

Inter-well Water - Heat Moving Law Study of Groundwater Source Heat Pump Based on The Radiotracer Test

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Abstract: Though introduction R&D of groundwater source heat pump in several years, the article point that unable to deeply recognize water-heat moving law of aquifer is a key question which restrain the groundwater source heat pump development. The article introduce to use the tradition way make much development on water-heat moving law at first, and then, on the basis of recommending the inter-well radiotracer test, prove the feasibility that applied to research water-heat moving law of aquifer, finally, point out the further research direction of the subject.

Keywords: R&D water-heat moving law, inter-well radiotracer test

1. FOREWORD

Entering 21st century, the mankind pays more close attention to the relationship among energy, environment and sustainable development than ever in the whole world. It must utilize clean regenerated energy as much as possible to realize sustainable development, and improve the rate of utilization of energy consumption. Building energy consumption occupies the important part in the total energy consumption of the country, the building energy consumption of the developed country generally takes total energy consumption 30% - 40%, and the proportion of our country is 26.7%^[1]. Strengthen building save-energy have a important meaning for sustainable development in our country.

The groundwater source heat pump utilizes the store water structure of the underground rock stratum, for example hole and crack etc, and utilizes two characteristic that small change temperature and slow speed of water is included, Irritate the cold water or the hot water into the aquifer adopt the artificial recharge, because the recharge water exists pressure, Push the original groundwater and store in the aquifer around the well^[2]. The air conditioner technology make the groundwater as cold source or hot source, and its cop is higher than other air conditioners system, the system can discharge the surplus cold or heat into soil at the same time, so it has higher environmental protection value. However, the system adopt the groundwater as cold source or hot source. Its complexity not merely lies in very deep underground, especially shown as that geological environment of different regions cause the complexity and the heterogeneity is different. So apply different date to different area, for example distance among the wells, depth of digging well, size of well diameter etc. Tradition way are mostly dig a test well and carry on dynamic observation through a hole, but this kind of test is inaccurate frequently and lack universality.

2. DEVELOPMENT OF THE GROUNDWATER SOURCE HEAT PUMP AND RESEARCH PROGRESS OF UTILIZING THE TRADITIONAL METHOD TO WATER-HEAT MOVING LAW OF GROUNDWATER

2.1 Development of the groundwater source heat pump and domestic and international research current situation

Run from the first water source heat pump system of Oregon of U.S.A. in 1948, raise the first climax of using of the water source heat pump in America and Europe^[3]. By the end of the seventies, people's attention begins to transfer to the effective energy source because of outburst of the oil crisis, people pay attention to groundwater source heat pump as a kind of environmental protection and green air conditioner way again. The ground source heat pump undergoes decades of development during this time, technology has been already perfect day by day.

The consumption of the groundwater source heat pump of America and Europe has been rising all the time at present, the investigation of American Ministry of Energy indicates^[4]: the output of the groundwater source heat pump in 1994, 1995, 1996, 1997 of U.S.A., including 5,924, 8,615, 7,603, 9,724, it has been on the rise all the time besides 1996, over the past 10 years, the annual growth of the underground water source heat pump is 12%, probably 500,000 sets (each set is equivalent to 12kW) are running now, probably there are 5,000 sets in installation every year, it was the school that was used most and handled official business in the building. Owner's satisfactory rate to the groundwater source heat pump is above 90% too^[5]. North in Europe, Because of climate being cold, groundwater source heat pump is used in heating mainly. The German government plans to produce 3,500,000 heat pumps by 1990, an underground water source heat pump accounts for 14%. Swedish

government's research in the ground source heat pump has certain subsidy measures in initial stage, but since 1990s, The government cancels subsidizing, ground source heat pump still had been growing by 1000 sets per year, have installed the source heat pump system of 230,000 sets totally in the whole country^[6].

Research of the groundwater source heat pump of our country since 1997 when we begin to study and introduce the European products, many heating demonstration project of the groundwater source heat pump has appeared, by the end of 1999, there is about 100 sets of groundwater source heat pumps system in the whole country^[6], among them not lack the example succeeding. In order to strengthen the cooperation in energy efficiency and recycled utilization of energy between china and the United States, enhance cooperation on energy-saved, environmental protection and resources, signed china-America energy efficiency and cooperative protocol of recycled energy in November of 1997, one of them is a development strategy of the ground source heat pump.

But the question of limiting the groundwater source heat pump developing rapidly in our country still exists, including the influence of the inter-well heat moving because of different geological state, different geological structure influence to recharge, standard of recharge water, etc, especially unable recognize inter-well heat moving law cause many project to fail. The flow state of recharge water in aquifer determine the inter-well heat exchange state directly. It's the key of solving these problems that realize the groundwater moving law and verify aquifer complicated geological situation.

