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THE ROTORUA GEOTHERMAL TASK FORCE - PRELIMINARY INVESTIGATIONS

Stephen R Drew

Geothermal Task Force, Rotorua

ABSTRACT

A Geothermal Task Force field team has been established in Rotorua to investigate urgently ways of reducing the wastage of geothermal anergy. The existing level of fluid withdrawal from the Rotorua field has been confirmed to be around 32,000 t/d (tonnes/day) from 350 medium enthalpy bores. The reasons for the wastage have beer. Identified and current technology could be used to reduce substantially the overall withdrawal. However, major modifications will be required and this will cost several millions of dollars for new reticulation piping, thermal insulation, new heat exchangers and control devices. There is not a simple and cheap way of significantly reducing the drawoff and satisfying the current heating requirements. It is also likely that most of the low pressure bores will not self-flow at reduced flowrates as their production is already throttled so increased bore-sharing or group heating looks like being an essential part of the future geothermal development in Rotorua. Downhole heat exchangers could also have a role to play.

INTRODUCTION

Many visitors both domestic and overseas come to Rotorua to enjoy the hot mineral and spa pools and to see the natural thermal activity at Whakarewarewa. Since the 1940's, over 900 shallow bores (typical depth 100m) have been drilled in the Rotorua field to satisfy the heating requirements in the commercial and residential sectors. Direct utilization has been made of the geothermal energy for space heating, hot water heating, pool heating and for steam cooking. Currently there arc 350 production bores, all medium enthalpy between 500 kJ/kg to 90C kJ/kg. The majority are low pressure bores in the 500 kJ/kg to 700 kJ/kg enthalpy range. However the utilization of the resource has been based on minimum capital cost systens except for some of the larger commercia: users; the Government Departments, Hospital and Hotels. It has been well-known that these basic systems are associated with high wastage of heat as characterised by the many risible steam plumes coming from the gas vents in the thermal area.

In the last five years, there have been significant changes In the surface activity at Whakarewarewa probably related to a decline in the Rotorua field pressure. Artificial drawoff could be a contributing factor to this decline and a substantial reduction in withdrawal should benefit field pressures for the future management of the resource.

In November 1983, a Geothermal Task Force field team was established in Rotorua to investigate urgently ways for reducing the withdrawal from the field by decreasing the wastage. A multi-disciplinary engineering team was formed with experienced staff from Ministry of Energy, Department of Scientific and Industrial Research, Ministry of Works and Development and the Rotorua District Council. [illegible]

doaestic users, were set up to measure drawoff and to field test promising control devices by retrofitting the existing heating systems. The technical programme has also included testing some of the production bores aad building a test facility to demonstrate the effective use of geothermal energy Tor space and hot water heating.

DRAWOFF ESTIMATION

An estimate of the level of withdrawal from the Rotorua field can now be made. The drawoff is regularly measured at the 50 test sites and this can be supported by conticuous flow monitoring of a small number of commercial users. The spot measurements of drawoff involve no more than bypassing the waste geothermal water into a calibrated drum. This has been effective but is very time consuming, however a sound data base is being produced. In the residential sector, usage patterns vary tremendously from less than 1 t/d (a very conscientious user) to over 40 t/d (last end-user on a reticrlation system). A typical home can use between 5 to 10 t/d geothermal drawoff from the higher enthalpy bores. The drawoff increases slightly for the users on the lover enthalpy bores where homes can use between 8 to 15 t/d. Continuous flow monitoring of several commercial users has beer. done using a vortex shedding type of flowmeter in the geothermal discharge line. 'he flowmeter measures the water flowrate while the gas is bypassed to avoid the errors created by the two-phase flow. Again the pattern of drawoff is variable from low 20 t/d to high 700 t/d usage and an invaluable data base is being produced. Hore recently a portable separator rig has been commissioned to measure the total mass output and enthalpy from the larger production Sores.

