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Analysis of Marketing Prospect on Technology of Application of Heat Pumps

Zhu Jialing[1] Dong Zhilin[2] Hong Qinghua[3]

[1]TianjinGeothermal Research and Training Center, Tianjin University, Tianjin, 300072, China

[2] Geothermal Testing Research Center, Tanggu, Tianjin, China

[3] School of Constructions Engineering, Tianjin University, Tianjin, 300072 China

tgrtc@public.tpt.tj.cn

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ABSTRACT

Heat pumps are one of the energy saving pieces of equipment for heat applications, such as low temperature geothermal resources, industrial heat. According to environment requirements, the heat pump in a heating system is more available for current heat marketing. This paper describes direct and indirect economic benefits and environmental aspects of the utilization of the heat pump. Optimal design and applicable heat pump size are evaluated further. A heating system measurement with a heat pump shows that using the heat pump is more economical than the gas boiler.

1. INTRODUCTION

Direct utilization of geothermal resources have been extended from industry and agriculture to district heating, hot water supplies, swimming pools and medical utilization etc in China. By the end of 2003, there were 218 geothermal wells (12 reinjection wells), which are operated by 106 heating companies, utilized in Tianjin City, which is at the top of geothermal utilization in China. The utilized flux has achieved 21.25 million m^3/a and the heating area amounts to 8,040,000m^2, which is 77% of the total in China using geothermal energy. The hot water supply can cover 218,000 families for daily life, and 102,800 inhabitants for bathing.

The heat pump is one of the energy saving devices in heat applications. It can absorb more heat from low enthalpy resources or waste heat while expending energy, such as electricity resources or high temperature resources. For a compression heat pump, the amount of power consumption is the most important point of the heat pump operation. According to different policies on the electricity use in different countries, the electricity price of each city or region is completely controlled by the local power company. In China, the electricity price is mainly adjusted by local government, different prices are available to residence, industry and commercial sectors. The local government will favor policies comparatively according to the type of project. The heat pump power consumption would cover more than 80% of the entire operating cost, particularly for a large scale district heating system. The compression heat pump is more suitable for a small scale heating system. In Eastern Europe, some countries have utilized the compression heat pump for their district heating system in the early eighties, which increased power generation because of its great electricity consumption. Air pollution in the process of generating electricity is an important consideration, especially the greenhouse effect induced by carbon dioxide. The government can raise electricity prices on policies accordingly. On the other hand, the government supports producing heat from the combined heat plant or incineration plant as the driving heat resource of the absorption heat pump with integration of geothermal heat production. In the mid nineties, a number of geothermal heating companies changed to install lithium bromide absorption heat pumps. So the energy source policies and operating costs of national government are one of the main factors for choosing heat pumps and heat pump methods.

Whether using the heat pump with geothermal utilization or not, it mainly depends on the consumers' demand on a heat load, balance of supply, geothermal resources evaluation and market prospect. If the market demand and price of the equipment is not only reasonable, but has the advantage over other energy sources, electricity prices take on an important part in the marketing spread of the heat pump application technology, besides energy source policies and environmental protection policies of the national government. On the other hand, mature technology is stable and the heat pump technology can't be used widely in the heating market if the power cost is not accepted by the majority of the consumers.

Consumers in the US, and Europe can choose heating companies according to selling the price of heat. Once its price changes, consumers could switch to other heating companies, which would supply cheaper energy. Therefore, geothermal plants should operate their companies carefully, trying their best to compete with other conventional energy.

However, there is a big difference in the heating market in China. China has researched heat pump technology for thirty years, which was not applied widely and developed slowly because of restrictions on the power cost and other factors. In recent years, with the environmental protection consciousness of national people raised and national government policies adjusted, especially concerning the success of application of 2008 Olympic Games, conventional energy, as main heat supplying, has been restricted in some regions. Therefore, it doesn't only impel the application of energy-saving product and environmental protection, but also creates a good opportunity to utilize the integration of the heat pump and geothermal resources.

