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The Research Work of Low Temperature Geothermal Space Heating

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ABSTRACT

The low temperature (<100ºC) geothermal resources is distributed all over China, the depth of geothermal well is usually within 3000 m for space heating. The geothermal space heating area in China was only 1,900,000 m2 in 1990, but from 2002 it is already over 14,000,000 m2. In order to use that geothermal water, we need to solve plenty of economies related problems such as cut down the temperature of discharging water, increase the ratio of geothermal energy utilization, anti-corrosion, prolong the service life of reservoir etc. This article introduce the Chinese research work on that domain, including various techniques such as the direct space heating system and discharge water temperature control, the indirect space heating system and it is optimization, the non-metal space heating system, the low temperature floor radiation space heating system, the double well re-injection, the heat pump regulate peak load, heating storage etc.

1. INTRODUCTION

The research work of low temperature geothermal space heating in China has had a great development these years. The geothermal space heating constructional area of building in China was only 1,900,000m^2 in 1990, but from 2002 it is already over 14,000,000m^2, among which Tianjin is 9,000,000m^2, Beijing is 900,000m^2, Xi'an is 1,300,000m^2, they're all the big cities of largest area of space heating in China.

The direct utilization of low temperature geothermal project in space heating has bright development prospects in China. As China is transiting from planned economy to market economy, lots project's funds in geothermal space heating are self-raise money by the proprietor of real estates and the developer. The national appropriations are mainly used for scientific and development utilization research works of geothermal energy. Since 2002, China has set the development and Utilization research of new and renewable energy sources (including geothermal energy) into the Nation's 863 project (National high-technology research develop project).

The geothermal exploration, drilling, resource evaluation and dynamic monitor's work is undertaken by the department of oil or underground mineral resource, but the space heating utilization's work is mainly managed by the department of heat input. Some cities with rich geothermal resources of and large area for geothermal space heating all have geothermal energy's administrative office that manage geothermal resources on behalf of the government, organize the feasibility demonstration of geothermal engineering projects, examine and approve the drilling of geothermal well, collect the resource fees of geothermal (geothermal water fees), and the research work of organize develop geothermal re-injection, improve the utilization ratio, anti-corrosion, anti-scaling and environment protection etc. The standard fees of geothermal water is stipulated by each city; in general it depends on the height of water temperature. For instance in Tianjin, under 80ºC(>80ºC) geothermal water is 0.8 RMB per ton, 0.7 RMB per ton and if geothermal water is over 70ºC, 0.5 RMB per ton if over 60ºC and 0.4 RMB per ton if the water over 50ºC, etc. The drilling fee is decided after consultation or discussion by the developer and the drilling company according to the market price. The drilling fee is around 800~1000 RMB/m within 1000m depth, 1100~1300 RMB/m within 2000m, 1300~1400 RMB/m within 2000~3000m in TIANJIN and BEIJING area, and the drilling fee of directional well (inclined well) is more expensive than the straight well for 10% to 20%.

2. RESEARCH ON GEOTHERMAL SPACE HEATING SYSTEM

There are two obvious different points of space heating between geothermal and normal boiler (a) The geothermal water is provided with corrosion (b) The space heating of geothermal water is open system, and the drainage is not circulated-use. Besides, the water temperature of geothermal space heating is not fix, it goes from 50ºC to 100ºC. Sometimes it meets the space heating system of boiler turn to the geothermal water, the water temperature is different as designed, but the heating delivery area of radiator is already fixed.

This characterization of space heating geothermal energy bring the special demand for system design, the main problems to be solved are: (a) anti-corrosive of the system; (b) how to cut down the temperature of drainage after geothermal space heating; (c) how to keep the system hydraulic steady and the room temperature constant; (d) economically (development and running cost) good.

There are a number of ways to solve, depending on the condition of geothermal water (water temperature, water capacity, and water quality) and the load of space heating (heating load, building distribution and load design, etc).

