TUAROPAKI MIRAKA CLEAN STEAM SUPPLY PLANT

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ABSTRACT

This paper is a case study of the Tuaropaki Miraka Clean Steam Supply Plant which demonstrates an example of a new use for existing geothermal resources. The Tuaropaki Trust and its associated braches the Tuaropaki Power Company, Tuaropaki Farms and Tuaropaki Greenhouses are known for their innovative use of their geothermal resources in both power production and greenhouse heating. In 2010 MB Century were selected to provide a design build solution for a clean steam generation plant using existing high enthalpy geothermal resources to provide clean steam to be supplied to Miraka Ltd. This clean steam is being used in the production of milk powder.

The generation of clean steam by converting geothermal condensate into boiler quality feedwater and reboiling that water using geothermal steam on the primary side of the exchanger is not new and has been successfully used in the pulp and paper industry in New Zealand for a number of years. The new challenges that arose from the specification for this plant included a high degree of reliability during the diary season and a high degree of purity for the clean steam with the chemistry requirements laid out in the contract.

The process design for the plant is discussed, where previous plant design was simplified to provide a cost effective and reliable solution. The number of vessels was reduced from fourteen pressure vessels to six pressure vessels and four atmospheric vessels. The clean steam generation side of the plant was treated as a conventional boiler plant with a single hotwell elevated above the feed water pumps that feed directly to the preheater and heat exchanger banks. The non pressurised condensed geothermal steam stripping process is considered, with a comparison to previous pressurised designs.

1. MIRAKA CLEAN STEAM PLANT DESIGN BUILD

1.1 Background- Tasman and SCA Steam Plants

Geothermal steam has been supplied to the Tasman pulp, paper and timber mills at Kawerau since about 1957. Some of this steam was used in two heat exchangers to generate "clean steam", that is, steam free from the geothermal gases. These two heat exchangers have been in continuous service since the late 1950s. Two further heat exchangers were installed in 1974 and a fifth in 1984.

A problem with these 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. Because of the feedwater problems Tasman developed a process to treat the condensed geothermal condensate for use as feedwater. The process involves flashing the geothermal steam 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 dissolved 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 been greatly reduced.

When the SCA paper product mill in Kawerau approached NTGAL (geothermal field operator) for a supply of clean steam, NTGAL decided to adopt the Tasman (now Norske Skog Tasman, NST) 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 runs at. Construction of the clean steam plant was completed in September 2010. The process is almost the same as 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 varying the discharge flow controls the system. In the new SCA/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.

1.2 Miraka Clean Steam Supply Plant

The Tuaropaki Power Company Miraka Clean Steam Plant is clean steam supply plant for the Miraka Dairy Ltd Milk Powder Plant located at Mokai. The steam plant was a turnkey design build project undertaken by MB Century for the Tuaropaki Power Company from May 2010 until it's completion in June 2011. The brief called for a plant to reliably supply up to 30t/h of clean steam at 20 Bar(G). The plant is comprised of a number of 2x 100% duty and standby streams to ensure maximum availability of the plant during operational periods. The design philosophy was based on information from existing plants that was modified to meet the specific requirements of the steam chemistry for this application. The relatively small size of the plant meant it was possible to combine a number of functions in single vessel structures such as the use of a baffle plate to divide the steam and separated geothermal water in the separator vessels rather than having individual vessels for the steam and water components. This methodology was carried through all vessels where there were requirements to separate gasses from liquids. This approach enabled MB Century to offer a cost effective and easy to maintain solution for the clean steam plant.

