Several Thinks about Geothermal Use and Geothermal Storage Applications

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【Abstract】 Recently years，geothermal use and geothermal storage applications become focus on air-conditioning field in China. This paper makes discussions about its background， concepts， application mode and system classification， interrelation between two specialities and two industries，as well as risk of these applications，and talk myself viewpoints. I hope that can discuss and consult these problems together with colleagues be designing these applications.

【Keywords】 Geothermal Use, Geothermal Storage, Water-Source Heat pump, Heat pump Air Conditioning.

1, Introduce

Because the weather conditions of north cities in China are colder than other cities in abroad with same latitude in winter and hotter than in summer, there are generally heating systems in common residential buildings. With limiting electricity is removed, new residences have left the place in which split air-conditioner is installed and electrical capacity used for air-conditioning. For advanced apartments and villas, various queries is suggested for separately set up two systems of central heating and air-conditioning cooling. The requirements for annual comfortable air-conditioning and high air quality of advanced villas, and dispersion of villas and performance of low load density have promoted designers bold in making innovations to probe into new cooling heating sources and seek appropriate air-conditioning modes.

Improving atmosphere environment in Beijing, government has order all of fire-coal boilers to change fire-gas within third loop road, but natural gas price is expensive. After heating system burden by state would change metering charge, economic burden of users and basic unit also will be a problem thought deeply by everyone.

With air-conditioning popularization in cities, the emission of condensing heat in summer has been concerned. Either air-cooling air-conditioning and water-cooling air-conditioning, their condensing heat all is directly and indirectly discharged into atmosphere at present. High temperature over 35 ℃ that occur continuously in north China in the last ten-day period of June 1999 continued eight days, the electrical load arisen to 496.8 million kW in Beijing area 29 June [1]. Maximum load of Beijing-Tianjin-Tangshan net reached to 12.125 million kW. The electricity used air-conditioning of them was 2.5 million kW or so [2]. Therefore, according to conservative calculation, the condensing heat discharged by air-conditioning had 3 million kW heat, corresponded to the heat which was discharged continually into atmosphere when 368.6 thousands of standard coal were fired every hour. “Pour oil on fire” in summer of hot wave billowing, which made city temperature arising further, strengthened hot inland effect, and worsened environment.

In order to shift peak demand for filling valley, Beijing Supply Electricity Bureau has implemented peak-valley time price in commercial buildings, so that using valley electricity after midnight is encouraged for air-conditioning with cool storage in summer, for heating with heat storage in winter. But only by resistance for heating, its COP is approach 1 at the most, can not is greater than 1. It only can fill valley, but can’t shift peak demand. It only increases using efficiency of generators and distribution facilities during valley time. With evaluation from energy using angles, it is very no reasonable. Then electric-driven heat pump is thought, since only it is able to increase COP to 3～4.

Under above background, persons with breadth of vision suggested various imagines of using geothermal or geothermal storage, and begin try to construct different geothermal use or geothermal applications at center of electric-driven heat pump.

In abroad, electric-driven heat pump had stridden into mature development period in 1980's. Not only quantity increased quickly and quality, performance and energy efficiency all had significant improvement, but some of air/water heat pumps and water/air heat pumps suitable commercial buildings, as well as geothermal storage systems for cooling and heating [3] had developed. These systems were small size early, only suited for single-family or multiple-family residences and villas. With progressively extension of size, they had been begun to apply to commercial and institutional buildings in 1990's [4].

In China, since middle of 1990's, air/water heat pump units have developed by leaps and bounds, and had more extensively applied in small, middle size of buildings of large-middle cities at the middle part of China and Yangtze River valley, and had basically realized native. But water/air heat pump units（e.g. water-source heat pumps）also mainly reliance on import at present. The studies relative to storage and to release heat for underground soil or rock and performances of hydrogeology still just begin. Therefore, for engineering applications of various geothermal use and geothermal storage with electric-driven heat pump, we should see that either they are a direction of future development, and also should soberly recognize that our technology preparations and design foundations are still very weak. Our brains would not been got dizzy with of news medium, because all of engineering constructions must own reliable data and is in an invincible position. For this reason, this paper is written specially. I will make some sober thoughts for some of the problems, and hope to approach and exchange views together with same trade who is going in for this aspect of design.

