

# Streamlined connections mean longer slimhole ERD

**THE TREND TO** drill deeper and longer extended reach slimhole wells with 6-in. to 6 ¼-in. final hole sections has revealed serious limitations in the standard 3-½ in. drill pipe conventionally used in these applications. **Saudi Aramco** and **Total Indonesia** realized significant drilling performance and economic benefits by utilizing 4-in. drill pipe with advanced design, slimhole connections in place of standard 3 ½-in. drill pipe. The streamline design configuration resulted in successful drilling of longer slimhole intervals with enhanced torsional and tensile strength and improved hydraulic performance at a lower overall cost.

Saudi Aramco's QTF field required extended reach drilling to deliver pay zone objectives located at measured depths of 18,000 ft to 25,000 ft with horizontal reach values up to 20,000 ft.

Total wanted a drill string design that could deliver higher torsional capacity and improved hydraulic performance to enhance drilling efficiencies and lower drilling times and costs in their Kalimantan field.

A high performance, double shoulder connection for 4-in. drill pipe was selected that maintained a tool joint OD similar to conventional 3 ½-in. drill pipe tool joints. This connection maintains fishing ability in both cased and open hole sections while providing enhanced torsional strength. The high performance connection provides 22,000 ft/lb working torque, an OD of 4 7/8-in. and an oversized internal bore that promotes hydraulic efficiency.

Other major drilling improvements realized included higher buckling resistance, more available pressure at the bit resulting in better MWD/LWD telemetry transmission, improved hole cleaning and higher penetration rates. In addition, the 4-in. high-performance drill pipe was suitable for drilling larger diameter top-hole sections eliminating a requirement for 5-in. drill pipe.

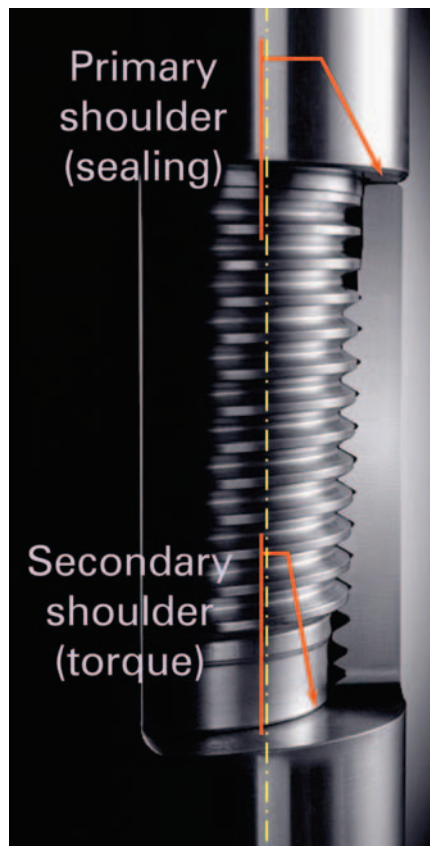
## STREAMLINE CONNECTIONS

Today's severe ultra-deep and extended reach slimhole wells require drill pipe with enhanced mechanical performance capabilities and improved hydraulic efficiency relative to standard API 3 ½-in. drill pipe that has traditionally been used to drill the final 6-in. to 6 ¼-in. hole sections of these wells. The desire to utilize

4-in. drill pipe has been confounded by the lack of a connection with a suitable dimensional configuration combined with exceptional mechanical properties. The challenge was to design a high performance, slimline connection that could be welded to 4-in. drill pipe and provide the same fishing clearance as NC38 connections combined with higher torsional strength, a larger ID bore to improve hydraulic performance and adequate elevator lifting capacity.

## MECHANICAL PERFORMANCE

The drill pipe and tool joint assembly must be capable of withstanding the anticipated service loads including axial force (tension or compression), torsion,



Grant Prideco's high performance streamline connection for 4-in. drill pipe results in reduced pressure losses through the drill string to improve penetration rates and hole cleaning and lower overall costs.

pressure (internal and/or external) and bending. A key consideration that drives connection design and selection is torsional strength. The case histories detailed later had a basic requirement for maximum anticipated working torque

in the range of 20,000 to 22,000 ft/lb. The 4-in., 14 lb/ft drill string design was preferred to improve hydraulic performance and enhanced drilling efficiency.

A connection with a restricted OD is required to maintain the ability to fish the connection with a full strength overshot assembly. A maximum outside diameter between 4 7/8-in. and 5-in. must not be exceeded, otherwise fishing becomes problematic. The internal diameter will result from the selected type of connection and its ability to transmit torque.

The XT39 connection design, optimized for this pipe configuration, was selected for these challenging well projects because it combined a streamline profile with a slimhole OD and oversized bore while maintaining the necessary torsional strength to efficiently drill the long extended reach well intervals.

