URBAN HEATING FROM GEOTHERMAL AQUIFERS IN THE PARIS BASIN

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Abstract

A total of 10,000 apartments are heated at present by combining the geothermal source with auxiliary boilers and heat pumps in an area of normal geothermal conditions (average geothermal gradient 33°C/km = 1.8°F/100 ft.). The geothermal contribution which supplies domestic hot water as well amounts to about 70% of the total heat consumed. The resource consists of a deep aquifer (porous Dogger limestone). Due to the high salinity of the formation water (up to 25 g/L) produced, reinjection is necessary. This is performed by the "doublet" system which consists of a twin well (production-reinjection). Typical production rates are 100 m^3/h (440 gpm) at 60-70°C (140-158°F). Noticeable temperature drawdown at the production well is not expected before 30 years. Economic analysis shows that the geothermal system is slightly less expensive (at 1977 fuel prices) than conventional fossil-fuel schemes. The French authorities strongly support this development (the risk of the production well is covered by the government) which aims at 800,000 geothermally-heated apartments in the Paris basin by 1990.

1. Introduction

Geothermal installations for space heating and domestic water supply have been in operation in the Paris basin since 1969. The main characteristic of these sites of low-temperature geothermal energy utilization is the relatively high density of dwellings (apartment blocks) which are heated by combining the geothermal source with heat pumps and conventional sources. Geothermal heating for the majority of the dwellings (with a total of 10,000 apartments at present) has been installed quite recently, thus data on the long-term performance are not yet available. The systems are claimed to be economic; it must be pointed out, however, that the main factors affecting the economics are the interest rates that are paid on funds borrowed to carry out the project and the sales price of energy sold which in turn are determined by government decision. In France, the government strongly supports the development of geothermal energy, a domestic energy source.

2. The Resource

The Paris basin is a regularly structured sedimentary sequence which resembles a pile of dishes, the deepest part being located at the center of the basin. Several formations are known from hundreds of oil exploratory drillings to be independent aquifers. At successively greater depths one finds Albien, Middle Cretaceous and Purbeckien sandstones, porous Lusitanien and Dogger limestones and various other porous rocks (Lias, Rhaet, Trias, Devon). The aquifers contain essentially old connate water (water trapped at the time of deposition) with correspondingly high salinity.

The geothermal setting of the Paris basin is quite normal; pronounced anomalies are absent. The mean temperature gradient is around 33°C/km (1.31°F/100 ft). Detailed documentation (Housse & Magis, 1976) summarizes the aquifer characteristics: depth, porosity, permeability, transmissivity (=permeability x thickness), temperature and salinity of formation fluids.

The main target of exploitation is the porous Dogger limestone. Typical reservoir parameters (at the Creil site) are: water temperature 65°C, useful reservoir thickness 90 m (300 ft.), porosity 15%, permeability 300 md, salinity 25 g/L, artesian flow rate 150 m^3/h (660 gpm). The total extension of the Dogger reservoir within >50°C (>122°F) formation temperature is about 15,000 km (5,800 mi^2).

3. Extraction Technology

The main characteristic of the Paris basin installations is the so-called doublet system which consists of two drillholes: a production and a reinjection hole. Fig. 1 shows the installation scheme. Reinjection of the used fluid is necessary mainly due to environmental concerns since it is unacceptable to dispose the high salinity fluid produced (around 60 tons of dissolved solid per day) into any surface drainage system. The advantages of reinjection are:

- chemical and thermal pollution of the environment is minimized
- the aquifer is kept recharged so that pressure should be maintained throughout the lifetime of the system

- recycling the water offers the possibility to extract heat from the rock matrix as well.

Disadvantages are:

- precipitation of dissolved solids from the cooler reinjected water may plug the strata surrounding the reinjection well
- the electric power required by the reinjection pumps reduces the energetic balance of the installation
- short-circuiting of cool water could result in premature lowering of the output temperature.

