GEOTHERMAL COMPREHENSIVE UTILIZATION IN TUANBO LANDSCAPE REGION, TIANJIN, CHINA

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ABSTRACT

Tuanbo Landscape Region is one of 9 geothermal abnormal area in Tianjin. The total thermal energy stored in the reservoir is obtained from estimates of 6.36x10^18 J and can be extracted heat about 92.73x10^18 J from the reservoirs. Mean values of the thermal energy recoverable from the surface depend on estimates of the number of production wells. The quantity of exploitation is 23.4x10^6 m^3 without injection at a maximum draw down of 100 m.

The geothermal engineering plan will drill up to 4 deep wells in bed-rock and 2 shallow wells, located at Ming Hua Zhen group Tertiary. The deep wells (82°C) support space heating, which heats about 277700 m^2 of floor space and major parameters have been defined. The geothermal waste water (about 45°C) will be able to use in bathing, swimming pool and physiotherapy with a series of water processing system. In addition, the shallow wells (60°C) will be utilized on greenhouses, producing mineral water, breeding, and so on. The direct using geothermal energy will save coal 7326 t/yr., and geothermal utilization efficiency will be 48.4%.

1 INTRODUCTION

A large geothermal utilization scheme in Tuanbo Landscape Region is located at the center of Wanglanzhuang geothermal field. In the conduction-dominated system, upward circulation of fluid is less important than the existence of high vertical temperature gradients (6°C/100 m) in rocks that include aquifiers of significant lateral extent. The total area of the surface covers about 8700 ha, where 6000 ha of them is Tuanbo reservoirs.

In 1984, first well has been drilled outside of the Tuanbo Landscape Region. The exploitation layer sits 988.24 m depth. After 10 years ago, the temperature remained almost constant with reasonable exploitation (below 54°C). The residents get a better economic benefit from the geothermal comprehensive utilization. The demonstration engineering of geothermal system has launched and accumulated a wealth of experience. Tuanbo Landscape Region is a development project for further along on geothermal utilization. Feasibility study has been done in 1993, and proves implementation of the plans each of them separately. The diagram shows that it is reliable to use geothermal energy in Tuanbo (See Fig. 1). The survey of geological and geophysical made the stratigraphic correlation with same layer outside the area, and forecast the stored heat of the reservoir.

2 GEOTHERMAL RESERVOIR ASPECT AND ASSESSMENT

The conduction-dominated system within which low-temperature geothermal resources occur is discussed, and the methods used to estimate accessible resource base, resource, and beneficial heat are described. The well testing and assessment of geothermal resources indicate that 6.36x10^18 J thermal energy is stored within 640 km^2 of area 600 m thickness in upper Tertiary. The production rate is 80 t/h of 82°C water. The flow rate of single well will be impacted due to unstable porosity of the reservoir, but the quality of water and temperature still are uniform. The method used here to calculate recoverable energy involves estimation of the number of wells, and each reservoir can support over a development period of 15 years, assuming that cold water will be injected into the reservoir (100,100 t/yr). The resource is given by:

\[ q_w = (\rho c_p)NQ(t - t_e) \]

Where \( q_w \) is the resource, \((\rho c_p)\) is the volumetric specific heat of the fluid, N is the number of production wells, \( Q \) is the average volumetric discharge of each production well, and \( P \) is the development period. Fluid temperatures at the well-head are assumed to equal the corresponding reservoir temperatures, the reference temperature is 15°C.

To determine optimum values of N and Q, several reservoir parameters must be known, and economic and engineering aspects of the process for which the resource is to be used must be considered. A detailed analysis of field design for each reservoir is beyond the scope of this assessment. At present, Tertiary reservoir has been limited to exploit due to subsidence of 7.8 mm per year without injection. Therefore, the production well has to drill more deep to bed-rock reservoir (1500 m or more).

3 ENVIRONMENTAL IMPACT ASSESSMENT

Environmental impact assessment is a process whereby a conscious systematic effort is made to assess the environmental consequences of choosing between various options which may be open to the decision-maker. Environmental assessment must begin at the inception of a proposal, when there is a real choice between various courses of action. In early stage, as well as looking at environmental consequences of choosing between options, environmental impact assessment should provide baseline data against which to measure future environmental impact. It should also identify aspects of the environment that require investigation.

In Tuanbo Landscape Region, environmental protection is very important. It is necessary to examine the environmental impact of geothermal wastes water, such as the polluted soil and river by salt, F, Hg and so on. The major pollution is F (7.84 mg/l) which goes beyond the limitation of standard. Particularly, the excess waste water imitates to the surface of Dulijian river. The more perfect way of the possibilities for disposal are:
(1) Reinjection system is proposed for Tuanbo Landscape Region. Drilled the additional wells should be consider during the development Tuanbo region.

(2) Release the waste water into the river for dilution the content of F. The content of F is estimated about $20 \text{mg/l}$ in bottom of the river without using space heating, and $30 \text{mg/l}$ within production rate up to $32 \text{mg/l}$ in winter.

