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Detecting Water Flow Behind Pipe in Injection Wells

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DETECTING WATER FLOW BEHIND PIPE IN INJECTION WELLS

by

Jerry T. Thornhill
U.S. Environmental Protection Agency
Ada, Oklahoma 74820

Bobby G. Benefield
East Central University
Ada, Oklahoma 74820

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Project Officer

Jerry T. Thornhill
Extramural Activities and Assistance Division
Robert S. Kerr Environmental Research Laboratory
Ada, Oklahoma 74820

ROBERT S. KERR ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
ADA, OKLAHOMA 74820

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FOREWORD

EPA is charged by Congress to protect the Nation's land, air and water systems. Under a mandate of national environmental laws focused on air and water quality, solid waste management and the control of toxic substances, pesticides, noise and radiation, the Agency strives to formulate and implement actions which lead to a compatible balance between human activities and the ability of natural systems to support and nurture life.

The Robert S. Kerr Environmental Research Laboratory is the Agency's center of expertise for investigation of the soil and subsurface environment. Personnel at the laboratory are responsible for management of research programs to: (a) determine the fate, transport and transformation rates of pollutants in the soil, the unsaturated and saturated zones of the subsurface environment; (b) define the processes to be used in characterizing the soil and subsurface environment as a receptor of pollutants; (c) develop techniques for predicting the effect of pollutants on ground water, soil, and indigenous organisms; and, (d) define and demonstrate the applicability and limitations of using natural processes, indigenous to the soil and subsurface environment, for the protection of this resource.

This report presents one technique for detecting flow behind pipe in injection wells. This modification of an existing technique provides, in many instances, a more accurate and precise method for detecting both flow behind pipe related to injection and not related to injection. This capability will help to assure that use of injection wells for disposal of waste will not endanger underground sources of drinking water or the environment.

Clinton W. Hall
Clinton W. Hall
Director
Robert S. Kerr Environmental
Research Laboratory

ABSTRACT

Regulations of the Environmental Protection Agency require that an injection well exhibit both internal and external mechanical integrity. The external mechanical integrity consideration is that there is no significant fluid movement into an underground source of drinking water through vertical channels adjacent to the injection well bore.

The oxygen activation method for detecting flow behind pipe employs a measurement technique in which a stable isotope of oxygen is temporarily converted to an unstable nitrogen isotope. Unstable nitrogen-16 decays with a half-life of 7.13 seconds and acts as a radioactive tracer to enable measurement of flow of water-bearing fluid past a series of detectors.

Thirteen tests have been conducted at the Mechanical Integrity Testing and Training Facility to determine the accuracy and reliability of this method. This technique has also been applied commercially in almost two hundred privately owned wells.

The oxygen activation technique, which is a modification of an existing technique, provides, in many instances, a more accurate and precise method for detecting flow behind casing both related to injection and not related to injection (interformational flow).

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Introduction

One of the responsibilities of the U. S. Environmental Protection Agency (USEPA) is to insure that drinking water supplies are not endangered as a result of injection of fluids into the subsurface through injection wells. The Safe Drinking Water Act, as amended, and the RCRA amendments of 1987 contain the guidelines for protection of underground sources of drinking water through the regulation of "underground injection."

Regulations of the USEPA require that injection wells demonstrate mechanical integrity prior to operation and at least every 5 years thereafter. The regulations stipulate that a well has mechanical integrity if:

(1) There is no significant leak in the casing, tubing or packer; and

(2) There is no significant fluid movement into an underground source of drinking water through vertical channels adjacent to the injection well bore.

Investigating the part 1 (internal) and part 2 (external) mechanical integrity stipulations has been the focus of this research over the past three years. The purpose of this report is to relate the results of research conducted on a nuclear logging technique for detecting flow behind pipe in injection wells (external mechanical integrity).

Research Facility

A Mechanical Integrity Testing and Training Facility has been developed to evaluate various tools and techniques used to determine mechanical integrity of injection wells. The test facility, which is located 10 miles west of Ada, Oklahoma, includes three "logging wells", a "calibration well", a "leak test well", and three "monitoring wells" (Figure 1).

Research conducted at the Facility has contributed to improved methods for evaluating cement behind pipe in injection wells to assure isolation of the injection zone and protection of underground sources of drinking water. Wells at the site have also been used to develop and refine pressure tests for "internal" mechanical integrity determinations.

Mechanical Integrity Test Facility

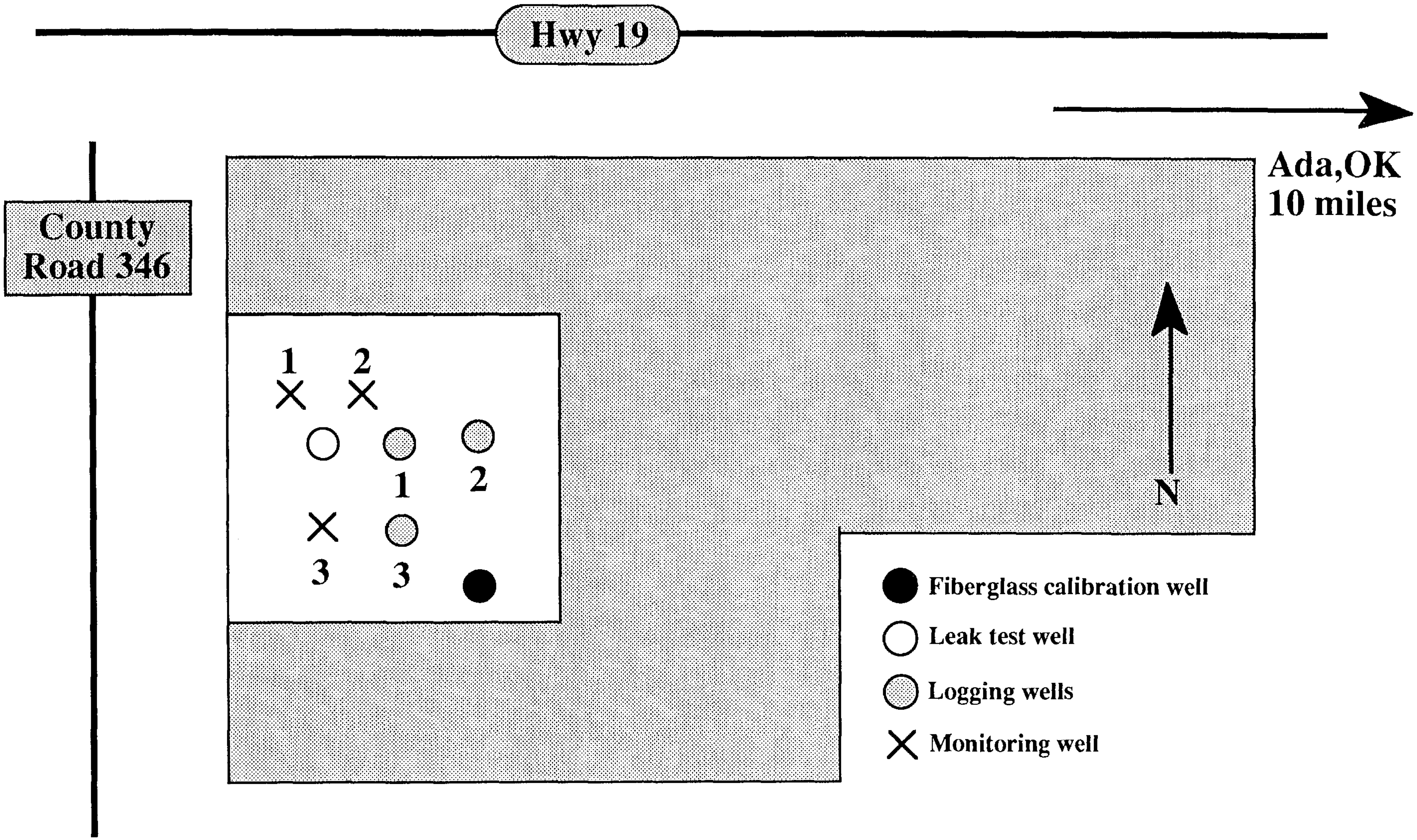


FIGURE 1

The results of this research have been documented in reports EPA/625/9-87/007 and EPA/625/9-89/007.

In addition to EPA sponsored research conducted at the facility, logging companies and exploration and production companies have tested new tools at their own expense. For example, some of the major logging companies in the United States (Schlumberger Well Services, Atlas Wireline Services, Halliburton Logging Service, and Wedge Wireline, Inc.) have used the facility on a number of occasions to test specific tools. Personnel from Sunburst Perforating Services, Ltd., a wireline company from Canada, spent two weeks at the facility testing various tools. They indicated that this was the only facility of its kind where a variety of tests could be performed. After using the Facility, a representative of the company stated, "We were very pleased with the data aquired, which enabled us to expand our data base to the point where we feel very confident in interpreting and identifying problem areas in most of the wells we are asked to service".

The Facility is also a center for mechanical integrity training activities. Courses are offered twice each year relating to methods for evaluating cement behind casing and methods for detecting flow behind pipe. The classes are limited to thirty students, and include consultants as well as state and federal regulators.

Nuclear Logging Technique

Wichmann et al. (1967) discussed a miniaturized Neutron Lifetime Logging instrument that was capable of detecting water flowing outside casing by activating the oxygen in the water with 14 million electron volt (MeV) neutrons and by detecting this oxygen activation as the water moved past a gamma ray detector. The authors concluded that the ability to "tag" any fluid containing oxygen by making it radioactive, even when it is not in close contact with the logging tool, is unique and probably the only way to possibly detect flow of water outside casing when the water cannot be tagged by conventional tracer techniques.

In 1977 Arnold, Paap and Peelman used this principle in the development of an "oxygen activation" system for detecting flow behind pipe. Arnold and Paap (1979), cited the work of Wichmann et al and noted that Texaco, Inc. had developed a water-flow monitoring system that measures the direction, linear flow velocity, volume flow rate, and radial position of water flowing vertically behind or in wellbore casing. The Texaco system is based on a nuclear activation technique in which flowing water is irradiated with neutrons emitted by a logging sonde. These neutrons interact with oxygen nuclei in the water to produce the radioactive isotope nitrogen-16 through the oxygen-16 (n,p) nitrogen-16 reaction. Nitrogen-16 decays with a half-life of 7.13 seconds emitting 6.13 and 7.12 MeV gamma radiation. They concluded that the utility of the water-flow monitoring system could be improved greatly if a slim-hole sonde was available for through-tubing operations.

Williams (1987) reported on the Texaco Behind Casing Water Flow (BCWF) measuring system which is capable of measuring vertical water flow in or behind multiple casings. He described the laboratory apparatus used to calibrate a BCWF sonde and gave four field examples of successful use of the tool for detecting flow behind casing. He noted that, "....the water velocity and volume flow rates can be determined from gamma ray spectra measured by the BCWF sonde without knowledge of the location and cross-sectional area of the flow channel and the intervening material".

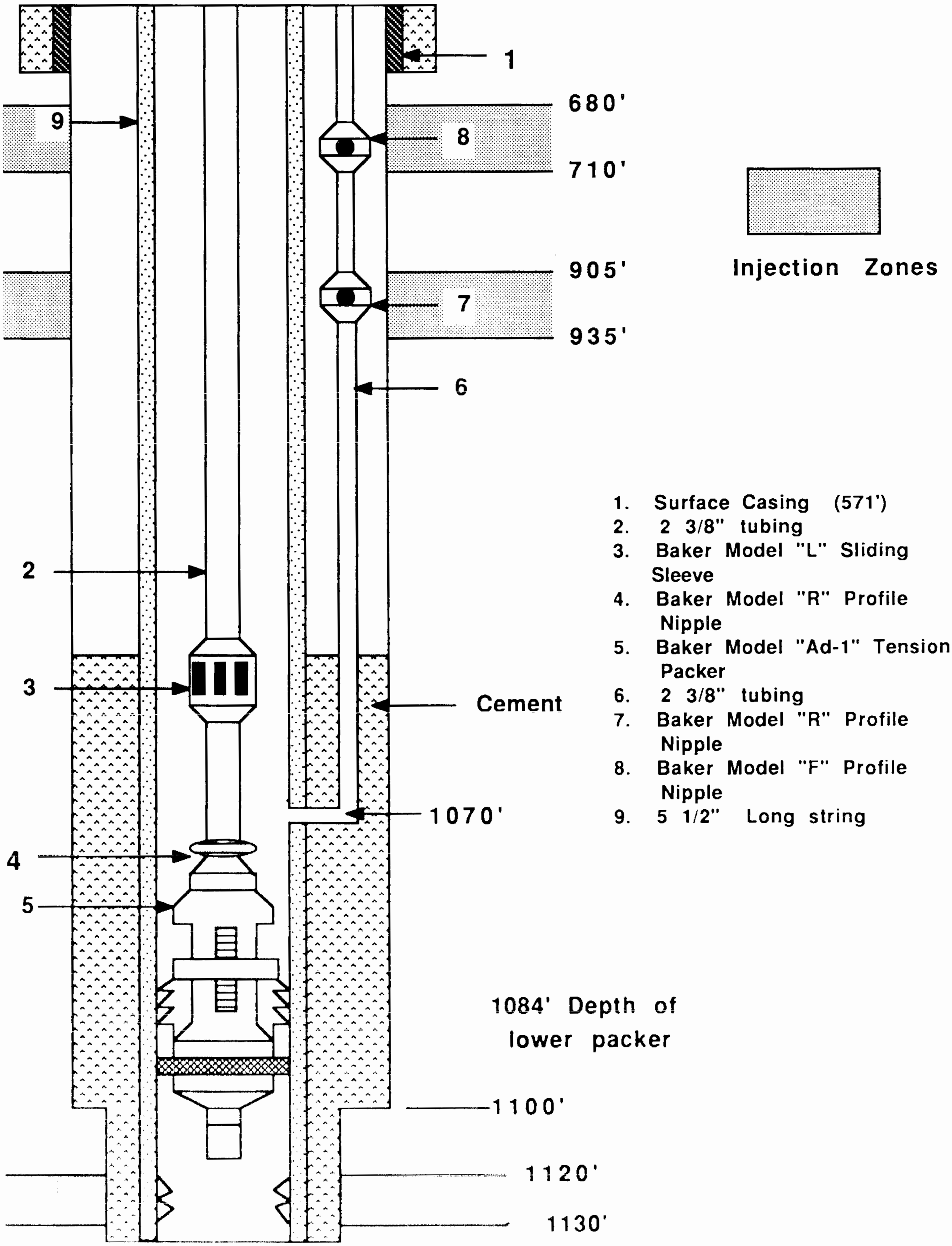
The pulsed neutron technology was brought to the attention of the mechanical integrity project personnel in late 1986. At that time, contact was made with service companies to determine their capability for making such measurements for detecting flow behind pipe.

Testing Equipment and Procedure

Equipment used in the research into detecting flow behind pipe includes the Leak Test Well, injection pump, pressure gauges, flow meters and a pulsed neutron logging device.

In many ways, the design of the Leak Test Well corresponds to a typical salt water disposal well used in the oil and gas industry. That is, it includes surface casing, long string, tubing and packer. The deviation from the norm in this well is that there is a sliding sleeve on the injection tubing and a 2-3/8 inch tubing string is attached to the outside of the long string from a depth of 1,070 feet to the surface (Figure 2). Details on the drilling and completion of this well are found in the report "Injection Well Mechanical Integrity" (Thornhill and Benefield, 1987).

The flow into the injection well can be controlled by a pressure relief valve on the flow line and is metered using a Halliburton Services



LEAK TEST WELL
FIGURE 2

Model MC-II Flow Analyzer, a Brooks in-line flow meter and a calibrated bucket and stopwatch. Flow into the well can be controlled so that the injected fluids are directed into the injection tubing, the tubing/long string annulus or the "outside" tubing. Flow out of the well is possible through the injection tubing/long string annulus , the "outside" 2-3/8 inch tubing or the long string/surface casing annulus and is measured using a calibrated bucket and stopwatch (Figure 3).

The procedure for running each test was to place the tool in the well at a predetermined depth in either the up or down-flow mode and take a reading under a no-flow condition. Injection would then start at a flow rate unknown to the service company personnel. After completing a series of flow rates at this depth the tool was moved to a different depth and the process repeated. In all instances very low flow rates were included in the tests so that one could determine the lowest flow the tool being tested could detect in the test well.

Upon completion of this series of tests, the tool was removed from the well, "turned over" and the tests repeated to detect flow in the opposite direction. Details of each test are included in the appendix of this report.

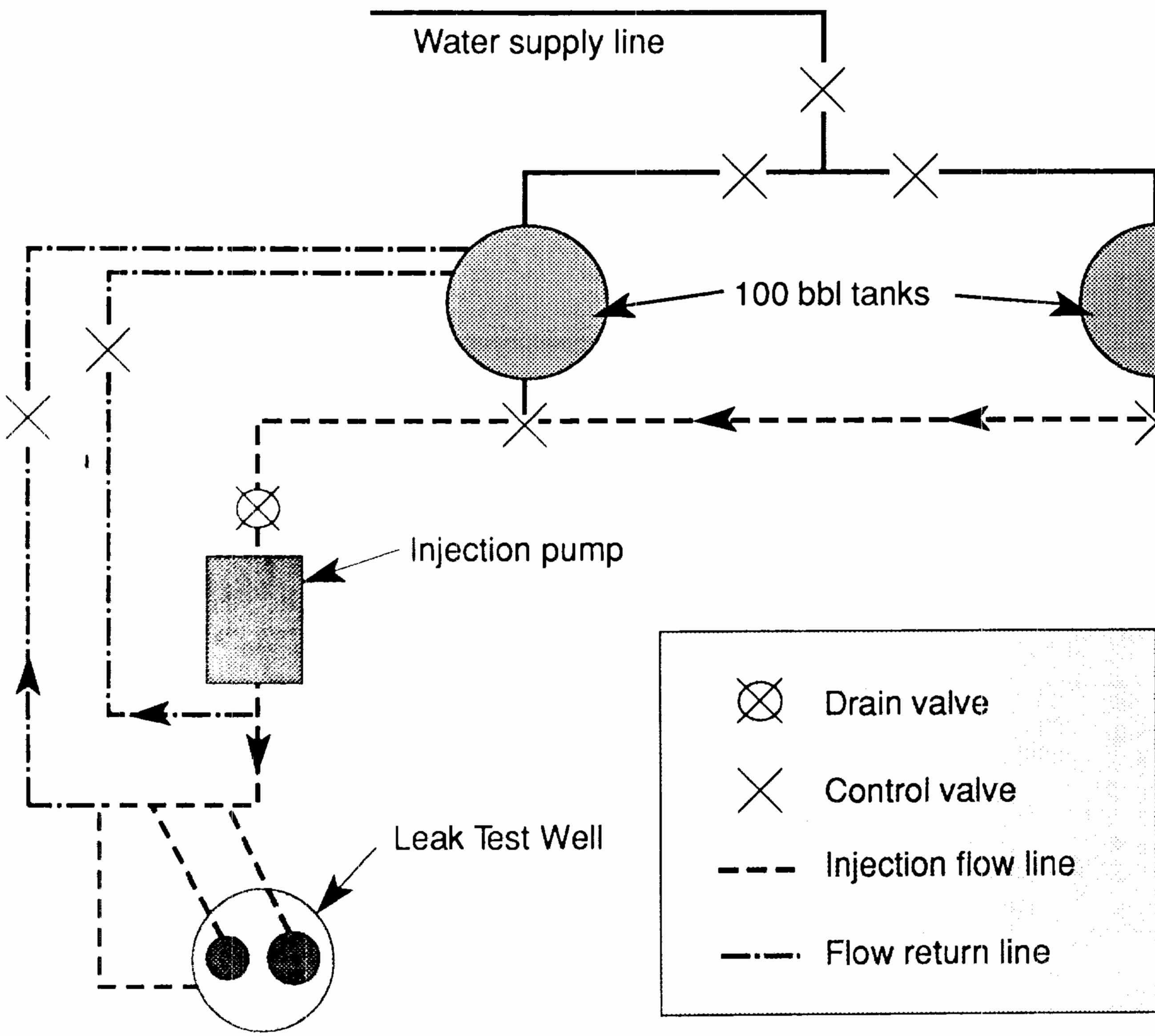
Atlas Wireline Services

Atlas Wireline (then Dresser Atlas) has been licensed by Texaco to offer a BCWF system and they had developed a 3-5/8 inch diameter "Cyclic Activation Tool" which was modeled after the Texaco system. They also had a 1.72 inch diameter pulsed neutron tool called the PDK-100 Tool (Pulse-and-decay, 100 channels).

Randall et al. (April 1986 & June 1986) described the PDK-100 pulsed neutron capture logging system as a new generation pulsed neutron logging instrument designed to measure the macroscopic cross section for thermal neutron absorption. The tool could identify the type of hydrocarbons present in the formation and identify and locate fluid changes in the borehole.

On January 23 and 24, 1987, the Cyclic Activation and PDK-100 tools were tested at the Mechanical Integrity Testing and Training Facility. The conclusions were that the Cyclic Activation Tool was able to detect 7.8, 6.1 and .79 gallons per minute (gpm) flows in the outside 2-3/8 inch tubing. With the PDK-100 Tool located in the injection tubing,

Surface Schematic of Leak Test Well



flows of 8, 4 and 1 gpm were detected when the flow was up or down the injection tubing/long string annulus. The tool was not able to detect flows up or down the outside 2-3/8 inch tubing (Test No. 2).

