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THE ANALYSIS OF SPACE HEATING INDEX ON LOW ENTHALPY GEOTHERMAL HEATING SYSTEM

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ABSTRACT

Geothermal heating systems started to develop around the northern part of China since 1970. Since then the geothermal sources for heating have revealed further potential to extend heating areas at basic heat supply.

Test of geothermal (3 geothermal heating plants) and boiler heating plants have been carried out over a long period of time. It was deduced from the operating and monitoring tests that variations in percentage of the space heating index between geothermal and conventional heating systems do exist and that the index may be a factor of 30% if geothermal energy is used.

As a particular, testing parameters of temperatures, well-head pressure, return and supply water temperature and flow rate have been employed to calculate the index. The results also point out that related parameters may have a strong effect upon the index.

1. INTRODUCTION

China has acknowledged the importance of developing renewable energy alternatives in order to protect the environment. The average annual growth rate for thermal related applications of geothermal energy was 11% during 1990-1995. Under the Ninth 5-years Plan from 1996-2000, the rate will be projected at 8%. The total coal replacement of 5.1 million tons was documented in 1995. The forecast of coal savings will increase up to 7.5 million tons by the year 2000, and 13.4 million tons by the end of 2010.

Concerning the development tendency of geothermal heating, experience shows that high initial cost and the low operation costs make geothermal heating systems highly suitable for base heat load as well as for peak load (if necessary). However, due to the lack of annual reference cases of geothermal heating by the year, it is necessary to specify characteristics of space heating index between geothermal and conventional heating systems.

Following a regulation of heat payment at present, geothermal is capital-intensive, and unit costs depend strongly upon the amounts of heat extracted from the geothermal fluid or heating areas. As a decision or calculation of the heat load or the index, the relative size of the heat load and the thermal power of the wells shall play important roles in the economy planning of a geothermal heating plant.

The design of the index is likely to identify the different systems. So far no official design of identification has been acknowledged. However, practical measurement detected that the most obvious features of geothermal resources seem to prove it is a stable heat supply and that a geothermal heating system has potentials for expansion of the heating area and/or for extended sales of heat to the consumers after a plant has been established. The main reason is probably due to different and exacting operating systems both in terms of geothermal heating plants and coal boiler plants at a moment. This situation has influenced the decision about the operation and administration of the index.

This paper mainly describes key features of geothermal heating systems, and summarizes the index of choice based on different constructions of buildings. According to thermal analyses, the index of space heating can be a principle point for the design and calculation of heat load in the geothermal heating systems.

2. THE CHARACTERISTICS OF A HEATING SYSTEM

Following the aspects of geothermal energy, the development of geothermal heating systems has significant potential. Regardless of the indirect and direct heating systems (with heat exchangers or without heat exchangers), it is necessary to analyze the system performance taking into account the heat load in relation to temperatures and flows of geothermal water.

2.1 Geothermal Heating System

A geothermal heating system is supplied from a deep well. A typical geothermal heating system consists of geothermal production and injection well(s), well-head equipment, including pumps, heat exchangers, tanks and filters, a pipe network and boilers for a peak load if necessary (See fig.1). As a geothermal plant, the main additional cost for the geothermal heating system are represented by the drilling and completion of the well, and heat exchangers. Conversely fuel costs during the life of the project are drastically reduced.

Fig.1 shows a typical indirect heating system connected to consumers in series. When producing and supplying heat to the first stage of the consumers only, an efficiency rate of no less than 45% is economic request. Thus, design of outlet hot water from first stage is lead to the second stage at a temperature of 56-58ºC as supply heat. This means that the total efficiency goes up when decreasing the return temperature up to 38ºC.

2.2 Main Difference between Geothermal and Conventional Heating System

As the conventional heating system, such as coal boilers, the substantial problem is, that it is impossible to supply heat successively to consumers due to costly fuel and treatment for prevention of pollution caused by CO_2 and dust from smoke. In the cases, the result is fluctuating heat supplies and, consequently, varying indoor temperatures. This, again, means unregulated heat/cool and thereby reduced comfort to the consumers.

