PHILIPPINES GEOTHERMAL DIRECTIONAL DRILLING

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ABSTRACT

Two major geothermal fields in the Philippines are being developed by the use of directional drilling. Wells are up to 3200 m deep vertically, and are deviated from 15° to 45°, in order to explore and to produce fluid economically from otherwise-inaccessible areas of the reservoirs, and to reinject fluid to appropriate areas effectively. Equipment and techniques used to drill these wells are described.

INTRODUCTION

At Tongonan, on the island of Leyte, and at Southern Negros, the initial scientific work indicated that in each area, the geothermal resource was located under steep mountainsides (i.e. the relict volcanoes). This assessment was subsequently confirmed by a series of vertical wells, drilled from the more accessible low level platforms. At the same time roads were constructed and drilling sites were prepared on the mountainsides to enable further vertical wells to be drilled.

Due to the geographical constraints it became apparent that it would not be possible to exploit the reservoir fully by drilling vertical wells. Consequently a study was made of the relative economics of drilling vertical wells, including roading to the well platform and pipeline costs, as opposed to drilling directional wells to the same targets, but from more accessible sites closer to the proposed power stations. Agreement to drill directional wells was reached on the basis of this study and of knowledge of the reservoir gained for the early vertical wells, in particular the proven difficulty of initiating discharge from high altitude wells with low water tables and relatively cool temperatures at the top of the water column.

At this stage ninety wells have been drilled, of which twenty one are directional.

TYPICAL WELL DESIGN

Drilling and reservoir data gained from the vertical wells was used for planning the casing program for each directional well. A typical casing program is shown in Table 1.

Table 1: A typical casing program

Surface casing	20" dia., 94 lb/ft, H40, buttress (85 m)
Anchor casing	13 3/8" dia., 54.5 lb/ft, K55, buttress (320 m)
Production casing	9 5/8" dia., 43.5 lb/ft, K55, buttress (1400 m min.)
Liner	7 5/8" dia., 26.4 lb/ft, K55, Hydril FJWP with 8-2" x 3/4" slots per foot (1600 m maximum length)

The larger diameter surface and anchor casings are run vertically, and the deviation of each well is started at least 30 m below the anchor casing shoe in order to prevent key seating at the shoe. After building up angle to the required azimuth and drift (15° minimum to 45° nominally) the hole is drilled in a straight line to the designated target. Computer programs have been prepared by KRTA to assist in the design of these wells by calculating minimum casing depths, all important vertical and horizontal distances related to each target from each platform, and nearest approach distances to other wells. The strength of the wellheads, casings and liners are checked to ensure they can resist all of the loadings they are likely to be subjected to during their service life. The plan and elevation of a typical well is shown in Figure 1.

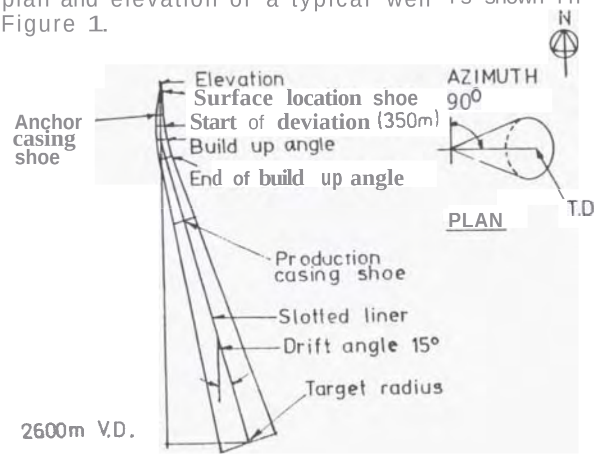

Figure 1: Plan and elevation of a typical well

DRILLING TECHNIQUES

The Downhole Motor

There are a number of methods which can be utilised to deviate the well, including whipstocks and downhole mud motors such as the turbodrill and Dynadrill, which are used with bent subs. Each tool has its advantages and its proponents. All of the geothermal directional drilling in the Philippines has been initiated (and controlled when necessary) by the use of Dynadrills.

The Dynadrill is a positive displacement downhole mud motor which operates on a reverse application of the progressive cavity pump principle, and supplies rotational power directly to the bit without drill string rotation. Dynadrills used in the Philippines are 6.4 m long and 7 3/4" diameter. The stator consists of an outer tube lined with Buna rubber, and a spiralled cavity with an obround cross section. A helical steel rotor with a round cross section is fitted inside the stator, and when mud is pumped through the motor, the rotor is forced to turn.

