New materials for sour gas drill pipe

THE OILFIELD COUNTRY tubular industry has made significant advances in manufacturing pipe related specifically for use in areas with high hydrogen sulfide (H_2S) content.

Sulfide stress cracking (SSC) was traditionally prevented by controlling the environment by maintaining a pH of water base drilling fluids above a certain level, use of H_2S inhibitors or drilling H_2S bearing formations with oil base fluids.

However, as the severity of sour drilling applications increased and due to the desire to safely realize the benefits of underbalanced drilling in sour environments, the need for drill stem materials resistant to SSC has accelerated.

For the drill string designer, API drill pipe material grades E-75, X-95, G-105 and S-135 are all acceptable if SSC is avoided by controlling the drilling environment. Implementing the following practices can aid in controlling the drilling environment.

- Maintain the drilling fluid density to minimize formation fluid influx.
- Neutralize H_2S in formation fluids by maintaining a mud pH of 10 or higher.
- Utilize sulfide chemical scavengers and/or corrosion inhibitors.
- Use oil-base drilling fluids.

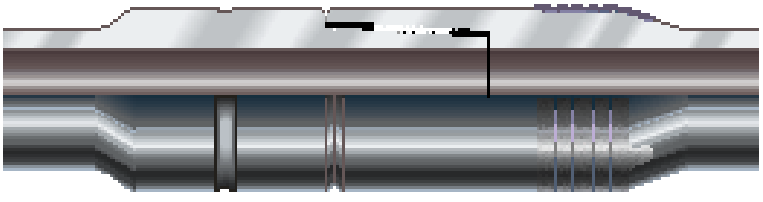
Operating companies often have internal policies to deal with high concentration H_2S gas wells such as limiting the drill string material to G-105 or lower strengths combined with the environmental control steps outline in NACE MR0175 plus use oil-base drilling fluids when possible.

With the desire to safely drill in more areas with high H_2S concentrations, and the growth of underbalanced drilling (UBD) in sour environments, operators and pipe manufacturers recognize that new materials and specifications are required.

Developing drill pipe for sour drilling has been evolutionary rather than revolutionary. Grant Prideco manufactured its first string of sour service drill pipe in 1993.

This pipe consisted of tubes with minimum yield strength of 95,000 psi that were resistant to SSC combined with standard API tool joints.

The pipe, designated TSS-95, was initially developed for use in the Rocky Mountain region of Wyoming where operators were experiencing SSC related failures with standard API drill pipe.



Second-generation double-shoulder drill pipe connection proivdes increased torsional capacity, promotes more streamline configurations and tolerates more tool joint wear than standard API rotary shoulder connections.

The pipe was later used extensively in the Middle East and in some parts of Canada. Over 5 million ft of TSS-95 pipe has been manufactured since 1993.

No documented SSC failures have occurred in the pipe bodies or tool joints of the TSS-95 pipe even though the tool joints were manufactured to standard API and Grant Prideco specifications.

Since the stress levels are relatively low in the tool joint assemblies, the product has performed well in moderate to high intensity H_2S environments when combined with the proper control of drilling fluid parameter.

The next evolution in sour service drill pipe was to develop a higher strength material grade resistant to SSC for the pipe body and controlled yield tool joints that could provide better cracking resistance than standard tool joints. Grant Prideco worked with Chevron to develop a 105,000 psi minimum yield strength grade, designated XD-105, for use in the Tengiz oil field in the former Soviet Union.

Standard API G-105 drill pipe had experienced SSC failures in that high H2S concentration area.

The first string of 5-in. XD-105 drill pipe was used in the Tengiz area in early 1998. Four strings of 5-in. and two strings of 2 7/8-in. XD-105 drill pipe were ultimately used in the area.

The strings are still in use with no recorded SSC failures. Additional strings of XD-105 drill pipe are in use in the Gulf of Mexico and in Canada.

More recent work related to sour service drill pipe development has focused on higher strength material grades, tool joint metallurgy and welding technology with improved SSC resistance for high H_2S concentration environments including applications where environmental control may be difficult such as during well control or UBD operations.

INDUSTRY RECOMMENDED PRACTICE

A driving force behind the development of new drill pipe materials relates to sour gas fields in Canada, where a committee of operators, contractors and manufacturers was formed in 1999 to develop two critical sour drill pipe Industry Recommended Practice (IRP) documents.

The committee developed IRP 1 Critical Sour Drilling, Section 1.8 Drill String Design and Metallurgy. Effective 1 Jan 2002, all drill pipe manufactured for use in critical sour gas applications must comply with the IRP specifications, which includes specifications for three sour service drill pipe grades and one sour service tool joint.