The results from this sample have Seen used to estimate the output of each Sore and the overall vithdrawal from the field is calculated using a computer data base. This can only be an approximate estimate but is the best that can be done without far many more test sites. The current split in production between the two end-user sectors appears to be similar:

	NUMBER OF PRODUCTION BORES	NUMBER OF USERS	DRAWOFF (t/d)
Commercial	175	375	15,000
Residential	175	1414	17,000
			32,000

TYPICAL SYSTEMS

A typical minimum cost geothermal heating system in both the commercial and residential sectors has the following features:

- BORES
- The bores produce a steam-water mixture, with steam qualities varying from 8 to 3% w/w. *The* non-condensible gas content is generally low at 1% w/w of the steam fraction.
- RETICULATION
- Bores are normally shared by more than one user, especially in the residential sector. In most cases, the geothermal drawoff is supplied by a one-pipe system to each user. There are a few small central heat exchanger systems with a two-pipe system, with a supply and return of hot water. Most of the steel pipework is bare and is above ground.
- HEAT EXCHANGERS
- Most systems use cheaply made tube-in-pipe or shell-and-tube heat exchangers, arranged in parallel. The geothermal steam-water mixture condenses in the tubes and the secondary water flows longitudinally outside the tubes. Most heat exchangers are piped up in a counter-current manner and *very* few of the exchangers use segmental baffles to promote cross flow. The secondary water circulation commonly depends on a thermosyphon for houses and a pumped system for larger buildings.
- CONTROL
- Cheap manual valves are used to adjust the geothermal drawoff, In most cases these valves are sized incorrectly and do not have the correct characteristics for accurate control. The normal positions for the commonly used ball valves are 'heating on' - a quarter open and 'heating off' - fully closed.
- EFFLUENT DISCHARGE
- The waste geothermal fluid is discharged to a shallow soak bore (less than 30m) or soak hole. Each *soak* bore is rented to atmosphere to remove the *gas* (and steam if the temperature exceeds 100°C) at elevations to avoid high ground concentrations of *gas.*

SAVING TEE WASTAGE

The Task Force has concentrated on identifying where the geothermal energy is wasted and the scope for making savings. A typical system will waste energy by bypassing at the bore, high heat losses from the reticulation piping, in the discharged waste fluid and from the secondary systems. This wastage is reflected in increased fluid withdrawal from the field.

(1) At the Bore

The higher pressure bores produce geothermal fluid with enthalpies between 700 kJ/kg to 900 kJ/kg and show the characteristic boiling curve in their temperature and pressure profiles. These bores are self-starters and can be completely throttled so there *is* scope for reducing production by the implementation of improved heating systems. Unfortunately, there are only 20 to 30 bores in this category on the eastern side of the field and the scope for saving overall drawoff may only be around 3-5,000 t/d.

The low pressure bores (300 +) produce from hot water between enthalpies 500 kJ/kg to 700 kJ/kg which flashes in the casing over an upper 30m to 50m boiling zone where the flow is two-phase. There is a temperature drop in the boiling zone due to the reducing saturation pressure. *The* production rate declines rapidly just prior to calcite (calcium carbonate) cleaning which is required usually every 6 - 12 months. The main wastage at the bore is the need to bypass a fraction of the drawoff to keep the bore flowing. Calorimeter testa have shown that the bores are operating below their maximum well-head pressure and that their output is already throttled. Further turndown of their output producen instabilities in the vertical two-phase flow and separation of the rising steam-water

The Task Force is currently obtaining field data on this problem in an attempt to quantify the minimum output but the scope for further throttling the majority of these low pressure bores appears limited.

(2) Reticulation Piping

The one-pipe geothermal reticulation systems can beat be described by the two extremes; the 'spiders web', a ring-main with branches everywhere and the 'octopus* with pipelines emerging in all directions from the bore.

The piping is carbon steel and is not insulated therefore the transmission heat losses are considerable, A high pressure bore reticulation system is quite extensive and may hare 200m2 of piping surface area above 140°C whereas a low pressure system may have a surface area of 50m2 at 120°C. On windy days the heat losses can represent a major part of the drawoff, At lower flowrates the temperature and enthalpy drop along the pipelines will be even more noticeable. The Task Force worked on a 100m length of line of 32mm od carrying fluid at 650 kJ/kg and 138°C. Without insulation the minimum flowrate for a 4 kW space heating duty was 5 t/d. With 25.4mm of fibreglass insulation, this flowrate could be reduced to 1.4 t/d. Thermal insulation of the supply pipelines is essential. One uncertainty is to find the cheapest and best way of cladding or waterproofing the fibreglass. The Task Force is field testing a number of alternatives: aluminium, malthoid and PVC tubing, Other options are also being investigated.

Apart from the high heat losses from the bare pipelines, there are a number of other problems associated with this one-pipe two-phase flow reticulation:

- Flow Splitting - at every tee and junction where the flow splits, there will be a corresponding change in the enthalpy (the steam quality) of each stream. On one bore, next-door neighbours receive 600 kJ/kg and 1,400 kJ/kg drawoff. This sakes control and design difficult.
- Balancing - there are problems in providing a supply to cope with both normal and peak requirements and often there is a delicate balance found in each system such that if one user takes slightly more drawoff (pool filling), it starves all other users.
- Cleaning - the supply pipelines also hate to be regularly cleaned of calcite and this is now done using waste acid. Future insulation will hare to provide for cleaning. Thermal insulation of the pipeline from the bore will mean that the drawoff boils entering the heat exchanger and this will be the problem area for calcite deposition.

