GEOTHERMAL GREENHOUSE HEATING AT OSERIAN FARM, LAKE NAIVASHA, KENYA

Bruce Knight[1], Hagen M Hole[2], Tracy D Mills[3],

[1] Oserian Development Company, P O Box 209, Naivasha, Kenya. (bruce.knight@oserian.com / www.oserian.com)
[2] Geothermal Consultants New Zealand Ltd, P O Box 34391, Birkenhead, Auckland, New Zealand. (gcnzl@ihug.co.nz)
[3] Sinclair Knight Mertz Ltd, P O Box 9806, Newmarket, Auckland, New Zealand. (tmills@skm.co.nz)

ABSTRACT
This is a re-presentation, of a paper presented at the 2nd KenGen Geothermal Conference, April 7 – 9, 2003. Some minor updates have been made.

A low output exploration well located on Oserian Farm in the Olkaria geothermal field has been used to supply geothermal heat to a greenhouse complex. Heating controls night-time humidity levels in the greenhouses, thereby alleviating fungal disease and enhancing flower growth. The non-condensable gases (predominantly CO_2).produced from the well are used to enrich the atmosphere in the greenhouses, further enhancing flower growth.

Fresh water is the heat storage and transport medium, which is stored in a hot water storage tank and circulated through the greenhouse heating loop when heating is required. The geothermal heating equipment is located on the well site, while the hot water storage tank is remote from the well site, near the greenhouses.

This paper discusses the geothermal-side heating system, the characteristics of the well (notably its cycling flow) and the main features of the design and construction of the heating process and control system.

Key Words: *Geothermal, heating, greenhouse, Olkaria, Oserian, Kenya, East Africa.*

1. INTRODUCTION

Oserian Development Company owns and operates a large flower farm at Lake Naivasha, Kenya. The farm overlies part of the Olkaria geothermal area, and several exploration wells have been drilled there over the years. As is usually the case with exploration wells, they are few in number, far between each well, and can have a range of drilling outcomes.

Well OW-101 was an early exploration well drilled in 1983; it is fairly isolated from the power plant production areas, and has a very low power generation potential. Additionally, tests of the well show it has very significant flow cycling which poses difficulties for power generation. For these reasons it would be impractical to connect the well to any of the existing or planned power plants within the Olkaria geothermal area.

Oserian initially made use of a small portion of well OW-101's capacity for greenhouse heating, and has subsequently expanded use of the well in a larger heating project. New greenhouses were constructed for the purpose.

The primary aim of Oserian's greenhouse heating is to control night-time (and wet season) humidity levels in the greenhouses, thereby alleviating fungal disease. The project provides some tangible benefit from the earlier exploration drilling efforts, and has the added benefit of allowing Oserian to provide greenhouse heating without having to burn fossil fuels.

The greenhouse heating system comprises the following sub-systems:

- a geothermal heating circuit located at the well site,
- a secondary fresh water heating circuit to transport heat from the well site to the greenhouse area,
- a large heat storage tank adjacent to the greenhouses, and
- a distribution network to supply heat to the individual greenhouses as required.

The purpose of this paper is to discuss the technical aspects of the geothermal heating sub-system, including the characteristics of the well (notably its cycling flow), and the main design and construction features of the heating process and its control system.

2. WELL CHARACTERISTICS

Oserian carried out a series output test measurements of well OW-101, for a range of conditions. These tests indicated that the well has a typical average output of about 8 or 9 MW_{th} (which corresponds to less than 1 MW_e), while instantaneous values vary from about 6 MW_{th} to 15 MW_{th}.

Under constant throttle conditions, the well shows dramatic swings in all flow parameters (mass flow, wellhead pressure, and enthalpy). The flow conditions cycle over a period ranging about three hours to almost five hours, and this is caused by the well having two feed zones; at times one or other zone predominates yielding the observed cycling. Table 1 summarises the extent of flow cycling at several throttle settings. Figure 1 shows the well's behaviour for discharge through a 5" lip pipe with an average wellhead pressure of 3.87 bars (absolute).

