APPLICATION OF DOWNHOLE FLOWMETERS TO WORKOVER OPERATIONS ON GEOTHERMAL WELLS

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ABSTRACT

The downhole flowmeter logging system for high temperature geothermal wells, developed at Wairakei by Ministry of Works & Development and Geophysics Division of D.S.I.R., has proved to be an invaluable tool for use during workovers to repair or reinstate problem wells. In addition to identifying the exact nature and location of certain common problems, such as natural cool downflows, the tool can be used to effectively caliper the hole *so* that drillable cementers can be properly located, and then used to manage cementing operations designed to block cool infiow zones.

For some of these investigations a very simple flow indicator which can be run on a regular single-strand wireline has been tested. Results to date indicate that if operated carefully, useful results can be obtained by this method for a minimal financial outlay.

INTRODUCTION

One application of the downhole flowmeter developed jointly by M.W.D. and D.S.I.R. Wairakei (Syms and Bixley (1979)) has been to resolve problems in production wells of the Wairakei qeothermal field. The flowmeter contains an impeller which is rotated by water flowing through the instrument and its rotational frequency is recorded at the surface. Measurements are made while the instrument is in motion at a known rate either up or down the bore. The water velocity throuqh the flowmeter is determined by: the rate of movement of the tool, the cross-sectional area of the well, and also the volumetric flow of water in the well (due to pumping from the surface or natural pressure inequalities). Analysis of flowmeter records requires separation of these effects and this can be difficult where the hole area is large, since much of the water then flows, around the spinner rather than throuqh it. The technique of interpreting recorded logs to determine flow structure in a well is given in detail by Syms (1980).

WAIRAKEI 107

After a routine maintenance shutdown in February 1976, well Wairakei 107 could not be restarted. Temperature profiles showed a drastic change had occurred. Up to this time, temperatures over the production interval had been 220 to 230°C and now they had fallen to about 170°C throughout the liquid column in the well. This was interpreted as indicating that the well had effectively been quenched by a 'cool' downflow from near water level to below 600 m. In March 1979, spinner flowmeter measurements confirmed the presence of a very large natural downflow entering the well at 290 m and continuing to at least 600 m. The flow was estimated to be 50 litres/sec, with an error of ± 15% (due to the large and variable area of the bore outside the slotted liner).

Repair operations commenced in January 1980. It was planned to seal off the inflow zone by cement grouting, but this could not be done until the flow was stopped, since otherwise the cement would be washed away. A special cementing plug was designed to be placed in the hole below the inflow zone. It would first be cemented in position with the flow passing through the plug, then a valve would be operated to stop the flow. To ensure the success of this operation, the plug had to be placed in a section of hole which was near the original drilled size, so the calipering effect of the spinner was used to select the plug location.

Figure 1 shows spinner runs made with and without the slotted liner in place. Since the flow is presumed to be constant below the inflow zone, the spinner frequency should be inversely proportional to bore area. It is evident that the shape of the hole was changed by the extraction of the liner, especially where the hole area was smallest. The narrow region from 310 to 320m was almost completely broken away, and also the narrowest portion of the 370 to 385 m zone. The 487 m squeeze and most of the long 555 *to* 575 m zone appear to be unaltered.

By placing the plug just below the inflow zone, the amount of grout required to seal off the inflow could be kept to a minimum. The most suitable part of the well was the section from 377 to 383 m (fig. 1) and the plug was eventually placed at about 377 m, with a small quantity of grout on top. When the grout had hardened, spinner logging was done while injecting water at 10 litres/sec. The water level in the well was found to be nearly 100 m higher than before,

