DOMESTIC AND COMMERCIAL HEATING & BATHING ROTORUA AREA

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INTRODUCTION

Geothermal resources in the Rotorua area have been put to a number of practical uses, many of which are described in this article.

The use of the geothermal resource in this region has a long history, well and truly pre-dating European settlement. The earliest uses were for bathing, washing and cooking, these being made possible by the existence of suitable natural features.

Today, geothermal is applied to a variety of domestic and commercial heating and other purposes. It is used for both the heat it can provide and the "mineral" water content of the fluid; however, geothermal is not available over the whole city.

Increasing usage during the post-war decades was linked to the apparent decline natural activity at Whakarewarewa. In the 1980s, the government implemented a control program that, amid other things, resulted in the closure of wells within 1.5 km of Pohutu geyser.

CURRENT USES OF THE GEOTHERMAL RESOURCE

Parklane

This is a housing development with a geothermal group heating scheme. There are 13 units on this site, which share a well with six other dwellings on adjoining properties. Sixteen of the total are supplied with a circulating supply of hot water from a single heat exchanger. The other three receive geothermal fluid and have their own, smaller heat exchanger arrangements. This is a relatively early example of a scheme that distributes secondary water rather than recirculating geothermal fluid. The heat is used for space heating, domestic hot water heating, and, in some cases, heating small pools.

This system is quite successful and relatively neat, with much of its distribution piping underground. However, there are a number of design weaknesses which have contributed to piping corrosion, internal and external, and difficulty in getting adequate circulation to some users.

Queen Elizabeth Hospital

Queen Elizabeth Hospital is an example of institutional use of geothermal. Geothermal fluid is used not only for space heating and domestic hot water heating; but, the water phase is taken for therapeutic purposes.

Millennium Hotel

Commercial use of geothermal occurs in a number of hotels and motels, and other facilities. The Millennium Hotel is a case in point. Here geothermal is used for space heating, domestic hot water heating, pool heating (in this case, a medium-sized swimming pool and a number of spa pools, all using fresh water). High-temperature hot water is also generated for cooling purposes and, perhaps the most interesting of all, there is an absorption chiller for the air-conditioning.

Aquatic Centre

The Rotorua District Council's Aquatic Centre is another good example of the use of geothermal on a relatively large scale. This complex has two indoor pools and a larger outdoor pool. All three are heated. In addition, geothermal energy is used for space heating and for domestic hot water heating.

All of the geothermal fluid is passed through a single plate-type heat exchanger, which heats the secondary water, which is a circulating system of town water. This, in turn, supplies all the various heating services.

In this case, because of the high capacity of the geothermal heating system, the domestic hot water (DHW) supply (used for showers and hand basins) is heated on an as-required basis, avoiding the cost of installing a large storage calorifier. The cold mains water feed is passed through a small heat exchanger fitted with an automatic temperature control. There is a small buffer tank in the circuit, sized to absorb the swings in temperature in the hot water that occur when there is a big change in the demand.

Figure 1. Aquatic Center indoor pool.

The ventilation system for the pool building has been designed to minimize chlorine odor and keep the internal atmosphere as pleasant as possible. To achieve this, a relatively high air flow rate, once-through system has been provided. No air is recirculated. The incoming air is heated to maintain the building's internal temperature. A heat pipe, heat recovery unit has been incorporated to significantly reduce the high heat losses that would otherwise occur. The hot, moist, chlorine-laden air being extracted gives up most of its heat as it passes through the heat recovery unit, which uses it to preheat the incoming air. This unit recovers about 75% of the heat in the exhaust air. The heating of the fresh air is completed by a heating coil through which low-temperature hot water (LTHW) is circulated.

OTHER EXISTING USES

Space heating generally refers to the provision of comfort heating in an occupied building. Another variant is in-building heating for commercial purposes such as glasshouse operations. The Rotorua District Council nursery in the Government Gardens is a case in point.

Space heating is virtually always accomplished by the use of a LTHW system. This is a system in which a heat source–in this case hot geothermal fluid–is used to heat "clean" secondary water. "Low" temperature in this context does not mean cold. It refers to a heating system operating at a relatively low temperature, typically less than 100ºC. The secondary water is circulated through a heat dissipating device, usually flat panel-type radiators, but sometimes fan coil units, unit heaters or bare pipes.

Domestic hot water (DHW) means hot tap water, used for normal washing and sanitary purposes, in dwellings and other premises. DHW heating is a natural adjunct to space heating where geothermal is employed as heat is normally available throughout the year. This is not always the case with LTHW heating systems which are fueled by gas or coal since they are often only put into service during the heating season and the DHW is heated by electricity to assure a year-round supply.