On April 8, 1987, Atlas Wireline (then Dresser Atlas) tested a modified PDK-100 Tool at the Mechanical Integrity Testing and Training Facility. In this test, five flow rates were initiated and the tool detected four of the five. Flows of 8, 6, 4 and 2 gpm were detected but a flow of 0.105 gpm was not. (See Test No. 5 in Appendix).

The results of the second test of the small diameter tool were so encouraging that seven other tests of the Atlas Wireline oxygen activation tool were conducted at the test facility. One test was conducted in an abandoned gas well in the Shell Little Creek Field near McComb, Mississippi. (See Tests No. 7, 14, 15, 20, 23, 26, 28, and 29 in Appendix for details). The lowest flow rate detected during these tests was .25 gpm.

Hill et al. (1989) described the Atlas Wireline Services Pulsed Neutron logging system, which is marketed as "Hydrolog." The tool is designed to allow quantitative measurement of water-flow velocity, and incorporates several modifications to the existing pulsed neutron capture (PNC) logging systems. Hill et al. (1989) outlined significant modifications to the existing PNC logging instrument design and operation as follows:

1. Stationary measurements are made to eliminate variable logging speed from the velocity determination and improve the statistical accuracy.

2. The HYDROLOG instrument is calibrated to detect only those gamma rays associated with oxygen activation by setting a discrimination level of 3 MeV. Gamma rays with energies below 3 MeV are not recorded since they are due either to naturally occurring radioisotopes (e.g., potassium, uranium, thorium) or those produced by activation of other elements (e.g., silicon and iron).

3. The source-firing sequence has been modified from the "conventional" method used by PNC instruments to increase the background-measurement cycle during which oxygen activation-related gamma radiation is detected. The neutron source pulses at a 1 kHz repetition rate for 28 milliseconds and is turned off for a

period of 8 milliseconds to allow the oxygen activation background measurement. Note that the oxygen activation measurement is made in the latter part of the 8 millisecond time window, well after the neutron source has been turned off. The pulse-background cycle is repeated continuously for the duration of the stationary measurement.

4. The source-to-detector spacing has been optimized to detect maximum count rate over a wide range of water-flow velocities.

5. The instrument can operate in an inverted mode, to allow water-flow detection in the downward, as well as upward, direction.

An example of the data presentation from the tool is shown in Figure 4. The nomenclature for the presentation is as follows:

Oxygen SS (cts)	The count-rate (counts per second) of gamma rays measured by the Short Space (SS) detector, the detector closest to the neutron generator.
Oxygen LS (cts)	The count-rate of gamma rays measured by the Long Space (LS) detector, the detector farthest from the neutron generator.
BKG SS (cts)	The count-rate of the Short Spaced detector. This count-rate is representative of a "no-flow" condition.
BKG LS (cts)	The count-rate of the Long Spaced detector. It is representative of a no-flow condition.
Flow Ind. SS (cts)	Oxygen Short Space count-rate minus the Background Short Space count-rate equals Flow Indicator SS.
Flow Ind. LS (cts)	Oxygen Long Space count-rate minus the Background Long Space count-rate equals Flow Indicator LS.

OXYGEN ACTIVATION ANALYSIS
ATLAS WIRELINE SERVICES

Date	:03-NOV-87	Time	14:58:20
Company Name	:EAST CENTRAL UNIVERSITY EPA		
Well Name	:LEAK TEST WELL NO. 1		
Field Name	:WILDCAT		
County Name	:PONTOTOC		
State Name	:OKLAHOMA		
Service Name	:OCT. ACT. LOG		
Bkg. File Name	:INELASTIC CORRELATION		
Disk File Name	:ST6E.DAT		
Tool Position	:1UP		
Real Time	:300.0		
Depth	:800.0		
Station Number	:46		
Spectrum Number	:1		
Comment	:1.5 GAL/MIN INJ.		

****

OXYGEN SS (cts)	BKG SS (cts)	FLOW IND SS (cts)
15.374 +/- .535	8.771 +/- .404	6.604

OXYGEN LS (cts)	BKG LS (cts)	FLOW IND LS (cts)
3.272 +/- .247	.253 +/- .069	3.019

VELOCITY (ft/min)	LODR	ISS (cts)	ILS (cts)	GR (cts)	BGR (cts)
9.779 +/- 1.652	30.45	4407	125	32.5	463.5

#CYCLES	SYNCS/ CYCLE	#BKG GATES	BKG WIDTH us	SPACING	SS LLD	LS LLD
8405	28	16	400.0	1.31	240	240

****

HYDROLOG DATA PRESENTATION
FIGURE 4

Velocity (ft/min)	The calculated linear flow velocity of the fluid.
LODR	Long Spaced Observed Decay Rate scaled as a long spaced capture thermal neutron cross-section.
ISS (cts)	The inelastic gamma ray count rate of the Short Space Detector.
ILS (cts)	The inelastic gamma ray count rate of the Long Space Detector.
GR (cts)	Gamma Ray detector can be used to record correlation log.
# Cycles	The number of cycles completed during the sample period.
SYNCS/CYCLE	The number of neutron source pulses per cycle.
# BKG GATES	Number of background gates.
BKG WIDTH	The background gate width.
SPACING ft.	Spacing between the LS and SS detectors.
SS LLD & LS LLD	A discriminator setting which corresponds to the minimum gamma ray energy value that will be measured

Since the N-16 half-life and detector spacing are known, velocity can be calculated based on the ratio of the two detector count rates (Hill et al. 1989). The following criteria must be met for a valid velocity calculation: (1) the Oxygen Short Space (SS) Flow Indicator value must be at least 3 times the error bar, (2) the Oxygen Long Space (LS) Flow Indicator value must be at least 2 times the error bar, (3) the LS Flow Indicator value must be less than the SS Flow Indicator value, and (4) neither the LS nor SS Flow Indicator values can be zero.

At this point in the research, the velocity of flow is not the primary concern in the use of this tool for flow determinations. The primary concern is the capability to accurately and precisely detect flow behind pipe. The velocities of interest are the minimum and maximum that can be detected by the tool.

Schlumberger Well Services

Intermittent contact was maintained with personnel with Schlumberger Well Services during 1986 and 1987 regarding the capability of tools they market to detect flow behind pipe. On January 20, 1988, personnel from Schlumberger tested their 1-11/16 inch diameter Dual Burst TDT-P Tool at the Mechanical Integrity Testing and Training Facility. Basically, the tool was not able to adequately detect water movement behind the casing in these experiments (Test 19 in Appendix).

Schlumberger personnel returned to the test facility on October 4 and 5, 1989, to test a modified Dual Burst TDT-P tool which would be marketed as the "Water Flow Log." The tool successfully detected flows down to 0.22 gpm. The tool was retested on March 1, 1990 and March 11, 1991, with excellent results. (See Tests 25, & 27 in Appendix).

McKeon et al. (1990) described the Water Flow Log measurement as using the Impulse Activation technique. The presence of water can be determined by detecting gamma rays that are emitted following the fast activation of oxygen nuclei in and around the borehole by high-energy neutrons. Activated oxygen moving up or down can be traced sequentially by three detectors spaced along the tool (WFL Water Flow Log Service). This oxygen activation technique is based on a very short activation period (2-10 sec) followed by a longer acquisition period (typically 60 sec). Theoretically, because of the short activation period, it is possible to detect the signature of the flowing activated water as it passes the detector. Flow is detected by comparing the measured count-rate time profile with the characteristic oxygen activation decay profile. Water flow is detected when the measured oxygen activation profile does not decay exponentially. If a zero-flow condition exists, the total measured gamma ray count rate resulting from oxygen activation will decrease exponentially (McKeon et al. 1990).

Oxygen activated in stationary water, mud, or cement decays at a predictable, characteristic exponential rate. Thus, background, stationary oxygen, and flowing oxygen signals are determined from the total count rate profile using an iterative linear regression technique (WFL Water Flow Log Service).

The WFL tool includes a near, far and gamma detector that are spaced 1, 2 and 15 feet, respectively, from the source. The output of the WFL (Figure 5) includes the actual recorded decay rate curve and a fitted exponential decay rate curve. The area between the two curves is a qualitative indication of flow. A flowing signal curve is included when flow is detected (WFL Water Flow Log Service).

Experiments at the Mechanical Integrity Testing and Training Facility and Schlumberger test facilities indicate the following characteristics of the tool:

The near detector is capable of measuring channel flow of less than 2 feet/minute. The near detector results should be used for flow identification only when the logging conditions are stable and well understood.

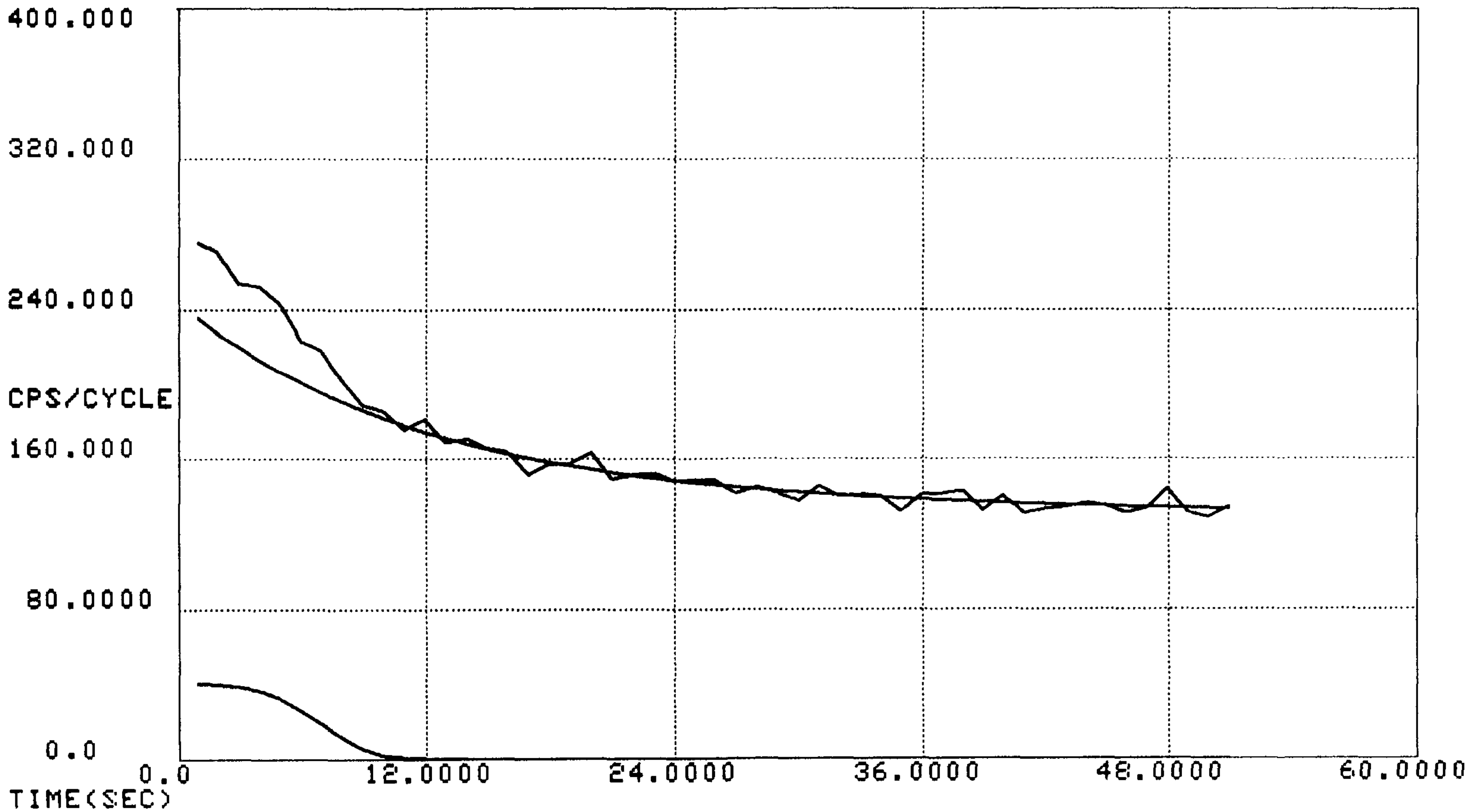
The far detector is capable of detecting channel flow from about 2 feet/minute to 50-90 feet/minute. The far detector sensitivity peaks at abut 10 feet/minute.

The Gamma Ray detector is capable of detecting channel flow from about 20-30 feet/minute to 200 feet/minute. The GR detector sensitivity peaks at about 75 feet/minute.

From 2 feet/minute to about 38 feet/minute the far detector is more sensitive to flow than the GR detector. Above 38 feet/minute, the GR detector is more sensitive to flow (McKeon et al. 1991).

Schlumberger scientists predict that the tool will reliably detect flows ranging from 1.4 feet per minute to 120 feet per minute. As casing size increases, this capability is reduced. For example, in 9-5/8 inch casing the range would be 3.0 feet per minute to 30 feet per minute and in 13-3/8 inch casing the range is 4.5 feet per minute to 30 feet per minute.

The WFL measurement is not capable of distinguishing between flow inside and outside casing. The velocity of flow can also be determined, as with the Hydrolog. However, as stated earlier, this is not a primary concern at this point in the research.



DETECTOR = FAR TDT-P DEPTH = 983.5 F

CASING SIZE = 7.757 IN
NEAR TCHK = 47085.0 CPS
NEUTRON ON TIME = 10.0 S

SFT TYPE = 178
FAR TCHK = 21091.0 CPS
NUMBER OF CYCLES SUMMED = 11

FLOW DETECTED
FLOW VELOCITY = 17.4 FT / MINUTE
FLOW RATE = -1.0 BWPD

PEAK BACKGROUND SIGNAL = 134.4 +/- .8 CPS / CYCLE
PEAK STATIONARY SIGNAL = 105.7 +/- 5.4 CPS / CYCLE
TOTAL FLOWING SIGNAL = 258.8 +/- 30.2 COUNTS / CYCLE

FLOW LOG DATA PRESENTATION
FIGURE 5

Pennwood

On April 7, 1988, personnel from Pennwood tested their 1-11/16 inch neutron activation tool at the test facility. The tool was unable to detect any of the flow rates, and the test was aborted. (Test No. 18).

Conclusions

Presently, there are only two service companies with the capability of accurately detecting flow behind pipe using the oxygen activation technique.

Both the Hydrolog and the Flow Log successfully detected flows behind casing in the Leak Test Well in the upflow and downflow modes. The tools are capable of detecting low flows on the order of 2 feet per minute and high flows on the order of 120 feet per minute. Table 1 provides a summary of the test results at the Mechanical Integrity Testing and Training Facility for the Hydrolog and Flow Log.

The tool diameter restricts its use in small diameter wells to those with casing with an inside diameter or restriction that is greater than 1-11/16". On the other end of the scale, the tool may not produce reliable data in casing with a diameter greater than 13-3/8 ".

Atlas Wireline personnel indicate that a positive number for the Flow Indicator SS that is greater than 3-4 times the standard deviation indicates fluid flow. A statistical analysis, conducted at the Robert S. Kerr Environmental Research Laboratory (RSKERL), of data from a number of wells indicates that a Flow Indicator LS reading of one or greater is a positive indicator of flow.

In addition to the research conducted at the Mechanical Integrity Testing and Training Facility, both Atlas Wireline and Schlumberger have conducted tests of their tools in other test facilities. Also, between October 1, 1988, and February 28, 1991, approximately 186 oxygen activation logs have been run in commercial wells throughout the country. Twelve of these logs have been reviewed by the authors, at the request of either the operator, regional or state personnel. A review of these logs has supported the conclusion that this is an excellent logging technique for detecting flow in or behind pipe.

TABLE 1

FLOW BEHIND PIPE

(X) - ATLAS WIRELINE
X - SCHLUMBERGER

FLOW(GPM)	*VELOCITY('/MIN)	FLOW DETECTED YES	NO
20	122	(X)X	
15	92	(X)	
10	61	X	
8	49	(X)	
7.8	47	(X)	
6.1	37	(X)	
6	36	(X)	
4	24	(X)	
3	18	(X)X	
2.4	14	X	
2	12	(X)	
1.7	10	(X)	
1.5	9	(X)	
1.3	8	X	
1.0	6	(X)X	
0.9	5.5	(X)	
0.79	4.8	(X)	
0.75	4.5	(X)	
0.53	3.2	X	
0.5	3	(X)X	
0.35	2	X	
0.25	1.5	(X)	
0.23	1.4	X	
0.22	1.3	X	
0.105	0.6		(X)
0.0023	0.0001		X

*Velocity calculated for 2-3/8 inch tubing

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APPENDIX

Nuclear Activation Technique for Detecting Flow Behind Casing

Introduction

On January 23 and 24, 1987, personnel from the Robert S. Kerr Environmental Research Laboratory (RSKERL) and Dresser Atlas conducted a series of tests for determining flow behind pipe using two neutron activation tools.

The purpose of the tests was to determine if flow of water at various rates could be detected behind pipe using the data presented by a pulsed neutron lifetime logging system (PDK-100), and a Cyclic Activation Tool.

Tools to be Tested

Two tools were tested during the two-day period:

- A 1-11/16 inch diameter PDK-100 Tool; and
- A 3-5/8 inch diameter Cyclic Activation Tool.

The operation of both tools is based on a nuclear activation technique in which flowing water is irradiated with neutrons emitted by a logging sonde. These neutrons interact with oxygen nuclei in the water to produce nitrogen-16. ^{16}N decays with a half-life of 7.13 seconds, emitting gamma radiation. The flow is then computed from the energy and intensity response of two gamma ray detectors mounted in the logging sonde.

Test Well Conditions

The tests were developed in four phases, the first three using the PDK-100 Tool and the last using the Cyclic Activation Tool.

the attached diagram, Neutron Activation Tool Liquid Flow Test - Phase I, indicates the configuration of the Leak Test Well for the initial test. In this configuration, water was pumped down the tubing/casing annulus into the injection zone with the PDK-100 Tool held stationary in the injection tubing. This condition represented flow in the free-pipe condition, i.e., with no cement behind the pipe (2-3/8 inch tubing in this case). A valve at the surface on the outside tubing was closed so that circulation was not possible up that tubing.

The second diagram, Neutron Activation Tool Liquid Flow Test - Phase II, indicates the well configuration for the second test, which was designed to simulate upward flow in a channel in cement. Water, pumped down the tubing/casing annulus, moves through a 1/4 inch hole in the 5-1/2 inch casing at 1,070 feet and up the outside tubing. The section of the well between 1,070 and 950 feet has cement behind the 5-1/2 inch casing and thus around the outside tubing. The tubing in that area represents, to some degree, a channel in the cement.

The third diagram, Neutron Activation Tool Liquid Flow Test - Phase III, indicates the well configuration for the third test, which was designed to simulate downward flow in a channel in cement. Water, pumped down the outside tubing, moves through the 1/4 inch hole in the 5-1/2 inch casing at 1,070 feet and up the 5-1/2 inch casing to the surface.

The fourth diagram, Neutron Activation Tool Liquid Flow Test - Phase IV, indicates the well configuration for the final test, which was designed to simulate downward flow in a channel in cement using the larger Cyclic Activation Tool. Water, pumped down the outside tubing, flows into the 5-1/2 inch casing through the 1/4 inch hole and out through perforations into the injection interval from 1,120 to 1,1230 feet.

Test - Phase I

The PDK-100 Tool was oriented with the two detectors located below the neutron generator so that downward flow could be detected. With the tool positioned at 300 feet inside the injection tubing, data was obtained under conditions of no flow and flow of 8, 4, and 1 gallon per minute (gpm). Two replications of these flow rates were conducted. Flow was detected by the tool in all instances.

Test - Phase II

The PDK-100 Tool was oriented with the two detectors located above the neutron generator to determine if flow up the outside tubing could be detected. With the tool located at 600 feet inside the injection tubing, data was obtained under no flow, and 8 gpm flow conditions. Flow up the outside tubing was not detected.

Test - Phase III

The PDK-100 Tool was positioned at 600 feet in the injection tubing in the upflow mode. Water was pumped down the outside tubing and up the 5-1/2 inch casing at three different rates (8, 4, and 1 gpm.). Upward flow was detected for all three flow rates.

The tool was repositioned in the injection tubing in the downflow mode and the tests repeated. Flow down the outside tubing was not detected.

Test - Phase IV

This test was conducted with the Cyclic Activation Tool. With the tool positioned for detecting downflow, water was pumped down the outside tubing, through the 1/4 inch hole in the 5-1/2 inch casing and out the perforations into the injection zone. Flow rates for this test were 7.8, 7.1, and .79 gpm. All three flow rates were detected by the tool and flow velocities were calculated from the data collected by the tool.

Conclusions

The PDK-100 Tool detected all three flow rates when flow was immediately adjacent to the tool. However, the tool did not detect any flows when the flow was in the outside tubing.

