Changing the look and feel of UBD requires industry to break out of conventional thinking

By John Ralmalho, Shell

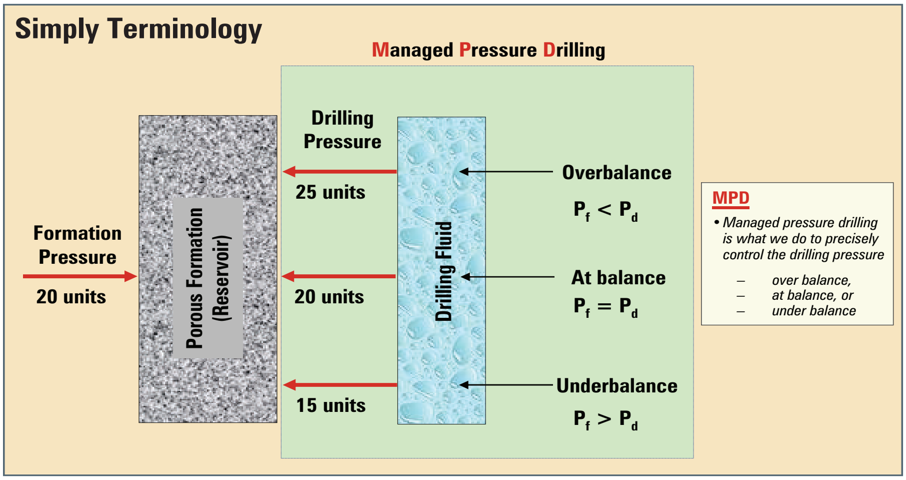
EVER SINCE SHELL introduced underbalanced drilling (UBD) in the offshore environment in 1997, the company has been looking at ways to reduce the footprint of equipment required for UB operations. Much of this work involved reducing the size of the separator (volume) and modularising the UBD kit by stacking and containerising.

As UBD takes hold in low-cost operating areas, Shell has actively looked at ways to reduce not only the footprint but also the unit's operating cost, driven mainly by the need for experienced expatriate personnel to man the equipment.

Recent introduction of new or improved tools and equipment combined with growing recognition that the primary value driver for UBD applications is dynamic reservoir characterization create a window of opportunity to move this initiative forward.

This article presents the conceptual framework to replace large, manpower-intensive surface equipment with a combination of downhole and surface tools and equipment having the same functionality but improved efficiency, which enable a reduced footprint. It illustrates how the functionality of the four-phase separator can be replaced by combining inline phase separation, a gas buster and downhole multiphase metering.

Furthermore it describes how massive surface snubbing systems are being replaced with downhole isolation systems and proposes replacing intrusive and high-maintenance BHA equipment with low-cost rotary steerable systems, non-intrusive MWD systems and the development of non-return valves (NRVs) that are compatible with through-bore solutions to optimise data gathering while drilling. Every piece of equipment is driven by a functional need, has an impact on efficiency and therefore cost, and may offer opportunity for enabling add-ons if the UBD process is viewed from a different perspective.



IADC has defined MPD as "an adaptive drilling process used to precisely control the annular pressure profile throughout the wellbore." Further, the IADC UBO and MPD Committee has agreed that UBD means "drilling under conditions where the pressure being exerted inside the wellbore from the drilling fluids is less than the pressure of the water, oil or gas in the formation being drilled."

INTRODUCTION

It has been pointed out many times and by as many individuals that UBD is not a new technology. In its simplest form, it is "making hole" with cable tool rigs. The next evolution was rotary air drilling, followed by air hammer drilling; underbalanced techniques designed primarily to improve rate of penetration in hard formations. Mist and foam drilling were technological tweakings to mitigate water influx to the wellbore and to aid in hole-cleaning while primarily drilling with an aerated fluid. In the mid- to late 1980s, drilling high-angle or horizontal boreholes to maximize exposure to reservoir rock created the need for further enhancements but for a different purpose — to reduce formation damage caused by fluid invasion as a result of the longer exposure time required to drill the lateral sections.

Today, UBD has evolved to where the primary well control function of the mud column used in conventional drilling is replaced by a combination of flow and pressure control. Bottomhole pressure and return well flow are continuously measured and controlled by means of, respectively, pressure while drilling (PWD) measurements and a closed circulating system.

