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ADDENDUM 1

Scope: Scope shall be changed as indicated by the red markup below:

1 Scope

This standard covers the gas and arc welding of butt, branch, and fillet welds in carbon and low-alloy steel pipe and piping components used in the compression, pumping, and transmission of crude petroleum, petroleum products, fuel gases, carbon dioxide, nitrogen, and, where applicable, covers welding on distribution systems. It applies to both new construction and in-service welding. The welding may be done by a shielded metal arc welding, submerged arc welding, gas tungsten arc welding, gas metal arc welding, flux-cored arc welding, plasma arc welding, or oxyacetylene welding process, or by a combination of these processes using a manual, semiautomatic, or mechanized welding technique or a combination of these techniques. The welds may be produced by position or roll welding or by a combination of position and roll welding.

This standard also covers the procedures for radiographic, magnetic particle, liquid penetrant, and ultrasonic testing, as well as the acceptance standards to be applied to production welds tested to destruction or inspected by radiographic, magnetic particle, liquid penetrant, ultrasonic, and visual testing methods.

This standard includes acceptance standards for girth welds using engineering critical assessment, to include engineering critical assessment for girth welds in offshore pipelines installed by reeling.

The values stated in either U.S. customary units (USC) or metric units (SI) are to be regarded separately as standard. Each system is to be used independently of the other, without combining values in any way.

The figures depicted in this standard are not drawn to scale.

It is intended that all work performed in accordance with this standard meets or exceeds the requirements of this standard.

While this standard is comprehensive, it may not address all issues that may arise. The absence of guidance or requirements is not to be considered prohibitive to a particular activity or approach that is based upon sound engineering judgment. For example, other industry standards, reliable engineering tests and analyses, or established industry practices may provide useful reference to establish sound engineering judgment.

Section A.1 General: Section shall be changed as indicated by the red markup below:

A.1 General

The acceptance standards given in Section 9 are based on empirical criteria for workmanship and place primary importance on imperfection length. Such criteria have provided an excellent record of reliability in pipeline service for many years. The use of fracture mechanics analysis and fitness-for-purpose criteria for determining acceptance criteria is an alternative method and incorporates the evaluation of both imperfection height and imperfection length. Typically, but not always, the fitness-for-purpose criteria provide more generous allowable imperfection length. Additional qualification tests, stress analysis, and inspection are required to use the fitness-for-purpose criteria. Performing analysis based on the principles of fitness-for-purpose is alternatively termed engineering critical assessment, or ECA.

The fitness-for-purpose criteria in the prior versions of this annex required a minimum crack tip opening displacement (CTOD) toughness of either 0.005 in. or 0.010 in. (0.13 mm or 0.25 mm) and were independent of any higher values of fracture toughness. Improvements in welding consumables and with more precise welding procedures, especially with the increased use of mechanized welding devices, have resulted in higher and more uniform toughness and ductility in most welds. At the same time, toughness values below 0.005 in. (0.13 mm) have been observed, particularly with more stringent notching procedures of CTOD specimens than those in the prior versions of this annex. Welds with CTOD toughness below 0.005 in. (0.13 mm) have shown to perform adequately when the acceptance criteria are properly adjusted to account for the lower toughness. The acceptance criteria are revised so that they are commensurate with the measured toughness and applied load levels.

This annex includes three options for the determination of acceptance limits of planar imperfections. In numerical order, the options are increasingly complex in application but offer wider range of applicability. Option 1 provides the simplest methodology. Option 2 allows for the full utilization of the toughness of the materials, thus providing a more accurate criterion but requires more calculation. The first two options were developed with a single set of underlying procedures but are limited to applications with a low to moderate fatigue loading as described in A.2.2.1. Option 3 is provided for those cases where fatigue loading exceeds the limit established for the first two options. Option 3 is not prescriptive, and its consistency could be significantly less than Options 1 and 2. Option 3 should only be exercised, when necessary, by skilled practitioners with demonstrated knowledge of fracture mechanics and pipeline load analysis.

It is usually impractical to qualify individual pipeline welds for the alternative acceptance limits after a defect under Section 9 is detected, because destructive testing is required to establish the required mechanical properties for the welding procedure under consideration.

