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 6.36×10^{18}J and can be extracted heat about 92 73×10^{16}J from the reservoirs Mean values of the thermal energy recoverable at the surface depend on estimates of the number of production wells The quantity of exploitation is 23 $4\times10^{6}m^{3}$ without injection at a maximum draw down of 100m

The geothermal engineering will plan to drill up to 4 deep wells in bed-rock and 2 shallow wells, located at Ming Hua Zhen group Tertiary. The deep wells (82℃) support space heating, which heats about 277700m^2 of floor space and major parameters have been defined. The geothermal waste water (about 45℃) will be able to use in bathing, swimming pool and physiotherapy with a series of water processing system. In additional, the shallow wells (60℃) will be utilized on greenhouse, producing mineral water, breeding, and **so** on. The direct using geothermal energy will save coal 7326t/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℃/100m)** in rocks that include aquifers of significant lateral extent. The total area of the surface covers about 8700ha, where 6000ha of them is Tuanbo reservoirs.

In 1984, **first** well **has** been drilled outside of the Tuanbo Landscape Regon. The exploitation layer sits 988.24m depth. After 10 years ago, the temperature remained almost constant with reasonable exploitation (below 54t/h). 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

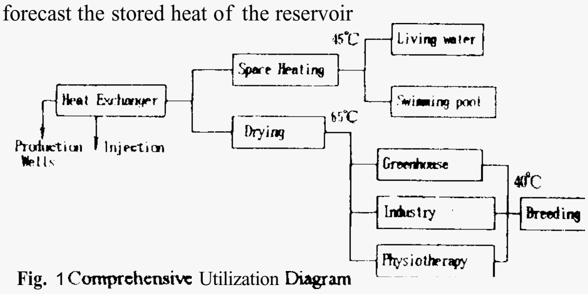

Fig. 1 **Comprehensive** Utilization **Diagram**

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 6.36×10^{18}J thermal energy is stored within 640Km^2 of average 600m thickness in upper Tertiary The production rate is 80t/h of 82℃ 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, 100l/yr.). The resource **is** given by:

$$q_{wh} = (\rho c)_f NQP(t - t_{ref}) \qquad (1)$$

Where q_{wh} is the resource, $(\rho c)_f$ **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℃
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 well-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 8mm per year without injection Therefore, the production well has to drill more deep to bed-rock reservoir (1500m 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 environment 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 84mg/l) which goes beyond the limitation of standard. Particularly, the excess waste water imgates to the surface or Duliujian river The more perfect way of the possibilities foe 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 2 02mg/l in bottom of the river without using space heating, and 3 19mg/l within production rate up to 320t/h 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

4 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 320t/h of geothermal fluid is supplied annually to 2777000m^2 in Tuanbo, including hot water supplying The total capacity, in the heating period, will amount to as

* The heat **loss** conduction per year	kJ/m yr	560022
* The load of living water	kJ/m yr	52747
* The heat **loss** of pipeline system	kJ/m yr	21099
* The stored heat of indoor	kJ/m yr	-88585
* The supplied heat from sun	kJ/m yr	-81375
* The total capacity of heat	kJ/m yr	463908

(l) The Design of Meteorological Parameters

* Indoor Temperature

The design of indoor temperature depends on the standard of comfort Usually, 18℃ is adopted for civil building as a design of indoor temperature in China Considering the topographer, weather and quality of the building in Tuanbo, the indoor temperature is designed 20℃ in this engineering

* Outdoor Temperature

The design of outdoor temperature relates with meteorological condition of different region, and four types of the outdoor temperature can be chosen for designing space heating, -9℃, -11℃, -12℃ and -13℃.

* Heating Period

The heating period not only depends on weather of different region, but also comfortable sense with economic analysis Tuanbo Landscape Region sits outside of down *town* and the quality of buildings also require a better heating condition The heating period is added from 122 days/yr to 147 days/yr

(2) Design of Heat Load Per Unit Area

The design heat load per unit area is bases on the temperature of indoor and outdoor, building construction mainly The standard design indicates range of the heat load per unit area with different kind of building and using **As** considering different using, such as hotel, meeting center, shopping center, public place of entertainment, hot spring resort and physiotherapy center, the calculated heat load per unit area and heat load see the Table 1.