(3) Effluent Discharge

All too commonly the geothermal drawoff is discharged at temperatures exceeding 100°C and at enthalpies over 450 kJ/kg. The cheap heat exchanger systems and the lack of control arc the main reasons. These high discharge enthalpies can lead to boiling in the secondary water circuits which causes noise and Vibration problems, scalding hot water which is dangerous and corrosion problems arising from the open rent at the *soak* bore.

Heat Exchangers

The performance of the geothermal heat exchangers is limited by the seconday water side and the low flowrates induced by the thermosyphon circulation systems. The low velocities and lack of cross-flow outside the tube(s) arc the controlling factors. Many systems can only operate successfully at high rates of drawoff, where high temperature differences are required to compensate for insufficient heat exchanger surface area. Performance iaprovenento can certainly be made by new heat exchangers and pumped circulation systems. The Task Force has designed a shell-and-tube unit based on two-phase methods incorporated in the H.T.R.I. computer programmes. The field testing of this unit and some plate heat exchangers with pumped circulation systems is inhand.

Control Devices

It was recognised early in the Task Force work that control devices would be essential to automatically regulate the drawoff to the heating requirements. Two types of control devices are currently being field tested:

(1) Thermostatic Traps - these are used in the process industries on clean steam/condensate systems. They are cheap,(around $150) robust and are capable of limiting the temperature of the geothermal drawoff to 70 to 90°C acd can continuously pass the non-condensible gases. The performance of the Spirax-Sarco LE8 device is particularly promising.

(2) Temperature Activated Valves - these consist of a sensor filled capillary and modulating valve and can be used to control the temperature of the secondary water circuit. The valves have been developed for clean hot water supplies, Noae-the-less there are several types which art made from suitable materials for this geothernal duty and have given good service in Rotorua. The longterm performance of the most promising valves is being evaluated,

The field testing of 20 control devices on heating system using geothermal energy from the higher enthalpy bores has highlighted nany problems. In most cases the savings in drawoff have not been as high as expected because of the magnitude of the reticulation heat losses and the poor performance of the heat exchanger and secondary systems. It is now clear that control devices alone will not universally save 75% of the wastage. Some devices have failed due to deposition. On bore 501, the hard deposition product was found to be hiqh in silica as well as aluminium and it could be a sodium aluminium silicate. Devices on this bore will require regular cleaning and maintenance. The control devices have also been relatively expensive to install because of piping modifications and they have created many balancing problems between interconnected users and parallel heat exchanger systems.

It has been shown many times before in Rotorua and now by the Task Force that 80°C and 330 kJ/kg are reasonable discharge temperatures and enthalpies for the design of geothermal heating systems. The Task Force has modified one house with a new heat exchanger, pump and control device such that the geothermal effluent is discharged below 75°C. The drawoff requirements were reduced from ? t/d to , t/d.

(4) Secondary Systems

As the geothermal drawoff is essentially free, there has been little incentive to users to install well designed secondary systems to make effective use of the heat- The piping, much of it external to buildings is unlagged so again the heat losses are high. There is a lack of basic thermostat controls to regulate radiator temperatures, hot water and pools. Scalding water from taps is common so too are hot thermal pools requiring excessive amounts of cold water to coo? them to 40°C. Many of the hot swimming and spa pool; operate on a once-through water heating system and nos: of them remain uncovered when they are not in use so the evaporation heat losses are high. Tt has been estimated that a considerable number of pool. are wasting 90% of the heat.

It has also tecoae apparent that future improvements to the geothermal side of tho heating systems will also have to go hand-in-hand vith improvements to the secondary systems if significant savings in drawo If are to be made.

AN EXAMPLE OF THE SCOPE FOR SAVING WASTAGE

A not untypical residential heating syoten could be using 12 t/d drawoff at an enthalpy of 600 kJ/kg for space heating. The bore does not require bypassing as it supplies several users and the system consists of the typical bare piping, a thermosyphon heat exchanger system and manual valves (see figure 1). The geothermal drawoff is discharged at 105°C and at an enthalpy of 440 kJ/kg. The performance of the system can be described by the T/H (temperature/heat content) diagram in figure 2 and the heat load distribution in figure 3. The thermal effectiveness of the system is 5%; 2.5 kW of useful heat in the radiators for space heating from an available 50 kW in the drawoff. This is the heat available above 60°C which is the return secondary temperature and the target approach temperaturo if all the heat could be utilized in the goothermal drawoff.