2, Two Concepts and Two Applications

First the two concepts of geothermal use and geothermal storage should be distinguished. As everyone knows, the earth is rich in gigantic heat energy. This heat comes from earth inside. It also is an energy resource. In the building application field, the geothermal resource is generally refer to heat sources with heat water as carrier. The geothermal use is refer to using heat which is contained within underwater of 25～95 ℃. Reasonable, scientific geothermal use not only should be used gradually, but also the problems of wasted water emission and environmental protection should be resolved. Because in HVAC applications using earth heat only would be a middle ring in entire geothermal step development use process, the effect which upstream ring would give to itself and which it would give to downstream ring must be considered in engineering designs.

Geothermal storage is referred to using soil, rock and aquifer as thermal storage medium. The heat is stored for heating in winter or the cool for cooling in summer. For example, the deep wells which are charged in winter for using in summer, use low air temperature to cool well water to 6～7℃, and then recharged into underground. By summer, water which is stored in underground in winter is taken as cold water for air conditioning; Water-source heat pump system with geothermal storage stores condensation heat released when refrigerated in summer to underground. By winter, this condensation heat with low quality is taken again from underground, through water-source heat pump, then arises to temperature with quality for heating. This system either reduces direct emission of great condensation heat to atmosphere, mitigates hot-island effect of cities, and also increases annual operation energy efficiency of water-source heat pump. It is noted that these applications either do not make earth as cooling source or teat source for air-conditioning. The earth itself only is a thermal storage body, and is seen as a “source” or “sink” as viewed only from water/air heat pump system operation.

3, Temperature Range of Geothermal Heating and its Heating Mode

It is noted first that underwater can not generally supply directly heat, because it commonly contains corresponding quantity of heavy carbonates or sulphates, corrosive gases, radioactive gases and silt, generally requires to insulate with plate heat exchanger. In engineering design, therefore, it must be considered that 1.5～3.0℃ temperature loss are caused by using plate heat exchanger.

In heating and air-conditioning, using geothermal also must determine heat mode according to usable temperature range of underwater. The temperature range of 70-95℃ underwater may be used in heating systems that consist of radiators; 50-65℃ underwater may be used in center air-conditioning system for heating or floor board radiant heating systems. If underwater of 25-45℃ temperature range again would be directly used in air-conditioning and heating, it needs that transmission heat areas would be greatly increased. It is not economic, reasonable, and even no feasible in practical applications. For these underwater with this low temperature range, it may be increased temperature by water-source heat pump as low temperature heat-source for air-conditioning heating, except for used in breeding, growing and bathing.

When underwater is used to design heating system, either inlet temperature which could be provided after used by upstream ring should be considered, and heat quantity which could be absorbed or released by terminal equipment of heating or air-conditioning system with conventional design flow rate. In other words, it should be considered that how many degree would be decreased for underwater? In order to provide basis for further step development using of downstream ring.

4, Two Modes of Air-Conditioning for Geothermal Storage

Annual comfortable air-conditioning must emit “condensing heat” of “electricity used by refrigeration ×（1+COP_C）”times when supply cooling in summer. If this heat could be stored underground and again be taken from underground in winter, after increased it’s temperature by electric-driven heat pump, it would be supplied to air-conditioning rooms for heating, which would save（COP_H-1）times than with only resistance（where COP_C is coefficient of performance with cooling mode of heat pump, COP_H with heating mode of heat pump）. Therefore, the heat pump with geothermal storage is a air-conditioning mode of best efficient, reasonable using energy, and best friendly to environmental, so that called as green air-conditioning mode.