2.2 The research advances in the traditional research method on the moisture and heat transfer in aquifer about the ground water-source heat pump

As the kinds of environmental protection and sustainable development cooling/heating supply form, the deep-well recharge water-source heat pump has been extensively adopted^{[7][8]}. The reference^[9] has presented the fundamental and the correlative technique economic analysis. The system form uses the annual temperature relatively invariant ground water as the water source of water-source heat pump. It builds the pumping and recharge well group, achieves the operation process of pumping cold water, recharge hot water in summer and pumping hot water, recharge cold water in winter. The heat within underground aquifer can be extracted, stored and transferred. The well group is the crucial part of the deep-well recharge water-source heat pump system. Its distribution decides the success or failure of project. At present, in the process of the domestic well group design and construction of this kind project, the system scheme feasibility criterion are the singer well water flow rate and the achievement of the favorable recharge. But in the process of well group feasibility analysis and design, hereinafter, several problem must be taken into account.

(1) The local aquifer thermal energy storing, transfer process

While utilizing the deep-well recharge system form, it needs to know the local aquifer thermal energy

supply capacity, that is the limitation of the system burdenable building cubage rate. When the building annual cooling/heating load is not regularity, what perennial influence effect that the system makes on aquifer water temperature, whether bring about aquifer "background temperature" reduction or increase year by year, lead to the system operation fail, how to constitute the relative reply strategy?

(2) The avoidance of "heat penetrating" effect

Because of the difference between recharge water temperature and initial aquifer water temperature, under the influence of conduction and convection, recharge water "temperature front" will induce the pumping well vicinity inlet water temperature increase or reduction, the phenomena always be called as "heat penetrating". How to ascertain the fitting well spacing, how to ascertain the well group distribution, how to avoid the "heat penetrating" effect, are the regardful problem to designer. In application of deep-well recharge water heat pump to high density residential district or the city commercial building, because of the restricted building space, how to optimize the well group distribution and respectfully corresponding pumping and recharge role, are the crucial part for avoiding "heat penetrating" effect.

(3) Hydrogeological condition effect

The core of the problem is how to consider the effect that local relatively larger flow velocity natural flowing ground water makes on the underground aquifer temperature field and the well group distribution, when the building annual cooling/heating load is not regularity, how to utilize the natural ground water flow field to optimize the singer well pumping or recharge role and their transform form, achieve the rational utilization of energy.

(4) The effect of ground unit and ductwork form and function mode

While utilizing the "small flux, large temperature difference" system function mode, it can achieve the most use of aquifer thermal energy storage and reduce the use of underground water resource^{[8][1]}. The discrepancy of well group distribution that in the two operation situation of "small flux, large temperature difference" and "large flux, small temperature difference", the underground aquifer water temperature field variation lead to is the designer concerned problem.

The above-mentioned questions always adopt the numerical simulation method to study at present.

The modeling of underground water movement and the numerical simulation work have already carried on for long time and deeply study on the relative field, such as aquifer seasonality thermal energy storage. The application and study of aquifer seasonality thermal energy storage have developed from the middle period of 1970's in China, North Europe, North America^{[11][15]}. The Lawrence Berkeley Laboratory (LBL) in American University of California set up the relevant single well aquifer thermal energy storage finite difference numerical simulator CCC, simulate and analyze the practical experiment by the simulator.^[16] The study result on the natural convection effect on the aquifer thermal energy transform by Buscheck, Molson, Zhang Zhihui and K.Nagano indicate that, because of the influence on the aquifer by the underground water

horizontal flow, the seepage coefficient of horizontal direction is far greater than that of vertical direction, the natural convection difficult to form. Shanghai Jiao Tong University has applied the fund project of national natural science about underground water thermal energy storage, mainly study on the heat conduct and flow coupling simulation and has made a series of achievements. The IEA ANNEX 8: Implementing Underground Thermal Energy Storage, that has accomplished between 1993 to 2000 by IEA, had a sub project that was about the application and evaluation of the underground thermal energy storage design and analysis implement. Gran Helström^[25] listed the fitting software for analyze the aquifer water and heat movement in the summarize report of the sub project, including AST, TWOW, SUTRA, Tradiken, HST3D. The Chiasson's dissertation has also listed the fitting software for analyze the aquifer water and heat movement, beside listed above, also including SWIFT, AQUA3D, FEFLOW and so on.

