LARGE HEAT PUMP PLANTS FOR DISTRICT HEATING UTILIZING GEOTHERMAL ENERGY

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ABSTRACT

In Sweden large heat pumps in the 10 MW range have been in operation in district heating networks for more than a year. These heat pumps utilize low energy sources like treated sewage water from communities, industrial waste water and lake water.

In the southernmost part of Sweden projects are now under way where geothermal energy in combination with heat pumps will be used for production of district heat for this region. The size of the project is about 60 MW of heat.

HEAT PUMP MARKET

The changing of raw energy costs has had a profound impact on demand and supply, but also brought about new opportunities for energy conservation.

The Swedish energy picture is characterized by heavy dependence on imported oil at high cost and an expanding nuclear power programme providing electricity at a moderate cost. Although the nuclear programme will stop at 12 reactors, there will be several years of ample supply of non-oil based electricity as shown in fig 1. Under such circumstances it is highly desirable to reduce the use of oil even at the expense of higher electricity consumption.

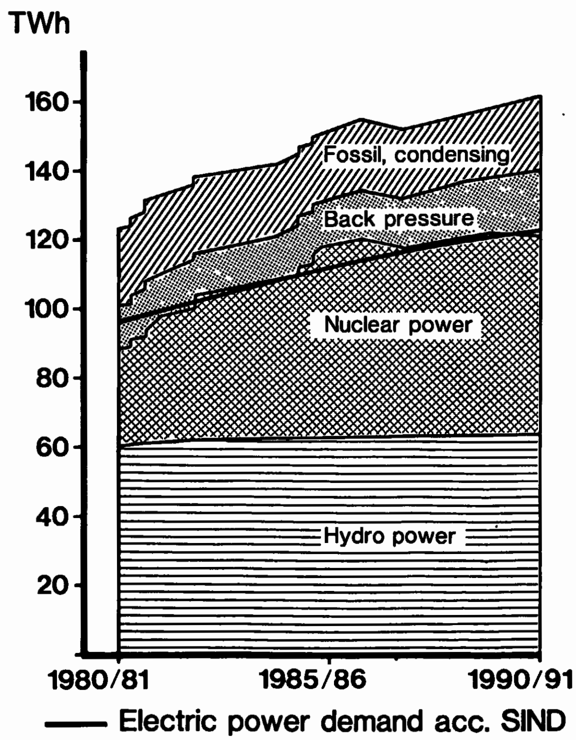
An appreciable share of the Swedish oil barrel is used for domestic heating, and hence, substantial savings can be achieved, raising efficiency or introducing substitues for oil. Here, the electrically powered heat pump brings about interesting possibilities which were identified by STAL-LAVAL, a wholly-owned subsidiary of ASEA, some four years ago.

The basic principles underlying the heat pump technology have been known for about a hundred years. A heat pump works by extracting heat from a low-temperature source-such as water, air or the ground-and using it to provide useful energy for water heating.

Interest in the technique was stimulated during the early 1970s because of the oil crises. Application, however, was limited to small heat pumps for domestic use. Hence, the size of the heat pump unit and the low temperature of the energy source made STAL-LAVAL's venture unique.

ELECTRIC ENERGY BALANCE FOR THE ENTIRE COUNTRY.

Normal year



The fact that all large cities and a number of medium sized communities had already benefitted from district heating networks in Sweden, indicated that large heat pump systems were ripe for further development.

To get good economy in heat pump operation with large electrically powered heat pumps you need:

- Cheap electrical power
- Large heating systems
- Possibilities to replace oil or other expensive fuels

Sweden has all these essential factors present, as well as a wide range of low-temperature energy-sources. Here the geothermal energy is a new and very interesting opportunity.

BREAKTHROUGH IN 1981

There was immediate interest in the development of this large type of heat pump and the breakthrough came in 1981 when the municiaplity of Västerås ordered a 13 MW heat pump plant.

The district heating system in Västerås is one of the most extensive in Sweden (900 MW). This installation utilizes heat from treated waste water with a temperature of 9 - 20 °C, and then supplies heating power of 10 - 13 MW to the district heating network. The heat pump provides an annual thermal production of approximately 75 000 MWh.

