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Testing Green Canyon Wells With a Pressure-Pulse-Controlled DST System

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ABSTRACT

Green Canyon development wells are perforated and tested using the IMPULSE* testing method before completion or recompletion. This method allows a controlled underbalance stimulation of unconsolidated formations so that an initial reservoir pressure and reservoir data can be obtained. A pressure pulse controlled drill stem test (DST) system is used to carry out these well testing operations.

This new DST control concept overcomes some of the limitations of conventional DST tools; equipment reliability is increased in difficult well conditions. This new system has improved the efficiency and safety of well testing in this area.

INTRODUCTION

Conventional DST strings require mechanical pipe manipulations and/or increasing levels of annulus or pipe pressure to actuate sequentially the tools in the DST string during the different test phases. These operations can become difficult, time consuming or limited under certain conditions for the following reasons:

- The control of DST tools through pipe manipulation is difficult to monitor in deviated wells because of pipe drag inside the casing and on offshore floaters because of rig movement with the heave; this difficulty in controlling the string may jeopardize the operation with unwanted situations such as an unseated packer.

- Pipe manipulations are dangerous when operating with differential pressure between the pipe and the annulus; this is the case during underbalanced perforating.

- Conventional DST tools operated by pressure can only be actuated in the sequence planned during the design of the test, no deviation from this preset sequence is allowed once the tool string is in the hole. Excessive pressure may jeopardize well safety with, for example, a burst casing or a collapsed tool; the number of increasing sequential pressure levels to be applied to the annulus to operate the different tools in the string is therefore limited. The problem is worse when perforating a deviated well since a pressure actuated tubing conveyed perforating (TCP) firing system is normally preferred to a drop bar system. In a workover situation, where an inplace casing must be protected because of questionable integrity, the maximum pressure that can be applied to the annulus can be quickly reached.

- Finally, severe sand production during the flow period of a test affects the correct mechanical operation of conventional DST tools.

References and illustrations at end of paper.
* Mark of schlumberger.

A DST string, controlled by low pressure pulses in the annulus, eliminates these conventional string limitations in difficult conditions. This new testing technique, the Intelligent Remote Implementation System (IRIS*), provides flexible and simplified control of the different tools in the string and reliable and safe operation to optimize test data acquisition.

THE PRESSURE PULSE CONTROL SYSTEM

Control commands, or "signature commands", are sent through the annulus in the form of predefined sequential pressure pulses. A signature command is defined not only by its pressure levels but also by the timing of the different pulses; a typical command is shown in Figure 1. Each tool of the DST string is assigned a given signature command.

A battery powered downhole intelligent electronic controller analyzes the output data of a pressure transducer to recognize commands, confirm their validity and transfer the order to the hydraulic and mechanical actuator section of the tool to be operated. The downhole mechanical energy used to physically actuate the tools is generated by the transfer of hydrostatic pressure to an atmospheric chamber.

EQUIPMENT DESCRIPTION

Today's pressure pulse activated tool consists of a combined flow control valve and a multicycle circulating valve, both independently operated. The application of this tool is cased hole DST since the valves are annulus operated. This fullbore tool has a 5-in. outside diameter and 2 1/4-in. inside diameter; its 18-ft length, is considerably shorter than the length of typical equivalent conventional tools. A simplified diagram of this equipment is presented in Figure 2.

The IRIS system is combinable with any existing complementary DST tool (Figure 3). It is designed to operate without specialized surface equipment; conventional mud pumps and bleed-off lines have been used successfully to send commands down the annulus. A laptop commercial computer is used at the rig floor to initialize the electronic controller before running in the hole and to retrieve a downhole history file after the job to use for quality control.

EQUIPMENT OPERATION

To ensure total operating flexibility, the system accepts and implements three types of commands to independently control in any order the flow control valve and the circulating valve. The command types used by the valves of one string are selected during job design. The available commands are:

- Direct command: The controller recognizes a single pressure signal signature and always implements it regardless of previous events or state of the tool. This mode is used to operate either valve in the string.

- Sequential commands: The controller recognizes not only commands but also their sequence. Typically, a set of commands enables / disables the mode, and another set of commands controls the tool once enabled. This set is used to ensure a short, reliable flow control valve operation.

