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DEVELOPMENT OF DRILLING TECHNOLOGY FOR DEEP-SEATED GEOTHERMAL RESOURCES

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ABSTRACT

Concept of the deep-seated geothermal resources

Deep-seated geothermal resources is defined as the depth of 3000-4000m at temperature of approximately 350 degrees C.

And it is considered that those deep-seated geothermal resources exist below shallow geothermal reservoirs whch already exploited.

In Japan, the total power generation capacity is about 580,000 KW.

And it is indispensable to explore " deep-seated geothermal resources " to increase it rapidly.

Development of drilling technology for deep-seated geothermal resources

There are many problems remained to drill "deep-seated geothermal reservoirs ·· safely and efficiently.

We are developing a heat-resistant bit ,drilling mud, and heat resistant cement slurry.

DEVELOPMENT OF HEAT-RESISTANT DURABLE BIT

In geothermal well drilling the average bit life below 2,000m is only about 30 hours. Deep-seated geothermal reservoir has hotter and harder formations and it is certain much more trip time for bit is required.

So total Mling cost can be cut by using bits which have longer life and better ROP (Rate of Penetration)

By the investigation whch was done in 1992 when this development was begun, it was proved that the heat-resistant temperature of the bit is depended on the heat-resistance of the elastomer parts used.

Also, it was proved that the durability of the bit is depended on the abrasion of insert clups wluch are used for the bit.

This bit has features as

1. The heat-resistant durable bearing, and the seal mechanism
2. The heat-resistant durable cutter mechanism
3. The pressure compensated lubrication system
4. The gage protection mechanism

The main specifications are as follows.
Diameter : 8-1/2"(215.9mm)
IADC code : 537X
WOB : 10 - 18 t
Revolutions : 40 - 100 rpm
Maximum temperature : 350 deg.C (survival, 6 hours)
: 250deg.C (drilling, 30 hours)

We decided to improve the heat-resistance by replacing the part made of rubber with metal. These are the development of the pressure compensated lubrica' on system and the bearing seal system.

However, in 300 deg.C system, we adopted some part made of fluoride elastomer, in the bearing seal system, As for the grease, we adopted fluoride grease wluch can be used under the high temperature. Then, we adopted a mechanical seal for the bearing seal system to prevent wearing.

Moreover, we developed insert chips for heel-rows, gauge rows and gauge protections.

The developed parts were evaluated by temperature test and so on. Then, we manufactured three bits which are composed of the fluoride elastomer bearing seal systems and the insert chips after the evaluation.

In 1996, we field tested prototype bits in Kakkonda in Japan.

It showed defects on bearing seals made of ceramic and heel-row insert chips.

In 1997, we improved heel-row insert chips, and the toughness of the bearing seals.

And we manufactured new eight bits. three are for 300 deg.C and five are for 350 deg.C. These eight bits were field tested in Sumikawa area (Table 1) and Okuaizu area in Japan.

Table 1 Field Test Result In Sumikawa Area

Bit	Depth (m)	Meter -	Time (hr)	ROP (m/h)	WB (ton)	RPM	Reason pulled	T.B.G.
350℃ A	1604--1712	108	28:37	3.71	12-15	70-80	BHA	2, 2, -1/32
Other Bit A	1712--1793	81	41:30	1.95	-	-	-	4, 3, -3/32
Other Bit B	1793--1828	35	25:50	1.35	-	-	-	8, 8, -1/4
350℃ B	1715--1828	114	4:30		2-3	50-60	Reaming	
	1828--1871	43	21:30	2.0	12-13	50	PR & TQ	4, 4, -1/4

BHA : CHANGE BOTTOMHOLE ASSEMBLY
PR : PENETRATION RATE TQ : TORQUE

As the result it proved the both types of the bit had longer bit life and better ROP(Rate of Penetration) compare to say conventional bits used in these area.
No heel-row chips were broken in these field tests, and proved that these chips have enough toughness.
However, because the treatment to improve the toughness of insert chips became of practical use, we planed to do this treatment against all the insert chips.
By the way, these where only one damaged bearing seal, which had been used for a long reaming tight hole operation, but there's not a remarkable trouble at all.
Besides, the mechanical diaphragm type pressure compensation mechanisms and so on didn't have any malfunction.
In 1998, we plan to manufacture three bits for 350 deg.C which are equipped with the tougher insert chips and the bearing seal systems and now we are planning to do the last field test.