This annex provides procedures to determine the maximum allowable imperfection sizes. It does not prevent the use of Section 9 for determining imperfection acceptance limits for any weld. Use of this annex is completely at the company's option.

In this annex, the use of the phrase imperfection acceptance limits and other phrases containing the word imperfection is not intended to imply a defective condition or any lack of weld integrity. All welds contain certain features variously described as artifacts, imperfections, discontinuities, or flaws. These terms are widely accepted and used interchangeably. The primary purpose of this annex is to define, on the basis of a technical analysis, the effect of various types, sizes, and shapes of such anomalies on the suitability of the whole weld for a specific service.

This use of this annex is restricted to the following conditions:

— circumferential welds between pipes of equal specified wall thickness;

— nondestructive inspection performed for essentially all welds;

— no gross weld strength undermatching, see A.3.2.1;

— maximum axial design stress no greater than the SMYS;

— maximum axial design strain no greater than 0.5 %;

— welds in pump and compressor stations, fittings, and valves in the main line are excluded;

— Repair welds are excluded for Options 1 and 2, but can be assessed using Option 3 with the company's approval, see A.5.1.5.1.

ECA of offshore pipelines installed by reeling, where axial strains are greater than 0.5% during installation, shall use Annex C.

New Annex C: New Annex C shall be added:

Annex C
(normative)

Engineering Critical Assessment of Offshore Pipelines Installed by Reeling

C.1 Introduction

C.1.1 This Annex to API 1104 provides guidelines for performing an Engineering Critical Assessment (ECA) of girth welds in offshore pipelines installed by reeling, that once installed, will not experience strains > 0.5% during commissioning or operation.

C.1.2 During reel installation pipelines experience multiple plastic strain cycles as the pipe is reeled onto the lay vessel and then reeled off the lay vessel as it is installed offshore.

C.1.3 Since the strain cycles during reeling on and reeling off generally exceed 0.5% strain the ECA procedures in API 1104 Annex A cannot be applied since the Annex A ECA procedure is limited to strains less than 0.5%

C.1.4 The ECA guidelines in this Annex cover the entire pipeline life cycle and include, as a minimum, the following assessment stages:

a) Installation Fracture assessment (Tearing analysis)

b) Installation: Fatigue analysis

c) Hydrotest: Fracture assessment (Fracture stability check)

d) Operation: Fatigue analysis

e) End of Life (EOL): Fracture assessment (Fracture stability check)

NOTE Girth welds that are made offshore (i.e., they are not reeled) can also be analyzed using the above methodology but with the first step (Reeling Installation Tearing Analysis) replaced by the Option 3 Method in API 1104 Annex A.

C.1.5 Prior to commencing the ECA the Contractor shall prepare a detailed ECA Methodology that shall be submitted to the Company for review and approval. The ECA methodology should include:

a) A detailed description of the overall ECA approach (Installation Fracture, Installation Fatigue, Hydrotest, Operational Fatigue, End of Life Fracture Check).

b) Pipe Details (Pipe Grade, Diameter, Wall Thickness [WT], WT Tolerance etc.)

c) ECA Weld Procedure Qualification and Testing matrix.

d) Girth Weld Details (Weld Cap & Root Profile, Hi-Lo Misalignment etc.).

e) Design Life.

C.1.6 The general ECA approach for a Reeled Pipeline is to select an initial flaw size and then perform a Reeling Installation Tearing Analysis followed by an Installation Fatigue analysis, an As-Laid and Operational Fatigue analysis (which includes lateral buckling if applicable) and finally an End of Life (EOL) Fracture Assessment. The final flaw size from each step is used as the initial flaw size for the subsequent step.

C.1.7 If the EOL Fracture Assessment demonstrates that the flaw is safe (i.e., it is below the critical size for fracture) then the ECA may be repeated assuming a larger initial flaw size in order to determine the maximum initial flaw size that can be tolerated without resulting in EOL fracture.

C.1.8 If alternatively, the EOL Fracture Assessment demonstrates that the flaw will fail due to fracture, the initial flaw size shall be reduced and the analysis repeated to determine the maximum initial flaw size that can be tolerated without resulting in EOL fracture.