These two commands assume that the annulus is filled with an incompressible fluid:

- "Nitrogen" command: This special command sequence closes the circulating valve when nitrogen is present in the tubing / pipe. It overcomes the command pressure pulse transmission stability problem created by the compressibility of the gas. The nitrogen close command is activated only after a nitrogen open command is executed. The nitrogen open command is similar to a direct command, but with different timing pattern.

Figure 4 shows a sketch of these three commands, which are available any time during a job. The downhole software identifies the type of command received thanks to the pressure levels and timing patterns of the pulses. The pressure levels and timing patterns of the different commands are defined in the tool software and cannot be modified by the DST operator at the wellsite. A fourth command type exists:

- Surface preset command: This command is executed automatically when predetermined downhole conditions are met. For example, the circulating valve will close when the required hydrostatic underbalance is reached while running in the hole.

This array of commands allows the operation of any pulse controlled tool that may be required during a DST even if unplanned at the time of the test design.

OPERATIONAL EFFICIENCY

The tool is functionally tested and programmed with the proper job setup at the rig site in a short period of time right before running in the hole. There is no need for the high pressure nitrogen charging or mechanical cycling required with conventional tools. Field redress and reset

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can also be done promptly in case a second run in the hole is immediately required.

Pressure control pulses are typically of a few hundred psi in magnitude and several minutes long. Tolerances on the pressure levels and timing of these commands are adjusted to accommodate usual rig pump output and to eliminate parasitic nonvalid commands. The control and operation of the different DST string tools are therefore simplified compared to annulus pressures in excess of 1000 psi or drill floor pipe manipulations required by conventional DST strings. Pressure profiles required for a typical job by both a conventional and a pressure pulse controlled string are illustrated on Figure 5. As seen on this figure, pressure pulse controlled strings require considerably lower pressure levels for operation.

In some cases pressure levels required by conventional DST tools cannot be allowed in the annulus. The weak point can be the casing, the liner at the packer level, the top of the liner or a tool in the DST string (Figure 6). In such cases, where the difference between the hydrostatic pressure and the maximum allowed pressure is small, a pressure pulse controlled string is required.

This new test system has improved reliability compared to conventional DST tools in wells flowing debris, sand, gun debris or mud solids. It is mud-immuned by design; critical moving parts are protected from wellbore fluids.

An automatic underbalance closure feature also simplifies the operation; it allows either the test valve or the circulating valve to be run in the hole in the open position and to be closed when the required underbalance hydrostatic pressure is reached. This operation automatically takes place while running in the hole without any rig floor intervention. This is an important feature in deviated wells.

If required, full redundancy can be provided with a second pressure pulse controlled system operated with different signature commands or with conventional DST tools.

Finally, during the well test operation, the tool controller records annulus pressure data versus time in a discrete electronic memory; it also creates and records a command status history file indicating commands received versus commands executed. Back at surface, these files are downloaded on a portable computer and used as a postjob evaluation check (Figure 7).

SAFETY FEATURES

Built-in operational tool specifications improve the safety of perforating and DST operations. Low pressure pulses (minimum 250 psi) to control the tools are always within the maximum allowable pressure that may be applied to a casing. This is particularly important whenever these operations are contemplated during a workover or recompletion where casing integrity must be protected.

These pulse controlled tools can be operated at any depth, going in or coming out of the hole. This feature allows better well control while tripping in or out in case the mud weight has to be adjusted to control a zone left with open perforations.

Additional safety features to prevent an unsafe situation are:

- The flow control valve can be preprogrammed to close automatically in the event the annulus is overpressured. Also, the tool is designed to close in the event the annulus pressure is bled or lost. In both cases the flow control valve can be reopened once the problem is solved.
- The logic of the downhole controller prevents the flow control valve from opening if the circulating valve is open.
- In a similar fashion the logic of the downhole controller prevents the circulating valve from opening if the flow control valve is enabled either open or closed.
- In case of emergency, both circulating and flow control valves can be shifted in a preselected failsafe position by applying a selected pressure to the annulus.

Both the operational and safety features of this pressure pulse controlled system allow perforating and testing in wells with conditions too restrictive for conventional DST equipment.

FIELD EXPERIENCE

Mobil perforating and test objectives normally include one or more of the following:

- Clean-up and stimulation effects of underbalanced perforating.
- Initial reservoir pressure, permeability•thickness, productivity index and skin.
- Hydrostatic pressure of the completion fluid.

