by 2-m diameter fans. Radiata pine is dried in batches of up to 100-m^3 at a time. Typically the moisture is reduced from 150% to 10% in 20-hours. The timber is then reconditioned for six to eight hours to ensure a constant moisture content through the thickness of the timber. (Scott and Lund, 1998).

The steam demand follows a more-or-less saw tooth pattern, with high demand at the beginning of the cycle. The overall demand can be smoothed out by staggering the start up time of different kilns.

1.6 Geothermal Heat Exchangers

As previously noted, some of the geothermal steam supplied to the mills is used to generate clean steam in heat exchangers. Two heat exchangers were installed in the late 1950s. Two further heat exchangers were installed in 1974 and a fifth in 1984. (Hotson, 2007).

Figure 3: Original Tasman heat exchanger tube bundle (courtesy Joe Hotson)

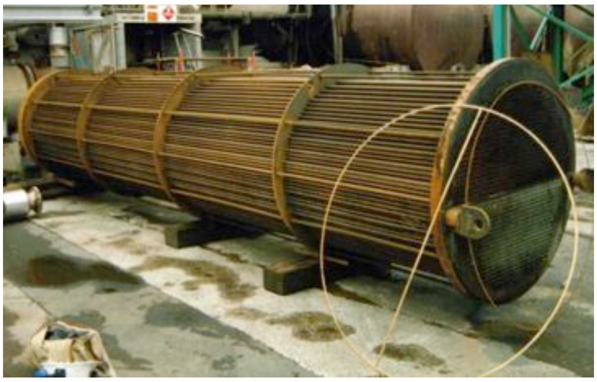

Figure 4: later Tasman Whessoe heat exchanger tube bundle (courtesy Joe Hotson)

A problem with the heat exchangers was fouling on the feedwater side owing to the variable and sometimes poor quality of the feedwater. To restore heat exchanger efficiency chemical cleaning was necessary, typically twice a year. Although chemical cleaning of the geothermal side had been considered earlier, it was rejected, as any geothermal deposition did not cause a significant change in efficiency. There is no record of the geothermal side ever having been cleaned.

Figure 5: Geothermal supply main and stripper towers (Photo courtesy of CHHT from www.teara.govt.nz).

Because of the feedwater problems Tasman developed a process to treat the geothermal condensate for use as feedwater. The process involves flashing the condensate after it leaves the heat exchangers; this removes most of the non-condensable gases. The condensate is then passed through a stripping column, which removes the remainder of the carbon dioxide and hydrogen sulphide, but can be controlled to maintain a certain level of ammonia. The ammonia has the highly desirable effect of maintaining a high pH in the steam so controlling corrosion. The condensate treatment process was introduced in 1989. It was so successful that the heat exchangers no longer require cleaning and feedwater process costs have greatly reduced.

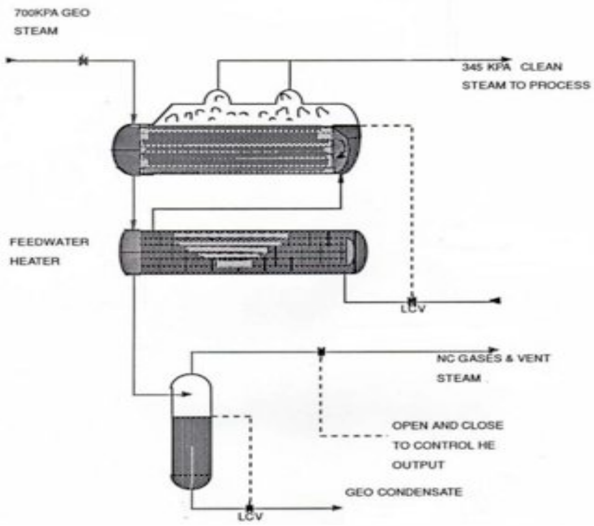

Figure 6: Tasman heat exchanger and condensate scrubbing schematic (courtesy Joe Hotson)

1.7 Greenhouse Heating

A small quantity of steam from the NTGAL steamfield supply system was used to heat greenhouses of about 5,000-m^2 to grow capsicums. The first greenhouse of about 3,600-m^2 was constructed in 1982, with the second being constructed in 1994. (Dunstall, Foster, 1998). Steam was supplied from a small separator on the KA27 two-phase pipeline, with the pressure being controlled to 5-b.g or about 160°C. The estimated annual heat use was about 700,000-kWh. The greenhouses have since been closed and the area taken over as a log yard.

