FITNESS-FOR-SERVICE

API 579-1/ASME FFS-1, December 2021

AN INTERNATIONAL CODE





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FOREWORD

In contrast to the straightforward and conservative calculations that are typically found in design codes, more sophisticated assessment of metallurgical conditions and analyses of stresses and strains can more precisely indicate whether operating equipment is fit for its intended service or whether fabrication defects or in-service deterioration threaten its integrity. Such analyses offer a sound basis for decisions to continue to run as is or to alter, repair, monitor, retire or replace the equipment.

The publication of the American Petroleum Institute's Recommended Practice 579, Fitness-For-Service, in January 2000 provided the refining and petrochemical industry with a compendium of consensus methods for reliable assessment of the structural integrity of equipment containing identified flaws or damage. API RP 579 was written to be used in conjunction with the refining and petrochemical industry's existing codes for pressure vessels, piping and aboveground storage tanks (i.e., API 510, API 570 and API 653). The standardized Fitness-For-Service Assessment procedures presented in API RP 579 provide technically sound consensus approaches that ensure the safety of plant personnel and the public while aging equipment continues to operate and can be used to optimize maintenance and operation practices, maintain availability and enhance the long-term economic performance of plant equipment.

API RP 579 was prepared by a committee of the American Petroleum Institute with representatives of the Chemical Manufacturers Association, as well as some individuals associated with related industries. It grew out of a resource document developed by a Joint Industry Program on Fitness-For-Service administered by The Materials Properties Council. Although it incorporated the best practices known to the committee members, it was written as a Recommended Practice rather than as a mandatory standard or code.

While API was developing Fitness-For-Service methodology for the refining and petrochemical industry, the American Society of Mechanical Engineers (ASME) also began to address post-construction integrity issues. Realizing the possibility of overlap, duplication, and conflict in parallel standards, ASME and API formed the Joint Fitness-For-Service Committee in 2001 to develop and maintain a Fitness-For-Service standard for equipment operated in a wide range of process, manufacturing, and power generation industries. It was intended that this collaboration would promote the widespread adoption of these practices by regulatory bodies. The Joint Committee included the original members of the API Committee that were involved in the development of API Recommended Practice 579, complemented by a similar number of ASME members representing similar areas of expertise in other industries such as chemicals, power generation, and pulp and paper. In addition to owner representatives, it included substantial international participation and subject matter experts from universities and consulting firms.

In June 2007, the API and ASME Fitness-For-Service Joint Committee published the first edition of API 579-1/ASME FFS-1 Fitness-For-Service. The main enhancement in this publication relative to 2000 Edition API 579 was the addition of Part 10 covering the assessment of components operating in the creep range.

The 2016 Edition of API 579-1/ASME FFS-1 included many modifications and technical improvements. Some of the more significant changes are the following: reorganized the standard to facilitate use and updates by renumbering annexes that are directly associated with the relevant part of the document, Expanded equipment design code coverage, added a new annex for establishing an allowable Remaining Strength Factor (RSF), re-wrote weld residual stress solution annex for use in the assessment of crack-like flaws, updated guidance on material toughness predictions for use in the assessment of crack-like flaws, updated evaluation procedures for the assessment of creep damage, added an annex covering metallurgical investigation and evaluation of mechanical properties in a fire damage assessment, and developed new Part 14 covering the assessment of fatigue damage.

Numerous changes have been made for the 2021 Edition of API 579-1/ASME FFS-1 to address user feedback and to introduce new technology. A summary of these changes is provided on pages xxxv to xl.

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This publication is written as a standard. Its words *shall* and *must* indicate explicit requirements that are essential for an assessment procedure to be correct. The word *should* indicate recommendations that are good practice but not essential. The word *may* indicate recommendations that are optional.

Most of the original technology that underlies this standard was developed by the Joint Industry Program on Fitness-For-Service, administered by The Materials Properties Council of the Welding Research Council, Inc., (WRC). The sponsorship of the member companies of this research consortium and the voluntary efforts of their company representatives are acknowledged with gratitude. Most of the next generation technology has been developed by WRC with some funding from API and ASME.

