OBTAINING FORMATION PRESSURE MEASUREMENTS WITHOUT A WIRELINE

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ABSTRACT

The goal of managing brown fields is to maximize the efficiency of recovering as much hydrocarbon as possible. Techniques such as the drilling of horizontal and multilateral wells are a cost-effective approach to increasing production and adding reservoir value. A critical element of drilling these wells is the efficient acquisition of formation evaluation data. In these brown fields, the understanding of formation pressure is necessary to understand reservoir connectivity and compartmentalization along the lengths of these wells. Conventional formation testing techniques have proven to be less-than-adequate for efficiently determining these reservoir parameters due to high operational costs and extreme operational risks. In this paper, a low-risk solution for obtaining formation pressures is described. This solution involves the use of a very small sized formation testing tool which is conveyed in and out of the well using robust operational planning, practices, and techniques.

The Compact Repeat Formation Tester (MFT), with a diameter of approximately 2.4 inches, is the only wireline testing tool that can be operated in memory mode without a wireline. The slim design allows it to be conveyed safely inside the drill pipe whilst maintaining the drill-string operational aspects of rotation and circulation. These operational aspects make this technique suitable for entry into wells with high dogleg severity and with extended reach. Two-way communication with the tool using mud pulse technology allows for interaction with the tool and for the monitoring of test results. In addition, all tool data is stored in onboard memory for retrieval after the formation tester is returned to the surface.

In this paper, several actual operations are discussed. In these operations, extensive operational planning and pre-job modeling was completed to allow for optimum data acquisition while minimizing total operational time. This pre-job planning allows the formation tester to be pre-programmed to accommodate as wide of range of test scenarios as possible. In the operations described, twenty two pressure stations were attempted in two wells to a depth of 2250.0 m under borehole conditions where information is usually not attainable. The data obtained from the stations was of good quality and the pressure results were subsequently confirmed by production. Additional examples are presented to demonstrate this new technique was successful in obtaining pressure data of highest quality and confidence allowing reservoir insights that would otherwise have been unavailable.

INTRODUCTION

Rejuvenating and sustaining production from brown fields involves employing technologies throughout the remainder of their lives to ensure maximum recovery can be achieved. Due to a past history of production, reservoirs in brown fields are commonly considered to be depleted and exhibit much lower formation pressures compared to original pressures. Contained in these reservoirs however, are undeveloped reserves which can be developed for incremental production. To recover these reserves, a strategy of drilling of horizontal injection sidetracks is often employed. In some cases, due to economic constraints, ultra-slim lateral wells are drilled from the mother bore. In these situations an understanding of formation pressures is critical in order to increase the injection volume under pressure lower so that it remains less than at frac pressure, and to determine efficiency of enhanced recovery techniques such as water or steam flood.

To measure formation pressure, wireline testing tools have been traditionally used. In high angle or horizontal wells, these tools are commonly attached to the end of the drill-string and pushed to the bottom of the well. To power the tools and to establish communication, an electric wireline is inserted through a side entry assembly on the surface, and is threaded inside the drill pipe where it connects to the top of the tools using a down-hole wet connector. Once the latch is connected to the tools, they are powered up and data is captured by operating the winch on the logging truck and draw works of the drilling rig in unison. There are however, several disadvantages to this method of traditional pipe-conveyed logging. These disadvantages are listed below:

- The tools are exposed to wellbore while running in blind, which means any bridges or obstructions encountered, can damage the tools directly. Also, the driller cannot circulate or rotate the pipe while running in the hole. These issues can limit the depth in which the tools can be conveyed.
- The wireline must be kept protected inside the casing, which limits the length of open hole that can be logged with a single latch to the length of casing.
- Multiple latches (runs) must be used for longer laterals due to the above limitations. The more wet connects (latches) that are made, the greater the risk of a latch failing. Also, multiple latches dramatically increase the amount of rig time required for logging operations.
- If the above precautions are ignored and wireline is run outside of the casing, it may easily be crushed or cut between the drill pipe and the borehole wall.
- Access into ultra-slim lateral wells is extremely risky or prohibitive due to the diameter of traditional open hole logging tools.

