

Safer Choices on Drilling Tubular Products and BHA's in HPHT Wells

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Abstract

Inherently high pressure and high temperature wells carry greater risk when drilling complex reservoirs on a daily basis and requires safer choices in the decision making process for real world environments. When risk management programs fail in their design to mitigate those risks it can carry significant non-productive time and cost to the wellsite. The American Petroleum Institute has revised their recommended practices on inspection by product and class of service for used drill stem elements with the understanding of how drilling tubular products and BHA's are associated with many types of drilling environments. API's new view efforts have offered the industry solutions on multiple levels to help mitigate risk by product and class of service. New required and additional inspections to specific product specification levels are organized to reduce drilling costs, protect the assets and is intended to promote specialized technology for controlling corrosion and preventing major failures. The industry has a greater movement to reducing risk for the unexpected, given a well's complexity of pH concentration, additive levels with possible gas contaminations such as O₂, CO₂, or H₂S in conjunction with higher temperatures. Service companies have also stepped up their actions to develop products to survive in the required operating environments.

Introduction

The HPHT success at 15,000psi with 350°F reservoir completions arrive with many lessons learned on containing pressures, tolerating temperatures, while pushing extended reach well depths. Now the bar has been raised to Ultra and Extreme HPHT wells, the new frontier of drilling and completions. These wells pose enormous challenges to the industry. API has been proactive on many fronts with starting task groups to establish standards and protocol for equipment greater than 15,000psi in designing, manufacturing operating and maintaining equipment segments. For the past few years great achievements were made by a mixed work force, old school experience embracing new generation technology. Risk management programs that focus on optimizing tubulars, DSE and BHA's have provided design integrity to their projects without over-designing. When drill stem elements including BHA average 25% (\$7m to \$10m) of the total well cost a spotlight shines on knowing more tubular dimension information to be used for a complete string design where fundamental product limits are established.

History

It all started out as procedure "Table 19" when it was adopted as tentative in 1964 at the API Standardization Conference. At the 1968 Standards Conference it was revised and approved as the *Standard* and placed in Spec 7. At the 1970 Standards Conference additional revisions were made to add Premium Class to Table 19. At the 1971 Standards Conference the drill pipe classification procedure was removed from the appendix in API Spec 7 and placed in API Recommended Practice 7G. At the 1979 Standards Conference "Table 18" was revised to cover classification of used tubing work strings. The guidelines established in this Recommended Practice have been used for several years. Use of the practice and classification guide has been successful when applied in general applications. There have been situations where additional inspections were required. This RP7G has carried Drill Stem Design and Operating Limits for 16 revisions, now it's moving to the next level, merging with ISO 10407 to better provide security to the industry.

New Standards

API subcommittee on tubulars has worked very hard with ISO to harmonize product specifications and recommended practices. This can be seen with the changes of traditional documents 5D (5th edition), Spec 7 (40th Edition) and RP7G (16th edition). A new approach has been adopted by API and incorporated in these documents, relative guidelines for selecting suitable inspections per operational environments.

The New Drill Pipe Specification API 5DP / ISO 11961 (first edition) was harmonized from parts of 5D, Spec 7 and 11961 to generate a single document that now contains a complete drill stem (upset pipe body with weld-on tool joints) within one document. Being carried forward from ISO 10407 is product specified at three levels called PSL's (product specification levels). For PSL-1 requirements are contained in the main document "body of text" while PSL-2 and PSL-3 are located in Annex G. Supplementary requirements are still available in Annex E.

For PSL-2 grades E, X and G it is required to have SR2 inspection, SR15 certificates, SR19 Charpy V-notch impact testing, special m_{tu} and a greater frequency in weldline testing in addition to all PSL-1 requirements.

For PSL-3 grades E, X and G require a higher V-notch absorbed energy value, Max tool joint yield strength, tool joint surface hardness range and a tool joint through wall hardness range in addition to all PSL-1 and PSL-2 requirements.