## HYDRAULIC EFFICIENCY

The primary driver for moving from 3 ½-in. to 4-in. drill pipe with streamline connection was to reduce pressure losses through the drill string to improve penetration rates, hole cleaning and lower well drilling costs.

With a typical pump rate of 500 gpm for the 8 ½-in. bit drilling phase, the pressure drop per unit of length is improved by more than 60% over the API configuration and around 45% over the first generation double shouldered connection. Similar hydraulic performance improvements were realized in the smaller hole size sections and, generally speaking, the larger the pipe for a hole size, the better the hydraulic performance. Therefore, the tube body and tool joint internal diameters are crucial and should be as large as possible provided that increases in equivalent circulating densities (ECD) do not create well control issues. Consequently, the effect of increased drill pipe size on ECD's must be evaluated for each potential application. In these applications, increasing the drill pipe size from 3 ½-in. to 4-in. did not create adverse ECD related issues.

## FISHING CONSIDERATIONS

The need to be able to retrieve the pipe in the event of a failure of the pin connection is the driving factor to the selection of the tool joint OD. The ideal situation is to be able to use a full strength overshot to catch the fish. Having the necessary

clearance in a 6-in. or 6 1/8-in. hole, commonly requires that the tool joint's OD be 5-in. or less.

After compiling and evaluating the information discussed above for the subject well projects, the drilling engineers involved selected the drill pipe design described below:

Nominal size	4 in.
Weight	14.0 lb/ft
Type of upset	IU
Grade	to match environment
Connection	XT 39
TJ OD	4 7/8-in. or 5-in.
TJ ID	2 9/16-in.

Under certain conditions, the 4-in. drill pipe can be used to drill both the lower, smaller hole sections and the upper larger hole intervals eliminating the requirement for 5-in. drill pipe.

The relatively small difference between the tube and the tool joint outside diameters led to a limited elevator surface area for lifting the string of pipe. Although the elevator capacity is somewhat reduced compared to the 3 1/2-in. drill pipe configuration, it was more than adequate for the target applications. If a higher lifting force is required than provided by the elevator shoulder area a sub can be made up into the top of the string to provide additional lifting capacity.

## CASE HISTORIES

The Saudi Aramco well designs mandated that the hole size in the producing zone be 6 1/8-in. and that 7-in. casing be run from surface to the top of the producing zone. In wells without this design constraint the 7 in. is normally run as a liner thereby allowing a combination of 5-in. x 3 1/2-in. drill pipe to be used. The QTF well design precluded the use of 5-in. drill pipe in the drill string for the 6 1/8-in. hole section.

The torque and drag simulation required a high performance slimhole drill string capable of transmitting a torque up to 20,000 ft/lb and withstanding high tension. Another requirement was to provide the ability to fish the pipe both in the 7-in. casing and the 6 1/8-in. open hole with a high strength slimhole overshot.

ERD was required for this oilfield due to the proximity of surface infrastructures requiring that the drill sites be moved away from these facilities. Therefore, to

reach the reservoirs underneath these facilities ERD technology was required. Since the field also extends offshore, it was determined that ERD drilling was more cost effective than building offshore platforms.

In the typical well design, the kick off depths are usually in the 17-in. hole section below the 18 3/8-in. casing shoe at 700 ft. Long radius build rates are used for the initial and final build into the producing zone following a long tangent section. Intermediate casings strings of 13 3/8-in. and 9 5/8-in. are run prior to the long 7-in. production casing set at the target entry and top of the producing zone. The wells are completed with approximately 5,000 ft of 6 1/8-in. open hole.

Torque simulations were performed based on three friction factor levels (maximum, expected and target). The anticipated drilling torque was then compared to the drill pipe capacity. The retained option was the 4-in. drill pipe with XT39 connection.

Drilling performance was improved with the high torque 4-in. XT39 connection. In particular, the following performance improvements were realized:

- Higher rotary speeds (and the corresponding higher ROP) could be maintained without fear of twisting off the connections;
- The torque capacity of the XT39 connection provided sufficient safety margin due to uncertainties of well path tortuosity and friction factors. As drilling progressed, the directional control and friction factors became known and measured depths were increased accordingly;
- The buckling resistance of the 4-in. drill pipe is higher than that of the 3 1/2-in. drill pipe, therefore additional weight on bit could be applied;
- There was no loss of rig time, which would have been associated with tripping to add additional 3 1/2-in. drill pipe if a combination string of 5-in. x 3 1/2-in. drill pipe were used (as in the case of a 7-in. liner well design).

Savings due to the elimination of twist-offs, increased ROP and the ability to tap hydrocarbon reserves at significant lateral distances from the surface location were realized successfully.

Total Indonesia drills "S" shape wells in East Kalimantan to produce its Tunu field. Starting from existing production

structures, there was a need to step out further to reach more remote pay zones. Therefore, the drop off at the end on the 55° slanted section was extended to start at a greater depth. The previously used 3 1/2-in. drill pipe was not able to transmit the required torque, leading to the selection of the above described pipe.