Occasionally an extended DST (12-hr) is required to test for depletion or to measure drainage radius, sand production potential and gather well productivity parameters. The above data are used for adjusting the completion fluid weight, determining reserves to justify development or completion costs and evaluating gravel pack efficiency.

Both the conventional and new DST tool strings have been successfully used in placing seawater underbalances ranging from 300 to 1000 psi. At Green Canyon, sand production is frequent during the perforating and DST operation. To date, no guns have remained stuck in the hole. However, conventional DST tools are susceptible to debris and sanding problems; consequently they may fail to operate as desired. The new DST tools offer the advantage of sand immunity, as demonstrated in case history #1.

The second case history presented in this paper is a typical IMPULSE test, as run in the Green Canyon area. Pressure pulse controlled DST tools, a flow control valve and a circulating valve performed as specified. Maximum 1000-psi pressure was applied to the annulus to operate these tools.

So far, nine perforating/DST jobs have been completed in this area with pressure pulse controlled tools.

Case History #1

During recent completion of a development well, a DST was required to test the commerciality of a sand. The silty sand contained a water contact, and its aerial extent was unknown. A short flow period (IMPULSE test) followed by an extended (24-hour) flow/build-up period was proposed. Actual well results found the sand uncommercial. Following the IMPULSE test, the sand watered out during the extended flow period. By this method, unnecessary completion costs were avoided and a different interval up-hole was completed.

The DST job featured a pressure pulse controlled circulating valve run in a conventional DST string. This circulating valve was run in the hole in the open position. The valve was closed with a "direct command" after displacing the tubing with sea water. The well was produced for several hours with 25 to 45% sand production. At the end of the shut-in, the valve was re-opened with a second "direct command" to reverse out the tubing. Two additional commands were sent subsequently: one to reclose the valve to bullhead through the conventional flow control valve and a second to reopen the circulating valve to pull out after the conventional flow control valve was plugged by sand.

Four commands were sent and executed; the range of the pressure pulses sent was 490 to 540 psi. The pressure pulse controlled tool was operated in spite of important sand production.

The pressure pulse profile of this DST is presented in Figure 8.

Case History #2

The completion of this development well included a perforating / IMPULSE test. The job, in a 41-degree deviated well, was completed with a pressure pulse controlled flow control valve and a circulating valve as primary test tools. The well was perforated during the same trip using tubing-conveyed guns.

During this job, the circulating valve was operated in direct mode while the flow control valve was operated in sequential mode. Eleven commands were sent to the flow control valve, and two commands to the circulating valve; all commands, staying well below the safe well maximum allowable pressure, were accepted.

The pressure pulse profile of this job is shown in Figure 9.

CONCLUSION

The pressure pulse controlled DST system has improved the efficiency and the safety of well testing operations in the Green Canyon area. Downhole tool is simplified and more flexible. Quality control of the test validity is available, and built-in equipment features ensure a safer well test environment. Associated with the IMPULSE well testing method, the IRIS system is particularly useful in wells with restrictive conditions such as deviated wellbore profile, casing pressure limitation or potential sand production.

ACKNOWLEDGMENTS

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SI METRIC CONVERSION FACTORS