These conveyance challenges using this method of pipe conveyed logging are also present when attempting logging operations with other forms of logging tools such as triple combos.

In recent years the development of slimmer, more power efficient logging tools has allowed the use of a battery memory system to provide the ability to collect data without the use of a wireline, and a novel method developed to convey the tools in and out of the wellbore. Additionally the system allows duplex communication with the surface via pressure pulses in the mud column.

Initially this technique was used with a standard formation evaluation suite of tools comprising resistivity, density, neutron porosity, sonic, and natural gamma ray. The technique involves the latching of the tools inside a special BHA assembly for the trip into the well, and once at total depth, pumped into the open hole. The log data is then recorded to a down-hole memory sub as the drill pipe is pulled from the well. The advantages of this type of logging operation are listed below:

- The tools are protected from the potentially harsh conditions in the wellbore and can survive any encounters with any bridges or obstructions. Also, the driller can circulate or rotate the pipe while running in the hole, which means if drill pipe can get to TD, the logging tools can also get safely to TD.
- There is no need for wireline in this operation. This features eliminates the following:
    - time consuming operation of the logging truck winch in unison with the draw works of the drilling rig.
    - any issues of electrically latching to the logging tools
    - no need for time consuming multiple latches
    - no risk of having the wireline crushed or cut between the drill pipe and the borehole wall.
- Safe access into ultra slim wells is possible.

The application of this technique was recently extended to include a slim formation tester. As the successful operation of formation testing tools is dependent on the interactions between an operator on the surface and the down-hole tool, numerous challenges were overcome in order for tests to be conducted with verification of the results. The use of this method greatly improved the ability to obtain formation pressures in challenging well bore conditions while reducing the risks associated with traditional methods.

THE COMPACT FORMATION TESTER OVERVIEW

The compact formation tester used in battery memory operations is 2.4" diameter and can be fitted with a range of pads to conform well to the borehole wall when set. This tool has been used in a range of hole sizes from 3 7/8 inches to 12 ¼ inches. The current tool measures formation pressures only however it is planned to add sampling capability in the near future. It may be combined with a range of other tools, typically a gamma ray for depth correlation and a navigation sub for orientation purposes. A simple gamma ray tester combination in wireline mode is only 7.45m long.

The "Scissor Jack" design of the tester predicates centralised operation, an added advantage being less susceptibility to differential sticking in the well bore. Consequently, over-body centralisers are utilized to optimally position the tool. The Figure 1 shows the significant size reduction compared to previous generation tools.