2.1 For the geothermal water with good quality, light corrosion, direct space heating system of geothermal can be chosen. The geothermal backwater space heating method (figure 1) is used in order to cut down the drain geothermal temperature. It assembles a temperature control valve at the gate of geothermal water drain, the valve is opened or closed automatically with the drain temperature set; the valve close down when the drain temperature is higher than set, the drainage after space heating transport to the gate of geothermal water through backwater tube will mix with high temperature geothermal water from geothermal well, until the drain temperature is lower than set and the temperature control valve open for drainage. The mixed ratio between high temperature geothermal water and low one is adjusted automatically by the change of the outside temperature. The advantage of this method is the constancy of system discharge, the hydraulic is steady and the water temperature increase automatically with the change of temperature outside in order to make the inside temperature constant.

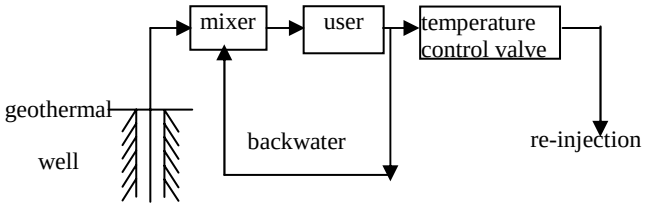

Figure 1

2.2 For the geothermal water with worse quality and lower temperature (such as 60~70ºC), geothermal direct space heating system can be used as well in order to improve utilization of temperature difference, however anti-corrosive measure must be adopted for this system. At present, the non-metal material is the most commonly used method in China. The geothermal water transport tube outside adopt the fiberglass pipe (FRP) or PP-R tube material; and the space heating tube inside adopt the tube of PEX, PEX-A1 or PP-C; the radiation use the cast iron; store canister and water tank adopt the fiberglass as well. The method that consist on putting rid of oxygen with anti-corrosive chemical preparation into geothermal water can also be applied, but it is not common, because there's no guarantee that even a little air can't enter the system. In the past, the method of adding chemical preservative into geothermal water has been publicized and used for sometimes in China, but it is been against by majority of technicians, not only because it cost a lot of money but also because the environment would be polluted by drainage (the anti-corrosive chemical preparation include composition what pollute environment such as phosphorus zinc and so on). The practice proves the way is not recommended. The geothermal engineering that comes to use this method had to change for the indirect space heating system, the investment was squandered and a bitter lesson was learned.

2.3 The geothermal indirect space heating system is generally adopted in China for geothermal water with corrosion water quality. The geothermal water and circulation water is separated with Titanium plate heat exchanger (PHE), the quantity of heat will space heating after the transform from geothermal water to clean circulator water through PHE, it avoids corrosion to space heating system metal from geothermal water. The geothermal drainage after space heating is used to supply baths, life-use heat water or reinjection. The advantage of this method is that the anti-corrosive is advisable, the service life of system is long; but the shortcoming of it is the increase of the primary investment (the selling price of Titanium PHE is 2000-2500 RMB/□) and the geothermal drainage temperature is higher unless multiple use the ending water. Picture 2 show the system principle picture of geothermal indirect space heating in zi jin xin li living area, Tianjin. The original constructional area of building was 80,000□, and directed space heating with two 6t/h boilers. As geothermal resource condition is relatively good, there was a geothermal well (inclined well) made by Tianjin heating energy power company in 1993, with 2010m inclined depth, 1800m vertical depth, 92.5ºC water temperature and 156t/h water measure next to original heating station. it could space heating and provide life-use heat water instead of boilers, and the geothermal space heating area has increased up to 188,500□. There were two boilers as regulate peak load with temperature -3ºC, 46 days of regulation and 237.5t coal consuming in the whole space heating term (135 days), representing 4.1 % of total energy consuming in space heating time. As the space heating area of 80,000□ is designed with boiler water temperature and it is not easy to change the radiator, thus the system was designed with two levels series connection: on one hand, it supplies the building with boiler used, and the water temperature is 90-65ºC; on the other hand, it supplies the new buildings with 65-40ºC water temperature and geothermal space heating drain temperature is 45ºC.