(3) The typical pipeline packs waste water to the special pool, where growing plants can absorb F and salt, then release the water to the river.

4. GEOTHERMAL COMPREHENSIVE UTILIZATION

(1) Geothermal Space Heating

The geothermal space heating is the most major scheme in Tuanbo. There are three primary reasons our society should promote greater of geothermal resources instead of increased use of fossil energy on space heating:

* Geothermal energy is, in many cases, a low-cost option today, but it would be much more competitive economically if direct and indirect subsidies for the traditional fuels were removed or reduced;

* Geothermal energy is one of the most environmentally advantageous sources available,

* Greater use indigenous energy resources, such as geothermal energy, would allow decreasing conventional energy sources and increasing our energy security.

In Tuanbo Landscape Region the municipal space heating scheme serves about 95% of the 5000 tourists. About $32 \text{kg/m}^3$ of geothermal fluid is supplied annually to 2777000m$^2$ in Tuanbo, including hot water supplies. The total capacity, in the heating period, will amount to as

<table>
<thead>
<tr>
<th>Content</th>
<th>Heat Area (m$^2$)</th>
<th>Heat Load Per Unit Area (W/m$^2$)</th>
<th>Heat Load (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Service Region</td>
<td>43,000</td>
<td>74.4</td>
<td>3.2665</td>
</tr>
<tr>
<td>Convalescent Hospital</td>
<td>40,000</td>
<td>75.125</td>
<td>3.005</td>
</tr>
<tr>
<td>Hot Spring Vacationland</td>
<td>90,000</td>
<td>76.11</td>
<td>6.85</td>
</tr>
<tr>
<td>Traditional Zone</td>
<td>35,000</td>
<td>75.0</td>
<td>2.625</td>
</tr>
<tr>
<td>Meeting Center</td>
<td>30,000</td>
<td>80.0</td>
<td>2.4</td>
</tr>
<tr>
<td>Water Town</td>
<td>28,000</td>
<td>75.0</td>
<td>2.1</td>
</tr>
<tr>
<td>Playing Zone</td>
<td>8,000</td>
<td>70.0</td>
<td>0.56</td>
</tr>
<tr>
<td>Municipal Building</td>
<td>3,700</td>
<td>74.05</td>
<td>0.274</td>
</tr>
<tr>
<td>Total</td>
<td>277,700</td>
<td>78.185</td>
<td>21.1</td>
</tr>
</tbody>
</table>

(3) The Typical Heating System

The heating system can be divided direct and indirect use. If geothermal fluid has a good quality, it is a better to use in direct heating system without heat exchangers. However, big problem usually exists as corrosive so that equipment and pipeline are damaged in short order due to high chloride concentration. Especially, the heating circulation systems are difficult to seal very well, and Oxygen of air comes in to react with CI, so that pipeline system is seriously corroded. To date there are very few installations using direct heating system in China.

The principle heat extraction device is heat exchanger which utilizes town water to transfer the energy from the well to the load. Then geothermal waste water, which outflows from the heat exchangers, can still use in swimming and bathing (See Fig 2).

(4) Material Choice of Heat Exchanger

The choice material makes from final report of geothermal water analysis first. Ellis diagram points out principle of selection material. (See Fig. 3) According to survey of exploration and information of monitoring, the chloride concentration is more $500 \text{ppm}$, and more $80^\circ \text{C}$ of water. Following the Ellis diagram, the point just sits the region of corrosion, and corrosion will occur whatever choice 304 or 306 stainless steel. Therefore the material of the heat exchanger must choose Titanium, although this kind of material is so expensive (2.5 times of stainless steel). The economic analysis has been done before carrying out the engineering.

(5) Type Choice of Radiator

In comparing low-temperature geothermal space heating with conventional energy space heating it is found that the indoor radiator in use is different in three aspects: hot water temperature, temperature drop and flowing through radiators. Most of the heating systems used in China supplied water is $95^\circ \text{C}$, while that of the return water is $50^\circ \text{C}$ and cast iron radiator is chosen as indoor radiators. In geothermal space heating, the used geothermal water flowing out of the heat exchangers usually drops to $45-50^\circ \text{C}$, which...
can satisfy the requirements of space heating. The number of radiator has to increase more 1-2 times comparing with conventional energy space heating. However, it is very difficult on architecture design, and affects artistic of the rooms too. Fan coil, as a radiator, is used widely in geothermal space heating. The heat transfer coefficient is more 1.8 times than cast iron radiator, because of the typical heat transfer enhancement. The inlet temperature requires below 60°C, and temperature difference can be 30°C. It uses series-parallel connection with the geothermal system. The Table 2 listed are test results of technical index of two type.

The heat transfer coefficient can be calculated as,
\[ K = \alpha T \beta \]  \hspace{1cm} (2)

Where \( \alpha , \beta \) are experimental coefficients. For cast iron radiator: \( \alpha = 2.62, \beta = 0.269 \); For fan coil: \( \alpha = 11.6, \beta = 0.002 \).

