Proc. 6th NZ Geothermal Workshop 1984

MEASUREMENT OF FORMATION PRESSURES WHILE DRILLING

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ABSTRACT

A simple technique to measure formation pressures at lost circulation zones while drilling has been developed and tested. To minimise loss of rig time and maintain well condition, a method has been developed where measurements are made inside the drill pipe using normal mechanical downhole pressure gauges. Tests have shown that the technique can measure formation pressure within the normal gauge accuracy.

INTRODUCTION

When a new geothermal field is being investigated, one of the most useful pieces of information needed to develop a conceptual field model is the vertical pressure gradient. This is normally obtained after four or five wells have been drilled, and have encountered permeable features at several different depths. Formation pressures at the major feed points (which are usually not the same as measured well pressures) can then be plotted against depth to give the vertical gradient (as long as there is no significant horizontal gradient over the area explored).

Theoretically, the vertical pressure gradient can be identified during the drilling of a single well if several permeable zones are encountered and appropriate measurements made. The normal drilling process actually provides an ideal situation where permeable levels are gradually cased off and new levels, unaffected by those above, can be measured.

However, in practice there are economic and technical reasons why the ideal set of measurements cannot be made. In order to develop a measurement technique of practical value we decided that it must fit into the existing drilling practice with minimal disturbance. The technique must also use robust equipment that will survive the rigors of life on a rig

MEASUREMENT OF DOWNHOLE PRESSURE

If a complete loss of circulation fluid occurs while drilling, normal practice is to either plug off the loss zone or to convert circulation fluid to water. While there are no returns back to the surface there will be a fluid level in the well which depends on fluid density, depth to loss point and pump rate. If the pump rate is reduced to zero, pressure in the formation and in the well will equalise at the loss point. Experience shows that in the "complete loss" situation, pressures equalise within a few minutes.

A the fluid density and the depth to the fluid level in the annulus could be measured while pumping was stopped. Such a method would suffer from significant excess if the fluid density measurement were not accurate and measurement difficulty if the fluid level in the annulus was more than a few metres down the well.

A more reliable system would be to measure the internal pressure at the bottom of the drillstring and relate this to the external pressure, making allowance for the effect of the non-return valve.

In theory, it should be possible to use the pressures measured inside the drillstring while pumping, and after subtracting pressure losses due to the downhole assembly obtain bottomhole pressures. If these pressures are plotted against flowrate the resulting line can be extrapolated back to zero flow to obtain formation pressure. Because pump rate is in fact reduced to zero in the "complete loss" situation, such complication seems unnecessary, although it may be of use where partial losses are encountered. Another analytical technique being tried is to measure the pressure transient on stopping injection, plot pressure against log Horner time and estimate formation pressure at time equals unity.

DRILLING PRACTICE

In New Zealand operations, a complete circulation loss while drilling above production casing depth is handled as follows. As soon as the loss is noted, the drillstring is pulled back about 10 metres off bottom, then circulation is stopped and the string is reciprocated by about 2 metres and rotated slowly. If necessary a single stand of drillpipe is removed. A supply of lost circulation material is made up, then pumped into the loss zone. About 30 minutes is required to make up the loss materials and this time provides an ideal opportunity to measure the bottomhole/loss zone pressure.

A complete circulation loss in the shallow sections of a geothermal well is one of the most risky parts of the drilling operation. So, there is little incentive to the drilling engineers to deviate from their normal practice for the sake of some scientific tests. Therefore any technique that is developed must fit into the drilling practice with minimal interruption. Because of the urgent action required to control a complete loss there is insufficient time to call-out a specialist downhole crew, so the technique must also be suitable for use by the drilling crew.