How the condensing heat could be stored to underground and taken from? Generally there are two ways of engineering practices: one is referred to as ground-coupled heat pump system, other is referred as groundwater heat pump system.

Ground-coupled heat pump system couples water-source heat pump with earth transfer heat through buried heat exchanger with large numbers of transfer heat surface areas. For annual comfortable air-conditioning, this heat exchanger is generally buried in constant temperature layer of 60-120 m deep below ground, where the temperature is generally mean value of local annual air temperature. Commonly this heat exchanger is made from engineering plastic tubes which can bear pressure, protect from corrosion and is durable. This heat exchanger is mostly consisted of U-tube plastic tubes that are inserted in well bore with 100-200 mm diameter. The bores are filled with grouts and backfill. One of air-conditioning system ground-coupled heat pump needs to configure corresponding quantity of well bores with parallel, series connection as heat exchanger. The temperature rising or reducing that is performed within each U-tube or each set of U-tubes should generally equate the temperature reducing or rising through parallel water-source heat pumps. The total flow through U-tubes with parallel, series connection should equate the total flow through parallel water-source heat pump units in this system. Because the transfer heat of U-tube heat exchanger relies mainly on conduction of solid body, but the conduction of soil and rock is very low, so require configure enormous transfer heat areas. Consequently, the drilling cost of this air-conditioning system and installed cost of U-tube heat exchangers are maximum resistance for popularizing and developing this system.

The groundwater heat pump system uses underground aquifer as thermal storage body. Several wells are drilled on two aquifers that are not permeate each other and have not useful earth heat. These initial temperatures of two aquifers all are of constant temperature of local groundwater, e.g. 15℃ or so. When requiring cooling in summer, first the 15℃ groundwater is drawn from wells of one aquifer（generally are referred as production wells）, through water-source heat pumps that operate at cooling mode. After supplied cool quantity for air-conditioning rooms, the water with carried condensing heat（it's temperature arises to 20℃ or so）is injected into wells of other aquifer（generally are referred as injection wells）. Let is be supposed that the water in the two aquifers does not move and injected speed also is very low, then it is considered that the aquifer stored a number of 20℃ water heat around the injection wells. When requiring heating in winter, the injection wells in summer become winter production wells. The 20℃ groundwater is drawn from these wells and passes water-source heat pumps that operate at heating mode. After supplied heat quantity for air-conditioning rooms, the water that is absorbed heat（it's temperature reduces to 15℃ or so）again is injected into the summer production wells（generally are referred as injection wells in winter）. If this system operation is compared to air/air heat pump units, they not only do not be effected and limited by outdoor climate, but also their SEER and HSPF all are more 1-1.5 than those of air/air heat pump units. As a result, this system could bring significant saving energy efficiency. It is noted that, under condition that groundwater does not move, only when stored total condensing heat Q_C equates winter total heat load Q_H, the heat equilibrium between the two aquifers could be attained. When $Q_C>Q_H$, after through several years, the water temperature in the two aquifers would slowly arise, the HSPF also would increase a few and but the SEER would decrease somewhat. On the contrary, When $Q_C<Q_H$, the HSPF also would decrease a little and but the SEER would increase to some extent.

The distance between heat wells and cool wells should be determined by distance between the two aquifers and their thickness, so their distance would not be too near often. It should be noted that if there is a movement of groundwater from injection wells to production wells, and the production wells and injection wells are drilled into same aquifer, or their distance also is closer, the mixed loss of “cool” and “heat” must occur. The “stored heat” and “stored cool” functions of the aquifers would be greatly decreased

Only as to heat well or cool well, in order to ensure needed cooling water flow or heating quantity, when the maximum drawn flow rate of one well or injected flow rate is limited by conditions of local hydrogeology, it requires drill multiple heat wells or cools. In order to avoid looting water between parallel production wells each other, and interference between injection wells each other, the well distance should be determined from the total productive flow and injection flow as well as local hydrogeology data.

