

DRILLING STRING INSPECTION- THE DILEMMA BETWEEN: 1) OIL OPERATING COMPANIES, 2) DRILLING CONTRACTORS and 3) TUBULAR INSPECTION COMPANIES

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Abstract:

This paper concerns drilling string inspection, API and DS1 Specification requirements, and the way these should be handled in the oil industry.

For the time being the requirements are stated by the Clients (Oil Operating Companies) but the services are called by the Drilling Contractors. This actual inter-company relationship is not the best way to tackle inspection, risk, and perfect understanding of what should be tubular inspection for the oil drilling industry. Techniques are used for the purpose of inspection but the most important fact is the relation between inspection results and fatigue against time. An inspected pipe is not a granted piece of equipment. Inspection would only detect the first sign of fatigue, if any. The extent to be evaluated and the "risk taker" (Oil Operating Companies) should decide up to which acceptable level they would still take the risk to use these pipes again. Periodicity of inspection is also a risk to be assessed taking in consideration many factors (Pipe age, strength vs requirements, percentage of rejection, well conditions, etc.). As a Tubular Inspection Services Company, we are not giving ideal solutions but questions are to be asked to clear the permanent misunderstanding between the Oil Operating Company, the Drilling Contractors and pipe Inspection Companies.

1. Drill String Inspection

A component is designed to perform certain functions. The user buys a product with every expectation that it performs the assigned function well and gives trouble-free service for a stipulated period of time (reliability). Reliability comes through improving the quality level of the component. Quality is also related to defects which are generated during service. Inspection is used for routine monitoring of various items during service to predict and assess the remaining life of the component while retaining its structural integrity.

Reliability of inspection depends on standards. Standards are used to ensure reproducible results during inspection/ testing, no matter when, where or who conducts the inspection. Standards also helps to compare results and to take decisions on acceptance/rejection.

Drill String inspection employ standards i) API RP 7G: Recommended practice for Drill Stem Design and Operating Limits
ii) Standard DS-1 Volume 3: Drill Stem Inspection

Primary objectives of this standard are:

- a) To publish procedures for inspecting used drill string components that, when employed, will optimize the uniformity and economic benefit of inspection to the inspection buyer. "Inspection buyer" means the party at economic risk in the event of a drill stem failure.
- b) To provide an engineered approach for accepting or rejecting used drill stem components during inspection on the basis of their fitness for the intended purpose instead of on arbitrary attributes.
- c) To provide the user with methodology and data needed for drill stem design.
- d) To establish uniform benchmarks against which the internal process quality control of inspection and threading companies can be evaluated by their customers.

Major differences

- API RP 7G: ■ Recommendations only
- Drill Stem Design & operating limits
 - Non specific
 - Limited options

- Standard DS1: ■ Standards for Inspection- Accepting & Rejecting used drill Pipes
- Drill Stem Inspection covering wide range of components
 - specific Procedures & Methodology
 - Flexible options
 - Training & Qualifications
 - Calibration mandatory requirement
 - Quality Control measures outlined for equipment & processes

Process Comparison

 Features covered by inspection

Drill Pipe Inspection	DS-1 Category					API RP7G
	1	2	3	4	5	
Tube Body						
Visual Tube						Not Addressed
OD Gauging						Table only
UT Wall Thickness checks						
Electromagnetic Scanning						
MPI/Slip Area						Not Addressed
UT Slip Area						
Tool Joint						
Visual connection						Optional requirement
Fluorescent MPI of connection						
Thread profiling w/gauge						Not identified
OD/ID Gauging						OD only
Seal width/Condition						Condition only
Shoulder width						Table only
Bevel Diameter						
Seal Flatness						Not Addressed
Counter-bore depth						
Counter-bore Diameter						
Pin stretch						
Box Swell						Option on request
Tong Space						

Most of the time API Inspection loosely called as “Standard Rack Inspection”. This “Standard Rack Inspection”(or Its rough equivalent, since its meaning varied by company and location) was adopted by the DS1 sponsor committee as DS1 Category 3.

The cost of a Category 5 inspection is roughly twice that of the normal program represented by Category 3 or Standard Rack Inspection. DS1 Category 5 is intended for drill string components that are to be used in extremely adverse conditions where the potential cost of failure is very large.

DS1 Category 5 includes the Ultrasonic End Area Inspection of Upset and Slip areas of the Drill pipe, where the accumulated fatigue at both the areas together contribute 96% probability of failure.

2. Inspection Capabilities

API Recommended Practice 7G Address

“13.2.1 Limitations of Inspection Capability

Most failures of drill pipe result from some form of metal fatigue. A fatigue is one which originates as a result of repeated or fluctuating stresses having maximum values less than the tensile strength of the material. Fatigue fractures are progressive, beginning as minute cracks that grow under the action of the fluctuating stress. The rate of propagation is related to the applied cyclic loads and under certain conditions may be extremely rapid.

