Future developments – in geothermal

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Abstracts: .

A number of other approaches are being developed to increase the efficiency o generation from lower temperature fluids, using either different working fluids or new power cycles such as the Kalina cycle. Thelatter uses as working fluid an ammonia-water mixture, the composition of wich varies throughout the cycle. Capital costs are expected to be significantly lower than for ORC and the net generating efficiency up to 40% higher; at an inlet temperature of 130^0C the net efficiency is estimated at over 13%. The early demonstration plant are still showing teeting problems, but the operators remain optimistic.

Keywords: ***heat pumps, geothermal, low-enthalpy***

RESOURCES FOR DIRECT USE GEOTHERMAL ENERGY

Some of the countries that are exploiting Geothermal resources for non-electrical purposes have chosen to develor these direct use applications in areas flanking the main steam fields. Japan, new Zealand, Iceland and Italy are obvious examples, where wet steam or warm water at a range of temperature is readily available for industrial, domestic and leisure applications. We are concerned principally with the low-temperature resources found in sedimentary basin areas, several of wich have been developed across central Europe. Drilling techniques resemle those discussed earlier, but the process is generally less hazardous since the geothermal fluid is found under much lower pressure and temperature conditions than in hot steam fields, and pumps are usually required to bring the fluid to the surface at adequate flow rates. However, the hot water is usually too saline an corrosive to be allowed directly into heating systems, so once again corrosion-resistant heat exchangers are widely used. The secondary circuit might be a vast greenhouse complex using both aerial and underground pipes, or it might be a domestic heat load with a combination of underfloor and radiator pipes. The dense multistorey apartment blocks of the Paris suburbus are ideal heat loads for these local resources.

The French led the development of these low-entalpy resources in Europe. Over the last 30 years no less than 55 group heating schemes were installed in the Paris Basin, with several more in south-western France. At the design stage, a twin production and reinjection borehole system would be planned on the basis of supplying between 3 and 5 MW_t of heat energy (25-50 ls^{-1} of water at 60-70^0C) over a lifetime of 30-50 years. The spacing of the wells must be designed to maintain high fluid pressures by reinjection while avoiding the advance of a cold front (i.e. fluid at reinjection temperatures) towards the production well until capital costs are paid back, and this means that flow conditions in the aquifer need detailed study. A typical layout for a twin production well scheme, with a schematic of the heat transfer technology, is shown in Figures 1 (a) and (b). In figure 1(b) note the interesting application of heat pumps to enhance the system efficiency by reducing the reinjection temperature. Heat pumps work on the same principle as refrigerators, but here produce a concentrated high temperature output. Of course, they consume electrical energy but, in the example shown in Figure 1 (b), they enable the number of heated apartments to be doubled.

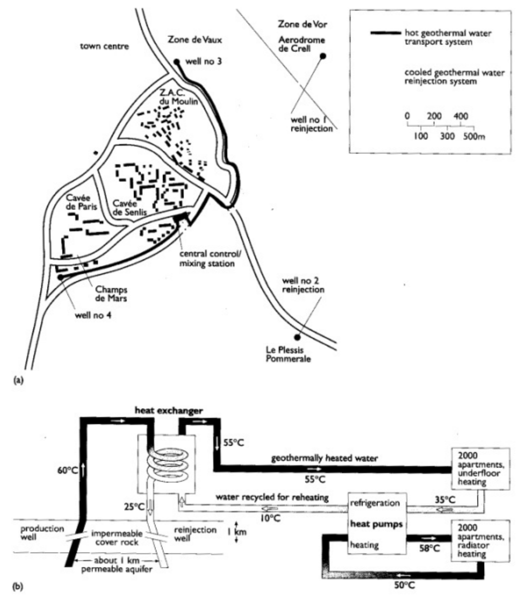

Figure 1. The Creil district heating scheme installed in 1976 noth of Paris

(a) Map showing location of two production and two reinjection wells, and the various apartment blocks served by the system

(b) This shows how the geothermal heat is exchanged to a secondary freshwater circuit

Although the Franch group heating schemes have been a great practical success, their economc benefits were only marginal at times of low oil prices, increasing availability of natural gas and high interest rates. For this reason, development work stopped during the period 1989-1992. A few schemes were abandoned, for tecnical or economic reasons, but some 45 remain in operation and new and extended schemes are being planned. Currently, they produce a saving of over 200000 tonnes of oil (or equivalent in other fossil fuels) per year in an area which, 30 years ago, had no obvious geothermal potential. The same concept applies to the analogous UK scheme in Southampton.

In Germany, reunification has had a significant effect on the way in which geothermal developments have occured; the better (though still low temperature) resources tend to be concentrated in the eastern part of the country. Although a few schemes existed before reunification, with the freeing of capital folowing unification these are really beginning to take off. Several large scale district heating schemes are already in operation and even more under active development. By the end of 1999 direct thermal use of geothermal energy in Germany amounted to an installed thermal power of roughly 397 MW_t. Of this total, 27 major centralized installations accounted for approximately 55 MW_t. Ground source heat pumps are estimated to contribute an additional 342 MW_t and a substantial number of new schemes, both large and small, are under development.

GROUND SOURCE HEAT PUMPS

Between 1992 and 2000 the capacity of direct heat installations worldwide increased from 400MW_t to 16000 MW_t. In fact, the increase in large installations like those described above has been accounted for by a new type of geothermal installation, the ground source heat pump (GSHP). The general arrangement is illustrated in Figure 2.

