STUDIES ON THE DRILLING MUD AND CEMENT FOR GEOTHERMAL WELL

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Japan, one of the most volcanic lands in the world, is rich in the geothermal energy. At present, 6 geothermal power plants are in operation and one is under construction for a total generated output of about 200 MW.

The recent energy situation and environmental pollution problem have stimulated geothermal research and development, gradually increasing the number of drilled wells within the geothermal tone.. As a national long-range project, tho efforts to develope of geothermal energy as a substitute for petroleum is included in the "Sunshine Project*.

This report deals with the outline of our investigations of drilling mud and cement used for high-temperature geothermal wells.

I. Drilling mud

In this country, water-base BH mud is generally used to drill geothermal wells. The typical BH mud consists of bentonite, asbestos, Telnite BH (lignite system), Telflow (polyacrylate) and caustic soda.

In geothermal walls, the specific gravity is not so important as in oil wells. Thus, it is easier for geothermal wells to control the rheological properties of mud. However, even BH mud which is stabilized up to about 200°C is inclined to be gradually destabilized between 200°C and 230°C, and subject to gelation, increasing in fluid loss. Therefore, continuous drilling requires frequent mud conditioning, necessitating unnecessary waste of material and time.

Thus, research and development of drilling mud, stable when used at highor-temperature geothermal conditions, and the related technology is being carried out.

1. Drilling mud material

We collected reference data on sepiolite clay, lignite, various control agents of fluid loss, presumed to be able to resist a setting temperature between 300°C and 350°C and conducted a number of tests. Thus we found it advisable to select, as the main component for water-

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base mud, easily obtainable sepiolite clay with a high degree of thermal resistance, or lignite systems suitable for controlling both rheological properties and fluid loss, or certain types of polymers favorable as dispersants and assistants to fluid loss control.

We are continuing performance tests of mud additives which are experimentally made from brown coal and lignite at high temperature.

Among drilling mud materials in use, the brown coal comes from Australia, Japan (A), Japan (B), China and U.S.A. , and lignite from Japan.

2. Behavior of clay suspension at high temperature pressure

As the water-base mud is mainly composed of clays, it is especially important to select the most favorable type of clay. From examinations checking the fundamental properties of sepiolite of 5 different origins Southeast Asia, Korea, Japan, Spain and U.S.A., we have determined that:

(1) Sepiolite may be classified into two types; type a, excellent in fibrous structure and high in crystallinity, and type β, inadequate in fibrous structure and low in crystallinity.

(2) Type a is small in apparent specific gravity and CEC value while type β is large in those values.

(3) Type a is high in viscosity while type β is generally low in the same.

(4) The effects of viscosity are influenced by the stirring process and stirring time.

The sepiolite utilized may be classified into:

type a derived from Southeast Asia, Korea and Japan
type β derived from Spain and U.S.A.

Without considering hydrothennal change, it may be advisable to select the Type a sepiolite for geothermal drilled wells. It is, however difficult to obtain quantities of Type a sepiolites in the existing circumstances. Thus, we pursued examinations of the hydrothermal change and rheological properties at high temperature and high pressure, on Type β sepiolites from Nevada, U.S.A. Furthermore, we provided a sampling of Type a sepiolites from Southeast Asia, for a comparative study.

From our examinations, we recognized that Type β sepiolites began to form saponite at 150°C, or 100°C with NaOH, the quantity formed increasing at higher temperature; on the bther hand, the same sepiolites were set into extinction at 250°C or 200°C with NaOH.

Along with temperature, both the viscosity and CEC increased in value in proportion to the quantity of saponites formed. With NaOH, the dispersion effected the almost constant low viscosity whatever the temperature. But the viscosity sharply lowered at 350°C.

On the other hand, we recognized that Type α sepiolite caused saponite to begin to form at 200°C and sepiolite disappears at 300°C, being subject to a transition to saponite and talc. It was exhibited that the CEC increased in value up to 250°C, maintaining the specified value at temperature more than 250°C.

3. Mud properties at high temperature

Water-base mud as in the clay-water system is mainly composed of clays, liable to gelation at high temperature. Thus, clays with the least possible heat change should be selected.

Our investigations until now show that sepiolite is stable at high temperature compared with other clays and its suspension can be of the correct viscosity; however, the fibrous structure of sepiolita worsens the wall building ability and the property of fluid loss. Therefore, with both bentonites and fluid loss control agents, the mud cake formability and the property of fluid loss should be improved. The conventional studies indicate that Ca- or Ca-Na-bentonite is less liable to gelation at a certain temperature than Na-bentonite. Furthermore, we discovered that a certain type of polymer was advisable as a fluid loss control agent.. Thus, as a result of a number of investigations of mud with the above materials, we found it advisable that mud for use at-high temperatures consist of:

Ca-Na-bentonite, sepiolite, asbestos, GT-8 (lignite series), PA-1 (dispersing agent, polymer) PA-20LL (fluid loss control agent polymer) and caustic soda.

A field experiment on this mud took place at two geothennal wells (250°C to 270°C) in Yoyasu Akita Prefecture.

Drilled wells are exploratory ones using the small holesize boring, wire line process. Thus the mud had to be of the low viscosity. The mud of drilled well A was left for 19 hours at a depth of 1,100 m. The mud collected was heated for another 90 hours at 300°C at the laboratory to measure the properties of mud before and after heating.

We drilled from 1,244 m to 1,285 m with the mud in the well B. The collected mud from the same well was heated for 90 hours-at 300°C at the laboratory to measure the properies of mud before and after heating.

The mud's viscosity, gel strength and fluid loss are little changed. The above mud ate found usable before drilling geothermal wells at high temperature. We are conducting further investigations.