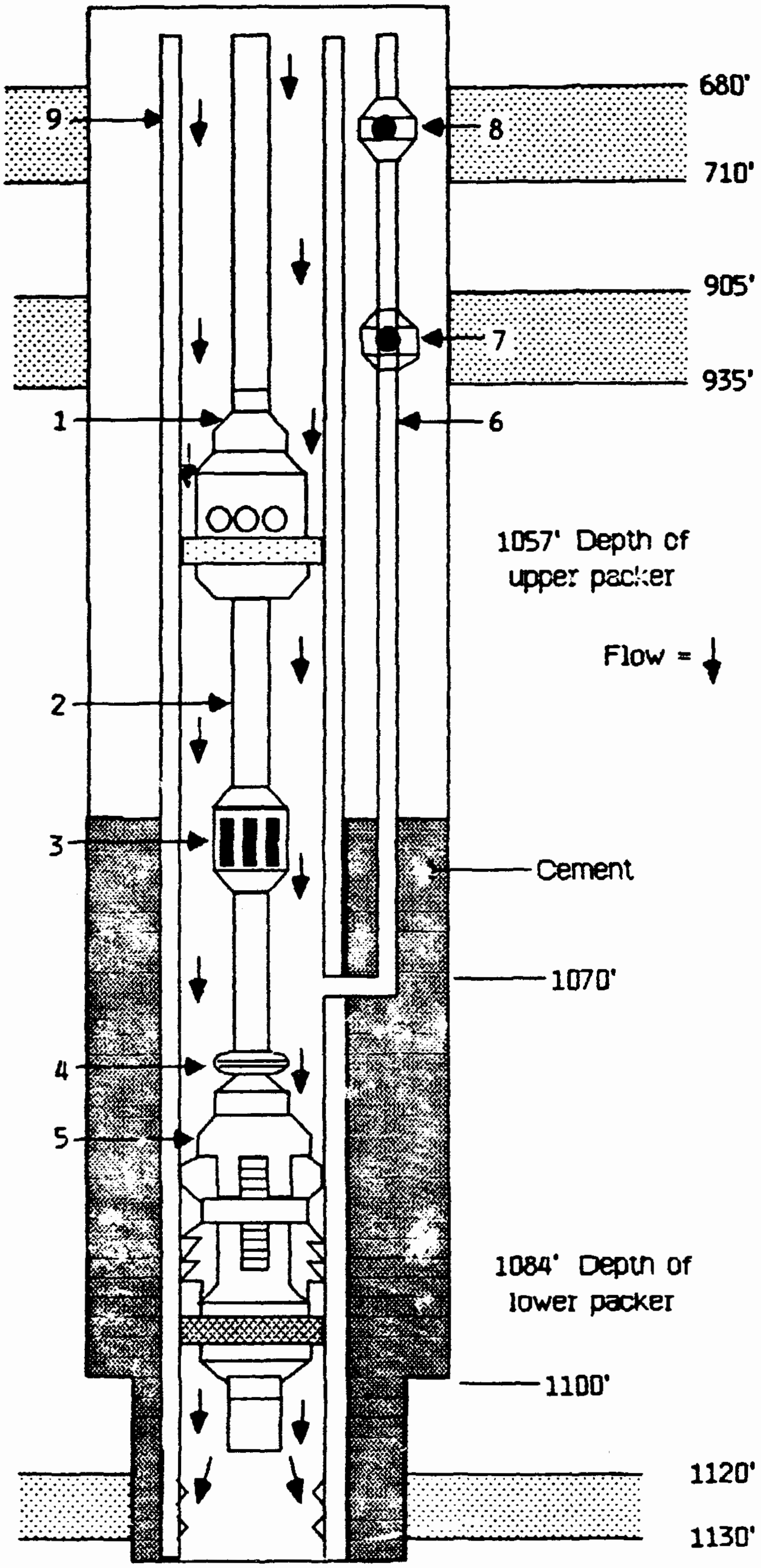
The Cyclic Activation Tool detected all three flow rates in the outside tubing. In addition, the computed associated with the tool has the capability to compute the velocity of flow for each flow rate.

Recommendations

Additional work should be done to increase the sensitivity of the PDK-100 Tool. It should be noted that since the tests were conducted, Dresser Atlas personnel have made some modifications to the tool and have been able to detect flow in outside tubing in a test facility constructed very similarly to the Leak Test Well. The modified tool will be retested at the RSKERL Test Facility as soon as it can be arranged. In the meantime, Dresser Atlas personnel will run the tool in several wells owned by Mobil, and will make those results available to RSKERL personnel.

The Cyclic Activation Tool should be tested under "real well" conditions to verify the results seen during the tests on the Leak Test Well.

The capability of these tools to detect flow behind pipe could be a significant breakthrough for mechanical integrity testing. Especially the PDK-100 Tool which can be run in tubing, thus reducing workover costs.



Injection Zones

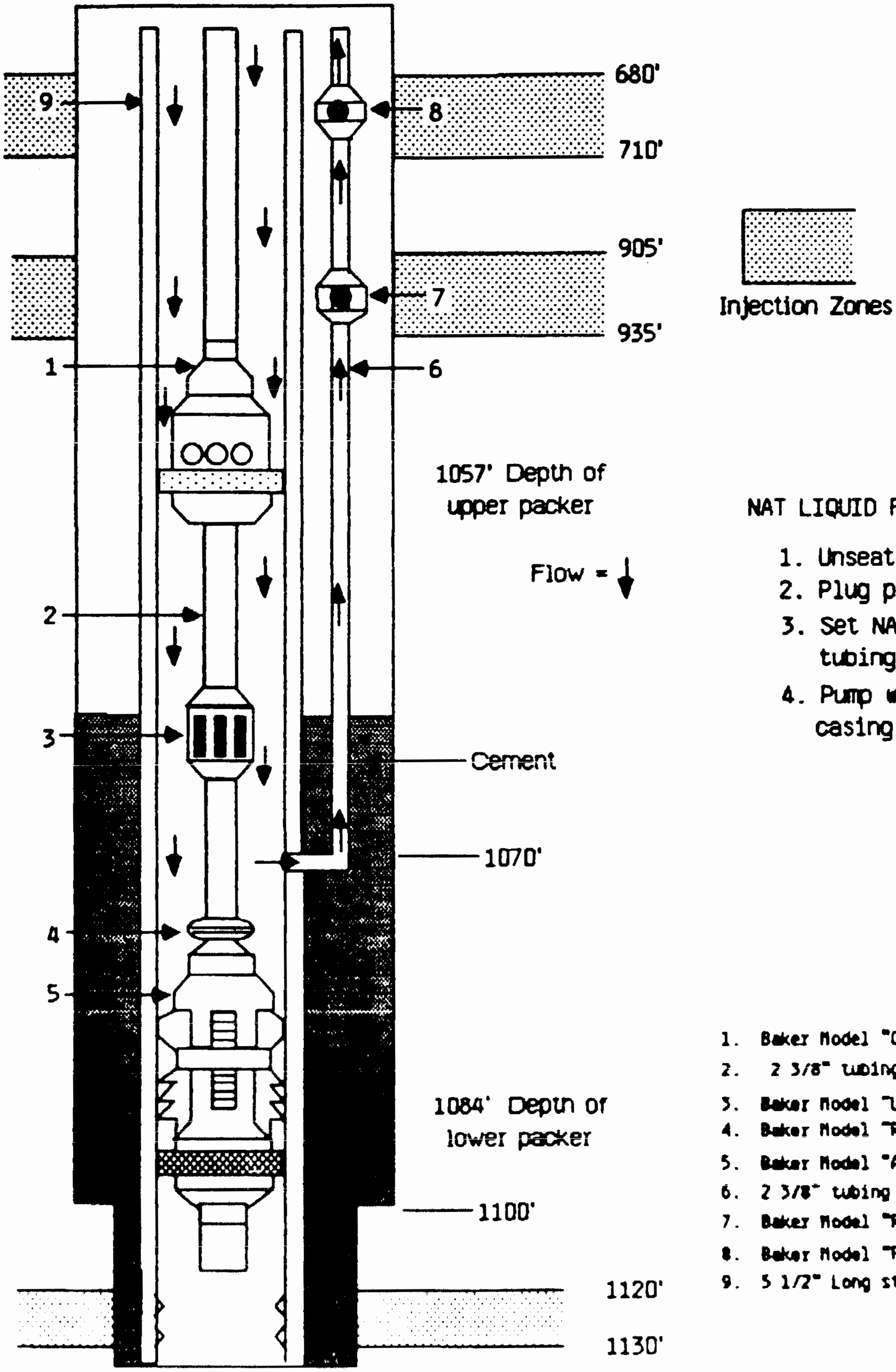
NAT LIQUID FLOW TEST - PHASE I

1. Unseat packers #1 & #5
2. Set NAT tool in 2 3/8" tubing at variable depths
3. Pump water down 5 1/2" casing at 3 different rates

1. Baker Model "C-1" Tandem Tension Packer
2. 2 3/8" tubing
3. Baker Model "L" Sliding Sleeve
4. Baker Model "R" Profile Nipple
5. Baker Model "Ad-1" Tension Packer
6. 2 3/8" tubing
7. Baker Model "R" Profile Nipple
8. Baker Model "F" Profile Nipple
9. 5 1/2" Long string

LEAK TEST WELL

NEUTRON ACTIVATION TOOL LIQUID FLOW TEST - PHASE I



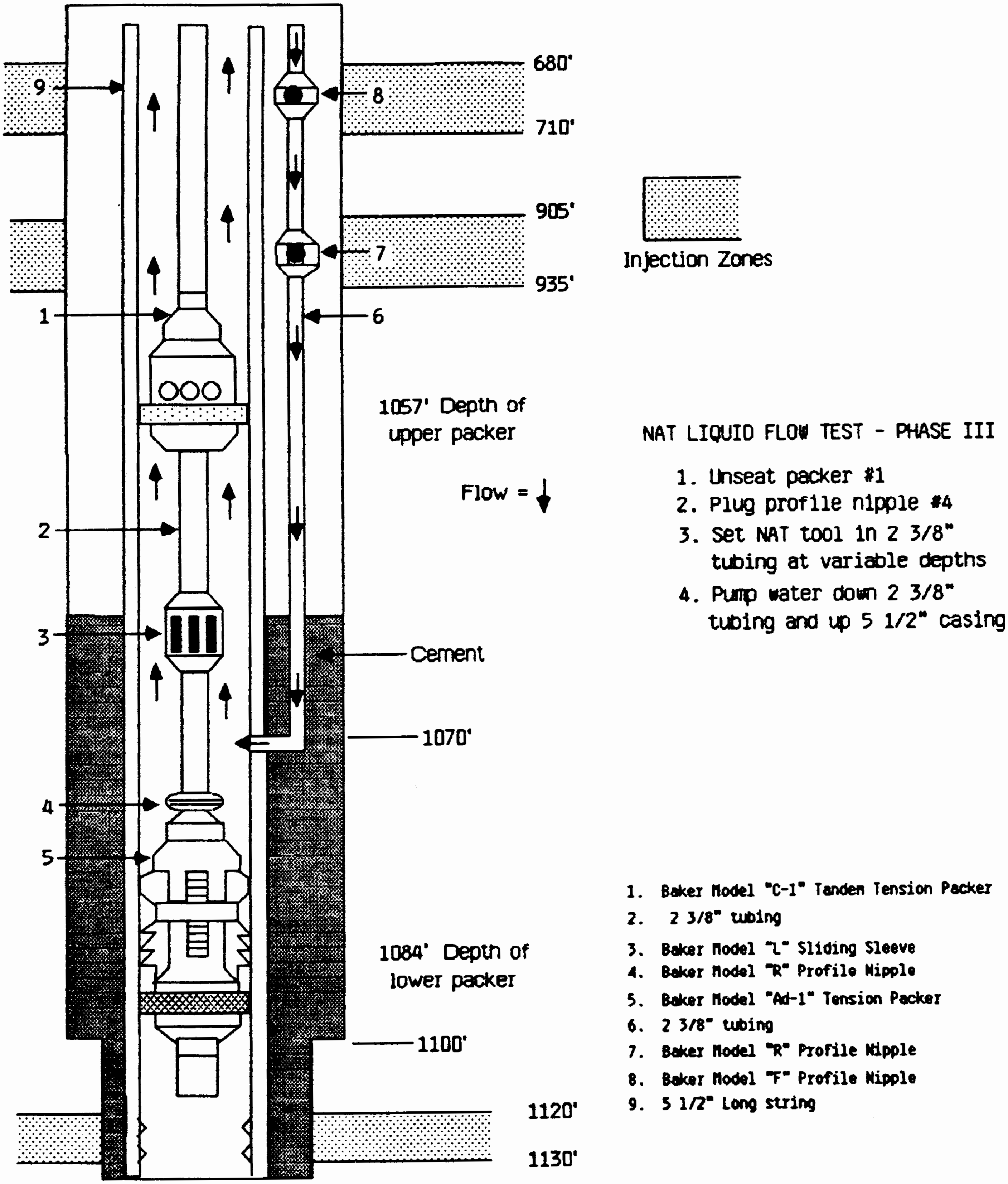
NAT LIQUID FLOW TEST - PHASE II

1. Unseat packer #1
2. Plug profile nipple #4
3. Set NAT tool in 2 3/8" tubing at variable depths
4. Pump water down 5 1/2" casing and up 2 3/8" tubing

1. Baker Model "C-1" Tandem Tension Packer
2. 2 3/8" tubing
3. Baker Model "L" Sliding Sleeve
4. Baker Model "R" Profile Nipple
5. Baker Model "Ad-1" Tension Packer
6. 2 3/8" tubing
7. Baker Model "R" Profile Nipple
8. Baker Model "F" Profile Nipple
9. 5 1/2" Long string

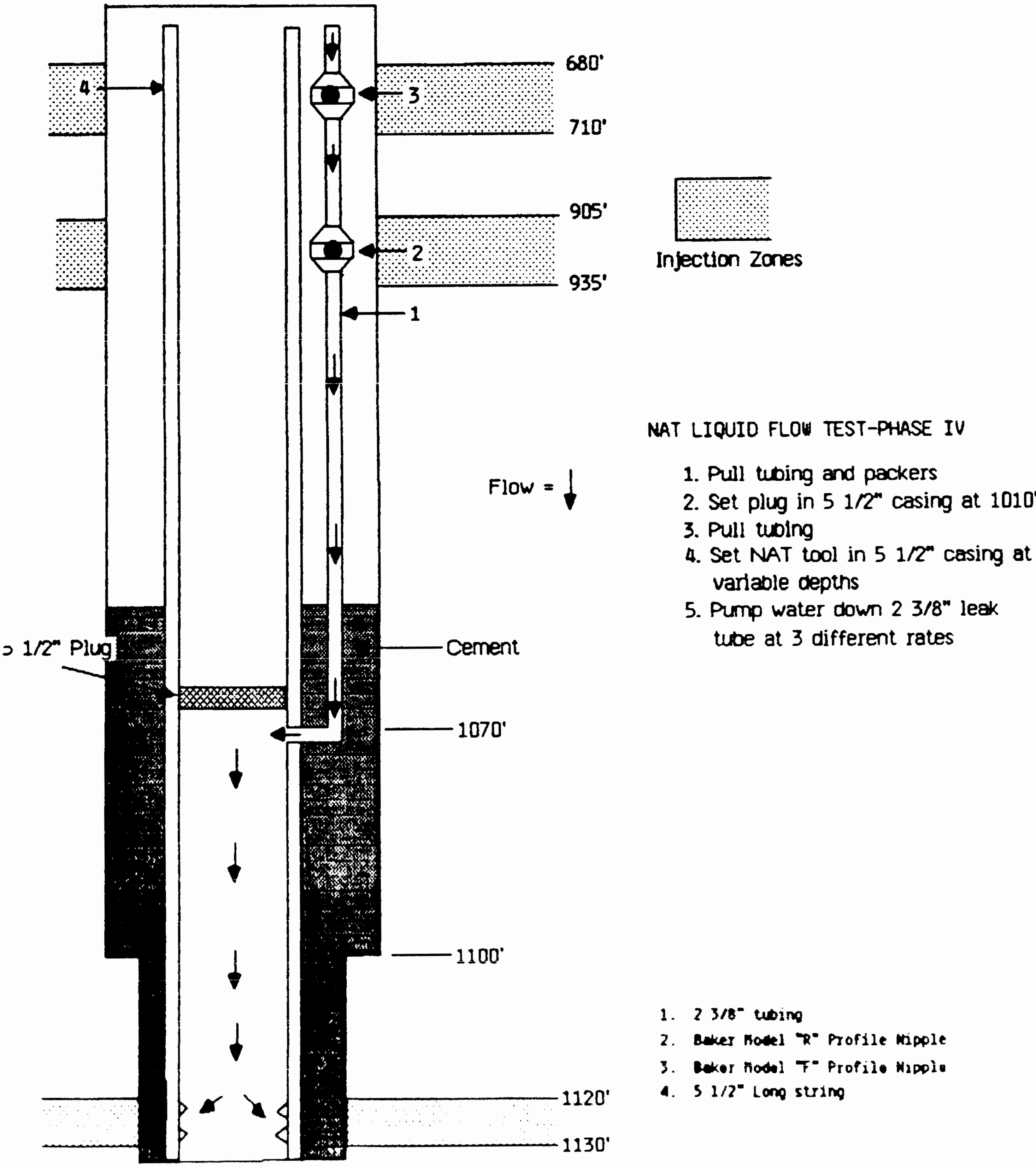
LEAK TEST WELL

NEUTRON ACTIVATION TOOL LIQUID FLOW TEST - PHASE II



LEAK TEST WELL

NEUTRON ACTIVATION TOOL LIQUID FLOW TEST - PHASE III



LEAK TEST WELL

NEUTRON ACTIVATION TOOL LIQUID FLOW TEST-PHASE IV

Nuclear Activation Technique for Detecting Flow Behind Casing

Introduction

On April 8, 1987, personnel from the Robert S. Kerr Environmental Research Laboratory (RSKERL) and Dresser Atlas conducted a series of tests to determine flow behind pipe using the PDK-100 Flow Tool.

The purpose of the tests was to determine if flow of water at various rates could be detected behind pipe from data presented by a pulsed neutron lifetime logging system (PDK-100). The 1-11/16 inch diameter tool has been tested on January 23 and 24, 1987, and could detect flow immediately behind the injection tubing but could not detect flow in the outside tubing in the Leak Test Well. The tool has been modified for the new series of tests.

Test Well Configuration

Figure 1 indicates the configuration of the Leak Test Well for the test. Both packers were set, the sliding sleeve was open and injection was maintained down the outside tubing a varying injection rates.

Tool Testing

For each flow rate the PDK-100 was held stationary at a depth of 300 feet in the injection tubing. After taking two background checks, flow was initiated down the outside tubing at a rate of 8 gallons per minute (gpm), 6 gpm, 4 gpm, 2 gpm, and .105 gpm. The results of the tests for detecting flow:

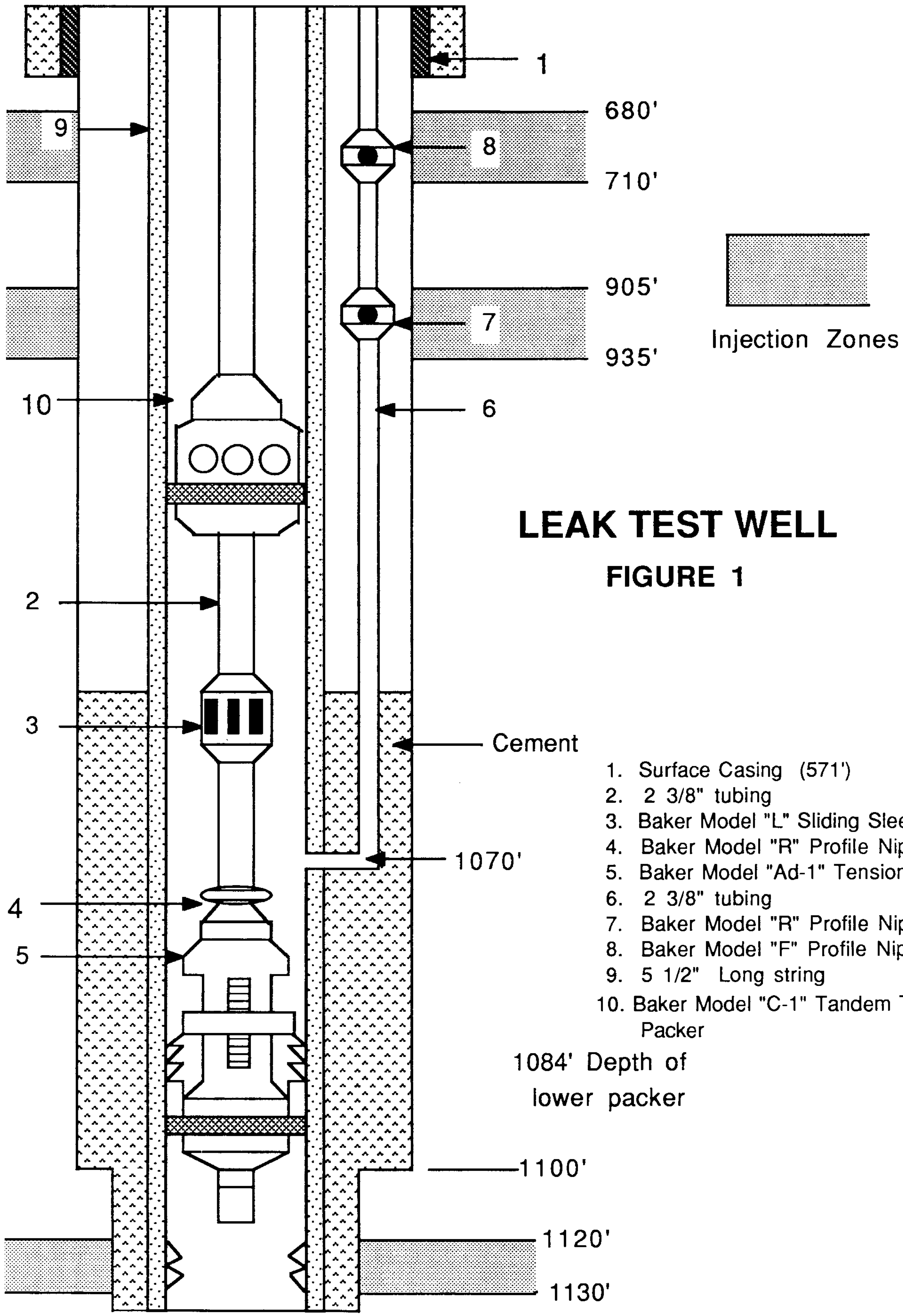
Flow Rate	Flow Detected
8 gpm	yes
6 gpm	yes
4 gpm	yes
2 gpm	yes
.105 gpm	no

Readings were taken three (3) times at each flow rate. An example of the printout for the tool is attached.

