Deepwater testing, trials & triumphs

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Testing exploration and appraisal (E&A) wells offshore is becoming increasingly costly; in particular when operating in deeper water environments – deepwater wells require deep pockets. Ron Fordyce, Expro Drill Stem Testing (DST), discusses the challenges of meeting key well test objectives in high cost operating conditions, and how Expro is strategically aligned to do so.

Expro is committed to advancing technology in the field of Drill Stem Testing and our investment is driven by the requirements of existing and emerging markets; not least meeting the demands of offshore deepwater well testing. This has resulted in the development of the EXAL DST tool suite.

From a downhole perspective, primary objectives are to capture pressure and temperature data during flowing (drawdown) and shut-in (build-up) periods and to acquire representative reservoir fluid samples. A downhole tool string therefore must facilitate perforating the well, displacement of under-balancing and treatment fluids, opening and closing the well to allow such data to captured and transmitted, and to provide the necessary well control capability during deployment, well testing and subsequent well-killing.

E&A well testing (often referred to as a DST), is performed during the evaluation phase of a reservoir; therefore the principle objective is to acquire data, both at surface and downhole. The integration and analysis of such data allows operators to establish key parameters such as initial reservoir pressure, permeability and skin. This allows for informed decisions on further appraisal work and ultimately, the commercial viability and optimum exploitation of the reservoir.

In essence, the DST string is a temporary ‘completion’ comprised of a ‘major’ and ‘minor’ string. The minor string, the DST tool bottom-hole assembly (BHA), is connected to surface by the major string, which is the production tubing. In subsea applications from a floating vessel, a ‘landing’ string will be deployed within the marine riser. Should it become necessary, the well can be quickly shut in and disconnected via a subsea test tree situated within the BOP stack.

Fundamentally, the DST BHA facilitates:

- The string to self-fill while running in hole
- Multiple pressure testing of the tubing string
- Isolated annulus and producing formation
- Through-tubing access to the producing zone
- Displacement of under-balancing fluid (liquid or nitrogen cushion)
- Perforation of the casing/liner adjacent to the formation
- Allows the well to be flowed (multiple openings)
- Shut-in the well downhole to avoid wellbore storage effects (multiple shut-ins)
- Reverses produced fluids from the well
- Killing of the well
- Tubing string to expand and contract during flow and stimulation operations, respectively
- Records pressure and temperature data using downhole memory gauges; with the option to transmit data to surface via wireline pick-up or wireless telemetry
- Downhole PVT samples
- DST tools, gauge data and PVT samples are brought to surface
- Offers redundancy/contingencies to facilitate the above

Expro's philosophy has been to advance the design and performance capabilities of hydraulically operated cased-hole DST tools, rather than adopting systems that require electronics and batteries. This can add complexity to tool operation and maintenance, and constrains working temperatures and the number of available operating cycles.

The EXAL DST tool suite is therefore fully annulus operated and optimised for fast and efficient deployment and operation down hole - paramount in high cost operations such as deepwater.

Deepwater applications from a downhole tool perspective

What makes deepwater applications different? Essentially, not a great deal when considering how downhole (DST) tools operate. The technology is set up to operate with the application of annulus pressure over hydrostatic pressure, exerted by the annulus fluid; typically a mud or brine.

Annulus fluid has to allow pressure transmission, therefore must be well conditioned; more so with solids-laden muds than clear brines. The hydrostatic pressure is a function of mud weight and true vertical depth (TVD). The datum is effectively the rig floor (RKB), therefore, DST tools will see the same hydrostatic pressure for a given TVD irrespective of whether the

well is on land or offshore; meaning water depth is not a significant factor in how the tools operate.

How fast and efficiently they can be safely deployed, operated and retrieved, which includes functional consolidation within the tool suite, is the key factor. As stressed previously, the drilling vessels that operate in deeper waters command premium day rates and in these conditions, time is money.

The DST BHA can be considered as modules, depending on what functionality operators require in any given well.

- DST tools including pressure/temperature memory gauges (base case)
- Real-time surface read out (SRO) system with full telemetry or wireline pick-up (optional)
- Tubing conveyed sampler carrier (optional)
- Tubing conveyed perforating system (optional)

Although ‘optional’, the systems above are commonly deployed in deep water DSTs; principally to minimise critical path rig time.

Real-time SRO system

In addition to conventional downhole memory gauges, SRO can be incorporated to provide real-time downhole pressure and temperature data, which also includes the downloading and transmission of the data already recorded to memory.