C.1.9 The approach in C.1.5 can be applied to a range of initial flaw sizes (e.g., different flaw heights, lengths and aspect ratios) to enable flaw acceptance criteria to be developed for a range of flaw sizes.

C.2 Pipe and Girth Weld Qualification Requirements

C.2.1 Parent Pipe Qualification Testing

C.2.1.1 The longitudinal stress-strain behavior of the pipe shall be determined in each of the following conditions.

a) As-received; the stress strain curve shall be determined by testing pipe in the as-received condition, i.e., with no prior straining.

b) Strained; the stress strain curve shall be obtained by testing pipe material that has been subjected to a single strain cycle, i.e., the pipe material is subjected to a tensile strain equal to the peak reeling strain followed by a compressive strain that takes the pipe material back to zero strain. A reel cycle is defined as an entire bending and straightening cycle.

c) Strained and aged; the stress strain curve shall be obtained by testing pipe material that has been subjected to simulated reeling (maximum number of reel cycles and strain ranges) followed by aging at a temperature of 250 deg C for 1 hour. Stress-strain curve shall be obtained for strain cycles representing both 6 and 12 o'clock positions of a girth weld during reeling, where the 12 o'clock position starts in tension, and the 6 o'clock starts in compression. A reel cycle is defined as an entire bending and straightening cycle.

C.2.1.2 The simulated reeling can be performed by small scale straining of samples or by subjecting a pipe sample to full scale simulated reeling.

C.2.1.3 The stress strain curves shall be generated out to the maximum load in the test.

C.2.1.4 The stress strain curves used in the Reeling Installation Tearing Analysis shall be adjusted so that they represent “upper bound” stress strain curves, e.g., high yield strength and low work hardening to represent a “worst case” stress strain curve.

C.2.1.5 The method of adjusting the stress strain curves shall be submitted to the Company for review and approval.

C.2.1.6 The Stress-Strain curves shall be used as follows in the Reeling Installation Tearing Analysis:

a) first reel cycle; as-received stress strain curve;
b) subsequent reel cycles; strained stress strain curve.

C.2.2 Girth Weld Procedure Qualification

C.2.2.1 General

C.2.2.1.1 For offshore pipelines installed by reeling the girth weld procedures can be broken down into the following two categories:

a) Onshore Girth Weld Procedures (Girth Welds that will be reeled);
b) Offshore Girth Weld Procedures (Girth welds that are not reeled).

C.2.2.1.2 The ECA methodology shall define the type and number of tests to be performed for each weld procedure together with the detailed test procedures.

C.2.2.1.3 The ECA methodology shall also describe in detail how test results will be processed and used in the ECA Analysis.

C.2.2.2 Offshore Girth Weld Procedures

C.2.2.2.1 Offshore girth weld procedures shall be qualified to API 1104 Annex A.

C.2.2.3 Onshore Girth Weld Procedures

C.2.2.3.1 General

C.2.2.3.1.1 In addition to the girth weld procedure qualification (WPQ) requirements and essential variables in the main body of API 1104 and API 1104 Annex A the following additional tests shall be performed for each onshore girth weld procedure.

C.2.2.3.2 All Weld Tensile (AWT) Tests

C.2.2.3.2.1 AWT Tests shall be performed to determine the stress strain curve of the weld metal and verify that it overmatches the upper bound tensile properties of the pipe.

C.2.2.3.2.2 Girth weld overmatching is required to perform a standard reeling ECA (i.e., without the use of finite element analysis).

C.2.2.3.2.3 The definition of weld overmatch is somewhat subjective and the simple requirement that the full weld tensile curve should sit above the upper bound parent pipe material curve is generally conservative. Commonly, it has been shown if the weld tensile curve passes above the upper bound parent material curve before the assessment strain level, then overmatch is satisfied. It is advised that all parties should agree on suitable definitions of the upper bound tensile properties of the pipe.

C.2.2.3.2.4 If overmatching cannot be guaranteed (e.g., CRA Clad pipe) then the Contractor shall propose an alternative ECA approach to Company for review and approval. This is generally based on Finite Element Analysis.