Conclusion

The PDK-100 was able to detect four of the five flow rates with no problem. Movement was detected for the .105 gpm flow but it was probably the column of water in the injection tubing moving toward static conditions since at this extremely low flow the fluid level in the tubing could not be maintained.

The capability of this tool to detect flow behind casing looks very promising. The next phase should be field testing under "real well" conditions.



LEAK TEST WELL

FIGURE 1

1. Surface Casing (571')
2. 2 3/8" tubing
3. Baker Model "L" Sliding Sleeve
4. Baker Model "R" Profile Nipple
5. Baker Model "Ad-1" Tension Packer
6. 2 3/8" tubing
7. Baker Model "R" Profile Nipple
8. Baker Model "F" Profile Nipple
9. 5 1/2" Long string
10. Baker Model "C-1" Tandem Tension Packer

OXYGEN ACTIVATION ANALYSIS
ATLAS WIRELINE SERVICES

COMPANY NAME: EAST CENTRAL UNIVERSITY
WELL NAME: LEAK TEST WELL NO. 1
DATE: 08-APR 87
COMMENTS: INJECTING AT .105, 2, 4, 6, & 8 GPM.
RECORDED BY: KOENN WITNESSED BY: THORNHILL, BENEFIELD

DEPTH	: FILE: #	FLOW IND. SS,	LS	: COMMENTS: (VEL. ETC.)
300	: ST1A	.000	.000	: BACKGROUND IN 2 3/8 INCH
300	: ST1B	-.837	.000	
300	: ST2A	7.781	6.578	: FLOW DOWN 2 3/8 INCH 8 GPM
300	: ST2B	9.351	5.596	:
300	: ST2C	6.133	4.684	:
300	: ST3A	8.753	6.057	: FLOW DOWN 2 3/8 6 GPM
300	: ST3B	8.784	6.342	:
300	: ST3C	8.775	5.875	:
300	: ST4A	9.515	6.280	: FLOW DOWN 2 3/8 4 GPM
300	: ST4B	10.485	7.808	:
300	: ST4C	10.801	6.600	
300	:ST5A	127.572	45.562	: FLOW DOWN 2 3/8 2 GPM
300	:ST5B	80.951	21.844	:
300	:ST5C	42.351	10.373	:
300	:ST6A	9.444	.613	: FLOW DOWN 2 3/8 .105 GPM
300	:ST6B	5.856	.539	:
300	:ST6C	1.486	.093	:

Nuclear Activation Technique for Detecting Flow Behind Casing

Introduction

On August 28 and 29, 1987, personnel from the Robert S. Kerr Environmental Research Laboratory (RSKERL), East Central University, EPA Region IV, Atlas Wireline and Shell Western E & P, conducted a series of tests to determine flow behind pipe using the PDK-100 Pulsed Neutron Logging System.

The purpose of the tests was to determine if flow of water at two different rates could be detected behind pipe in a "real world" well. Shell personnel had agreed to the use of an abandoned 10,600 foot gas well in which a 100+ foot channel had been identified using a radioactive tracer survey.

Test Well Conditions

The well, Little Creek 2-6A, has 5-1/2 inch long string which had been cleaned out to perforations at 4,162 feet. The test was conducted in two stages; with a packer set at 4,000 feet and the PDK-100 located below the packer in the long string, and with the packer set at 4,125 feet and the PDK-100 located with the tubing.

Test Procedure

The first objective was to determine if the previously identified channel was still present behind the casing. This was done with a radioactive tracer survey as follows:

A. Tracer Flolog

1. Rig up Atlas Wireline Services and go into the hole with 1-11/16 inch O.D. dual detector Tracer instrument. Place instrument 5 feet above perforations.

2. With the instrument stationary, start water injection into the perforations at 4,162 feet with the pump truck operating at a rate of 1/2 barrels per minute (BPM).3

3. When the injection rate stabilizes, eject a slug of radioactive iodine-131 into the flow and verify its mode of travel. The material should travel downward past the two radiation detectors and into the perforations. If upward channeling exists, the material should travel up behind the casing within the channel, passing the detectors again, but in reverse order.

4. After channeling has been detected and the radioactive material has moved past the instrument, move the instrument upward rapidly, catching and recording the travel path of the radioactive material. (The instrument is moved up and down past the slug repeatedly to accomplish this).

5. Reposition the FloLog instrument 5 to 10 feet above the perforations and repeat steps 2 through 4 to verify all previous measurements.

6. Stop water injection and remove the Tracer Flolog Instrument from the well.

This procedure established that a channel existed behind the casing from 4,162 feet to about 4,020 feet. Having established this fact, the following procedure was used to test the PDK-100:

1. Configure the tool with the pulsed neutron source beneath the detectors so that upward flow may be identified.

2. Go into the hole and position the tool 5 to 10 feet above the perforations but below the tubing and packer.

3. Turn the PDK-100 on and record the no-flow response.

4. Start the water injection at a rate of 1/2 BPM.

5. Turn the PDK-100 on and record the results. Adjust the flow to 1/4 BPM and record the results.

6. Move the PDK-100 to the mid-range of the channel.

7. Turn on and record the results at both 1/2 and 1/4 BPM.

8. Move to the top of the channel and record the results at both flow rates.

9. Move out of the channel area and record the results. If no movement is present, stop the water injection and remove tool from the well.

10. Reset packer at 4,125 feet and rerun surveys with the PDK-100 within the tubing.

11. Rig the wireline unit down and review results of both surveys.

Conclusions

The first series of tests, with the tool below the tubing and packer, included stations at 4,180, 4,150, 4,100 and 4,050 feet. The second series, with the tool located within the tubing, included tests at 4,100, 4,050, 4,000, 3,990, and 3,950 feet.

The PDK-100 detected both flow rates with the tool either in the casing or within the tubing. The top of the channel was determined to be between 4,000 and 4,050 feet. Data summaries from each station are attached.

The PDK-100 has the potential for providing an excellent method for detecting flow behind pipe. However, additional work needs to be done to determine specific applications for the tool.

PROCEDURE FOR OBTAINING CHANNEL INFORMATION

Atlas Wireline Services will run a Tracer FloLog, and PDK-100 (nuclear activation log) in the Little Creek 2-6A well as soon as possible. The Tracer FloLog will be run first. This sequence should display two things:

1) That a channel does exist, and
2) That the PDK-100 is unaffected by the "common" Tracer materials.

It should take approximately 7 hours to conclude both surveys.

The procedures for running these surveys are as follows:

A) Tracer FloLog

This instrument is configured with an Ejector (radioactive I-131 reservoir), CCL and two Gamma ray detectors. The Ejector is positioned above both Gamma ray detectors.

1. Rig up Atlas Wireline Services and go into hole with 1-11/16 inch dual detector Tracer instrument to 5 feet above the perforations.

2. With the instrument stationary, start water injection into the perforations at 4162 ft. with the pump truck at a rate of 1/2 Bbl. per minute. (Adjust the rate if needed).

3. Once the injection rate has stabilized, eject a slug of Radioactive Iodine-131 into the flow stream and verify its mode of travel. (The material should travel downward past the two radiation detectors and into the perforations. If upward channeling exists, the material should also travel up behind the casing within the channel passing the detectors again, but in reverse order).

4. After channeling has been detected and the radioactive (R/A) material has moved past the instrument, move the instrument upwards rapidly, catching and recording its travel path. (The instrument is moved up and down past the R/A slug repeatedly to accomplish this).

5. Reposition the FloLog instrument 5 to 10 feet above the perforations and repeat steps 2 through 4 to verify all previous measurements.

6. Stop water injection and remove the Tracer FloLog instrument from the well concluding this portion of the survey.

B) PDK-100 Log

The PDK-100 is configured with a pulsed neutron source and two radiation detectors. The source is positioned beneath the detectors.

1. Go into the hole approximately 5 to 10 feet above the perforations.

2. Turn the PDK-100 instrument on and record the no flow response.

3. Start the water injection at the rate which manifested the channel with the Tracer FloLog survey (1/2 BPM).

4. Turn the PDK-100 on and record the results. Adjust flow to 1/4 BPM and record results.

5. Move the PDK-100 to the mid-range of the channel measured by the FloLog.

6. Turn on and record the results at both 1/2 and 1/4 BPM.

7. Move to the top of the channel region and record the results.

8. Move out of the channel region and record the results. If no movement is present, stop the water injection and remove the PDK-100 instrument from the well.

9. Rig the Wireline unit down and review the results of both surveys.

10. The above tests were run below the tubing and packer. The packer was reset at 4125 and test were run with the PDK-100 in the tubing.

OXYGEN ACTIVATION ANALYSIS
ATLAS WIRELINE SERVICES

COMPANY NAME: SHELL WESTERN E & P
WELL NAME: LC 2-6A
DATE: 29-AUG-87
COMMENTS: TOOL BELOW TUBING AND PACKER INJ 1/4 AND 1/2 BPM
RECORDED BY: KOENN WITNESSED BY: THORNHILL, BENEFIELD

DEPTH	FILE: #	FLOW IND. SS	LS	COMMENTS: (VEL. ETC.)
4180	ST1A	.000	.000	BACKGROUND TOOL BELOW PERFS
4180	ST1B	.000	.000	
4150	ST2A	47.520	3.928	NO INPUT AT SURFACE
4150	ST2B	73.425	3.208	
4150	ST3A	60.006	21.372	INPUT OF 1/4 BPM
4150	ST3B	57.458	21.694	
4150	ST4A	41.499	20.992	INPUT OF 1/2 BPM :
4150	ST4B	47.310	24.951	
4100	ST5A	21.686	27.430	INPUT OF 1/4 BPM
4100	ST5B	22.469	28.837	
4100	ST6A	11.568	18.420	INPUT OF 1/2 BPM
4100	ST6B	9.240	16.883	
4050	ST7A	72.848	35.987	INPUT OF 1/4 BPM
4050	ST7B	70.042	38.733	
4050	ST8A	68.157	44.486	INPUT OF 1/2 BPM
4050	ST8B	56.128	44.832	
4050	ST8C	52.874	40.887	

LOGGED WELL WITH TOOL BELOW TUBING AND PACKER WHILE 1/4 AND 1/2 BARREL OF WATER WAS BEING INJECTED. FLOW WAS OBSERVED IN A CHANNEL ABOVE PERFORATIONS AT 4162-6163. TOP OF CHANNEL WAS NOT LOGGED

OXYGEN ACTIVATION ANALYSIS
ATLAS WIRELINE SERVICES

COMPANY NAME: SHELL WESTERN E & P
WELL NAME: LC 2-6A
DATE: 30-AUG-87
COMMENTS: TUBING LOWERED TO 4125'.
RECORDED BY: KOENN WITNESSED BY: THORNHILL, BENEFIELD

DEPTH	: FILE: #	FLOW IND. SS	LS	: COMMENTS: (VEL. ETC.)
1000	: ST1A	.000	.000	: DEFAULT HEADER
4100	: ST2A	.000	.000	: NO FLOW
4100	: ST3A	6.202	14.861	: INPUT OF 1/4 BPM
4100	: ST3B	3.565	13.934	:
4100	: ST4A	3.718	13.269	: INPUT OF 1/2 BPM
4100	: ST4B	2.300	10.826	:
4050	:ST5A	21.403	13.604	: INPUT OF 1/4 BPM
4050	:ST5B	19.470	13.943	:
4050	:ST6A	14.894	17.141	: INPUT OF 1/2 BPM
4050	:ST6B	17.490	17.603	: INPUT OF 1/4 BPM
3950	:ST7A	1.024	-.196	: INPUT OF 1/4 BPM ABOVE CHANNEL
3950	:ST7B	27.053	3.796	: INPUT OF 1/4 BPM ABOVE CHANNEL
3950	:ST7C	-11.720	-1.155	: INPUT OF 1/4 BPM ABOVE CHANNEL
3950	:ST7D	-6.366	-.596	: INPUT OF 1/4 BPM ABOVE CHANNEL
3950	:ST8A	8.720	1.646	: NO INPUT
3950	:ST8B	47.808	8.062	:
3950	:ST8C	29.717	5.169	:
4000	ST9A	3.266	.107	: INPUT OF 1/2 BPM ABOVE CHANNEL
4000	ST9B	17.889	1.930	:
3990	ST10A	-9.671	-.969	: INPUT OF 1/2 BPM ABOVE CHANNEL
3990	ST10B	-12.266	-.965	

TUBING WAS LOWERED TO 4125. STATIONS WERE TAKEN IN CHANNEL AND ABOVE CHANNEL. TOP OF CHANNEL WAS DETERMINED TO BE JUST BELOW 3990'. DATA TAKEN WITH THE WELL SHUT IN SHOWS A SMALL FLOW DUE TO FLUID MOVEMENT IN THE TUBING AS THE WELL LOADS UP.

Nuclear Activation Technique for Detecting Flow Behind Casing

Introduction

On November 3, 1987, personnel from the Robert S. Kerr Environmental Research Laboratory (RSKERL) and Atlas Wireline Service conducted a series of tests to determine flow behind pipe using an Oxygen Activation Tool.

The purpose of the tests was to determine if flow could be detected behind pipe in the Leak Test Well and, if possible, the detection limit of the tool.

Test Well Conditions

Figure 1 indicates the configuration of the Leak Test well. A packer was set at 1084' and a profile nipple was open at 700'. Injection was maintained down the injection tubing/long string annulus, out the 1/4" hole in the long string and up the outside tubing.

Tool Test

The test was conducted with the Atlas Wireline 1 11/16 inch diameter oxygen activation tool (Serial No. 24334) located in the 2 3/8 inch injection tubing. Stationary "no flow" background gamma ray count rates were taken for both the long spaced (LS) and short spaced (SS) detectors at depths of 300', 800' and 1,000'.

A background count rate was computed for each depth of investigation by determining the inelastic gamma ray and oxygen count rates for three no-flow measurements at each station. For each no-flow measurement, the ratio of the oxygen count rate to the inelastic count rate was computed, and the average of these ratios was determined. The results of this activity gives a long-space factor and short-space factor that is then multiplied times the measured inelastic long space and inelastic short space count rate, respectively, to compute the proper background.

After determining the background factors for each depth investigated, the tool was moved down the well at speeds of 15 feet per minute and 30 feet per minute to check the velocity calculations. The final part of the test involved injecting water down the tubing/long string annulus at different flow rates and determining what flow could be detected coming up the outside tubing. Flow measurements were taken at depths of 1,000, 800 and 660 feet and the data from these tests are included in the Oxygen Activation Analysis sheets attached to this summary.

Table 1 is a summary of specific data taken at a depth of 1,000 feet. d The determination of interest during this investigation was a flow or no-flow indication. The velocity data are of interest, although not critical to this series of tests.

The criterion for flow indication is that the long space count rate must be greater than 1.0 counts/second after subtracting the background reading. Thus, from Table 1 flows were indicated at stations 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 36, and 37.

As previously stated, the velocity measurements are interesting but are not significant in the use of the tool for determining flow behind pipe at this point in the development of the tool, with one exception, one must determine the sensitivity of the tool, i.e. the slowest velocity the tool can identify as flow. The criteria for a valid velocity measurement are that:

(1) The flow indication signal for the SS must be at least 3 times the error bar;
(2) The flow indication for the LS must be at least 2 times the error bar;
(3) The LS signal must be less than the SS signal; and,
(4) Neither signal can be zero.

If any of these criteria are not met, the velocity should be shown as zero in the data listing. A review of the data sheets from this test indicates that the velocity measurements meet this criteria.

Conclusions

The 1 11/16" Oxygen Activation tool was successful in detecting flow up the outside tubing in each of the tests while injecting at 6/7, 4, 1.5, and .75 gallons per minute. The tool did not detect flow at the .46 or the .32 gpm rates.

The minimum velocity the tool was able to detect during the tests was 3 ft/min. The results of this and other test indicate that the velocity range of the tool in its present configuration is approximately 3 to 100 ft/min.

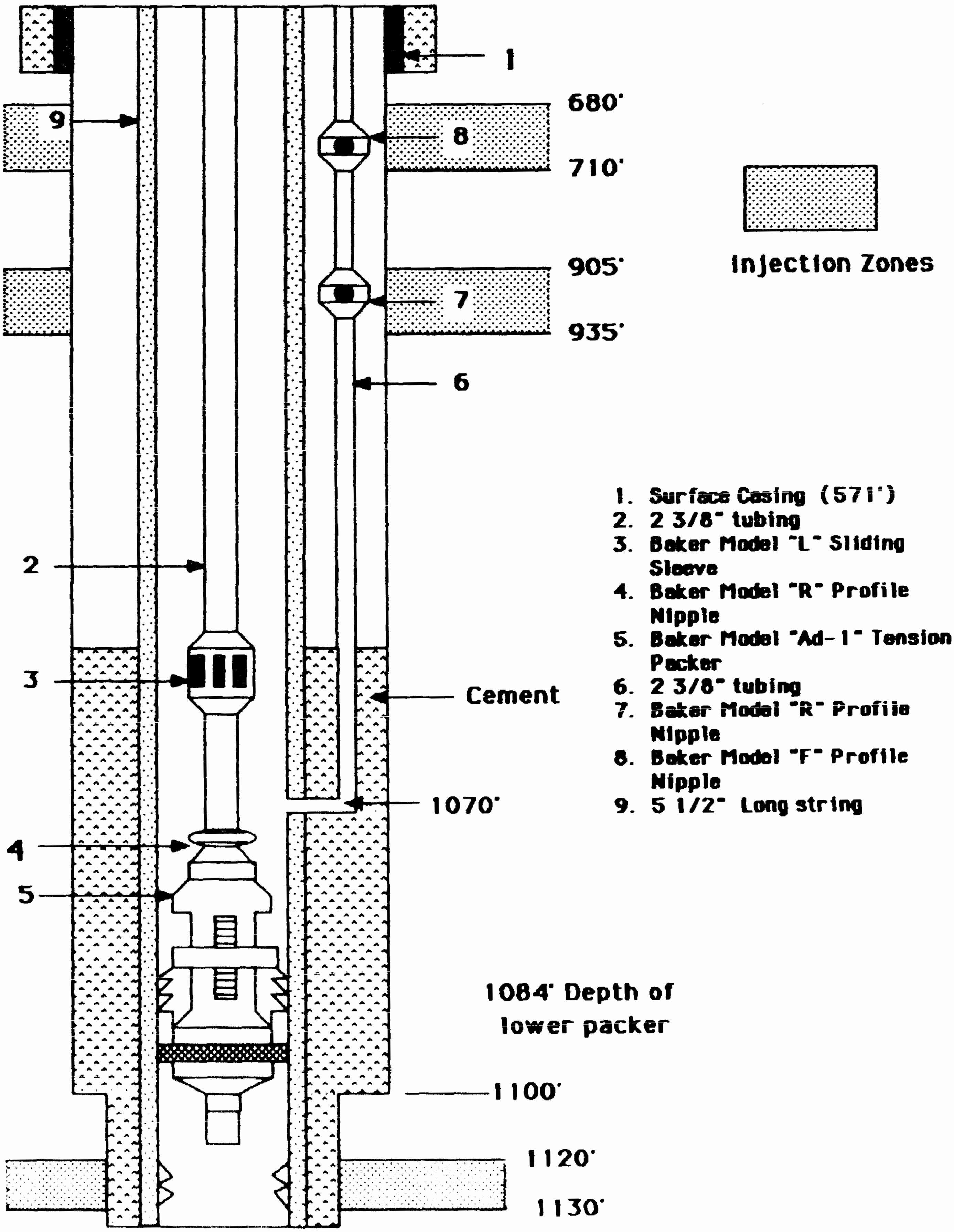


FIGURE 1 LEAK TEST WELL

Table 1
Oxygen Activation Log Data
Leak Test Well
November 3, 1987

DEPTH	STATION	FLOW IND. SS	FLOW IND. LS	VELOCITY	COMMENTS
1000'	11	.35	.19	None	Not injecting
1000'	12	-.01	.16	None	Not injecting
1000'	13	.05	.11	None	Not injecting
1000'	17	5.18	3.02	14ft/min	Injecting 6/7 gpm
1000'	18	3.52	3.35	155.88ft/min	Injecting 6/7 gpm
1000'	19	3.68	2.60	21.88ft/min	Injecting 6/7 gpm
1000'	20	3.17	3.36	0	Injecting 6/7 gpm
1000'	21	5.24	4.32	39.43ft/min	Injecting 4 gpm
1000'	22	6.29	3.73	14.69ft/min	Injecting 4 gpm
1000'	23	4.50	3.91	54.65ft/min	Injecting 4 gpm
1000'	24	5.46	2.88	11.97ft/min	Injecting 1.5 gpm
1000'	25	6.36	3.16	10.94ft/min	Injecting 1.5 gpm
1000'	26	5.59	2.60	9.98ft/min	Injecting 1.5 gpm
1000'	28	.26	.43	0	Injecting .46 gpm
1000'	29	.80	.24	0	Injecting .46 gpm
1000'	30	1.99	.51	5.67ft/min	Injecting .46 gpm
1000'	31	.95	.32	0	Injecting .46 gpm
1000'	32	1.33	.17	0	Injecting .32 gpm
1000'	33	.02	.04	0	Injecting .32 gpm
1000'	34	-.49	.004	0	Injecting .32 gpm
1000'	35	3.47	.99	6.09ft/min	Injecting .75 gpm
1000'	36	3.02	1.19	8.18ft/min	Injecting .75 gpm
1000'	37	2.82	1.05	7.78ft/min	Injecting .75 gpm
1000'	38	.60	.45	0	No injection
1000'	39	-.11	.12	0	No injection
1000'	40	.05	.29	0	No injection