The complete UBD system comprises the drill pipe circulating system, a rotating control device (RCD), a UBD choke manifold, a separator and a flare stack or flare pit. In addition, non-return valves (NRVs) are installed in the BHA and drill string to prevent flow up the DP.

As part and parcel of the evolution of this technology, a new term — "managed pressure drilling," or MPD — has taken root, and like a tree, it has many branches.

The International Association of Drilling Contractors (IADC) defines MPD as "an adaptive drilling process used to precisely control the annular pressure profile throughout the wellbore. The objectives are to establish the downhole pressure environment limits and to manage the annular hydraulic pressure profile accordingly."

In an attempt to reduce confusion, the UBD drilling industry, represented by the IADC Underbalanced Operations and Managed Pressure Drilling Committee, has agreed to the following definitions for UBD and UBO:

Underbalanced drilling is "drilling under conditions where the pressure being exerted inside the wellbore from the drilling fluids is less than the pressure of the water, oil or gas in the formation being drilled."

Underbalanced operations (UBO) is "any operation conducted with the reservoir pressure being greater than the hydrostatic head of the fluid in the wellbore plus any surface backpressure."

Shell is a major player in the global deployment of MPD and views the technology as "a basket of drilling techniques, in most cases involving the use of a rotating control device (RCD) and a closed circulating system as falling under the MPD umbrella. The tool kit includes overbalance, at balance and underbalance techniques that can be adapted to solve drilling-related problems (usually but not limited to near-balanced techniques), reduce formation damage and or dynamically characterize production reservoirs (while drilling) to enable improved reservoir management."

It is anticipated that the biggest portion of the value chain from deploying MPD will result from dynamic reservoir characterization, which requires the use of UBD techniques. Hence, reducing the footprint of the equipment required for underbalanced drilling operations is key to realizing this value, especially in but not limited to the offshore environment.

CURRENT BASIS OF DESIGN

The equipment currently used in UBD operations is not much different than described by Milligan et al. Non-return valves in the bottom of the drill string, a rotating control device RCD for jointed pipe as opposed to coiled tubing, a UBD choke manifold, a four-phase separator and a flare stack comprise the UBD flow control equipment. Design of current equipment dates back to the early 1990s, when mobile production test equipment was used as an enabler for the closed circulation system required for UBD in hydrocarbon-bearing reservoirs on land-based projects.

The closed system mitigates one of the two primary hazards introduced as a result of UBD operations on the drilling rig: the potential for a spill or uncontrolled flow of hydrocarbons at surface. A rig assist snubbing unit is used to mitigate the other primary hazard introduced in underbalanced operations: pipe light. Whether tripping pipe with the well flowing or shut in, there is a point in wells under pressure where a "pipe light" situation can exist. This occurs when the force inside the wellbore acting to push the string out is greater than the force acting to keep it in the wellbore (a combination of the weight of the drill string and friction at the RCD).

When Shell took UBD technology offshore in 1997, basically the same tried and tested equipment used in North America UBD operations was used with minor tweaking. Since those early days, Shell has looked at ways to reduce the footprint for the equipment required for underbalanced operations in the offshore sector. However, much of this work involved reducing the size of the separator (volume) and modularising the UBD kit by stacking and containerizing. As the technology takes a foothold in low-cost land operating areas, Shell recognises the need to not only reduce the footprint but the unit operating cost of the system; in other words, change "the look and feel of underbalanced drilling."

As UBD takes hold in low-cost operating areas, Shell has actively looked at ways to reduce not only the footprint but also the unit's operating cost, driven mainly by the need for experienced expatriate personnel to man the equipment.

THE CONCEPT

In simple terms, we replace large, manpower intensive surface equipment with a combination of downhole and surface tools and equipment having the same functionality but improved efficiency, which enable a reduced footprint, less time to rig up and less manpower to operate. To illustrate, lets look at each component piece of equipment used in the current process strictly with respect to the functional specification/requirement relative to the basis of design.

RCD, ESD VALVE, CHOKE

With the current state of the technology, there are some critical parts of the system that cannot be functionally replaced with another piece of kit. The RCD, the ESD valve and the choke manifold are three such components. The RCD is a drill-through device with a seal that contacts and seals against the drill string (jointed pipe, casing, kelly, etc.) for the purpose of controlling the pressure or fluid flow to surface. It can also be a non-rotating control device as in a stripping head when used with coil tubing or for stripping jointed pipe tubing underbalanced during workovers.