C.2.2.3.3 Fracture Toughness: J or CTOD R-curve Tests

C.2.2.3.3.1 The J or CTOD R-curve fracture toughness tests shall be performed to measure the toughness of the Weld and HAZ in the As-Welded condition and used for the assessment of all strain cycles during reeling.

C.2.2.3.3.2 The J or CTOD R-curve tests can be performed on either Single Edge Notch Tension (SENT) specimens or Single Edge Notch Bend (SENB) Specimens.

C.2.2.3.3.3 The fracture toughness tests shall be performed at the minimum installation temperature and must exhibit fully ductile behavior, i.e., no unstable fracture.

C.2.2.3.4 Fracture Toughness: Strained & Aged Tests

C.2.2.3.4.1 For girth welds that have been reeled the EOL Fracture Assessment shall be performed with fracture toughness values obtained by testing SENB or SENT specimens that are in the “Strained and Aged” condition (i.e., they have been subjected to simulated reeling followed by aging).

C.2.2.3.4.2 The final strain cycle in the simulated reeling shall end in tension.

C.2.2.3.4.3 If SENT specimens are used, the effect of biaxiality shall be accounted for when determining the crack driving force (for example see DNV-RP-F108). This is not required when SENB specimens are used as the higher crack driving force due to biaxiality is offset by the higher constraint SENB specimens.

C.2.2.4 Project Specific Tests (Sour [H_2S or Sweet [CO_2] Service)

C.2.2.4.1 For pipelines that operate in sour (H_2S), sweet (CO_2) or Hydrogen (H_2) service the Operational ECA should account for the effect of the Environment on the fatigue and fracture toughness properties of girth welds.

C.2.2.4.2 If a Project Specific Sour (H_2S), Sweet (CO_2) or Hydrogen (H_2) fatigue and/or fracture toughness test programs is proposed, then the ECA Methodology should contain full details of the proposed test program including:

a) the fatigue and fracture toughness test matrix;

b) test environment;

c) detailed test procedures.

C.3 Reeling Installation Tearing Analysis

C.3.1 General

C.3.1.1 The Reeling Installation Tearing Analysis shall be performed to determine the stable crack growth (ductile tearing) that may occur during reel installation.

C.3.1.2 The Reeling Installation Tearing Analysis shall be performed using an industry proven and accepted procedure such as DNV-RP-F108, encompassing BS7910 fracture assessment procedures.

C.3.1.3 Once a procedure is selected then the entire ECA shall follow the methodology defined by the procedure, i.e., procedures cannot be combined or sections of one procedure substituted for sections of another procedure.

C.3.2 Reeling Tearing Analysis

C.3.2.1 The Reeling Tearing Analysis shall be described in detail in the ECA methodology and approved by the Company. It should follow an industry accepted method.

C.3.2.2 If the pipeline welds will include known strain concentration effects, then the assessment strains should be obtained from a detailed reeling installation analysis (i.e. finite-element analysis).

C.3.2.3 Typical examples leading to strain concentration would be geometry changes such as wall thickness transitions and counter bored pipe ends, stiffness discontinuity that can arise from thick insulation coating with weak field joint material and system effects such as increased strain in the inner pipe of Pipe in Pipe (PIP) systems due to centraliser interaction.

NOTE the strength mismatch associated with pipe strength difference due to wall thickness and yield strength tolerances is a low probability statistical event and the strain impacts the weak pipe rather than directly the weld and so is not proposed for use in ECA when determining nominal weld strain.

C.3.2.4 For pipe to pipe girth welds with the same nominal wall thickness and material grade, and without strain raisers listed in C.3.2.2 – C.3.2.3, the nominal reeling strain can be determined through pipe bending engineering formula using the pipe and vessel drum/aligner dimensions.

C.3.2.5 The reeling analysis should consider the entire reeling installation, including planned reel cycles to cover re-reeling, abandonment and recovery.

C.3.2.6 The reeling installation analysis does not need to consider strain intensification due to girth weld Hi-Lo misalignment if this is included directly in the Reeling Tearing Analysis. Otherwise Hi-Lo misalignment should be included in the reeling analysis.

C.3.2.7 The reeling installation analysis does not need to include Mk factors to account for local SCFs at weld toes. However, Mk factors shall be included in the Installation Fatigue, analysis, Hydrotest and analysis, As-Laid and Operational Fatigue analysis and End of Life Fracture Assessment.