The relationship between the heat transfer coefficient \( K \) of radiators and water flow rate \( G \) passing through radiators can be found out under the condition that the average temperature going in and out of radiator is kept constant. The obtained data can be coordinated as: (See Fig. 4 and Fig. 5)

Because of the low-temperature energy, it is impossible that a large heating area is supplied by geothermal energy only. When the outdoor temperature is below -1°C, the per unit area needs very large heat in order to keep room temperature. It is necessary to put other resources to rational use and raise rate of use as far as possible. A fossil fuelled peaking station (84 MW) is used to boost temperature (75°C to 95°C) during the coldest days, and geothermal energy bears others (144 MW). The relationship between geothermal energy and boiler is calculated as:

The proportion of geothermal energy supplying
\[ R = \frac{T}{T_1} \times 100\% \]  \hspace{1cm} (3)

The proportion of boiler supplying:
\[ R_1 = \frac{T_{11}}{T_{12}} \times 100\% \]  \hspace{1cm} (4)

Where:
\( T \): Inlet temperature of boiler;
\( T_1 \): Outlet temperature of boiler;
\( T_{12} \): Temperature of geothermal waste water;
\( T_2 \): Outlet Temperature of indoor radiator

Geothermal space heating requires very little space, taking up only a few hundreds meter square for heated 100000m² or more. In general, the peaking station is more 5 times than geothermal heating plant. Therefore, using geothermal energy for space heating reflects economic and social benefit upon Tuanbo Landscape Region.

4.2 INDOOR SWIMMING POOL

Indoor swimming pool is a necessary facilities of Landscape Region. It requires temperature lower than those needed for the space heating and drying. The heat sources of swimming pool mainly utilizes the waste water, which is out of the heat exchanger, and water processing system should clear away \( F_c \) from geothermal waste water in order to prevent it to deposit on wall of the pool. The water of the pool should maintain at 28°C in winter, and hot water also need to supply at all time due to heat.
The heat loss of water surface evaporation
\[ W_1 = \tau (0.0178 + 0.0152V)P_0P_2F \quad (\text{kw}) \] (5)

Where:
\( \tau \) = Latent heat of evaporation, \( \tau = 582.2 \text{ kcal/kg} \)
\( V \) = Velocity of water surface
\( P_0 \) = Pressure of saturated steam
\( P_2 \) = Pressure of air
\( F \) = Area of the pool.

The heat loss of surface conduction
\[ W_2 = \alpha F(t_s - t_g) = 0 \quad (\text{kw}) \] (6)

Note: The design temperature \( t_s \) and indoor temperature \( t_g \) is same in this engineering. The heat loss can be ignored.

The heat loss of heat transfer in wall and bottom of pool:
\[ W_3 = \sum K \cdot F_P(t_s - t) \quad (\text{kw}) \] (7)

Where:
\( K \) = Heat transfer coefficient of wall; \( K = 1.163 \)
\( F_P \) = The area of wall and bottom
\( t_s \) = Soil temperature (\( \mathbb{C} \))

4.3 Benefits of Direct Use
The main advantages of direct utilization of geothermal energy are:

(1) High conversion efficiency
(2) Use of low temperature resources which are numerous
(3) Use of existing engineering technology (pumps, well-head equipment, controls, pipe etc.)
(4) Short development time when compared with other energy development
(5) Water can be transported long distances with a better thermal insulation properties.

Of course these benefits are only realized if the economics is favorable.

6. CONCLUSION

(1) The lack of the data of Ming Hua Zhen Group in upper Tertiary, The stored heat can be appraised recently. In Scenic Spot, economic geothermal resources of Wu Mi Shang Group, in bedrock, stores 6.36x10^18 J, and can be extracted about 92.73x10^15 J from the reservoirs. The plans will carry out that the two reservoirs must be exploited at same time with injection.

(2) The only 4 deep wells can be drilled in the Scenic Spot in order to keep the space of the well. The surveys of geological and geophysical indicate that no subsidence happen due to characteristic of the reservoirs.

(3) Direct using geothermal energy for space heating is, not only protecting environment, but also saving on the conventional energy. The coal will cut down 7326t/yr., and reduce SO2 1760t/yr., NOx 64t/yr., dust 172t/yr., and coal slags 2198t/yr.

(4) The space heating must be supplied by both of geothermal energy and conventional energy. The peaking station accounts for 36 per cent of the capacity load (8.4MW) Geothermal plant is 14.5MW, which covers 64 per cent of the capacity load (14.5MW), includes the heat load of living water

(5) The geothermal waste water can be still used in bathing and swimming pool. The economic temperature of waste water is controlled at 45 \( ^{\circ} \text{C} \) or more through optimum design with the computer.

(6) The geothermal drying requires a higher temperature water. It can be carried out with the space heating. The production of drying has a good channel and a great variety. The investigation of market points out that this utilization has prefect prospects.

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