ft	x	3.048	E-01	=	m
in	x	2.54	E+01	=	m
psi	x	6.894 757	E=00	=	kPa

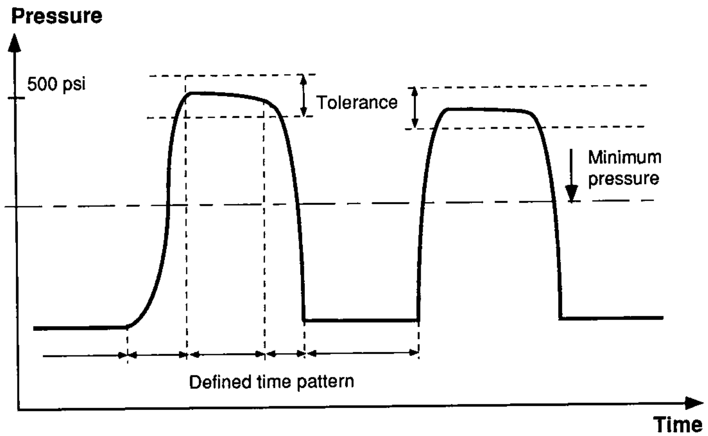

Fig. 1- Signature command profile

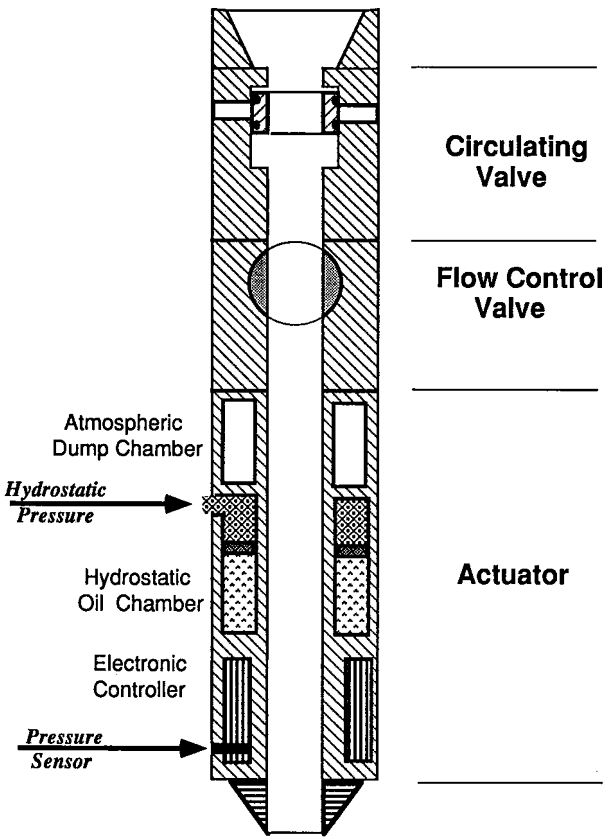