The New Drill Stem Elements specification has been harmonized with to the API Spec 7 and ISO 10424 to generate two separate documents. The new API Spec 7-1 / ISO 10424-1 "Specification for Rotary Drill Stem Elements" (first edition) specifies how to manufacture upper and lower kelly valves; square and hexagonal kellys; drill stem subs; standard steel and non-magnetic drill collars; drilling and coring bits with allowable tolerances to meet the standard.

The second standard API Spec 7-2 / ISO 10424-2 "Specification for Threading and Gauging of Rotary Shouldered Thread Connections" (first edition) specifies dimensional requirements for threads and thread gauges, stipulations on gauging practice, gauge specifications, as well as instruments and methods for inspection of thread connections.

New Recommended Practices

Used Drill Stem Design and Operating Limits RP7G harmonized with ISO 10407 to produce two new separate documents. The first document is API RP7G-1 / ISO 10407-1 (first edition) "Recommend Practice for Drill Stem Design and Operating Limits" at this time it continues to be under development by API / ISO committee work groups.

The second document created API RP7G-2 / API 10407-2 (first edition) "Recommended Practice for Inspection and Classification of Used Drill Stem Elements" recommends required inspection levels and procedures for used drill stem elements including drill pipe body, tool joints, rotary-shouldered connections, drill collar, HWDP and the ends of drill stem elements that make up with them. Also RP7G-2 / 10407-2 recommends qualification of inspection personnel, description of inspection methods, calibration of inspection apparatus, standardization procedures for inspection methods, evaluation of imperfections and the marking of inspected drill stem elements.

Carried forward from ISO 10407 are parameters of drilling that correspond with different levels of load, risk and operating life creating four levels of inspection; Standard, Moderate, Critical and Extreme conditions. Additionally Operational Environments will also be considered at their various levels of corrosiveness, abrasiveness, fatigue and mud weight. Cumulative rotating hours between inspections shall play a very important part in the decision making process of when to re-inspect. More details are given in RP7G-2 / ISO 10407-2 Section 5, Annex B and Annex E.

Criteria of operating/inspection levels:

Standard (< 40% load – low risk – short operating life),

Moderate (40-70% load – med risk – standard operating life)

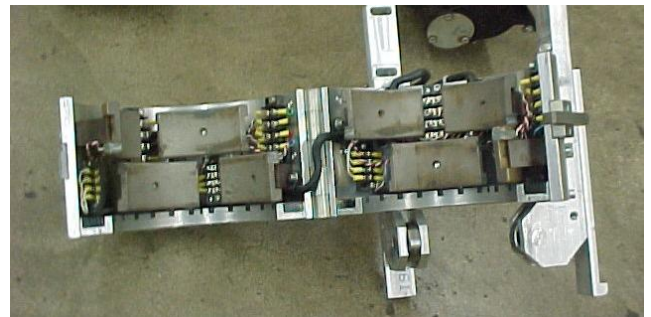
Critical (70% load – high risk – long operating life)

Extreme (80% load – very high risk – very long operating life)

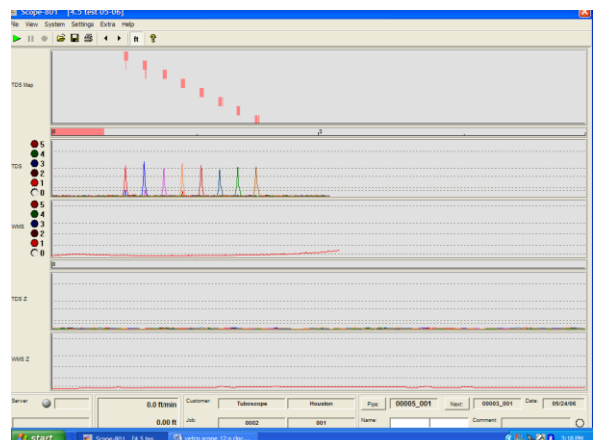
Additional Requirements and Accepted Technology

Section 10 of RP7G-2 / 10407-2 has 63 parts focusing on inspection and classification for Drill Stem Elements containing a greater amount of details on how the processes are to be used. Each clause will have description, preparation, equipment, illumination, written procedures, evaluations, frequency, etc. when applicable. Inspection personnel must be qualified and certified with documentation of their training, examinations, vision test, certifications and re-qualifications.