This is equivalent to a saving of 7 800 cubic meters of oil. The Västerås plant came into commercial operation on schedule in June, 1982, after a very successful test period. Interior see fig 2 below.

LARGEST HEAT PUMP IN THE WORLD

In 1981, Uppsala Kraftvärme AB, a municipal power company, ordered a 39 MW heat pump to meet the needs of the district heating systems.

The installation utilizes treated waste water from the sewage plant in Uppsala and produces enough heat to reduce annual fuel consumption by 25 000 cubic meters of oil, representing a large saving in public funds.

Out of STAL-LAVAL's nineteen units delivered or on order so far, eleven units use sewage water, five use lake water and three are intended for the use of industrial waste water.

LOW TEMPERATURE HEAT SOURCES

Among available heat sources, the treated water from public sewage plants and water from lakes has proven to be the most interesting. However, there are a number of options which may be considered as well. Among others there are projects now under way in Sweden dealing with geothermal energy in connection with heat pumps.

GEOTHERMAL ENERGY

As a result of drillings and test-pumpings during the winter of 1983 in Scania, the Southernmost province of Sweden, very low temperature geothermal water is now considered as a substantial energy source to the district heating net of the nearby city of Lund. The actual tested formations are, by comparison, at a very moderate depth of about 600-800 m. The formations consist of up to 90 m of homogenous and unconsolidated coarse to medium grained sand horizons. Water temperature is about 25 °C, total salt content is about 5.5 % and TDS about 6.5 %.

From an early interpretation of draw-down data it is seen that 100 l/sec can be produced with a draw-down of about 40-50 meters. Static head corresponds to ground-surface level. With shallow formations like this, one can diminish drilling costs to a great extent and the water has, corresponding to the situation at deeper levels, only a moderate salt content. Low salt and TDS concentrations will diminish production and reinjection problems.

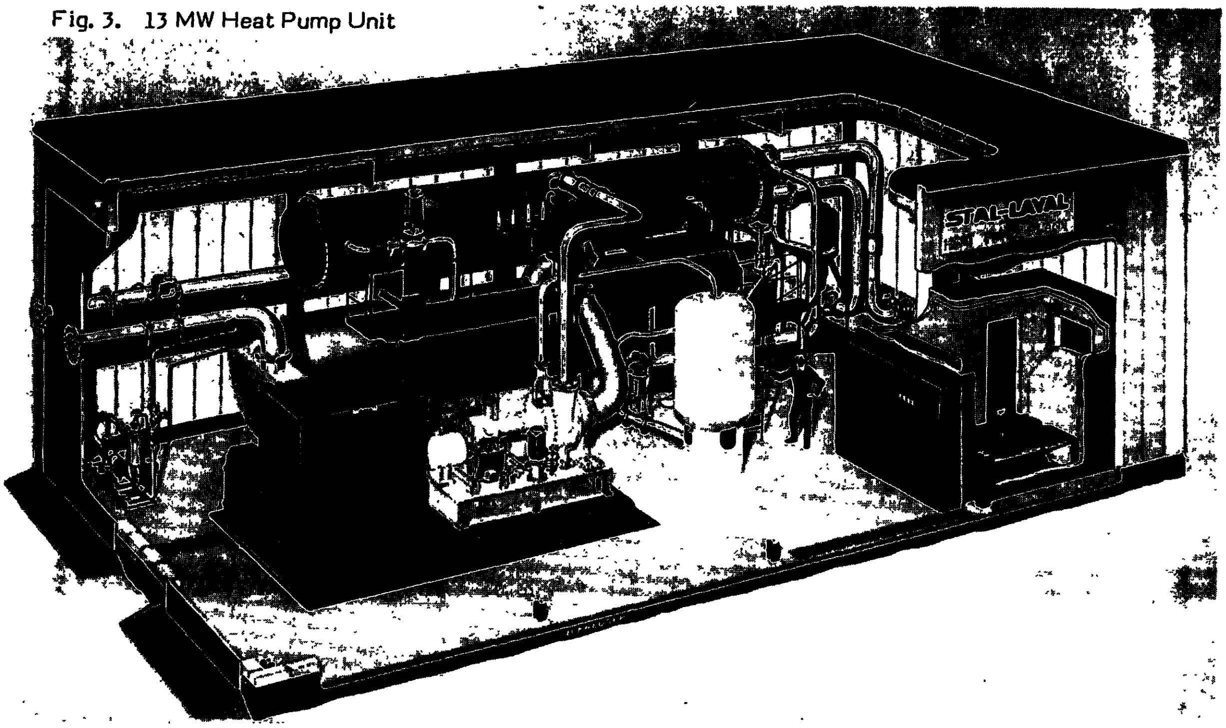
The main reason why this very low temperature geothermal water is of such great interest is the combination between this energy source and large heat pumps suitable for this temperature level.
In the city of Lund the idea is now to build a geothermal heat plant with 5 heatpumps producing about 55 MW heat energy. This will save about 35 000 tons of oil per annum. See fig 7.

