FIELD EXAMPLES OF A NEW OXYGEN ACTIVATION LOG TO DETERMINE WATER FLOW BEHIND PIPE

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ABSTRACT

Previous methods to detect and locate fluid flow behind well casings such as temperature, radioactive tracer, or acoustic noise have been successful but often difficult to interpret. An alternative method which is specific for detecting water flow (or CO_2 flow) is the oxygen activation log. This paper presents field examples from West Texas of the Water Flow Log which is based on a new approach to oxygen activation logging. Each example demonstrates the importance of this measurement in obtaining a conclusive interpretation to difficult production problems caused from channeling fluids behind pipe.

BACKGROUND

Oxygen activation is a relatively new technique (1971) as applied to the determination of water flow in oil and gas wells. It is the direct measurement of gamma rays versus time, produced from the decay of activated oxygen following fast neutron bombardment by a pulsed neutron capture tool. Almost all the oxygen atoms in the region of approximately one foot radius from the tool (centralized in the borehole) will be activated by the 14 MEV neutrons (Figure 1). The purport is to distinguish the oxygen that is moving either in an up or down direction as it passes a gamma ray detector located a known distance from the neutron generator source.

Previous methods of determining water flow with oxygen activation have met with limited success for several reasons:

1. The old steady state method (versus new dynamic method) requires a zero-flow calibration zone (Figure 2) which is not possible to determine absolutely.

2. Errors will then follow when the borehole environment changes from the zero-flow calibration point; i.e., casing size, cement sheath, borehole size or fluid.

3. Errors also result when the formation characteristics change from the zero-flow calibration point; such as lithology, porosity, and water saturation.

Therefore, the validity of this traditional approach depends upon the zero flow calibration point being truly zero-flow and identical to every point where a flow determination is desired.

A NEW TECHNIQUE

The Impulse Activation Technique as presented by McKeon et al, is a substantial improvement over the traditional method of determining water flow with oxygen activation. The major advantage is that a measurement in a known zero-flow zone is not required. This eliminates the concern of showing false positive indications of flow that could lead to unneeded and costly well repairs. The Water Flow Log (WFL) is the name given to this new technique which measures the flow velocity directly from the count rate flow profile (Figure 3). More simply put, it is a timing measurement over a known distance to each of three available detectors. The user must choose whether to configure the tool for upflow or downflow detection (Figure 4), and then with each station measurement, he must choose the detector with the optimum spacing for a given velocity. The total counts in the measured flow profile, together with an estimate of the radial distance to the flow channel, provide an estimate of the flow rate that can be calibrated in units of BWPD.

FIELD EXAMPLES

Giving answers to our customers' producing well problems is part of our purpose and a growing part of our business. However, it can be extremely challenging and requires intense detective work as can be attested to by anyone who is experienced or has even attempted it. In the following examples, the new Water Flow Log has demonstrated its capability to help solve many difficult production problems that involve water channeling in the casing formation annulus.

Those experienced in the conventional techniques for detecting fluids channeling behind pipe, such as temperature, radioactive tracer and noise logs, know how difficult and inconclusive they can be. The temperature log is the most common production logging device in use today, yet it is probably the most difficult to interpret. Many conditions in the borehole and the formation can produce temperature anomalies which, when misinterpreted, lead to incorrect and sometimes expensive conclusions as we will see in the first example.

Example 1

The first example is a Fusselman well in Martin County, Texas which had an initial production rate of over 300 BOPD, flowing. The well produced 10,000 barrels, water-free, for one month and then went on a 70% decline as soon as water production started. A debate began over whether this well was positioned barely up structure to a water contact or whether the water was channeling from another zone. The oil company engineer believed that the water was channeling from some deeper porosity which was a major lost circulation zone during drilling.

To test that theory, he elected to run the WFL in the upflow configuration and, at the same time, to log the Dual Burst TDT to see if the bulk volume water of the perforated zone had increased since production began. Through the open hole evaluation, bulk volume water was determined to be at irreducible, which is 2% for this Fusselman dolomite. There were serious financial implications to this debate that must be pointed out here. A drilling rig was scheduled to move in and drill the next location the day after logging this well. In fact, the pad was being laid the day we logged the TDT! If the conclusion is that there is no channeling and the zone has pulled in water, then the new well will be cancelled which would save them over one million dollars.