The committee encourages the broad use of the state-of-the-art methods presented here for evaluating all types of pressure vessels, boiler components, piping and tanks. The committee intends to continuously improve this standard as improved methodology is developed and as user feedback is received. All users are encouraged to inform the committee if they discover areas in which these procedures should be corrected, revised or expanded. Suggestions should be submitted to the Secretary, API/ASME Fitness-For-Service Joint Committee, The American Society of Mechanical Engineers, Two Park Avenue, New York, NY 10016, or SecretaryFFS@asme.org.

There is an option available to receive an e-mail notification when errata are posted to a particular code or standard. This option can be found on the Committee Web at http://go.asme.org/ffscommittee after selecting “errata” in the “Publication Information” section.

This standard is under the jurisdiction of the ASME Board on Pressure Technology Codes and Standards and the API CRE Committee and is the direct responsibility of the API/ASME Fitness-For-Service Joint Committee. The American National Standards Institute approved API 579-1/ASME FFS-1 2021 in December 2021.

Although every effort has been made to assure the accuracy and reliability of the information that is presented in this standard, API and ASME make no representation, warranty, or guarantee in connection with this publication and expressly disclaim any liability or responsibility for loss or damage resulting from its use or for the violation of any regulation with which this publication may conflict.

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SPECIAL NOTES

This international Code was developed under the ASME/API Joint Committee on Fitness-For-Service Policies and Procedures, which were approved by ANSI and accredited as meeting the criteria for American National Standards and it is an American National Standard. The Standards Committee that approved this Code was balanced to assure that individuals from competent and concerned interests have had an opportunity to participate. The proposed Code was made available for public review and comment that provides an opportunity for additional public input from industry, academia, regulatory agencies, and the public-at-large.

This document addresses problems of a general nature. With respect to particular circumstances, local, state, and federal laws and regulations should be reviewed.

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SUMMARY OF CHANGES

A summary of editorial corrections, updates, and clarifications that are included throughout the standard along with several technical changes and enhancements are described below.

Part 2: *Fitness-For-Service Engineering Assessment Procedure*

- Added provision that permits $MAWP$ to be determined using the stress analysis procedures in Annex 2D.

Annex 2C: *Thickness, $MAWP$, and Stress Equations for an FFS Assessment*

- Added Svensson method for burst pressure calculation.
- Removed option to use ASME VIII-2 allowable stress for ASME VIII-1 equipment. This was originally a carryover from API 510 before the allowable stress criteria in ASME VIII-2 changed from a factor of safety of 3.0 to a factor or safety of 2.4.
- Removed requirement for nozzle reinforcement check for small nozzles to be consistent with ASME VIII-1.
- Removed legacy limit load nozzle reinforcement procedure which was previously eliminated in ASME VIII-1.

Annex 2D: *Stress Analysis Overview for an FFS Assessment*

- Elastic load cases reference ASME VIII-2 for simplicity.
- Removed option to use ASME VIII-2 allowable stress for ASME VIII-1 equipment.
- Modified coefficients for use in elastic-plastic calculation to cover the appropriate design margins with various current and legacy construction codes (including the appropriate design margins for pipelines).
- Added explicit guidance on capping the yield stress used in a limit load analysis to the yield stress at temperature to prevent misapplication of the method when evaluating components fabricated from materials that have a design Code elastic allowable stress equal to 90% of the Minimum Specific Yield Stress (MSYS).
- Limited the allowable remaining strength factor, RSF_a, for buckling assessments to no lower than 0.9.

Annex 2E*: Material Properties for Stress Analysis*

- Updated the Ramberg-Osgood stress-strain model for use in a Level 3 evaluation.
- Added guidance for material properties for Level 3 evaluations involving pipeline materials.
- Updated correlations for estimating material Ultimate Tensile Strength (UTS) using hardness testing.