OXYGEN ACTIVATION LOG
ATLAS WIRELINE SERVICE

COMPANY	:	EAST CENTRAL UNIVERSITY/EPA
WELL	:	LEAK TEST WELL NO. 1
FIELD	:	WILDCAT
COUNTY	:	PONTOTOC
STATE	:	OKLAHOMA

LOCATION : NW
SEC 25 TWP 4N RGE 4E

OTHER SERVICES
NONE

PERMANENT DATUM	GL	ELEV. 1049.5	KB	1054.5
LOGGING MEASURED FROM	KB	5 FT. ABOVE P.D.		
DRILLING MEASURED FROM	KB		GL	1049,5

DATE	:	11-3-87
RUN	:	ONE
SERVICED ORDER	:	
DEPTH-DRILLER	:	1084'
DEPTH-LOGGER	:	1000'
BOTTOM LOGGED INTERVAL	:	1000'
TOP LOGGED INTERVAL	:	300'
TYPE FLUID IN HOLE	:	FRESH WATER
SALINITY PPM CL	:	NA
DENSITY LB/GAL.	:	NA
LEVEL	:	FULL
MAX. REC. TEMP. DEG. F	:	NA
OPR. RIG TIME	:	7.0 HRS.
EQUIP. NO./LOC.	:	HL 6340 HOUSTON
RECORDED BY	:	KOENN/HARVEY
WITNESSED BY	:	BENEFIELD/THORNHILL

BIT SIZE : NA

CASING RECORD				:	TUBING RECORD			
SIZE	WGT.	FROM	TO	:	SIZE	WGT	FROM	TO
13-3/8		SURF	568'	:	2-3/8	6.5	SURF	1,080
5-1/2		SURF	TD	:	2-3/8	6.5	SURF	1,070

EQUIPMENT DATA

RUN	TRIP	TOOL	SERIAL NO.	SERIES NO.	POSITION
1	1	OCT-ACT	24334	2725	FREE
1	1	GR	24334	2725	FREE

COMMENTS:

STATIONARY NO FLOW BACKGROUND LEVELS TAKEN AT 300, 800 AND 1000'. INJECTION RATES TAKEN AT 1000 TO DETERMINE THE LOW FLOW LIMIT OF THE INSTRUMENTATION. MEASUREMENT AT 660 IS IN LIMESTONE FORMATION. INELASTIC DATA FROM 300', 800' AND 1000' WAS AVERAGED AND USED TO BACKGROND CORRECT THE DATA.

PAGE NO 1

OXYGEN ACTIVATION ANALYSIS

ATLAS WIRELINE SERVICE

COMPANY NAME : EAST CENTRAL UNIVERSITY E.P.A.
WELL NAME : LEAK TEST WELL NO. 1
DATE : 11-3-1987
COMMENTS : TUBING FLOW

DEPTH:FILE: #		FLOW IND. SS.	LS	: COMMENTS (VEL. ETC.)
300	:ST1	.38	.06	:BACKGROUND NO INJ
300	:ST1A	.39	.07	:BACKGROUND NO INJ
300	:ST1B	.04	-.005	:BACKGROUND NO INJ
300+	:ST2	1113	697	:LOGGING DOWN AT 15 FT/MIN VEL 16.4
300+	:ST2A	1177	701	:LOGGING DOWN AT 15 FT/MIN VEL 15.0
300+	:ST2B	949	733	:LOGGING DOWN AT 30 FT/MIN VEL 30.6
300+	:ST2C	905	709	:LOGGING DOWN AT 30 FT/MIN VEL 31.4
800	:ST3	1.0	.06	:BACKGROUND NO INJ.
800	:ST3A	-.73	-.08	:BACKGROUND NO INJ
800	:ST3B	.27	.13	:BACKGROUND NO INJ
1000	:ST4	.35	.19	:BACKGROUND NO INJ
1000	:ST4A	-.006	.16	:BACKGROUND NO INJ
1000	:ST4B	.05	.11	:BACKGROUND NO INJ
1000	:ST5B	5.2	3.0	:INJ 6-7 GAL/MIN VEL 14.2
1000	:ST5C	3.5	3.3	:INJ 6-7 GAL/MIN VEL 156
1000	:ST5D	3.7	2.9	:INJ 6-7 GAL/MIN VEL 21.9
1000	:ST5E	3.2	3.4	:INJ 6-7 GAL/MIN VEL 0
1000	:ST5F	5.2	4.3	:INJ 4 GAL/MIN VEL 39.4
1000	:ST5G	6.3	3.7	:INJ 4 GAL/MIN VEL 14.7
1000	:ST5H	4.5	3.9	:INJ 4 GAL/MIN VEL 54.6

PAGE NO 2

1000:ST5I	5.5	2.9	:INJ 1.5 GAL/MIN VEL 12.0
1000:ST5J	6.4	3.2	:INJ 1.5 GAL/MIN VEL 10.9
1000:ST5K	5.6	2.6	:INJ 1.5 GAL/MIN VEL 10.0
1000:ST5M	.26	.43	:INJ .46 GAL/MIN VEL 0
1000:ST5N	.80	.24	:INJ .46 GAL/MIN VEL 0
1000:ST5O	1.99	.51	:INJ .46 GAL/MIN VEL 5.7
1000:ST5P	.95	.32	:INJ .46 GAL/MIN VEL 0
1000:ST5Q	1.33	.17	:INJ .32 GAL/MIN VEL 0
1000:ST5R	.02	.04	:INJ .32 GAL/MIN VEL 0
1000:ST5S	-.5	.004	:INJ .32 GAL/MIN VEL 0
1000:ST5T	3.5	1.0	:INJ .75 GAL/MIN VEL 6.1
1000:ST5U	3.0	1.9	:INJ .75 GAL/MIN VEL 8.2
1000:ST5V	2.8	1.1	:INJ .75 GAL/MIN VEL 7.8
1000:ST5W	.60	.45	:NO INJ VEL 0
1000:ST5X	0.11	.13	:NO INJ VEL 0
1000:ST5Y	0.05	.29	:NO INJ VEL 0
800 :ST6	3.2	1.3	:INJ .75 GAL/MIN VEL 8.3
800 :ST6A	2.7	1.4	:INJ .75 GAL/MIN VEL 11.5
800 :ST6B	2,9	1.4	:INJ .75 GAL/MIN VEL 10.9
800 :ST6C	6.0	3.1	:INJ 1.5 GAL/MIN VEL 11.4
800 :ST6D	6.1	3.3	:INJ 1.5 GAL/MIN VEL 12.4
800 :ST6E	6.6	3.0	:INJ 1.5 GAL/MIN VEL 6.8
660 :ST7	.008	.18	:LIMESTONE NO INJ VEL 0
660 :ST7A	.886	.24	:LIMESTONE NO INJ VEL 0

Nuclear Activation Technique for Detecting Flow Behind Pipe

Introduction

On April 7, 1988, personnel from the Robert S. Kerr Environmental Research Laboratory (RSKERL) and Penwood conducted a series of tests to determine flow behind pipe using a 1-11/16 inch neutron activation tool from Penwood.

The purpose of the tests was to determine if flow of water at various rates could be detected behind pipe from data presented by a pulsed neutron logging system.

Test Well Configuration

Figure 1 indicates the configuration of the Leak Test Well for the test.

Tool Testing

For each flow rate the tool was held stationary at depths of 850, 935 and 1,065 feet in the injection tubing. Injection was maintained down the injection tubing/casing annulus and up the outside tubing at rates of 5, 4, 3 and 2 gallons per minute (gpm). The results of the tests for detecting flow:

Flow Rate	Flow Detected
5 gpm	No
4 gpm	No
3 gpm	No
2 gpm	No

The results indicate that the tool could not detect flow coming up the outside tubing. The test was terminated at 12:28 p.m.

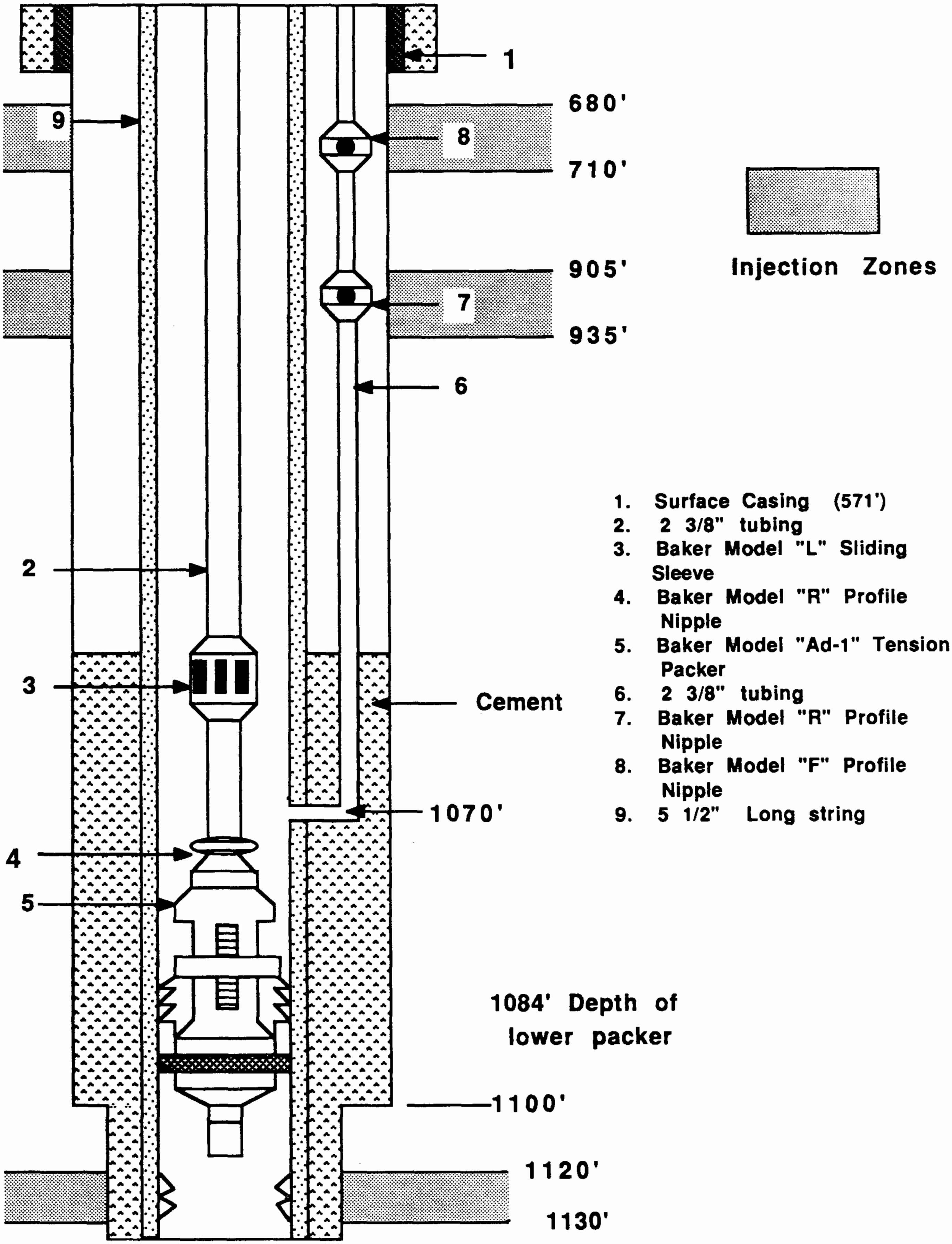


FIGURE 1 LEAK TEST WELL

Nuclear Activation Technique for Detecting Flow Behind Casing

Introduction

On September 14, 1988, personnel from the Robert S. Kerr Environmental Research Laboratory (RSKERL) and Atlas Wireline Service conducted a series of tests to determine flow behind pipe using an Oxygen Activation Tool.

The purpose of the tests was to determine if flow could be detected behind pipe in the Leak Test Well, both in 2 3/8 inch tubing and in a channel in the mud system, and, if possible, the detection limit of the tool.

Test Well Conditions

Figure 1 indicates the configuration of the Leak Test well. A packer was set at 1084' and a profile nipple was open at 700'. Injection was maintained down the injection tubing/long string annulus, out the 1/4" hole in the long string, up the outside tubing, out the tubing through the profile nipple at 700', through a channel in the mud to the surface of the ground.

Tool Test

The test was conducted with the Atlas Wireline 1 11/16 inch diameter oxygen activation tool located in the 2 3/8 inch injection tubing. Stationary "no flow" background gamma ray count rates were taken for both the long spaced (LS) and short spaced (SS) detectors at a depth of 1,075', which was below the injection activity. Readings were taken during injection at depths of 300', 600', and 1,000' to determine both flow/no-flow and velocity.

A background count rate was computed for the 1,075' depth by determining the inelastic gamma ray and oxygen count rates for three no-flow measurements at this station. For each no-flow measurement, the ratio of the oxygen count rate to the inelastic count rate was computed, and the average of these ratios was determined. The results of this activity gives a long-space factor and short-space factor that is then multiplied times the measured inelastic long space and inelastic short space count rate, respectively, to compute the proper background

After determining the background factor, the final part of the test involved injecting water down the tubing/long string annulus at different flow rates and determining what flow could be detected coming up the outside tubing, and through the channel in the mud from 700' to the surface of the ground.

Table 1 is a summary of specific data taken during the test The determination of interest during this investigation was a flow or no-flow indication within both the outside tubing and the channel in the mud. The velocity data are of interest, although not critical to this series of tests.

The criterion for flow indication is that the long space count rate must be greater than 1.0 counts/second after subtracting the background reading. Thus, from Table 1 flows were indicated at stations 2 (1,000'), 4, 5, 6, 7, 8 and 9.

The tests began with a flow of approximately 20 gpm coming from the pump. Stations 2, 4, 6, and 7 were taken at that flow rate with the stations opposite the 2 3/8 inch outside tubing (Stations 2 & 4) and the channel in the mud (Stations 5, 6 and 7). Although flow was detected at each station, a much higher flow indication was seen at stations 5, 6, and 7. Stations 8 and 9 were taken opposite the channel but at a flow rate of about 10 gpm. A reduced flow indication is evident for these stations.

Conclusions

The 1 11/16" Oxygen Activation tool was successful in detecting flow at all stations, although the flow indication was much lower at the stations opposite the 2 3/8 inch outside tubing than those stations opposite the channel in the mud system. This was probably due to the larger size of the mud channel.

Additonal tests should be run with this tool in "real" wells to provide data for evaluating the total capability of the tool for detecting flow behind pipe.

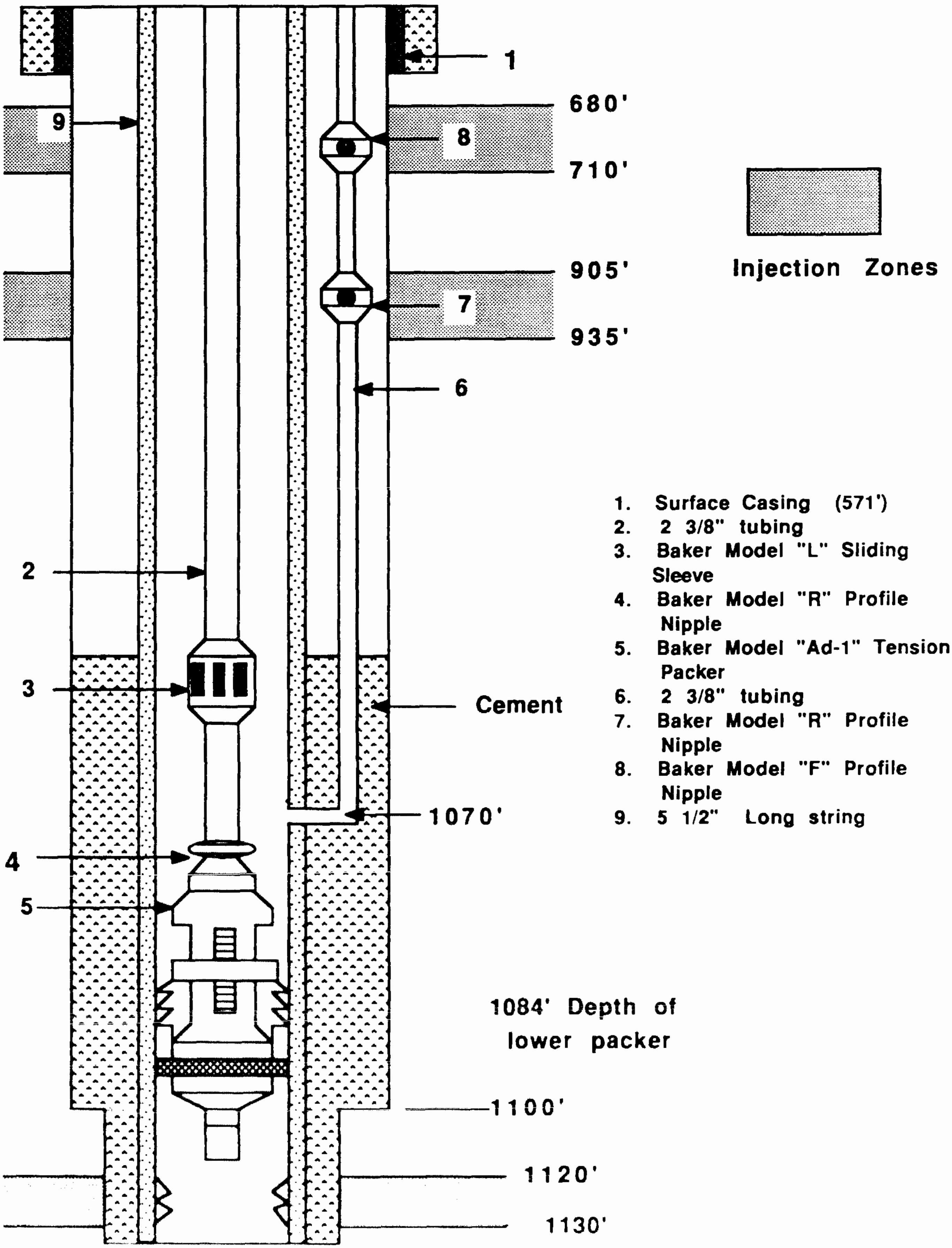


FIGURE 1 LEAK TEST WELL

Table 1
Oxygen Activation Log Data
Leak Test Well
September 14, 1988

DEPTH	STATION	FLOW IND. SS	FLOW IND. LS	VELOCITY	COMMENTS
1075'	0	-.61	.03	None	Below injection
1075'	1	.16	-.01	None	Below injection
1075'	2	.51	-.02	None	Below injection
1000'	2	1.24	1.72	0	Tubing flow
1000'	4	.89	1.68	0	Tubing flow
600'	5	71.70	29.10	8.49ft/min	Channel flow
600'	6	71.17	26.19	7.66ft/min	Channel flow
300'	7	93.87	23.76	5.57ft/min	Channel flow
300'	8	57.01	10.05	4.41ft/min	Channel flow
300'	9	62.19	10.07	4.20ft/min	Channel flow

RSKERL Leak Test Well
Test No. 19

Nuclear Activation Technique for Detecting Flow Behind Pipe

Introduction

On January 20, 1988, personnel from Schlumberger and the Robert S. Kerr Environmental Research Laboratory conducted a test to detect flow behind pipe using the Schlumberger Dual Burst TDT-P Tool.

The purpose of the test was to determine if flow of water at various rates could be detected behind pipe using the data presented by the TDT-P tool.