FIGURE 1: EQUIPMENT FLOWSHEET OF A TYPICAL RESIDENTIAL SPACE HEATING SYSTEM

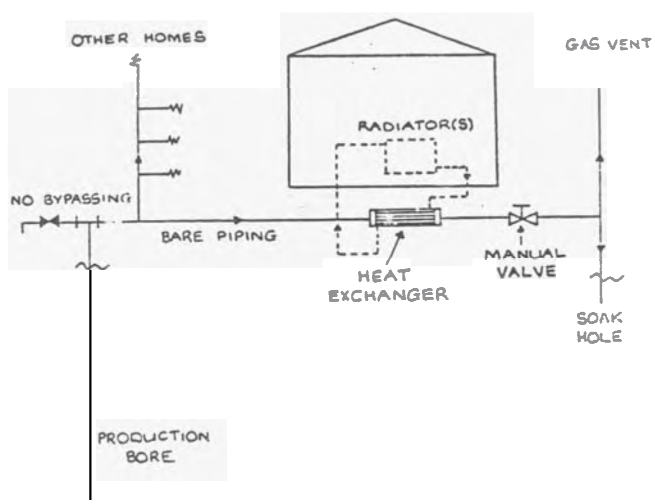
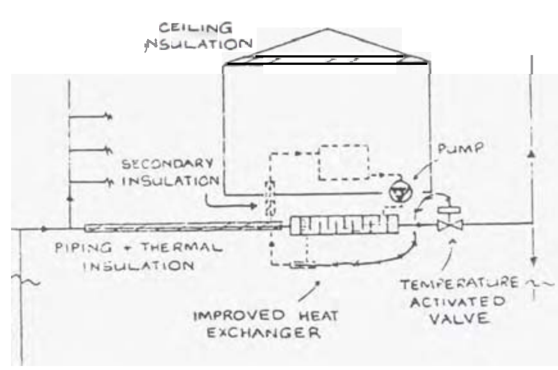


FIGURE 4: EQUIPMENT FLOWSHEET OF A MODIFIED RESIDENTIAL SPACE HEATING SYS



The heating system can he improved by the following features shown in figure 4:

- Thermal insulation of the geothermal supply and the secondary piping and in the ceiling space of the building,
- A new heat exchanger and pumped secondary systen,
- A temperature activated control device.

3 t/d of drawoff is now required. The thenal effectiveness of the system has been increased from 5% to 40% 'out more importantly 75% of the original drawoff has been saved, Figures 5 and 6 illustrate the improvements in the T/H diagram and the magnitude of the heat losses. In particular it is worth noting that:

- 5 kW heat is available for the space heating, the domestic hot water and the pool heating,
- the geothemal effluent is discharged at 80°C and enthalpy 330 kJ/kg so there will be less problems at the soak Sore,
- the system is controlled automatically to balance the geothermal supply with the heating requirements,
- thermostat control devices can be used on individual radiators for improved home comfort levels,

FIGURE 2

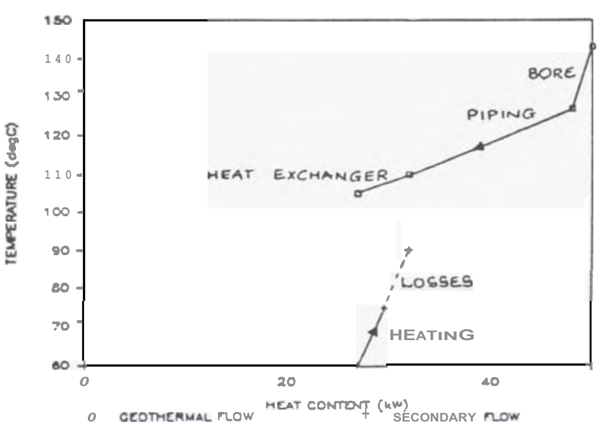
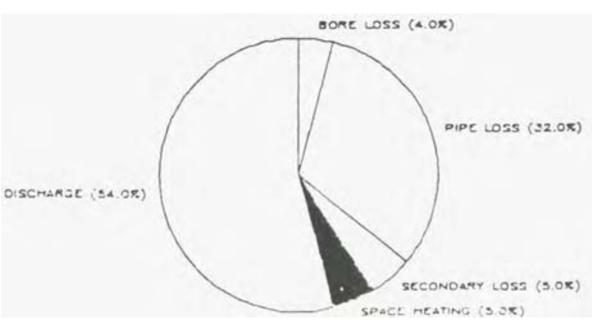