Part 3: *Assessment of Existing Equipment for Brittle Fracture*

- Clarified that the use of design codes/standards as an alternative to Part 3 is considered a Level 3 Assessment.
- Corrected errors related to the Minimum Allowable Temperature (MAT) for bolting and nut material specifications.
- Expanded the definition of shock chilling and added the requirement that a Level 3 evaluation is necessary to evaluate conditions where the shock chilling screening is not satisfied.
- Added thickness limits for Level 1 impact test exemption curves to be consistent with ASME VIII-1.
- Clarified that no $PWHT$ credit is permitted in a brittle fracture evaluation of a component if previous repairs were completed using alternative weld methods (such as high preheat or temper bead).
- Added supplemental inspection requirements for brittle fracture evaluations performed on component identified to have metal loss that exceeds the original design tolerances.
- Explicitly excluded mill tolerance effects in a brittle fracture assessment.

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- Modified impact test exemptions for flanges to address recent changes to ASME VIII-1.
  - Flanges Fabricated Pre-1989:
    - As-Forged SA-105 is Curve B. Heat-treated condition is Curve C.
    - MAT for ferritic flanges meeting ASME B16.5, ASME B16.47, or the Long Weld Neck (LWN) requirements of ASME VIII-1, UCS-66(c)(4) in the as-forged condition is -29°C (-20°F).
  - Flanges Fabricated in 1989 or Later:
    - As-Forged SA-105 is Curve A
    - Heat-treated condition SA-105 is Curve B
    - MAT for ferritic flanges meeting ASME B16.5, ASME B16.47, or LWN requirements in the as-forged is 0°F. Note: The basis for the 1989 cutoff comes from a 1996 report indicating "a number of flange failures have been reported during the past 5 years within the various Amoco operating units" and a Chemical Risks Directive requiring impact testing of all flanges in Europe being issued in response to a failure that occurred in 1998 on a flange that was installed in 1990.
  - MAT for ferritic flanges meeting ASME B16.5, ASME B16.47, or the LWN requirements in the normalized condition after forging shall be set at -29°C (-20°F) regardless of the year of manufacturing. (Note: Wording regarding "produced to fine grain practice" as currently included in ASME VIII-1 is not included).
  - For all ASME B16.5, ASME B16.47, and LWN flanges, MAT is set equal to the impact test exemption temperature "unless the MAT determined by the governing thickness at the flange nozzle neck weld joint together with the curve associated with the flange material gives a higher value."
- Added requirement that components not exposed to general primary membrane tensile stress shall be evaluated using the pressure rating basis in a Level 2 Assessment.

$$R_{ts} = \frac{P_a}{P_{rating}}$$

  - Added guidance that pressure rating in the stress ratio calculation can be calculated using paragraph 2C.3.4 for nozzle assemblies and paragraph 2C.3.6 for flanges.
  - Limited MAT to no lower than -48°C (-55°F) in as-welded condition even if Level 1 MAT was established using impact testing. (Note: MAT can still be reduced to -104°F (-155°F) if $PWHT$.)
    - Impact tested at or below -46°C (-50°F):

$$MAT = \max\left[\left(MAT_{Level\,1} - T_R\right), -104^\circ F\,(-155^\circ F)\right]$$

    - Impact tested above -46°C (-50°F):

$$MAT = \max\left[\left(MAT_{Level\,1} - T_R\right), -48^\circ F\,(-55^\circ F)\right] \quad (As-Welded\ Condition)$$

$$MAT = \max\left[\left(MAT_{Level\,1} - T_R\right), -104^\circ F\,(-155^\circ F)\right] \quad (PWHT\ Condition)$$

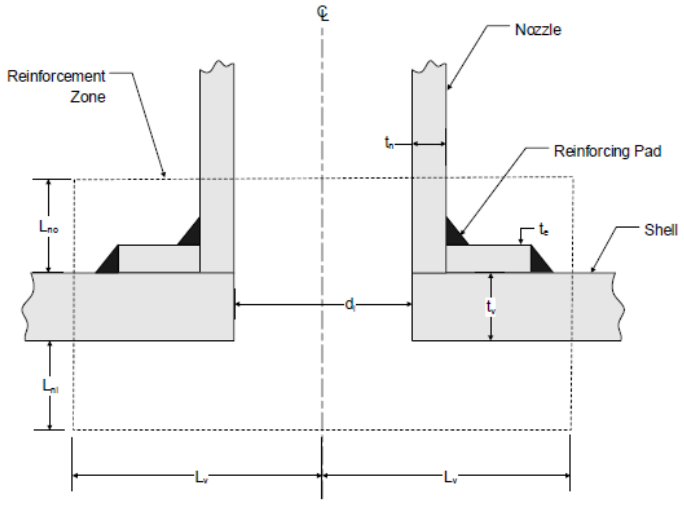
Part 4: *Assessment of General Metal Loss*