As a heat source, geothermal energy is more stable, productionwise, in terms of temperature and flow. This fact means stable indoor temperatures as well as stable supply. These benefits have been reflected in an increaseing in the total heating area as well as in an improved efficiency of the district heating system.

Apart from the matter of the operational aspects, in principle the two heating systems are not obviously different, both being based on heat source and thermal dynamic circles, and having special needs for modification of the parameters of radiator section, mainly due to mean temperature difference between supply and return water from the district heating system.

Considering the comparison, it is necessary to made an approach to the index of space heating.

3. CALCULATION METHODS OF INDEX

As key design factors of space or district heating systems, the index is an important parameter for calculation of the maximum heat load.

3.1 Unit Area Method

In principle, the heat consumption is based on the function of a building's structure, its insulation characteristics, volume of building, and local climate, rather than on the type of heat resource being employed for heating.

Following the reference from the Heating Design Handbook, design heat consumption per unit area of 46-70W/m^2 in typical residential buildings is employed to calculate heat load of a conventional heating system. The value indicates that heat consumption should be subscribed for a duration of 147 days, a standard outdoor local temperature of -9ºC, and an indoor temperature based on 18ºC. It is easy to find out the value of use from the Handbook. However, as a fixed value between 46-70W/ m^2 , the choice should be taken with due respect to the actual situation.

With a detailed approach, the value can be calculated. The formula is listed below:

$$q = \frac{(t_n - t_w)}{N}\{0.37nh + (1+b)\frac{2h(a+b)}{ab}\times [R_{wa} + d(R_w - R_{wa})] + (a_1 R_T + a_2 R_{sy})\}\times 3.6 \quad (1)$$

Note: the symbols mentioned are ignored.

It is, normally, not necessary to calculate the index by the formula for each case, such as feasibility study as well as estimating heat demand.

On the other hand, it is figured out easily by a series of known parameters, which the geothermal heat supply is given by:

$$Q = G \times C_p(t_{in} - t_{out}) \quad (2)$$

$$q = \frac{Q}{A} \quad (3)$$

Where: G: Flow rate (m^3/h)
C_p: Specific heat capacity of geothermal water (J/kg ºC)
q: Index of space heating (W/ m^2)
Q: Heat consumption (W)
A: Total heating area (m^2)
t_{in}: Inlet temperature (ºC)
t_{out}: Outlet temperature (ºC)

3.2 Unit Volume Method

$$q_v = \frac{Q}{V} \quad (4)$$

$$q_0 = \frac{q_v}{t_n - t_w} = \frac{Q}{V(t_n - t_w)} \quad (5)$$

Where: q_V: Volume index of space heating (W/ m^2)
V: Volume of building (m^3)
q_0: Unit volume of heat consumption (W/ m^{3}ºC)
t_n: Indoor temperature (ºC)
t_W: Outdoor temperature (ºC)

The ratio of the volume index for the temperature difference between indoor and outdoor is presented as the heat consumption per unit volume as t_n-t_W=1ºC.

At the individual level, the nature index or heat load can be difficult to define uniquely. This is because the interaction between diverse and variable human habits and attitudes, and the complex physical influences. This makes the problem difficult to analyses and model in all of its aspects. Consequently, a assumed index is able to be used for a favourable design.

4. DATA MEASUREMENT AND ANALYSIS

The energy consumption is expected to be subjected to a substantial growth in the future economy. In fact, the energy consumption by residential consumers is expected to decrease as a result of implementation of energy saving measurements. It is assumed that several modifications as a result of analyses, investigations and measurements will improve the energy efficiency and accordingly decrease the consumption. The overall energy efficiency of the heat production can be evaluated by comparing the produced energy with the energy content of the consumed fuel. The analysis will provide the basis of the determination of the impact on the index of space heating.

4.1 Purpose of Measurement

In terms of key design factors, the measurement of the index is an important parameter for accurate calculation of the maximum heat load as well as for adjusting purposes.

Concerning the heat cost, the basic rule of payment used for long time has been the area of consumer's houses only. Therefore, it has been impossible and not necessary for the consumers to control and modify the amount of supply heat or room temperature even though the heat may have exceeded the required level. The distribution of room temperatures have stressed the problems (See Fig.2). However, normally, income from selling heat can not cover the operating expenses of the coal boiler plants, because the price of coal rises year by year. Thus, plants have to find a solution to the problem, and one way has been the non-continually heat supply where the intervals have been used for maintenance and repair work.