At first, the WFL channel detection was confusing. It showed two positive indications of channeling from the bottom of the well, and one "no flow detected" just beneath the perfs (Figures 6, 7 and 8). On the other hand, the CYBERSCAN was clear. It showed that BVW had increased to 5% in the lower third of the porosity zone (Figure 9). This looked like the problem was not channeling; therefore, there would be no new well. However, the engineer's company was skeptical of the TDT/WFL and wanted more data for proof, so the temperature log was run (something they could believe in) (Figure 10). The temperature overlays were straight (without gradient) below the perfs, indicating channeling. So now the new well was back on. But why was the producing zone slightly warmer than the zone where the water was channeling up from? This is where the detective work comes in. The only good explanation for both the WFL "no-flow" indication under the perfs and the small temperature anomaly was fractures.

A fracture cutting the wellbore could carry warmer water from a deeper zone up into the producing zone without completely warming up the borehole. And it also would explain why there is no activated oxygen moving on the WFL just below the perfs, but only where the fracture actually cuts the wellbore further down the hole. With more support for fracturing coming from both the open hole logs and the geologist, the offset well was cancelled because of the extreme risk of quickly pulling water from below through the high permeability of fractures. It is important to note that the temperature log alone would not have stopped the new well.

Example 2

The radioactive tracer log is a good method for determining flow direction inside the borehole, and the relative amounts of fluid entering or leaving the perforations. However, for identifying channels behind pipe, it is a poor technique since tracer fluid must get into the casing annulus and move in the flow stream. Pumping the tracer into the perfs to find the source of water flow will only put it in the zone of least pressure which is almost never the source. The second example illustrates the limitation of both the temperature log and the tracer log in channel detection.

A new well in Loving County, Texas was considered a high potential gas well from drilling shows, but never made gas to surface after setting pipe and perforating. The accepted theory was that substantial water production must be killing the gas production. A temperature log was the operator's first choice to determine the source of the water. The temperature profile seemed to tell the story. Water was flowing from the lower perfs, up from the bottom of the well, and killing any gas production. (Figure 11) A tracer log was also run and determined the flow was not only coming from the bottom of the well, but it was also leaving the well at 18,500 feet (Figure 12). This lower pressured "thief" zone was probably the source of gas during drilling. The operator decided to squeeze off the lower perfs and only produce out of the top two sets of perfs. The lower perfs were successfully squeezed, yet the water production did not stop!

Now the water must be coming from the perforated zone because of all the cross-flow into it. However, after several weeks of water production, there was still no gas, so abandoning the well was being considered. On closer inspection of the temperature log, an unusual temperature gradient of $1^{o}/140$ feet is observed above the perfs. Could there also be downflow? But from where? The Water Flow Log was run in the downflow configuration to answer these unresolved questions. (Figures 13 and 14)

The WFL confirmed the downflow suspicion, and indicated that water was coming from several points in the Woodford Shale. These points cannot be seen on the temperature log. A second squeeze was attempted at the perfs, but was unsuccessful in shutting off the downflow. They will attempt another squeeze, and my recommendation is to squeeze the points of water entry, which has not been done yet.

Example 3

This horizontal well had a small water flow to surface before the well was even perforated. The culprit was most likely a leaky liner top (Figure 15). A temperature log was run from the bottom of the well, and showed no change through the horizontal section as would be expected. It showed nothing that was conclusive about the liner top either. The WFL was also run to the bottom of the hole, and clearly shows the water flowing from the end of the horizontal section. The leak was found to be in the float shoe. (Figures 16 and 17)

CONCLUSIONS

There are many applications for the new Water Flow Log from the Class I and II injection wells previously presented, to solving difficult production problems as presented here. The WFL has demonstrated its ability to enhance the interpretation of temperature and tracer logs and, in most cases, will replace the need for one or both of them.

ACKNOWLEDGMENTS

I would like to express my appreciation to my West Texas customers who released their examples for this paper and a subsequent publication; to Hugh Scott, Don McKeon and George Patton for their technical support; and to Tom Adkins for his long-term moral support of this and many other projects important to the TPS business in WTD. THANK YOU.

REFERENCE

McKeon, D. D.; Scott, H. D.; Olesen, J. R.; and Mitchell, R. J.: "Improved Method for Determining Water Flow Behind Casing Using Oxygen Activation." Paper 20586 presented at the 1990 SPE Annual Technical Conference and Exhibition, New Orleans, Louisiana.

