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2004-2014: A Decade of Drill Pipe Grades and Industry Standards Evolutions to Address Increasing H_2S Challenges

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Abstract

Hydrogen Sulfide (H_2S) can interact with steel tubular, such as drill pipe,and through the unfavorable combination of different factors a crack can initiate in the material and propagate until catastrophic failure, even with stresses largely below the yield limit of the material. The combination of tubular failures due to Sulfide Stress Cracking and the rising HSE concerns when dealing with sour gas has led the industry to develop new grades of drill pipe with enhanced resistance to SSC.

Material selection for drill pipe in a sour environment is significantly complex, mainly due to the absence of dedicated international standard. Nonetheless, at a regional level the "Industry Recommended Practices" Volume 1 has been published in 2004 in Canada. The standard was created to insist on people safety, and provide specification and guidelines to manufacturers on material properties, quality control, testing and inspection of drilling products intended to be used in critical sour wells.

Sour Service Drill Pipe as defined in the IRP have been used for a decade in Canada, as well as in other regions and continents, along with a variety of other proprietary Sour Service grades of drill pipe and BHA. This paper proposes a review of different field cases in the Middle East and Asia, as well as an outlook of the different practices for material selection and qualification guidelines which have emerged since the past 10 years.

More recently, with the increasing demand of domestic gas in different part of the world, some highly sour oil and gas reservoirs are being explored with H_2S contents beyond what could have been imagined a decade ago. To explore, appraise and eventually develop such fields, most of the time combined with complex well profiles or deeper reservoirs, significant technical challenges need to be addressed regarding drill pipe integrity and operations safety. This paper proposes a non-exhaustive review of the newest emerging industry trends as far as international standard guidance, regional normative initiatives, and new steel developments.

Introduction

H_2S is hazardous to human health, living organisms, and more generally to the environment. Historically, this is the reason wells found with sour gas were often carefully plugged and abandoned. Depending on H_2S concentration, symptoms such as coughing, eyes irritations, loss of sense of smell, respiratory disturbances, unconsciousness and even death could occur between two minutes and two days.

Steel tubular, such as drill pipe, could be exposed to Hydrogen Sulfide (H_2S) during drilling operations in the event of loss of well control. If unfavorable combinations of different factors coincide, this contact can lead to a crack initiation that can propagate and lead to catastrophic failure, and this even with stresses largely below the yield limit of the steel (Figure 1).

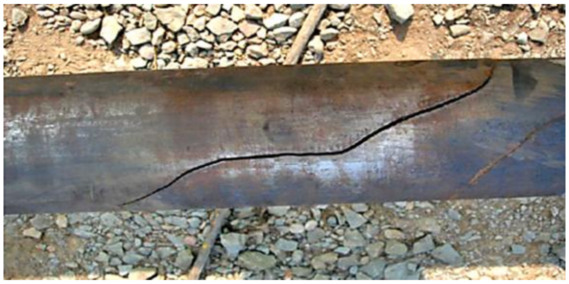

Figure 1. Example of Drill Pipe failure due to H_2S.

The combination of tubular failures due to Sulfide Stress Cracking (SSC) and the rising HSE concerns when dealing with sour gas has led the industry to develop new grades of drill pipe with enhanced resistance to SSC.

Material Selection for H_2S resistant Drill Pipe

Material selection for drill pipe in a sour environment is significantly complex, mainly due to the absence of any dedicated international standard. Both API and ISO have not included any requirement for Sour Service drill pipe in the API 5DP, API 7-1 or ISO11961.

The NACE Material Recommendation MR0175 was written in 1975, although left drilling products out of the scope, as those products are supposed to be used in a controlled environment (drilling fluids). BP's and Elf's works in the early 90's contributed in fine tuning the Sour Service domain knowledge. The NACE MR0175/ISO15156, reviewed in 2004, defines clearly four application domains which provide a range of susceptibility to H_2S, related to well conditions (Figure 2).