Expro's CaTS™ system uses advanced wireless telemetry technology to transmit data using electromagnetic (EM) through-tubing/casing communication. Access to surface readout data provides early confirmation that the quality and quantity of data collected is adequate to characterise the reservoir, leading to early decision making and dynamic optimisation of the testing program.

This ensures:

a) The well has been flowed long enough to meet the test objectives, such as fault or boundary recognition; hence a valid well test and no retest required.

b) Visibility in minimising pressure build-up periods to save associated rig time.

The fully wireless system means no wireline intervention is required; reducing risk and rig time.

Tubing conveyed sampling (TCS)

The collection of representative bottom-hole PVT fluid samples is a key objective in most DST's. Expro's tubing conveyed sampling system provides a multi-unit, flexible, high-quality alternative to traditional wireline conveyed sampling. As the samplers are run with the DST string, no wireline intervention is required; again reducing associated risk, resource and time. The samplers can be activated at will, either by applying annulus pressure to burst pre-selected rupture disks or electronic triggers using signature commands.

Tubing conveyed perforating systems (TCP)

E&A wells are generally cased, with the casing/liner cemented in place. This is required in unstable boreholes (e.g. unconsolidated sandstone), or when zone isolation is required. In many cases, more than one zone of interest will be tested in a single well, either in isolation or co-mingled.

The producing formations (zones) are accessed by perforating through the casing and cement, and into the rock itself. Single trip underbalanced perforating, utilising TCP guns, is preferred in E&A DSTs. TCP guns also allow maximum well productivity and whilst this may not be necessary for a well test; it is an opportunity to assess and confirm the optimum perforating strategy for ensuing development wells.

To this end, Expro's full range of high performance TCP gun systems which includes proprietary firing heads, gun releases, vent subs and other associated equipment for fully intervention-less operations; preferred in deep water applications.

DST tools

The DST tools incorporated in the BHA are dictated by functional and sometimes mandatory/regulatory requirements. Whilst Expro has a 25+ year track record in conventional cased-hole DST tools (which are 5" OD and 2.25" ID rated to 15,000 psi and 350°F, as per NACE MR-01-75), newer tools have been developed to specifically meet the demands of E&A well testing across the well type spectrum, with a particular emphasis on deepwater applications. The additional functionality from our new generation EXAL DST tools means that fully integrated solutions can be provided at 15,000 psi differential pressures up to 350°F, with planned upgrades available at 400°F for multi-cycle tools and 450°F for single-shot tools.

Self Fill - Tubing Test Valve (SF-TTV)

Expro's new generation 'flapper-type' SF-TTV is a departure from traditional designs. The main purpose of the valve is to allow the tubing string to fill from below for multiple pressure tests whilst running in hole. After the final pressure test, the valve requires to be locked out

of service leaving an unobstructed bore. A lower and upper SF-TTV can be incorporated in HP/HT DST strings, with the upper SF-TTV isolating the DST tools (having atmospheric chambers) and pressure/temperature gauges from unnecessary high pressure tests i.e. the tools see absolute pressure down hole which, for example, would be 30,000 psi in the case of 15,000 psi hydrostatic plus 15,000 psi applied from surface.

The Expro SF-TTV achieves this by using a unique tubing-to-tubing bypass (patent pending). The flapper, which is housed in a ported inner sleeve sub-assembly, is pinned closed and never leaves its seat, and therefore cannot wash out whilst running in-hole.

Moreover, it is debris tolerant, meaning no debris can lodge across the seat and cause the valve to fail. A string pressure test is achieved by pumping down the tubing, which at minimal rates, creates back-pressure moving the flapper assembly downwards to close the bypass. On releasing the pressure, a spring returns the flapper assembly to the self-fill, run-in-hole position.

There is no limit to the number of pressure tests and when required, the SF-TTV is locked out of service by applying pressure to the annulus to burst a pre-selected rupture disk, shifting the flow mandrel up through the flapper before locking out.

The incorporated tubing-to-tubing bypass feature delivers additional functional benefits in the following scenarios:

- When exiting seal-bore packers during space-out operations, traditional flapper valves of this kind, will seal and therefore pressure lock. The solution is to incorporate an annulus-to-tubing bypass, below the flapper, which can compromise string integrity.

- When making tubing string connections at the rotary table on floating vessels, traditional flapper valves will hold fluid, and hamper make-up operations; due to mud spilling over on the upstroke. This results in non-productive time and also has safety implications. Our tubing-to-tubing bypass allows fluid to drain back as the string is raised with rig heave.