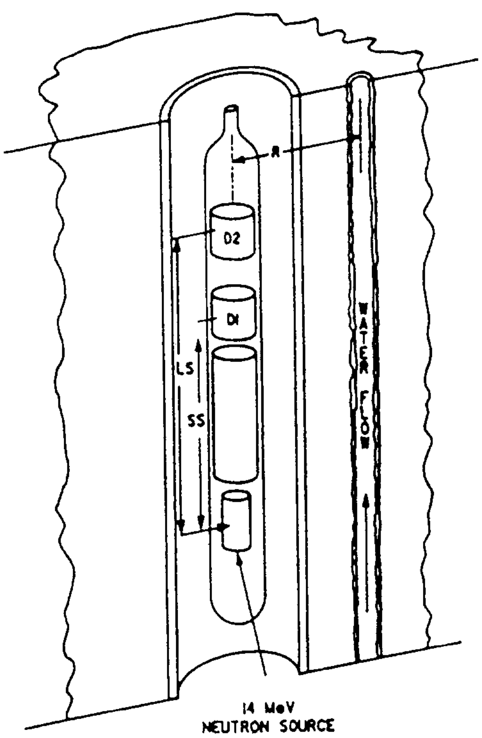

Figure 1 - The oxygen activation log

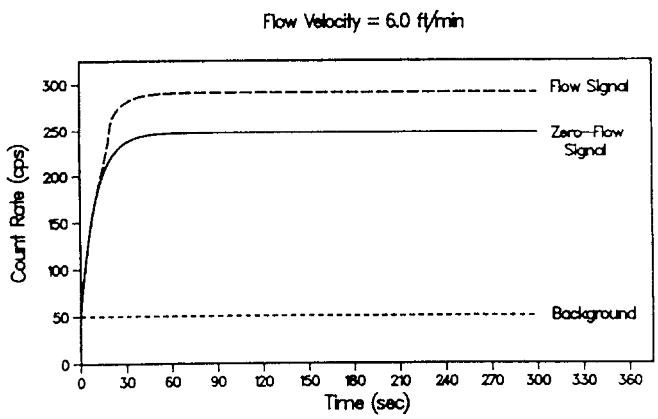

Figure 2 - Texaco method for detecting flow behind casing

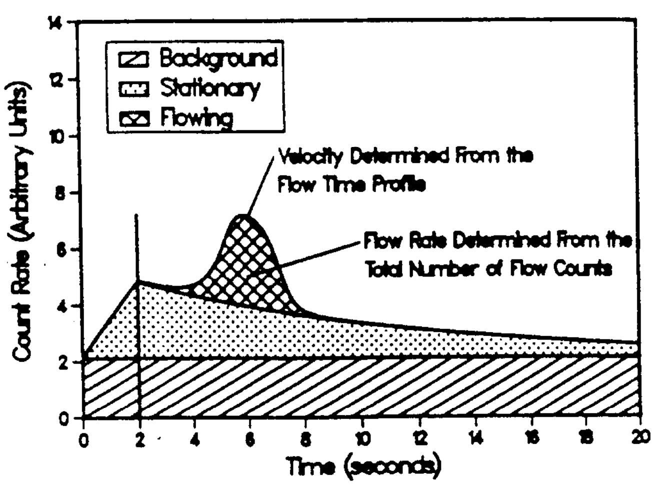