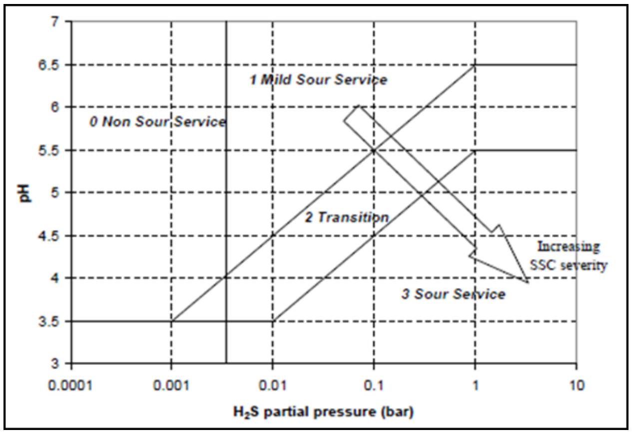

Figure 2. NACE MR0175/ISO 15156 diagram.

NACE MR 0175 is considered as a reliable selection guide for casing and tubing materials. NACE also defines normalized test methods gathered in the NACE Testing Methods TM-0177. They were created in 1977 and reviewed in 2005. Four testing methods are specified by NACE for oil and gas tubular: A, B, C and D. The testing methods are not equivalent and each can play a specific role. Method A evaluates the suitability for service through a testing of the material resistance to axial stresses (pure tension) which can be close to the maximum operational stresses that will actually be applied to the drill pipe (Figure 3).

Figure 3. Example of Drill Pipe sample under testing.

At a regional level, however, the "Industry Recommended Practices" Volume 1 was published in 2004 in Canada [1]. The standard was created with people's safety in mind and provides material property specifications and guidelines for manufacturers including quality control, testing and inspection of drilling products intended to be used in critical sour wells.

A decade of H_2S resistant Drill Pipe use

Sour Service Drill Pipe as defined in the IRP have been used for a decade in Canada, as well as in other regions and continents, along with a variety of other proprietary Sour Service grades of drill pipe and BHA.

For instance, the development of several gas fields in Sichuan basin, China, has involved numerous drilling and safety challenges, due to the important depth of the reservoir, and to the high content of sour gas (around 14% H_2S). The occurrence of several drilling incidents due to H_2S during the exploration and development phases has led operating companies to select highly engineered drilling products, to avoid such problems in the future. Here are some examples of major drill pipe failures which occurred prior to 2006 in this region [2]:

- Blowout accidents on two wells were all resulted from SSC drill pipe failures before the operation of killing the well.
- In the case of one of these well accidents, a string of 5,030m of brand new G-105 drill pipe was broken into 19 parts.
- Another unfortunate event happened in Chuandong (Eastern part of Chuandongbei Area), when the well was drilled at the depth of 3,570m. A blowout occurred due to improper and untimely treatment of lost circulation. 10 hours later, the drill pipe string near to the wellhead failed due to SSC failure, and was lost in hole.
- Back in October 2005, another well, located in Maobei Town, Xuanhan County, was drilled with a targeted depth of 4,840m. On July 24th 2006, a H_2S gas zone was encountered at the well depth of 3,450m.The drill pipe string used was composed of 3,165 meters of S-135 drill pipe in the lower section, and 608m of G-105 drill pipe for the upper section. Suddenly, H_2S gas went into the well bore due to a well kick and a SSC failure occurred at a depth of 2,000m, resulting in a complete lost in hole. It took over 40 days to complete the fishing operation.

Based on the experience and expertise of well-known manufacturers, fit-for-purpose grades of drill pipe have been selected, in order to resist to these harsh sour conditions and encourage safe drilling conditions. Such proprietary grades largely exceed the resistance of API grades to SSC, and are being manufactured using the NACE TM0177-Method A and as per specifications largely inspired from the IRP 1.8 [3]. Starting from December 2006, several critical wells have been drilled using Sour Service grades, instead of standard products. It has then been proven since late 2006 that the use of such Sour Service grades minimizes the risk of failure, even in the harshest well sections, and no incident has been reported so far.