FIELD TESTS

To evaluate the method, tests were made on two

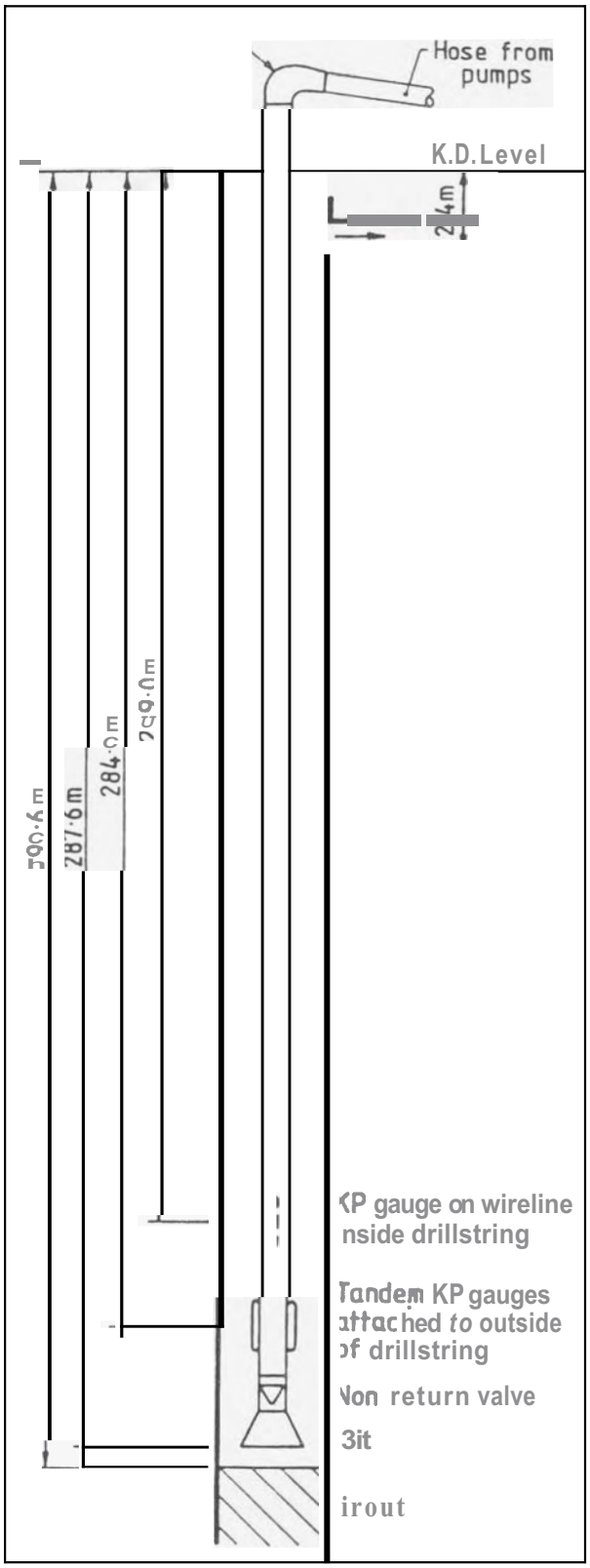

figure 1. Test set up to measure pressure response inside and outside drillpipe. Water was allowed to overflow at the wellhead to maintain an essentially constant bottomhole pressure.

measurement arrangement is shown on fig 1.

Downhole gauges used for the tests were Kuster KPG with full scale ranges of 83 and 135 bar for external gauges, and 83 bar for the internal gauge. For the smaller range gauges accuracy is 0.5% or ±0.4 bar.

The drillstring was run into the hole to 287m making the depth to the external gauges 284m and the internal gauge run in to 259m.

Measurements made while reciprocating the drillstring up and down by 25m showed that a differential pressure of less than 0.2 bar is required to operate the non-return valve. To investigate the repeatability of measurements and effect of pumping, several cycles of pumping-no pumping were made. Internal and external measured pressures in the no pumping situation did not vary by more than 0.4 bar, i.e. within the gauge accuracy. Measurements while pumping showed that above 1000 ℓ/m pressure fluctuations were too great to allow accurate measurement, and even at 700 ℓ/m (150 gpm) there was 0.6 bar pressure loss between the internal and external gauges (5½ inch drillpipe, NRV, 12¼ bit with 1¼ inch jets).

Thus the tests show that within the gauge accuracy (±0.4 bar), pressures measured inside the bottom of the drillstring are the same as those outside when circulation is stopped.

FIELD PROCEDURE

To minimise inconvenience to drilling operations a shock-protection case has been built for the normal Kuster KPG downhole pressure gauge. When a complete loss is encountered, the driller pulls off bottom, then makes up the pressure gauge, places it into the protective case and while the single stand of drillpipe is being removed, places the gauge assembly into the drillpipe. The gauge free falls to the "crowsfoot" at the bottom of the monel collar which normally serves as the reference point for the deviation survey instrument.

The driller then carried on with his normal procedure except that the pumps are operated intermittently to check the repeatability of measurements.

When the loss zone is under control and circulation regained, the pressure gauge is recovered using a wireline overshot.

ACKNOWLEDGEMENT

The authors acknowledge the permission of the Commissioner of Works to publish this information.