THE GEOTHERMAL ENERGY RESOURCES AND GEOTHERMAL DRILLING IN CHINA

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SYNOPSIS

The geographic location and girdle distribution of geothermal energy in China are described. Both the Yangbajing high temperature geothermal field in Tibet, southeast China, and Tianjing middle-low temperature geothermal field, north China, are typically developed latest decade. The situation of geothermal derilling and development tend of drilling in China are also described.

THE GEOTHERMAL ENERGY RESOURCES OF CHINA

In China, the geological structure is very complex and rich, and the geothermal energy resources cover all of the country, since being affected by geothermal girdle of Mediterranean Sea—Himalayas and several geotectonic fault zones, as well as uplift and depression of many structural basins.

The geothermals of China can be divided into six geothermal girdles: (a) Tibet-Yunnan; (b) Shichuan-Yunnan; (c) Yancheng city-Lujiang river fault zone; (d) Qilian mountain-Luliang mountain; (e) southeast coastal; and (f) Taiwan.

The Chinese geothermals belonging to middle-high temperature range (100° — 150℃ and more) have about ten areas which are majorly convection type, for example, Yangbajing of Tibet, Hot Sea of Yunnan and Datuen of Taiwan etc. while the geothermals belonging to middle-low temperature range (30° — 100℃) are mostly conduction type including the well-known Beijing-Tianjing in north China and Shongliao basin in northeast China. They have a variety of earth temperature difference e.g. in north China, the temperature difference averages 3.5° — 8℃ per 100m, the highest up to 11℃, the Beijing-Tianjing 3.5°— 8 ℃, and the Kunming basin 3 °— 5 ℃ etc..

The geothermal fields of wet vapour type in China are only Yangbajing geothermal field (YGF) in Tibet (Fig. 1), Tengchong geothermal field in Yunnan and Datuen geothermal field in Taiwan, where 10 per cent of flow is vapour. Most geothermals in China just like Beijing-Tianjing zone, southeast coastal and other areas belong to hot water type formed by underground water conducted and heated in deep. The sources of heat are made of the energy released by radioactivity elements decay of deep rock, the energy created by friction of deep fault moving and heat conduction produced by quantity of heat inside the earth.

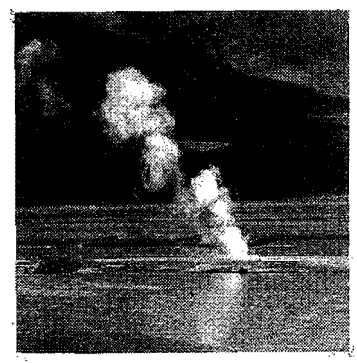

Fig. 1 Yangbaing Geothermal Field

DEVELOPMENT AND UTILIZATION OF GEOTHERMALS IN CHINA

China is a country with a ancient civilization and also has a long histroy in geothermal utiliza-tion involved in life service and sightseeing. so far, the hot springs and geothermal wells drilleld in China have been more than 3,000, in recent years, some smaller scale power stations have been built in high-tamp. field, but the estimated potencial capability can be total up to 3,500,000Kw. Meanwhile the extremely rich middle-low temp. (less than 100℃) geothermals have. also been widly used in respects of industry, agriculture, and medical treatment etc..

GEOTHERMAL DRILLING TECHNIQUES IN CHINA

Drilling Equipments

Recently, geothermal well depth drilled by various rigs in China have reached 3,000m. During the early days, the water well drilling rigs and techniques were majorly used, most of which aimed at explorating middle-low temp. ground water. After YGF was developed in 1975, some oil rigs listed in table I and oil drilling techniques were started to use.

Drilling Techniques

The drilling technology of both Yangbaijing high temp. geothermal field and Tianjing middle-low temp. geothermal field will be described below.