Test Well Configuration

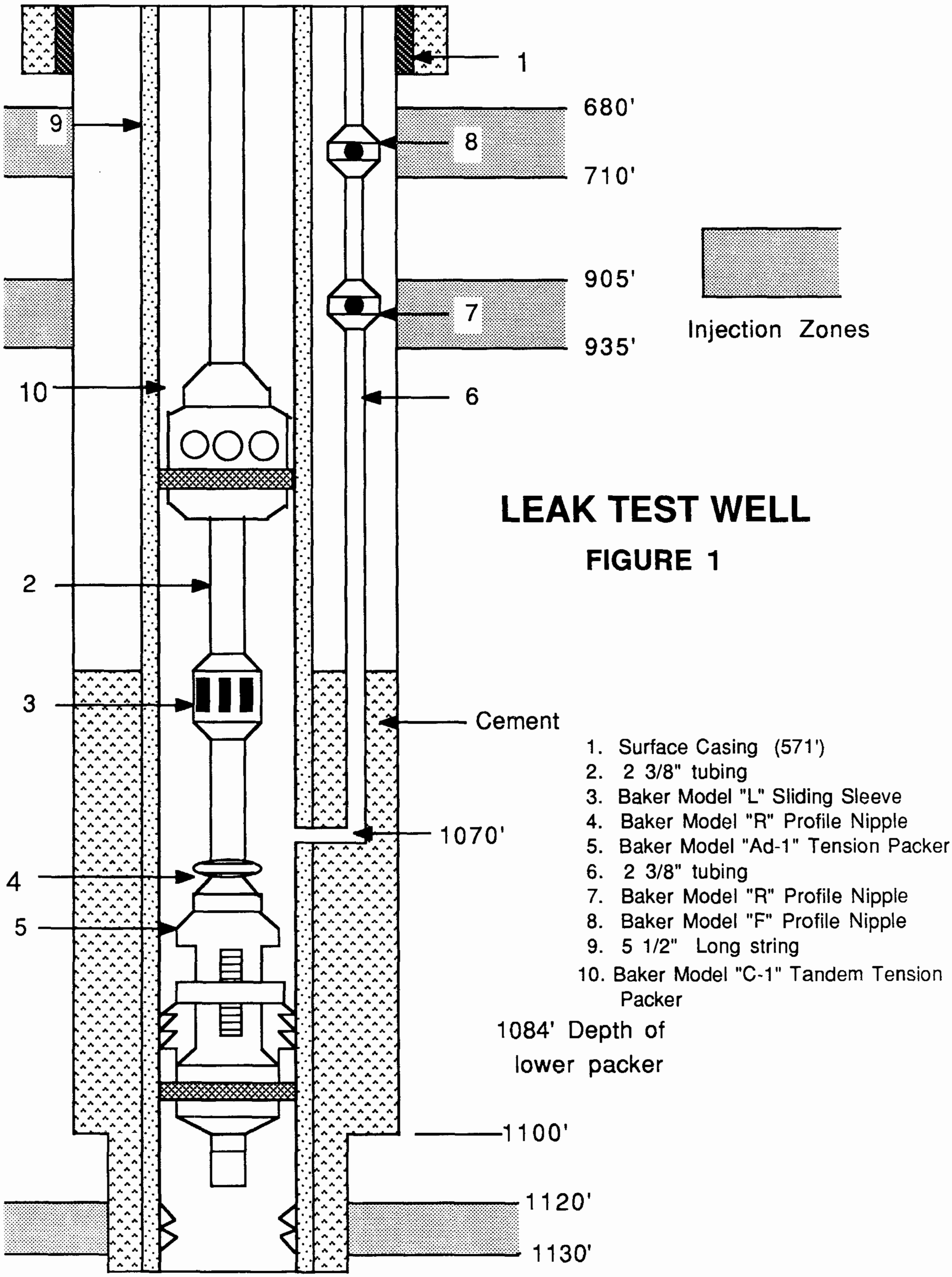
Figure 1 indicates the configuration of the well for the test. Flow could be initiated up or down the outside tubing at varying rates.

Tool Test

The tool was tested with the well flowing approximately 1/2 gallon per minute (gpm) up the outside tubing. A log was prepared indicating background measurement, results of logging up while upward flow was occurring in the outside tubing, results of logging down while upward flow was occurring in the outside tubing and while downward flow was occurring down the outside tubing.

Conclusions

The tool was not able to detect flows under the conditions as given. Schlumberger engineers will reevaluate the problem and return for further tests after tool modifications.



LEAK TEST WELL

FIGURE 1

1. Surface Casing (571')
2. 2 3/8" tubing
3. Baker Model "L" Sliding Sleeve
4. Baker Model "R" Profile Nipple
5. Baker Model "Ad-1" Tension Packer
6. 2 3/8" tubing
7. Baker Model "R" Profile Nipple
8. Baker Model "F" Profile Nipple
9. 5 1/2" Long string
10. Baker Model "C-1" Tandem Tension Packer

Introduction

On May 19, 1989 personnel from RSKERL and ECU began preparation for a test at the Mechanical Integrity Test Facility that would involve the Leak Test Well and two of the monitoring wells. The plan was to inject water at varying pressures into the Leak Test Well with the profile nipple open at 700 feet and determine the horizontal and vertical movement of water through the use of pressure transducers installed in the 700' and the 900' monitoring wells and the Hydrolog Tool.

Water levels were measured in monitoring wells 1 and 2 and transducers were placed in the wells. The taking of background data was begun on May 20, 1989.

On May 22, 1989 personnel from RSKERL, ECU and Atlas Wireline began the test which would result in data to determine the horizontal and vertical movement of injected water in the immediate area of the Leak Test Well.

Test Configuration

The Leak Test Well was configured as shown in Figure 1. The profile nipple was open to the 680-710 foot zone so that water injected down the tubing/long string annulus would move through the hole in the long string at 1070 feet, up the 2 3/8 inch tubing and out the profile nipple at 700 feet. Pressure transducers were placed in monitoring wells 1 and 2 (Figure 2) to detect any horizontal movement of fluid in those zones.

The Hydrolog Tool was placed in the injection tubing at various depths with the detectors set to detect upward flow.

Test

A background count rate was computed at a depth of 750 feet by determining the inelastic gamma ray and oxygen count rate for three no-flow measurements at this depth. For each no-flow measurement, the ratio of the oxygen count rate to the inelastic count rate was computed, and the average of these ratios was

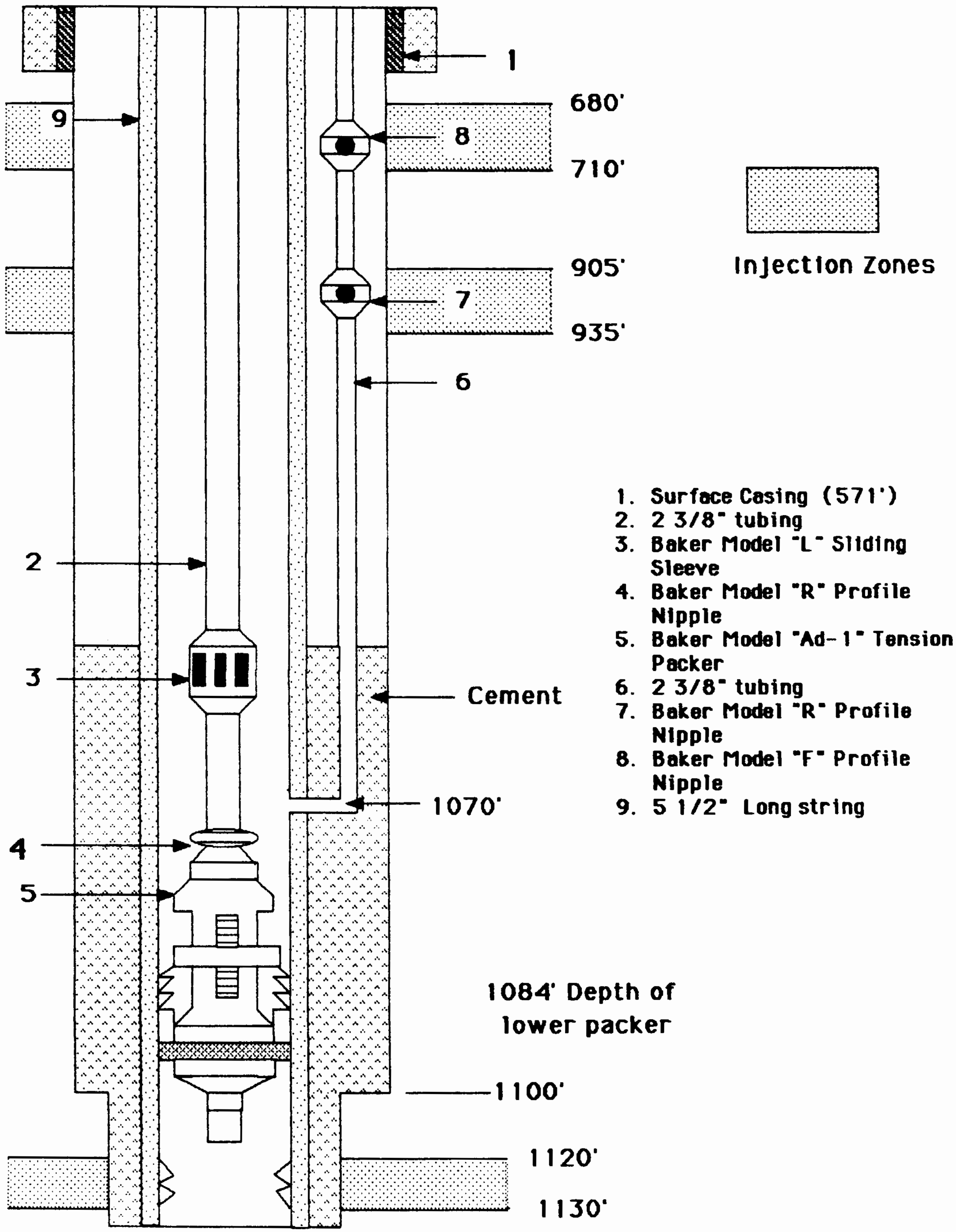


FIGURE 1 LEAK TEST WELL

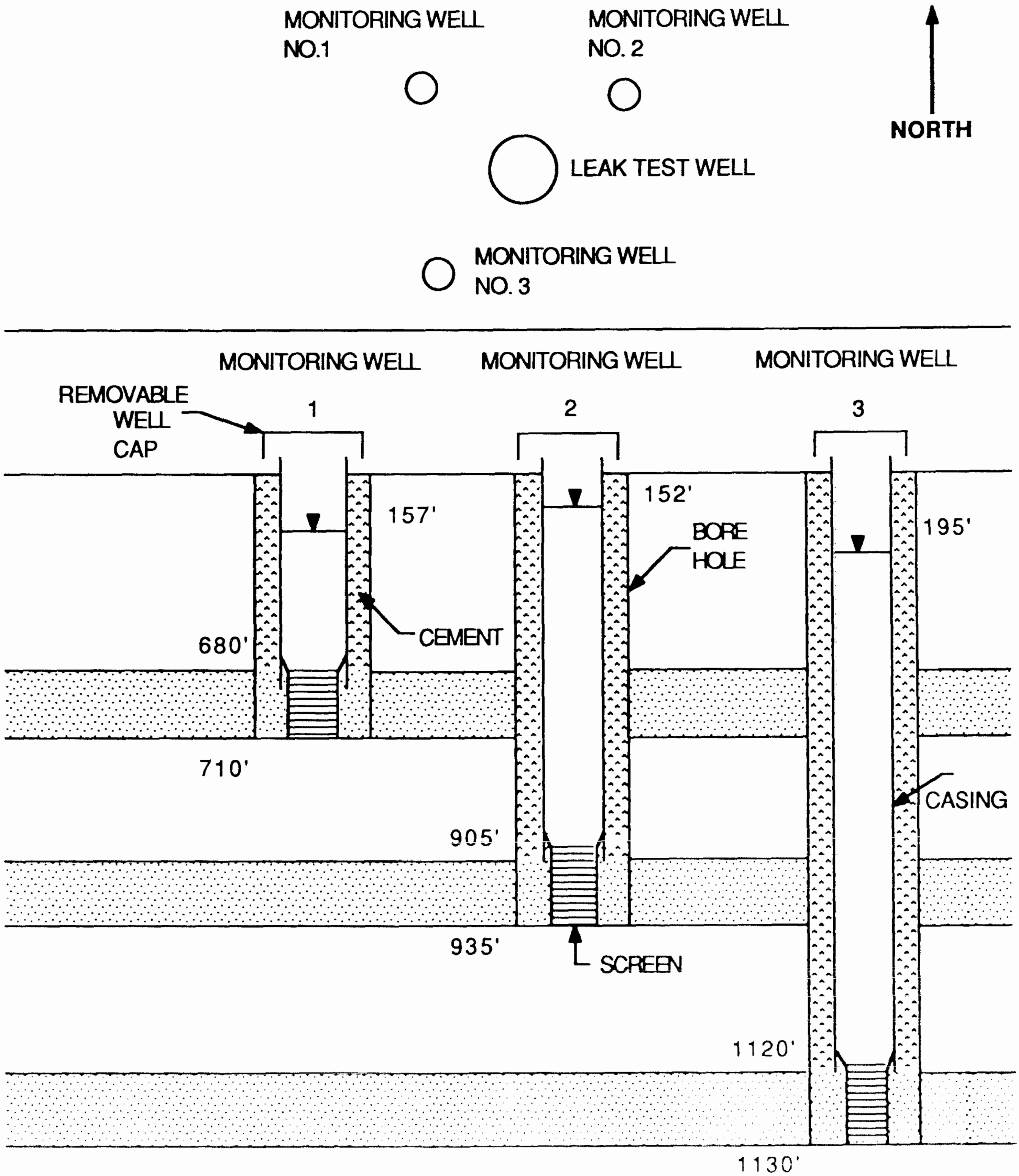


FIGURE 2 MONITORING WELLS

determined. The results of this activity gave a long-space factor and short-space factor that was then multiplied times the measured inelastic long space and inelastic short space count rate, respectively, to compute the proper background.

Vertical Movement

Table 1 indicates the time of each measurement, the depth of the tool detectors, the injection pressure and whether or not upward flow was detected at that depth.

Injection into the Leak Test Well was maintained between 2.5 and 3.7 gallons per minute during the test.

Flow was detected in the 2 3/8 inch outside tubing at both the 50, 100 and 200 psig injection pressure. However, no flow was detected at 660 feet, which is above the zone open to the profile nipple. Thus , it appeared that the water being injected at 50, 100 and 200 psig was going into the zone opposite the profile nipple.

When the injection pressure was increased to 400 psig, with the detectors at 660 feet, flow was detected. The tool was then moved up the well to determine the upper limit of the flow. No flow was found at 580, 450, 430 or 380 feet. However, flow was indicated at 550 feet. The tool was then located at 620, 650 and 660 feet and no flow was detected.

These results may indicate that at the initial change from 200 to 400 psig injection pressure the injected water began moving up the well bore adjacent to the casing, hence the indication of flow at the 660 foot zone.

Horizontal Movement

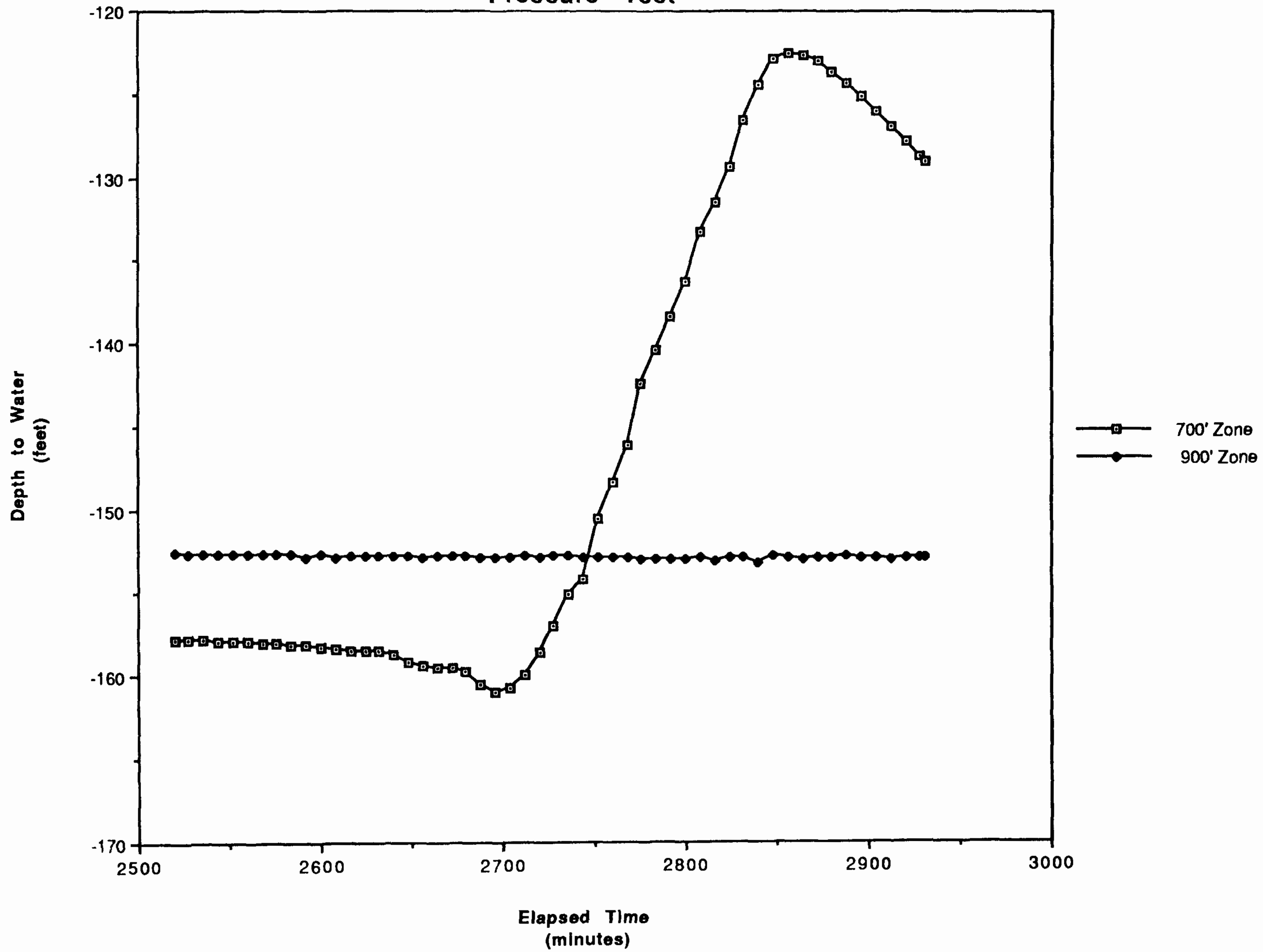
Figure 3 is a graph of the pressure transducer data from the 700 and 900 foot zones. The 900 foot zone was not affected by the injection. The 700 foot zone showed a significant effect, especially at the 400 psig injection pressure.

Injection at 50 psig was begun at an elapsed time of 2555 minutes, 100 psig at 2585 minutes, 200 psig at 2635 minutes and 400 psig at 2675 psig. Injection was shut down at 2820 minutes. A rise in pressure, and water level, began in the 700 foot zone

TABLE 1
VERTICAL FLOW DETERMINATIONS

Time (hr/min)	Depth (feet)	Injection Pressure (psig)	Flow Yes/No
10:39	750	50	yes
10:45	750	50	yes
10:53	660	50	no
11:00	660	50	no
11:13	660	100	no
11:19	660	100	no
11:36	750	100	yes
11:49	750	200	yes
11:58	660	200	no
12:04	660	200	no
12:27	660	400	yes
12:33	660	400	yes
12:46	580	400	no
12:52	580	400	no
13:00	550	400	yes
13:07	550	400	yes
13:15	450	400	no
13:28	430	400	no
13:39	380	400	no
13:49	620	400	no
13:57	650	400	no
14:04	650	400	no
14:12	660	400	no
14:17	660	400	no

FIGURE
Pressure Test



around the 2700 minute elapsed time period and continued to increase until the pump was shut down.

Conclusions

The Hydrolog very effectively allowed the investigators to trace the movement of water vertically adjacent to the Leak Test Well.

OXYGEN ACTIVATION ANALYSIS

ATLAS WIRELINE SERVICE

COMPANY NAME: EAST CENTRAL UNIVERSITY
WELL NAME: LEAK TEST WELL NO.1
DATE: 22-MAY-89
COMMENTS: INJECTING AT 50, 100, 200, AND 400 PSI.
RECORDED BY: KOENN WITNESSED BY: THORNHILL,BENEFIELD

DEPTH	FILE: #	FLOW IND. SS	FLOW IND. LS	COMMENTS: (VEL. ETC.)	ISS	ILS	SS	LS
750	ST1A	6.785	.335	BACKGROUND	3030	122	.00224	.00275
750	ST1B	6.376	.335	"	3025	124	.00211	.00270
750	ST1C	6.776	.242	"	2979	125	.00227	.00193
						AVE=	.00221	.00246
750	ST1A	.088	.034	BACKGROUND NO FLOW NO INJ.				
750	ST1B	-.309	.029	" " " " "				
750	ST1C	.183	-.066	" " " " "				
750	ST2A	4.854	2.769	INJ 50 PSI. APX. 2.5GPM VEL=13.6'/MIN.				
750	ST2B	6.433	2.993	" " " " " " VEL=10.0				
660	ST3A	4.287	.556	INJ. 50 PSI. VEL=3.75				
660	ST3B	4.392	.287	" " " VEL=2.81				
660	ST4A	3.626	.274	INJ. 100 PSI. VEL=2.96				
660	ST4B	3.563	.195	" " " VEL=LOW				
750	ST5A	5.227	3.406	INJ. 100 PSI. VEL=17.88				
750	ST6A	4.496	3.580	INJ. 200 PSI. VEL=33.63				
660	ST7A	2.362	.416	INJ. 200 PSI. VEL=4.41				
660	ST7B	1.932	.225	" " " VEL=3.56				
660	ST8A	13.704	6.104	INJ. 400 PSI. VEL=9.47				
660	ST8B	12.349	6.201	" " " VEL=11.12				
580	ST9A	.273	.382	INJ. 400 PSI. VEL=0.00				
580	ST9B	.454	.304	" " " VEL=0.00				
550	ST10A	7.243	5.058	INJ. 400 PSI. VEL=21.32				
550	ST10B	7.455	3.748	" " " VEL=11.13				
450	ST11A	.202	.545	INJ. 400 PSI. VEL=0.00				
430	ST12A	.211	.586	INJ. 400 PSI. VEL=0.00				

OXYGEN ACTIVATION ANALYSIS

ATLAS WIRELINE SERVICE

COMPANY NAME: EAST CENTRAL UNIVERSITY
WELL NAME: LEAK TEST WELL NO.1
DATE: 22-MAY-89
COMMENTS: INJECTING AT 50, 100, 200, AND 400 PSI.
RECORDED BY: KOENN WITNESSED BY: THORNHILL,BENEFIELD

DEPTH	FILE: #	FLOW IND. SS, LS	COMMENTS: (VEL. ETC.)	
380	ST13A	-.676 .013	INJ. 400 PSI.	VEL=0.00
620	ST14A	.073 -.086	INJ. 400 PSI.	VEL=0.00
650	ST15A	1.647 .183	INJ. 400 PSI.	VEL=3.48
650	ST15B	1.575 -.057	" " "	VEL=0.00
660	ST16A	8.721 .645	INJ. 400 PSI.	VEL=2.939
660	ST16B	8.213 .593	" " "	VEL=2.913

RSKERL Leak Test Well
Test 23

Evaluating Flow Behind Pipe

Introduction

On September 12-14, 1989, A training course was conducted to provide a basic knowledge of methods for evaluating flow behind pipe in injection wells. The course focused on discussions of the theory of state-of-the-art methods for evaluating flow behind pipe and demonstrations in the field of oxygen activation, noise, temperature and radioactive tracer logging techniques for detecting flow behind pipe.