Although the RCD cannot be functionally replaced in all applications, there is effort in the industry to simplify and adapt the existing technology to the standard operating equipment on the rig, especially on low-pressure operations in the offshore environment.

The Emergency Shutdown Valve (ESD) is a remotely actuated safety device used to isolate well inventory from personnel and equipment, to prevent the severity of the incident escalating due to fire and/or explosion.

The UBD choke manifold is used for controlling wellbore pressure and reducing it, if required, to an acceptable level prior to the separation equipment. The manifold provides alternate flow paths to allow choke inserts to be replaced or repaired as required without having to shut in the well. The choke manifold is composed of isolation valves (usually a gate type design) for each choke and flow path, two chokes (variable and/or fixed choke box), bleed off valves between isolation valves and measuring points for upstream and downstream pressures.

Although the choke cannot be functionally replaced, there is also much ongoing work to reduce the footprint and improve the efficiency for maintenance in addition to automating the functioning of the choke with drilling hydraulics software, logic controllers remotely operated via web-based or satellite link.

THE GEOLOGICAL SAMPLE CATCHER

The geological sample catcher is a high-pressure manifold that partially diverts well flow to specialized screen-containers, which allow fluids (gas and liquids) to pass through while trapping solids within the pressurized containers.

The design provides alternate flow paths to allow the pressurized sample containers to be isolated, de-pressured and samples recovered without having to shut in the well.

The functional requirement for this device is geological evaluation of the reservoir rock quality. Other than the physical cuttings (which may or may not be required by regulations), that can be handled, examined under magnification and exposed to physical testing, the information derived from the cuttings can be obtained by alternative methods currently available to the industry.

Shell has used GR, neutron porosity, neutron density and sonic tools in various combinations, all in LWD format, to identify rock properties on many of our UBD drilling operations. The neutron porosity and neutron density tools, having nuclear source, is usually run only in the final BHA to TD and only if the lost-in-hole risk is deemed low. Although the FMI can also provide facies information, to date it has not been run underbalanced since it is a wireline tool usually run in tubing conveyed mode for horizontal well logging.

FOUR-PHASE SEPARATOR

There are two basic designs for separators used in underbalanced drilling operations: vertical and horizontal.

Vertical separators are the optimum design for separating gas from liquid, and horizontal separators are the optimum design for the separation of liquids of various densities. The type and design of the separator is influenced by the well design and a number of parameters such as the type of drilling fluid and the pump rate, expected production rate and type of reservoir fluid, hole size and length of reservoir to be drilled, and the environment (offshore or onshore). By far the most used type of separator is the horizontal four-phase design described by Milligan et al.

The functional requirements for the separators currently in use are:

1. Separate oil/gas/water/solids into different streams for additional processing; and

2. Facilitate measurement of component flow rates, enabling calculation of productivity of the well or section and/or enable calculation of sandface inflow potential relationship (IPR). Current inline separation technology such as the voraxial separator manufactured by **Enviro Voraxial Technology Inc** when combined by vertical gas busters, installed downstream of the choke manifold, can fullfill the first requirement.

Current multiphase inline metering technology can fullfill the second requirement. For example **Schlumberger**'s three-phase meter called Vx could be used to replace the various kit used to measure component flowrates during the UBD operation. The Vx meter is capable of handling small-sized solids in the

Shell recognises the need to reduce the footprint of equipment required for UBD operations in the offshore sector, such as the snubbing units seen above.

fluid, and fluid temperatures up to 150°C with minor impact on results, although the accuracy of the water cut measurement will decrease as the solids content in the fluid stream increases.

However, it is possible using a third gamma ray energy level present in the Vx to quantify a fourth phase such as drilled solids. Other manufacturers such as CIDRA have also been working on non-intrusive multiphase metering technology and may also have progressed their designs to warrant a fresh look.

TRIPPING UNDERBALANCED

As mentioned, there is a point in wells under pressure where a "pipe light" situation exist. To control the hazard of pipe being ejected from the well during underbalanced tripping operations, push-pull equipment and snubbing systems have been successfully and safely used in UBD operations.

Special snubbing units designed to operate below the rotary table have been deployed in our offshore operations, thereby reducing the risk of injury from dropped objects common to conventional operations utilizing a snubbing personnel basket. In recent years, downhole isolation valves (DIV) have been used either in parallel to snubbing systems or as stand-alone downhole barriers to enable tripping of more complex BHAs and/or completion equipment.