- Moved component type definitions and examples to a table to simplify designations.
- Exempted the cylinder side of 2:1 elliptical head-to-shell junctions as Type C components and structural discontinuities for metal loss assessments (applicable to Part 4, Part 5, and Part 6 Assessments).
- Revised qualifications to utilize Point Thickness Reading (PTR) approach to prevent misapplication of the method and "washing out" of local damage.

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- Eliminated the check on Coefficient of Variation (COV).
- Added limitation on minimum measured thickness, i.e., $t_{mm} \geq 0.9 \cdot t_{avg}$.

- Revised length for thickness averaging at nozzles (Figure 4.13) to ensure method does not permit greater damage at nozzle junctions vs. away from nozzle junctions.



Nozzle with a Reinforcement Element

Notes:

1. Thickness averaging zone in the horizontal direction (see paragraph 4.3.3.4.a): $L_H = \min[L,\ L_v]$. L is calculated using Equation 4.7. $L_v = \max[d_i,\ (d_i/2 + t_n + t_v)]$.
2. Thickness averaging zone in the vertical direction on the outside of the shell (see paragraph 4.3.3.4.a). $L_{vno} = \min[L, L_{no}]$ L is calculated using Equation 4.7. $L_{no} = \min[2.5t_v,\ (2.5t_n + t_e)]$.
3. Thickness averaging zone in the vertical direction on the inside of the shell (see paragraph 4.3.3.4.a): $L_{vni} = \min[L, L_{ni}]$. L is calculated using Equation 4.7. $L_{ni} = \min[2.5t_v,\ 2.5t_n]$.

Figure 4.13 – Zone for Thickness Averaging – Nozzles and Fabricated Branch Connections

- Revised recommended UT grid spacing for scenarios when "corroded surface is not accessible for visual inspection, $L_s = \min[2t_{rd}, 25\ mm\ (1\ inch)]$.
- Documented the purpose of the minimum measured thickness limit in Level 1 and Level 2 Assessments.
- Included recommendations for validation of inspection results when thickness readings are less than or equal to 2.5 mm (0.100 inches) (also referenced in Part 5 *Assessment of Local Wall Loss* and Part 6 *Assessment of Pitting*).

Part 9: *Assessment of Crack-Like Flaws*

- Redefined crack-like flaw interaction and recategorization rules to reduce conservatism and for better alignment with ASME Section XI.
- Table 9.2 updated to reflect new Wallin Master Curve fracture toughness correlation for carbon and low alloy steels in Annex 9F.

Annex 9B: *Compendium of Stress Intensity Factor Solutions for Crack-like Flaws*

- Expanded K-solutions to cover thick-wall cylinders.

Annex 9C: *Compendium of Reference Stress Solutions for Crack-like Flaws*

- Updated solutions for circumferential flaws in cylinders.
- Expanded reference solutions to cover thick-wall cylinders.

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Annex 9F: *Material Properties for Crack-like Flaws*

- Updated Wallin Master Curve fracture toughness correlation for carbon and low alloy steels,

$$K_{Jc} = 20 + \left(11 + 77\exp\left[0.0190\left(T - T_0\right)\right]\right)\left(\ln\left[\frac{1}{1-P_f}\right]\cdot\left(\frac{25}{L}\right)\right)^{0.25} \qquad \left(MPa\sqrt{m}, {}^{\circ}C, mm\right)$$

$$K_{Jc} = 18.2 + \left(9.9 + 70.1\exp\left[0.0106\left(T - T_0\right)\right]\right)\left(\ln\left[\frac{1}{1-P_f}\right]\cdot\left(\frac{1}{L}\right)\right)^{0.25} \qquad \left(ksi\sqrt{in}, {}^{\circ}F, in\right)$$

- Added ductile tearing material property data. The data was included in the 2007 edition of API 579, but mistakenly removed in the 2016 edition.
- Updated guidance on fracture toughness estimates for stainless-steel base metal and welds.
- Incorporated guidance from WRC Bulletin 562 *Recommendations for Establishing the Minimum Pressurization Temperature (MPT) for Equipment* and the API white paper *The Effects of Hydrogen for Establishing a Minimum Pressurization Temperature (MPT) for Heavy Wall Steel Reactor Vessels* to address material toughness modifications due to hydrogen and temper embrittlement effects.
- Added guidance for ASME VIII-3 equipment (high pressure).