Rigs used in Chinese geothermal drilling Table 1

Type	Drilling Depth m	Application areas
SPJ—300 (China)	300	Tibet
Hongxing—400 (China)	400	Tianjing
SPC—600 (China)	600	All of China
By—40 (USSR)	1,200	Tibet
SPC—1,500 (China)	1,500	Beijing and Tianjing
T—50B (Romania)	1,700	Beijing and Tianjing
MR—700 (Italy)	3,000	Tianjing
Daqing—130 (China)	3,000	Tibet
XB—1,000 (China)	1,000	All of China

1. YGF'S Geothermals Drilling

The YGF is the first geothermal field which has been explored, exploited and utilized to build power stations in China. The depth of the geothermal reservoir in YGF is about thirty to one thousand metre or more, with the average temp. 150° to 170℃, the highest up to 201℃. The daily yields of a single well is about several thousand to ten thousand tons. In general, the depth of wells only reach 150 to 400m, the deepest up to 1725m. The YGF has some geological features as follows:

(a) The geothermal reservoir being very shallow, from about ten to one thousand metres, and often pouring vapour and water out of the ground with huge quantity of heat;

(b) High temp. and temp. difference;

(c) Broken and unstable formation having high abrasive resistance, which mainly consists of volcanic rock;

(d) The very loose and weak overburden e.g. clayish sand and gravel, and shallow geothermal reservoir causeing easily blowout of heat flow;

(e) The 20—30 per cent porosity of the geothermal reservoirs generally showing a low of normal formation pressure (0.3—2.0 MPa) and a higher pressure gradient in somewhere of low-lying area in southeasten YGF.

The drilling techniques in YGF are mainly as follows:

(1) Casing Program.

The casing program is illustrated in Fig. 2, from which we can see two casing programs of production system (a,b) in YGF. The well structure or casing program is designed in accordance with the formation condition, pressure gradient, and well depth. These two casing programs have all obtained a good result.

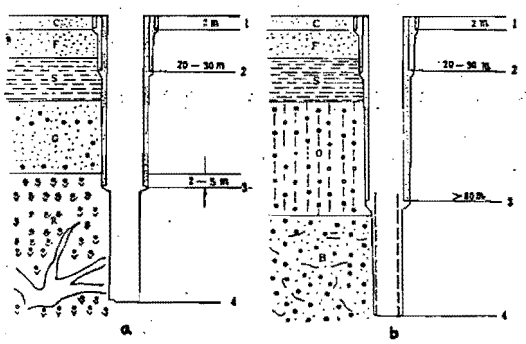

Fig. 2 Casing program for southern YGF

a. Stable sillceous sandstone geothermal reservoir

b. Unstable sandy gravel geothermal reservoir

1, ϕ 720 Conductor; 2, ϕ 470 Surface Casing; 3, ϕ 13 3/8″ Casing; 4, ϕ 9 5/8″ Slotted liner or open hole.

C, Silt layer; G, Sandy gravel (reservoir); F, Drifting sand layer;

R, Siliceous sandstone (reservoir); S, Varved clay; O, Boulder clay (caprock);

B, Sandy gravel (reservoir).

(2) Well head equipment

The production well in YGF is usually not very deep, and the well head pressure is lower,

but the large volume of heat flow and the high temp. easily cause blowout. To solve this problem, a kind of light blowout prevention system has been used to shut the well immediately during drilling, while the circulation of mud is still kept.

(3) Drilling mud system

On the premise of detailed research of the formation pressure and pressure gradient, the drilling programe can be carried out safely by mud pressure balance techniques, i.e. the annular space pressure control by regulating mud gravity and flow parameter, or by selecting suitable the volume of mud flow and the bottom hole assemble (BHA) so as to make the annular pressure nither lower than the formation pore pressure nor higher than the formation fracture pressure. As the result of that, the goal of blowout prevention and lost circulation control can be achieved. The mud problems in YGF are mainly the high temp. and pressure gradient, lost circulation zone and difficulty to remove cutting caused by the enlarged hole dia..

In view of this problems, first of all, the fresh mud treated by humic coal dug locatlly, ferrochromo-lignosulfomate and carboxymethyl cellulose (CMC) etc, were used in drilling to keep it stable at 150℃ — 160℃ in the well. In humic coal there are lots of grass-roots fibres which is effective for lost circulation control in the porous formation.

