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New Progress in Geothermal Energy Research of CNPC

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ABSTRACT

Development and utilization of geothermal resources are being taken into consideration. Researches for hot dry rock resources and electricity generation on enhanced geothermal resources have attracted much attention. Electricity generation technologies by middle-low temperature geothermal resources are commercial now.

Direct use of geothermal resources in China is always in a leading position in the world. The technologies for the use of shallow geothermal resources have been developed rapidly in recent years. Heating and cooling applications of geothermal pumps are increasing quickly. At the end of 2012, the total area of heating and cooling by geothermal pumps in China was up to 200 million square meters. According to the Twelfth Five-year Plan for building energy conservation, the total area of heating by geothermal resources in China will be even more than 500 million square meters by 2015 (around 350 to 400 million square meters of heating and cooling by geothermal pumps and 100 million square meters of heating by geothermal water).

The current research on geothermal resources in China focuses on hot dry rock and deeper formations. Chinese energy corporations involves in the research and development of geothermal resources. Petrochina provides many projects for the utilization of geothermal resources in its oilfields. Sinopec has founded enterprises and scientific research institutions for the research and development of geothermal resources.

1. INTRODUCTION

Direct use of geothermal energy in China is in a leading position in the world. Chinese government has been popularizing energy-saving policy in recent years. This offers an opportunity for the development of shallow geothermal energy and the applications of geothermal pumps for space heating and cooling. At the end of 2013, the total area of heating and cooling by geothermal pumps in China was up to 240 million square meters. The total area of heating from geothermal energy in China is expected to be more than 500 million square meters in 2015, with around 350 to 400 million square meters of heating and cooling by geothermal pumps, and with 100 million square meters of heating by hot water.

CNPC participates in the research and development of geothermal resources and offers projects for the utilization of geothermal resources in its oilfields. Enterprises and research entities for the research and development of geothermal energy is founded by SINOPEC.

2. EARLY RESEARCH ON GEOTHERMAL ENERGY BY CNPC

Different tectonic backgrounds of all large petroliferous basins in China cause the difference in development and evolution of geological history. Therefore, the types of geothermal resources formed in deep reservoir in hydrocarbon basins have obvious differences, including the decrease in gradient of temperature and thermal current values and the gradual increase in salinity from west to east. China has not only the good resources of geothermal water for energy development but also the nice resources of hot mineral water for therapeutic function and the resources of hot brine for chemical extracting.

North China is rich in geothermal resources. From the year of 1980 to 1985, researchers in Geological Institute of Chinese Academy of Sciences did a lot of works on geothermal resources in North China with the help of former petroleum ministry. They pointed out that the development and application of geothermal energy in North China is promising. The high-efficiency way to develop and use geothermal water in North China is to utilize the hot water wells drilled in petroleum exploration and the abandoned oil production wells which can be used to produce geothermal water after low-cost repairing.

According to the projects related to geothermal resources survey and evaluation in oilfields, in 1985, the former petroleum ministry, asked oilfields like Huabei, Jidong etc. did a systemic evaluation of the geothermal resources in their oilfields. On the basis of national standard (GB11615-89), area of geothermal reservoir was determined and the amount of geothermal resources under different geological conditions and the amount of geothermal water were estimated using lots of geological data and information of well temperatures during the exploration and development of petroleum. There are abundant geothermal resources with low and middle temperature in the north part of Songliao basin. In 1998, Petrochina Daqing branch did research and evaluation on geothermal resources in the east area of north part of Changyuan ,Daqing, and the north part of Songliao basin.

In Beijing, Tianjin and Hebei, the central uplift zones constructed with Nituozhen, Gaoyang, and Ningjin saddle-backing are abnormal high temperature geothermal areas, in which gradients of temperature ranges from 3.2^{o}C/100m to 6.0^{o}C/100m, and the maximum gradient of temperature is more than 10^{o}C/100m in Niutuo saddle-backing (Fig 1).

Based on the research on geothermal resources, projects for the utilization of geothermal energy, such as heating the office buildings, constructing greenhouses for planting by the Service Departments of oilfields, had been developed in Huabei oilfield, Dagang oilfield respectively, which made economic benefits and offered job opportunity.