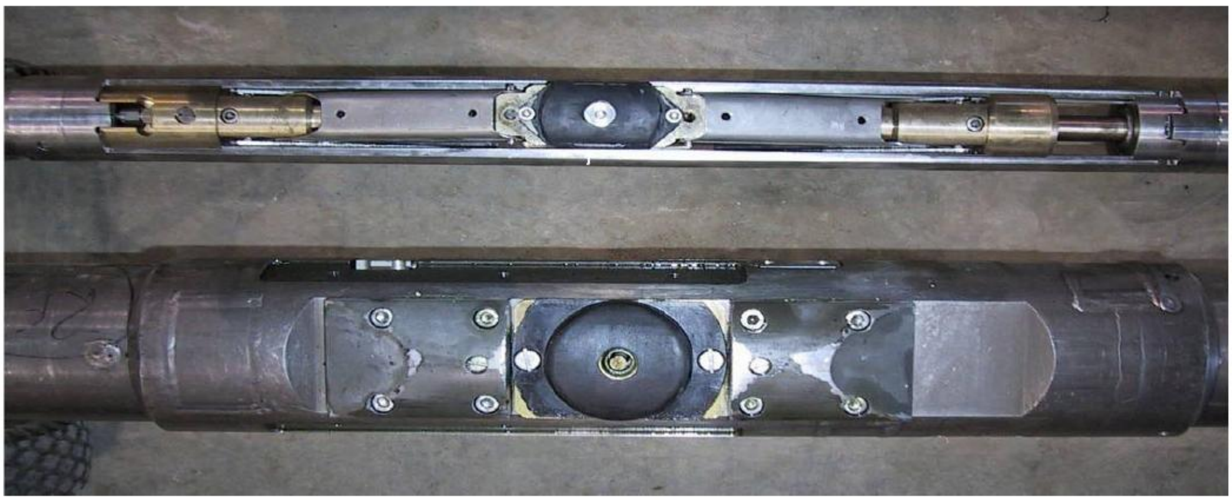

Figure 1. The Compact Formation Testing Tool (top) compared to traditional sized testing tools.

The design specifications are as follows:

- Sidewall force = variable to 3,307 lb
- Drawdown = 8,000 psi max.
- Maximum pretest volume = 40 cc
- Pretest can be repeated without retracting tool
- Pretest drawdown rate - programmable (max.1cc/sec)
- Quartz gauge with Strain gauge back up
- Combinable
- 9cc Flowline Storage
- Choice of pad sizes

CONVEYANCE METHOD

To convey the formation tester along highly deviated and horizontal wellbores a well shuttle type system is used. Battery/memory functionality is added to formation tester along with a control tool and orientation hardware. These tools are held within the BHA of the drill string by a latching system, completely protected from the open hole, and conveyed to the end of the well on drill pipe. When total depth is reached and space out performed, the tools are unlatched from within the BHA by means of pressure and deployed into open hole, a no go on the top of the tool body engaging with a landing ring at the bottom of the BHA. The drill pipe is then moved back along the hole to position the tester at the required depth. An optional navigation tool may be run with the formation tester to provide tool orientation data while testing.

COMMUNICATION METHOD

Communications to and from the tools are via mud pulse. The rig pump is used to generate pulses to issue commands the tool; the response from the tool is generated by throttling the mud flow through the control tool, thus causing the circulating pressure to rise The control tool is driven by the memory tool and contains a pressure sensor which measures hydrostatic pressure and inputs that data into an algorithm running in the memory tool and a motor drive arrangement that restricts the mud circulation through the tool in response to commands from the memory tool. The memory tool responds to pressure variations in the mud column as measured by the control tool, and issues varying commands to the tools below dependent on the pressure variations.

APPLICATIONS OF MEMORY FORMATION TESTING

Using the above communication method in conjunction with a small memory formation tester allows rudimentary duplex communication between the surface and down-hole tools using pressure pulses of predetermined level and height. The memory tool continuously analyses the pressure data looking for pulses that match preprogrammed parameters, and on making a match instructs the tester accordingly. After a command is issued to the tester, the memory awaits a status reply from the tester. Once received, the memory tool communicates this status reply to the surface by changing the mudflow through the control tool, thereby changing the circulating pressure in the rig standpipe. This pressure modulation can be recorded at surface. The parameters for the actual formation test itself are stored in the tester itself and can be preprogrammed prior to the job. The programmed tests are adjustable in terms of time, drawdown rate and volume. The maximum drawdown rate is 1cc/second and total pretest volume available is 40cc. It also possible to pretest twice during a test sequence at two different rates (Figure 2).