Electromagnetic inspections performed for the detection of flaws in the tube body have been traditionally flux-leakage detection type equipment utilizing search coils. Now Hall-effect sensors have been added as an acceptable testing apparatus for flaws. This inspection technique is not new to the industry, for many years the industry has put it to use with success. However it is the first time to be written in the API RP7G for tube body inspection. Flaws are detected when passing through a fixed encircling scanner in a magnetized pipe or by propelling the encircling sensors along the length of the magnetized pipe. This NDT method is known as flux density detection and should be considered different than the flux-leakage technique while producing similar results. Hall-effect sensors are also capable of being orientated for the detection of wall loss areas. Known as EMI Wall the level of accuracy is not to be compared to UT Wall measuring. Most documents and papers written refer to EMI Wall as wall loss indicator, with the recommendation that all suspected areas be verified with UT Digital Wall Gauge.



EMI field inspection drill pipe buggy with EMI Wall



EMI computer display of eight hole standard and wall

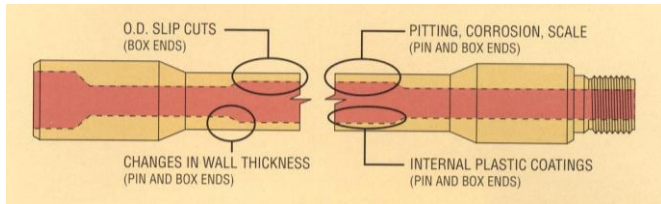
Standardization of EMI inspection equipment is extremely stringent; it shall be performed at the beginning of each job with many periodic standardization checks throughout the production period. While DSE is processed the system is verified at the beginning of each inspection shift, at least every 50 lengths measured or inspected in a continuous operation, after any power interruption, prior to equipment shutdown during a job, prior to resuming operation after repair or change to a system component that can affect the system performance, whenever the detector, connector or current setting are changed and prior to equipment shutdown at the end of the job. If for any reason the system fails all inspected product shall be re-inspected from the last acceptable standardization check with the new acceptable unit standardization.

Ultrasonic end area inspection systems have been extremely successful detecting very small cracks in the critical areas of drill pipe. A very comprehensive inspection is available by using the shear wave technique with water as the couplant to propagate ultrasound in hard to reach areas and for thicker walls products. This inspection is provided on location in very remote area by hand scanning with multiple UT probes through the transition zone and beyond the slip area searching for external and internal fatigue cracking. Tong marks are many times are found to be excessively deep with the presence of fatigue cracking at their base. This inspection has helped to greatly reduce washouts and almost eliminate twist offs.



UT system standardization and verification

When a risk management programs contains regular scheduled inspections severe conditions can be found to prevent a bad chain of events. Inspections performed find and remove damaged drilling components from service prior to being put back into the hole.



Critical areas



Severe crack found during routine inspections



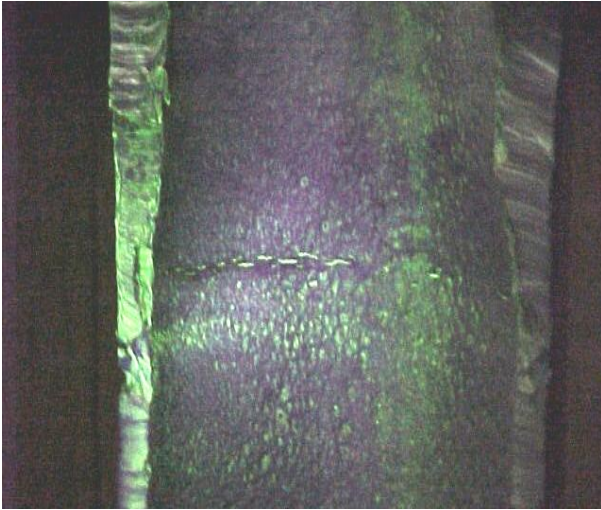
UT hand scanning critical areas with multiple probes