WHP (bara)			Mass Flow (kg/s)			Enthalpy (kJ/kg)		
Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
3.4	4.8	7.7	7.77	10.55	16.80	1089	1238	1523
3.8	5.2	7.8	8.52	10.84	16.67	1091	1226	1464
4.1	6.0	9.5	7.17	10.00	15.99	1141	1222	1417
4.2	6.1	9.6	6.66	9.31	15.08	1221	1292	1463
4.7	7.1	11.2	6.42	8.89	14.65	1252	1384	1558

Table 1: Extent of Flow Cycling.

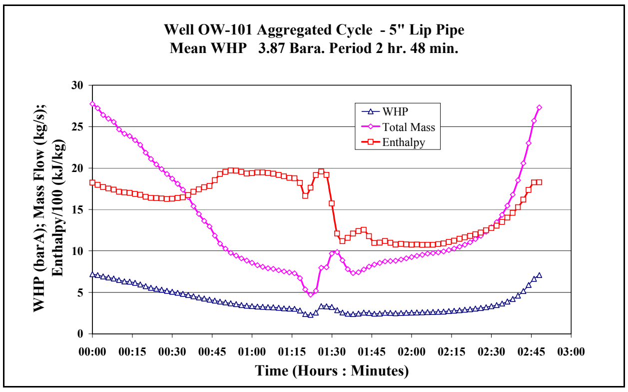

Figure 1: Extent of Flow Cycling.

There is a relatively narrow band of wellhead pressure (with average values of about 5 to 7 bars abs.) where the well has less extreme changes in output. At lower wellhead pressures (larger well openings) the flow has more severe cycling, such as shown in Figure 1, while at higher wellhead pressures the well can cease flowing.

It was decided that two-phase fluid would be used in the heating system, thereby avoiding the cost of a steam separator, and also allowing the heat in the brine to be used without the need for a separate brine heat exchanger. In addition The choice of utilising a two phase system provided a significant construction time advantage.

Careful consideration was given to the possibility of silica scaling. The well fluid has relatively high pH which tends to lower the potential for scaling. It was also considered that the residence time of the geothermal fluid within the heating system would be very short, giving a further safety margin due to kinetics of silica scaling. Based upon available silica chemistry data, even without considering kinetics, conductive cooling of the two-phase fluid considered to be safe to 90 ^{0}C.

As was expected, the well fluid contains a small proportion of non-condensable gas. This is predominantly CO_2, with minor amounts of other gases including H_2S. The design of the heating system included piping and an air blower that enabled the non-condensable gases to be diluted with air, then transported to the greenhouses to enrich the air in the greenhouses with CO_2. A significant improvement in plant growth due to elevated CO_2 levels, as well as a reduction in disease due to traces of H_2S have resulted. It should be noted that gas levels are monitored and controlled in relation to plant growth and, importantly, to ensure the safety of personnel.

The design of the geothermal heating sub-system took full account of the unusual well behaviour.

3. HEATING SYSTEM DESIGN FEATURES

The design concept for the geothermal heating sub-system is depicted in the P&ID drawings Figures 2, 3, and 4. The following sub-sections describe features of key elements of the design concept.