C.3.2.8 It is acceptable to perform the reeling tearing Analysis for OD surface flaws and apply the predicted flaw growth to other flaw locations, e.g., buried flaws and ID surface flaws.

C.3.2.9 Alternatively, separate reeling tearing analyses may be performed for OD surface, Buried and ID Surface Flaws.

C.3.2.10 The Reeling Tearing Analysis shall be performed with the minimum fabrication pipe wall thickness, i.e., the nominal pipe wall thickness minus the wall thickness tolerance or the minimum counter-bored wall thickness.

C.3.2.11 Alternatively, if the pipe ends have been measured, the minimum measured wall thickness may be used in the ECA. No corrosion allowance is required to be subtracted on the basis of a relatively fast installation process.

C.3.2.12 The Reeling Tearing Analysis shall start with an assumed initial flaw size.

C.3.2.13 A series of reeling Tearing analyses shall be performed using the measured lower bound J R-curve and the upper bound pipe stress strain curve to determine the flaw growth during each reeling cycle.

C.3.2.14 The same J-R curve can be used for all reeling cycles.

C.3.2.15 The final flaw size from each reel cycle shall be used as the initial flaw size for the subsequent reel cycle.

C.3.2.16 The total flaw growth (height and length) shall be determined by summing the flaw growth increments for each reel cycle.

C.3.2.17 The maximum total (accumulated) flaw growth (height) during reeling shall not exceed the lower of:

a) 10% of the pipe wall thickness
b) The maximum tearing measured in the J R-curve tests.

C.3.2.18 If the predicted flaw growth exceeds 10% of the pipe wall thickness or the maximum measured tearing in the J R-curve test the reeling ECA Tearing Analysis shall be repeated with a smaller initial flaw size

C.4 Installation Fatigue Analysis

C.4.1 The installation fatigue analysis can be performed using the standard Paris Fatigue Crack Growth method starting with the flaw size at the end of the Reel Installation.

C.4.2 The installation fatigue analysis shall be performed with the minimum pipe wall thickness at the pipe ends, i.e., the nominal pipe wall thickness minus the wall thickness tolerance or the minimum measured wall thickness.

C.4.3 The stress histograms used in the installation fatigue analysis shall be conservative and developed assuming:

a) The pipeline is installed in the “worst case” Sea State (wave and current) applicable for pipeline installation.
b) The stress histograms include all potential sources of fatigue damage, e.g., wave loading, vessel motions, Vortex Induced Vibration (VIV) during installation etc.
c) The installation duration is based on the normal installation period (Reel-lay vessel to seabed) plus the maximum allowable Hang-off time.

C.4.4 If required, separate installation stress histograms can be developed for normal pipe to pipe girth welds plus girth welds that are Held Off close to the Hang Off Clamp, e.g., installation of Pipeline End Terminations (PLETs) or Pipeline Manifolds (PLEMs).

C.4.5 Due to the short Installation times for a Reeled Pipeline an In-Air Fatigue Crack Growth (FCGR) Law may be used. The FCGR Law should be an upper bound curve with high R-ratio (e.g., M+2SD, R > 0.50).

C.4.6 The ECA methodology shall define the Installation Fatigue analysis methodology including:

a) The Installation Stress Histogram, if available at the time of preparing the ECA methodology
b) The maximum Allowable Hang-off Time
c) The Installation FCGR Law
d) The Installation Design Fatigue Factor (DFF), i.e., the Safety Factor assumed in the fatigue analysis.

C.4.7 A fracture assessment should be conducted for the final flaw at the end of the installation fatigue phase subject to the maximum stress during installation.

C.4.8 If the fracture assessment fails, then a smaller initial flaw size shall be used and the entire assessment (reeling and installation fatigue) repeated.

C.4.9 An installation Fracture Assessments is not required if the End of Life Extreme Event Stress (e.g., 100 Year Storm) is larger than the maximum dynamic stress during pipeline installation.

C.5 Pipeline Hydrotest Analysis

C.5.1 A Fracture Assessment shall be performed for pipeline commissioning (e.g., hydrotest) if the stress during commissioning exceeds the maximum dynamic stress during installation.