Unlike other geothermal techniques, this one relies on heat transfer by conduction from the walls of the borehole, not on the extraction of groundwater.

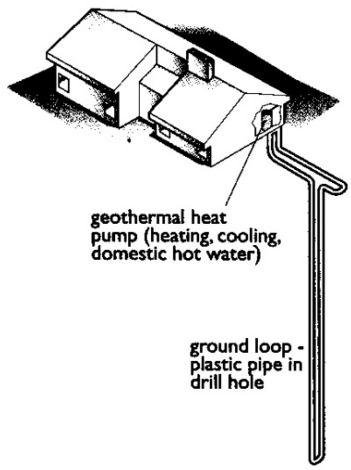

Figura 2. The geothermal heat pump (GHP) concept used to extract heat from warm shallow grounwater to supply a single domestic dwelling. In the winter heat is removed from the earth and delivered in a concentrated form via the heat pump. Because electricity is used, in effect, to increase the temperature of the heat, not to produce it, the GHP can deliver three to four times more energy as heat than the energy content of the electricity it consumes

The heat available from a well 100-150 m deep is only a few kW_t, but that is sufficient for a single domestic installation, and boreholes of this depth are cheap enough to make the installation competitive with conventional heating systems. A simple loop of pipe is inserted in the well and grouted in place. A heat transfer fluid (usually water) circulates in the loop and transfers heat from the surrounding sub-soil to a heat pump. More than 15 years`experience has shown that a few kilowatts can be extracted throughout the heating season; the sub-soil temperature drops by a few degrees but regenerates over the remainder of the year (Figura 3).

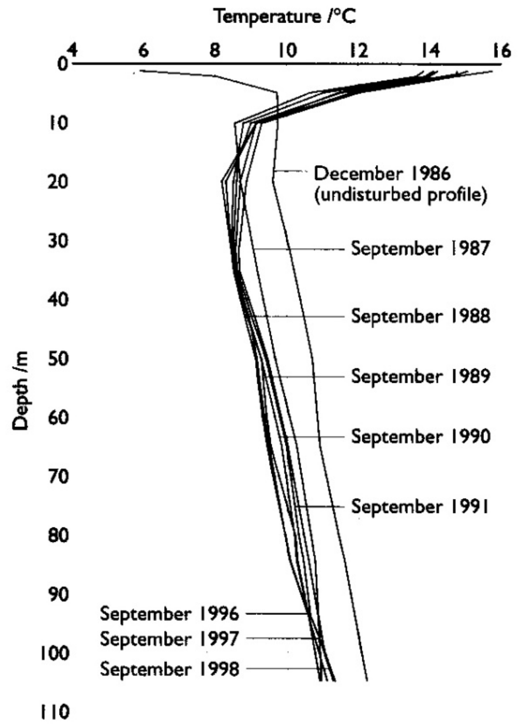

Figura 3. Measured data from a Swiss GSHP installation. After an initial drop, the ground temperature below the solar-dominated surface zone recovers to the same valur year after year. This appears to be a truly renewable operation.

Table 1 shows the rate at which energy can be extracted – on a quasi-continuous basis – from typical 100-150 m deep holes.

Table. 1 Borehole heat exchanger performane in different rock types

Rock type	Thermal conductivity ($Wm^{-1}K^{-1}$)	Specific extraction rate (Wm^{-1})	Energy yield per metre of borehole ($kWhm^{-1}a^{-1}$)
Hard rock	3	max 80	135
Unconsolidated rock, saturated	2	45-50	100
Unconsolidated rock, dry	1.5	max. 30	65

If reversible heat pumps are used, the same systems can provide cooling in summer with the advantage of helping to recharge the underground and so increasing the sustainable heat extraction from the system. It shouldbe emphasized that, unlike other geothermal systems, GSHPs are ideally suited to the domestic scale with a single module providing just a few kW_t.

Because the presence of groundwater is not a prerequisite, this technology can be applied almost anywhere. The types of buildings that are using ground source heating and cooling in this manner range from small, utility or public housing, through to very large (MW sized) institutional or commercial buildings. This technology can ofter up to 40% reductions in CO_2 emissions against competing technologies. Better still, if the electricity to drive the heat pump is supplied from non-fossil sources, then there should be no CO_2 emissions associated with heating and cooling a building. The concept was developed independently in the US and Europe and, although Sweden and Switzerland have installed many thousands of units to provide winter heating in houses (the growth rate in Switzerland is 10% per year), the activity in USA and Canada in the last fifteen years has overtaken the European installation rate. The number of installations in North America is now approaching half a million.

Recently, several large scale arrays have have installed in the US to feed larger complexes where suitable supplies of deep geothermal water are not available. In the largest developments to date, 4000 units – each with its own borehole – have been established on a US Army base in Louisiana to provide heating and cooling. Peak electrical demand has dropped by 6,7 Mw_e compared with the previous installation, gas savings, gas savings amount to 2,6TJ $^{a-1}$ and – perhaps most telling of all – service calls have dropped from 90 per day in summer to almost zero.

Installation of such units has begun only recently in UK; there are probably around 70 installations. A geotechnical consulting group has been heating its offices in this way since 1996. In 1998 a 4-borehole system was fitted in the new Health Centre at St. Mary`s, Isles of Scilly using a 25 kW reversible heat pump to supply hot water, heating and cooling to the building. Science then, there have been a number of larger, non-domestic installations in the UK.

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