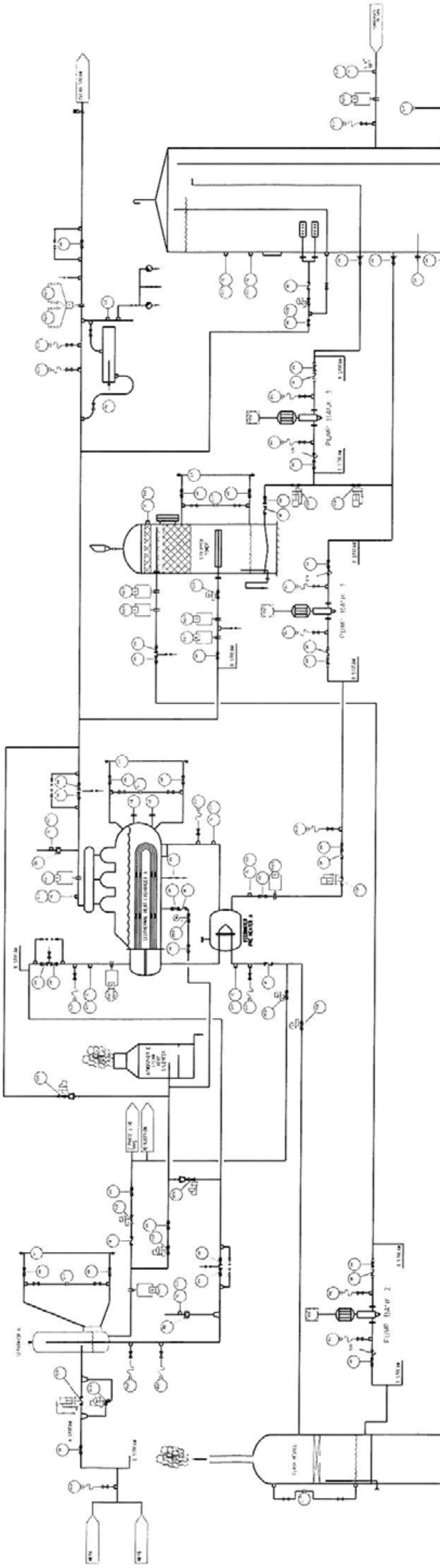

Figure 1: P&ID (Simplified to show single stream)

Figure 2: Steam plant overview

1.2.1 Geothermal Steam Source

The geothermal steam supply used by the Miraka steam plant is obtained from two existing high enthalpy (1625~2050kJ/kg) wells, Mk7A and Mk16 located in the Mokai steam field with well head shut off pressures of 72~85 Bar(G). This field is also used to supply the Tuaropaki Power Company power station and greenhouses. The steam plant draws off approximately 10% from either of the two wells available 2 phase supply at one time. The tie in connections to the well head piping are vertical up branches to minimise the water content of the steam at the take off point.

Figure 3: Top take off connections to Mk7A and Mk16 well head piping

This design has proved effective with SGW water content flows in the order of 0.5t/h for geothermal steam flows of 25t/h during normal operation when the steam plant is running in parallel with Tuaropaki Power Station at 38 bar(G) well head pressure. During power station shuts the well head pressure rises and the SGW water content flows in the order of 50t/h for geothermal steam flows of 25t/h at 63 Bar(G) well head pressure.

1.2.2 Pressure Reduction and Separation Plant

The pressure reduction plant is comprised of two paired pressure reducing control valves operating in parallel with split range control to give full pressure control over a wide range of inlet conditions expected from the well head supply. These conditions are dependent on the duty of the Tuaropaki Power Station that also draws 2 phase fluid from the Mk7A and Mk16 wells.

Figure 4: Split range pressure reduction valves supplying cyclone separators

The wells nominally operate at 38~44 Bar(G) when the power station and the steam plant are on line, however when the power station is taken off line for annual shuts the well head pressure to the steam plant rises to 80+ Bar(G). The outlet pressure from the separator inlet flow controlvalves is 20.5~27 bar(G) depending on clean steam flow. The flow control valves have been specified for high pressure drop and severe service flash conditions.

The separation plant is comprised of two conventional cyclone separators optimised for the geothermal steam flows required by the steam plant. The separated geothermal water from the separators is injected back into either the two phase line feeding the power station or the reinjection line to the reinjection wells. The connections to these lines are in the form of stab ins with cartridge diffusers encourage mixing of the streams. When neither of these options is available there is a soak pond available on site to provide a minimum of 3 days capacity of full flow of SGW and geothermal steam condensate.