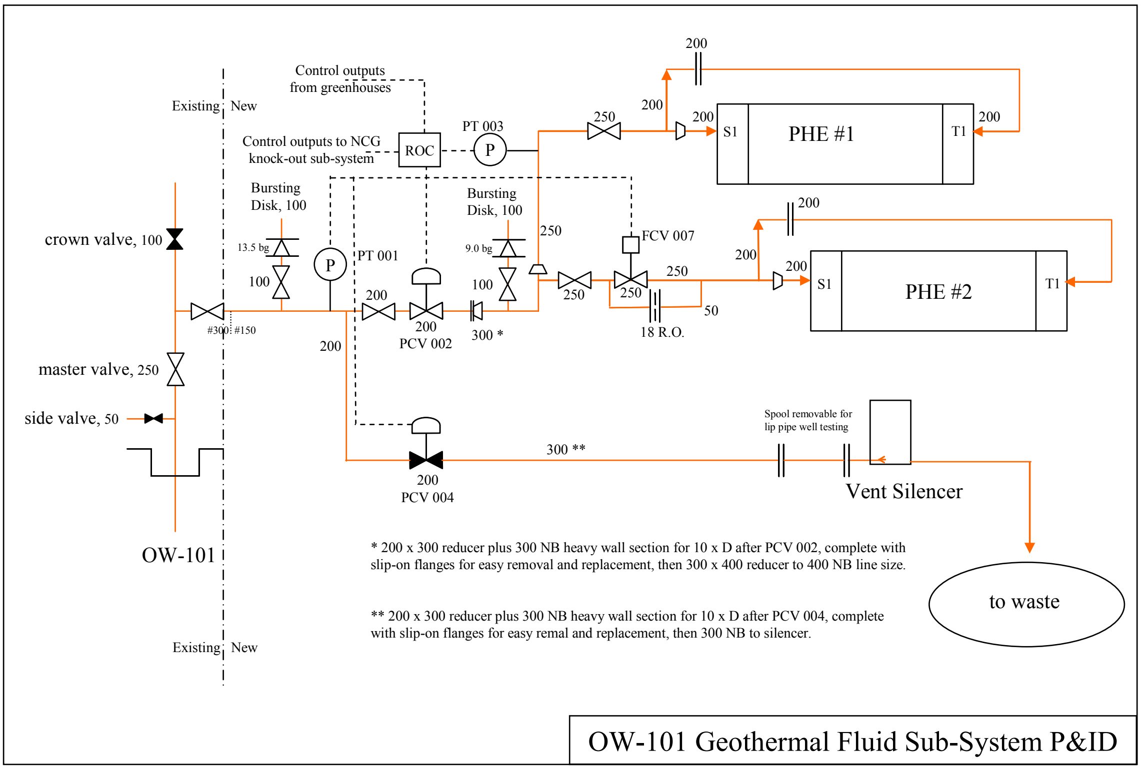

Figure 2: P&ID for Geothermal Fluid Sub-System.

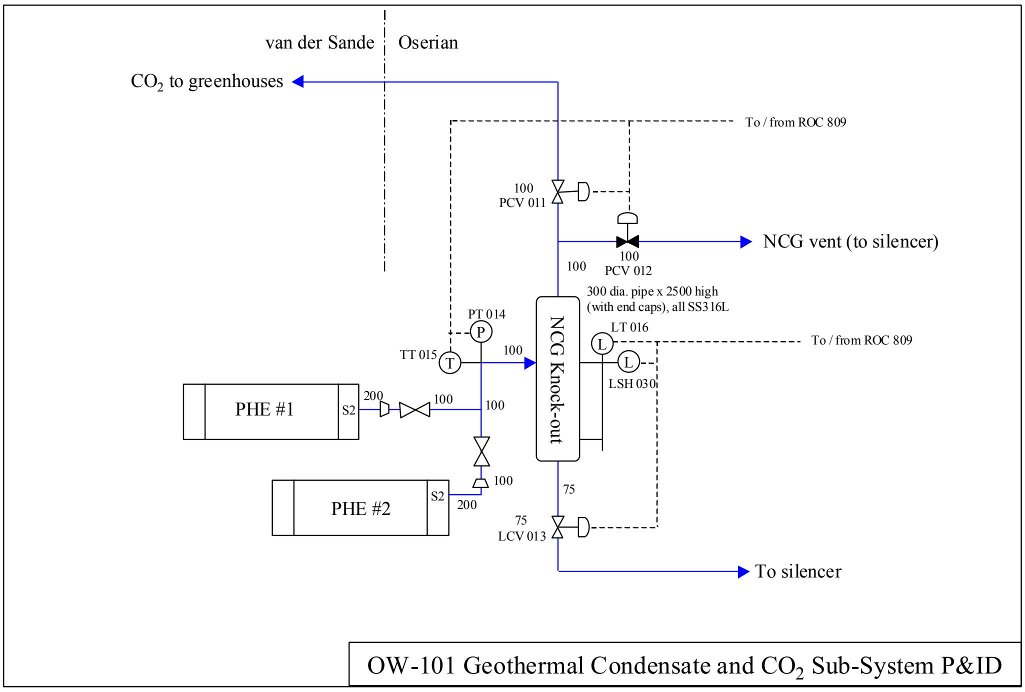

Figure 3: P&ID for Geothermal Condensate and CO_2 Sub-System.