2. RECENT DEVELOPMENTS

2.1 SCA Clean Steam Supply

Svenska Cellulosa Aktiebolaget Hygiene Australasia (SCA) operates a tissue manufacturing plant at Kawerau. The plant uses process steam, which was supplied by natural gas fired boilers, with some steam also being supplied by NST.

Figure 7: NTGAL's SCA supply clean steam plant

When SCA approached NTGAL for a supply of high-pressure clean steam, NTGAL decided to adopt the Tasman (now Norske Skog Tasman) process for generating feedwater. GNS was commissioned to model the chemistry of the proposed system, which was to run at a much higher pressure than the NST system was running at. SCA requires clean steam at 16-bar g., whereas the pressure of the clean steam in the mill is about 3.5-bar g. The GNS report confirmed that the stripping process would work at the higher pressures and gas contents and that the stripping steam requirements would be acceptable. (Mroczek, 2009). This proved to be the case when the plant was commissioned.

GNS also undertook a heat and mass balance to determine whether the process would be self-sufficient for condensate; this indicated that there might be a small shortfall. (Lind, Carey, 2009). As a consequence, a condensate pipeline from SCA was designed and installed. In practice the plant generates a small surplus of condensate, but the return line has been useful for priming the system and for restoring feedwater lost during plant faults. In general SCA uses all the hot condensate within the tissue manufacturing processes.

Geothermal steam is lost in the clean steam process, primarily in the stripping process, but small quantities are also used to keep the feedwater hot and in blowdown from the heat exchangers. The typical ratio of geothermal to clean steam is about 1.3. That is, it takes 1.3-t of geothermal steam to supply 1.0-t of clean steam. The objective is to keep the ratio as low as possible to minimise waste of the valuable geothermal resource. Once the system had been properly tuned, the ratio was about 1.25.

Construction of the clean steam plant was completed in September 2010. The process is similar to the NST system; the major difference being that the stripper runs at atmospheric pressure and the process is controlled by varying the stripping steam inflow. In the NST system the stripper is pressurised and the discharge flow is varied to control the system. In the new NTGAL plant it was found that the ammonia level and hence pH could be controlled in a narrow range by maintaining a constant stripping steam to condensate ratio. The relationship of pH and conductivity to ammonia is shown in Figure 8.

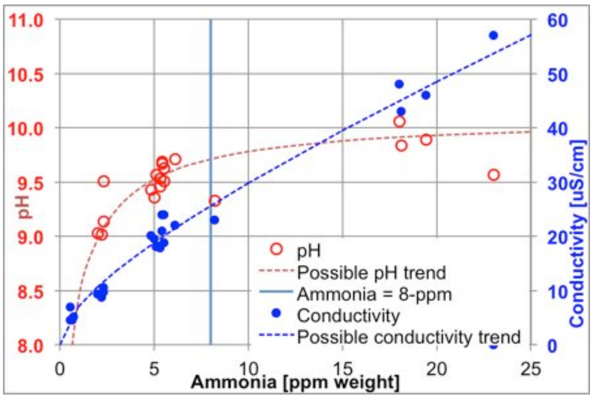

Figure 8: pH and Conductivity versus Ammonia in Steam

Conductivity is easily measured on line, so is used as a proxy for other less easily measured parameters, such as the ammonia content. However, it can be seen that the pH and conductivity both follow the ammonia content quite closely, so a change in conductivity will quickly signal a change in the process.