A more recent example is the exploration of Kurdistan region, North Iraq, where the extraction of oil and gas reserves began in 2007. Significant amounts of H_2S gas lies underground, with reservoir depths which could easily reach over 20,000 ft. The use of standard grades of drill pipe has led to several drillstring failures due to SSC during the year 2010, as a result of loss of well control (Figure 4) [4].

Figure 4. Example of cracked Drill Pipe after H_2S exposure in North Iraq.

Consequently, the majority of the operating companies having drilling activities in this part of the world have carefully selected H_2S resistant drill pipe since the series of incidents. As of today, the tubular inventory in this region largely meets IRP requirements. One of the first operators to have switched its inventory to Sour Service grades has drilled several exploration wells with two rigs equipped with 5,000m of IRP 1.8 compliant drill pipe. The strings have been used in pretty severe environments, 18-20% H_2S and high pressure conditions. The drillstrings have been exposed to fluids since underbalanced drilling techniques have been used for some sections of the wells. No SSC failure has been reported during the period of one year of operation.

2014 Outlook

With the increasing demand of domestic gas in different parts of the world, some highly sour oil and gas reservoirs are being explored with H_2S content beyond what could have been imagined a decade ago. In order to explore, appraise and develop these new fields, which often combine sour and deep/complex well profiles, significant safety challenges need to be overcome, including maintaining drill pipe integrity.

From a normative standpoint, regional initiatives are still pretty active, with the upcoming revision of IRP Volume 1, but also the emerging use of IRP Volume 6 in the industry. This volume has been published in 2004 and addressing critical sour underbalanced drilling, although barely used until very recently.

Also, the Chinese market has put together its own standard, in order to specify more stringent requirements towards Sour Service drill pipe used in sour gas wells. The standard has been issued by the National Energy Administration of China and implemented in 2012 [5]. The specification is largely influenced by IRP 1.8 & 6.3 sections, and includes high strength steels and SSC requirements in the assembly zone of the drill pipe.

From a product standpoint, drilling operations in sour wells are more associated with complex well profiles, such as deep reservoirs or extended reach wells. The use of high strength drill pipe is essential to achieve such drilling objectives. However it does represent significant technical challenges in terms of drill pipe integrity and operational safety with the current high strength grades available on the market. Because higher strength is generally detrimental to SSC, innovative chemistries and new heat treatment processes are needed to push Sour Service material limits even further. In 2013, the industry has seen the emergence of 120 ksi high strength grades exhibiting various degrees of SSC resistance [6].

Also, the new challenges associated with the particularly sour fields require new highly engineered drill string solutions in order to increase the safety margin related to Sulfide Stress Cracking (SSC) failure risks, especially in the upset and the welded zones [7]. Sour Service drill pipe has long been used with tool joints and tubes fulfilling separate criteria for Sour Service as defined by the IRP. Both the upset area and the friction weld present some challenges for preserving SSC resistance due to some metallurgical factors such as heterogeneous microstructure, different chemical compositions between the tool joint and the pipe body and high hardness values close to the weld line (figure 5).

Figure 5. Example of Drill Pipe friction weld under heat treatment.

Conclusions

H_2S resistant drill pipe is an industry driven product which has been developed in the past in order to provide some SSC resistance to the drillstring, in the event of loss of well control. Some regional specifications have been put together – such as IRP Volume 1 in 2004 in Canada – in order to provide guidelines to end users for material selection in critical sour wells. Such products have been successfully used in several parts of the world over the past decade, and have reached a sufficient level of maturity to be included within existing international standards, such as API or ISO. Emerging trends will lead both the manufacturers and the end users to look into new grades able to extend the current drilling envelope, and push the frontiers of sour gas development in a safe manner.

Nomenclature

H_2S	= *Hydrogen Sulfide*
SSC	= *Sulfide Stress Cracking*
IRP	= *Industry Recommended Practices*
BHA	= *Bottom Hole Assembly*
NACE	= *National Association of Corrosion Engineers*
API	= *American Petroleum Institute*
ISO	= *International Organization for Standardization*

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