Table 1

Content	Heat Area (m^2)	Heat Load Per Unit Area (W/m^2)	Heat Load (MW)
Service Region	43,000	74.4	3.2665
Convalescent Hospical	40,000	75.125	3.005
Hot Spring Vacationland	90,000	76.11	6.85
Traditional Zone	35,000	75.0	2.625
Meeting Center	30,000	80.0	2.4
Water Town	28,000	75.0	2.1
Playing Zone	8,000	70.0	0.56
Municipal Building	3,700	74.05	0.274
Total	277,700	78.185	21.11

(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 exacts 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 Cl, 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)

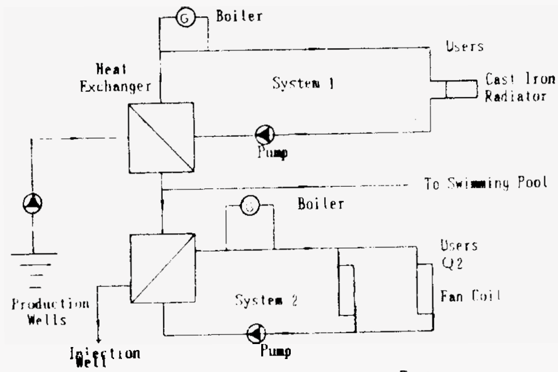

Fig 2 **Geothermal space Heating System**

(4). Material Choice of Heat Exchanger

The choice material makes from finial 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 500ppm, and more 80C 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℃, while that of the return water is 70℃, and cast iron radiator is chosen as indoor radiators In geothermal space heating, the used geothermal water flowing out of the heat exchangers aurally drops *to* 45-40℃, 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, hecause of the typical heat transfer enhancement. The inlet temperature requires below 60℃, and temperature difference can be 30℃ It uses series-parallel connection with the geothermal system The Table 2 listed are test results of technical index of two type.

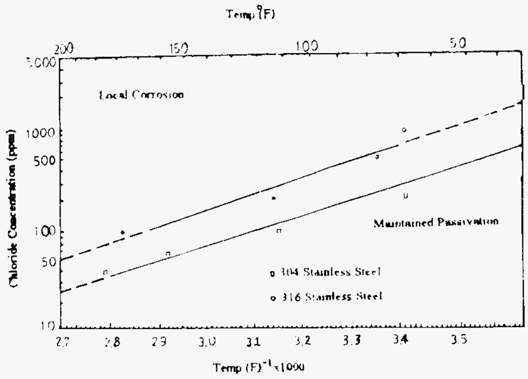

Fig.3 Ellis Diagram

Table 2

Types of Radiator	Flow rate kg/h	Heat Transfer Area m^2	Heat Transfer Coef. kcal/m^2℃	Heat Transfer Gain Kcal/h
Fan Coil	150	5.1	11.68	1787.0
Cast Iron Radiator	150	2.24	6.51	437.5

The heat transfer coefficient can be calculated as,

$$K=\alpha \Delta T^{\beta} \quad (W/m^2℃) \qquad (2)$$

Where α,β 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)