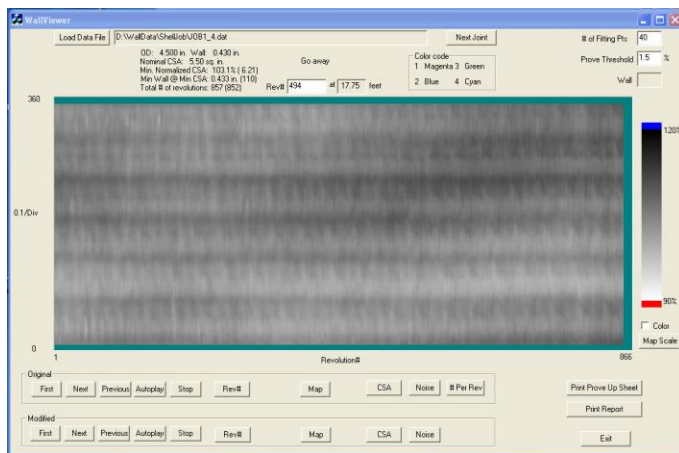
Washouts occurring from non-routine inspecting programs

Standardization of UT inspection equipment shall be performed at the same intervals as stated for EMI systems above. Most electronic type apparatuses used for testing and measuring follow similar quality control verification procedures to demonstrate its capability to perform within required standards.

As the drill string is driven to total well depth a continuous rotation and flexing occurs creating very small fatigue cracking at the end of the transition zone where the pipe nominal wall thickness begins. In the picture above more than 10 cracks were found less than .250" (6,25mm) in length. Reference indicators (EDM notches) used at .500" (12,5mm) length to replicate crack type flaws on the external and internal surfaces.



Fatigue cracking detected with UT confirmed with MPI



High resolution wall mapping

Ultrasonic full length (UTFL) automated testing systems use compression and shear wave techniques with computer controlled wave pulsars for a consistent scanning pattern to provide higher levels of resolution. Individual sound beams are transmitted to detect transverse, longitudinal and wall thickness flaws with an option of searching for oblique orientations. The combination of linear speed and rotation of the material and/or scanner shall produce greater than a 100 % coverage area based with overlapping EBW of the transducer successive pulses. Compression-wave sound beams are propagated normal to the material surface measuring wall thickness with a tolerance of ± 0.005 " (0,13mm). Wall probes can be gated to detect larger subsurface inclusions or planar

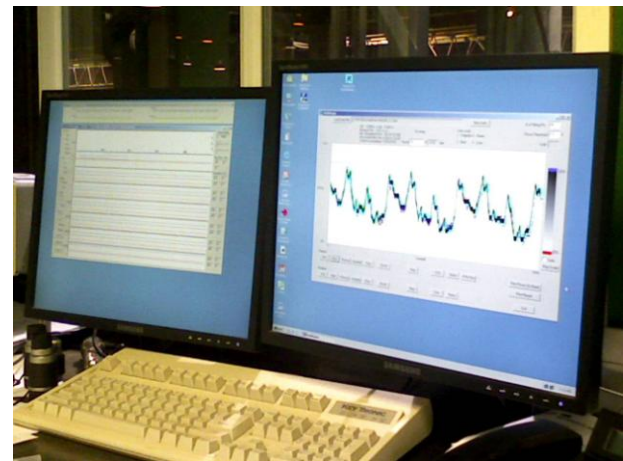
type flaws. Shear-wave sound beams are propagated parallel and circumferentially to pipe axis for the detection of imperfections in the transverse and longitudinal orientation. The system sensitivity is standardized quite often during production to demonstrate that components are continuously functioning properly. Automated systems require threshold mechanisms to alarm for flaws when reference levels are exceeded.