Pool heating is one of the major uses of geothermal. Pools either contain town water which is heated by geothermal, as at the Aquatic Centre, or geothermal water ("mineral" pools).

The Polynesian Spa is no doubt the best known example of direct mineral pools. The pools shown here are built around natural springs with the inflow coming up through the sandy bottom of the pools. Other pools in this complex, use piped-in mineral water.

Figure 2. Polynesian Spa outdoor pools with temperatures from 34 - 44ºC.

Cooking has been a use of geothermal heat from pre-European times. There are still to be seen households with small, enclosed steam boxes outdoors which are used for steaming food.

Therapeutic uses - the reputed therapeutic benefits for geothermal waters has long been exploited. In fact, it was intended early in Rotorua's existence that it should become a spa in the European fashion. The Bathhouse, opened in 1908 complete with the latest balneological equipment and related treatments then in vogue in Europe, was built for this purpose.

The Bathhouse is now the city museum; but, hydrotherapy still continues at Queen Elizabeth Hospital, to which these treatments were transferred in the 1950s. At QE, geothermal water is used for the usual space heating and DHW heating services. Part of the effluent (that is to say, the partially cooled geothermal water) is collected and cooled further, and degassed in a concrete vat, and then piped to the Hydrotherapy Department.

Figure 3. Rotorua Bathhouse, opened in 1910–now a museum.

SYSTEMS, PROCESSES AND EQUIPMENT

Wells

Two systems of heat extraction are used:

- fluid removal and re-injection
- downhole heat exchangers.

The former are by far the more common, there being about 240 operative in this area, of which about 100 are for domestic systems. Wells of this type typically can have maximum outputs of the order of 1 to 3 MW (thermal).

Referring to the extraction and re-injection system, supply wells in Rotorua can be classified as self-starting, self-sustaining, and pumped.

Self-starting wells will, when shutdown, maintain a pressure against the stop valve and will flow again when the valve is opened.

Self-sustaining wells do not maintain a positive well-side pressure when shut down and do not flow of their own accord when the shutoff valve is opened. Flow is induced by introducing compressed air into the well. Once a flow has been established, it will then continue without further assistance. The majority in Rotorua are of this type.

Pumped wells cannot be induced to flow without assistance and have to be continuously pumped or air assisted. The ususal process is to air lift the fluid. This is sensible in that the operating conditions of temperature and fluid contamination are very severe for mechanical pumps. However, the continuous introduction of air into a well has long-term corrosion implications.

The vast majority of wells in Rotorua have 100-mm diameter production casings; although, sizes from 65 to 125 mm do exist. The smaller sizes are often larger wells which have been repaired by fitting a sleeve inside the casing. Wells in Rotorua are typically about 100 m deep, ranging from about 45 to 190 m. Aquifer temperatures vary from about 125 to 175°C.

Distribution Systems

Distribution of the geothermal energy can be either by piping the geothermal fluid to each user or by employing a central heat exchanger and piping a circulating supply of low-temperature hot water (LTHW). Both types of systems are used. Systems can be a hybrid of the two.

Figure 4 is a schematic diagram of a well conceived system of the second type (LTHW distribution), which is quite close to the Parklane system referred to earlier.

The principal features are:

- A single heat exchanger supplies LTHW to a number of users,
- The geothermal effluent goes to a deep injection well,
- The flow of geothermal is controlled to maintain the secondary water supply temperature constant,
- The temperature control valve is on the outgoing side of the heat exchanger,
- The isolation valves are fitted, to enable the user's system to be shutoff from the main system,
- Space heating is by radiators fitted with thermostatic valves,