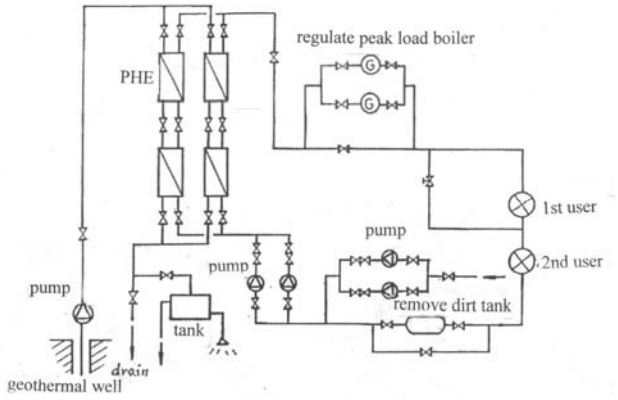

Figure 2

2.4 Concerning the lower temperature geothermal water of corrosion for quality water, in the past few years China has started research on the using of lower temperature heating floor radiation system. Except the outside network using non-metal tube, the interior network adopted non-metal underground tube (such as PE-X, PEX-A1, PP-C, etc). This kind of system can be adopted for geothermal drainage after indirect space heating as well; it can cut down the temperature of geothermal drainage and improve the geothermal utilization ratio. This system is designed mainly to make a better match between the high temperature part of indirect space heating and the low temperature part of floor radiation space heating.

The special features of low temperature floor radiation are: (a) It would make the same effort as comfortable if you cut down the inside temperature 1-3ºC designed; (b) It could conserve energy around 25%; (c) It would not destroy or occupy the space interior; (d) It is easy for amounting the space heating per every user; (e) The service life is long.

3. THE RESEARCH OF CERTAIN NUMBER OF QUESTIONS IN GEOTHERMAL SPACE HEATING

3.1 Regulate peak load

The regulate peak load of geothermal space heating system is a very important measure of improving the geothermal utilization ratio. Before 2002, the regulate peak load of Chinese geothermal space heating system all use coal burning boiler, but it pollute the environment although it is economically preferable. Since we enter the 21st century, Chinese government emphasize more about environmental protection, some big cities have already prohibited the using of boilers with under 10t/h for space heating; and the using of coal burning boilers for space heating in Beijing city has therefore been forbidden. As the capacity of regulate peak load coal burning boiler with the single well geothermal space heating system matched is small and not allowed to be used inside the city, hence the regulate peak load of geothermal space heating in big cities have no choice but to turn to regulate peak load of heat pump or natural gas burning boiler. The economical problems then emerged. According to national conditions of China, oil boilers for space heating can't be adopted, because the

domestic oil production can not meet the daily needs of developing and growing traffic transportation and chemical industry. The natural gas in our country is rich in reserve and has bright prospects of developing, but the selling price is still high (1.8RMB/m3) at the moment. Chinese electric power has develop rapidly and the price has been cut down relatively these years (0.4~0.5 RMB/kWh), however, the cost of space heating with electricity or regulate peak load are still higher. In such situation, heat pump started get use. According to the recent development tendency, the coal burning boiler has been headed by regulate peak load of geothermal space heating in the middle or small Chinese cities, so it is not yet possible to completely ban the use of coal burning boilers, including the smaller boilers with less than 10t/h. But the ratio of heat pump regulate peak load will increase rapidly. The research proves that if the regulate peak load is divided in two parts with the raised temperature, with low temperature part using the heat pump and the high temperature part using the boiler to raise the temperature, the heat pump COP will move over 5 with good economic result and less investment. It is an inexorable trend that the big cities such as Beijing have forbidden the use of coal burning boiler, but have adopted the regulate peak load of heat pump (the heating resource come with electricity or natural gas) or gas boiler. At present, the space heating air-conditioner system of re-injecting to the heat pump after take heat from shallow well is developing quickly in the big cities such as Beijing, Tianjin and so on.