New Annex 9H: *Constraint Effects for Surface Flaws in Carbon and Low-Alloy Steel Components in the Ductile-Brittle Transition Region*

- Established a procedure to adjust material fracture toughness to take advantage of constraint effects for surface flaws in a Level 2 Assessment.
- Technical basis is documented in WRC Bulletin 577 *Constraint Effects on Fracture Toughness in Ductile-Brittle Transition*.

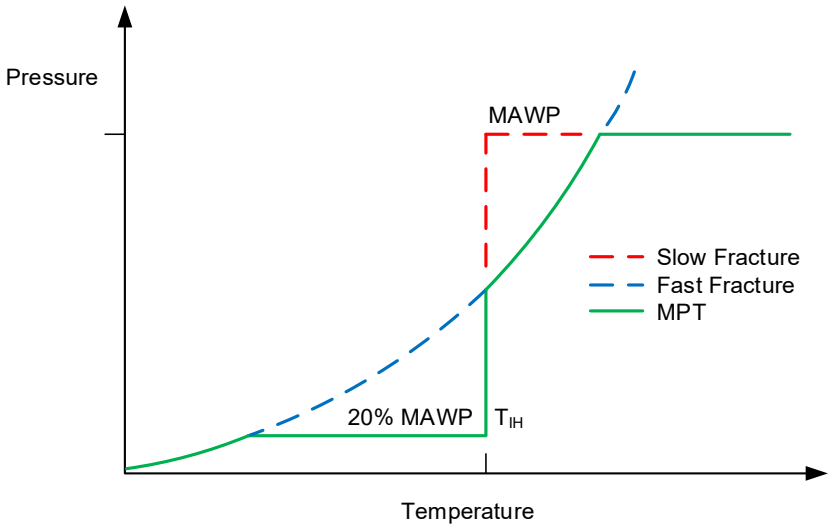
New Annex 9I: *Alternative Estimate of Mode I Stress Intensity Factors*

- Established a procedure to reduce conservatism with the Mode I stress intensity factors using an integrated crack driving force over the crack front (rather than peak values) in a Level 2 assessment.
- Technical basis is documented in WRC Bulletin 577 *Constraint Effects on Fracture Toughness in Ductile-Brittle Transition*.

New Annex 9J: *Determination of the Minimum Allowable Temperature (MAT) using a Fracture Mechanics Approach*

