Cemented completions reduce costs in North Sea

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THE POTENTIAL DOWNSIDES of cemented monobore completions, such as remedial cementation and the possibility of failing to get the string to TD due to hole problems, have previously stopped companies from using this technology.

But the need to deliver a low cost solution in today's high cost North Sea environment has driven **KCA Drilling** and **Shell Expro** to challenge the traditionally accepted practices and standards to design and deliver the first cemented completions.

KCA is the lead drilling contractor to Shell Expro's Northern Business Unit (NBU).

KCA manages NBU drilling operations including provision of drill crews and drilling engineering support for all nine NBU platform rigs, namely Brent A, B, C, D, Cormorant Alpha, North Cormorant, Tern, Eider and Dunlin. **Shell UK Exploration and Production** (known as Shell Expro) is operator in the UK sector of the North Sea for Shell, **Exxon Mobil** and other co-venturers.

THE CONCEPT

The cemented completion concept is a fundamentally simple one.

The reservoir open hole section is drilled to the required depth and following electric logging (if required) the completion tubing is run into the open hole and cemented back inside the previous casing shoe or window.

The Christmas tree is then installed and the well perforated in the normal manner.

TIME, HARDWARE SAVINGS

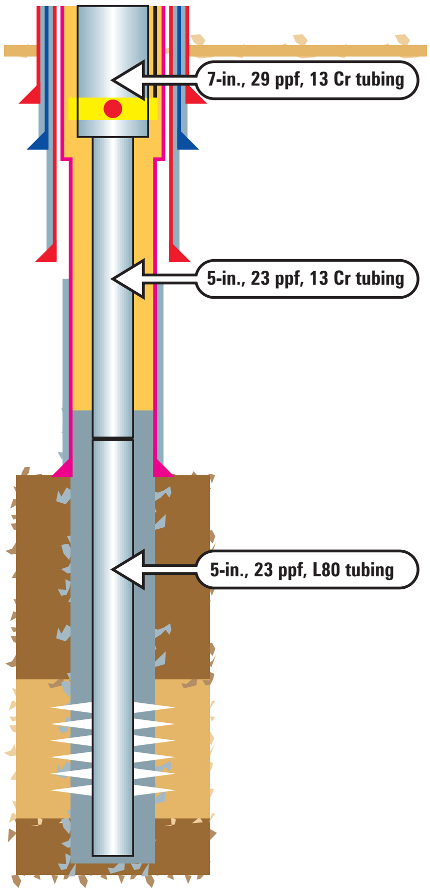
The key advantage of cemented over conventional completions is that it saves 5-7 days rig time during installation by eliminating such operations as running and cementing liner, wellbore clean up and packer setting procedures.

In addition, the number of liner and completion accessories required, such as packers, liner hangers, PBRs, nipples etc, is greatly reduced. The per-well time and hardware savings is estimated at £0.5 - 1.0 million.

Cemented completions have already been used in low cost operating areas around the world but well CA-28S2 on Shell Expro's Cormorant Alpha platform marked the first cemented completion to be performed in the North Sea.

At time of writing, two Cormorant Alpha and three North Cormorant wells have been successfully completed in this manner. All have demonstrated considerable cost savings as a result, with three of the five wells completed in 50% of the planned time.

Cemented completion scheme



CA-28S2 was selected as the ideal candidate for evaluating the method due to its short 6-in. open hole length of 708 ft and near-vertical inclination.

Since then, open hole lengths have been progressively increased, culminating in CN-28S1 which was successfully completed with 6,500 ft of 8 ½-in. open hole at 67 degrees inclination.

DESIGN CONSIDERATIONS

Although the basic concept is simple, careful planning and attention to detail are essential if the operation is to be performed effectively.

Prior to cementation, the tubing hanger is landed off, tied down and pressure tested. The control and balance lines are attached back to the control system. The big bore safety valve dummy is then removed to avoid a restriction for the cementing plugs.

The cementation takes place though the completion tubing with returns back through the A annulus valves. Both A annulus outlets should be used to minimize back pressures.

Since cement acts effectively as the completion packer in this design it is imperative that cement is returned back inside the previous casing window.

Careful consideration must be given to the cement volumes used, and in these circumstances an LWD or electric line caliper log is valuable. Extensive modeling is required to predict the likelihood of losses and channeling.

