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A SUCCESSFUL EXAMPLE OF A RETROFIT TO A GEOTHERMAL DISTRICT HEATING SYSTEM

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ABSTRACT

In order to utilize low temperature geothermal, it is often necessary to retrofit district heating systems in China. A coal burning district heating system which is known to have a floor area of 120,000m^2 has been successfully retrofitted to 74- 47C geothermal heating system. First, the peak heating load has to be analytically determined from previous boiler plant records of circulating flow rate and temperature. Then the heat output of the terminal equipment has to be analyzed and confirmed. The circulating water design temperature difference can be found as a changeable limit. Making use of this limit a suitable LMTD can be chosen for the titanium plate-type exchanger of the geothermal system for saving initial capital and raising the heat output of the geothermal well. The retrofitted geothermal district heating system was used 3 years. It has shown economic and environment benefits.

1.INTRODUCTION

In areas of North China that require significant heat for space heating, the coal fired boiler plant district heating system and indoor terminal transfer apparatus - a cast iron radiation column is most widely used. Space heating system radiator design temperature drop generally is 95 - 70C in Chinese coal burning boiler plant conventional district heating system. Since the boiler plant often uses intermittent heating, for example, usually the heating-up period is 6 - 8 hours per day. Sometimes more radiators need to be installed when the heating system is retrofitted for geothermal heating.

Geothermal heating is different than coal burning boiler heating system. There is no waste in the boiler plant heating system, because it is a recirculating system. The heat medium will returned to the boiler after heat is released. However, in a geothermal system, the heat medium should undergo as large a temperature drop as possible, otherwise, the heat medium - geothermal fluid will be disposed or rejected. The result is the geothermal system has to increase radiator surface area. Therefore, more radiators can be used and optimum design parameters chosen for the heat exchanger. The initial investment is reduced.

At present in Chinese geothermal space heating engineering, more than 70% of the systems are retrofitting engineering. The user requires as few as possible retrofitting terminal system and changing heat source only.

Physical Exploring Bureau department 1 of Chinese Petroleum and Nature Gas Corporation is located at Tianjin Jinghai, 76Km south of Tianjin urban area. The corporation has established a coal burning boiler plant district heating system, which provides 120,000 m^2 floor area office and dormitory. A geothermal well was drilled in 1996. The depth of well is 2,777m, the temperature is 92C, flowrate 40 - 50l/sec at wellhead. In order to save burning coal, labor services and lower environment impact, the corporation was required to retrofit the original 95 - 70C heating system to a geothermal heating system. As shown by chemical analysis of the production well, Cl^- is 2205mg/l and TDS is 5746mg/l, therefore, it is not possible to use geothermal fluid directly in the heating system. An indirect heating system with titanium plate heat exchanger was chosen.

The first step of the geothermal heating system will be to supply 120,000m^2 floor area space heating, 7000m^2 dormitory domestic hot water all year and 1250m^2 geothermal swimming pool. The system will eventually supply 200,000m^2 floor area when the original boiler plant is used as peaking load equipment, at the next step.

Design of heat load is decided first. If the calculated heat load is more than the practical heat load, only a waste of initial investment in the conventional coal burning boiler heating system. If it happened in the geothermal heating system, it will waste both initial investment and geothermal resources. It is important that the calculated heat load to be as close to the actual load, then it can make full use of the geothermal well.

Confirmed radiator output of the original heating system is necessary, in order to create favorable conditions for reducing retrofitting cost and fully utilize installed radiator potential, and to raise geothermal utilization efficiency, and cutting down disposal fluid temperature.

As the price of titanium plate is expensive, so how to collect the parameter of heat exchange is important, which can decrease the surface area of heat exchange to save the initial investment of the system.

2. INVESTIGATION AND DATA ANALYSIS

According to the operating record of boiler plant in the winter of1995 and meteorological data of Tianjin Jinghai region and speaking with operation workers and users, the operating condition can be confirmed.

2.1 Define Design Heat Load

On the basis of heating records arranged in order of the highest, and lowest heating power each day as shown in fig.1.

From fig.1, it can be seen that there were very shaky heat loads in early winter and early spring at the beginning and near the end of heating season. It seems as burning coal in the boiler plant and user both under anomaly conditions, however, in cold winter heating remained stable and users paid more attention to house insulation, as the result that the condition are close to normal. Therefore, the cold winter records can only be used in load analysis.