Pre-perforated liners and sand screens have been safely deployed using a DIV and/or an inflatable bridge plug. Further improvements in DIV technology to allow pressure monitoring above and below the valve and/or pressure testing of the valve from above when combined with a robust failure-free run record will provide the comfort factor, which will allow the industry to replace surface snubbing systems with DIVs in UBD operations.

THE VISION FOR CHANGE

Since 1992, changes to UBD equipment and functionality were driven by real estate and equipment available from the service industry. Even when designing newbuild kit, the frame of reference is still based on mobile separation and flow control equipment and surface flow measurements while drilling underbalanced are based on well test equipment and procedures. But, is it necessary for this to be so?

To move underbalanced drilling forward, we need to reduce the cost. We need to reduce its footprint in order to expand the use of the technology offshore. We have done well in these areas by improving efficiencies and packaging equipment that meets the requirement of the project rather than what is available in the store yard. But more can be done in terms of automation of equipment and data gathering, and managing UBD operations from real-time operating centres (RTOC). Shell recently completed a MPD project using an RTOC type of environment to manage the operation.

Enabling successful change requires vision, skills, incentives, resources and action plans. Vision is a key component because, without vision, we have confusion. In going forward, we must agree that every piece of equipment used in an UBO is driven by a need, has an impact on efficiency and therefore cost, and may offer opportunity for enabling add-ons.

For example, the need for a downhole isolation valve (DIV) and gas lift capability drives the need for a concentric re-usable casing string tied back to surface. This in turn provides an opportunity to install a non-intrusive, re-usable multiphase meter downhole on the outside of the concentric casing string. The downhole shut-in capability offered by the DIV also enables a mini pressure-build-up survey on every trip of the drill pipe above the DIV with the advantage of no wellbore storage effect to take into consideration. This results in real-time capture of not only the downhole flow rate but also the corresponding flowing bottomhole pressure and temperatures at a reference depth.

The benefit will be higher-quality flow and pressure data in real time, resulting in improved reservoir characterization analysis, and real time completion design. This will be especially useful for artificial lift (AL) design, resulting in potentially less workovers to replace improperly sized AL equipment.

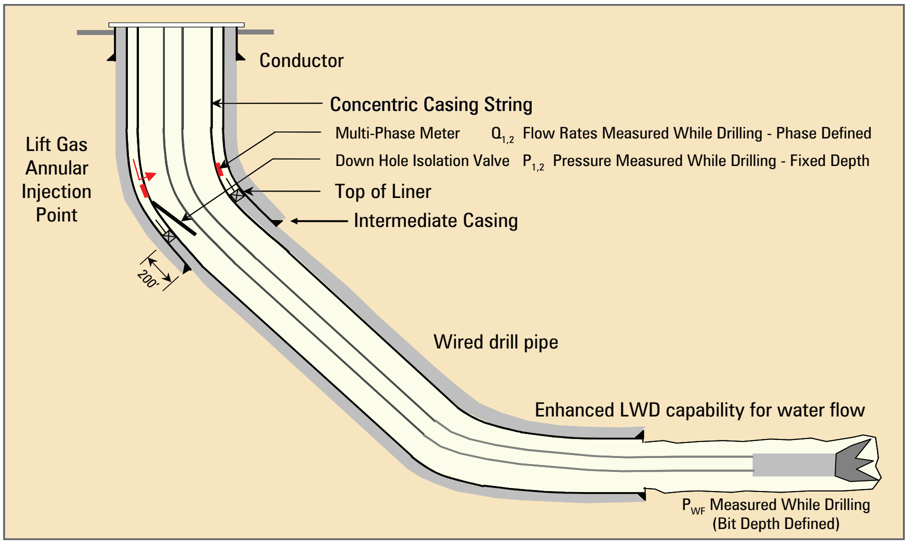
Gap: Downhole pressure/temperature gauge above and below the DIV and cable tied back to surface. The design of the current **Weatherford** DIV and other alternative designs need to have this capability built-in since having this capability also enables the qualification of the flapper type DIV as a tested down hole barrier.

The need for a cable tied back to surface also provides an opportunity to transmit data to surface via a higher speed link at a lower cost than is currently available. This capability will enable "Look Ahead of Bit Technology" to identify productive features as the well is drilled. It could also potentially be an enabler for real-time vertical seismic profiles (VSP) and, properly configured, could also result in improved MWD signal to surface.