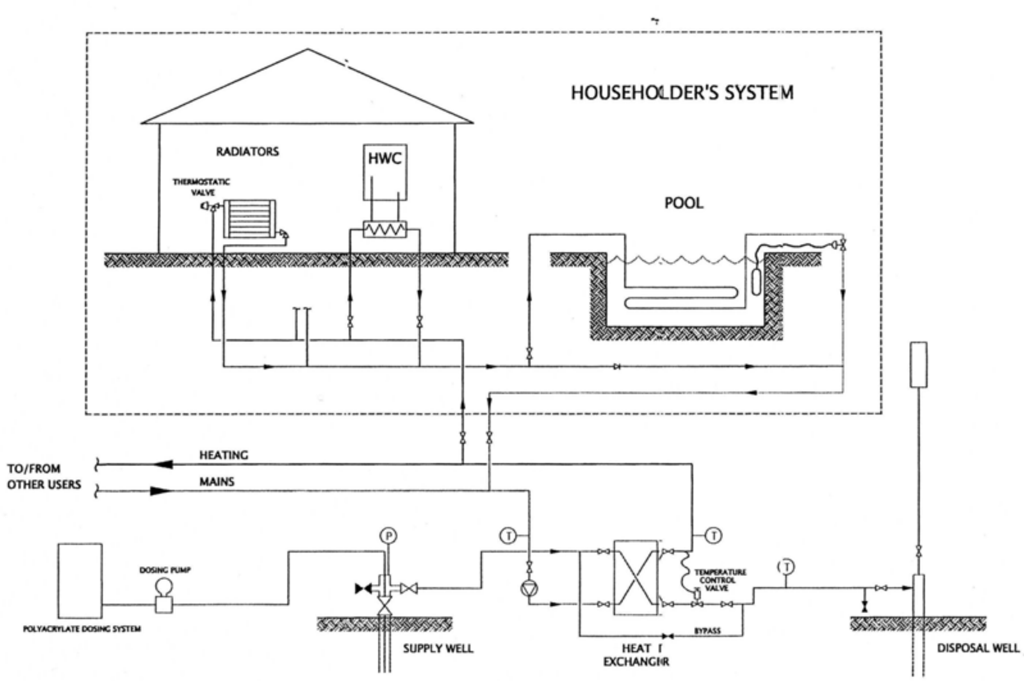

Figure 4. Group heating scheme - based on the reticulation of low-temperature hot water.

- The DHW cylinder has it own heat exchanger, or equivalent (such as pipe coil in hot water cylinder),
- The DHW system incorporates a mixing valve (not shown) which limits the water supply to a safe temperature,
- The pool, if any, is heated by the lower temperature, return side of the user's systems; thus, lowering the temperature of the return water and enabling more heat to be extracted from each kilogram of primary fluid, and
- The pool has a thermostatic control valve to maintain its temperature constant.

A system may have more than one heat exchanger, each serving a proportion of the users.

What this type of system des not do, is provide mineral water for pools or cooking. If raw geothermal fluid is required, then there can be either a separate geothermal fluid line to those users who want it or, alternatively, a geothermal distribution-only type system adopted, with each user having his own heat exchanger and LTHW system.

Heat Exchangers

The heat exchangers used these days are commonly of the plate type.

These heat exchangers have a very high capacity for their size. The main heat exchanger for the Aquatic Centre, for example, occupies less than one square meter of floor space, but can transfer several thousands kilowatts. They are also relatively easy to disassemble and clean.

Not all plate heat exchangers are suitable for geothermal duty and the manufacturer's recommendations should be sought when specifying or procuring them. Fatigue cracks have occurred in plates of an unsuitable design as a result of vibration induced by the two-phase geothermal flow. The plate seals also need to be correctly chosen. High-temperature seals are required for geothermal applications.

The alternative is the shell-and-tube type. These were once the standard, but are not now so common. For households and small systems, these were generally very simple, fully welded units with only a small number of internal tubes.

OTHER ISSUES

Hazards

The first is the presence of hydrogen sulphide gas in the geothermal fluid. H_2S is what gives Rotorua its characteristic smell. In small concentrations, it is easily smelt. In larger concentrations, it may not be detected and can be fatal.

It is not permitted to use geothermal fluid in plant in an enclosed space without ventilation or in a habitable space. Hydrogen sulphide is heavier than air. A small leak in a piping system will lead to the escape of gas and its accumulation at low levels in rooms, ducts, trenches, and the like. There have been fatalities as a result of H_2S escape.

Pools using geothermal water direct need to be fitted with a gas separator to ensure most of it is removed before the water gets to the pool. The pools enclosure also needs to be thoroughly ventilated.

A particular problem was the use of uncontrolled domestic hot water systems. Systems delivering water at near to boiling point were not uncommon at one time and, again, very unfortunate accidents have resulted. Fortunately, this is now easily fixed as there are relatively simple and low-cost thermostatic mixing valves on the market which control the water temperature to a safe level. These are mandatory in new installations.

Calcite Precipitation

Calcite (calcium carbonate) precipitation is frequently a feature in the operation of geothermal systems in Rotorua. This phenomenon occurs where CO_2 comes out of solution from the geothermal fluid. Precipitation, therefore, tends to occur in production wells in the zone where the fluid flashes to steam. For the same reason, it is important that where a throttling device (such as a control valve) is installed in the primary circuit, that it is fitted on the downstream side of the heat exchanger. Not only should flashing not occur at the lower temperatures prevailing there, but the solubility of calcite is greater at lower temperature.

Precipitation is sometimes suppressed by the dosing the supply well with polyacrylate. Systems where this is done have a small bore stainless steel pipe inserted into the well, so that the liquid polyacrylate is injected in the boiling zone by means of a small dosing pump.