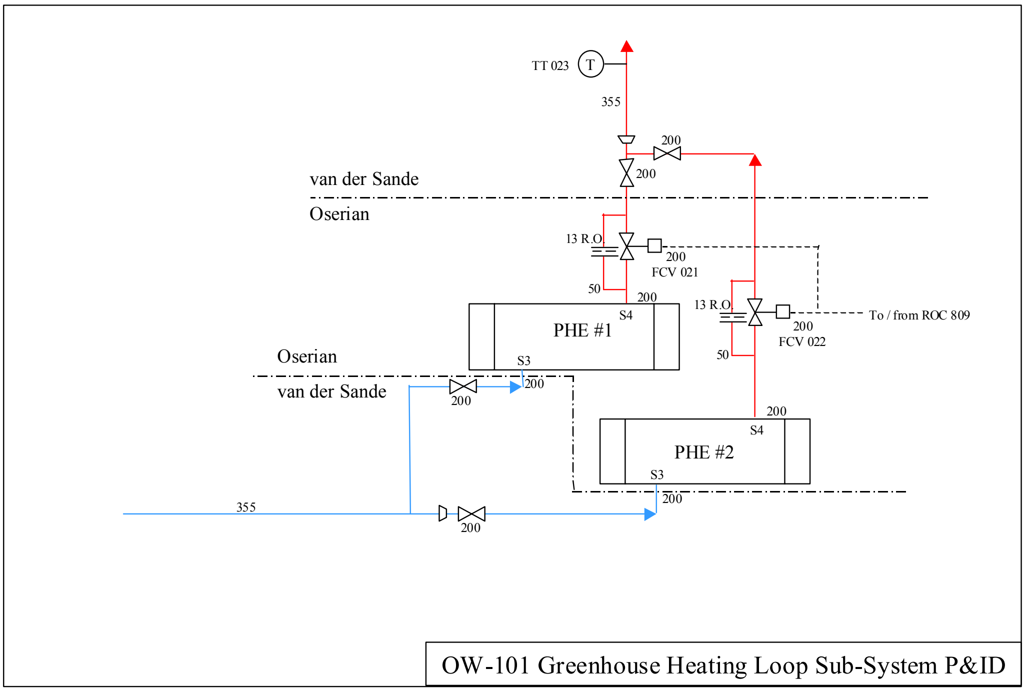

Figure 4: P&ID for Greenhouse Heating Loop Sub-System (at Well Site).

3.1 Regulation of Process Pressure

It is desirable to maintain steady conditions in the heating system; in particular, while flow rates fluctuate, the process pressure and hence temperature is to be maintained. A high-performance ball valve is used to regulate the downstream pressure.

3.2 Fluid Venting

Venting of the well flow has been allowed for, also by means of a high-performance ball valve. The three principal reasons for venting part or all of the flow are:

- Venting of high well flow rates;
- Avoiding high wellhead pressures (hence back-pressuring of the well) by maintaining some flow; the well can be extinguished at wellhead pressures in the range 10 to 15 bars (abs.).
- Venting well flow to waste when heating is not required. (The well needs to be kept flowing, otherwise it can take some time to re-start after being closed in.)

In relation to this last point, initially four (4) greenhouses of 1 hectare in area were connected to the system, requiring only 4 hours per day of heating system operation. Currently twenty four 1 hectare greenhouses are heated using the system which is therefore on continuously.

3.3 Heat Exchangers

A standard design of titanium plate heat exchangers were chosen for compactness, ease of maintenance, ease of shipment, and availability. In addition, plates can be added or removed to accommodate possible long-term changes in well output.

Because of the well's cycling flow, two identical exchangers were selected to maintain (as much as practicable) steady heat transfer conditions. As may be seen in Figure 1, the well operates for a significant proportion of time spent at low to moderate flows. So one heat exchanger will be used when the heat supply from the well is less than about 10 MWt, otherwise two will be used. Thus, the second exchanger will accommodate flow cycling (which is a short-term effect).

Two parallel exchangers also provide redundancy; if necessary one exchanger can readily perform most of the heating, except at the peak of the cycle.