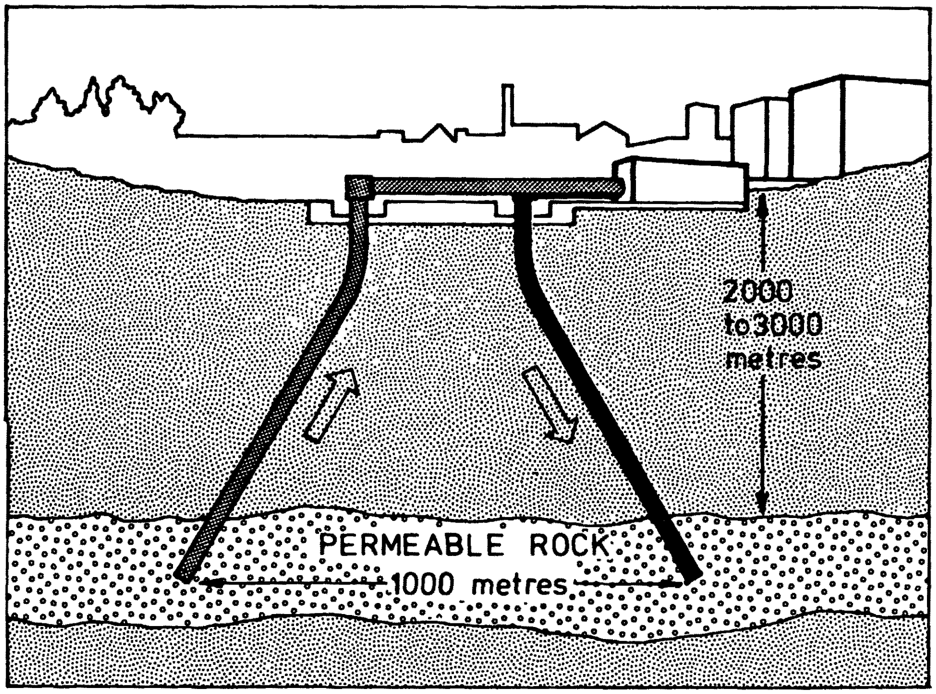

Fig. 1 Schematic representation of the "doublet" system

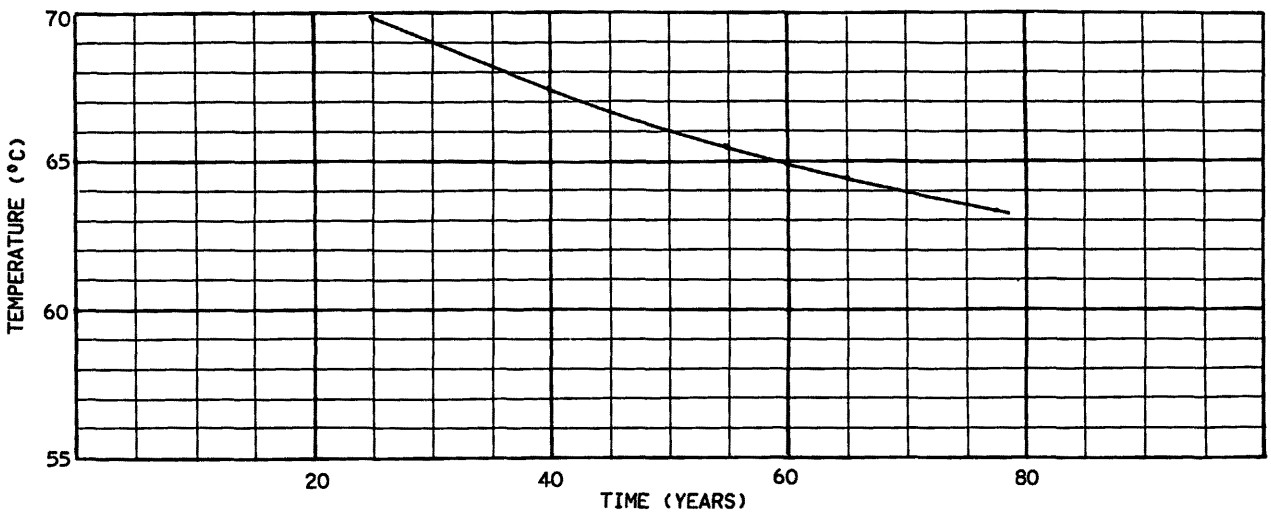

Fig. 2 Temperature drawdown for a doublet system. Model calculation for a doublet spacing of 1300 m, production/reinjection rate of 200 m^3/h (880 gpm) aquifer thickness 40 m, porosity 15% (after "La geothermie en France", 1978)

Operational lifetime (which depends on the production/reinjection rate, the doublet spacing and productive reservoir thickness) can to a certain degree be predicted by model calculations. Fig. 2 shows the result of computer calculations for a single doublet.