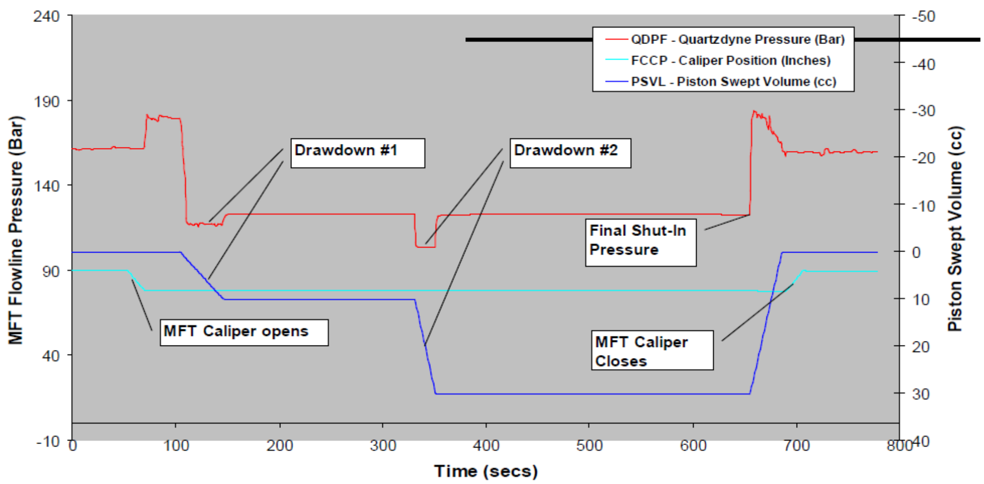

Figure 2. Plot of MFT Function during pre-test routine.

There are currently four commands available: Status Request (as described above), Release, Perform Formation Test, and Repower (Figure 3).

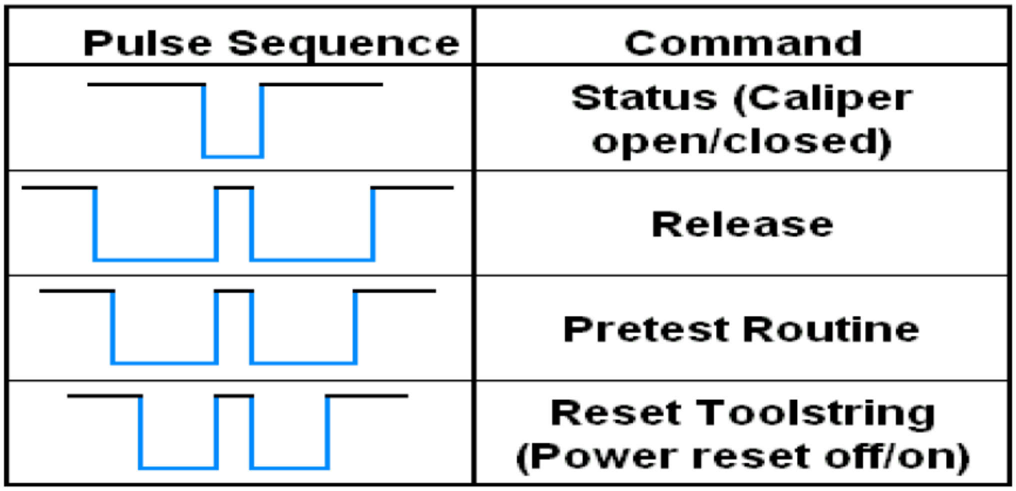

Figure 3. Mud Pulse Commands to operate MFT

As the tools are conveyed to total depth latched inside the bottom hole assembly, they must then be released and landed off to expose the sensors to open hole. This release is affected by sending two pressure pulses from surface. The memory tool recognises these pulses and causes the control tool to release the latches allowing the tool-string to be deployed into open hole, the top of the tool-string landed of in the landing ring. This release sequence can be seen at surface and confirms the correct deployment of the logging string (Figure 4).