The optimum operating pressure is achieved when the correct flow rate is obtained through the tool. This is 400 gpm on the 7 3/4" Dynadrill, and 325 gpm on the 6½" Dynadrill. These flow rates are well within the capacity of the pumps available.

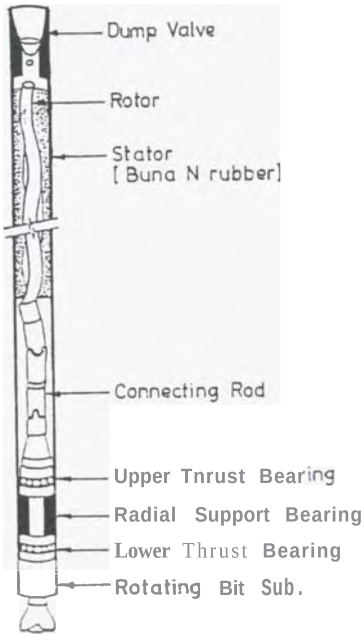

Figure 2: Dynadrill

Starting the deviation

All directional drilling has been initiated at least 30 m below the 13 3/8" anchor casing shoe i.e. starting from a depth of approximately 350 m. The deviation is accomplished using a 12¼" dia. bit driven by a 7 3/4" dia.Dynadrill with a 2° bent sub which gives a rate of build up of angle of 2° per 30 m.

The Dynadrill is used to drill 30 m before it is removed and normal rotary drilling techniques are used to continue building up angle to between 15° and 45°. Typical bottomhole assemblies (BHA's) are:

Initial kickoff assembly - 12¼" Smith F3 bit with 3 x 20 mm nozzles, 7 3/4" Dynadrill on 2° bent sub, on 7 3/4" K Monel (non magnetic) drill collar (MDC). on 5 x 7 3/4" drill collars (DC) on a cross over (X/O), on 12 x 5" heavy weight drill pipe (HWDP).

Angle building assembly - bit on near bit stabiliser (NBSTB) (3 fixed blades), on 1 x 7 3/4" short DC, on MDC, on 1 x 7 3/4" DC, on string stabiliser (SSTB), on 1 x 7 3/4" DC on SSTB, on 9 x 7 3/4" DC on X/O, on 12 x 5" HWDP.

Stiff assembly = bit on NBSTB, SDC, SSTB (with a Totco survey ring in the top), then MDC on SSTB, on DC, on SSTB on 13 DC's, on X/O, on HWDP. (The drill pipe used is 4½" dia., 16.6 lb/ft grade E, premium).

Control of Lost Circulation

Regaining circulation in loss zones in the formation prior to cementing the production casing has been a major problem in some of the Philippines geothermal wells. As rice husks, sawdust, and bagasse (sugar cane fibre) are readily available and inexpensive they are commonly used in the mud to seal the loss zones in the wells. In extreme cases, chopped up banana palms and abaca have been used, prior to placing very thick mud plugs, or cement plugs.

The control of lost circulation is a major problem at Southern Negros, where over 40 cement plugs were placed in one particularly difficult well. In this field we incorporate a strategy of flexible casing set depths, with blank liners, external casing packers and small cement plugs to isolate the loss zone. This leaves the zone accessible for future production if necessary. In other fields where loss circulation occurs deeper, we use the following strategy.

If circulation is lost below the production casing shoe, only minimal efforts are made to regain mud return to the surface. If these efforts are unsuccessful, and the hole is still relatively shallow, the mud is displaced to water and drilling proceeds as long as hole conditions allow (i.e. torque and drag on the drill string must not be excessive).

Rice husks and sawdust can be pumped through the Dynadrill, but not bagasse. Further, high viscosity mud complicates assessment of differential pressures through the Dynadrill as well as the operating pressure off bottom. Hence on losing circulation when trying to drill to an accurate line with the Dynadrill, the procedure used has been to lift the bit off the bottom of the hole, and then to circulate mud plus rice husks and sawdust to control the loss zone. The mud is then conditioned and Dynadrilling continued. However if the accuracy of the track of the well is not too important, drilling can proceed at the discretion of the directional drilling engineer, and drilling superintendent.

If the stiff assembly changes direction when drilling with no returns in 8½" hole, it is sometimes necessary to run the &" Dynadrill while drilling blind. However this results in the following problems:

1. The volume displacement of the 6½" Dynadrill is not sufficient to give an annular velocity that will remove the cuttings when drilling solely with water. Therefore high viscosity mud slugs must be pumped every 2-3 meters of hole, which upsets the operating pressures. The drilling is then controlled by correlating the rate of penetration with the weight indicator which requires a detailed knowledge of the area being drilled. During this operation it is extremely important to run jars in the drill string as the drill pipe is not turning and cuttings may pack off the annulus.