Costs

Costs vary widely from installation to installation and the following figures should be taken as a guide only

Domestic group schemes - These figures refer to the installation of new heating schemes (NZ$ 1.00 = US$ 0.50).

The typical costs of the elements of a group heating scheme are:

Well - supply or re-injection	NZ$ 24,000 each well
Installation of household heating system	NZ$ 8,000 - 16,000 per household
Central distribution system	NZ$ 2,000 - 4,000 per household

Normally, two wells will be required for a group heating scheme: one for the supply and the other for reinjection. Commercial or institutional systems may require more wells, to achieve the required capacity or for backup. For a group scheme, the cost of the wells will be shared among the users.

Installation costs for individual dwellings will be less where LTHW is distributed from a central system than for those on a primary geothermal fluid supply, since individual heat exchangers and some control elements are not required. However, a connection charge, to the central system will be greater because of the greater complexity and cost of that system.

For each user on a new scheme, the minimum cost will be about NZ$ 12,000, covering a share of two wells, a share of the distribution network, central heat exchanger and related equipment, and the user's own in-house equipment costs. The cost could well be considerably greater.

Running costs are likely to be of the order of NZ$ 20 - 40 per month, say $300 per year.

The monthly operating charge can vary significantly, depending on how the operating syndicate structures its charges and what items it covers. Charges need to recover well clean outs (about NZ$ 1,000 a time) which may be required very few months or at intervals of several years, general maintenance, well inspection costs and, if applicable, doing chemical costs. In addition, charges may be levied for long-term equipment replacement or for capital recovery.

Comparison with electric heating - A comparison with electricity, normally regarded as a high-running cost option, is instructive. An all-electric home, operated modestly and economically, is likely to spend NZ$ 1,200 per year on power, of which about $700 will be for water heating and space heating. On the (unlikely) basis that a geothermally-heated home used the same amount of energy, then:

Cost of geothermal system	NZ$ 12,000
Annual running cost	NZ$ 300
Electricity cost	NZ$ 700
Annual savings in operating cost	NZ$ 400
Rate of return	3.3%

Clearly, a geothermal user, not having to pay a unit charge for geothermal heat, will consume more energy. However, even if the consumption was four times that of the ordinary electricity user, the return on capital is still only about 13%.

A geothermal system for domestic heating is not, generally, a sound investment when the full cost of installing a new complete heating scheme has to be paid; although, it should be noted that each situation needs to be judged on its own merits. If pool heating is required, for example, the economics changes significantly.

The situation becomes less clear when considering a property in which geothermal is already installed. In this case, the premium, if any, that one pays for such a property, becomes the capital cost element. Valuers will add about NZ$ 2,500 to 3,000 to the value of a typical property, and up to $5,000 for a very large dwelling if geothermal heating is installed.

Large-scale users - The economics can be very different for large-scale users. In many cases, particularly with institutional users, fossil fueled heating systems will be of the low- or medium-temperature hot water type, similar to a geothermal system. In the one case, the secondary system will be heated by a boiler and the other with a heat exchanger; but, the secondary circuit system will be the same.

The equipment costs will be of a similar order of cost, unless of course, boiler plant is also installed to provide backup capacity.

Apart from the plant maintenance costs and minor items such as bore inspections, the energy costs are zero.

Of the large users in Rotorua, the Aquatic Centre has annual maintenance costs for its geothermal system of NZ$ 20,000. If natural gas were used to provide the energy, the estimated gas cost would be around $150,000. Another major user has heating plant maintenance costs of around $5,000 per year and achieves a similar energy cost savings, conservatively estimated at NZ$ 140,000 per annum.

SUMMARY

- Geothermal has been successfully used in Rotorua for many years,
- Geothermal energy is principally used for heating: space heating, domestic hot water and fresh water pool heating.
- Mineral pools, using geothermal water direct, are also a significant use,
- Most systems obtain the energy by using a well to extract geothermal fluid (water, steam and non-condensable gases), which is passed through a heat exchanger to heat fresh water and is then reinjected, preferably to the geothermal aquifer.
- Historically, geothermal heating systems, small-scale systems in particular, were simple and relatively primitive and had low-energy efficiency,
- The use of geothermal is being greatly improved by the use of appropriate designs and automatic controls, both in terms of energy use efficiency and the effectiveness, benefit and safety of the results,
- For households and small installations, geothermal heating has a high capital cost and the economics are poor, and
- For large installations, the capital costs are more akin to fueled heating systems. The unit incremental cost of the heat obtained (over and above the fixed costs) is very small. There is, therefore, little capital cost penalty for using geothermal, but potentially major savings in running costs. The economics of large systems can be excellent.