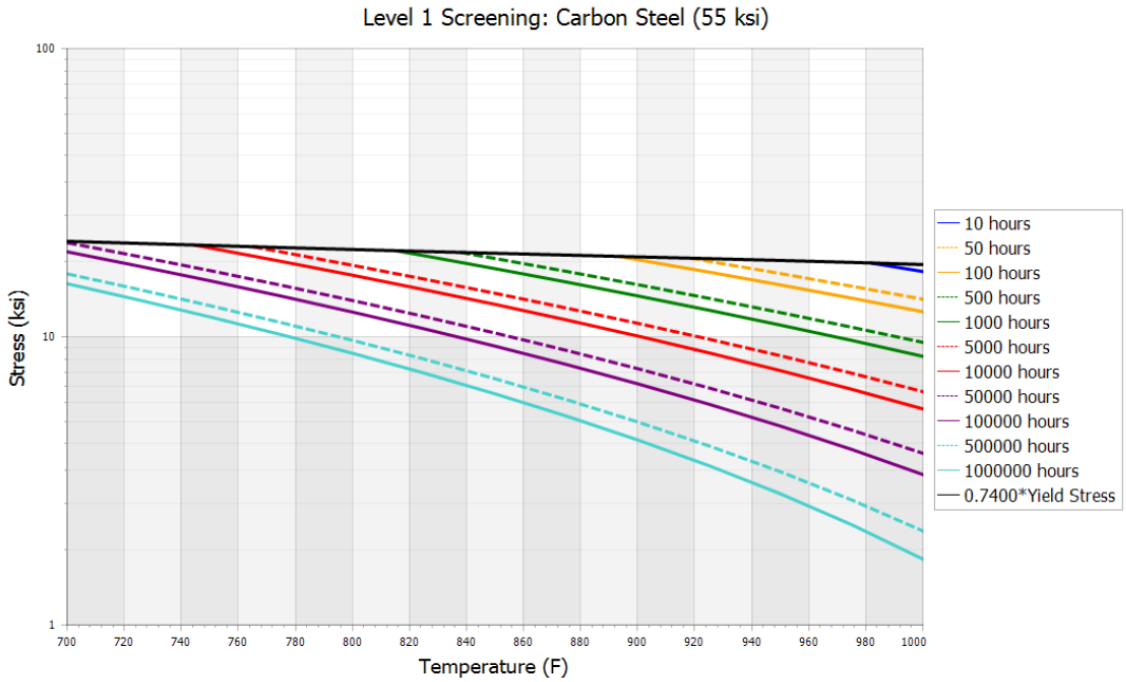
- Established procedure for using fracture mechanics to determine the MAT.
- Included a simplified brittle fracture screening procedure developed using fracture mechanics.
- Provided guidance on the necessary adjustments for 2.25Cr-1Mo steel in hydrogen service.

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Part 10: *Assessment of Components Operating in the Creep Range*

- Updated Level 1 screening curves to ensure consistency with results from a Level 2 Assessment and incorporate technology updates (updated material coefficients, etc.).



- Revised Level 1 maximum permissible damage limit to 0.8 in the evaluation of multiple operating conditions.
- Add structural thickness limit to Level 1 and Level 2 Assessments to protect against loss of containment due to the challenges and limitations associated with inspection of furnace tubes.

$$t_{\lim} = \min\left[0.9t_{nom},\ 2.5\,mm\ (0.100\ inches)\right]$$

Annex 10B: *Material Data for Creep Analysis*

- Updated existing and added new MPC Omega material coefficients.

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- Added WRC Bulletin 541 revision 3 Larson-Miller material coefficients.
- Fixed elevated temperature fatigue curve coefficients.

Part 11: *Assessment of Fire Damage*

- Extended the use of hardness testing to cover carbon steel, low chrome, and stainless-steel materials.

Part 12: *Assessment of Dents, Gouges, and Dent-Gouge Combinations*

- Updated Level 1 and Level 2 procedures, applicability and limitations, and acceptance criteria to align with The Pipeline Defect Assessment Manual (PDAM).
- Table 12.2 updated to reflect new Wallin Master Curve fracture toughness correlation for carbon and low alloy steels in Annex 9F.

Part 14: *Assessment of Fatigue Damage*

- Added closed-form equation for smooth bar fatigue curves and data for new materials.
- Added smooth bar fatigue curves based on fatigue testing in air.
- Added bounds for use of smooth bar fatigue curve equations.
- Updated fatigue screening Method C and Method D.
- Corrected plasticity correction factor, $K_{e,k}$.
- Elastic ratcheting procedure re-written using Bree Diagram.
- Updated Level 2 procedure for Method C Fatigue Assessment.

Annex 14B: *Material Properties for Fatigue Analysis*

- Added closed-form equation for smooth bar fatigue curves and added data for new materials.
- Added smooth bar fatigue curves based on fatigue testing in air.
- Added bounds for use of smooth bar fatigue curve equations.

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PART 1 – INTRODUCTION

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1.1 Introduction

1.1.1 Construction Codes and Fitness-For-Service

The ASME and API new construction codes and standards for pressurized equipment provide rules for the design, fabrication, inspection and testing of new pressure vessels, piping systems, and storage tanks. These codes typically do not provide rules to evaluate equipment that degrades while in-service and deficiencies caused by degradation or from original fabrication that may be found during subsequent inspections. API 510, API 570, API 653, and NB-23 Codes/Standards for the inspection, repair, alteration, and rerating of in-service pressure vessels, piping systems, and storage tanks do address the fact that equipment degrades while in service.