FIGURE 3

BREAKDOWN OF GEOTHERMAL HEAT LOADS

EXISTING (12 t/d)



The Task Force office has been set up to demonstrate

3 to 4 kW nnd it is anticipated that the normal rate of drawoff will he between 1 t/d to 2 t/d which compares to a drawoff of 14 t/d before the system was improved.

FIGURE 5

PERFORMANCE OF MODIFIED SYSTEM

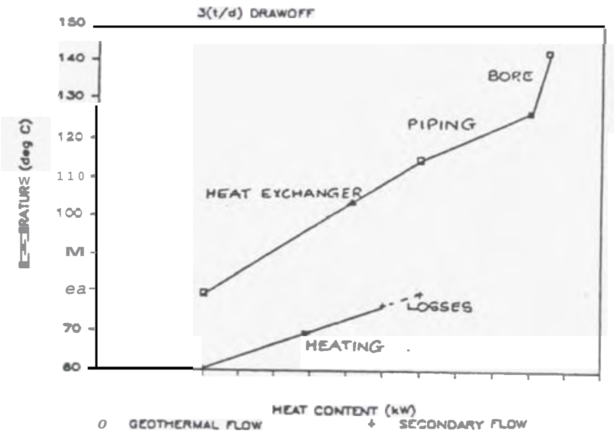
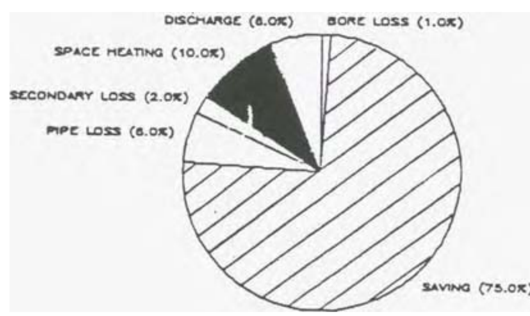


FIGURE 6

BREAKDOWN OF GEOTHERMAL HEAT LOADS

MODIFIED SYSTEM (3 t/d)



DISCUSSION

The level of drawoff from the production bores can now he confirmed at around 32,000 t/d. A more precise figure cannot be obtained unless far more random sampling is carried out and this does not appear to be practical. This level can also be compare.! to the natural outflow from the surface activity at Whakarewarewa which is around 8,000 t/d. It has been suggested that a recovery of the Rotorua field is possible if the production rate can be reduced to this level. The Task Force has shown that the wastage is such that there is scope for 75% savings by most users so it appears feasible to ai3 for this target level of production.

However there is not a simple and cheap was of doing this and major modifications, if not totally new heating systems will be needed. These will he more expensive which nap make geothermal not so commercially attractive especially as natural gas will he an alternative in Rotorua. The comparison of heating costs for tho various energy supply options it; being carried out by the Task Force.

There is also the possibility that more effective heating systems will provide additional problems which should not be overlooked:

Further throttling of the low pressure bores may not be practical so fewer bores will be needed.

- The one-pipe geothermal reticulation system will still have major balancing and calcite cleaning problems.
- The heat exchangers will have to be cleaned mare frequently to remove calcite deposits. This may not be a practical proposition as more effective heat exchangers may block over several days.
- There will be higher maintenance costs for the pumps and control devices.
- The new systems must be able to cope effectively with both winter and summer load conditions. Existing bores may not be able to satisfy this requirement.

There is no doubt that the total costs of modifications required for all ths heating systems will run icto millions of dollars if the total fluid withdrawal from the Rotorua field has to be reduced. A new approach for using the resource may be justified.

Group heating could replace a number of bores by one production bore with the drawoff going to a deep injection bore. A central heat exchanger and control device could heat a low or medium pressure hot water raticulation system. This would resolve all the problems associated with geothermal reticulation. Metering of hot water to consumers is also possible and this would encourage energy conservation.

Downhole heat exchangers may also have a role to play especially if they can provide sufficient heat from an existing low pressure bore. There will be no net removal of drawoff. Syndicate groups would be able to aaintain their current independence.

The Task Force will be investigating both of these future options in order to recommend the most cost effective way of reducing withdrawal for the future management of the Rotorua field.

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