THE STAL-LAVAL HEAT PUMP PLANT

The STAL-LAVAL heat pump plant is a standardized unit producing some 13 MW of heat. Fig. 3 shows a cut-away drawing of a unit working with cleaned sewage water of 8-20 °C.

When operating with water from the sea or a lake, the evaporator will be different so that the building area will be 100 % more.

Fig. 3. 13 MW Heat Pump Unit



The working principle of the heat pump will be the same irrespective of the heat source and is shown in fig 4.

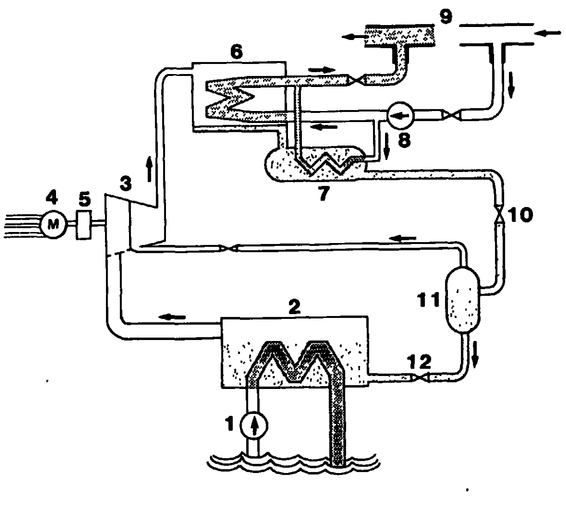
Water from the heat source is lead through the tube bundle of the evaporator (2) by means of a pump (1). Heat is emitted to the cooling medium which evaporates.

The gas is now introduced to the 2-stage turbo compressor (3), driven by an electric motor (4) via a gear box (5). The compressed and superheated gas flows to the condensor (6) where the heat is emitted as the gas condenses on the tubes. The saturated liquid phase then enters the condensate cooler (7) where maximum cooling is achieved.

Water from the district heating system is pumped by means of the pump (9) through the tube bundles of the condensor and condensate cooler, where it absorbs the heat emitted.

The cooling medium now enters the flash box (11) via the high pressure control valve (10) and expands to the intermediate pressure of the compressor. The gaseous phase reenters the compressor here before the 2 nd stage, and the liquid phase flows to the evaporator via low pressure control valve (12) and the cycle is closed.