Figure 5: Cyclone separators and discharge silencer

Figure 6: Separated geothermal water and condensed geothermal steam being returned via stab in's with diffuser cartridges to either 2 phase line for power generation (near side) or reinjection wells (far side)

1.2.3 Heat Exchanger Banks

The Hx banks fed from the separator plant operate on inlet conditions between 20.5 and 27 bar (G) dependent on clean steam flow to the diary company. The control logic calls for the inlet pressure set point on the primary side of the Hx to ramp up and down as clean steam demand ramps up and down allowing the Hx to respond rapidly to changes in the clean steam demand. The flow rates vary from 0~30 t/h with powder drying cycles operating in the region of 18~20t/h with peaks 2~3 t/h above that. During the diary season the drying cycles are expected to run up to22 hrs/day.

Figure 7: Heat Exchanger banks

The two heat exchanger banks are compromised of tube and shell heat exchangers paired with tube and shell pre heaters. The geothermal steam from the separators is fed into the primary side of the exchangers where it is condensed and then fed into the pre heaters for maximum heat recovery. The condensed geothermal steam can then be injected into either the 2 phase line to the power station or the reinjection line to the reinjection wells. Additionally it can also be passed through a flash and stripping process to be cleaned up for use as feed water on the secondary side of the exchanger banks. This make up water complements the condensate return from the dairy company and maximises the use of on site water without having to resort to outside potable water supplies.

1.2.4 Condensed Geothermal Steam Flashing and Stripping

The geothermal steam condensate is directed from the discharge side of the Hx bank primary circuit through a flash vessel where the non dissolved gases, such as portions of CO_2 and H_2S, are vented to atmosphere. The degassed condensate is then transferred by a pump bank at a fixed rate of 25t/h to the top of one of two stripper towers where it is sprayed over a bed of Raschig Super- #1 Rings that have been heated by an incoming steam supply at 700kg/h from the bottom of the tower. The stripping sequence is timed so that the steam is introduced to the spargers in the tower before the condensate is introduced to ensure the packed bed maintains a minimum temperature of 85^{o}C. The stripping process removes dissolved H_2S, CO_2 and NH_3 to the prescribed levels. It is anticipated there will be sufficient NH_3 left in the condensate to maintain a pH of 7.9 which acts as a corrosion inhibitor. The stripping process is undertaken in an open vented environment to ensure NH_3 is removed to the specified concentration. In other instances this process can be controlled by either increasing or reducing the pressure within the stripper tower to increase or reduce the concentrations of NH_3. In this instance the desired concentrations can be achieved by running the towers at atmospheric pressure. A clean steam supply is maintained to the towers at 50kg/h to ensure they are preheated for operational use as well as acting as a corrosion inhibitor. The degassed and stripped condensate is then transferred by a pump bank to the feedwater tank.

Figure 8: Flash and stripper vessels

1.2.5 Feedwater

Feedwater for the Hx Banks is stored in an 80m^3 silo located on a 3m high naturally occurring mound. The site afforded this feature which has enabled feed water pump NPSH to be met without having to artificially elevate the feed water vessel, sink the pumps into a pit or add booster transfer pumps. The feedwater tank is equipped with temperature controlled steam injection to maintain a water temperature of 92^{o}C .

Figure 9: Feedwater tank and pump bank

There is also a small steam bleed into the head of the tank. Both these features help maintain the dissolved oxygen content below 2ppm. The pump bank associated with the striper tower to feed water tank condensate transfer can also be used to recirculate water in the tank to avoid temperature stratification. There is also a conductivity measuring station that monitors and trends the conductivity level of the tank. Typical readings for feed water at 92^{o}C are 12μS/cm.

1.3 PLC and Security

The control system is based on a redundant GE RX3i Primary and Secondary PLC processor configuration. Each of the processors mounted in a separate 12 slot chassis with redundant power supplies fed from a no break DC power supply with battery back-up capable of sustaining the PLC processors, I/O modules and local HMI for approximately 8 hours. The processor racks are connected by high speed fiber reflective memory modules allowing for seamless failover between primary and secondary processor.