Figure 3 - Water Flow Log Service - determination of flow velocity and flow rate

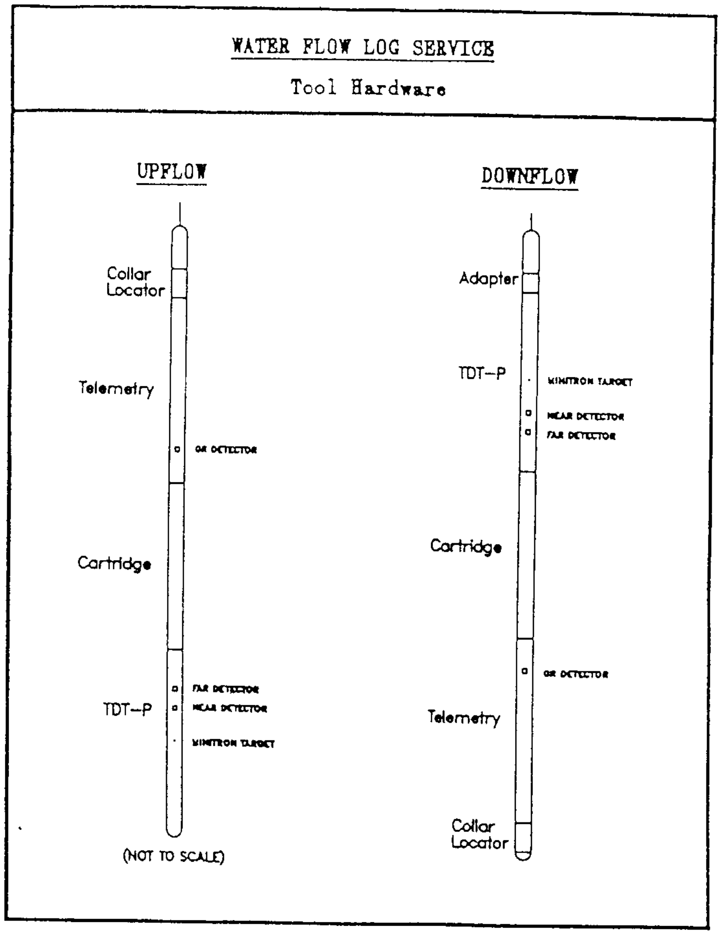

Figure 4

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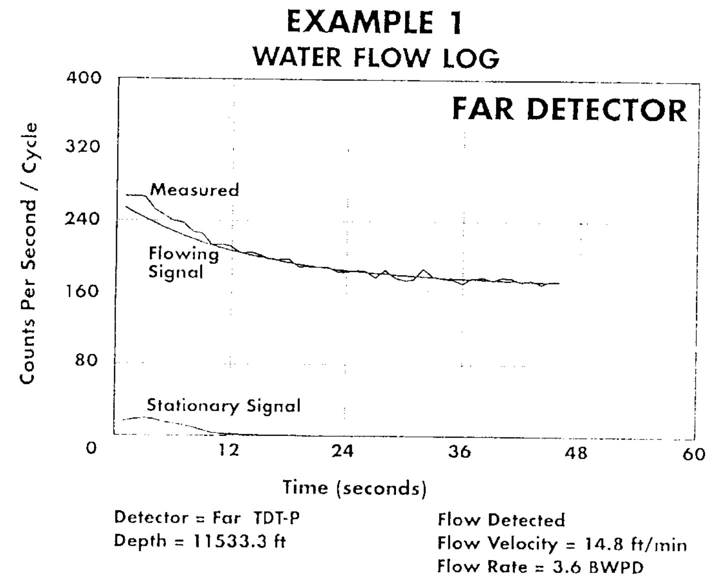