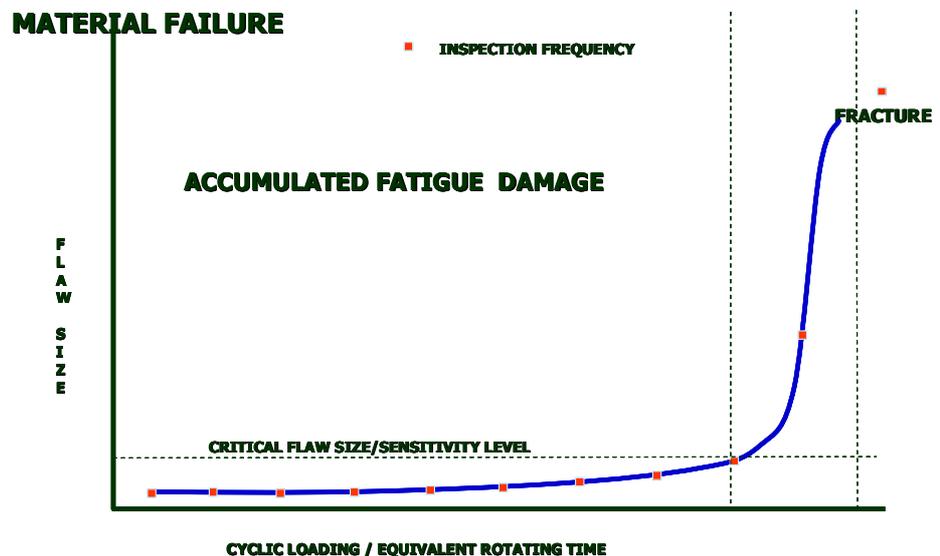
The failure does not normally exhibit extensive plastic deformation and is therefore difficult to detect until such time as considerable damage has occurred. There is no accepted means of inspecting to determine the amount of accumulated fatigue damage or the remaining life in the pipe at a given stress level.

Presently accepted means of inspection are limited to location of cracks, pits, and other surface marks; measurement of remaining wall thickness; measurement of outside diameter; and calculation of remaining cross sectional area. Recent industry statistics confirm that a major percentage of tube body in-service failures occur near the upset run out or within the slip area. Special attention to these critical failure areas should be performed during inspection to facilitate crack detection in drill strings which have been subjected to abnormally high bending stresses. Drill pipe which has just been inspected and found free of cracks may develop cracks after very short additional service through the addition of damage to previously accumulated fatigue damage.”

3. Detecting Fatigue:

No reliable method exists to quantify the amount of fatigue damage a component may have accumulated. Rather, present inspection technology is limited to looking for fatigue cracks, and even when these inspections are performed properly, they can still occasionally fail to find small cracks.

Most of the fatigue life of a drill string component will have been used up by the time a crack has formed and grown large enough to be detected by inspection, so a fatigue crack, once detected, is cause for immediate rejection of the component.



4. Drivers Affecting

Fatigue Life:

How quickly a fatigue crack will form and propagate to failure depends on many variables. The four major drivers are:

- (a) Mean tensile stress: Higher mean stress shortens fatigue life, other things equal.
- (b) Cyclic stress excursions about the mean stress: Larger stress excursions shorten fatigue life, other things equal.
- (c) Corrosiveness of the mud system: More corrosive environments shorten fatigue life, other things equal.
- (d) Fracture toughness of the material: Tougher material will have a longer fatigue life and support a larger crack before final failure, other things equal (Fracture toughness, rather than being a driver of fatigue damage, should be thought of as a retarder).

5. Possible Inspection Results:

The component being examined is actually either good or bad, depending on its condition and the acceptance criteria in effect. The inspector examines the part and decides whether to accept or reject it. Therefore, four possibilities exist. Two correct decision and two errors

Type 1 Error: (Accepting bad material) increase failure probability and may add catastrophic failure costs to the well costs

Type 2 Error: (Rejecting good material) increase inspection costs, cause undue hardship on drilling contractors and rental companies, and lead to logistical cost to unnecessarily replace good equipment.

6. Standard Procedure:

The purpose of different standards is to provide operators a specific guideline to perform different inspection by reducing the possible Inspection errors

To accomplish this, users of this standard establish specific rules to govern the inspection process. Taken together, these rules become the "Inspection Program". The inspection program defines:

- (a) Which inspection methods will be applied to each drill stem component.
- (b) How each inspection method must be conducted in a step-by-step procedure.
- (c) What acceptance criteria will be in effect during inspection -- that is, the user's definition of "good" and "bad".