Forty students participated in the course which was held at the Mechanical Integrity Testing and Training Facility, Ada, Oklahoma. Instructors for the course were experts in each logging technique from Atlas Wireline, Houston, Texas.

Test Well Configuration

Figure 1 indicates the configuration of the Leak Test Well for each of the tests conducted during the training.

Logging

Logs produced during the training as well as a paper on new instrumentation and interpretive methods for identifying shielded water flow using pulsed neutron logging.

Conclusions

The participants seemed to greatly appreciate the teaching format; lectures and then hands-on logging at the test well to demonstrate principles and theories just discussed.

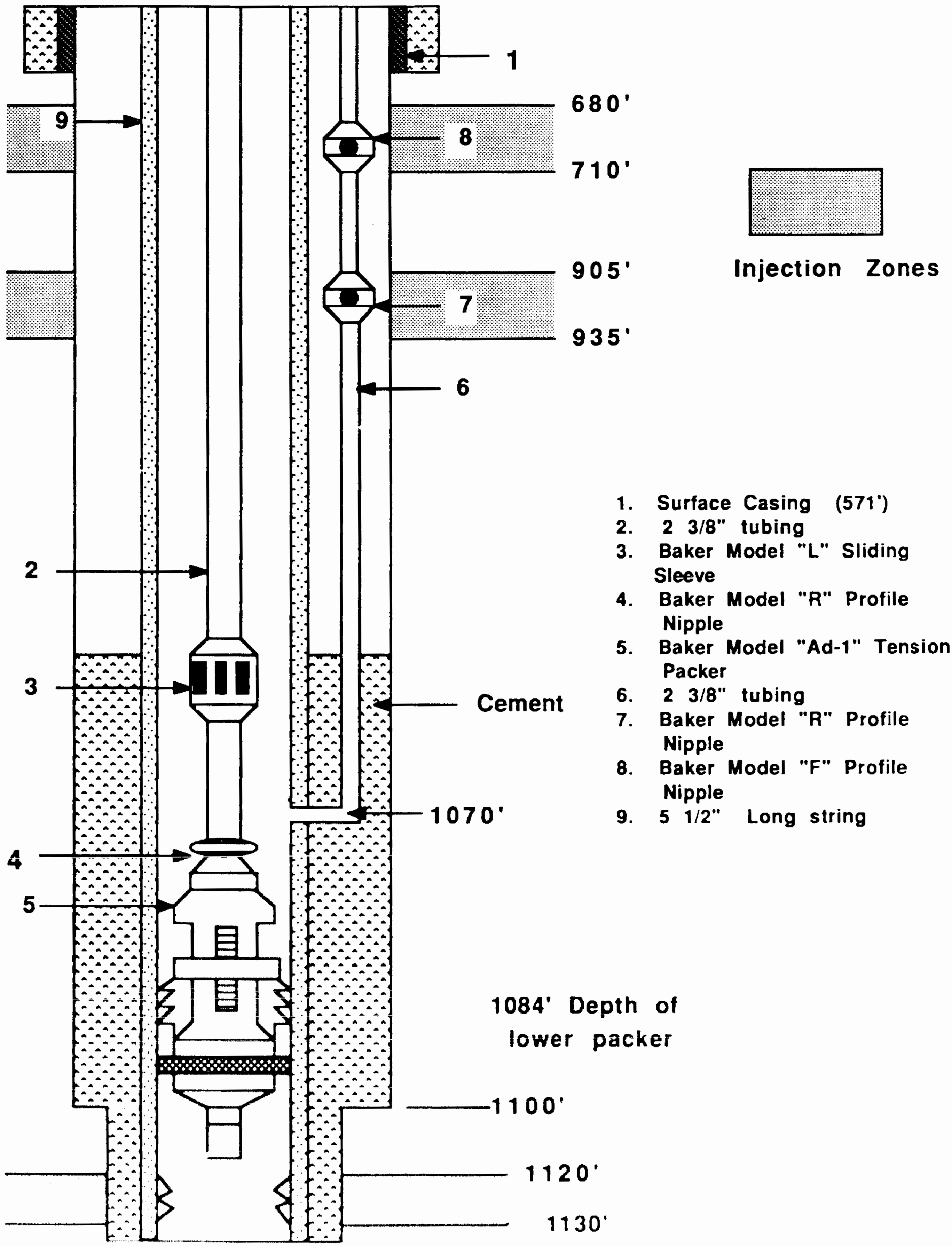


FIGURE 1 LEAK TEST WELL

HYDROLOG ANALYSIS
ATLAS WIRELINE SERVICE

COMPANY NAME: _E.C.U. EPA ____________
WELL NAME: _LEAK TEST WELL NO. 1_____
FIELD : _WILDCAT__________________
STATE & CO.: _PONTOTOC, OKLAHOMA_______
DATE: _9-13-1989_______________
COMMENTS: TOOL RUN INSIDE 2 3/8" TUBING INSIDE 5 1/2" CSG.
FLOW IS OUTSIDE THE 5 1/2" IN A 2 3/8" TUBING TO SURFACE.

RECORDED BY: _KOENN_______
WITNESSED BY: _EPA_________
TOOL #: _TP 1________

DEPTH METERS	FILE:	OXYGEN SS.	LS	COMMENTS:	ISS	ILS	CALCULATED SS	LS
1000	ST1A	6.506	.223	BACKGROUND	3126	95	.00208	.00235
1000	ST1B	5.875	.242	NO INJ.	3097	95	.00190	.00255
1000	ST1C	6.544	.167		3051	93	.00214	.00180

CALCULATED BACKGROUND CORRECTION FACTOR AVERAGE = .00204 .00223

DEPTH	FILE #	FLOW IND. SS	LS	COMMENTS:	VELOCITY FT/MIN
1000	ST1A	.129	.012	BACKGROUND NO INJECTION	00.00
1000	ST1B	-.442	.029		00.00
1000	ST1C	.320	-.039		00.00
1000	ST2A	-.018	-.018	INJECTING 18 GPM DOWN ONLY TO	00.00
1000	ST2B	.179	-.079	OPEN ZONE AT 1120'	00.00
1000	ST3A	537.1	299.0	INJECTING 16 GPM APX. 1/2 GOING UP	13.07
1000	ST4A	159.2	38.4	INJECTING 6 GPM 1.7 UP	5.38
1000	ST5A	33.14	3.120	INJECTING 3.8 GPM .5 GPM UP	3.24
1000	ST6A	26.07	2.543	INJECTING 3.7 GPM .25 GPM UP	3.29
1000	ST7A	.142	-.129	DOWN FLOW ONLY	00.00

Introduction

On October 4 and 5, 1989, personnel from the Robert S. Kerr Environmental Research Laboratory (RSKERL), East Central University and Schlumberger Well Service conducted a series of tests on their oxygen activation tool to determine its capability to detect flow behind pipe. The test was designed for two days, with the first day for calibrating their tool and the second day for testing their capability to identify specific flows.

Test Well Conditions

The Leak Test Well was configured as indicated in Figure 1. A packer was set at 1084 feet and injection was maintained down the tubing/casing annulus, out the 1/4 inch hole in the long string at 1070 feet and up the outside tubing.

Test Day 1

Schlumberger personnel were on site at 7:00 a.m. to begin the testing. The well was readied and the tool set up. The plan was for known flows to be pumped up the outside tubing while Schlumberger personnel operated the tool the flow they determined to the actual flow.

The flows involved during the day included:
.5 gallons per minute
.25 gallons per minute
1 gallon per minute
1.3 gallons per minute
10 gallons per minute
.35 gallons per minute

At 11:00 a.m. the well was shut in and the Schlumberger personnel proceeded to evaluate their data. They did not have the capability to perform the calculations necessary in the truck so they set up a satellite dish and transmitted the data to Houston for processing.

Test Day 2

The procedure for testing on this day was to pump the well at rates known only to the RSKERL/ECU personnel and Schlumberger personnel would determine that rate based on the data from their oxygen activation tool.

The results of the tests are as follows:

Actual Flow	Schlumberger Flow
.23 gallons per minute	Flow detected
.53 gpm	.57 gpm
No flow	No flow
20 gpm	13 gpm
No flow	No flow
.22 gpm	Flow detected
2.4 gpm	-

Conclusions

The tool detected flows down to .22 gallons per minute. They also determined velocities, however at this point our main interest was a flow/no-flow determination.

The next step for Schlumberger is to develop the capability to make the flow determinations from the truck.

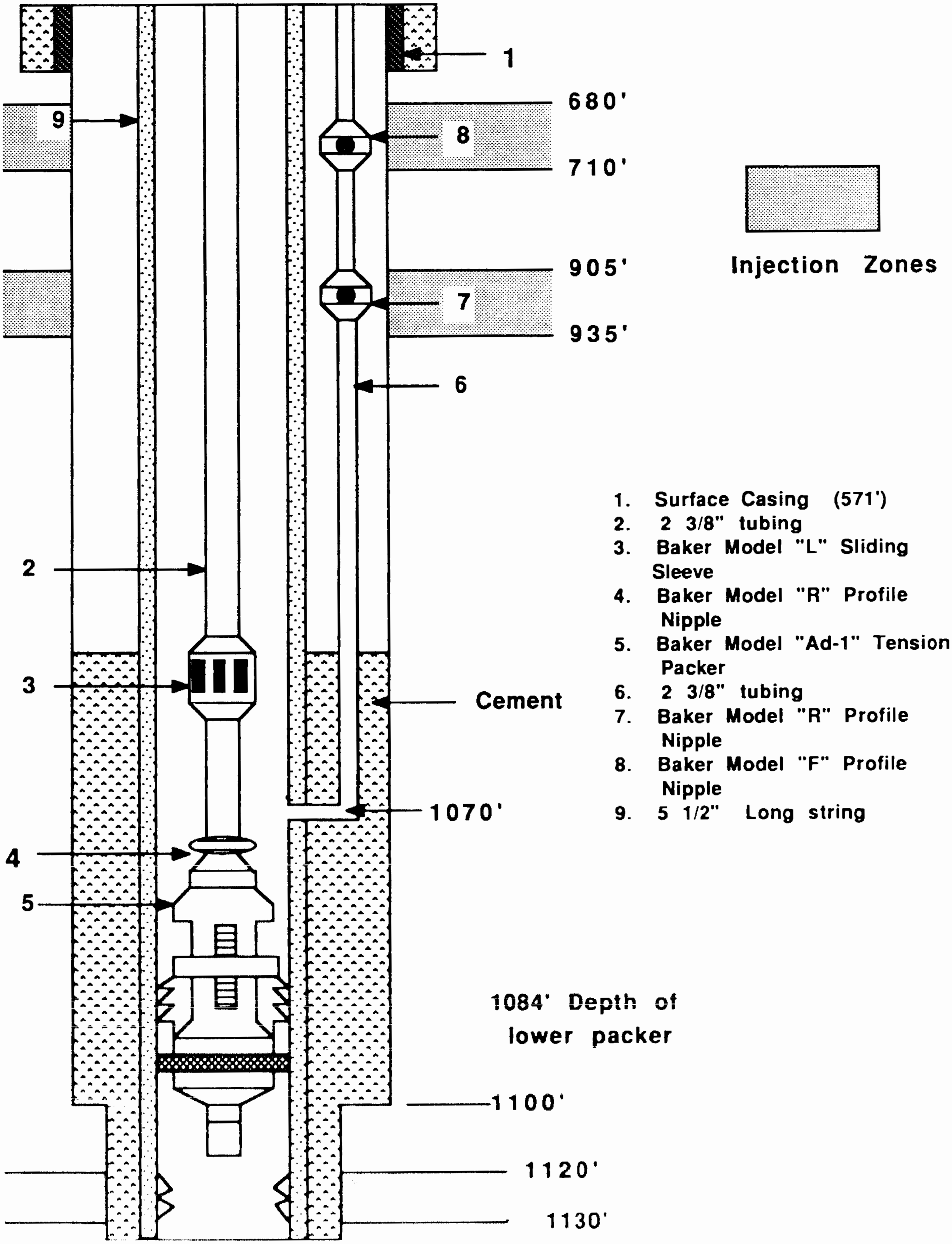


FIGURE 1 LEAK TEST WELL

RSKERL Leak Test Well
Test No. 26

Nuclear Activation Tool

Introduction

On November 13, 1989, personnel fro the Robert S.Kerr Environmental Research Laboratory (RSKERL), East Central University (ECU) and Atlas Wireline Services, conducted a series of tests on their Hydrolog tool to determine its capability to detect flow behind pipe. The test was designed for detecting flow vertically upward.

Test Well Conditions

The Leak Test Well was configured as indicated in Figure 1. A packer was set at 1,084 feet and injection was maintained down the tubing/casing annulus, out the 1/4 inch hole in the long string at 1,070 feet and up the outside tubing.

Test

Background data was taken with the tool at a depth of 950 feet. With the tool set at that depth the following flows were pumped up the outside tubing with the results as indicated:

Actual Flow	Flow Detected
2 gpm	yes
0.3 gpm	no
15 gpm	yes
no flow	no
3 gpm	yes
0.9 gpm	yes

Conclusions

The Hydrolog detected flows down to 0.9 gpm. The data presentation is very good, leaving no interpretation problems for the operator/regulator reviewing the data.

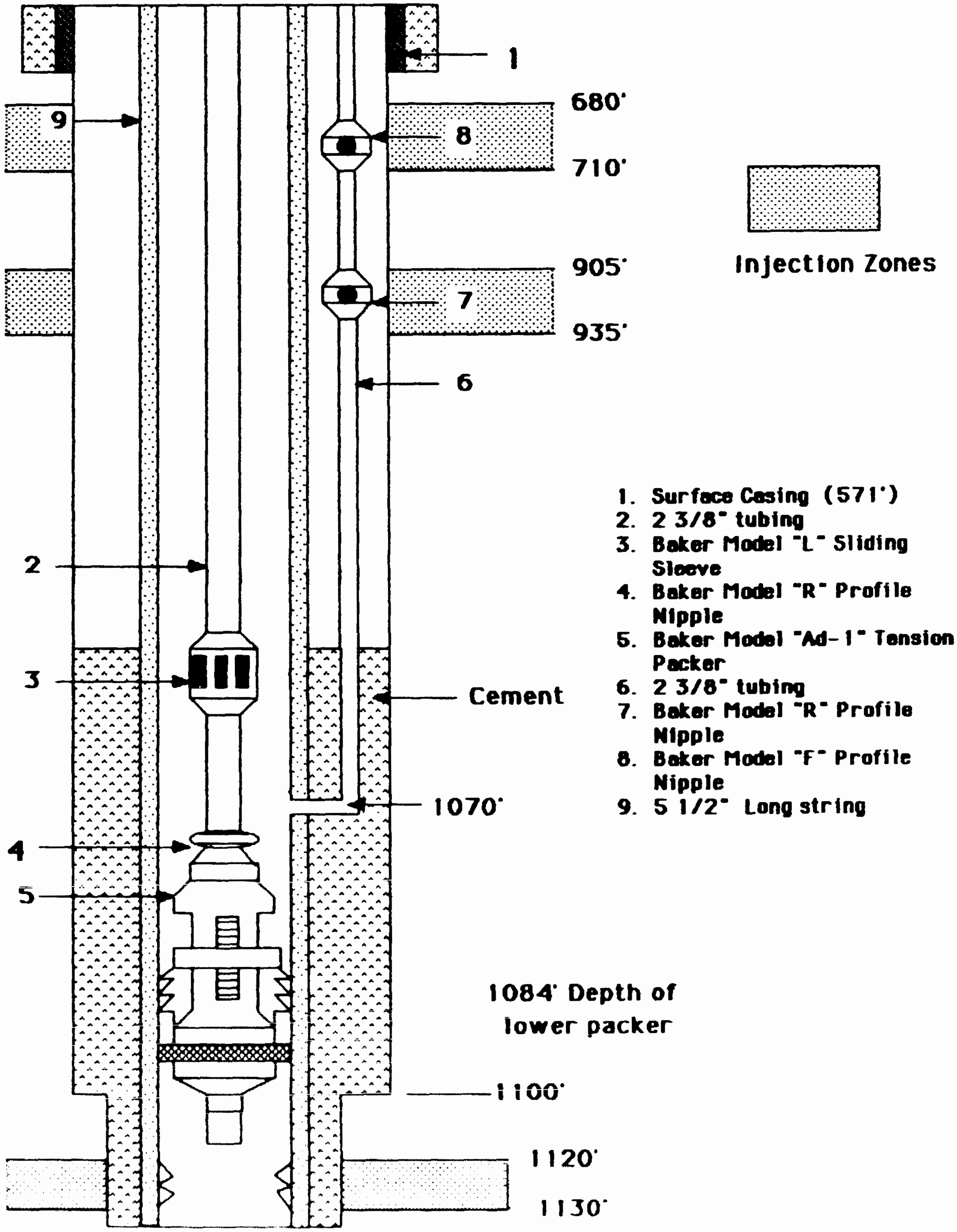


FIGURE 1 LEAK TEST WELL

HYDROLOG ANALYSIS
ATLAS WIRELINE SERVICE

COMPANY NAME: _E.C.U. E.P.A._________ RECORDED BY: KOENN/NEWK___
WELL NAME: _LEAK TESTWELL NO.1_______ WITNESSED BY: THORNHILL
FIELD : _WILDCAT_________________ TOOL #: TP-1_________
STATE & CO.: _PONTOTOC OKLA._________
DATE: _11/13/89_________________
COMMENTS:
MEASURED FLOW IS IN 2 3/8" TUBING OUTSIDE OF 5 1/2" CASING

DEPTH METERS	FILE:	OXYGEN SS.	LS	COMMENTS:	ISS	ILS	CALCULATED SS	LS
950	ST1A	6.226	.260	BACKGROUND	3206	107	.00194	.00243
950	ST1B	6.005	.242	NO	3144	111	.00191	.00218
950	ST1C	6.320	.204	INJECTION	3122	104	.00202	.00196

CALCULATED BACKGROUND CORRECTION FACTOR AVERAGE = .00195 .00219

DEPTH	FILE #	FLOW IND. SS	LS	COMMENTS:	VELOCITY FT/MIN
950	ST1A	-.025	.025	BACKGROUND NO FLOW	000
[illegible]	ST1B	-.125	-.001	" " "	000
[illegible]	ST1C	.232	-.023	" " "	000
950	ST2A	14.792	5.994	INJECTION RATE @ 2 GAL/MIN.	8.4
950	ST2B	7.273	4.235	" " " "	14.2
950	ST2C	7.602	4.386	" " " "	13.9
950	ST3A	1.421	.007	INJECTION RATE @ ~~.3~~ .375 GAL/MIN.	000
950	ST3B	.839	.110	" " " "	000
950	ST3C	.869	.073	" " " "	000
950	ST4A	2.687	2.287	INJECTION RATE @ 15 GAL/MIN.	47.6
950	ST4B	3.165	2.669	" " " "	44.9
950	ST4C	2.422	2.548	" " " "	~
950	ST4D	3.128	2.678	" " " "	49.3
950	ST5A	.392	.006	NO FLOW	000
950	ST5B	.030	.056	" "	000
950	ST6A	7.883	5.156	INJECTION RATE @ 3 GAL/MIN.	18.0
950	ST6B	6.984	4.815	" " " "	20.6
950	ST6C	8.168	4.130	" " " "	13.5
[illegible]	ST7A	3.871	1.158	INJECTION RATE @ .9 GAL/MIN.	6.35
[illegible]	ST7B	4.059	.920	" " ." "	5.15
950	ST7C	3.254	.943	" " " "	8.14

Introduction

On March 1, 1990, personnel from the Robert S. Kerr Environmental Research Laboratory (RSKERL), East Central University and Schlumberger Well Service conducted a series of tests on Schlumberger's Flow Log tool to determine its capability to detect flow behind pipe. The test was designed for detecting flow vertically upward.