At present, the lack of a reliable electrical supply has been resolved. Many different kinds of heat pumps are coming into application, such as the compression heat pump, and the absorption heat pump used as an air condition system. The heat resource can also be produced from shallow wells, waste water around 45℃ from geothermal heating plants, solar energy, soil, river, lake, and so on. On the other hand, the exterior conditions that apply to the heat pump system have been maturing gradually, with the environmental protection and restrictions on fuel consumptions, such as coal and gas. If the advantage is to improve, the geothermal heat pump market will open up more potential in China, and make industrialization of the heat pump in the field.

2. ANALYSES OF HEAT PUMP TECHNOLOGIC ECONOMY

2.1 Technologic and Economic Analysis

The compression heat pump is set up to reuse low enthalpy heat, which is technologically mature and applied in the overseas market. Because it causes more electricity wastage when it is operated during winter, the price of power is expensive compared with geothermal energy and coal. Therefore, the feasibility study must be done thoroughly when deciding to use the heat pump.

2.1.1 Direct Economic Benefit

The profit margin determines whether the geothermal heat pump is used or gas or oil boilers are used. Taking the supplied-water temperature 50℃,backwater temperature 35 ℃ and heating area 50 thousand square meters for example, the operating cost per square meter of the geothermal heat pump is 15.41 RMB/ m^2 which is 13% more than 13.65 RMB / m^2 of coal boiler. So, the direct economic benefit is lower than the boiler's. However, based on the environmental impact, the coal boiler as a peak load does not resolve the problem of using of geothermal resources. If the problems are considered, more money should be spent for the treatment. The heat pump system absorbs heat from discharged geothermal water. The heat is used as a heat source to the consumers as a second heating stage, and the temperature of the discharge water is reduced to 20℃ from 45℃ mostly so that the geothermal availability ratio can be increased by about 30%. As far as the heating system is concerned, it does not harm the environment. Therefore, the heating system not only protects the environment, but can also save geothermal resources. Secondly, it is much better to use an oil boiler or gas boiler than coal boiler from the point of view of protecting the environment. It must be considered for its economy because of their enormous price discrepancy. For instance, according to the respective combined efficiency of the oil boiler and gas boiler it takes as much as 80% to generate 700KWh heat, the costs of using each of them can be calculated and compared with the cost of using the heat pump in table 1.The specific heat of natural gas is 10.7kW*h/m^3, (9200Kcal/ m^3).The specific heat of fuel (light diesel oil) is 12.79kW*h/kg, (11000Kcal/kg).

Moreover, the heat pump set can also be used as an air conditioner in summer so as to improve equipment availability ratio and reduce the capital cost. As refrigeration in summer, the cool resource can be found from shallow wells, river and lake. The operating time in summer is longer than the heating season since the heat pump is used as the peak load, then, 50% even 60% of the capital cost of the air conditioner system can be attibuted to the equipment investment in summer when the cost took place. In addition, the power installation cost should be paid by the heating companies, when the system starts, more benefits can be got back through longer operation.

The coefficient of performance (COP) of the absorption heat pump is approximately 1.7, which means to obtain 1.7 low enthalpy heat units at the expense of consuming 1 high enthalpy heat unit. Based on the overseas operation experience and technological economy analyses, the absorption heat pump is suitable for a large district heating system. But first of all, it must find a solution to the100-140 ℃ high temperature sources as driving heat to make sure there is a high efficiency operation of the absorption heat pump. If it is not permitted to use a fuel boiler in local environmental conditions, with no combine heat plant to supply the heat, thought must be given to what can instead be the driving heat source. Secondly, it may be heavy-laden to invest because the equipment cost is extreme.

2.1.2 Indirect Economic Benefit

The differences of the indirect economic benefit are not allowed or are being neglected by comparing geothermal heat pump heating with the boiler heating system. As a result of the cost of possessing land, transportation, slag-off, smoke-let, dust disposal of the boiler and its accessorial equipment, which is restrained by multifarious subjective and objective factors, it is difficult to have a universal scale to measure so that it should be regarded as an indirect benefit. For example, if geothermal resources can not cover the heat demand, then the coal boiler as a peak load must be equipped with coal storage ground, slag deposited ground and transportation alley. The land-possessed area of a coal heating system could be 5 times more than that of a geothermal station. The oil boiler must be equipped with accessorial oilcans, which don't only take up more space, but make the management more difficult in a residential area. Although the gas boiler has the advantage of cleanliness and a small land-possessed area, it can not be put into full-scale application in the heating market because of its high operating cost. From experience, the heating cost is 35RMB/m^2 by gas boiler and 15RMB/m^2 in wintertime.