EXACT™ Tool

The EXACT tool is a fully annulus-operated combined multi-cycle circulating and tester valve. This in itself reduces potential leak paths. The ball valve allows the well to be shut-in downhole, and the circulating parts facilitate the spotting of under-balance or treatment fluids, and reverse and forward circulating during well kill operations.

It incorporates a nitrogen chamber which compensates for changes in annulus hydrostatic pressures at depth and a trap system (ARTS), which locks an operating reference pressure in the tool.

The tool has three functional positions: Ball open – Ports closed; Ball closed – Ports closed; Ball closed – Ports open. The tool is governed by an indexing sleeve which works in conjunction with a 'SmartCollet' and interlock, and can be moved to the desired functional position by applying and bleeding annulus pressure. In-house simulation software is utilised to determine the nitrogen pre-charge pressure for specific downhole pressure and temperature conditions, together with the required applied operating pressure at each tool position. Importantly, as the tool is mechanically coupled, the ball and ports cannot be open simultaneously.

The tool has been designed to fully operate with 2,000 psi applied annulus pressure. It is important to leave as large an operating widow as possible to activate other annulus operated tools in the BHA; in particular rupture disk fired PVT samples, which will generally be set-up to activate form 2,500 psi (upwards) applied annulus pressure. This tool is flexible and efficient, requiring minimal cycles, (max. 4), to get from one of the above functional positions to any other, and there are no waiting times between cycles.

The ball can withstand 15,000 psi differential from above and below and can be opened with 7,500 psi differential from above or below. The ports can withstand circulation rates in excess of 10 bbls/min at low back-pressures. This is primarily due the tool being annulus operated - tubing operated circulating valves, by design, will close when at a predetermined pump rate, hence forward circulating rate is limited. EXACT can therefore reduce circulating times by more than half.

Additional time savings can be realised in gas wells where with a tubing operated circulating valve, it takes longer to cycle tubing full of gas.

APEX Packer System

In deepwater DST applications, the subsea landing string becomes more complex and will generally utilise an electro-hydraulic control system, to reduce bleed off (response) times though the umbilical hoses. Such systems can prohibit rotation of the test string, which is the most common method required to set typical compression (weight) set retrievable hook-wall packers used in one trip DST applications.

Commonly, operators utilise a permanent production packer, with a seal-bore extension into which a locator seal assembly (incorporated in the DST BHA), is stabbed. These 'floating' seals therefore account for string movement (expansion and contraction) due to temperature

and pressure changes during the well test; thus negating the need to include multiple slip joints.

Though this is a high integrity solution, it requires two trips in the hole; one to run and set the packer (on drill pipe or wireline, depending on tailpipe weight and well deviation), the other to deploy the test string. It also requires a ‘space-out’ trip after the string is correlated on depth, should the seal assembly need repositioned; i.e. tubing may need to be added or removed and this has to be below the landing string as it lands out in the subsea wellhead.

Furthermore, should the permanent packer need to be removed from the well, yet another drill pipe run is needed to mill and retrieve the packer. These are consumable items and costly to purchase on a well-by-well basis, however this cost is low when compared to associated rig time.

Expro’s solution is the APEX packer system (APEX), which is a single-trip, hydraulically (hydrostatic) set, sealbore packer with integrated seal assembly. Combining production packer integrity with retrievable hook-wall packer functionality, it is set with the application of annulus pressure rupturing a pre-selected burst disk.

The tool’s multifunctional and compact design replaces certain DST tools and with no requirement for drill collars, significantly reduces the number of connections, saving rig time and removing potential leak paths. APEX features a locator seal assembly, which removes the need for multiple slip joints. There is also no need for a space-out trip as the locator is pre-set in the required position at surface before deployment. APEX can incorporate a single shot circulating device for efficient below-packer circulating.

APEX is released with straight pull and the entire string is retrieved from the well. Prior to fully un-setting, the string can be picked up to open a bypass, which equalises across the packer and also allows for bull-heading and flow-checking. Multi-opening and closing of the bypass is also possible without un-setting the packer. As a contingency, a back-up release (requiring over-pull) will release the locator and the DST BHA including the down hole gauges are recovered from the well. The packer assembly can then be retrieved on a separate ‘fishing’ trip using a dedicated retrieval tool. (The APEX tool is set to be qualified in accordance with ISO 14310 Level V3)

The EXAL tool suite provides a tailored solution, delivering exceptional value to clients, ensuring their well test objectives are met in a safe, functional and efficient manner; essential in deep water well applications.