As for the consumers, such procedures have an impact on the standard room temperature and individual comfort. Designers have realized the problems caused by fluctuations. Therefore, in order to meet the requests for room temperature, the index has to be designed to add a so-called "margin of safety" to increase capacity of facilities, such as capacity of boilers, and to cover maximum heat demand in accordance with the conditions of the operation. In fact, the index results should be higher to prevent problems during the heating period.

As for a geothermal heating system, it has been proven that it can provide a more stable heat source and a more stable room temperature compared with a conventional heating system. The main reason is that the system extracts heat from geothermal water 24 hours per day providing a constant and balanced source of energy.

In order to evaluate how the standard parameters vary when the heat demand is covered by different heat sources, and what the index of space heating between conventional and geothermal heating system should look like, it is necessary to find out, whether the index strongly depends on the way of operating and administration, or not.

4.2 Choice of Typical Building for the Index Measurement

In order to arrive at a reliable estimate of the specific space heating energy requirement, it is necessary to consider the heat loss per unit area in a typical buildings as well as the average space occupied by each person.

Residential building

To use geothermal resource for heating is most common of all geothermal utilization. The residential buildings in China are normally six floors high and built more concentrated on limited land. One of the favorable conditions is that the buildings to be heated are concentrated in certain areas and therefore constitute a big heat demand. This means that the heating areas are prone for extensive development.

Following Fig.1, the large heating system is located at Zijinxinli residential region in Tianjin with a single geothermal production well of 92ºC, flow of 150m^3/h and a peak load (by coal).

High standard building

It is a typical building in the geothermal heating system, and could be a high quality hotel (above 24 floors), large-scale library, and so on. Because of a high environmental requirement, the structure of building is a non-opened system in order to keep dust out mainly. Not only does the environment require fresh air from the outside on time through wind channels, but also a fixed room temperature of 20ºC shall be available every 24 hours. Concerning a particular structure of the building, and variable wind velocity with different floor levels, the design of the index of space heating should be considered higher than that of a normal building due to the different amounts of heat loss.

4.3 Basic Data Measurement

With the aim of processing measurements, a metering system was installed at the geothermal well head, in the pipe network and in the radiators. The system collected data automatically through a computer system. As for the measurement of indoor temperatures, they were measured through automatic temperature indicating recorders, which were installed in typical heating houses. As for the outdoor temperatures, they were offered by a local meteorological observatory.

4.4 Date Analysis

First, the measurements were performed both in the Zijinxinli geothermal plant and in a coal boiler plant, and the necessary parameters were monitored during a period of three years (1995-1996, 1996-1997, 1997-1998).

By the end of 1992, a part of the buildings (called first stage) were heated by hot water from a boiler house. The water was led through the standard design supply and return water system of the Zijinxinli boiler plant. Since 1993, a geothermal production well, located at the plant, has been in operation. The coal boilers did not run basically. The residence heating region has been expanded with the same amount of heat supply (See Table 1) whereas the average consumption (See Table 2) has decreased year by year since 1994.

It is significant to show the index of space heating variation since more stable heat sources were used through Table 2. It shall be noted from the table 2 that the official value of 70W/m^2 is higher than the measured values obtained during "normal" operation system. The measured results are also found out few of the minimum index to be used during processes of design, and it is fact when the index is lower than the minimum standard value of 46W/m^2, the room temperature still can reach above 18ºC.

In addition, the measurements were performed by the Environmental Agency and Xianda geothermal plants. They supply heat to the Tianjin library and the Tianjin Hotel.

The results of measurements are shown in Fig 3, Fig 4 and Fig 5 which include integrated analyses and operating experiences to detect more permanent solutions to the problems.

Gathering of data for the index of space heating and getting information about preceding actions taken during the operational phase, it has been established through a long period of monitoring and measurement in practical geothermal heating plants that the index can go down by 30% when using geothermal heating compared to the official design of the conventional heating systems.