5, Infiltration Between Two Specialities Each Other and Close Cooperation Between Two Industries

The applications of geothermal use and geothermal storage make two specialities and two industries to connect together, which originally are part of two scientific fields. For designers working on HVAC speciality, at past they only know transfer heat of building and equipment of refrigeration, air-conditioning and heating, but don’t know transfer heat of underground soil and rock and thermal storage performance. They further lack the slightest knowledge of distribution and movement law of groundwater and drilling technology. For engineers working on geological prospecting speciality, they have a good command of geological structure, distribution and characteristic of underground aquifers, as well as drilling technology. But they would not very understand for the performances of transfer heat and thermal storage of soil and rock, for the effects of distribution law of temperature field in aquifer by underwater movement. However, as to the geothermal storage applications at present, we should soberly recognize that, the key of success or failure is that how level the engineering constructors recognize on transfer heat and thermal storage performance of underground soil and rock. How deep they know on the effects of distribution law of temperature field in aquifer by underwater movement. The study for the new scientific field must break the dividing line of original speciality division of work and knowledge category. The persons of HVAC speciality could not say that we only have an interest in transfer heat of buildings and equipment, and take no interest in heat transfer and thermal storage in underground. But the persons of geological prospecting speciality could not speak that “we only could drill wells for finding water, and don’t consider the effects of distribution law of temperature field in aquifer by underwater movement.” Hear, it is required that two specialities study each other, infiltrate each other, and commonly research. In recent years, “The experiment and research with shallow buried vertical tube exchangers for cooling in summer and heating in winter” by Liu Xianying, professor, Chongqing University, is one example in this aspect [5] [6].

In order to construct well one practical application of thermal storage heat pump system, it needs also the two industries closely to cooperate. The designers of HVAC not only should ask for local hydrogeology data and understand drilling well scheme to geological prospecting companies during preliminary concept phase. But they also must make to select equipment and to design system on the basis of data that the company provided local geological structure, aquifer distribution, water temperature, water quality, stored water quantity, and stable produced flow rate and so on obtained in test well and physical prospect. Except for providing above accurate data in time, the geological prospecting companies also must conduct deep, scientific analyses on temperature field distribution effects by groundwater movement, stableness of produced flow water temperature and quality, as well as reliable use-life of wells. Only the closely cooperation of the two parties is mother of success for applications.

6, Concluding Remarks----All Each Aspects of Construction Should Have Sufficient Understanding of Risk of Success or Failure for Applications.

The air-conditioning applications with geothermal use and geothermal storage would obtain low-priced heat energy, improve greatly annual energy efficiency of air-conditioning system, so that the cost burden of everyday operation is reduced. But it must be noted that , at present, the drilling cost in cities is very expensive. The drilling Price not only would relate to well deep and produced flow rate, but also relate to geological structure. The drilling cost between sand soil and gravel, rock structure would have great difference. Therefore, the capital cost of constructing wells often would exceed in times the capital cost of constructing conventional cool or heat sources. Moreover, because the data of distributions of geothermal and underground aquifer at constructing site couldn't sufficiently be grasped, or the effects and destruction of geological structure of aquifers by drawing and injecting could be not enough estimated. It is possible that result in drilling failure or use-life greatly shorten, so that entail application couldn't supplied heat and cool in time, or the heating and cooling effect couldn't attain design requirements, lead to legal lawsuits of owners and complaint of users. Because there is objectively this type of risk in applications, so owners should have sufficient thought ready in initial stage of construction. Before owners determinate the program of this application, they not only should conduct complete, detail, accurate economic comparisons for various programs, but also should clearly divide risk responsibilities for each aspect of construction. In invite-tenders specification and contract, the clear equalization prescriptions for "benefits" and "responsibilities" must be made, so that each party of construction all could be of one heart and one mind, and could do all one can for cooperation. Everyone could see "application success" as oneself "vocation".

7, References

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