Communication:

In addition to errors caused by the inherent limitations of inspection tools and procedures, many inspection errors occur because the inspection buyer does not know or does not spell out his exact requirements. Two common phrases should be avoided because their meaning is undefined and ambiguous:

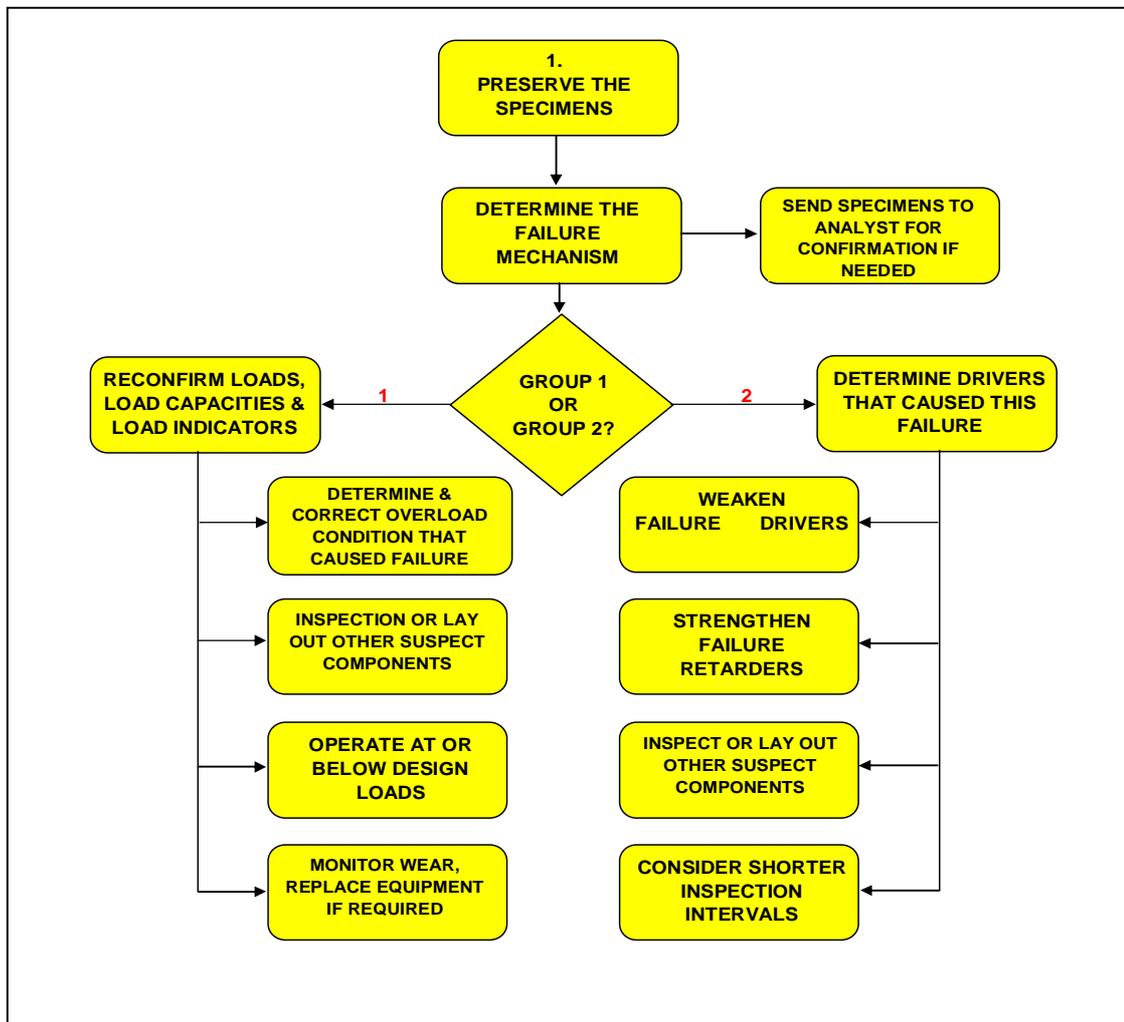
- (a) "API Inspection" is an often used but ambiguous phrase. The attributes of acceptable used drill stem components can be found in API RP7G for many types of equipment. However, that standard is essentially silent on how those attributes are to be evaluated. Therefore, the phrase "API Inspection" has no real universally understood meaning.
- (b) "DS-1 Inspection" is likewise a meaningless phrase when used alone. A DS-1 inspection can vary from very little (Cat 1) to a great deal (Cat 5). Therefore, for the term "DS-1 Inspection" to have a precise meaning, a category must also be stated. The term "DS-1, Cat 3" (for example) exactly establishes the inspection program and process quality controls that the inspector must use on certain equipment.

7. What are the Solutions?

i) Failure Analysis:

Group 1 Failure: if stress in a component exceeds some fairly high stress threshold. The threshold stress is also used for setting minimum acceptable dimensions for a component when the maximum load is fixed.