4. Foaming agents for foam-drilling

Using a test apparatus in accordance with the API Code, we examined 17 types of foaming agents (non-ion, anion and ampho-ion), which were dissolved in pure water and salt water. Thus the following foaming agents were selected:

- Sodium lauryl ether mulfate (anion)
- Polyoxyethylene alkyl ether sulfate, 30%aqueous solution (anion)
- Polyoxyethylene nonyl phenyl ether (ran-ion)
- Polyoxyethylene alkyl ether sulfate (anion)

These foaming agents are to be subject to further examination.

5. Waste mud disposal

In consideration of the severe circumstances involving environmental pollution, used drilling mud, waste mud, waste water, etc. should be completely disposed of so that applied regulations are faithfully observed.

a. Low-concentration waste mud disposal

Completing the automation of waste mud disposal equipment (capable of disposing mud at 1 kl/hr), we conducted a continuously waste mud disposal trial at the site of a geothermal well. Although the test results were almost satisfactory, the problem of lowering the COD remains for the future. We must continue our research and improve our ability to dispose of waste.

b. Sludge or high-concentration waste mud disposal

We hilt a device for continuous sludge hardening-disposal (capable of disposing sludge at 300 kg/hr).

Using this equipment, a series of examinations are to be conducted on the waste mud of geothermal wells.

II. Cement

Both the thfckening time of cement slurry and the compressive strength of hardened cement paste are important factors in well cementing, which are greatly influenced by temperature. Thus, it calls for tho study of both the composition of cement and the retarder.

We selected the correct fineness of ultra-retarding type trial cement, for use in high-temperature geothermal wells, mainly composed of belite ($2\ CaO.SiO_2$). Furthermore, baaed on a casing program of a 3,000 m deep geothermal well made for the purpose of our examination, we provided tho standard composition of slurry for liner cementing at conditions with a bottom hole static temperature of 300°C, a bottom hole circulating temperature of 250°C and a well depth of 2,200 m . (temporary depth). Thus, we performed examinations of the properties of slurry, including rheological property, thickening time, free water, the compressive strength of hardened cement paste, the measuring of water permeability, differential thermal analysis, X-ray diffraction analysis etc., to examine the decrease in compressive strength and thermal resistance at high temperature.

Note that both inorganic and high-temperature organic retarders are used as additives to cement.

From the above tests, we can conclude as follows:

(1) In order to select the correct fineness of ultra-retarding trial cement mainly consisting of belite, the fineness was varied to examine the influence of the fineness on the properties of slurry. Thus, the smaller the fineness, the worse the rheological property and tho shorter the thickening time.

The most suitable fineness of cement may be approx. 2500 ± 100 cm^2/g.

(2) We examined whether the retarder is suitable to ultra-retarding trial cement mainly consisting of belite. We found that, when the bottom hole circulating temperature approaches 250°C, both inorganic retarders and high-temperature organic retarders should be added, as neither type of agent alone should sufficient thickening time.

(3) The constant thickening time at a bottom hole circulating temperature of 250°C was otbained by adding both inorganic retarders and high-temperature organic retarders. For the standard composition of slurry (slurry's specific gravity of 1.87), the thickening time of 3 hrs to 5 hrs was exhibited by adding both 2.0% inorganic retarders and 2.5∿4.0% organia retarders. Thus, it was sufficient for the pumping time.

(4) The rheological property of cement slurry was improved as retarders increased in ratio to the addition.

Specifically, the rheological property was conspicuous when both inorganic retarder. and organic retarders were added. Slurries with an addition of 2.0% inorganic retarders and 1.0∿4.5% organic retarders in exhibited excellent rheological properties, a flow behavior index n' in the range of 0.910 to 0.997, and a consistancy index k' of 0.00074 to 0,00042.

(5) Free water from slurries with the ratio of water to cement of 0.435 (slurry's specific gravity of 1.87), was inclined to increase in volume when retarders were increased. When both 2.0% inorganic retarders and 3.0% high-temperature organic retarder were added, a relatively large amount of free water is shown, 18.5 ml (7.4%) at room temperature (27°C), but after one hour of heating at 250°C there was a suitable decrease to 6.7 mℓ (2.7%).

(6) The compressive strength of slurry's specific gravity of 1.87, cured every 50°C at 150°C to 300°C, (including a hardened cement paste with the addition of either inorganic retarder8 or high-temperature organic retarders, otherwise the addition of both retarders) exhibited much better conditions in the high temperature range of than at low temperature. Furthermore, in respect to the compressive strength of hardened cement after a long period of aging when a cement cured at 250°C and 300°C it exhibited 440 kg/cm^2 at the age of 180 days. When curing temperature was increased to 300°C, a high degree of strength of *600* kg/cm^2 was shown. In comparison with hardened cement cured at 250°C, the compressive strength increased by about 35%.

(7) The permeability of a hardened cement cured at 250°C and 300°C was inclined to increase at high temperature; it showed excellent permeability in that both a slight increase of 0.012 to 0.028 md at the age of 30 days and an almost constant increase of 0.017 to 0.029 md at the age of 180 days were exhibited.

(8) Hydrates of a hardened cement paste at curing temperatures between 250°C and 300°C caused xonotlite, gyrolite and tobermorite, the most contributory to the compressive strenth, to be formed after short-term aging and xonotlite and gyrolite to be mainly formed with long-term aging at 300°C.

Consequently, the ultra-retarding cement, mainly consisting of belites, exhibited both properties of slurry stabilized at high temperature and those of a hardened cement paste, giving a prospect €or practical applications suited to the circumstances of geothermal temperature of 300°C.

We are conducting further research.

(*This* report disclosure approved by Sunshine Project Promotion Headquarters, Agency of Industrial Science and Technology, Ministry of International Trade and Industry)