The highly corrosive geothermal fluid necessitates the use of special materials: e.g. fiberglass lining for the drillholes, titanium plate heat exchangers, etc.

Since only the base load for space heating and the domestic water requirement can be supplied by the geothermal source, the peak loads are carried by conventional fossil-fuel burners. The base load is supplied by a) heat exchangers drawing heat from the geothermal fluid and b) the heat pumps reducing the temperature of the return water to the heat exchangers (see Fig. 3). The contribution of each of these sources varies according to the meteorological conditions (see Fig. 4), but essentially, the geothermal source and heat pumps provide around 70% of the annual demand for heat and domestic hot water (for further details, especially about the special counter-current series arrangement of the heat pumps which is indicated on Fig. 3, (see Garnish 1977).

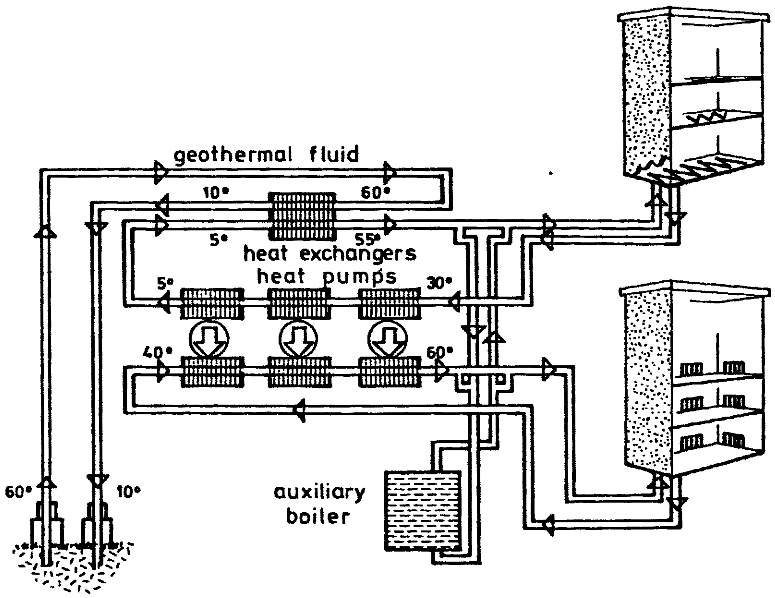

Fig. 3 Simplififed flow diagram of the geothermal heating installation at Creil. The upper block (2000 apartments) is equipped with floor panels, the lower block, where domestic hot water is supplied as well (2000 apartments) has conventional radiators. Temperatures in °C (after "La geothermie en France", 1978)