Group 2 Failure: can occur at low stress levels and heavily influenced by the drilling mud chemical environment and accumulated fatigue.



The response to a drill stem failure also depends on whether the failure mechanism is Group 1 or Group 2

In the planning phase of a well, the approach to preventing failures depends on whether the Failure mechanism is Group 1 or Group 2

- Example 1: “All wells in District A shall be inspected to DS-1 Category 3”
- Example 2: “Service category shall be determined independently based on depth, mud weight, well location, and H₂S concentration according to the following table. The highest service category shall be used to set the inspection program”.

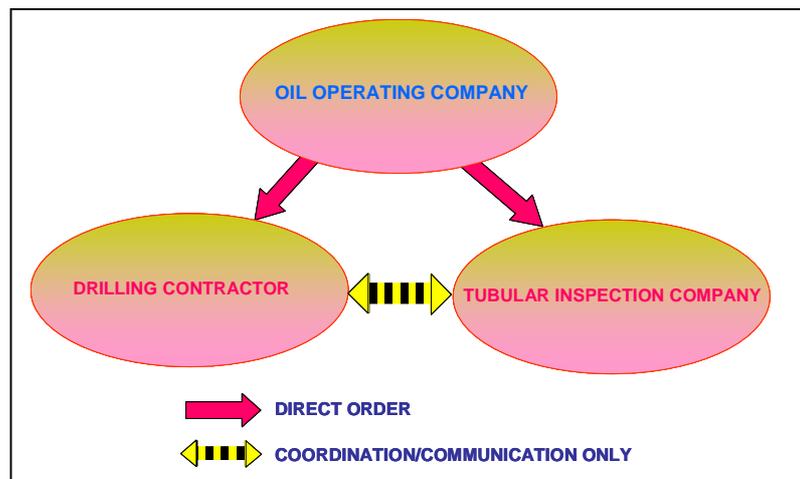
Well Depth (feet)	Minimum Service Category	Mud Weight (ppg)	Minimum Service Category
< 5000	2	< 9.0	2
5000 – 10000	3	9.1 – 11.0	3
10000 – 16 000	4	11.1 – 14.5	4

> 16000	5	> 14.5	5
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Offshore, inland water or remote locations, use minimum Service Category 4. For formation H₂S concentrations greater than 0.05 psia, use Service Category 5

ii) Tubular Management System

Evolution of a highly effective Tubular Management System can only be possible by good coordination and frequent communication between a) Oil Operating Company
b) Drilling Contractor
c) Inspection Service Company.



All these three parties should work together from the design stage of the proposed well Design Objectives are to

- Keep the maximum stress at any point in the drill stem less than yield strength down-rated by a design (safety) factor
- Select components and configure assemblies to retard fatigue as much as economically practical

Inspection Program specifying:

- Which inspection method will be applied to each drill stem component
- How each inspection method must be conducted in a step-by-step procedure
- What acceptance criteria will be in effect during inspection.

Inspection System: Inspection Program design the inspection system as per the specific requirements.

iii) Our Recommendations:

Based on our past experience in Drill Stem Inspection the recommendations to modify the present pipe management system to improve the quality level and reliability of the components are

1. Use Measurable Make-Up Equipment: The Calibrated Measurable Make-up equipment shall be used to monitor and make sure make-up torque is accurate/ within the tolerance.

2. Use Soft Die Slips: The slip cut contributes more than 25% of failure mechanism in tubular and the usage of soft dies can avoid the slip cut, the potential stress risers to initiate crack.
3. New design (Drill Pipe) : 72% of Drill Pipe failures occurs at internal/ external upsets, the area of thickness transition from thick Tool Joint to thin Tube Body. Thus the design of the internal upset shall be modified , such that the thickness transition zone(upset) extent at least 5 to 6 feet from the Tool Joint. The elongated Transition zone reduces fatigue accumulation and risk of failure.
4. Packing, Storage, Transportation & Handling of Tubular in Cradled System: The industry follows conventional method of bundling tubular for packing and transportation. The storage of the same bundles by stacked on precarious racks results in costly damages. Use of cradle system protects the tubular from metal to metal contact. Easy, safe to handle and transport & easy accountability of pipe as the pipe size are packed equally in each bundle.
5. Traceability of pipe through unique identification: API recommends the sample marking at the base of pin. But these identification marks vanishes , when the connection under goes re-cut. To have a better traceability, efficiency and sealing capacity of joint (a) the original marking should be re-die stamped and (b) the re-cut (RCT) should be timely identified by month and year.

References:

1. Standard DS1 : Drill Stem Design and Inspection, TH Hill Associates
2. API RP 7G : Recommended practice for Drill Stem Design and Operating Limits
3. IADC/SPE 87188 : An Innovative Design Approach to reduce Drill String Fatigue