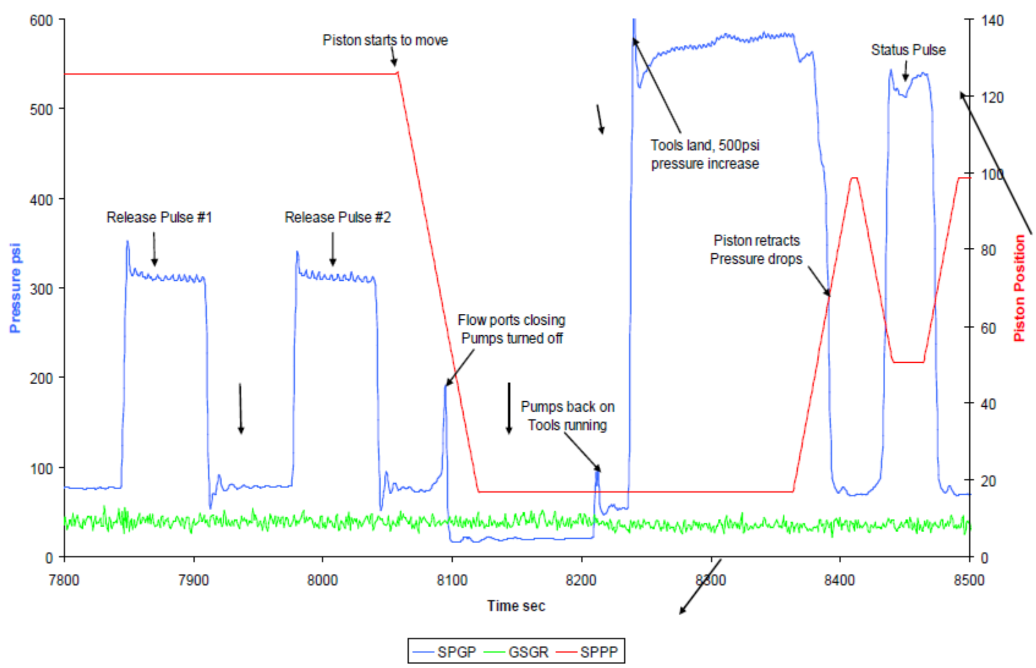

Figure 4. Release Pulse Detail

The drill pipe is then moved to each required testing depth station and the Perform Formation Test command issued via mud pulse. Upon receipt of this command the memory tool instructs the formation tester to set its packer against the borehole wall, perform the pre-programmed draw down and then retract the packer from the borehole wall. At the end on the sequence the tool will send a sequence complete signal to surface (Figure 5).