Leading Edge Technology

Several oil companies have extensive quality programs with the aim of being aggressive with inspections techniques. The Ultrasonic testing method provides the highest wall thickness resolution at normal production speeds capable of storing every wall reading (measurement) over 1,000,000 data points to form an image of the tube body.

Wall Data packages and Wall Mapping packages are produced to provide knowledge of actual pipe dimensions. Many values are retrieved of each pipe for analysis or to detail extreme conditions minimum wall thickness, maximum wall thickness, average wall and eccentricity.

Wall Mapping is when wall readings are displayed to show the pipe laid flat/open so wall thickness patterns can be easily seen using color contrast like black to white. For example this pipe shows a non-uniform thickness around the circumference as well as lots of changes full length, note black is thicker wall areas and white is thinner wall areas. If a blue color or red color appears then threshold were exceeded at those spots. This may appear to be very excessive, except when attempting to predict possible burst or collapse conditions for a drill string or in a string of casing and tubing.



View of three pipe revolution with four wall probes

When the DSE is in HPHT environments and is subjected to a strength reduction of 5% - 7%, wall thickness plays an extremely important part in preventing collapse or burst failures. Imperfections are too small to reject and naturally accepted during inspection could now become detrimental in HPHT severe conditions in thinner wall areas. The hanging weight can be 500,000lbs or much more in over-designed wells. The power of top drive rigs become game changers, pulling and pushing on stuck pipe causing major fatigue in the attempt to not lose the well.

Conclusions

Safer drilling environments are available and the standards have been established to meet today's operating limits. Non-Destructive Testing is very critical when searching for cracks less than a 1/4" in length to greatly reduce risk of failures. Knowing wall thickness values full length is just outside of the typical required specifications for today but will be more acceptable as pressures increase and temperatures continue to rise. Interaction of all components of the drilling system: bit design, BHA, rig capacity, well trajectory, mud program, etc. can subsequently cascade into costly drilling and completion problems. Additional non-destructive testing above the industry requirements should be explored when creating a risk management program for Ultra and Extreme HPHT projects

Nomenclature

<i>HPHT</i>	= <i>High Pressure High Temperature</i>
<i>BHA</i>	= <i>Bottomhole assembly</i>
<i>API</i>	= <i>American Petroleum Institute</i>
<i>pH</i>	= <i>Hydrogen</i>
<i>O₂</i>	= <i>Oxygen</i>
<i>CO₂</i>	= <i>Carbon Dioxide</i>
<i>H₂S</i>	= <i>Hydrogen Sulfide</i>
<i>psi</i>	= <i>pounds per square inch</i>
<i>DSE</i>	= <i>Drill Stem Elements</i>
<i>ISO</i>	= <i>International Organization for Standards</i>
<i>HWDP</i>	= <i>Heavy Weight Drill Pipe</i>
<i>MPI</i>	= <i>Magnetic Particle Inspection</i>
<i>EBW</i>	= <i>Effective Beam Width</i>

References

1. API RP7G 16th edition Recommended Practices for Drill Stem Design and Operating Limits
2. API 5DP / ISO 11961 Specifications for Drill Pipe
3. API RP7G-2 / 10407-2 Recommend Practice for Drill Stem Design and Operating Limits
4. API Spec7-1 / ISO 10424-11 Specification for Rotary Drill Stem Elements
5. API Spec7-2 / ISO 10424-2 Specification for Threading and Gauging of Rotary Shouldered Thread Connections
6. Drilling Contractor article "HPHT completions demand wider operating window for equipment, recognition of reservoir parameters" by Linda Hsieh May/June 2010 pg 106