2. The whole BHA does not rotate when using the Dynadrill, and it is lying on the low side of the hole so differential sticking is possible.

Bits

The 7 3/4" Dynadrill rotates at 310 rpm, which produces severe loadings on bits in the high temperature environment, (c.f. 60-80 rpm normally). The life of the bits is reduced, when using the Dynadrill, to 1/5 or 1/6 of their normal running time expectancy, but approximately twice as much hole per bit is drilled with the Dynadrills, depending upon the type of rock being drilled. Conventional BHA's with 35-40,000 lb on 8½" bits tend to grind the volcanic rocks, which is more successful than the Dynadrill which tends to 'fan' or polish the formation as they are run with only 10-20,000 lb on 8½" bits.

Temperature Limits

If the hole is very hot when running in with the Dynadrill, it is desirable, if not essential to stop periodically and circulate to cool the Dynadrill (120% is the temperature limit of Buna N rubber from which the stator is manufactured). Tripping out a rotary assembly and Dynadrill must be done as quickly as possible as the hole heats up quickly. A Dynadrill will normally operate for about 50 hours before requiring servicing but this is drastically reduced at high temperatures, (to say 5 hours if the bottomhole temperature is around 240%). The circulating fluid cools the Dynadrill when operating, but in hot, deep holes the rubber can be destroyed before the tool gets on bottom. From experience, the directional drillers are able to relate the flow line temperature to the approximate bottomhole temperature. The ratio varies from 2 to 5 depending upon the depth of the hole, and variables associated with the prior drilling as well as reservoir characteristics, (11).

Surveys

Sperry Sun (type B) single shot instruments, fitted with heat shields, are used for surveying. They are very reliable, durable, easy to use, and with the heat shield they resist temperatures up to 425°C or 315°C if soaked for 5 hours. Surveys are taken every 12 m when drilling with the Dynadrill, then generally every 50 m with the build up assembly, and approximately every 75 m with the stiff assembly.

The Sperry Sun instrument is a floating compass on a ball and spindle, which shows inclination and direction of the hole on a 16 mm photographic disc. The time taken for each survey depends upon the depth and speed of the wireline, varying from 15 minutes near the surface, to 90 minutes when near the bottom of the well. The survey instrument is run into the well on the sandline, - however, measures are being taken to use an 0.09" dia. s.s. wireline to enable the surveys to be run quicker, and under better control.

Multishot gyro surveys are run when there is concern that there is possible magnetic influence on the magnetic single shot instrument.

Deviation Correction

Anticlockwise drift can normally be corrected by increasing the weight on the bit (WOB), and decreasing rpm, which cause 'walking' to the right. However this has largely been proven ineffective in geothermal fields in the Philippines as a result of several factors -

1. Button (tungsten carbide insert) bits, which are used on the hard volcanic rock, do not have the 'traction' of a milled tooth bit,

2. Geothermal drilling is taking place in mountainous areas, where holes tend to be drilled obliquely to the dip of the strata. The bit tends to 'walk' with the strata due to gravity acting on the BHA. Faults in the formation will also kick the well off.

Our directional engineers have found that high rpm and, where possible, a reduction in WOB can assist in reducing clockwise, as well as anticlockwise drift. The BHA must be stiff. The directional engineers can use a range of stabiliser sizes (while not varying the design of the BHA) to assist in maintaining angle. If these techniques are not successful, the only recourse is the Dynadrill, if it can be run in the high temperature formation. (The complex factors involved in controlling deviation correction are discussed in detail in reference 9).

Inclination correction

If angle is dropping off in the hole, there are two ways of correcting it -

1. If the drop off in angle is slight, decrease the diameter of the stabilisers behind the near bit stabiliser.

2. If the drop off in angle is large (say 1^{o} in 30 m), increase the spacing between the near bit stabiliser and the first string stabiliser.

If angle is building up too fast, which could be caused by an unexpected change in formation, the economics of reducing WOB and carrying on drilling, must be compared with tripping out and changing to a BHA which can maximise WOB and therefore obtain the optimum rate of penetration. Another technique employed with limited success in geothermal fields is to ream every 12 m either once or twice, as the BHA will wear on the bottom side of the hole. Success obviously depends upon the hardness of the formation.

CONCLUSIONS

Geographic constraints and economic assessments led to the conclusion that directional drilling should be employed. This is now proven to be a reliable, and environmentally advantageous method of accessing extensive resources which cannot be extracted economically by drilling vertical wells. However, the directional drilling equipment used and techniques developed in Philippine geothermal operations are still being improved, principally in regard to raising temperature limits and controlling circulation losses.

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