According to Tianjin Meteorological Bureau record of the 1995 winter Tianjin Jinghai region, the Day Avg. Temp. were less than and equal -7C 0 day, less than and equal -6C 3 days, less than and equal -5C 1 day, less than and equal -4C 15 days. Weighted average with 19 days to find out the average day temperature - 4.4C corresponding heat load, then calculated outside design temperature - 9C peak heating load Qp. According to Chinese Heating Design Stipulate Tianjin Jinghai outside design temperature is -9 C.

Q=(6,995kW* 3days + 9,115kW* 1day + 6,163kW* 15days)/19days (2-1)

Q= 6,449kW.

It is shown the heat load is 6449kW with outside temperature - 4.4C.

Design peak heat load

Q_p= 6,449kw((18-(-9))/((18-(-4.4))

Q_p=7,773kw (2-2)

2.2 The Average Water Temperature of Terminal Radiator

In the past the heating practice of hot water system was a temperature drop of about 11C, supply water temperature < 70C and flow rate 570 m^3/h. The average supply water temperature, return water temperature and heat load are shown in Fig. 2. When outside temperature is -6C, the average water temperature of the terminal radiators is about 58.6C.

Radiator release heat q can be expressed by:

q=f*k(tp-tn) (2-3)

Where:

f -- surface of radiator m^2

k -- heat transmission coefficient $w/m^2.C$

four column 813mm cast-iron radiator

$k=2.047(tp-tn)^{0.35}$ (2-4)

tp-- average water temperature C

tp=(tg+th)/2 (2-5)

tg—supply water temperature C

th-- return water temperature C

tn--inside air temperature C

According to original operating record and formula (2-3) and (2-5), the heating requirement can be satisfied for an outside temperature at -9C when the average water temperature of radiators reaches to 62.3C.

3. DESIGN TEMPERATURE DIFFERENCE OF TITANIUM PLATE HEAT EXCHANGER

The heat exchangers of geothermal heating systems are distinguished from conventional boiler plant heat exchangers. Geothermal characteristics need to be satisfied. Geothermal is corrosive fluid. Titanium plate heat exchangers are often used. Since geothermal fluid temperature t_1 difference is small with circulating supply temperature t_3 and to improve efficiency, the contraflow is usually set up.

As shown in figure 3, there are 4 openings in the heat exchanger. The geothermal fluid temperature t_1 is constant, the fluid heat release QD can be expressed by:

QD = GD*(t_1- t_2) (3-1)

Where:

GD-- fluid flowrate t/h

t_2-- outlet temperature of fluid C

If the flowrare is unvarying and more heat needs to be released, t_2 has to be lowered. The t_2 must exceed circulating return temperature t_4. After cutting down the t_4 outlet temperature t_2 can be decreased. The t_4 is decided by terminal apparatus surface, average temperature of radiator and demanded heat load. Adequate heat must be supplied for the space heating and t_4 can't be reduced at random except by increasing the radiator surface. Otherwise t_4 should be as low as possible for geothermal utilizing efficiency.

After considering geothermal efficiency, the Logarithmic Mean Temperature Difference (LMTD) has to be chosen. Using above t_3 and t_4 variable range and match suitable peaking the titanium heat exchanger cost can be reduced.

Harrison et al (1990) indicate that number of transfer units N can be used in counter plate heat exchanger.

N=(UA)/(MC) (3-2)

Where:

U-- overall heat transfer coefficient of the heat exchanger $Wm^{-2}C^{-1}$

A-- surface area of the heat exchanger m^2

M-- mass flow $kg\ s^{-1}$

C-- specific heat $Jkg^{-1}C^{-1}$

For low temperature geothermal titanium plate heat exchanger heating system about 5 is often taken by N. Fig.4 has been shown this variation in a typical approximately case.

When flowrate ratio GD/GH is lower than 1, circulating flowrate HG has been limited the heat release of geothermal fluid. So, GD/GH should more than 1.1, circulating flowrate should more than the design geothermal flowrate.

Heat transfer increase is very small if circulating flowrate GH is too large.

The minimum temperature of t_4 is decided by terminal radiators, t_2 should be close to t_4, even $t_2 \cong t_4$. Thus geothermal use efficiency will be advanced.

Due to a decrease in the surface area of heat exchanger and lower initial investment, t_3 will be lowered and increase the temperature difference between t_1 and t_3. Peaking heat load can be used to reach the requirement of the total heat load.

Since the original heating system design parameters are 95 - 70C . In order to not change the pipeline diameter and the flowrate, the temperature drop is still 25C after retrofit to geothermal system.