THE DEVELOPMENT OF DRILLING MUD FOR HIGH TEMPERATURE

Maximum temperature of conventional drilling mud is 220-230 deg.C.
Once the temperature exceeds that range, drilling mud tend to loose.

1. Fluidity, due to gelletion.
2. Ability to convey and suspend cuttings, due to loss of viscosity.
3. Ability to form good mud cake.
4. Lubricability.

The decline of the mud property at high temperature causes trouble such as drag, instability of bore hole and pipe sticking. And as the result it causes longer operation days and much more drilling cost.
With the new drilling mud whch can stand 350 deg.C circumstances, we can escape from above troubles, and also amount of mud chemicals and mud disposal can be reduced.
The main specifications are as follows.

chemicals.
We mixed 3 types of new mud them tested them at .50 degrees C for 3 days, adding contaminators such as sodium which may exist in actual field
Finally as we call BMP Mud was chosen BMP stands for bentonite, synthetic mica, and polymer
They are main mud chemicals used for the new mud
It was field tested in Kakkonda, Japan in 1996, and it was proved all the specifications of the mud exceeded the target.

Material of drilling mud was field tested in Okuaizu area show Table 2.

Table 2 Materials of Drilling Mud

Fresh Water	1oog	
Viscosifer	7 g	(Bentonite : Synthetic Mica 50 : 50)
Dispersent	2g	(G-500S and *AMPS* genus polymer)
Fluid Loss Additive	0.3g	(*AMPS* genus polymer)
Lubricant	0.3g	(Synthetic soap)
H_2S Scavenger	Zn Compound	
pH Additive	NaOH	

THE DEVELOPMENT OF THE CEMENT SLURRY FOR THE HIGH TEMPERATURE

Cementing is essential for maintaining steam production for a long period.
In general there are so many weaker formation (or lost circulation zone) in geothermal wells, and they cause failures in cementing operation.
In such a case, the annulus between the casing and the formation may not be filled with cement, and later casing might be collapsed by its heat expansion.
Conventional ultra light weight cement contains low weight material such as micro balloon. And as the result they have serious problems as :

- Low compressive strength
- breakage of cement under high temperature circumstance.

With new ultra light weight cement, whch is heat-resistant and has high compressive strength, we can

- avoid lost circulation while cementingjob.
- prevent casing collapse.
- reduce work overjob

And totally reduce operation cost drastically.
Three main factors are as below.

- Low specific gravity slurry
- The dehydration prevention of the slurry under the high temperature
- High compressive strength under high temperature

Main specifications are:
Specific gravity of the sluny : 1.35
Thickening time : more than 3 hours
Bottom hole circulation temperature : Max.230 deg.C
Compressive strength after 24hrs : 35kgf/cm^2
Exposure condition : 350 deg.C
We succeeded to lower specific gravity to 1.50 in 1995.
We did not add low weight material like microballon, but did add more water to cement slurry.
We made up 3types of slurries whose specific gravity of 1.50.
They fulfilled the specifications.
In 1996 We succeeded to lower specific gravity fiom 1.50 to 1.35 by adopting API Class J cement (belite base) as the base cement and finer silica flour.
However, the test resulted the compressive strength after 7 days at 350 deg.C of this slurry was less than 70kgf/cm.
Therefore, we developed the cement slurry to add calcium carbonate flour to this sluny to achieve compressive strength of 70 **kgf/cm^2** . (Table 3)

Table 3 materials of cement slurry

Material:	(Finess)	%
Base cement : class J cement:	(0.36m^2/g)	50 %
(Belite or C_2S :	$2CaO \cdot SiO_2$)	
Silica powder:	(1.13m^2/g)	27 %
Silica Flour:	(14.8m^2/g)	12 %
Finer Silica Flour:	(151.9m^2/g)	5 %
Calcium Carbonate Flour: ($CaCO_3$)	(5.4m^2/g)	4 %
Another Additive (Fluid Loss Additive, Dispersent, retarder)	Total	2 %

We measured and compared bonding strength against casing and found ours is better than conventional ones.
In the future, we plan to accomplish the cement sluny which meets all the specifications by changing additives.

CONCLUTION

The development of the heat-resistant durable bit, the drilling mud, and the heat-resistant cement slurry haver nearly completed.
However it is pity to say there are few earnest compand who develops the deep-seated geothermal resources in Japan
Anyway these bit, drilling mud, and cement slurry can reduce total drilling cost for hot and hard formations.
And they will be applied in many aspects of geothermal development.

REFERENCES

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