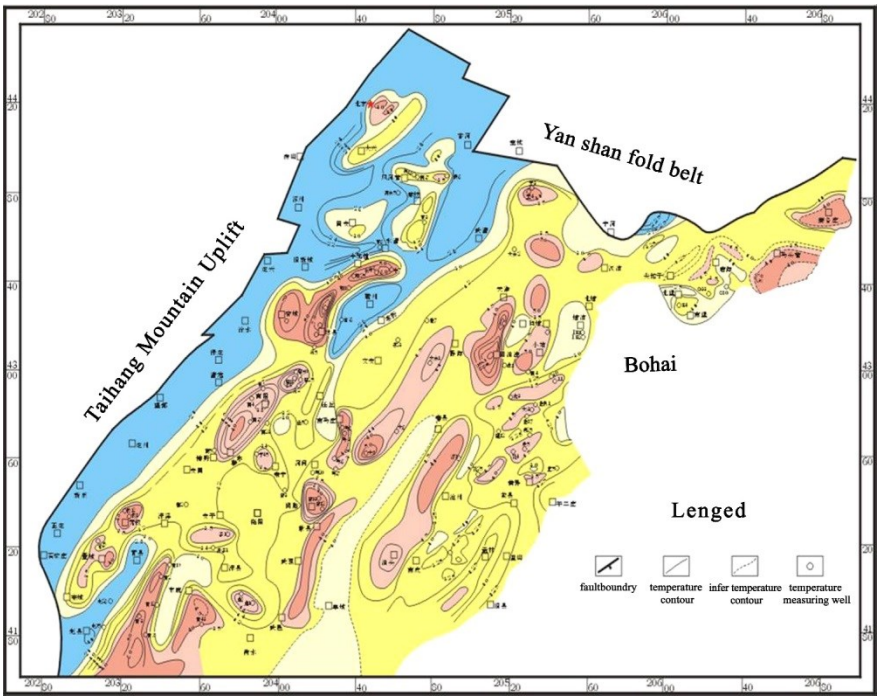

Figure 1: Geotemperature contour in Beijing, Tianjin and Hebei (within 3000m in burial depth).

3. PROGRESS FOR GEOTHERMAL ENERGY RESEARCH BY CNPC

Evaluation and classification standard for geothermal resources in oilfields was developed based on geological data, thermal attributes of rocks, features of geothermal resources abundance, etc., in the oilfields like Daqing, Huabei and Liaohe. The total amount of geothermal resources in three large oilfields was calculated and the prospects and economic effect were evaluated based on the data of thermal properties of rocks, the analysis of geothermal reservoir parameters and integrated study for the distribution of fields.

3.1 Definition of Evaluation Parameters

Evaluation of geothermal resources involves the key parameters as: thickness of geothermal reservoir, effective porosity, area of geothermal reservoir, temperature of geothermal reservoir, reference temperature, thermal capacity, density of rock, thermal capacity and density of oil and water and recovery factor.

Thickness of geothermal reservoir is the thickness of net pay which is calculated by well data logging which is based on the study on the relationship between the lithologies, properties, water bearing and electricity of geothermal reservoir. Effective porosities of geothermal reservoir are determined with core experiment and the interpretation of logged data. Area of geothermal reservoir is the area of sandstones in which the geothermal gradients are more than 3^{o}C/100m. The temperature of geothermal reservoir is calculated by downhole temperature measuring or data logging and it is estimated by the geothermal gradient of the area where there is no well. Reference temperature, i.e., the temperature of strata with constant temperature, is approximately equal to the local annual average temperature of atmosphere in theory and its value is taken as 15^{o}C in this paper. The maximum depth of the evaluated geothermal reservoir is 4000 m. The amount of recoverable resources in this paper means the volume of recoverable geothermal water and the value of thermal energy in it. The volume of recoverable geothermal water depends on the recovery factor. Value of recovery factor relies on the local economy level and the demand for geothermal water. The recovery factor of geothermal water usually ranges from 0.2 to 0.3 in stratiform geothermal reservoirs and from 0.05 to 0.1 in zonal geothermal reservoirs.