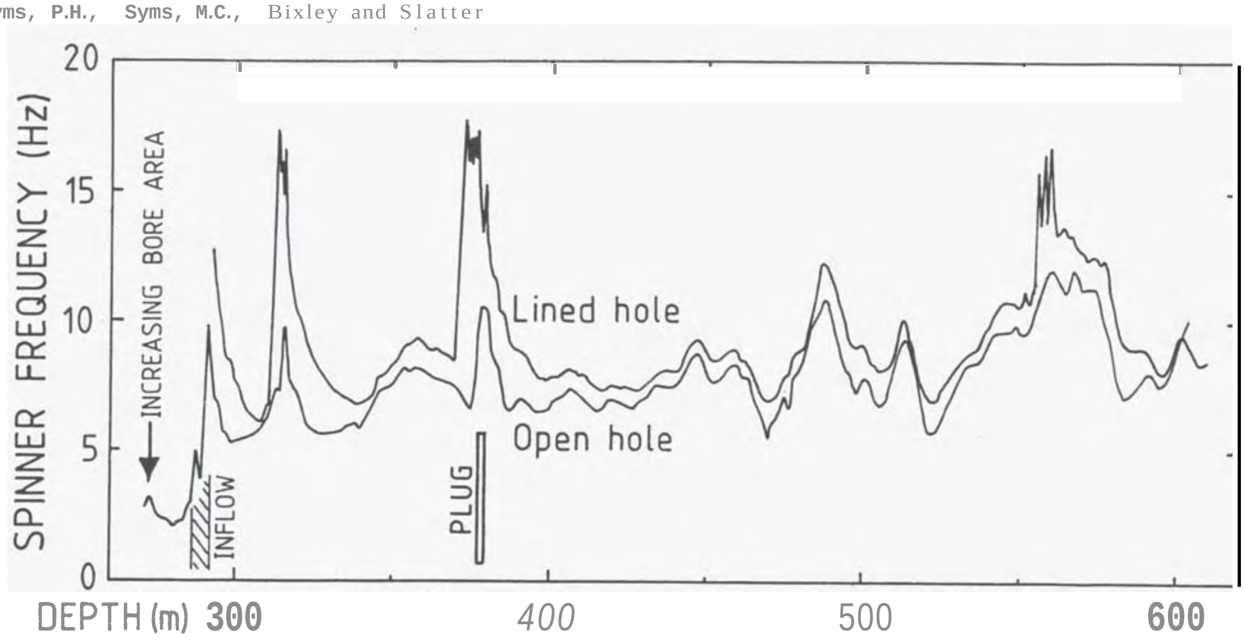

Fig. 1 Wairakei 107. Spinner flowmeter records with (March 1979) and without (January 1980) slotted liner in well, showing changes in hole size. Location of grout plug indicated.

suggesting a significant blockage had been made. The spinner showed that all of the injected water was lost from the well at 290 m depth leaving stagnant water between there and the plug. No leakage past the plug was detected.

Further grouting operations followed, using approximately 70 tonnes of cement, to close off the inflow zone. The hole was then redrilled through the grout, lined with $6\frac{5}{8}$ inch casing and left shut for four days so that the existence of any natural flows could be determined. The temperature profile (Figure 2) indicates the possibility of flow in the constant temperature regions around 520 and 600 m.

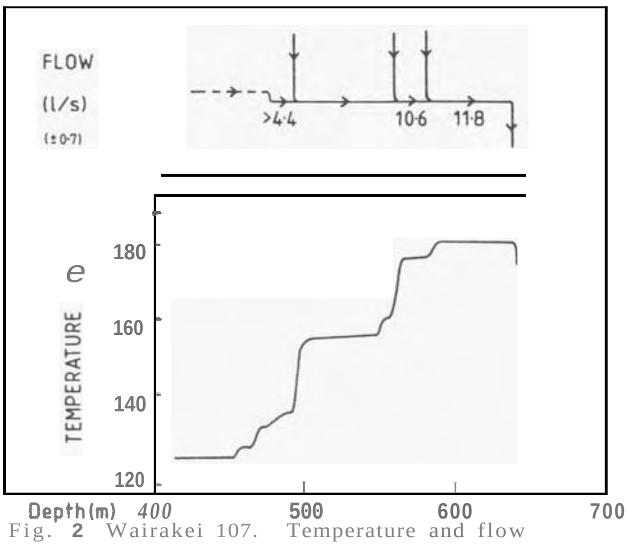

Fig. 2 Wairakei 107. Temperature and flow details from spinner instrument, February 1980. Well shut 4 days, followingworkover.

The drop in temperature below 640 m implies that any warmer natural flow has left the well' by this depth, with residual cold water from drilling operations below. Flowmeter measurements show stagnant water in the plain liner. At the top of the slotted section (478 m) an inflow of at least 4.4 litres/sec. occurs and this presumably originates behind the plain liner. All the flow is lost from the well at 637 m, with stagnant water from here to hole bottom at 646 m.

The well was subsequently allowed to heat up and after 10 days a maximum temperature of 188°C was measured, with an overall profile similar to Figure 2. The well would not spontaneously discharqe in this condition, but after injection of steam from the power station pipelines it was discharged and downhole runs during this showed a feed temperature of 228°C.

The repair of well Wairakei 107 was successful in reducing the natural downflow to about a tenth of its previous value. Output has been restored to its original level and the well is again supplying steam to the Wairakei Geothermal Power Station.