3.2 Reinjection

At present, the important problem of the geothermal focus on space heating in Chinese cities is the protection and sustainable development of geothermal resources, the more bigger is the geothermal space heating area, the more bigger is the geothermal water capacity. As the reservoir pressure and geothermal well water level constantly fall, as mined excessively, it badly affects the sustainable development of geothermal space heating. For instance in Tianjin, which is the city with the largest area of geothermal space heating in China, and it has reached 8,600,000□ until 2002, there are more than 200 different kinds of geothermal well, among them 44 wells with over 1400m of well depth, 7 wells with over 3000m, also the deepest one is 4041m and the total capacity of water draw reach to 20,000,000m3/y. The reservoir pressure and well water level constantly fall because of the capacity of water draw is more than the capacity of supplementary water. Taking Tianjin WR 38 well depth as example, it was drilled on Feb. 1994 with 1911m depth, initial stage, the water of product well flowed automatically and the temperature was 93ºC, water draw capacity was 110m3/h. The average height of static water level (April to October) was –1.3m in 1996, -25.8m in 1997, -31.3m in 1998, -36.9m in 1999, -43.8m in 2000, and the average speed ratio of falling water level over 5.3m a year. The situation of some wells is worse; the fallen ratio per year can reach 10m. At the moment, lots of water level of height geothermal well is over –60m in 2000 at present, and falling quickly tendency. For this, Tianjin has already consider mine re-injection as important point in the geothermal developing work of these years, research and stipulate that re-inject drill well and the geothermal drill well in the city should be produced at the same time. Beijing, Xi'an and some other big cities rich in geothermal resource are facing the same problem of re-injection.

Presently, there are three ways of re-inject mining in China: (1) Draw and re-inject of double well in same layer (the distance between double well >800m); (2) Draw and re-inject in different layer; (3) Two draw wells and one re-inject well. The importance of this research is the reservoir temperature field pressure, different changes of chemical field, set up the mathematical model, calculate the reservoir layer parameters, forecast the tendency of water level changing in the future and so on, they're all caused by re-injection. There are still lots of problems and difficulties through the research on re-injection, although some accomplishments have been reached.

There have been 9 double wells with re-injected and 3,528,800m3 re-inject capacity since re-injection rock foundation (Jiyan) in Tianjin for 5 years. The experiment shows that if the re-inject system is strict and sealed up, it could prove the original water re-injection, raise the ability of re-injection, prevent the tube of corrosion and scaling reduce the pollution of quality water in the reservoir layer. The re-inject ability with re-inject of double well in same layer is affected differently by fracture growth degree and the condition of reservoir. It researches the relation between the capacity, pressure of re-injection and time. At the beginning of re-injection, the re-inject capacity is hardly affected by re-injected pressure; the harder is the re-inject pressure, and the larger is the re-inject capacity. But the re-inject pressure is reduced progressively with the time of re-injection getting prolonged. Under the same pressure, the re-inject capacity will be weaker with time, and the main reason is block up by the physical and chemical around the reservoir layer. The main factors affecting the result of re-injection are re-inject water temperature, re-inject pressure, re-inject way, re-inject type, the friction resistance between re-inject water and well tube, pump tube; the stop up of oxygen dissolves in water and other matters.

Research experiment of re-inject mine realized at different places shows that, as it is affected by reservoir situation of different area and layer, the re-inject ways are different and it is difficult to get the unitary model. Hence, the research and experiment task of geothermal re-inject mine is arduous and urgent.

3.3 To raise the geothermal utilization ratio

The crux of rising geothermal utilization ratio is to try to cut down the temperature of geothermal drainage. From the environment protecting view, some related Chinese departments do not allow the temperature of geothermal drainage to be over 35ºC. But for the geothermal indirect space heating system, it is difficult to cut the geothermal drain temperature down to 40ºC, because of the backwater temperature of lower circulate water would lead to the large radiator area , it is also not economic and at the same time the existence of PHE will lose about 5ºC of the heating delivery temperature. These recent years lots of radiator's design can be seen only in rare geothermal greenhouse, obviously they're not of reasonable and good design.