Figure 6

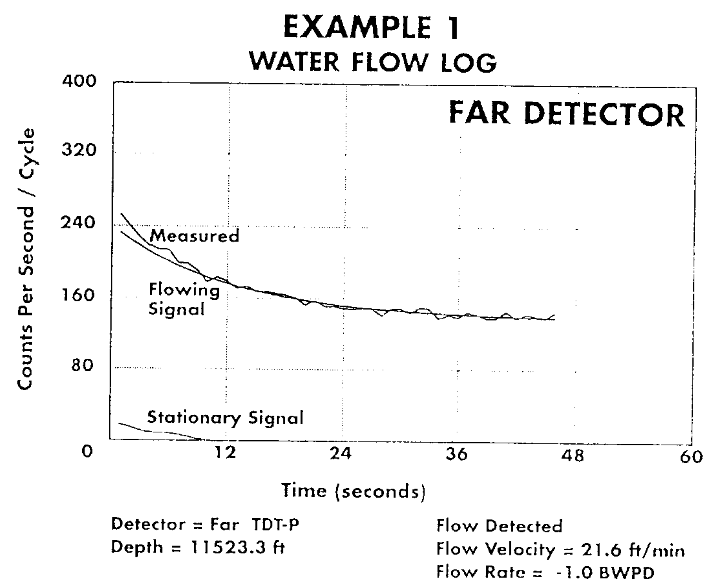


Figure 7

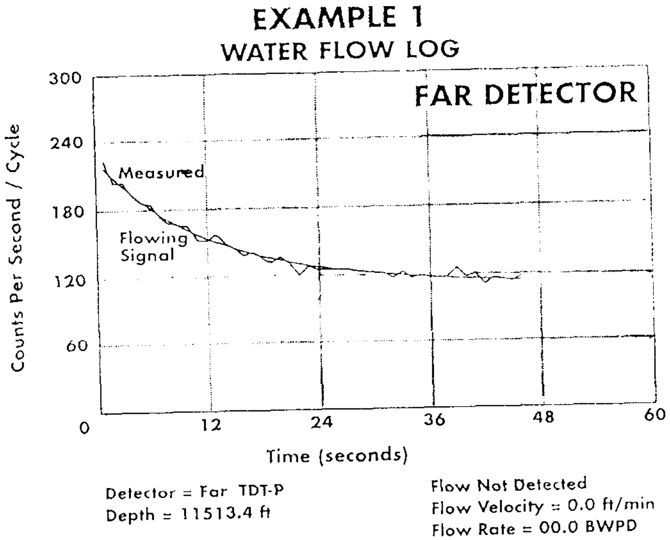


Figure 8

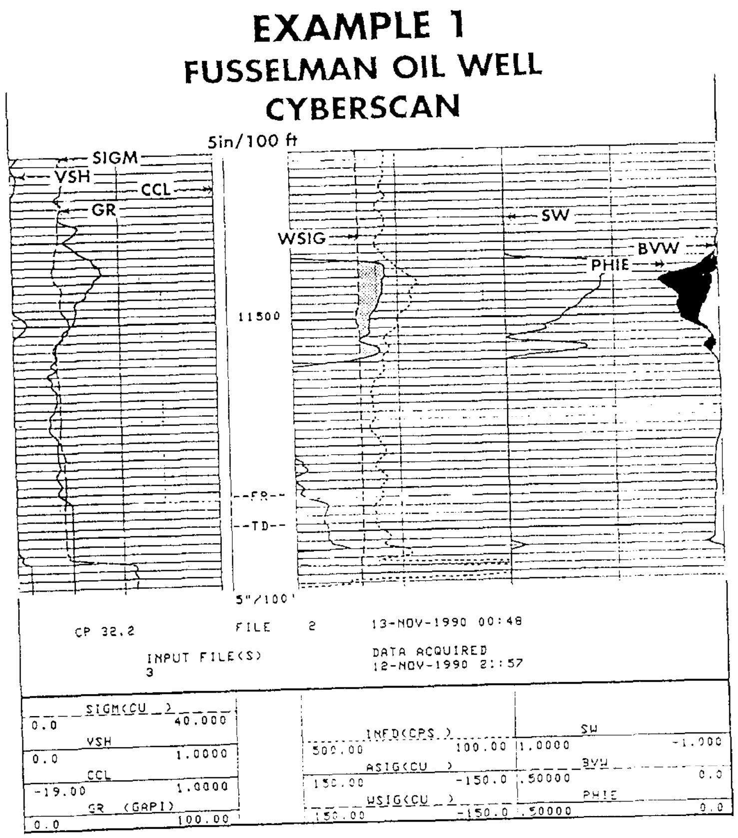