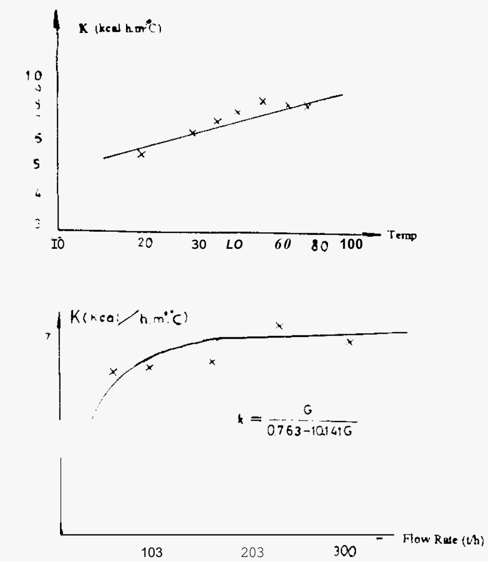

Fig. 4 Cast Iron Radiator's curves of K-G and K-T

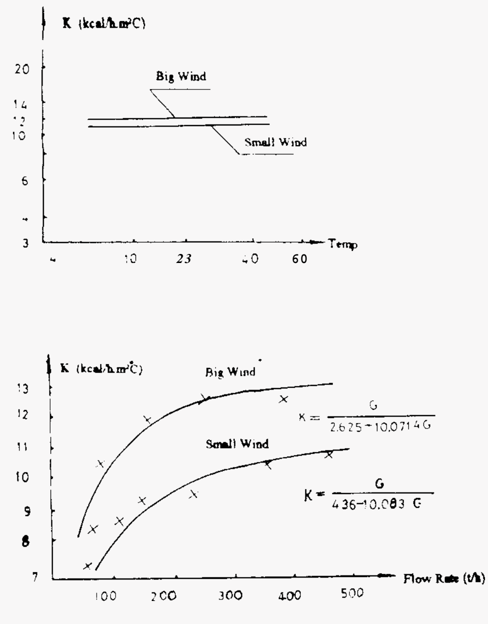

Fig 5 Fan Coil's Curves of K-G and K-T

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℃, 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 (8 4 W) is used to boost temperature (75C to 95℃) during the coldest days, and geothermal energy bears others (14 4MW) The relationship between geothermal energy and boiler is calculated as

The proportion of geothermal energy supplying

$$R=\frac{The-Th2}{Tpe-Th2}x100\% \qquad (3)$$

The proportion of boiler supplying:

$$R1=\frac{Tpe-The}{Tpe-Th2}x100\% \qquad (4)$$

Where:
The: Inlet temperature of boiler;
Tpe: Outlet temperature of boiler;
Th2: Temperature of geothermal waste water;
The: Outlet Temperature of indoor radiator

Geothermal space heating requires very little space, taking up only a few hundreds meter square for heated 100000m^2 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 utilities the waste water, which is out of the heat exchanger, and water processing system should clear away Fe^{3+} from geothermal waste water in order to prevent it to deposit on wall of the pool The water of the pool should maintain at 28C in winter, and hot water also need to supply at all time due to heat loss of water surface evaporation, surface heat conduction and heat transfer in wall and bottom of the pool.

The heat **loss** of water surface evaporation

$$W_1 = r\,(0\ 0178+0\ 0152V)(P_b-P_z)\ F \quad (kw) \qquad (5)$$

Where
r Latent heat of evaporation, r=582 2 (kcal/kg)
V Velocity of water surface, V=O 5 (m/s)
P_b Pressure of saturated steam, P_b =28 4 (mmHg)
P_z Pressure of air, P_z =17 02 (mmHg)
F Area of pool,

The heat loss of surface heat conduction

$$W_2=\alpha\ F\ (t_s-t_g)=0 \quad (kw) \qquad (6)$$

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:

$$W_3=\Sigma\ K\ Fp\ (t_s-t_t) \quad (kw) \qquad (7)$$

Where:
K: Heat transfer coefficient of wall; **K=l** .163
F_p: The area of **wall** and bottom
t_t: Soil temperature (5℃)

The capacity heat load is $W=W_1+W_2+W_3$. Using 45℃ geothermal waste water as supplying heat, the needed flow rate will be as:

$$G=\frac{W}{C_p(t_g-t_s)} \quad (t/h) \qquad (8)$$

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 **6.36×10^{18}J**, and can be extracted about 92.73×10^{16}J from the reservoirs. The plans will cany 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 cat down 7326t/yr., and reduce SO_2 176t/yr., NO_x 64t/yr., dust 172 t/yr., and coal slag 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 14.4MW, which covers 64 per cent of the capacity load (14 4MW), 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℃ 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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REFERENCE

1 Freston, D H (1989) Direct **uses** of Geothermal Energy in 1990 GRC Bulletin Vol 19, No 7 July/August 1990 PP 188-198

2 Assessment of Low-Temperature Geothermal Resources of the United States **1982, U** S Geological Survey Circular 892

3 Meng Xianji, Geothermal Utilization Engineenng, 1990, pp 227-238

4 Wang Wanda, The Methods of Calculated Low-Temperature Rate of Geothermal Utilization, Proceeding of the 1st Tianjin Geothermal Workshop, 1992, pp 169-174.

5.Cai Yihan, Geothermal Utilization and Development in Tuanbo, Tianjin, Proceeding of the 1st Tianjin Geothermal Workshop, 1992, pp 294-297.

6 Philip Michael Wnght, Promoting Greater of Geothermal Energy in U S , pp 449-454

7 Lichti, K A and Wilson, P T (1990) Geothermal Matenals Advisory System 12th New Zealand Geothermal Workshop, Geothermal Institute, University of Auckland, Auckland, New Zealand

8.Michael L. Sorey, Methods for Assessing Low-Temperature Geothermal Resources, pp. 17-29.