Multiple uses are one of the effective measures of cutting down the geothermal drain temperature and raising the utilization ratio. For instance, it could make the geothermal drainage as the heating water for swimming pool, bathroom and daily life-use hot water, or the fish fry breed supply for winter fish pound. But this way is obviously limited by particular conditions of space heating area such as swimming pool, fish feeing pool, which the dense resident areas do not possess. There are just bathroom and resident heat water supply that have a close relation with space heating, and it is also the most adopted one. But heating water capacity for baths is limited, it can not match with the hundreds tones per hour geothermal space heating of the geothermal drain, and the resident heating water supply need extra investment match with heating water delivery

tube or getting rid of iron device. Hence it is at the same time ideal to match the re-injection well with multiple uses.

Using heat pump to cut down the temperature of geothermal drainage is already getting a lot of attention these years. Although there are not yet many engineering cases on it, but the research and design department has add this kind of space heating engineering demonstration case into the recent undergoing feasible research of geothermal. It estimates that the using of heat pump suing will get the development rapidly in the coming 5 years.

3.4 The effective match between the geothermal and solar energy source.

The Chinese policy of developing new energy source (including geothermal and solar energy) in China is suit measures to local conditions, comprehensive utilization, multiple energies complement each other and seek benefit. It has formed the trend of developing modern agriculture field area by utilize geothermal and building a large area geothermal greenhouses these years. This is another form of geothermal space heating, the special feature of it is that ,firstly the heating load of greenhouse is hard. Secondly, the solar energy can be used efficiently on daytime. The geothermal greenhouses of northern area in China mostly depend on the solar energy to keep the temperature without space heating from 9:00 to 16:00, as long as the weather is sunny or cloudy and in most of cases water and heat supply can be stopped. The geothermal water with no space heating at daytime is delivered to the store pool or store tin with heat preservation and draw it to space heating in the evening, then increase the real capacity of water supplied without increasing the draw capacity of geothermal well, thereby increase the space heating area of greenhouses. Some research design department are doing different kind of research and experiment about the structure, heat warm, material, prevent leaking, of store pool and store tin as well as economical research and experiments.

3.5 The stipulate of reasonable draw capacity and using length of time of geothermal well

The draw capacity of geothermal well with one hole could change in a bigger range, for example we can determine that the discharge capacity of water draw experiment is 150t/h or 50t/h as well. Usually, the water temperature is steady and the more is the draw capacity, the more is the constructor area of space heating, but also the more is the reservoir pressure and water level fall as well. If the water level faces a certain depth and the deep well pump can't draw water, this geothermal well will no longer be used. What is the reasonable speed of water falling? How long is the service life of geothermal well? This problem has not yet got a clear and definite legal stipulation China. According to the request of Chinese geothermal management department, the service life of geothermal generate electricity well should be over 30 years; the service life of geothermal space heating and multiple use well should be over 100 years; the geothermal well of scenic travel spot should be use without limit. Although this kind of clarification exist in China, but geothermal space heating department everywhere make the service life as 30 years in their feasible demonstration, in general 30 years of service life is consider as demonstration proof. The fallen speed of water well level can guarantee that the well will be used for 30 years. This is human effort stipulation with non-science, lack foresight and just think about the benefit in the near future. For this problem, the management department could not solve it although everyone understands it.

4. CONCLUSION

Chinese geothermal space heating must go on a sustainable development way.

Chinese geothermal research and management department have noticed the momentum of geothermal space heating fast development, and realize the importance of sustainable development.

For this reason, the following important points are on research:

4.1 To protect the geothermal resource. On the basis of resource appraising, undertake a reasonable development of the geothermal resources.

4.2 To raise the geothermal utilization ratio, and find out economically how to cut down the drain temperature after geothermal space heating,

4.3 To strengthen the research of re-injection technology, and develop the re-injection experiment through research of the re-injection model and re-injection simulate, and take this work project as important point in the near future,

4.4 Continue to explore the geothermal resource within 3000m, further prepare the development of resources;

4.5 To research the technology law of geothermal develop utilization, complete the geothermal management method, go on the legal way.

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