Fig. 2- The pressure pulse controlled DST system

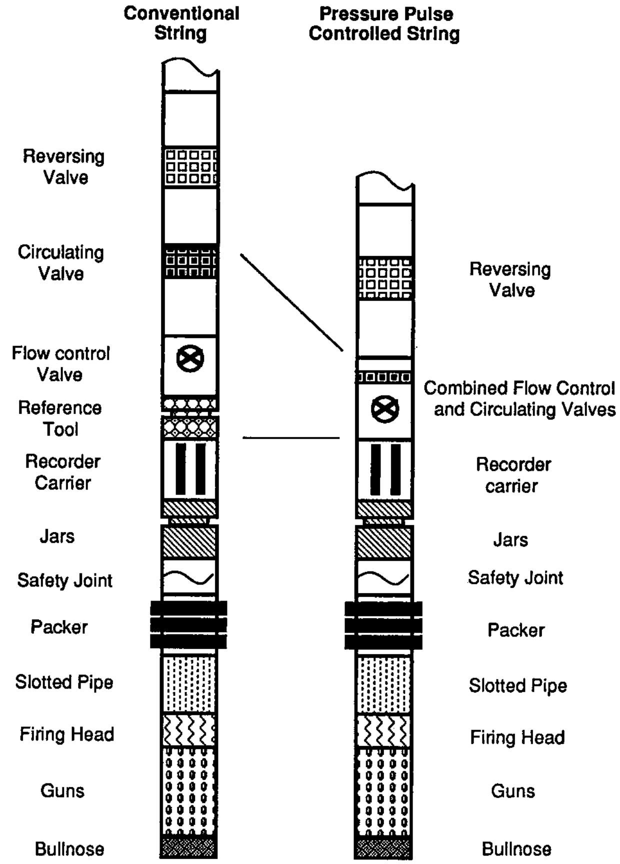

Fig 3- New string versus conventional string

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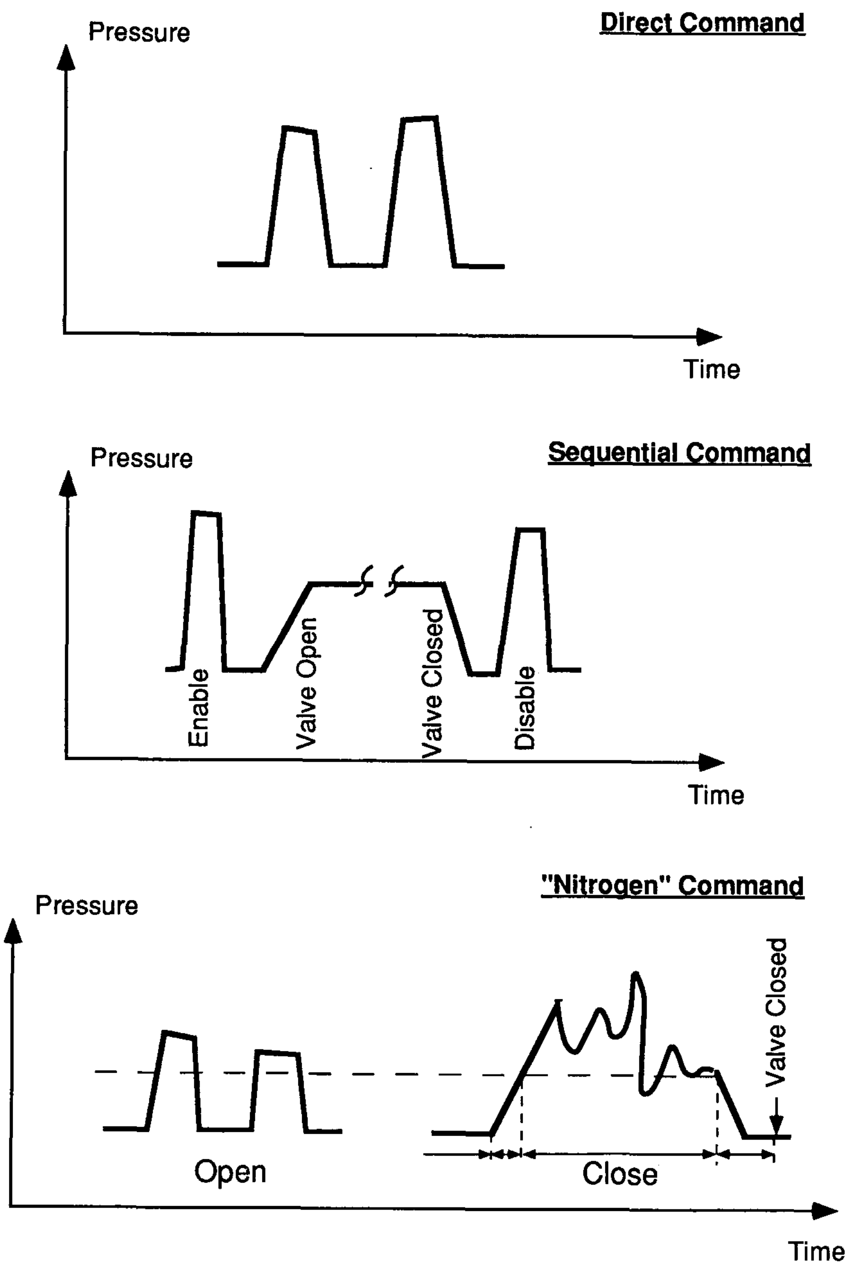