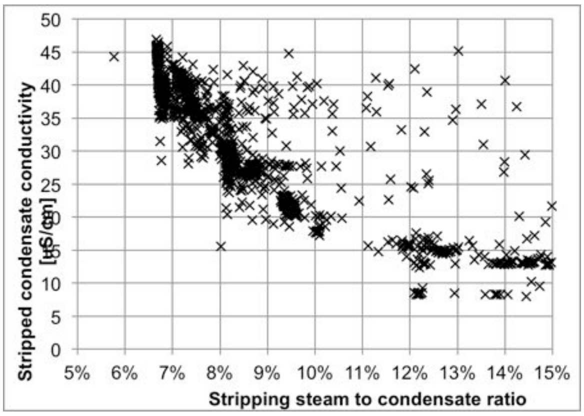

Figure 9: Conductivity versus stripping steam ratio

2.2 Review of Assets

NTGAL’s equipment at Kawerau comprises pipelines and equipment constructed from the 1950s until present. It has been added to and adapted over that time, to match supply to mills demand, to connect new production and reinjection wells and to reflect changes in water rights and resource consents. NTGAL is currently assessing the overall steamfield efficiency and maximum production. New process and instrumentation diagrams (P&IDs) are being prepared to capture all the equipment and controls and changes to those over time.

Steam is separated at four separation plants; these plants have established maximum flow ratings, but the actual capacities may change depending on the enthalpy and total mass flows of the wells feeding into the plant. As part of the above exercise, the ratings of the existing plants are being re-evaluated to ensure that they correctly reflect current operations. One or more of the separation plants may be modified to optimise them for current production wells and well enthalpy.

3. FUTURE DEVELOPMENTS

3.1 New Production

The existing production wells do not have sufficient spare capacity to ensure that peak demands can be met, accordingly NTGAL is investigating the benefits of connecting in existing well KA30. KA30 is located to the southwest of the mill; it had a high indicated output when tested shortly after it was drilled in 1980. The mass output was 580-t/h at an enthalpy of 1,300-kJ/kg.

An alternative is to drill a new production well. It is possible that both may be required to meet new demand with an adequate margin.

As production may shift towards the south of the mill, for example if KA30 is to be used, plans are underway to construct a new separation plant on NST land in the area. The separated steam would be fed into the existing LP main, with the separated water being piped north for reinjection.

3.2 Increased Reinjection

When the steamfield was first developed in the 1950s, waste geothermal water was discharged to the adjacent river, the Tarawera, as was the practice at Wairakei at the time. In the early 1980s investigations were carried out to determine the best means of reinjecting some or all of the waste geothermal water, without causing adverse impacts on the production field. An extensive pattern of monitoring wells was established and testing was carried out. Reinjection started, into KAM1, in 1991. Following observation of no severe adverse effects, reinjection into a second well, KA38, commenced in 1993. Two further reinjection wells have been commissioned since then.

NTGAL plans to increase reinjection of separated geothermal water. Reinjection options are being investigated, with the final location being dependent on land access as well as reservoir considerations.

3.3 Increased High-pressure Steam for Timber Drying

If more timber drying is to be carried out on the mill site it will require more HP steam. This will require an increase in the HP separation capacity as it is currently run near its limit. However, the new SCA heat supply plant was designed with this possibility in mind. The plant has duplicate separation plants and the separation plant not on SCA duty may be used to supply HP steam. The steam from this separation plant will be piped directly to the HP main, which runs from SP36 about 80-m from the plant. The separated water will need to be piped for reinjection into well KA39, which is located near SP21.

NTGAL is also reviewing the advantages of increasing the steam supply pressure and hence temperature. This will be feasible as the system was originally designed to supply at 14.0-b.g. However, the pressure control system will need to be modified: at present the pressure floats depending on demand.

3.4 Steam and Separated Water for Power Production

NTGAL is currently developing the steamfield to gather high-temperature separated geothermal water to supply a binary power plant being constructed by Norske Skog Tasman. The separated water is currently being discharged to the Tarawera River. The plant will also use some steam. As this is not a direct heat use it is not discussed further here.

3.5 Other Potential Uses

Other sawmills at Kawerau have shown interest in geothermal steam for kiln drying of timber. Negotiations are at an early stage so the source and pressure of the steam has not been decided.

CONCLUSION

The Ngati Tuwharetoa Geothermal Assets' geothermal steam supply to the pulp, paper, tissue and timber mills at Kawerau remains the world's largest industrial geothermal heat supply. The steam is supplied at different pressures and as raw or clean steam, as required by the different uses. Typical total supply is about 300-t/h with high load factors.

A recent new addition is the supply of 20-t/h, of 16-b.g. clean steam to SCA's tissue mill, using a purpose designed and built plant.

ACKNOWLEDGEMENTS

The permission of Ngati Tuwharetoa Geothermal Assets Limited (NTGAL) to publish this paper is gratefully acknowledged.

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