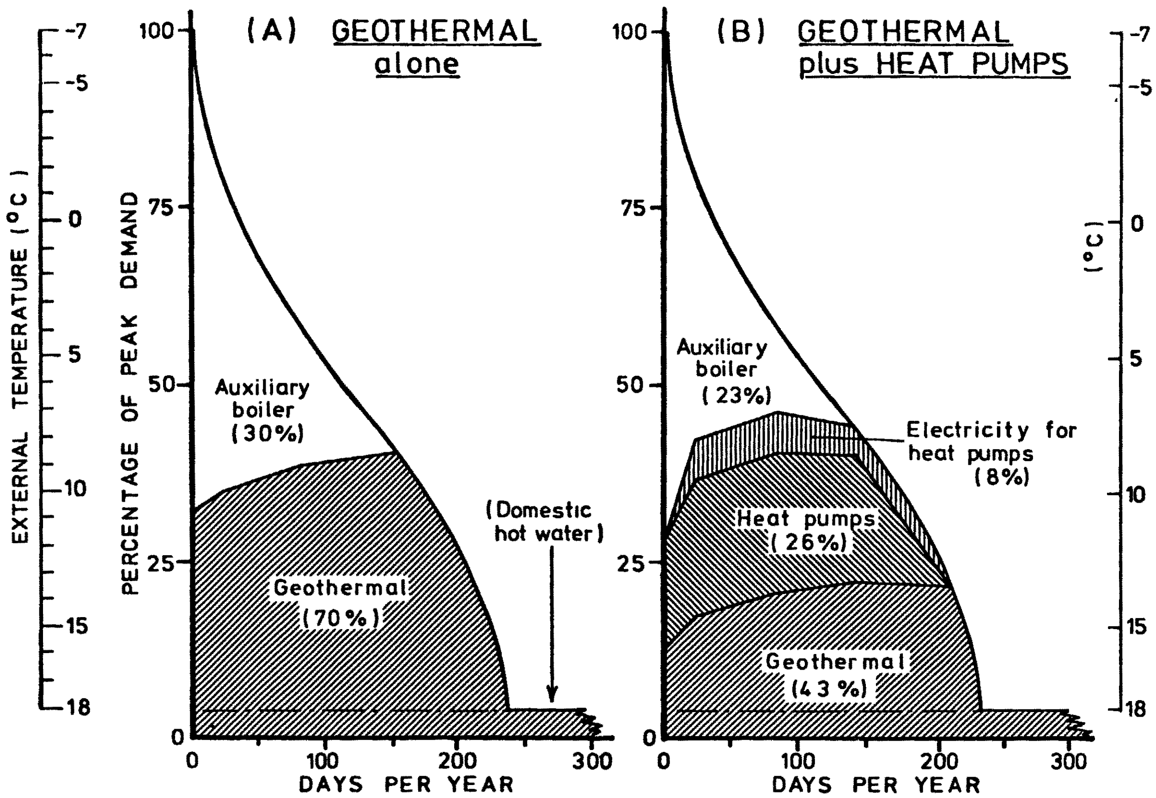

Fig. 4 Meteorological conditions and corresponding contributions from different heat sources to total energy demand

4. Economic Aspects

The economy of a given geothermal installation depends on local factors on the reservoir side as well as on the heat consumer side. A main factor is the amount of fossil fuel which can be saved due to substitution by the geothermal heat. Long-term economy will mainly depend on the development of fossil fuel price. Tables 1 & 2 summarize economic data of a typical geothermal installation in the Paris basin. Economic analysis shows that optimum utilization of the system described above calls for a certain concentration of dwellings next to the doublet: the optimum number of apartments is in the range of 2,500-3,500 ("La geothermie: Chauffage de logements", 1976).

Table 1. Basic data of a typical geothermal installation for urban heating (from "La Geothermie en France", 1978)

Number of apartments	2500
Energy demand p.a. (58 GJ/apartment)	145 TJ
Energy supplied by geothermal source (75% of total energy demand)	109 TJ
Resource yield (doublet, spacing 1800 m) flow rate (pumped)	200 m^3/h (800 gpm)
temperature (gradient 30°C/km) (1.65°F/100 ft)	65°C (150°F)
Installation costs (doublet, heat exchangers, heat pumps, distribution network)	10 Mfrancs[1] (4 K/francs apt.)

[1]corresponds to 2.5 M$ or 1 K$/apartment (at February 1979 exchange rates)

Table 2. Cost[1] analysis of a typical geothermal installation for urban heating ("La Geothermie en France) 1978)

Fuel costs	0.135 M$	0.525 M$
Electricity for pumping (250 kW on 150 days, 100 kW on 80 days)	0.040 M$	-
Maintenance (pumps and doublet)	0.025 M$	-
	0.200 M$	0.525 M$
Capital costs (10% for 20 years)	0.293 M$	-
TOTAL	0.493 M$	0.525 M$

SAVING (geothermal vs. conventional - 6%

[1]at February 1979 exchange rates

5. Outlook

The relatively new installations in the Paris basin do not yet provide long-term operational experience. Besides the information needed on performance of heat pumps and efficiency of heat exchangers, unanswered questions are:

- scaling and corrosion in long-term operation (wellbore linings, heat exchangers) as well as changes in solution equilibria in the produced geothermal fluid; possible effects of bacteria
- reservoir performance in time (temperature drawdown, effects of reservoir heterogeneity - directional permeability).

Ongoing research to answer these questions (first results of which are described in Desplain et al., 1977; Goblet et al., 1977) will supply the data necessary to test the models applied to predict the long-term performance of the geothermal heating systems.

The geothermal heating system developed in the Paris basin appears, even with the numerous unknowns at this time, a promising alternative to substitute (at least in part) for fossil fuel. The French authorities strongly support further development (e.g. the risk of drilling of production holes is covered by the government) which aims, according to the "Delegation aux energies nouvelles" (Paris), at 800,000 geothermally-heated apartments in the Paris area by 1990.

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