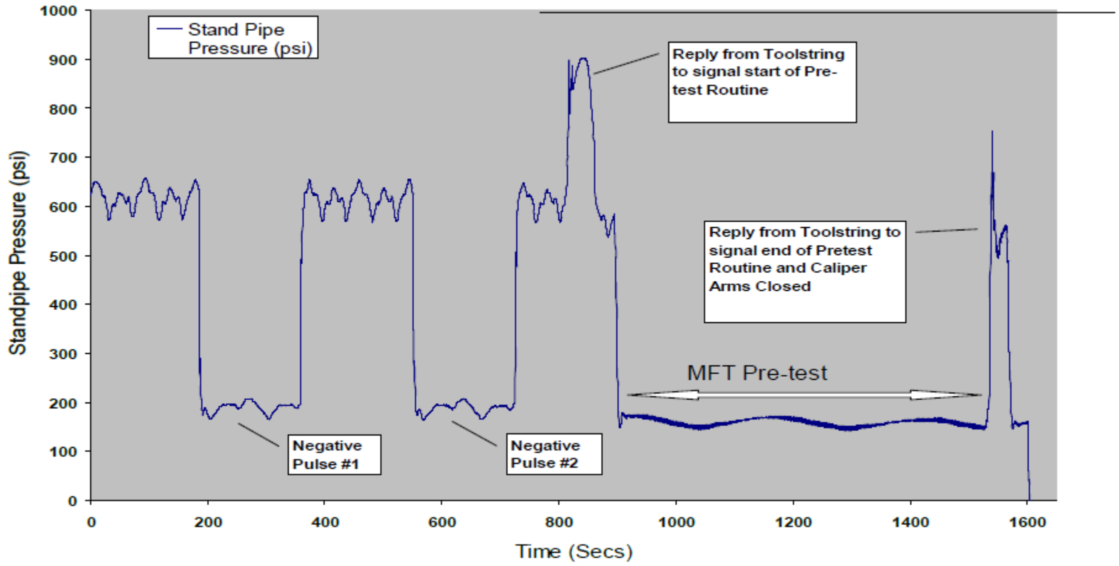

Figure 5. Stand Pipe Pressure During MFT

At this point an algorithm is run over the recorded pressure data to measure the ΔP (Figure 6).

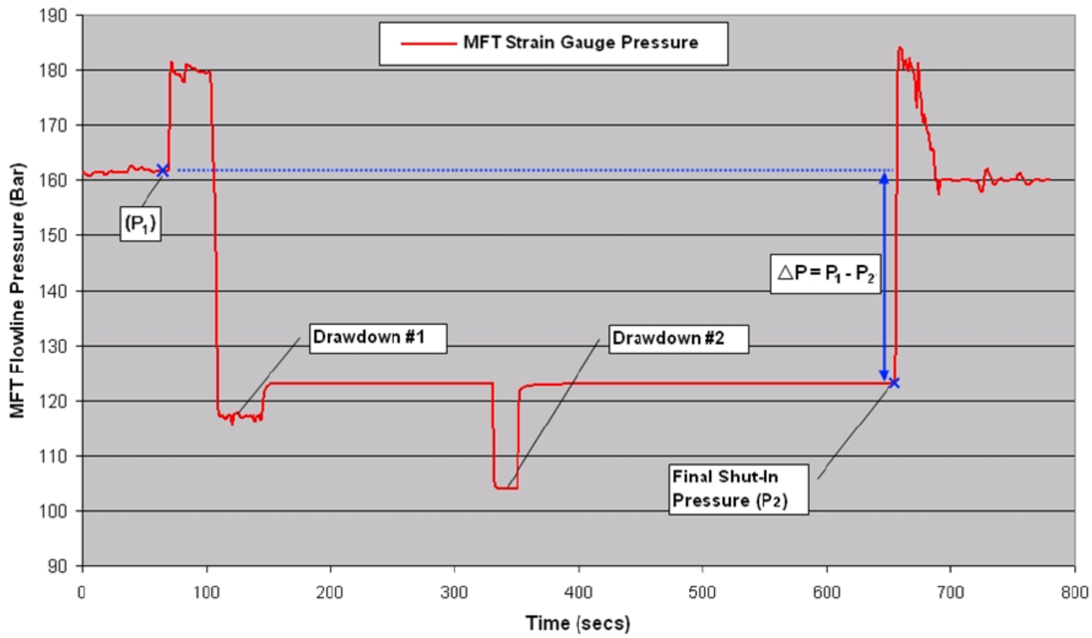

Figure 6. Measuring Delta P

The measured ΔP is then modulated onto the circulating mud column in the form of a 12 bit number by the control tool, which can be recorded at surface. The pulse width defines the value of each digit and is decoded real time on surface by pressure recording software (Figure 7).