3.2 Evaluation Method for Geothermal Resources in Oilfields

According to the DZ 40-1985 (the ministerial standard, ministry of geology and mineral of the P.R. China, 1985), the formula to estimate the amount of geothermal resources for normal geothermal fields is,

$$Q_R = A \cdot d \cdot \left(t_r - t_j\right) \cdot \overline{C} \tag{1}$$

$$\overline{C} = \rho_c \cdot C_c \cdot (1 - \Phi) + \rho_w \cdot C_w \cdot \Phi \tag{2}$$

Where A, d, φ, t_r, t_j, ρ_c, C_c, ρ_w, C_w are the area of geothermal resources (m^2), thickness of the area (m), porosity of geothermal reservoir (f), temperature of geothermal reservoir (^{o}C), temperature of constant temperature strata (^{o}C), density of reservoir rock (kg/m^3), specific heat of reservoir rock (J/(kg.^{o}C)), density of stratum water (kg/m^3) and specific heat of stratum water (J/(kg.^{o}C)), respectively.

3.3 The Results of Evaluation

3.3.1 Potential of Geothermal Resources in Huabei Oilfield

Huabei oilfield is located at Jizhong sag, Bohai bay basin. Its total amount of geothermal resources is 7.099×10^{24} J. The total volume of geothermal water is 5.37×10^{12} m^3 and its recoverable volume of geothermal water is 1.14×10^{12} m^3. The total amount of recoverable geothermal resources is 3.06×10^{13} J.

•3.3.2 Potential of Geothermal Resources in Daqing Oilfield

Daqing oilfield is situated at the north part of Songliao basin. The total amount of geothermal resources in the area with abnormal temperature gradient is 2.8×10^{21} J. The total volume of geothermal water is 2.44×10^{12} m^3 and its recoverable volume of geothermal water is 6.1×10^{11} m^3. The total amount of recoverable geothermal resources is 8.9×10^{12} J.

•3.3.3 Potential of Geothermal Resources in Liaohe Oilfield

Liaohe oilfield is located in Liaohe sag, Bohai bay basin. The total amount of geothermal resources in the area with abnormal temperature gradient is 1.0×10^{21} J. The total volume of geothermal water is 8.5×10^{12} m^3 and its recoverable volume of geothermal water is 1.8×10^{11} m^3. The total amount of recoverable geothermal resources is 2.93×10^{12} J.

4 DEVELOPMENT AND UTILIZATION OF GEOTHERMAL ENERGY BY OILFIELDS

All state-owned petroleum companies in China are the integrated energy companies which involve in the fields of petroleum exploration and development, crude oil refine, etc. Therefore, they have technologies, equipment and intellectuals to develop geothermal energy; meanwhile, they can save a large amount of money using geothermal energy instead of fossil fuels during the process of oil production.

Most projects for the utilization of geothermal resources of oilfield by company branches of Petrochina are taken by production units of them. Daqing and Liaohe oilfields, etc. have heating systems using geothermal pumps for office buildings and for oil production. Huabei oilfield not only has the test projects to generate electricity using middle-low temperature geothermal energy but also heats the oilfield by drilling geothermal wells or utilizing abandoned production wells.

Figure 2: Test for electricity generation based on middle-low temperature geothermal energy in Huabei oilfield.

The development and utilization of geothermal resources is growing rapidly in Sinopec. The state research and popularization center of applied technologies for the development and utilization of geothermal energy is founded in Sinopec. Geothermal developing branches in more than 10 cities of China are built to develop geothermal resources on a large scale and to build standard stations for heating and cooling by geothermal pumps. Sinopec commenced its geothermal projects at Xiongxian, Hebei province. 40 geothermal wells (24 wells for production and 16 wells for reinjection) and 20 geothermal stations, complete reinjection of the used-geothermal water, geothermal heating for 99% residential areas of the city, achieved the good balance between the geothermal water production on a large scale and the protection of geothermal reservoir. This attracted the attention of the Department of Energy Management, China. The geothermal heating mode of Xiongxian will be popularized in China.

Living base of CNOOC in Tanggu has developed the utilization of geothermal energy for many years. To date, living community of 140 million square meters employs geothermal heating using three gas pressure regulation stations.

The research on geothermal resources in China started at 1970's. However, the developing speed is slow. In recent years, the participation of petroleum enterprises in the research and utilization of geothermal resources brings a new era in the history of Chinese geothermal development.

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