3. PROGRESS ON THE STUDY OF HEAT PUMP WATER-HEAT MOVING SOURCING FROM GROUND WATER BASED ON INTER-WELL RADIOTRACER TECHNOLOGY

3.1 the progress on the study of inter-well radiotracer

Inter-well monitoring technology of Radioactive isotope tracer has been applied in the monitoring of oil well^[17]. Sampling from the oil well around input well injected radioactive isotope tracer, yield curve of radiotracer will be obtained by analyze the activity of these sample^[17]. Based on the comprehensive analysis on hump and yield curve of radiotracer and the feature of the reservoir infiltration flow, the inhomogeneity of reservoir of oil well can be calculated by processing software. The key technique is how to find out the calculation method of yield curve of radiotracer. Since radiotracer can effectively trace input fluid, actually monitoring the status of radiotracer in inter-well aquifer is to monitor the status of inter-well input fluid. In this way, the inter-well reservoir can be monitored. Normally, there are two moving type of radiotracer in pore medium: the one is convection, and the other is hydrodynamic diffusion. The molecular diffusion of radiotracer is caused by concentration variation in liquid phase. These molecular of radiotracer diffuse from high concentration area to low concentration area through its molecular heat motion, and eventually reach equilibrium where dilution zone forms. We find out the calculation method of yield curve of radiotracer by calculating necessary index of stratum based on dilution theory and relevant mathematic formation^[17], and sequentially do research on seepage rate of the fractures between pumping well and input well.

(1) the development of radiotracer.

The first water-drive radiotracer was produced in 1950s^[17]. In that time the study is based on the radiotracer applied in ground water tracing, and gradually people found that because of technical constraint, the cost of high usage of chemical radiotracer was very high. Thereafter, people began to find a new tracer and radiotracer became a focus since on one side its sensitivity is high and on the other side

its small usage will not produce any pollution in stratum and the fluid in it. Initially^[25] was successfully applied in mineral practice^[18], and then composite Co series: Co (CN)⁻³ marked by Co-60, Co-58 and Co-57, ¹³⁴Cs⁺, and ¹³⁷Cs⁺ were concerned^{[19][20]}. After 1990, radiotracer technology was rapidly developed in the world, and more water-drive radiotracer appeared, such as: Use the thiocyanato, isopropanol and other alcohols of the ¹⁴C mark and Use every alcohols ³⁶Cl⁻ and ²²Na⁺ of the Co (CN)⁻³ and ³H mark^{[21][22][33]}. (2) The development of interpretive technology and the progress of tracing method.

At the beginning inter-well tracing technology had been applied in leaning the moving status of ground water^[24]. In 1965 Brigham developed the density formation of five spot well-net radiotracer^[25], which make interpreting tracing statistics by analysis possible. In 1978 Poper applied analytic dynamic difference analytical method into tracing research, which also can be applied in hydrodynamics calculation of recharge flow, ext swept volume, velocity of movement.

Inter-well tracing testing method is based on the tracer's "loyal" accompany movement with input fluid body, without interaction with other fluid in rock and pores of rock stratum. Cook released his patent of testing saturation ratio of left oil by dispensability radiotracer chromatography partition method in 1971. In the end of 1980s, Tang successfully applied this theory in ore yard practice and then developed a spanning technology on data processing —terminus method, providing a new testing method on searching left-oil in oil reservoir.

3.2 Feasibility analyse of inter-well water - heat moving law study based on The Radiotracer Test

Water moving determine heat moving directly in aquifer. This subject base on the inter-well radiotracer test, combine numerical simulation analysis, and research the water - heat moving law of groundwater source heat pump.

Well group of groundwater source heat pump system is set up and had very big difference with the oil well, the entirety of media have not reported the news that study of groundwater source heat pump based on The Radiotracer Test. Each step of The Radiotracer Test are essential to the setting-up the groundwater moving law model, so we must optimize choosing to the existing scheme. There are several respects mainly: 1) Set up new radiotracer concept and method; 2) Choose suitable radiotracers and detection method; 3) Utilize the advanced explain technology of computer to improve the detection sensitivity, offer the accurate explanation for response among the wells based on the true data.

Through inter-well radiotracer test, survey and explain the complicated geological situation in aquifer mainly, for example connective among the wells, heterogeneity of the layer and Whether the high influent exists etc, combine numerical simulation analysis software of groundwater water - heat moving, can in-depth analysis relevant problems, such the flow velocity, movement direction, inter-well swept volume and so on, carry on optimization design for wells distribution.

4. CONCLUSION

It is common knowledge that the energy question has already become the focus question that countries all over the world pay close attention to, every countries look for one clean energy that is low energy consumption and to air pollution lighter. Building energy consumption takes the large percentage of national energy consumption, so we must utilize clean regenerated energy as much as possible and improve the rate of utilization of energy consumption. to realize sustainable development.

This article study the groundwater moving law in aquifer based on the Radiotracer Test, and recognize the heat moving law. The following is the work that we will continue being done:

1. Research of Radiotracer Test experimental facilities
2. The flow characteristic among wells :1) resident time 、progressing velocity、inter-well swept volume and percentage of recovery radiotracers about the flow ;2) connective among the wells;3) seepage channels among the wells;4) Whether the high seepage exists ;5) heterogeneity of the layer;6) directionality flow trend of the groundwater.
3. The water moving simulation analysis among the wells of groundwater heat pump.

Through researching this subject, discuss the application method of the scene of radiotracer test. This method can be used in carrying on optimization design which the distribution of pump well and recharge well, and offer the decision basis for design、operation and management of groundwater source heat pump system.

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