Also, with the presence of control and balance lines no rotation is possible during cementation. Optimal centralization therefore takes on an additional importance and again must be modeled.

Fallback options have been developed for most of the likely failure scenarios. If cement is not achieved back inside the window, for instance, one fallback option is to cut and recover the tubing above top of cement and then re-complete with an overshot and conventional packer.

Cementing is performed via a surface launch cement head. A single combination bottom plug is launched prior to cementation to confirm passage of the plug though the completion and calculate actual displacement volumes. Dual combination top plugs are launched behind the slurry to minimize the risks of cement bypass and a cement sheath remaining inside the tubing.

This is particularly important since the slurry is displaced with seawater with no planned clean out prior to perforation.

Bumping the plug is important under

these circumstances. Remedial cleanouts using coil and 2 $^7/_8$-in. pipe were, however, performed on the first two jobs due to cement plug bypass and congealed mud residue respectively.

Lessons learned here included further simplifying string ID changes and using dual top plugs behind the cement.

Rigorous well site procedures have also been developed for clean out of surface lines prior to cement displacement.

Interestingly, early concerns surrounding the passage of cement and plugs through an unprotected safety valve nipple have proven to be unfounded.

The nipple is greased internally prior to installation and hydraulic fluid is flushed through it continuously during the cementation.

To date, no problems with the subsequent installation and testing of the safety valve have been experienced.

The tubing is pressure tested on bump and both the tubing and annulus are inflow tested. Wireline runs are then performed to drift the tubing, clean the SSSV nipple profile and set a dummy or protection sleeve at this stage as required by the forward program.

Meanwhile, the cement slurry is designed to have achieved adequate compressive strength at this time.

A nominal annulus pressure test to a pressure in excess of the shoe fracture strength is then performed to ensure adequate well integrity prior to removing the BOP and installing the tree.

Later, following the cement bond log, an annulus pressure test to full design pressure is performed.

CONCLUSION

The cemented monobore completion concept has been refined as a proven method of delivering cost effective North Sea production wells.

Much learning has already taken place along the way to ensure the success of the procedure.

Meticulous planning and attention to detail are critical to minimizing the risks.

The results over the five production wells to date have been remarkable, with the revised economics now having an impact on field development potential. ■

Proven concepts compared for ultra deepwater seabed control

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DEEPWATER OPERATIONS present a number of technical challenges. Not the least of these is designing and providing cost-effective control systems for seabed deployed equipment.

The need for built-in reliability must be a key feature of such designs; however, the need to limit cost increases compared to conventional equipment is also critical.

COMPARING CHOICES

This article will compare a number of field-proven concepts for providing seabed control in deep water.

Speed of response, functionality, equipment costs, weight and size, installation costs, and reliability all have an impact on the choice made for each project.

The ability to integrate control systems from several vendors and the ability to "mix and match" modular components can provide cost reduction in almost all instances.

To compare a number of concepts and highlight the potential for cost reductions, this article will use the example of landing string controls during subsea well interventions such as completion installation.

The completion program often involves flowing the well via the landing string. In deepwater, the string must incorporate a primary well control barrier and an emergency disconnect function.

Figure 1 shows a typical configuration.

Operation of these functions must be swift, particularly when conducted from a dynamically positioned (DP) vessel, as the speed of response will determine the safe watch circle that the vessel must operate within.

A smaller watch circle would reduce the weather window for operations and could increase costs due to vessel downtime. Reliable operation of such functions is paramount due to the potential cost of system failure in an emergency.

The failure of any function that would call for deviation from the installation program would require a time-consuming and costly recovery to surface, repair or replacement, and re-deployment.

A secondary control system must therefore be considered in order to minimize total project costs.

Finally, the system must include a logic that provides emergency and planned shut-in and disconnect functions, at least one contingency control method, event sequencing, and the option for surface examination of data acquired at the mud line during operations.

All this must be incorporated in a control pod that can be deployed within a 19-in. ID marine riser without compromising the integrity of the production conduit to surface.

This production conduit frequently is a 7-in. ID, 10,000-psi working pressure tubing string.

There may also be some advantages in providing an interface with the subsea BOP system controls and ensuring the control logic is integrated within a wider control philosophy.

Although not permanently installed packages, landing string controls are nevertheless a good example of the complex nature of control system design.