1.1.2 Fitness-For-Service Definition

Fitness-For-Service (FFS) Assessments are quantitative engineering evaluations that are performed to demonstrate the structural integrity of an in-service component that may contain a flaw or damage, or that may be operating under a specific condition that might cause a failure. This Standard provides guidance for conducting FFS Assessments using methodologies specifically prepared for pressurized equipment. The guidelines provided in this Standard can be used to make run-repair-replace decisions to help determine if components in pressurized

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equipment containing flaws that have been identified by inspection can continue to operate safely for some period of time. These FFS Assessments are currently recognized and referenced by the API Codes and Standards (510, 570, and 653), and by NB-23 as suitable means for evaluating the structural integrity of pressure vessels, piping systems and storage tanks where inspection has revealed degradation and flaws in the equipment.

1.2 Scope

1.2.1 Supplement to In-Service Inspection Codes

The methods and procedures in this Standard are intended to supplement and augment the requirements in API 510, API 570, API 653, and other post construction codes that reference FFS evaluations such as NB-23.

1.2.2 Application Construction Codes

The assessment procedures in this Standard can be used for FFS Assessments and/or rerating of equipment designed and constructed to the following codes:

a) ASME B&PV Code, Section VIII, Division 1

b) ASME B&PV Code, Section VIII, Division 2

c) ASME B&PV Code, Section I

d) ASME B31.1 Piping Code

e) ASME B31.3 Piping Code

f) ASME B31.4 Piping Code

g) ASME B31.8 Piping Code

h) ASME B31.12 Piping Code

i) API Std 650

j) API Std 620

k) API Std 530

1.2.3 Other Recognized Codes and Standards

The assessment procedures in this Standard may also be applied to pressure containing equipment constructed to other recognized codes and standards, including international and internal corporate standards. This Standard has broad applications since the assessment procedures are based on allowable stress methods and plastic collapse loads for non-crack-like flaws, and the Failure Assessment Diagram (FAD) Approach for crack-like flaws (see Part 2, paragraph 2.4.2).

a) If the procedures of this Standard are applied to pressure containing equipment not constructed to the codes listed in paragraph 1.2.2, then the user is advised to first review the validation discussion in Annexes 3A through 14A. The information in these Annexes, along with knowledge of the differences in design codes, should enable the user to factor, scale, or adjust the acceptance limits of this Standard such that equivalent FFS in-service margins can be attained for equipment not constructed to these codes. When evaluating other codes and standards, the following attributes of the ASME and API design codes should be considered:

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1) Material specifications
2) Upper and lower temperature limits for specific materials
3) Material strength properties and the design allowable stress basis
4) Material fracture toughness requirements
5) Design rules for shell sections
6) Design rules for shell discontinuities such as nozzles and conical transitions
7) Design requirements for cyclic loads
8) Design requirements for operation in the creep range
9) Weld joint efficiency or quality factors
10) Fabrication details and quality of workmanship
11) Inspection requirements, particularly for welded joints

b) As an alternative, users may elect to correlate the pressure-containing component's material specification to an equivalent ASME, or API listed material specification to determine a comparable allowable stress. This approach provides an entry point into the ASME or API codes wherein the pressure-containing component is reconciled or generally made equivalent to the design bases assumed for this Standard (see Annex 2C, paragraph 2C.1.3). Hence, general equivalence is established, and the user may then directly apply the acceptance limits of the FFS procedures contained in this Standard. Equivalent ASME and ASTM material specifications provide a satisfactory means for initiating reconciliation between the ASME and API design codes and other codes and standards. However, the user is cautioned to also consider the effects of fabrication and inspection requirements on the design basis (e.g., joint efficiency with respect to minimum thickness calculation).

1.2.4 Remaining Life

The FFS Assessment procedures in this Standard cover both the present integrity of the component given a current state of damage and the projected remaining life. Qualitative and quantitative guidance for establishing remaining life and in-service margins for continued operation of equipment are provided in regards to future operating conditions and environmental compatibility.