4.5 Economics

Any energy saving technique involves initial installation costs which will lead to future reduced expenditures for fuels or energy. In order to decide whether the adoption of an energy saving scheme is justified, the related energy consumption and saving must be assessed and the costs involved must be calculated. Comparing to benefit from geothermal resources, different choices of the index with same target are more significant.

For example:

Heat from geothermal: 5MW; Heat price=18.5Yuan/ m^2:
If q=45W/m^2, A=0.11million m^2 , (total heating areas)
Total income(selling)=2.05million Yuan/year
If q=60W/ m^2, A=0.083million m^2,
Total income(selling)=1.54million Yuan/year, and
If q=70W/ m^2, A=0.071milliom m^2,
Total income(selling)=1.32million Yuan/year

The example shows that the decided index of space heating can influence a period of paying back all the investment and also the income of the plants. Operation costs are lower in a geothermal plant and it is therefore profitable to operate such a plant.

5. CONCLUSION

Tianjin, one of the largest cities and also one of the largest users of geothermal resources for district heating. Currently, around 3 million square meters of concentrated buildings are heated by means of geothermal resources replacing boilers, and approx. 85,000 tons of coal could be saved each heating season. If the efficiency of the existing heating systems can be improve by 10%, the same amount of energy can be saved according to the calculation carried out.

Geothermal and conventional heating systems are operated and managed differently in today's China. This fact should lead to considering the use of the index for space heating whenever a heat source is employed.

As for a residential buildings, the index is a target of main consideration due to the many concentrated dwelling areas in China. With regard to measurement and analysis, the index of space heating should be able to reduce the energy used by 31%-33% in comparison with the conventional heating system, such as coal boilers.

As for high level building, the standard index can be down by 16%-33% if geothermal resources are employed for heating purposes.

Geothermal resources have a large economic potential for development within the Chinese heating market. An increasing heating market expects to unfold before 2000. We are facing how to develop geothermal energy in sufficient quantities to fit the economic market and improve the efficiency of use.

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Table 1

Heating Period	Supply Temp.	Return Temp.	Heating Floor	Avg. In-Temp.	Index
-1993	95-50ºC	50-35ºC	67200 m^2	18ºC	70W/ m^2
1994-1995			125000 m^2		
1995-1996	65-70ºC	44-46ºC	165000 m^2	20.9ºC	50W/ m^2
1996-1997	65-70ºC	42-44ºC	182000 m^2	20.5ºC	46W/ m^2
1997-1998	65-70ºC	38-42ºC	200000 m^2	19.6ºC	44.6W/ m^2

Table 2

Plant	Case for Heating	Consumer	Design Index	Measured Index	Calculated to Standard	Ratio of M/D
ZiJinxinli	Geothermal	Residence	65W/ m^2	31.1W/ m^2	45W/ m^2	0.69
Environment Agency	Geothermal	Library	83W/ m^2	49.9W/ m^2	60.4W/ m^2	0.73
Xianda	Geothermal	Hotel		64.4W/ m^2	90.7W/ m^2	
Tianjin Univ.	Coal boiler	Residence	70W/ m^2	46.3W/ m^2	67.8W/ m^2	0.97