Grant Prideco manufactured more than 25 drill strings comprising over 275,000 ft to the IRP 1.8 specifications.

All drill pipe ordered and manufactured to date from the company has been in grades SS-95 and SS-105, which are manufactured using the quench and temper heat treatment process. After quenching the IRP requires a minimum

transformation to martensite of 90% across the full wall thickness of the pipe.

All tool joints for drill pipe manufactured to IRP 1.8 specification are resistant to SSC. Grant Prideco and most other drill pipe manufacturers typically produce tool joints from forgings, although the majority of SS-110TJ tool joints manufactured to date have been processed from thick wall tubes.

The company is experimenting with manufacture of sour service tool joints. Tool joint geometry must be determined prior to the heat process when forgings are utilized. The advantage is that the material may be kept in a semi-finished state and then heat treated to either SS-110Tj or other strengths as required. This research is ongoing.

Sour service tool joints have reduced yield strength relative to standard API tool joints so special consideration must be given to the connection torsional and tensile performance properties.

Grant Prideco utilizes a proprietary double-shoulder tool joint that provides several operational advantages.

High torsional strength. The connection provides an improvement in working torque of approximately 65-70% compared with a standard API connection of the same dimensions. This additional strength provides the required torque for critical drilling applications. It more than compensates for the approximate 8.5% reduction in yield strength of the sour service tool joints compared with standard API tool joints.

Streamline profile. The increased torsional strength allows for the use of a streamline tool joint that is suitable for the pipe's torsional strength. Second-generation double-shoulder connections can be configured with a smaller OD and larger ID compared to standard API connections without sacrificing torsional capacity, allowing a larger drill pipe size to be used for improved hydraulic performance.

True flush inside diameter. There is no gap or change in inside diameter from the box to the pin, resulting in a recess-free inside bore, providing a smooth flow conduit with less turbulence and eliminating the recess in other connections where solids can accumulate.

Damage resistance. The design incorporates more steel in the critical areas of the connection, resulting in less refacing and fewer recuts.

Increased wear tolerance. Because of the increased torsional capacity, the connection extends the service life of the joint by tolerating more OD wear before the pipe must be downgraded below Premium Class.

THIRD-GENERATION DRILL PIPE

The Drilling and Completions Subcommittee for Critical Sour Underbalanced Drilling developed a third generation specification designed to insure drill string integrity in critical sour UBD applications.

First generation sour service drill pipe consisted of NACE-tested drill pipe tubes with standard API tool joints. SSC resistant tubes welded to controlled yield NACE tested tool joints represents second generation sour service drill string metallurgy.

The material requirements and qualification procedures outlined in IRP 6 Critical Sour Underbalanced Drilling, 6.3 Drill String Design, are considerably more stringent and broader in coverage than IRP 1.8 requirements.

Grant Prideco manufactured one 18,000 ft string of 4-in. 15.70/SU-95 drill pipe with SU-105TJ tool joints to the proposed IRP 6.3 specifications with exceptions. The exceptions were no NACE Method D testing was performed and no NACE testing of the weld region was performed. The tubes, tool joints and upset ends did meet the specification requirements for NACE threshold stress level, maximum hardness and minimum Charpy impact toughness.

FIELD HISTORY

The majority of drill pipe manufactured for critical sour drilling to date has yet to be used for its intended purpose. Most of the pipe is intended for use in wells located in Western Canada, principally Alberta and British Columbia.

There are two critical sour service drill strings in service presently. One, manufactured to IRP 6.3, has been used in Alberta and British Columbia since its purchase in September 2000. The drill string has not yet been used in an underbalanced application.

The second string, manufactured to meet IRP 1.8 specifications, was delivered in January 2001 and was successfully used to drill a well in Alberta with an average H_2S concentration measured at 20%. No problems were encountered with the pipe during drilling.

Based upon limited field data, the SS-95 and SU-95 drill pipe has performed well in critical sour gas environments. However, additional field history is required to establish the effectiveness and reliability of pipe in that type of application. The drill pipe intended for use in Western Canada should provide additional field data.

REFERENCE

This article was written from a paper titled *Next Generation Drill Pipe for Critical Sour Gas Drilling* by **Michael Jellison** and **Jim Brown**, **Grant Prideco**, **Glenn Brown** and **Jim Mostoway**, **Grant Prideco Canada**, and **Karol Szklarz**, **Shell Canada Limited**.