The specifications of mud would depend on particular condition e.g. pore pressure and the fracture pressure as well as the flow velocity in annular space. In general the filtration loss should keep 5 to 8ml/30min and the mud cake thickness 0.5 to 1.0mm.

(4) Cementing

It is very important for geothermal well to select cement materials against high temp.. In YGF, a traditional oil well cement added 25% SiO_2 powder is efficiently used to increase its resistance to high temp. up to 180°—200℃.

(5) The stimulation

Since the pore pressure gradient is quite different in YGF, the equivalent density of drilling fluid ranges from 0.8 to 1.4g/cm³, thus in many cases, it is necessary to stimulate the wells with some stimulation measures including use of light mud, water and air-lift etc..

2. Tianjing's Geothermal Drilling

The middle-low geothermal energy resources area in Tianjing, north China, is very large, and belongs to the sedimentary basin of non-volcanic type. The geothermal anomaly is situated in the structure uplift of abnormal contact zone. Nowadays, in this area an amount of exploration and development have been carried out, including the 1842m deepest well with 97℃ temp. In general, the drilling technology of Tianjing is easier than that of YGF.

(1) The well structure and the casing program

When well depth isn't more than one thousand metres, genernally, the two-step casing program was used. In this case, at the 20—40m depth drilled by 394mm dia. bit, the casing and cementing are performed, then drilling is going on with 244mm bit untill to the target depth. If the well depth is over one thousand, the three-step casing program would be used. At the beginning, at a 150 — 200m depth hole drilled by 394mm dia. bit, a 340mm dia. casing and cementing are preformed, then the hole is drilled into base rock using 311mm dia. bit and 244mm casing and cementing are performed. Finaly, drilled to end depth with 215mm roll bits. The four-step casing program can also be used for the lost circulation control and prevention from caving.

(2) Drilling technique parameters

The drilling rigs, most of which is provided by China and the United Nation, with a capability of 2000—3000m, and the parameters of drilling technique (215mm dia. bit) depending on the stratum conditions are as follows,

Table 2

the parameters of drilling	above the rock base	in the rock base
weight on bit t	16	8—12
rotary speed r/min	60—80	50—60
pump rate l/min	1000—1200	800

(3) Coring technique

During the exploration drilling in base rock, it is necessary to offer test core samples once or twince. There are two types of core barrls used in Tianjing geothermal field, one made in China and the other in the Chrestensen company US. Both of them can gain more 90% recovery in fractured rock.

(4) The features of drilling mud technology

The mud efficiently used for the geothermal drilling in Tianjing has this featues such as: low solid (solid content less 3%), low viscosity, low filtration loss (10 to 15 l/min within 1,000m depth), low gravity (about 1.10) and resistance to heat etc..

(5) Well completion technology

Beside traditional methods of gravel packing, a new type of screen pipe sticked gravel is applicated in the well completion, that proves higher rate and quielity of well cmpletion and lower cost per well.

THE DEVELOPMENT TEND OF GEOTHERMAL DRILLING TECHNIQUES

So far, the developed geothermal area are only little proportion of whole geothermal area in China,thus more and more drilling footages for new fields will be expected. The key points of geothermal drilling in future are as follows:

1. increasing the complement of drilling equipments which have the capability of 2,000 — 3,000m for exploration and development of high temp. and deep geothermals, as well as studing and introduceing the techneques and experiences from some developed countries.

2. researches of a new direction drilling system to drill banch hole and the bigger inclined angle hole, which involved use of downhole drilling motors, new packer and all kinds of washing well techniques for increaseing yield of each well.

3. developing the resistance-high-temp. mud system (above 150°—200℃), corrosion proof flushing fluid and air-foam system, as well as the techniques of lost circulation control.

4. researches and development of resistance-high-temp. roll bits and polycrystalline diamond bits.

5. development of a efficent drilling techniques such as percussion-retation and down-hole-hammer tools etc. to solve the problem of drilling hard rock.

6. development of recharge well techniques for protection of geothermal energy resources and against surface subsidence.

7. training skilled drillers and engineers for being adapted to the development of geothermal in future.

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