DIRECT HYDRAULIC CONTROL

Direct hydraulic control has provided a simple, reliable and inexpensive way to control the landing string. Though the system is highly reliable, secondary control is often provided to permit safe and efficient recovery to surface for repair and replacement. This usually employs a one-off shut-in and disconnect function via a BOP choke/kill line. Specialists with knowledge of both hydraulics and electronics are not required.

For these reasons, direct hydraulics is the preferred method of control in moderate water depths.

However, as water depth increases, the size of umbilical reel quickly becomes prohibitive due to the number of hydraulic cores required to control the many functions the landing string can require. For example during a completion installation the following functions may be required:

- SSIT primary barrier open and close;
- SSIT secondary barrier open and close;
- Retainer valve open and close;
- Latch disconnection;
- Tubing hanger running tool latch/ unlatch/verification;
- Tubing hanger lock/ unlock/verification;
- Tubing hanger soft landing;
- Selector valve open/ return;
- SSSV open.

Speed of response is proportional to umbilical length, and therefore water depth. Operations from a moored semisubmersible or a DP vessel require fast response for the critical emergency shut-in and disconnect sequence.

Direct hydraulics is rarely considered suitable much beyond 2,000 ft water depths.

PILOTED HYDRAULICS

The piloted hydraulics concept uses accumulated hydraulic pressure held at the mud line in a pressurized reservoir. This is directed to tool functions by control valves that are operated by hydraulic signals from surface.

Response is much improved over direct hydraulics because the volumes of control fluid and the pressure differentials between surface and mud line are reduced.

However, response is still not completely independent of water depth. Such systems have been used for some 10 years in water depths up to 5,500 ft.

Performance repeatability and reliability are high and secondary control mechanisms similar to those used for direct hydraulics are sufficient.

The **Expro** system, known as the deep water vent pack, uses metal-to-metal sealing, multi-port shuttle valves as control valves.

These control valves provide repeatable operation and the ability to plumb in sequencing logic between the various tool functions.

However, a pilot hydraulic signal is required for each control valve meaning that a large diameter multi-core umbilical is required.

In addition, response times are unlikely to be fast enough for ultradeep water operations from DP vessels.