Fig. 4. Working Principle

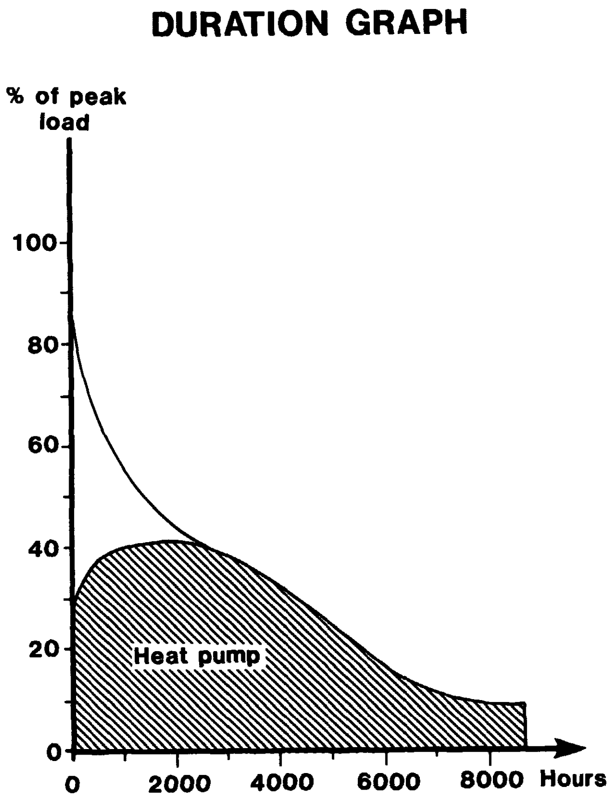


1. Waste water pump
2. Evaporator
3. Turbo-compressor
4. Electric motor
5. Step-up gear
6. Condenser
7. Condensate cooler
8. District heating pump
9. District heating pipe
10. Control valve-HP
11. Flash box
12. Control valve-LP

GOOD ECONOMY

The cost profile of a heat pump plant with its low running costs favours long operating time for low total production cost. Heat pumps should accordingly provide the base load of a district heating system fig 5.

Fig 5



The duration curve shows that normally heat pumps may provide as much as 80 % of the total energy demand of a district heating network.

Typical design temperatures of Swedish district heating systems are 120 °C in the winter and 80 °C during the rest of the year. Return temperature is typically 60 °C. A heat pump with R12 as cooling medium will give maximum 80 °C. Thus, the peak demand will have to be produced in fossil fired hot water boilers.

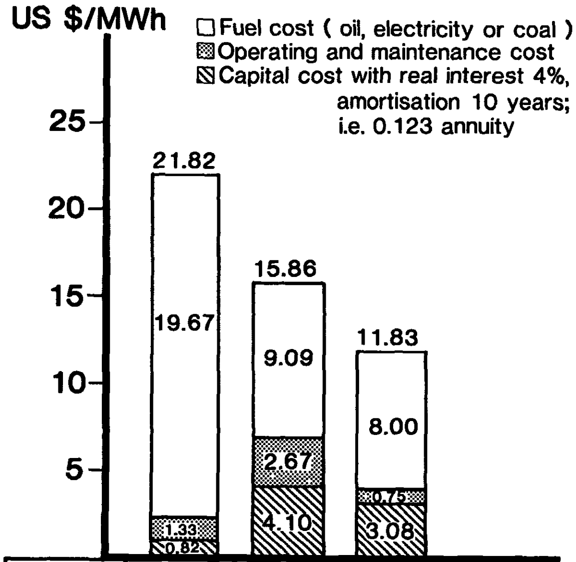
Heat pumps have proved to be a very economical way of producing heat for large heating systems.

Fig. 6 shows the cost of producing 1 MWh of heat with boilers or heat pumps, based on normal energy costs and equipment prices.

The oil alternative will be almost twice the cost per MWh of the heat pump, and the coal fired alternative will be 35 % more expensive.

Fig 6

ENERGY COSTS – A comparison, 1983



Conditions	Oil-fired boiler	Coal-fired boiler	Heat pump using waste water
η, COP	0.9	0.85	3.25
Investment USD/kW	40	200	150
Fuel price	0.77 USD/Gallon	64 USD/ton	2.6 cent/kWh
Operating hours/year	6000	6000	6000

PAY-OFF

A standard heat pump unit operating on geothermal water produces 13 MW of heat. Investment costs will be about 2 million USD for the heat pump plant and about 1 million USD for the wells.

If replacing oil in an existing plant, the gross saving will be about 78 GWh, worth 1.53 million USD.

The cost of powering the electric motor and maintaining the plant will be about 0.68 million USD, leaving 0.85 million SEK as a net annual saving. The corresponding pay back period will be 3.5 years.

OPERATING EXPERIENCE

The total accumulated operating time for STAL-LAVAL heat pump plants is at present (83-05-01) 25 000 hours and is rapidly increasing. Total energy production is 226 000 MWh. These installations have shown an average availability of more than 90 % over their present running hours.

SUMMARY

The use of large heat pumps in Swedish district heating systems has proved to be a very efficient way to save oil and reduce the dependence on imported energy. The same benefits will be obtainable also in other countries, where district heating networks and suitable low temperature heat sources exist.

Fig. 7. Showing the principle solution for a geothermal heat pump plant in the city of Lund in Sweden.