C.5.2 A pipeline commissioning Fracture Assessment is not required if the End of Life Extreme Event Stress (e.g., 100 Year Storm) is larger than the maximum hydrotest stress.

C.5.3 If a pipeline commissioning ECA is performed it should be described in the ECA methodology.

C.6 As-Laid and Operational Fatigue Analysis

C.6.1 The overall ECA methodology shall define the As-Laid & Operational Fatigue analysis methodology and justify all the key assumptions including:

a) The As-Laid & Operational Stress Histogram, if available at the time of preparing the ECA Methodology.

b) The As-Laid & Operational FCGR Laws for the different flaw geometries assessed. If FCGR laws for sour H_2S or sweet CO_2 environments are used in the Operational Fatigue analysis these FCGR Laws must be fully justified and account for the service environment and loading frequency.

c) The Design Fatigue Factor (DFF), i.e., the Safety Factor assumed in the As-Laid & Operational fatigue analysis. ECA DFFs can range from 1 to 5 depending on the application and the degree of uncertainty in the fatigue demand (number of cycles and stress ranges). The ECA Methodology should state the Operational ECA DFF with supporting justification. Note, for Risers installed in the Gulf of Mexico it is a legal requirement to adopt a DFF of 5.

C.6.2 The As-Laid & Operational fatigue analysis can be performed using the standard Paris Fatigue Crack Growth method starting with the flaw size at the end of the Installation Fatigue analysis.

C.6.3 The stress histograms used in the As-Laid & Operational Fatigue analysis shall be conservative, i.e., they shall include both the As-Laid and Operational phases and all potential sources of fatigue damage, e.g., wave loading, vessel motions, Vortex Induced Vibration (VIV), slugging, thermal stresses that may lead to lateral buckling etc.

C.6.4 If required separate Operational stress histograms can be developed for girth welds that are considered Fatigue Critical and Fatigue Non-Critical.

C.6.5 The As-Laid & Operational Fatigue Analysis shall adopt FCGR Laws which are representative of the environment the flaw is exposed to in operation.

a) For pipelines that do not operate in corrosive conditions, such as those involving H_2S, CO_2, etc., it is normal practice to assume:

- SW+CP FCGR Law (M+2SD, R > 0.50) for OD surface flaws, i.e., no credit is taken for the pipe OD coating.
- In-Air FCGR Law ((M+2SD), R > 0.50) for Buried Flaws and ID Surface Flaws

b) For pipelines that operate in sour (H_2S) or sweet (CO_2) service the Operational ECA should account for the environment by adopting an appropriate FCGR law.

- The FCGR Law can be determined by performing Project specific testing. Alternatively, an agreed environmental FCGR Law can be used with an appropriate Crack Growth Acceleration Factor (CGAF).
- If different FCGR Laws are proposed for ID surface and buried flaws close to the ID surface this should be justified in the ECA Methodology and agreed with the Company.

C.6.6 The As-Laid & Operational Fatigue analysis shall be performed using the minimum pipe wall thickness (nominal wall thickness minus the wall thickness tolerance or the minimum measured pipe wall thickness).

C.6.7 The pipe wall thickness shall be reduced to account for possible wall loss due to corrosion and/or erosion.

NOTE It is standard practice to assume that 50% of the Corrosion Allowance (if applicable) has been consumed, i.e., the Operational fatigue analysis is performed with an average wall thickness over the design life.

C.6.8 If the Operational fatigue analysis predicts flaw growth that extends through wall the entire ECA analysis shall be redone using a smaller initial flaw.

C.7 End of Life (EOL) Fracture Assessment

C.7.1 The EOL Fracture Assessment shall be described in the ECA methodology.

C.7.2 The EOL Fracture Assessment shall be performed to demonstrate that the flaw size at the end of the Operational Fatigue analysis will not fail by fracture when it is subjected to the maximum extreme event stress that may occur during operation, e.g., the 100 Year Storm or controlled lateral buckling (Strain ≤ 0.50%).

C.7.3 End of Life Fracture Assessments shall be performed using "Strained & Aged" stress strain curves from pipe that has been subjected to reeling simulation.