Fig. 4- Pressure pulse commands

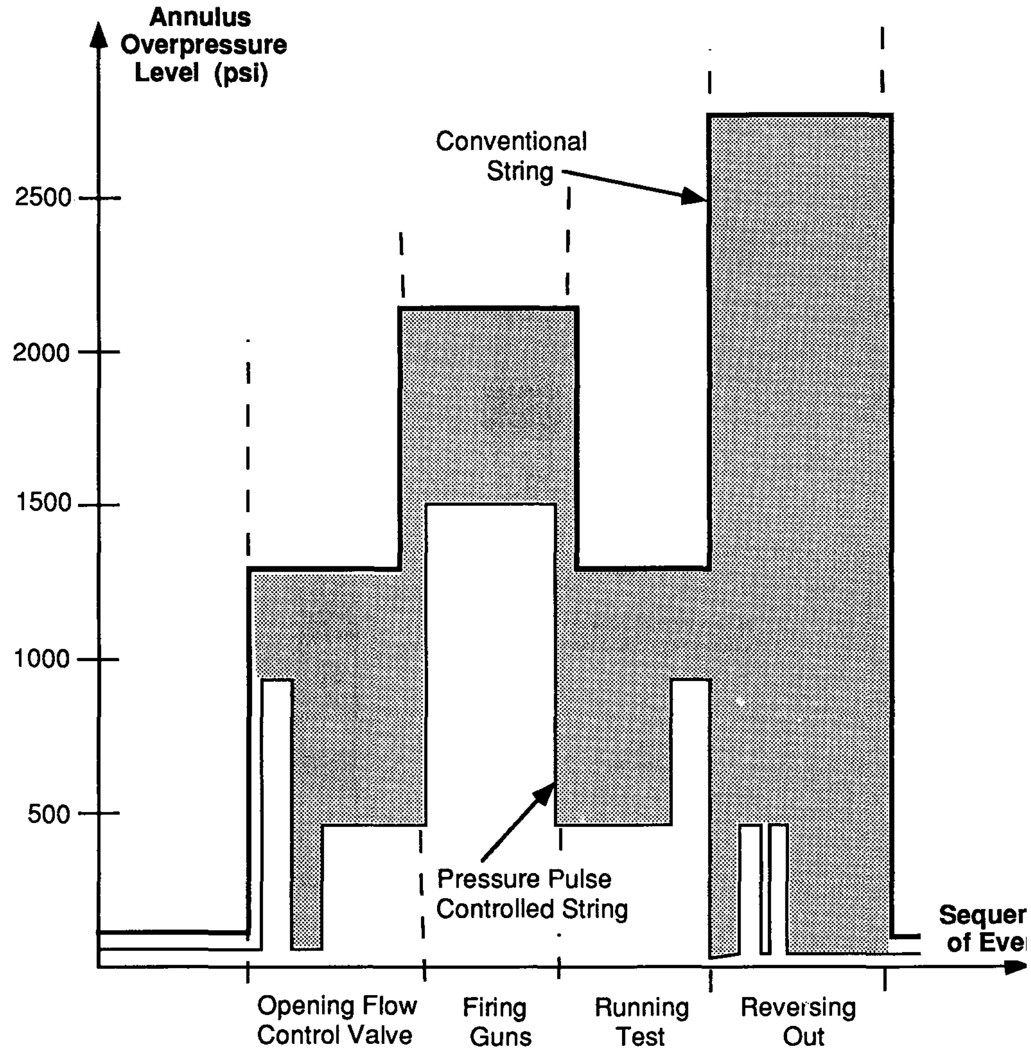

Fig. 5- Required annulus pressure profiles

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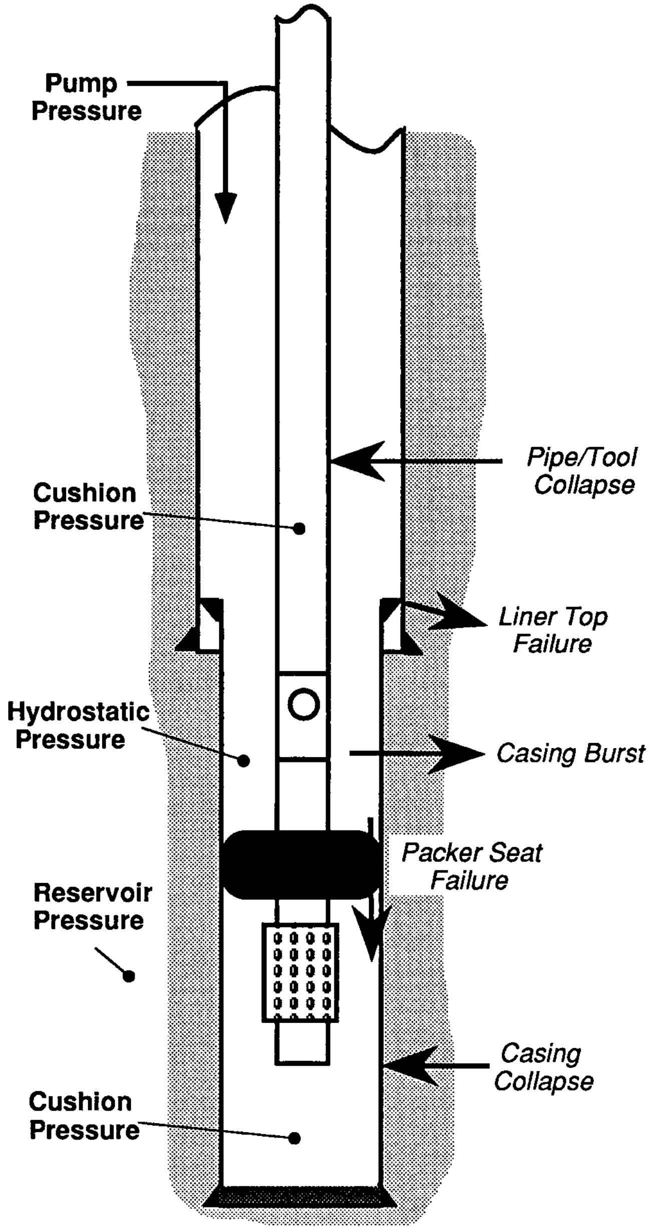