The dual 16 slot I/O racks are connected to the redundant processor racks via a redundant Ethernet network ensuring there is no single point of communications failure for the system. Local control is achieved via a 15" colour touchscreen GE QuickPanel (HMI) which is mounted into the door of the PLC cabinet in the Steam Plant Control Room (SPCR). The HMI in the SPCR can be used for full local control of the steam plant.

A fibre optic cable connects this plc to a stand alone pc at the Tuaropaki Power Station where the station operators are able to remotely control the plant and undertake soft interlock resets, such as motor restarts after power outages, without having to attend directly to the plant.

The fibre link also carries a digital video link to a locally mounted camera which enables the operator to visually monitor the plant. There is also security hardware for intrusion alert and smoke detection that is hard wired back to the plc.

2. MIRAKA CLEAN STEAM PLANT PERFORMANCE

The Miraka Steam Plant has been running for three months and has met performance requirements laid out in the contract as follows:

2.1 Steam Pressure & Flow

A consistent supply of 20 Bar(G), this has been maintained between 20.5 and 22.5 Bar(G). The ability to ramp up the inlet pressure to the primary side of the exchanges as the flow of clean steam from the secondary side of the Hx to the user increases has enable pressure to be maintained consistently across a wide range of flows (2~20t/h) as well as accommodating rapid changes in the flow rate.

Flow rates of 0~22t/h have been consistently seen during operation of the plant. The design parameter called for 0~30t/h; the higher flows have only been observed during steam blows; at this stage it is not known if user will call for demands exceeding 22t/h.

Hot switching between separator banks, heat exchanger banks stripper towers and pump banks has been effected in approximately 10 minutes without interruption to the clean steam delivery pressure or flow rates.

2.2 Stripping Process

At the time of writing a single set of steam chemistry results have been obtained from independent sampling and testing with the following results compared with target requirements:

Property	Target Value	Tested Value
Conductivity	< 10μS/cm	8.9μS/cm
Na	<10ppb	<10ppb
SiO_2	<20ppb	150ppb
O_2	<10ppb	<10ppb
H_2S	<100ppb	Null
CO_2	<10ppb	<10ppb
NH3	90ppb	<10,000ppb*
HCO_3	<20,000ppb	<20,000**
Dryness	>99.5%	>99.5%
pH	8.5~9.5	5.13

* Optimised to maintain the pH range

** detection limit 20,000ppb

These high levels of sodium, silica and bicarbonate may be due to the feedwater tank being partially filled with farm bore-water during the initial start up rather than full of degassed and stripped geothermal steam condensate.

However in the clean steam condensate all parameters are within the contract requirements, with the exception of sodium

The levels of H_2S in analyses from the clean steam gas far exceeds the <100ppb guideline in the contract. These high levels are highly likely to be the result of sample contamination, as sulphide levels in the feedwater tank are well within contract requirements, and there is no possible input of H_2S after the feedwater. This contamination is likely to be from the use of sample equipment generally used on raw geothermal steam. Samples would need to be collected with brand new T-piece and hose to prevent this contamination in the future.

The stripper towers have been in use to provide make up feed water and it has been noted that the on line readings for conductivity have reduced from 38μS/cm to 12μS/cm. It is expected the next round of steam chemistry testing will produce results in the desired range.

2. CONCLUSION

The vision of the Turapaki Trust in using their geothermal assets for novel applications is maintained with the successful completion of this geothermal to clean steam generation plant. The trust also has the philosophy of treating their resources as being available for all future generations so endeavour to ensure they are used in the most sustainable way possible. The use of geothermal steam as the primary heat source for milk powder drying is believed to be a first in New Zealand and world wide. This example of the application of this technology indicates it is possible to develop geothermal steam to clean steam generation plants for any industry that requires clean steam for process heat.

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