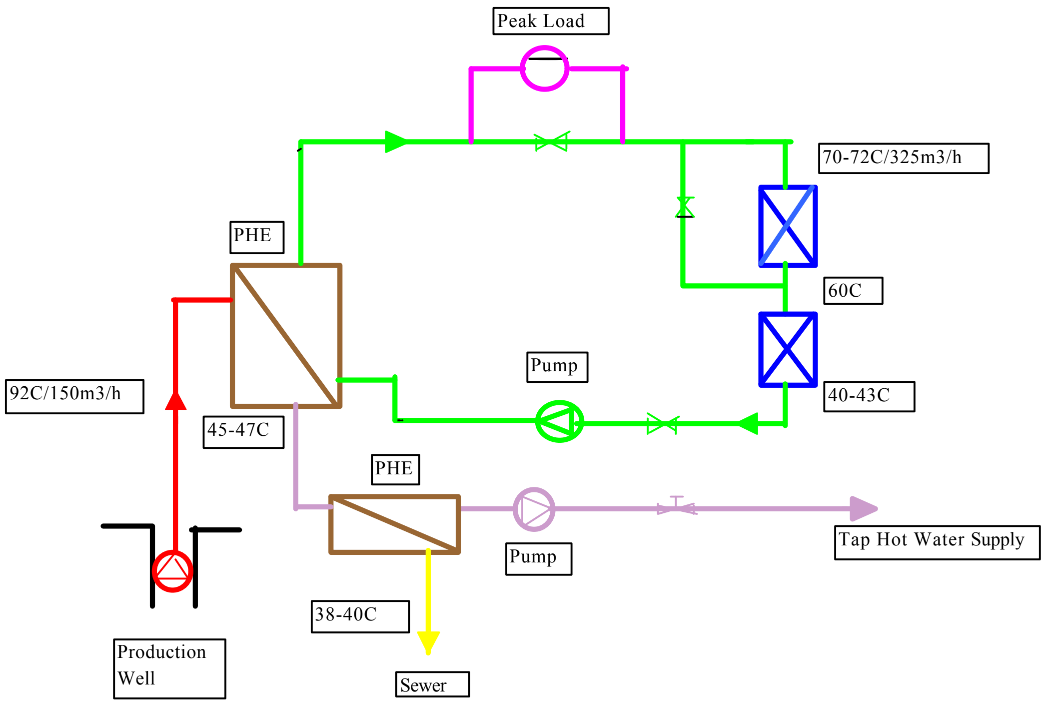

Fig. 1 Zijinxinli Geothermal heating plant

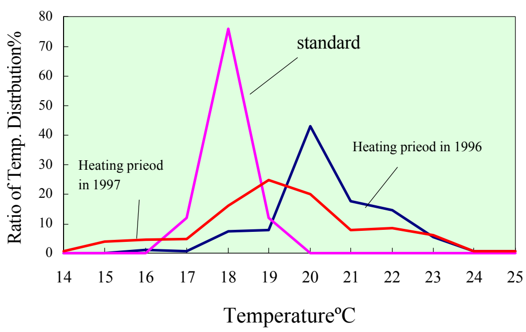

Fig.2 Indoor Temp. Distribution

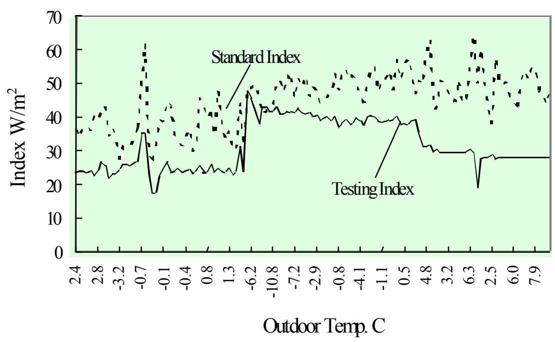

Fig.3 The Index Variation with Outdoor Temperatures at Zijinxili Geothermal Heating Plant

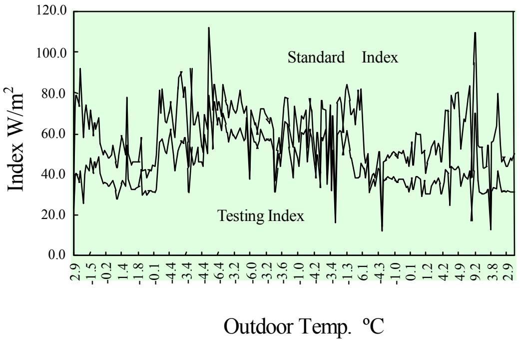

Fig.4 The Index Variation with Outdoor Temperatures at Environment Agency Geothermal Heating Plant

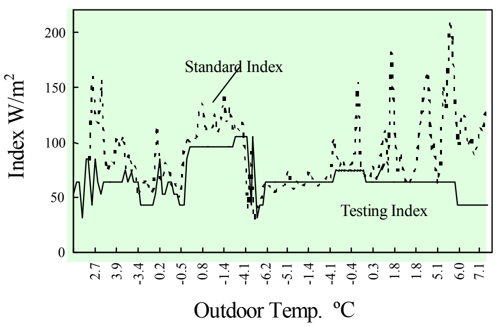

Fig.5 The Index Variation with Outdoor Temperatures at a Coal Boiler Plant