2.2 Environmental Benefit Analyses

According to the statistical data, 0.554 million tons of coal, 0.687million m^3 of carbon dioxide, 10916 tons of sculpture dioxide, 4987 tons of NOx, 3879 ton of coal dust have been reduced by using geothermal energy. The economic benefit is also significant. The treatment budget of RMB 620 million was saved and was environmentally friendly.

Using the heat pump as peak load, it can reduce general fuel demand and the quantity of ash, slag, sulfur dioxide and nitrogen oxide, reduce the quantity to be conveyed to cities accordingly. Therefore, it has obvious environmental benefits and society as a whole benefits. (See in table 2). Detail calculations show that the results are based on the 100,000m^2 heating area and 5300KW of heat load (See in table 3), and energy-saving, pollution reduction and benefit of geothermal resources are identified.

Table 1 Comparison of operating cost with different fuel

Oil boiler	Gas boiler	Heat pump
Oil consumption:68.4kg	Gas consumption: 81.8m^3	Power consumption:180KWh
Unit price of oil:3.0RMB/kg	Unit price of gas:2.5RMB/m^3	Unit price of power: 0.5RMB/KWh
Total cost: 205.2 RMB	Total cost: 204.25 RMB	Total cost: 90 RMB

Table 2 The reference of environment and social benefit analyses

Item	Unit	Quantity
Sulfur-percentage of coal	%	1.5
Sulfur in combustion residue	%	20
Theoretic quantity of smoke air	Nm^3 /kg	6.7
Nitrogen oxide quantity of smoke	G/Nm^3	1.3
Dust quantity of smoke	G/Nm^3	3.5
Ash quantity of coal	%	30
Average transportation distance in urban areas	km	10

Table 3 Environmental Benefit Data of Geothermal Resources

Item	Unit	Quantity
Quantity of saving coal	Ton per year	3146.3
Reducing emission of sulfur dioxide	Ton per year	37.76
Reducing emission of nitrogen oxide	Ton per year	27.4
Reducing emission of ash	Ton per year	73.78
Reducing emission of combustion residue	Ton per year	943.89
Reducing of transportations	Ton•kilometer per year	40901.9
Treatment cost saving of Sulfur dioxide	Ten thousand RMB	4.15
Treatment cost saving of Nitrogen oxide	Ten thousand RMB	6.58
Treatment cost saving of Smut	Ten thousand RMB	5.9

If the coefficient of the performance (COP) of the heat pump is 3, taking 100KW compression heat pump for example, the l00KW heat pump set can obtain approximately 300KW of heat. Thus, the electricity consumption is 100KW only, less than using electricity to heat water directly. For 200KW electric energy saved, it reduces the fuel consumption for generated electricity and the quantity of letting out carbon oxide, and to protect environment as well.

3. OPTIMIZATIONS AND DESIGN OF HEAT PUMP EQUIPMENT

3.1 Choice of Heat Pump Equipment

It primarily takes characteristics below into account to do comprehensive technical performance comparisons of all kinds of heat pump sets.

(1) The double-screw compressor is a main part of the compression heat pump and has the advantage of efficiency, little vibration, few damageable parts and a long lifetime.

(2) Evaporators and condensers must be produced and tested strictly according to a high quality standard. Because evaporators are a dry type, operate under high temperatures. The cryogen side design compression resistance of condensers must be strong in order to meet the special needs of high temperature hot water supplied by heat pump set.

(3) Techniques for producing the whole heat pump set must be performed strictly according to standard. Compression resistance must be strictly tested.

(4) The whole set is controlled by computer. As a result, it can not only refrigerate what is controlled by a single-chip, but can also be connected into the central computer system to implement a long-distance online auto-control.