4 THE RUNNING CONDITION

According to the requirement of no change in the terminal radiators and pipeline, lower returning water temperature. It can be determined that the return water temperature is 47C and supply water temperature is 74C. The flowrate of circulating side is constant during the entire heating period, so the return and supply water changes temperature along with outside average air temperature, which can be calculated by general temperature regulating formula.

In the geothermal fluid side the flowrate, pressure and electric power are changed with variable frequency of submersible pump. The frequency is auto controlled by disposal temperature t_2 or hand control. The geothermal submersible pump variable frequency running parameters index as shown in table1.

In table 1 the practical consumed power is little more then theoretical.

5 CONCLUSION

According to 120,000m^2 heating data analysis and estimate of 1995 winter data, the peak load is 7,774kW and unit heating load is 65W per m^2 floor area at present in this project.

The 40% superfluous radiator in original system can be fully utilized in geothermal system. Using the potential of superfluous radiator, firstly which decreases the temperature difference between return t_4 and disposal t_2, lower the dispose temperature t_2, increases the utilization efficiency. Secondly which increases the temperature difference between geothermal fluid t_1 and circulating supply water t_3, the investment of titanium heat exchanger is reduced.

The submersible pump flowrate G = 200t/h, using frequency regulator control capacity by disposal temperature t_2. At present geothermal fluid still has superfluous energy, so there is no consideration in peaking boiler. The original boiler plant can be used for standby or second stage peaking equipment, it can increase the heating floor to 200,000 m^2 area in the next step.

REFERENCES

Harrison, R., Mortimer, N.D., and Smarason, O.B., 1990 Geothermal Heating a Handbook of Engineering Economics. Pergamon Press 1990