The installation of a multiphase meter at the bottom of the well above the DIV increases the accuracy of the input to the inflow calculations. A downhole flow meter also enables faster identification of flow features. However, this is still at one point of the well, are all related to the well design, the need for downhole isolation and suitability of concentric gas lift for the overall operation.

As discussed, Shell believes that dynamic reservoir characterization aspect of UBD holds the greatest promise for providing an avenue to create value in both long and short term — in complex, difficult-to-evaluate reservoirs.

UBD reservoir characterization is a process that involves the integration of data gathered while UBD with conventional well log (LWD and or EL-PNC) data to develop a more complete picture of the relative value and spatial distribution of important reservoir parameters. Business value is created through careful trending and integration of the dynamic UBD data with conventionally acquired data applied in the context of a larger three-dimensional reservoir model.



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Currently the pulse neutron capture (PNC) tool is run on wireline (WL) after

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the well reaches TD in the 6-in. reservoir sections. The tool is available in the 8 ¼ in. size as a part of the LWD suite and depending on demand should be available in LWD format for the 5 ⁷⁄₈-in. hole sizes, hopefully in the not-too-distant future. To optimize the completion designs, especially in mature reservoirs undergoing water flooding, external zonal isolation packers (EZIP) has been run.

These tools work best in boreholes that are in relative gage without washed-out sections. Some sections drilled underbalanced have experienced problems with hole gage. It is expected that boreholes drilled underbalanced using rotary steerable systems (RSS) will overcome these problems. To date, very few wells have been drilled underbalanced using RSS, hence the lack of data.

The commercial availability of wired drill pipe has the potential to really create a step-change in data gathering during exploration and appraisal drilling, especially in the high-cost offshore areas. This tool, combined with improved LWD tools with capability for neutron gamma ray capture and or gamma ray-temperature components, can have a positive impact on underbalanced dynamic reservoir characterization. The ability to identify the water content of produced fluids at the bit and further back of the bit, for example at the top of the BHA or at other points along the drill pipe, will be enabled.

Water-sensitive wafers on the outside of the drill pipe along with water flow logging capability in the BHA will result in enhanced reservoir characterization capability. The idea behind this is to measure the state of and changes to the fluids flowing in the return stream, i.e., the drill pipe-wellbore annulus.

Increasing the accuracy and identification of the high-perm production features, when combined with improved quality of the borehole will enhanced placement of EZIP or other completion techniques to isolate water production or gascusping.

CONCLUSIONS

To enable changing "the look and feel of underbalanced drilling" requires the industry to break out of the box of conventional thinking, to see what can be instead of what is. View UBD equipment requirement from its functional objectives. This will enable us to reduce complexity of surface separator into two streams.

- Gas
- Oil/water/solids: Enables improved automation.

- Introduction of an automated choke control system that will enable maintaining constant bottomhole pressure while drilling underbalanced.
- Improved management of the UBD parameters.
- Centralized control at the rig or RTOC.
- Less wear and tear on the chokes and downstream lines.
- Less manpower required than is currently the case.
- GAP: Voraxial separator technology.

We need to focus on value rather than cost. To make the changes necessary to move forward with an integrated UBD RC process as described will require a partnership between the operators and service providers.

Finally we need to convince the petroleum engineers and geologist to get involved and move away from the commonly held view of UBD as a "drillers tool."

UBD RC is definitely a petroleum engineering tool. In order to extract the greatest value possible from UBD RC, petroleum engineers and geologists must take an active interest in the design, objectives and execution of UBD projects. It is the subsurface folks that will drive the need for change in the well design and the subsurface data capture systems that are required to deliver the real value of UBD from significantly higher production rates and increase ultimate recovery from damage prone formations.

UBD can save the industry millions of dollars during the life cycle of an asset by reducing CAPEX/OPEX and increasing asset value as a result of more efficient productive wells and improved field development plans enabled by dynamic reservoir characterization.

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SPE/IADC MPD/UBO Conference goes to the Middle East

The 2008 SPE/IADC Managed Pressure Drilling & Underbalanced Operations Conference & Exhibition will be held on 28-29 January 2008 in Abu Dhabi, United Arab Emirates. IADC and SPE's mutual purpose in taking this distinguished event to the Middle East is to share the UBO and MPD achievements across the region, as well as to introduce new and promising technologies to this prolific producing center.

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