Figure 9

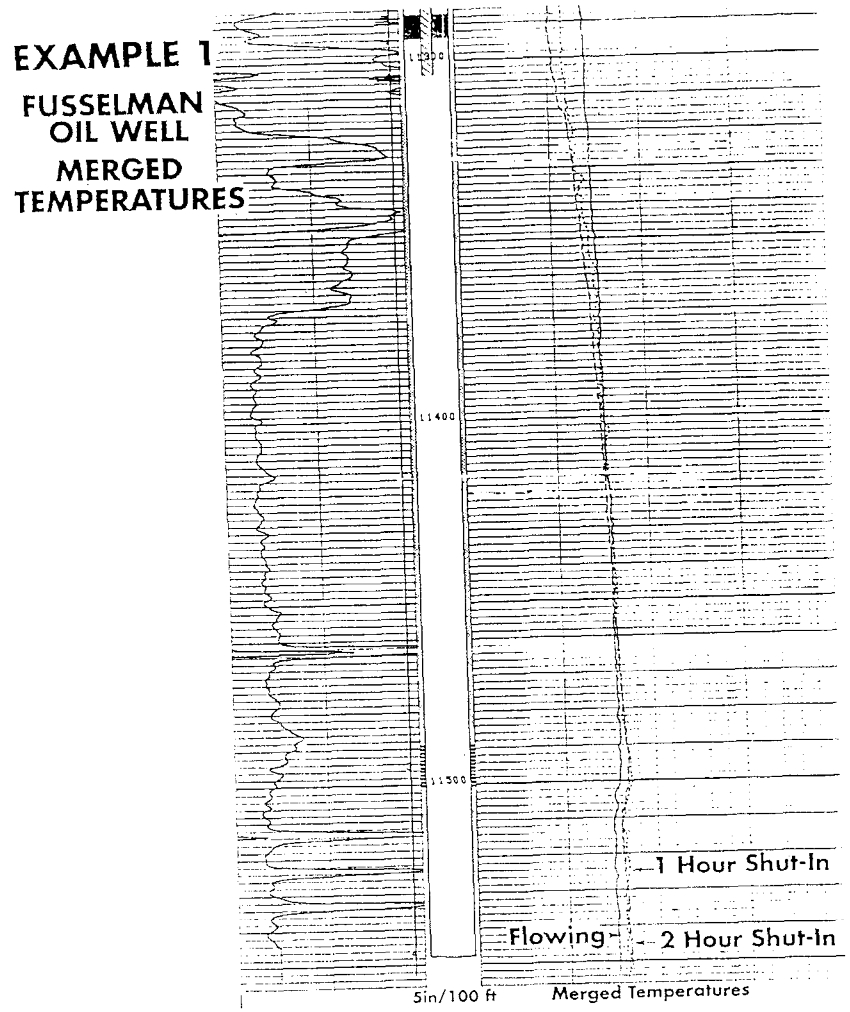


Figure 10

EXAMPLE 2
FUSSELMAN GAS WELL

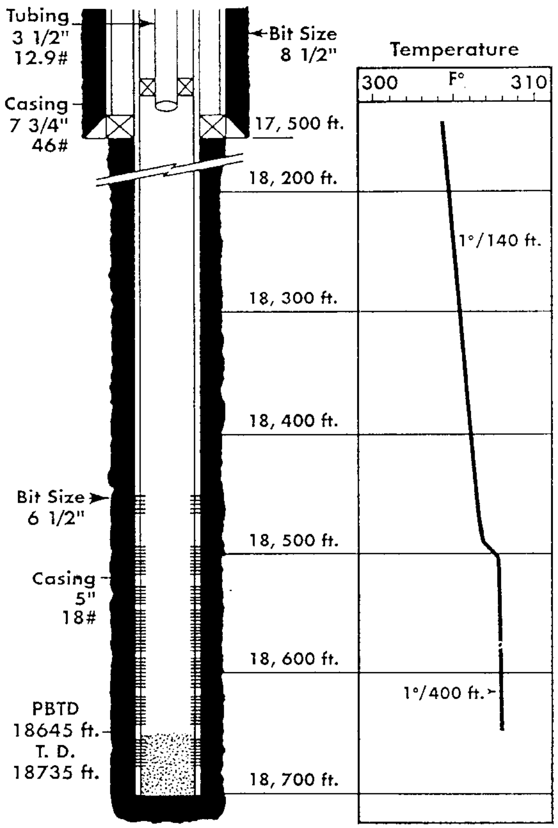