3.2 Choosing High Efficiency Heat Exchanger

The exchanger is pivotal equipment in making sure the operation of the heat pump set operates. Owing to strong causticity of geothermal water, it will greatly reduce the lifespan of the evaporator and condenser. Therefore, using the titanium-plate type the exchanger that is chosen for use in the heat pump set must have the characteristics listed below:

(1) The plate is made of rare metal titanium that is anti-corrosion, and functions under high temperatures.

(2) The material of the plate must be excellent. And the metal sheet must be multilayered and transfer high heat efficiently and takes up a small amount of land.

(3) A variety of plates can be combined which meet the needs of all kinds of parameters.

(4) The sealed exchanger can be operated with high temperature and high pressure.

3.3 State Analyses of Equipment Operation

The fig 1 below is related to increasing the heat load, temperature of letting geothermal water and electricity cost power of compression heat pump at peak load. From the fig 1, it can be seen that the discharge temperature of geothermal water is reduced with the delivered power of heat pump increased, thus the heating area is increased.

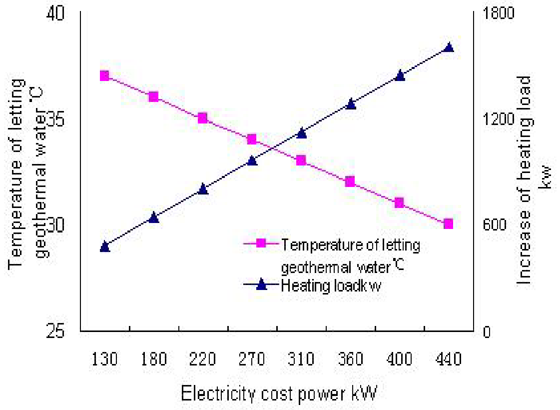

Figure 1: Situation graph of compression heat pump as peak load

From the analyses above, using the heat pump as the peak load equipment or assistant energy in a geothermal heating system makes for utilization and environmental protection to some extent. At the same time, it will certainly increase the capital cost of adding heat pump in heating system so that the economy of installation geothermal heat pump as a heating project must be taken into account.

4. EXAMPLE ANALYSIS OF GEOTHERMAL HEAT PUMP

GTRC is equipped with water-water heat pump technology provided by CIAT so that they have made an established aim come true, which is using the heat pump as a peak load, making good use of geothermal resources and improving heating quality.

The Tanggu geothermal field is a typical conductive sedimentary. The geothermal resource is the result of permeable sediments at a depth of (>2km) and greater than average heat conductive flow. The field is located at the sedimentary basin. The region of Tanggu is rich in geothermal resources, with its characteristic abundant water□100-160 t/h □, low water temperature□65-78□□, high water quality and low corrosion. The production well of GTRC is located in the yard of tap water company in the Tanggu district with water temperature 68□, flow rate 110t/h and discharge water temperature 42□. Due to the expansive district of Tanggu, the geothermal resources can't cover residents' heat requirement at the coldest period in winter until the heating area is increased from 65 thousand square meters to 80 thousand square meters since 2000. So, a coal boiler had to be instaled at the region as a peak load.

4.1 Determination of Project

GTRC and CIAT have completely designed the whole reconstruction project, which is required to increase 1400kW heat that 1050kW heat is obtained from geothermal water and the other 350kW heat is provided by the drive heat pump equipment. For the situation of the heat pump, the coefficient of performance can go up to over 4.

In the heat pump system, if we lead (50t/h) 42□ geothermal water to the end of heat pump evaporators and provide 1050kW low temperature heat source to heat pump equipment, the water temperature of input end of evaporators will rise to 18□; Water temperature will drop to 12□ after exchanger and geothermal water will be let after its temperature dropping to 22□. The temperature of 1400kW 54□ heat source provided by heat pump equipment will drop to 47.7□ after the plate exchanger. Geothermal tail water will be heated up from 42□ to 50□ after the plate exchanger, then will be transported to users. It should add plate exchangers at the end of evaporators and condensers to prevent geothermal water from infusing into heat pump set directly in order to make sure the operation of heat pump equipment is safe and reliable for a long time. As a result, it will meet the need of heating in winter after the reconstruction of the heat pump system and its accessorial match-equipment. (See in Map 2).