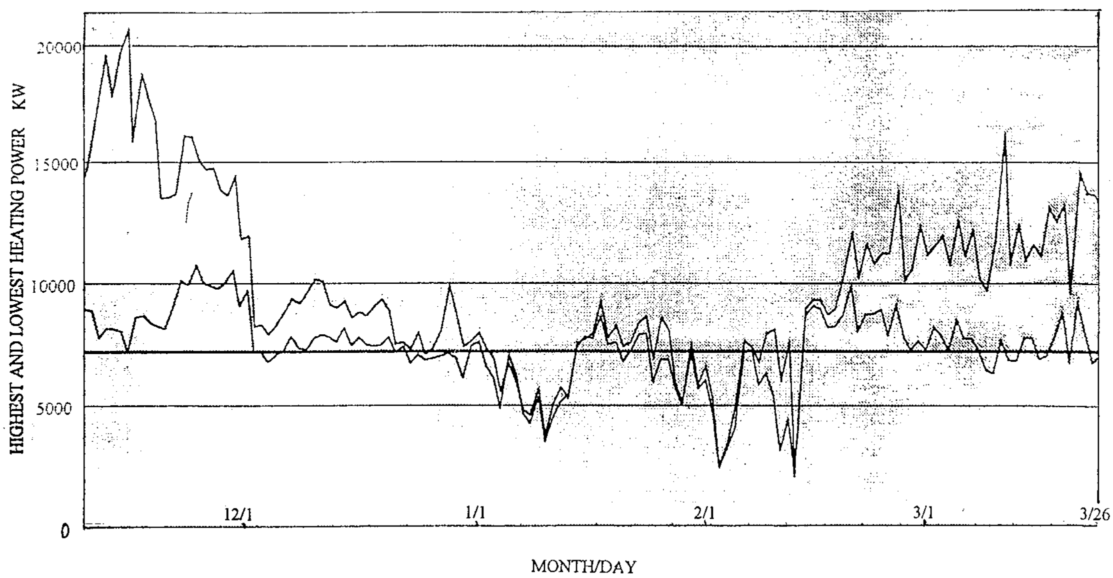

Figure 1. The highest and lowest heating power in winter

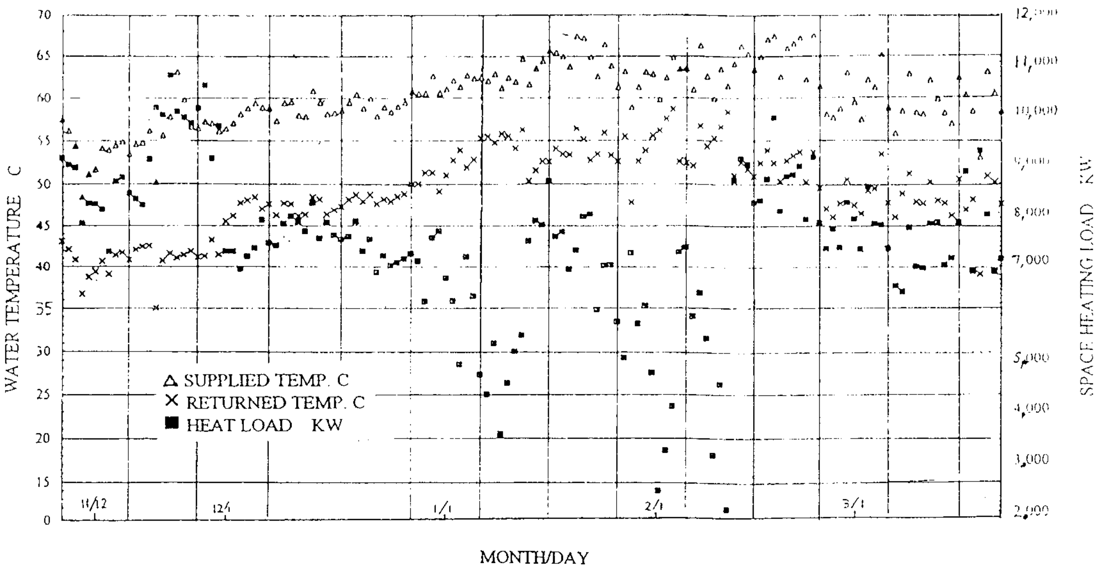

Figure 2. Supplied and returned water temperature and heating load

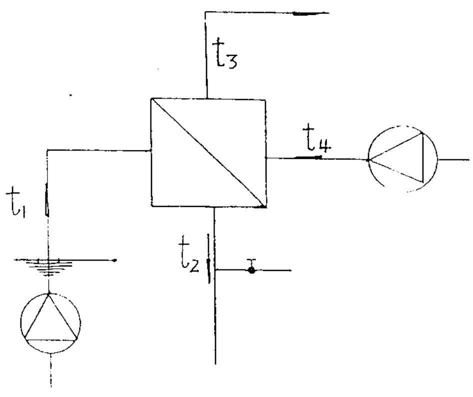

Figure 3. Inlet and outlet temperature of heat exchanger

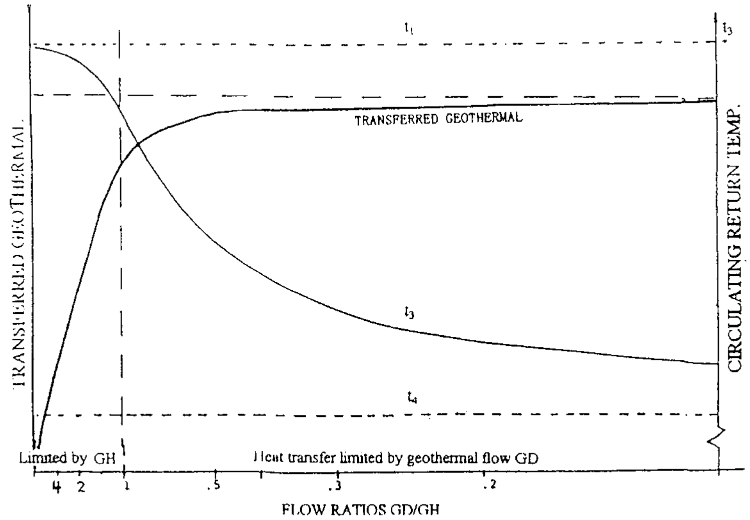

Figure 4. Effect of changing circulating flow

Table 1. Submersible pump vary frequency running data

No.	Title	Symbol	Unit				
1	Outside ave. temp.	t_w	C	5	0	-6	-9
2	Peak heat load	Q_p	kW	3745	5183	6910	7774
3	Circulating flowrate	G_H	t/h	250	250	250	250
4	Circulating supply temp.	t_3	C	49	59	69	74
5	Circulating return temp.	t_4	C	36	41	45	47
6	Geothermal fluid temp.	t_1	C	90	90	90	90
7	Geothermal disposal temp.	t_2	C	50	50	50	50
8	Frequency	Hz	Hz	20	28	38	43
9	Geothermal fluid flowrate	Gd	t/h	80	113	150	170
10	Lift of geothermal fluid	ΔH	m	13	25	45	58
11	Consumed power	N	kW_e	4.8	13	32	47