ALTERNATIVE FLOWMETER

A simple flowmeter, the "Slatter plate", has been developed as a cheap and easy to use alternative to the spinner instrument. This consists of a horizontal circular plate suspended in a well on the standard 1.8 mm wireline used for routine downhole measurements. Wire tension is monitored at the surface, with the plate held stationary in the well. The tension increases steadily with increasing length of wire as the plate is' lowered in the well (Figure 3), for no-flow conditions.

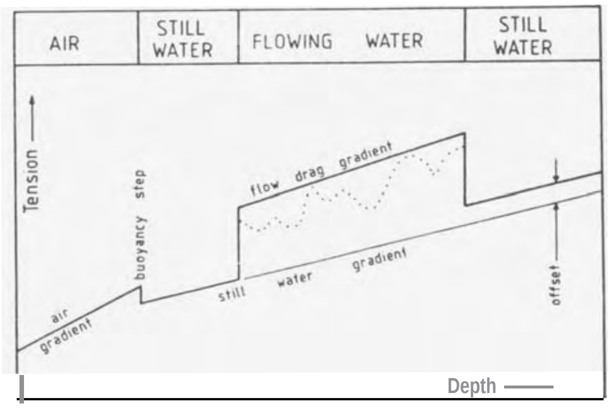

Fig. 3 Slatter plate flowmeter. Expected line tension in a well. Response to changing bore area shown dotted.

If a downflow of water is present, the force of this flow on the plate increases the line tension above the expected still-water gradient. The increase in tension with depth is slightly higher in flowing water because of the flow drag on the wire, If the plate is lowered further into a region of'still water, the tension again follows the still-water gradient, but with an offset equal to the total drag of the flowing region on the wire.

Most New Zealand geothermal wells are of variable cross-section (outside the slotted liner) because of erosion or collapse of the bore walls. For a constant volumetric water flow, the water velocity will be high where the bore is narrow and vice versa. Therefore the wireline tension varies inversely with bore area in zones of flowing water, as shown dotted in Figure 3.

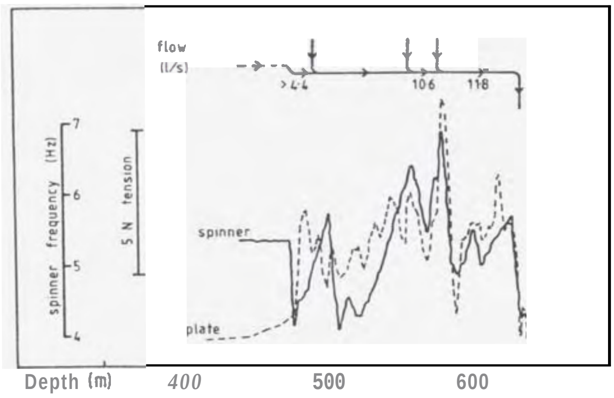

Fig. 4 Wairakei 107. Comparison of spinner and plate flowmeters, February 1980. Tension is relative to flow drag gradient.

Measurements were carried out with the plate flowmeter in Wairakei 107 after the workover was completed. A comparison of results from the two flowmeters is given in Figure 4. Wire tension values for the plate aye plotted relative to the flow drag gradient and show great variation in the region of flowing water, while in still water the tension is reasonably steady. The fluctuations in spinner frequency are similar in nature to those in wire tension, showing that both are responding to hole area changes. Identical responses are not expected, since the spinner is less of a blockage to the flow and samples a greater length of well than the plate. The spinner frequency values in the two regions of stagnant water (above 478 m and below 637 m) are not equal, because of different hole areas.

It can be seen from the flow diagram of Figure 4 (derived from spinner measurements) that there is no apparent relationship between wire tension and volumetric flow. However, the hole size is known to be significantly larger than originally drilled for most of the well, except at a few narrow sections (e.g. 487 m and near 580 m) and it is only in these sections that the tension will approach the expected values. In a well as badly eroded as this one, it is not feasible to obtain estimates of flowrate from the plate tension readings. It is possible, however, to detect the difference between flow and no flow with very good depth resolution.

In wells with a slotted liner, any`flowmeter which is held stationary while measurements are taken will respond to differences in hole area. It will thus be difficult to obtain an interpretation of flow structure unless sufficient measurements are taken to delineate narrow parts of the well, over which it may then be possible to determine flowrates with acceptable accuracy. This could be done with a more sophisticated downhole recording flowmeter, once suitable zones for measurement are found.