Test Well conditions

The Leak Test Well was configured as indicated in Figure 1. A packer was set at 1084 feet and injection was maintained down the tubing/casing annulus, out the 1/4 inch hole in the long string at 1070 feet and up the outside tubing.

Flow Log Tool

The Flow Log is based on the Schlumberger TDT-P tool which has been slightly modified to respond to this specific use. The technique for making measurements with the Flow Log does not require zero flow calibration and the tool can detect up or down flow by turning the tool upside down. The modifications made have increased the sensitivity of the tool to slow and fast flow. They predict that the tool will detect flows ranging from 1.4 feet per minute to 120 feet per minute. As casing size increases, this capability is reduced. For example, in 9 5/8 inch casing the range would be 3.0 feet per minute to 30 feet per minute and in 13 3/8 inch casing the range is 4.5 feet per minute to 30 feet per minute. The tool will be centralized in the casing when running in the well.

Detection of water flow depends upon the distance to the flow, the velocity of the flow and the volumetric flow rate. Detection of flow is also influenced by the well bore environment, stability of the tool and natural background radiation.

The reported sensitivity of the instrument:
- Near Detector - 1.4-2 feet/minute
- Far Detector - 2-60 feet/minute
- Gamma Detector - 60-120 feet/minute

The proposed logging procedure being considered by Schlumberger personnel at this time includes a 15 minute station measurement with 10 second activation and 60 seconds standby. If flow is detected no more measurements are necessary. If flow is not detected, then a 30 minute reading is taken with activation for 2 seconds and standby for 60 seconds.

Test

The well was set up so that the tool was attempting to detect flow coming up the outside tubing. The flows and test results are as follows:

Actual Flow	Flow Detected
0.0023 gpm	no
0.5 gpm	yes (far detector)
No Flow	no
20 gpm	yes (far and gamma detectors)
3 gpm	yes (far detector)
10 gpm	yes (far detector)

Conclusions

The Flo Log detected flow down to 0.5 gpm. The data presentation gives information for each detector as well as a flow/no flow determination. The tool now needs to be used in the field to gain valuable field experience in detecting flows under varying conditions.

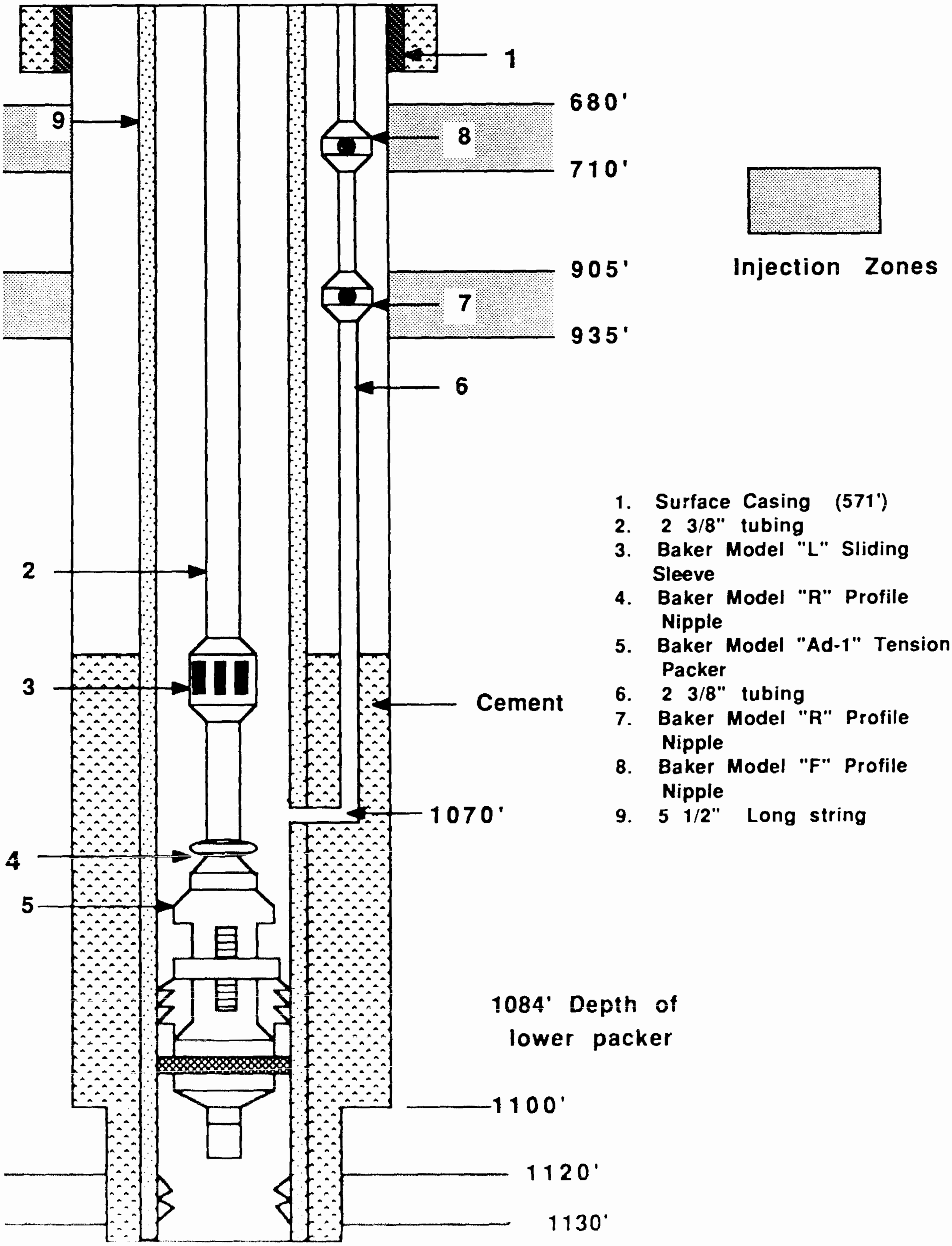


FIGURE 1 LEAK TEST WELL

Evaluating Flow Behind Pipe

Introduction

On July 17, 18, 19 & 20, 1990, a training course was conducted to provide a basic knowledge of methods for evaluating flow behind pipe in injection wells. The course focused on discussions of the theory of state-of-the-art methods for evaluating flow behind pipe and demonstrations in the field of oxygen activation, noise, temperature and radioactive tracer logging techniques for detecting flow behind pipe.

Fifteen students participated in the course which was held at the Mechanical Integrity Testing and Training Facility, Ada, Oklahoma. Instructors for the course were experts in each logging technique from Atlas Wireline Services, Houston, Texas.

Test Well Configuration

Figure 1 indicates the configuration of the Leak Test Well for each of the tests conducted during the training.

Logging

Water was pumped into the well and attempts were made to detect flow in the 2 3/8 inch outside tubing with noise, temperature, and oxygen activation logging techniques. A radioactive tracer survey was also run in the well to monitor flow of the fluid out of the tubing.

Conclusions

The participants seemed to greatly appreciate the class format: ie lectures and hands-on at the well site.

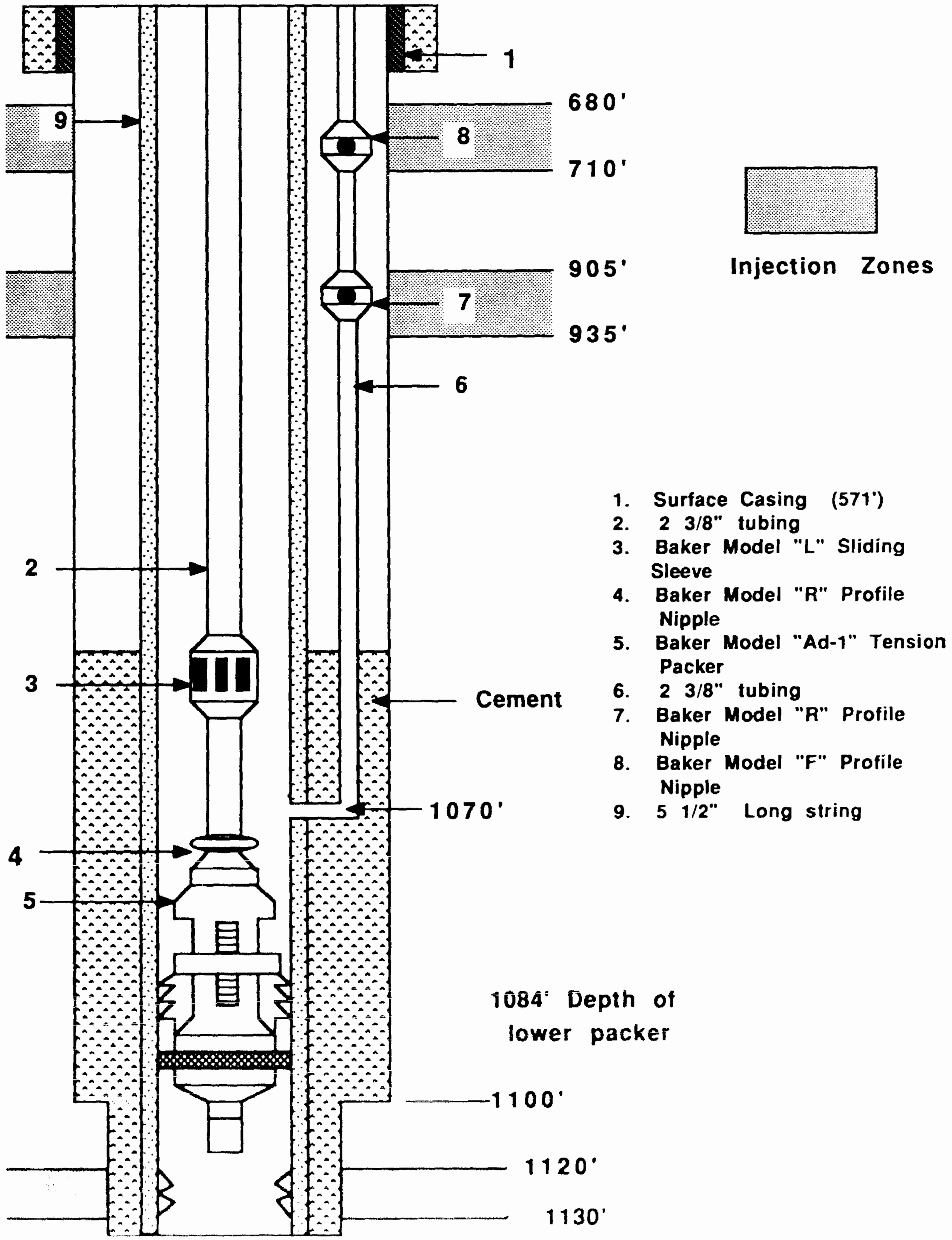


FIGURE 1 LEAK TEST WELL

RSKERL Leak Test Well
Test No. 29

Oxygen Activation Technique for Detecting Flow Inside Casing

Introduction

A significant question that has arisen regarding oxygen activation logging for detecting flow behind pipe is whether or not flow inside casing can interfere with detection of flow behind casing. The specific question for this study relates to the effect of density inducted flow on capability of the oxygen activation method to detect flow.

A glass tube was set up in the laboratory to simulate the diameter and depth of Logging Well No. 2 (5-1/2 inch casing, 1,575 feet deep). The tube was filled with fresh water and the equivalent of 10 gallons of 25% brine added to the water column. Dye was added to the brine to aid in visualizing movement down the well.

The brine moved down the well at a significant pace reaching the bottom in approximately 5 minutes. "Eddy" currents were plainly visible as the brine moved down the water column. The experiment was repeated four times to confirm that the movement was basically the same each time.

Plans were then made to conduct tests at the Mechanical Integrity Testing and Training Facility on Logging Well No. 2. (Figure 1). The water level in the well was to be lowered until 10 gallons (10 feet) of brine could be added. An oxygen activation tool would be placed in the well in the upflow mode and ten gallons of brine added to the well. The experiment would be repeated with the tool in the downflow position. This series of tests would be performed on both the Schlumberger Flow Log and the Atlas Wireline Hydrolog.

Sequence of Events

1. Placed the OA tool in the well, in the upflow configuration, at a specified depth.

2. Run OA measurements with the well in a static condition.

3. Add 10 gallons of 25% brine.
4. Run OA measurements .
5. Move tool deeper in well, repeat measurements.
6. Remove tool, run tubing and swab brine out of well.
7. Fill well with fresh water.
8. Place OA tool in hole in the downflow configuration at a specified depth.
9. Run OA measurement with well static.
10. Add 10 gallons of 25% brine.
11. Run OA measurements.
12. Move tool downhole. Repeat OA measurements.
13. Remove tool, run tubing and swab water out of well.
14. Fill well with fresh water.

Field Tests

On March 11 and 12, 1991, respectively, Schlumberger and Atlas Wireline were at the site to test the capability of their oxygen activation tools to detect density induced flows inside casing.

The Schlumberger engineer placed the WFL tool in the hole at a depth of 413.4 feet with the tool in the upflow configuration. Readings taken at 9:11 a.m., under static conditions, indicated no flow on either of the three detectors.(far, near and gamma). Ten gallons of brine was added to the column and at 9:35 a.m. the tool detected upward flow. At 9:58 a.m. a very slight signal was identified on the near detector, indicating the possibility of a very low flow. A velocity could not be calculated for the possible flow.

The tool was lowered to 613.6 feet and readings were taken at 10:47 a.m. A slight upward flow was identified on both the near and far detectors. No velocity calculation could be made for the near detector. The velocity calculation for the far detector indicated a flow of 3.7 feet/minute.

Downflow measurements began at 4:41 p.m. with the tool at 415 feet. No flow was indicated under static conditions i.e. prior to adding brine to the system. Ten gallons of brine was added to the column and at 5:13 p.m. a very, very slight signal was indicated on the near detector. The tool was moved to 615 feet and at 5:50 p.m. a slight signal on the near detector indicated the possibility of downward flow.

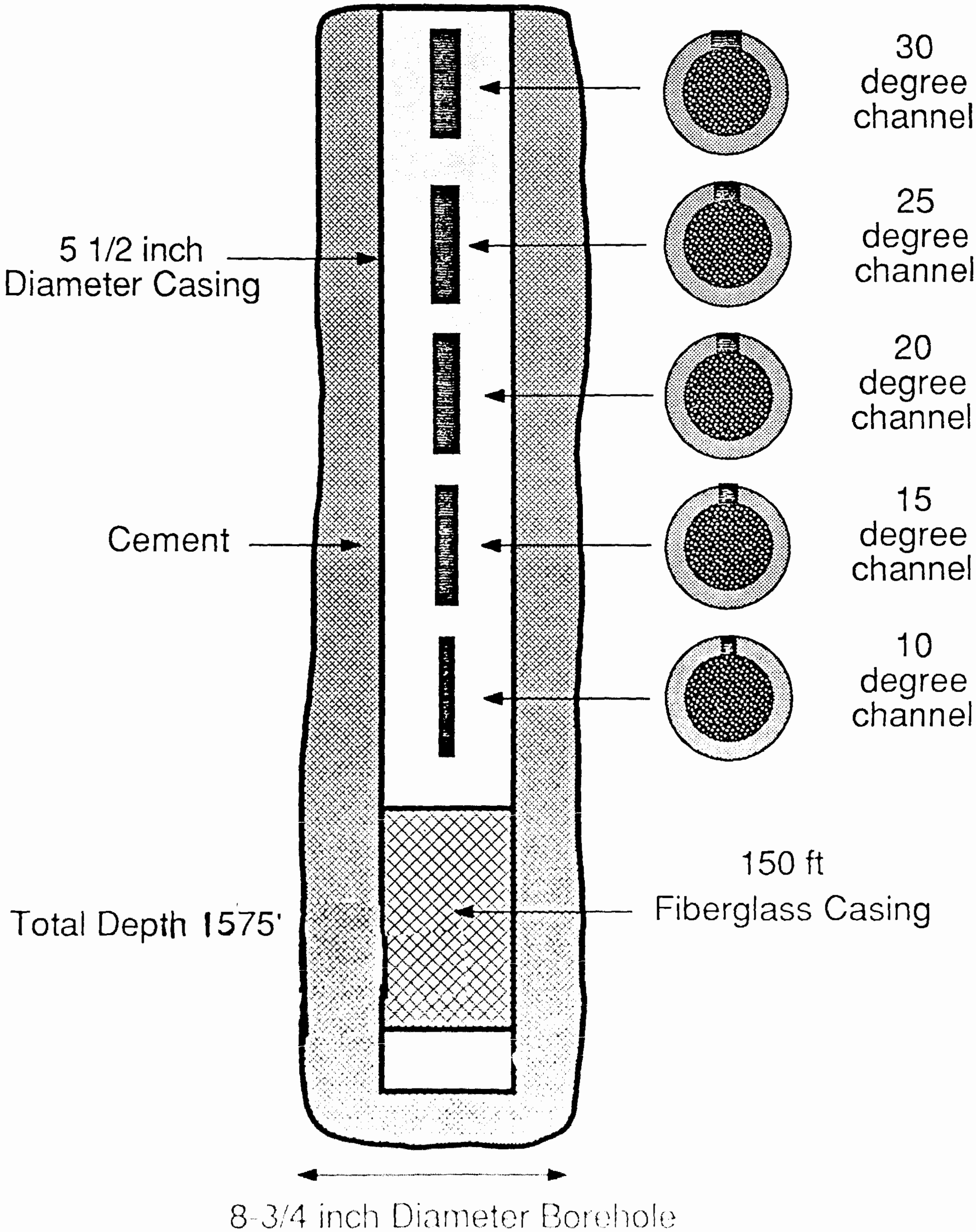
On March 12, 1991, the Atlas Wireline engineer placed the Hydrolog tool in the well at a depth of 400 feet with the tool in the upflow configuration. Background readings taken at noon, 12:10 p.m. and 12:17 p.m. indicated no flow in the system. Brine was added and readings taken at 1:46, 2:32 and 3:11 p.m. did not indicate any flow. A final reading was taken at 3:37 p.m. with no flow detected.

Downflow measurements began at 7:51 p.m. with background measurements prior to additon of brine to the system. Brine was added and at 8:03 p.m. (5 minutes after brine was added), downflow was indicated on the long spaced flow indicator with the tool at 62' in the well. The tool was moved to a depth of 200 feet and readings were taken at 8:27, 8:43, 8:58 and 9:09 p.m. with no indication of flow in the system.

Conclusions

The density induced flow caused by the specific conditions created in Logging Well No. 2 should not create a problem with interpreting behind pipe flow data in a well. The flow induced in this experiment was very slow. It created a very weak response on the oxygen activation logging devices used, and was a one time phenomena, that is after the initial flow had passed a certain point, no more internal flow was induced.

LOGGING WELL #2



HYDROLOG ANALYSIS
ATLAS WIRELINE SERVICE

COMPANY NAME: _EAST CENTRAL UNIVERSITY__ RECORDED BY: KOENN/JOHNSTON
WELL NAME: _LOGGING WELL NO.2________ WITNESSED BY: _BENEFIELD___
FIELD : _WILDCAT________________ & _THORNHILL___
STATE & CO.: _PONTOTOC,OKLAHOMA_______ TOOL# RB-1
DATE: _3-12-91________________
COMMENTS: 5 1/2 15.5# CSG TO 1575; FLUID LEVEL AT 12' FOR BG.
PIPE THEN FILLED WITH SW FOR FLOWING TESTS. (250 K)

DEPTH FEET	FILE:	OXYGEN SS.	LS	COMMENTS:	ISS	ILS	CALCULATED SS	CALCULATED LS
0400	ST1A	6.599	.167	BK	3042	89	.00217	.00187
0400	ST1B	6.302	.167		3070	90	.00205	.00185
0400	ST1C	6.135	.168		2990	86	.00205	.00194

CALCULATED BACKGROUND CORRECTION FACTOR AVERAGE = .00210 .00189

DEPTH	FILE #	FLOW IND. SS	LS	COMMENTS:	VELOCITY FT/MIN
0400	ST1A	.212	-.001	BACKGROUND	0.0
0400	ST1B	-.144	-.003	NO SALT WATER	0.0
0400	ST1C	-.144	+.005	NO SW	0.0
0400	ST2A	.107	-.007	10 FEET SW ADDED	0.0
0400	ST2B	-.179	+.192	DITTO ABOVE	0.0
0400	ST2C	-.702	+.083	DITTO ABOVE	0.0
0300	ST3A	+.227	-.023	DITTO ABOVE	0.0
				TOOL REVERSED TO MEASURE DOWN FLOW AT THIS POINT	
0062	ST4A	+210.7	+70.5	15 MIN. AFTER HOLE FILLED (FROTHING)	6.99
0062	ST4B	+1.152	+.015	USED AS BACKGROUND	0.0
0062	ST4C	+7.76	+1.14	5 MIN. AFTER SW ADDED	4.0
0062	ST4D	-1.47	+.044	10 MIN. AFTER SW ADDED	0.0
0062	ST4E	-1.135	-.085	20 MIN. AFTER SW ADDED	0.0
0200	ST5A	+.227	+.161	35 MIN. AFTER SW ADDED	0.0
0200	ST5B	+.058	-.041	50 MIN. AFTER SW ADDED	0.0
0200	ST5C	+.119	+.093	70 MIN. AFTER SW	0.0
0200	ST5D	-.452	+.050	85 MIN. AFTER SW	0.0

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