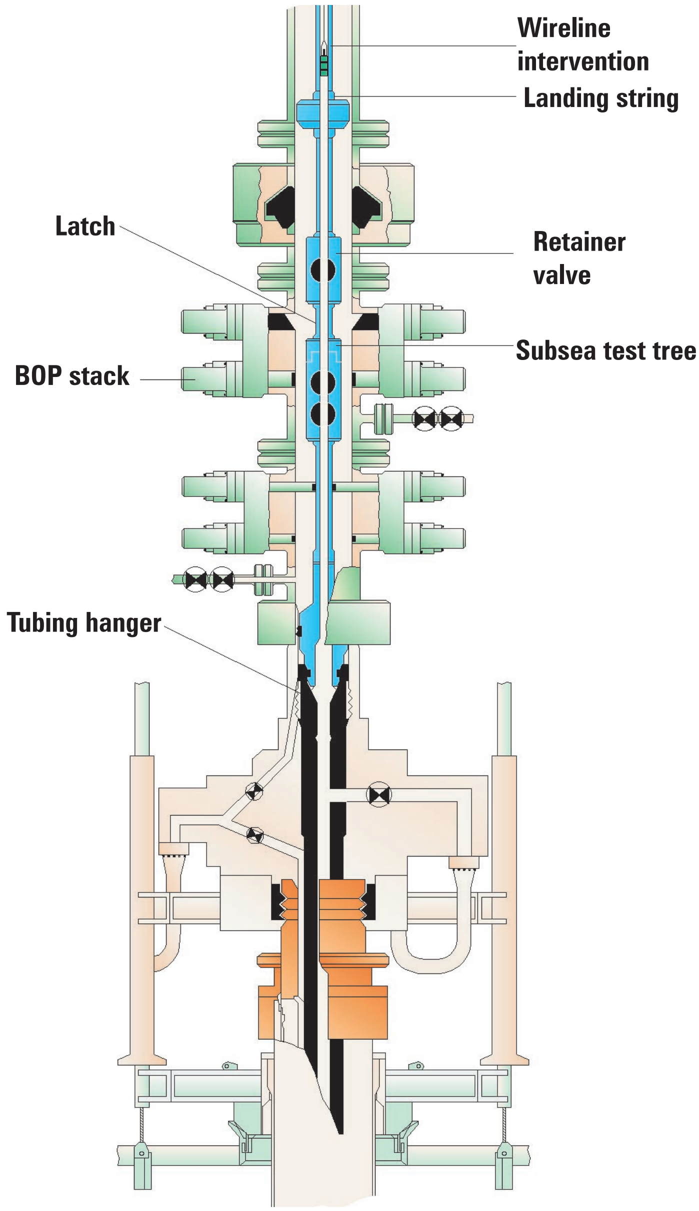

Figure 1: This Expro large bore intervention string is an example configuration.

ELECTRO-HYDRAULIC CONTROL

The obvious method of ensuring swift response times is to perform surface-to-mud line communications with electrical rather than hydraulic signals.

The simplest method of electro-hydraulic control is direct, or simplex, control. This concept employs a separate electrical signal path for each control valve.

Expro has recently taken this approach to provide fast-response emergency shut-in and disconnection for DST-type operations.

In this system, each signal acts on a solenoid which controls the delivery of signal pressure to a shuttle control valve, which in turn delivers the control signal to the tool function. (See Figure 2).

The system can now easily incorporate several control stations or emergency initiation points.

The use of direct electrical signaling eliminates the need for electronics within the mud line control pod, which in turn minimizes costs and concerns over component reliability.

Expro continues to use as many field proven components as possible, retaining the existing control shuttle and accumulator designs from the piloted hydraulic control system.

Use of an intermediary solenoid has allowed us to keep the fluid flowing through the solenoids separate from that which operates the tools, minimizing the risk of fluid contamination.

The continued use of shuttle valve control via hydraulics has enabled us to retain piloted hydraulics as a secondary control mechanism.

These features may not be desirable in some instances; it is necessary to understand particular project drivers and conditions before recommending a specific control concept and design. Finally, it should be noted that this system, in isolation, provides no opportunity for data feedback to surface.

Temperature, pressure and tool function confirmation become more desirable during operations in deep water, so integrated control and data acquisition, or an additional data acquisition pod utilizing multiplex signaling technology should be considered.

MULTIPLEX

The technology to permit addressed signals to be sent to a number of control valves via a single electrical communication cable—multiplexing—is well established. This simplifies umbilical design by reducing the number of electrical cables and saving weight, deck space and cost.

Also, the introduction of electronics at the mud line adds opportunities for sophistication, including:

• Data confirming component operation can now be fed in two directions providing the opportunity for an integrated control and data acquisition system;

Figure 2: Electro-hydraulic control pod for DST operations has undergone extensive testing.

• A secondary control system can be added at little extra cost and the two systems can run diagnostic programs to check for faults;

• Integration of the landing string control system with host platform or rig systems such as the subsea BOP can be achieved relatively simply;

• The introduction of PC-based surface control facilities can assist in the logging and analysis of recorded data.

All this sophistication and extra functionality comes at a price. The electronic components add significant cost and the complexity requires operators to have a broad range of skills covering hydraulics and electronics.

Flexibility of control logic and system configuration has also been reduced, although surface software and mud line firmware can be reconfigured.

On the whole, multiplexing can provide much more functionality in a system.

DISTRIBUTED MULTIPLEX

To maximize the benefits of a multiplex control system while minimizing the costs and technical risks, Expro has been developing a distributed electronics architecture. Such architecture has already been developed for use as data acquisition—and potentially control systems—as part of intelligent well systems.

The majority of the mud line components is physically sited with each sensor or control valve.

Thus the failure of any one of these components does not immediately result in total system failure.

In addition, electronics hardware and firmware designed and qualified for downhole applications can be transferred to the mud line environment. Also, customizing a system to specific project requirements can be done on a modular basis.

Finally, the Expro system uses communications architecture called MZS™. This permits data transfer frequencies to be set and modified for both control and data nodes during operation.

It is anticipated that this approach will provide access to the advantages of multiplex systems without the need for expensive development of bespoke firmware.

We believe simplex, or direct, electro-hydraulic control offers a feasible, simple option for landing strings ensuring that the critical control functions can be performed swiftly, reliably, and with minimum cost.

The addition of a distributed multiplex data acquisition system can then provide additional functionality. ■