The typical Total Indonesia "S" shape well starts vertically and turns in a 45-55° slanted section leading to a final drop off just above the pay zone. The various end sections are typically equally spaced on a grid with a spacing of about 1,600 m (5,250 ft). The first wells drilled with the 3 1/2-in. drill pipe had the drop off located as far as 2,000 m (6,562 ft) away from the drilling rig. The latest wells drilled with the 4-in. pipe had the drop off point in the range of 3,000 m (9,842 ft). Total measured depth for these new longer wells was approximately 5,500 m (18,045 Ft).

Depending on the expected pore pressure, Total Indonesia uses two different well architectures: type 4 for 10,000 psi wells with a mud specific density of 1.55 (12.93 ppg), and type HPHT for higher pressure-rated wells of 15,000 psi with a specific density of 2.25 (heavier mud of 18.78 ppg).

Note that a tapered casing string (9 5/8-in. x 7-in.) is set in the type 4 wells that is necessary to safely run the combined 5-in. x 4-in. string of drill pipe in the 6-in. open hole section. With this architecture the 4 1/2-in. or 3 1/2-in. tubing will be cemented in the 6-in. hole and the production liner is eliminated.

Originally the 4-in. drill pipe was supplied with 5-in. OD x 2 1/16-in. ID tool joints capable of delivering a drilling torque of 22,200 ft/lb, which corresponds to the connection maximum MUT rating (with a standard API 50% zinc compound).

In view of the good hydraulic performance, the decision was made later to reduce the ID of connections to 2 9/16-in. This brought a small increase in pressure losses that was acceptable and a rise in the maximum MUT up to 24,500 ft/lb, which was the driver for change. Additionally, the use of a copper-base thread compound with higher friction factor allowed Total to further increase this torque value by 10%.

Regarding fishing of the drill string in the open hole, the objective is to catch a 5-in. OD tool joint in a 6-in. hole using a full strength overshot. A standard overshot

fishing tool was not available with full strength capability. Consequently a modified stainless steel 5 7/8-in. slimhole over-shot, with a skirt to restore it to the full strength rating was utilized.

The drilling rigs available on location are equipped with pumps rated to 5,000 psi or 7,500 psi. Although hydraulic loss was not the main concern, the selection of 4-in. pipe ensured that sufficient pressure would be available at the bit for reaching the more remote pay zones.

The impact on ECD was evaluated before changing the size of the drill pipe from 3 1/2 to 4-in. Total used its in-house hydraulic model called "ECD Elf". On the type of wells drilled in Kalimantan, the variation was found to be of 0.04 sg (0.33 ppg). This was found acceptable.

Additionally, on the high-pressure slim-hole wells a system must be available to ensure control of well pressure. It is essential in this configuration to have a hydraulic model developed that allows anticipating the pressure system that will be encountered.

Using 4-in. drill pipe instead of 3 1/2-in. will slightly alter the dynamic pressure in the annulus due to the reduction of clearance between the formation or casing ID and the pipe body. Total Indonesia developed a model that has been validated in the field and monitors the annular pressure losses very closely during the drilling operation.

The cost of drilling, logging and completing one of these highly deviated "S" shape wells is found to be in the range of \$5.5 million, and the typical drilling curve is 30 days.

From an economical standpoint, the driver for selecting drill pipe with a second generation double shouldered connection, with its much higher torque rating than the previously used API connection, is the ability to reach more remote pay zones from a single surface facility.

It simply removes the need to invest in additional expensive structures and achieve savings that significantly exceed the added investment necessary to acquire the pipe and bring minor modifications to the drilling rig.

## CONCLUSION

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The 4-in., 14.0 lb/ft drill pipe with the XT39 second-generation double-shouldered connection has shown its ability to drill slim holes successfully and effectively replace the previously used 3 1/2-in.

and 5-in. drill pipe. This configuration of 4-in. pipe has brought a substantial hydraulic improvement, delivering more pressure at the bit that allows better hole cleaning, significant increases in penetration rates and overall improvement in drilling performance.

As a consequence, this drill pipe system can substantially reduce the cost of drilling deep and ERD slimholes. The 4-in. XT39 drill string designs can increase possible step out or reach distances from the drilling site, permitting the exploitation of previously unreachable

pay zones while reducing the number of drilling sites or offshore platforms.

## REFERENCE

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This article is based upon *Advanced Drill Pipe with Streamline Connections Enhance Slim-Hole Drilling Performance*, **Michael J Jellison, Guillaume Plessis, Grant Prideco; Andre Glowacz, Total; John M Pasnak, Saudi Aramco**, presented at IADC World Drilling 2005 Conference & Exhibition, 9-10 June, Rome. ■