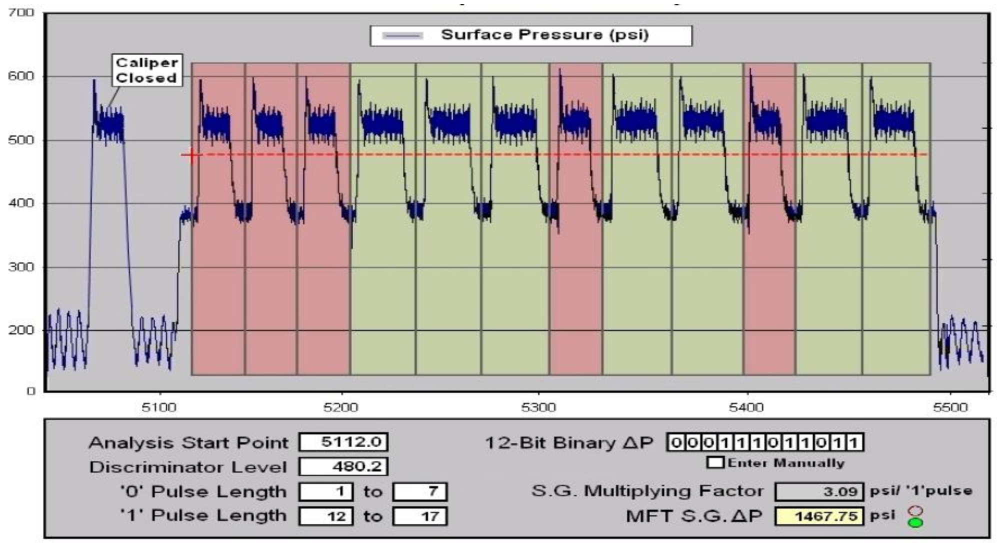

Figure 7. 12 bit analysis of Delta P

The ΔP data is valuable as a quality control measure for the data as it defines the success or otherwise of the pressure test. With these data three test differing test results can be defined: no seal, tight test and good test. A test may be repeated if a lost seal is indicated, or the pipe moved to the next station in the case of a good test. As the data is transmitted with the most significant bit first a tight test can be quickly identified (Figure 8).

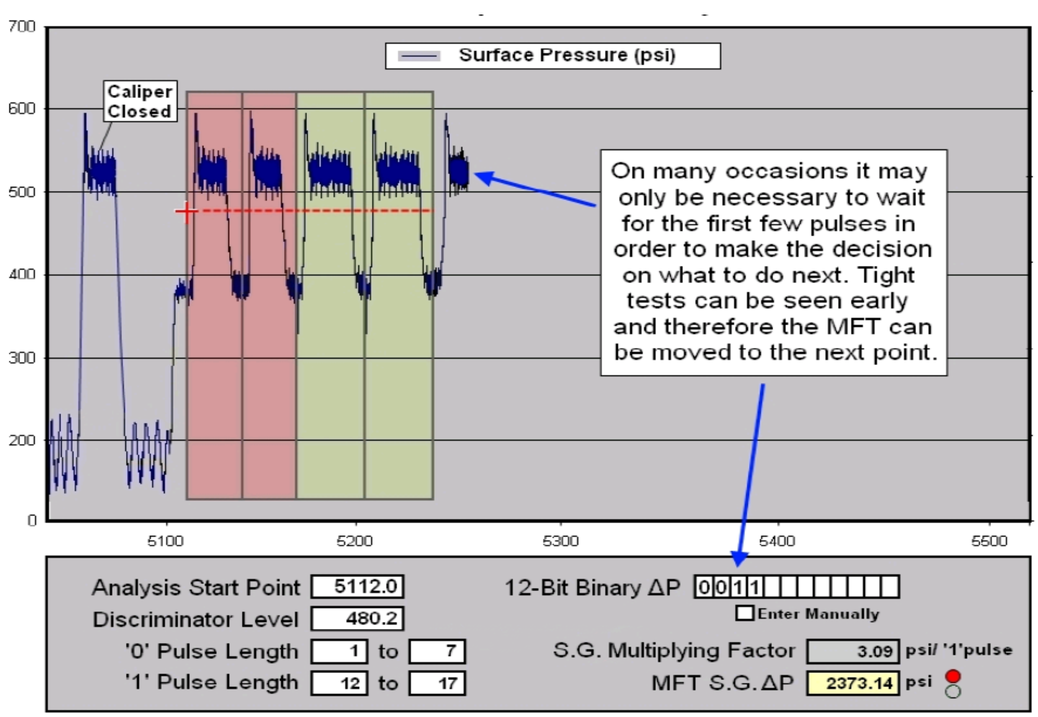

Figure 8. Tight tests can be identified with only a few return pulses

REAL TIME RESULTS

The system has been used in several wells in the past few years in the following countries:

Austria. This country was the first location where this technology was employed. In this case, the objective was to obtain formation pressure information along the length of horizontal wells to generate pressure gradients in a faulted reservoir in order to measure the amount of reservoir depletion and assess the suitability of the well for gas storage. In addition, the need to perform testing operations with the least amount of risk while maintaining full control of the well was essential. The ability to rotate the drill pipe and circulate while deploying the testing tool was an obvious advantage in maintaining well control.

In this first deployment of this technology, it became apparent that the lack of immediate feedback and control during the formation testing operation limited the available options during the test sequence. As mentioned earlier, the tool was pre-programmed with what was thought to be the "best" options for the tool operations based on experience operating the tool in conventional wireline operations. These scenarios were then modeled to try and identify the best operational sequence.

Testing Experience – Well #1 The first run of this technology was a proof of concept of the measurement. For the first well, an additional run was made with a formation caliper tool to aid in selecting the best points where it was felt a mechanical seal could be made. Seven stations were attempted with no direct feedback to the surface indicating whether the individual test was successful. Once the tool was retrieved at surface the data was downloaded for analysis. Several key things were learned during this first field test.

- The lack of feedback about test quality hindered operations. Development was immediately started on a simple algorithm for identifying and communicating the relative quality of a given station to the surface.
- The downlink operation to the tool took longer and was less reliable than initially hoped. The 8 stations that were attempted took almost 24 hours with all the tool issues.
- There was a firmware issue that shut the tool down if there was an "overcurrent" condition

The data from this initial field trial provided enough value that the client decided to continue to aid in the development of the technology.

Testing Experience – Well #2 The second run of this technology proved to be more reliable in gathering station pressure measurements. However, the lack of real time feedback again proved to be a limiting factor on the success of the operation. During the second well, 15 stations were attempted with 5 stations classified as "no-seat" tests. The lack of other information about the hole condition proved to be a limiting factor. From this field test, it became apparent that the need for a near time feedback algorithm was critical to the success of this technology.

Testing Experience – Well #3 The third run of this technology proved to be the most successful to date. All the stations that were attempted during the run were successful.

New Zealand. The successful operations in Austria led to the deployment of the technology in an offshore environment in the Tasman Sea. Due to the fact that testing operations can be conducted without a wireline, the need for a wireline unit on the platform was not necessary. This eliminated the logistics and costs associated with employing a wireline unit in the offshore platform. The need for formation pressure measurements in this application were a key part of the strategy in a redevelopment plan of an aging field that was intended to extend life by 10 years. In this application, this technology was deployed in slim sidetrack wells that were drilled to unlock large pockets of remaining gas.

Russia. The use of memory based formation pressure testing has been adopted in Russia as alternative to wireline drill pipe conveyed logging. Successful formation pressure acquisition was performed in several slim highly deviated S -shaped sidetrack wells with less risk compared to deploying larger wireline testing tools. Data from the memory formation tester obtained from the clastic reservoirs of both the Priobskoe and Malobalykskoe fields, is used to monitor depletion, optimize injection program, and identify fluid contacts.

CONCLUSIONS

- The acquisition of formation pressure measurements are an integral part of formation evaluation programs in brown fields.
- Running the compact formation tester in memory mode is a viable alternative to wireline drill pipe conveyed or LWD formation tester conveyance technologies, due to reduced operational risk, and access into slim and ultra slim side track wells.
- Operational success improves dramatically with proper pre-job planning and careful evaluation of other measurements.
- Improvements in operational techniques in recent years have expanded the use of this technology.

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