Fig. 6- Pressures in a DST design

Client:	ALPHA OIL	Test Number:	NAM #4
Well Name:	PQ 72	Tool Powerup Date:	12-MAR-91
Well Location:		Tool Powerup Hour:	09 hr 52 min
Service Order #:	329001	Header Filename:	MAR14DV.HDR
		Data Filename:	MAR14DV.JH1

OPERATION #00001
CMMD RCVD: 01-CLOSE CV #1
TL TIME RCVD: 00009 HRS, 00054 MIN
dP: 00466psi dt: 00018, 00024 sec
TOOL ID: 2 VLV TOOL, TOOL #1
COMMAND EXECUTED Y
+Vb: 00009.5v -Vb: - 00019.2v

OPERATION #00002
CMMD RCVD: A3-ENABLE TL #1 SM
TL TIME RCVD: 00018 HRS, 00059 MIN
dP: 01039psi dt: 00102, 00000 sec
TOOL ID: 2 VLV TOOL, TOOL #1
COMMAND EXECUTED ?
+Vb: 00009.7v -Vb: - 00019.3v

OPERATION #00003
CMMD RCVD: 70-SM OPEN TV
TL TIME RCVD: 00019 HRS, 00002 MIN
dP: 00505psi dt: 00000, 00000 sec
TOOL ID: 2 VLV TOOL, TOOL #1
COMMAND EXECUTED Y
+Vb: 00009.7v -Vb: - 00019.3v

OPERATION #00004
CMMD RCVD: 7A-SM CLOSE TV
TL TIME RCVD: 00019 HRS, 00013 MIN
dP: 00000psi dt: 00000, 00000 sec
TOOL ID: 2 VLV TOOL, TOOL #1
COMMAND EXECUTED Y
+Vb: 00009.7v -Vb: - 00019.3v

OPERATION #00005
CMMD RCVD: 75-LO PR DISABLE SM
TL TIME RCVD: 00020 HRS, 00008 MIN
dP: 00000psi dt: 00000, 00000 sec
TOOL ID: 2 VLV TOOL, TOOL #1
COMMAND EXECUTED ?
+Vb: 00009.7v -Vb: - 00019.3v

Fig. 7- Downhole job history file

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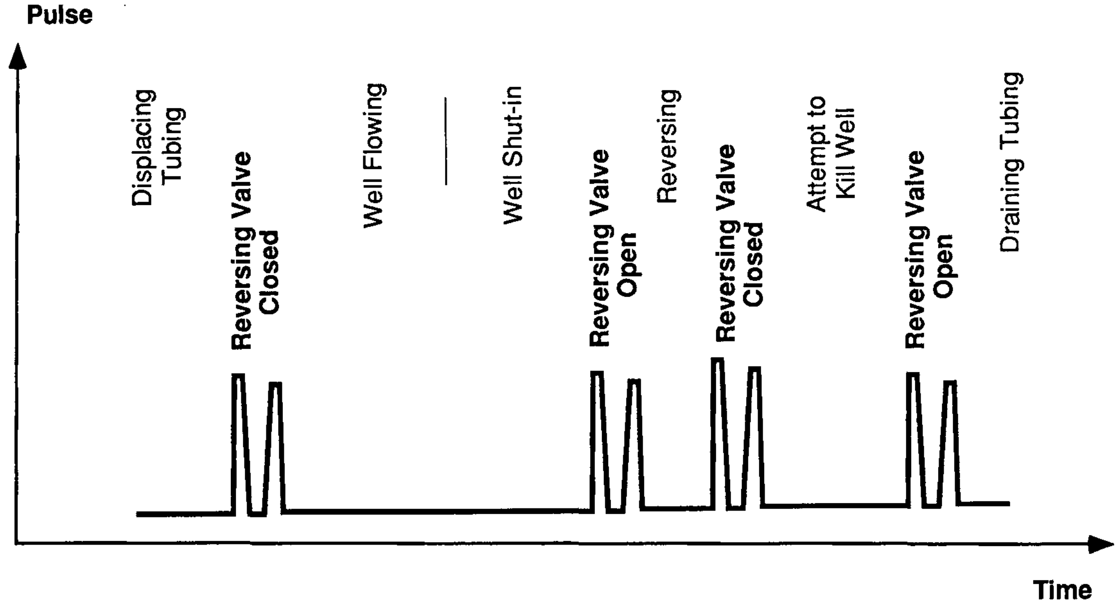