Figure 11

EXAMPLE 2
FUSSELMAN GAS WELL

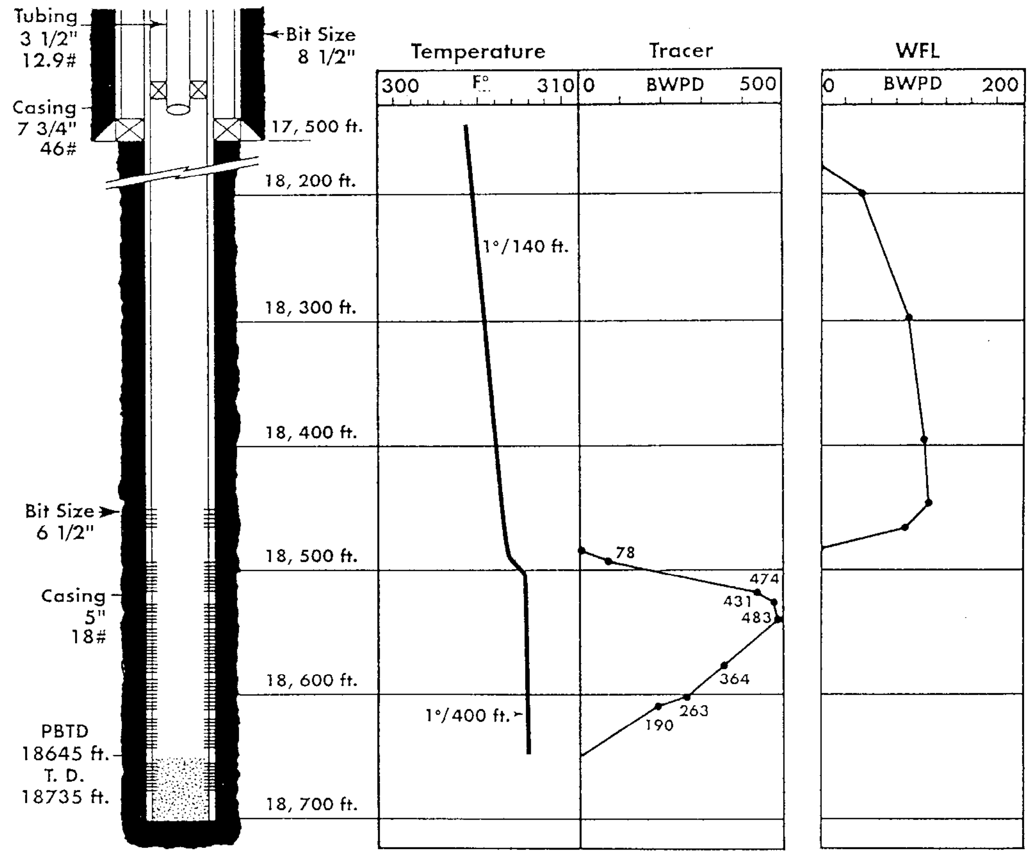
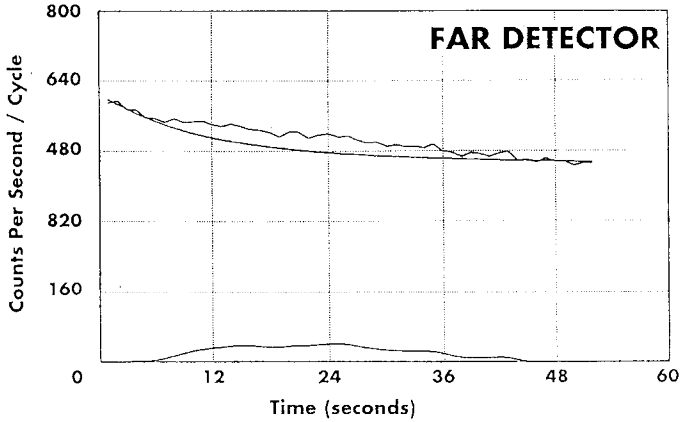