An unlimited number of measurements can be made with the plate flowmeter and results plotted immediately to show features in the required detail. Preliminary experiments with this flowmeter indicate an approximately square law response to flow.

WAIRAKEI 101

In November 1968, this well was closed to bleed during the annual shut-down of the Wairakei Geothermal Power Station. The well could not be restarted and was no longer used for production purposes.

Temperature profiles (while shut) showed a region of approximately constant temperature from near water level down to at least 600 m depth. The mean temperature of this region fell from 204° to 145°C over a period of 10 years from 1966. A natural downflow of cool water was again suspected to be the cause of the loss of output.

Flowmeter measurements carried out in 1979 confirmed the presence of a significant downflow of water. The well has eroded to a large cross-

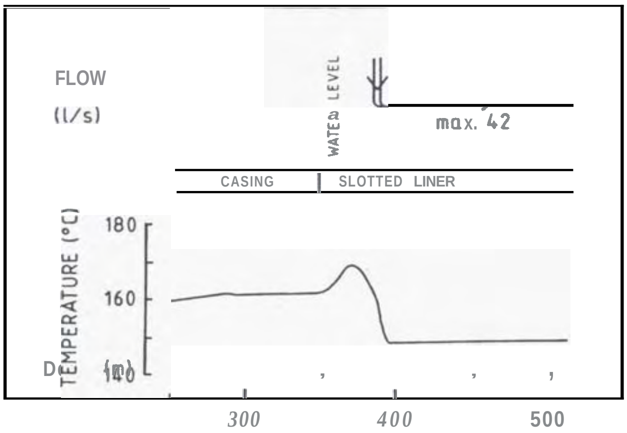

Fig. 5 Wairakei 101. Temperature and flow details from spinner instrument (March 1979). Well shut.

sectional area and thus it is difficult to interpret the measurements accurately. The estimate of maximum volumetric flow is about 42 litres/sec. Figure 5 gives flow and temperature details derived from spinner measurements. Between 360 and 386 m, the well contains stagnant water. An inflow of 150°C water occurs in the zone 386 to 392 m and continues down until at least 516 m (the maximum clear depth for the instrument). No repairs have yet been attempted on this well.

Figure 6 compares results from the two

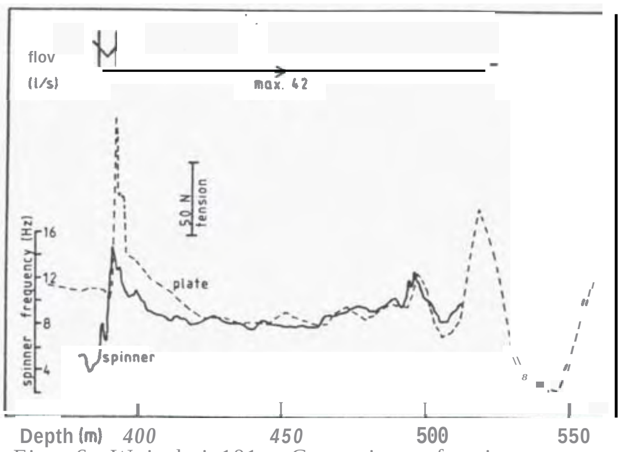

Fig. 6 Wairakei 101. Comparison of spinner (March 1979) and plate (December 1979) flowmeters in downflow region. Tension is relative to estimated flow drag gradient.

flowmeters below 360 m. The plate flowmeter readings are relative to the estimated flow drag gradient. It is apparent that water is still flowing down the well to at least 560 m (plate maximum depth) since the tension has not settled to a steady value by then. There are several sections where the tension is constant with increasing depth (e.g. near 430 and 540 m) probably caused by the plate becoming stuck in the well.

This was the first trial of the plate flowmeter, before the measuring technique was properly established. It is important to take tension readings as the wire is being pulled very slowly upwards. This leads to reproducible values being recorded for the tension (sliding friction, plus flow forces, plus weight of wire and instrument).

SUMMARY

In many cases, the simplicity and reliability of the plate flowmeter outweigh its limitations. The provision of surface readout and its inherent resistance to heat and dirty fluids are strong points in its favour. As a preliminary survey instrument it can provide rapid information on flow conditions in a well.

To obtain reliable quantitative analysis of flowrates requires the more sophisticated and expensive spinner instrument (which is still under development). Its ability to caliper holes through slotted liner (whether or not water flow is present) has proved extremely useful.

ACKNOWLEDGEMENTS

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