Fig. 8- Case history #1 pulse profile

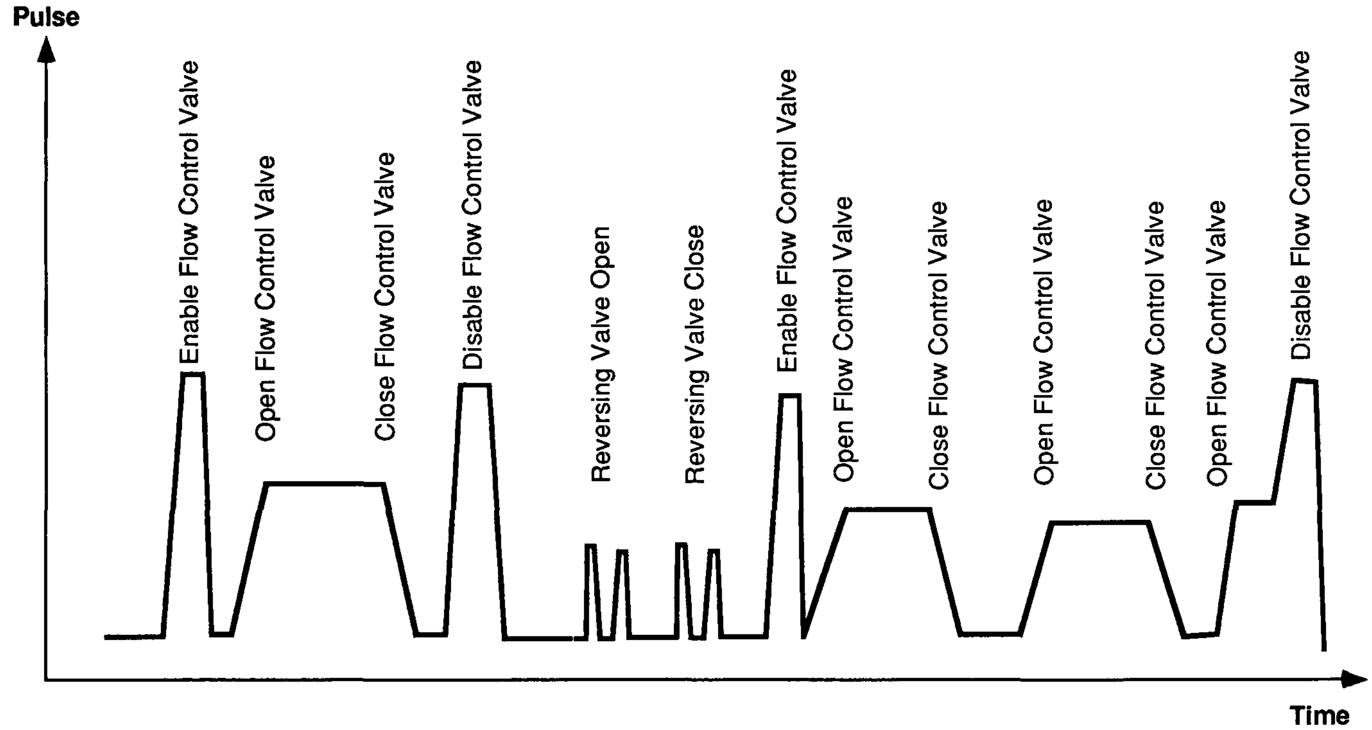

Fig. 9- Case history #2 pulse profile