Figure 12

EXAMPLE 2
WATER FLOW LOG

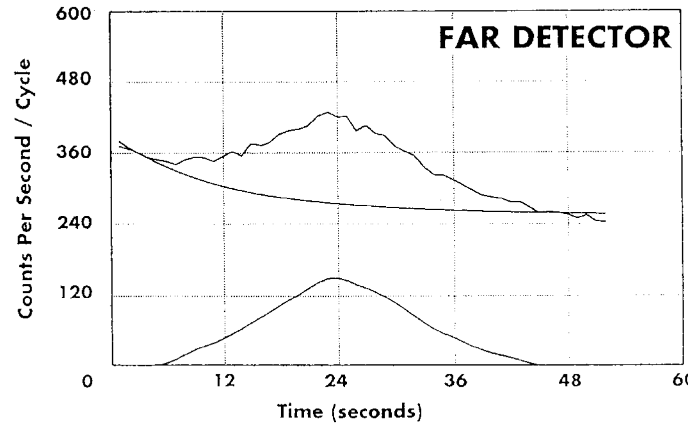


Detector = Far TDT-P
Depth = 18200.2 ft

Flow Detected
Flow Velocity = 2.5 ft/min
Flow Rate = 37.4 BWPD

Figure 13

EXAMPLE 2
WATER FLOW LOG



Detector = Far TDT-P
Depth = 18443.2 ft

Flow Detected
Flow Velocity = 2.2 ft/min
Flow Rate = 105.6 BWPD

Figure 14

EXAMPLE 3
HORIZONTAL WELL

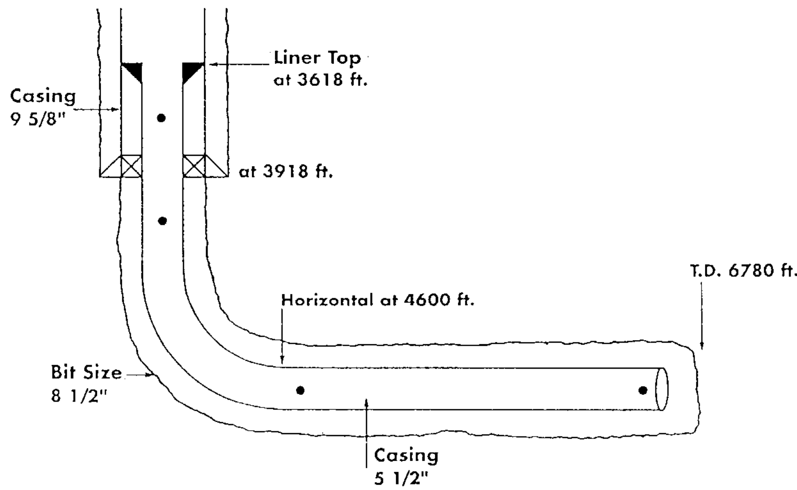


Figure 15

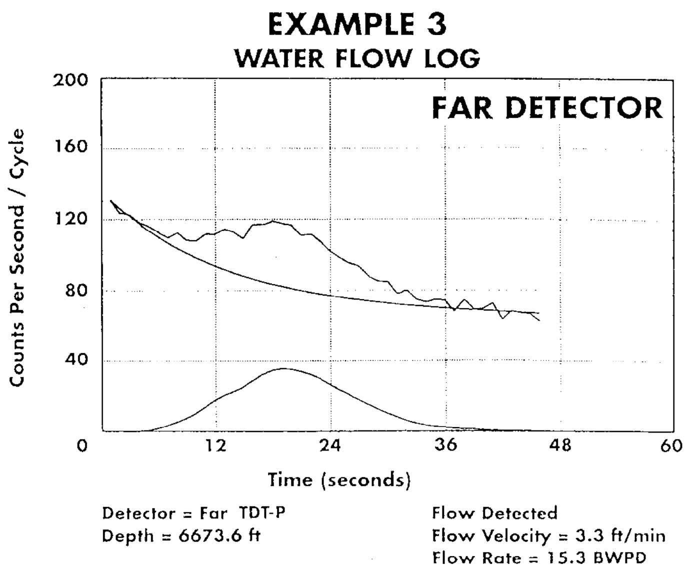


Figure 16

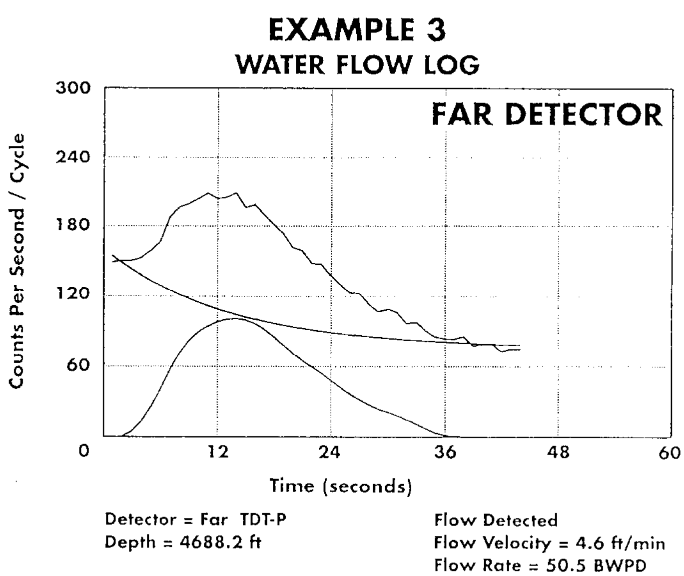


Figure 17