In opting for two exchangers, it was necessary to ensure that a minimum flow was maintained in the unused exchanger. This avoids stagnation of geothermal fluid, and was achieved by having by-pass flows of both geothermal fluid and secondary water via small orifice plates.

3.4 Condensate & Non-condensable Gases Separation

The heat exchanger(s) condense virtually all of the steam in the two-phase fluid provided by OW-101. A knock-out drum is provided after the heat exchangers to separate the non-condensable gases from the liquid phase. The pressure in the knock out drum is controlled to a set value (related to the pressure upstream of the heat exchangers), and CO_2 from the knock-out drum is diverted to the air enrichment system and/or discharged to waste, depending on the greenhouse CO_2 demand.

3.5 Fluid Disposal

Fluids vented via the vent line, and the separate flows of non-condensable gas and liquid (brine combined with steam condensate) from the knock-out drum, are discharged into a vent silencer. Steam and gases are thence vented to atmosphere, and liquids to the existing discharge area.

3.6 Control System

The geothermal heating sub-system is controlled by a stand-alone Remote Operations Controller (ROC), which provides PID loop control, monitoring and alarm indication, logging of process parameters, and control interfacing with the greenhouse heating control system. The ROC is provided with mains and battery back-up power supplies.

The geothermal control is largely independent from the heating system controller, but certain on/off signals need to be exchanged; these are for heating on/off, and CO_2 on/off. The ROC signals which pumps are to be run, based upon which heat exchanger(s) are in heating mode.

The controls for the system are designed to be fail-safe; ensuring that equipment is protected while at the same time keeping the well flowing.

3.7 Mechanical Design Aspects

The following are the key features of the mechanical design and construction of the geothermal heating sub-system.

- Piping designed to ANSI/ASME B31.1;
- Over-pressure protection provided by bursting disks;
- Knock-out drum fabricated from pipe sections and hydrotested;
- Heat exchangers operate at low pressure;
- Carbon steel piping, except that stainless steel type 316L is used for pipe from the heat exchangers to the knock-out drum, the knock-out drum itself, and the NCG and condensate pipes downstream of the knock-out drum.
- Typical sliding pipe supports are used, which provide for movement due to thermal expansion.
- Concrete vent structure, incorporating discharge chamber and impingement plate in stainless steel 316L.

4. CONCLUSION

At the time that this paper was originally written, the heating system was under construction. Initially the system was connected to four (4) greenhouses, each 1 hectare in area. Subsequently the system has been expanded and now supports forty (40) 1 hectare of greenhouses, with an additional ten (10) 1 hectare greenhouses currently under construction.

In 2005 Oserian farm installed a 1.2 MWe Ormat binary generation plant on another Olkaria West exploration well – OW-306 which now provides Oserian with an independent electricity source primarily used to support the farms very large water pumping requirements.

In addition to utilising the separated non-consable gases produced by Well OW-101, the separated non-condensable gases from the nearby OrPower 4 (Ormat) 12 MWe plant is piped to the farm area, diluted with air and distributed through the greenhouses.

5. ACKNOWLEDGEMENTS

The authors wish to thank Oserian Development Company and, in particular its Chairman, Mr Hans Zwager, for permission to present this paper.

Mr Zwager has long promoted and pursued the use of geothermal energy for heating. While others have made use of geothermal surface features to capture steam, the use of the geothermal resource tapped by well OW-101 is the only known direct use of deep geothermal energy in Kenya, and under Mr Zwager's leadership the use of this well has been expanded. Mr Zwager is to be regarded as a pioneer of geothermal direct use in Kenya.

The early exploration work by the Kenya Power Company (now the Kenya Electricity Generating Co. Ltd - 'KenGen') and others is also acknowledged. Although well OW-101 has little practical capability for power generation, it's current use for heating demonstrates that exploratory efforts can have tangible and useful benefits, even for relatively unattractive wells such as OW-101. The benefits include the use of a naturally occurring energy source, and the environmental benefit of avoiding the use of fossil fuels.

6. BIBLIOGRAPHY

Melaku, M., Thompson, S., Mills, T., (1995). Geothermal Heat for Soil Sterilisation. In: *Proceedings of the World Geothermal Congress, 1995*. International Geothermal Association, pp 2281-2284.