C.7.4 If the assessment is deemed stress based then the strain cycle ending in compression is appropriate, while if the assessment is deemed strain based then the strain cycle ending in tension is appropriate. If the assessment type cannot be clearly defined, then both testing regimes and assessments should be performed and the more limiting EOL Fracture Assessment shall govern. A stress-based assessment is commonly used when the applied load does not exceed 90% of the minimum yield stress at the design temperature.

C.7.5 All parties should agree on the requirements for a stress or strained-based EOL Fracture Assessment.

C.7.6 The "Strained & Aged" stress strain curves used in the End of Life Fracture Assessment shall be adjusted so that they represent "lower bound" stress strain curve for a stress based calculation and the "upper bound" stress strain curve for a strain based calculation. The method of adjusting the stress strain curves shall be submitted to Company for review and approval.

C.7.7 If needed, the tensile properties should be adjusted to account for temperature, e.g., temperature derating.

C.7.8 The EOL Fracture Assessment shall be performed using the minimum pipe wall thickness (nominal wall thickness minus wall thickness tolerance or minimum counter-bored wall thickness) assuming 100% of the Corrosion Allowance (if applicable) has been consumed.

C.7.9 The weld residual stress assumed in the EOL Fracture Assessment can be either:

a) The specified minimum yield strength value of the pipe material at room temperature and allowed to relax for large applied primary load where applicable.

b) The maximum predicted residual stress after reeling. If credit is taken for residual stress relaxation due to reeling this should be justified in the ECA Methodology and approved by Company.

C.7.10 For girth welds that have been reeled the EOL Fracture Assessment shall be performed with fracture toughness values obtained by testing SENB or SENT specimens that are in the "Strained & Aged" condition (i.e., they have been subjected to simulated reeling followed by aging). The final strain cycle in the simulated reeling shall end in tension.

C.7.11 If SENT specimens are used the effect of biaxiality shall be accounted for when determining the crack driving force (for example see DNV-RP-F108). This is not required when SENB specimens are used as the higher crack driving force due to biaxiality is offset by the higher constraint SENB specimens.

C.7.12 For girth welds that have not been reeled (i.e., girth welds made offshore) the EOL Fracture Assessment shall be performed with fracture toughness values obtained by testing SENB or SENT specimens that are in the "As Received" condition (i.e., they have not been subjected to simulated reeling followed by aging).

C.7.13 If SENT specimens are used the ECA shall include a correction for biaxiality.

C.7.14 The fracture toughness values used in the End of Life Fracture Assessment should be representative of the pipeline environment.

a) For pipelines that do not operate in sour (H_2S) or sweet (CO_2) service it is normal practice to assume In-Air fracture properties.

b) For pipelines that operate in sour (H_2S), sweet (CO_2) or Hydrogen (H_2) service the Operational ECA should account for the environment by adopting an appropriate value of fracture toughness.

- The fracture toughness can be determined by performing Project specific testing. Alternatively, an agreed lower bound toughness can be used based on historical test results.
- If different fracture toughness values are proposed for ID surface and buried flaws close to the ID surface this should be justified in the ECA Methodology and agreed with the Company.

C.8 AUT Validation

C.8.1 An AUT Validation Program shall be performed using girth welds with intentionally seeded flaws to determine the sizing accuracy of the AUT system to be used for girth weld inspection.

C.8.2 The AUT Validation Program shall follow an industry accepted method and shall have a minimum of 30 flaws.

C.8.3 Flaws shall be representative of those that may be encountered during welding.

C.8.4 If an AUT Validation Report is produced it should be referenced in the ECA Methodology and included in the ECA Report.

C.9 Development of Flaw Acceptance Criteria

C.9.1 The results of the ECA analysis can be used to develop girth weld flaw acceptance criteria by adjusting the ECA results to account for NDE (AUT) sizing accuracy.

C.9.2 The flaw acceptance criteria shall include flaw interaction criteria to enable the assessment of multiple flaws in close proximity.

C.9.3 The proposed flaw acceptance criteria shall be submitted to Company for review and approval.

Annex C: Requests for Interpretation and Requests for Revision to the Document shall be changed to Annex D.

Bibliography: Section shall be changed as indicated by the red markup below:

Bibliography

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