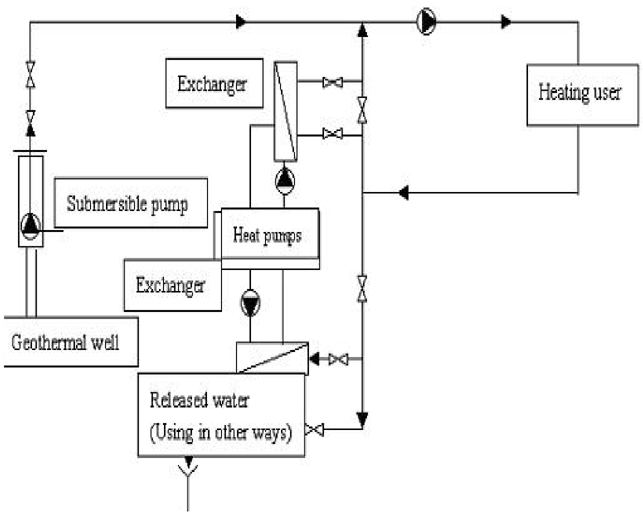

Figure 2: Sketch of geothermal heat pump heating system

4.2Analysis of Operating Process

This item has been installed and was adjusted in January, 2001, which basically fits the design requirements after running for a period of time and withstands high heat demands in cold weather. The table 4 indicates remarkable effects after using the heat pump combined with geothermal resources according to system running data.

According to preliminary parameter measurement of running a heat pump set, the plant extracts up to 889.6KW with the heat pump from geothermal water. The power cost was 216KW and the COP is 4.12 for operation during the test period. (Because one of the compressor instruments was destroyed under construction, the heat pump set could not run more than 60% of full heat load at that time.

It can be seen that the heat pump has a much greater capital cost according to that of heat pump, gas boiler and oil burner at present. Comparison of using different heating equipments in capital cost and operation cost based on producing 700KW thermal units shows in Table 5.

From the table above, the heat pumps have more capital cost than coal boiler, whereas the cost can be compensated by outlays saved for running heat pump with winter and summer seasons. Furthermore, the heat pump set can be utilized for cooling in summer, this means that the plant could have saved half the part of the investment. So it is of a comparative advantage of investing such a suit of the equipment which can be used both in winter and summer.

Table 4 Operating data comparisons between before and after using heat pump

	Before using heat pump	After using heat pump
Flow rate of geothermal water	110t/h	110t/h
Temp. of geothermal water	48℃	53℃
Temp. of discharge water	42℃	22℃

Table 5 Comparisons of capital cost, operating cost with different facilities

	Gas boiler	Heat pump
Heat load	700KW	700KW
Equipment investment	250 thousand RMB	620 thousand RMB
Power construction investment	0	85 thousand RMB
Gas plant investment	166 thousand RMB	0
Civil construction	100 thousand RMB	100 thousand RMB
Others	50 thousand RMB	200 thousand RMB
Totals	566 thousand RMB	1005 thousand RMB
Operating cost in winter	588 thousand RMB	259 thousand RMB

5. CONCLUSIONS

Geothermal water is a precious mineral resource, though it has a much greater expense at the beginning of the investment. However, most of geothermal waste water (45-50℃) has a greater possibility to use further, after heating.

It has taken a long time to apply heat pump use in order to extract more heat from geothermal waste water or other low enthalpy energy, such as shallow well ground water. Utilizing low enthalpy energy not only improves geothermal efficiency, but drops the temperature of poured geothermal water and comes up to the environmental protection. Consequently, using the geothermal heat pump for heating instead of coal boiler has the long-term benefit of saving energy, saving coal and protecting the environment.

The heat pump has a higher capital cost than the coal boiler, which can be compensated by outlays saved for running the heat pump in both winter and summer. Furthermore, the heat pump set can be used in cooling, which is of a comparative advantage to invest.

The electricity price is the main factor in deciding to use the heat pump. The capacity of the installed heat pump scale is directly related to the operation cost which primarily rests with the electricity price. Therefore the operating cost is one of the main factors in choosing to use the heat pump.

It may take some time to generalize geothermal heat pump technology and its application from the point of view of environmental protection and saving energy. The economical drawbacks also need to be taken into consideration.

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