1.2.5 Assessment Methods for Flaw Types and Damage Conditions

Assessment methods as well as material properties, Nondestructive Examination (NDE) guidelines, and documentation requirements are included to evaluate flaws including: general and localized corrosion, widespread and localized pitting, blisters and hydrogen damage, weld misalignment and shell distortions, crack-like flaws including environmental cracking, laminations, dents, and gouges. In addition, evaluation techniques are provided for condition assessment of equipment including resistance to brittle fracture, creep damage, and fire damage.

1.2.6 Special Cases

The FFS Assessment procedures in this Standard can be used to evaluate flaws commonly encountered in pressure vessels, piping, and tankage. The procedures are not intended to provide a definitive guideline for every possible situation that may be encountered. However, flexibility is provided to the user in the form of an advanced

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assessment level to handle uncommon situations that may require a more detailed analysis.

1.3 Organization and Use

The organization, applicability and limitations, required information, analysis techniques and documentation requirements are described in Part 2 of this Standard. In addition, an overview of the acceptance criteria utilized to qualify a component with a flaw is provided. First time users of the FFS Assessment technology in this Standard should carefully review Part 2 prior to starting an analysis.

1.4 Responsibilities

1.4.1 Owner-User

The Owner-User of pressurized equipment shall have overall responsibility for FFS Assessments completed using the procedures in this Standard, including compliance with appropriate jurisdictional and insurance requirements. The Owner-User shall ensure that the results of the assessment are documented and filed with the appropriate permanent equipment records. Many of the Owner-User responsibilities are given to the Plant Engineer (see paragraph 1.4.4).

1.4.2 Inspector

The Inspector, working in conjunction with the Nondestructive Examination (NDE) engineer, shall be responsible to the Owner-User for determining that the requirements for inspection and testing are met. In addition, the Inspector shall provide all necessary inspection data required for an FFS Assessment in accordance with the appropriate Part of this Standard and be responsible for controlling the overall accuracy of the flaw detection and sizing activities. In some instances, as determined by the Owner-User, the Inspector may also be responsible for the FFS Assessment, i.e., a Level 1 Assessment (see Part 2, paragraph 2.4.1.1).

1.4.3 Engineer

1.4.3.1 The Engineer is responsible to the Owner-User for most types of FFS Assessments, documentation, and resulting recommendations. The exception is that a Level 1 Assessment may be performed by an Inspector or other non-degreed specialist (see Part 2, paragraph 2.4.1.1). However, in these cases the Engineer should review the analysis.

1.4.3.2 In the context of this Standard, the term Engineer applies to the combination of the following disciplines unless a specific discipline is cited directly. A FFS Assessment may require input from multiple engineering disciplines as described below.

a) Materials or Metallurgical Engineering – Identification of the material damage mechanisms, establishment of corrosion/erosion rates, determination of material properties including strength parameters and crack-like flaw growth parameters, development of suitable remediation methods and monitoring programs, and documentation.

b) Mechanical or Structural Engineering – Computations of the minimum required thickness and/or $MAWP$ (MFH) for a component, performance of any required thermal and stress analysis, and knowledge in the design of and the practices relating to pressure containing equipment including pressure vessel, piping, and tankage codes and standards.

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c) Inspection Engineering – Establishment of an inspection plan that is capable of detecting, characterizing, sizing flaws or damage, and selection and execution of examination procedures in conjunction with available Nondestructive Examination expertise.

d) Fracture Mechanics Engineering – Assessment of crack-like flaws using the principles of fracture mechanics.

e) Nondestructive Examination (NDE) Engineering – Selection and development of methods to detect, characterize, and size flaws or quantify the amount of damage, and the analysis and interpretation of inspection data.

f) Process Engineering – Documentation of past and future operating conditions, including normal and upset conditions, and identification of the contained fluid and its contaminant levels that may affect degradation of the component being evaluated.

1.4.4 Plant Engineer

In the context of this Standard, the term Plant Engineer applies to an engineer with knowledge of the equipment containing the component requiring the FFS Assessment. The Plant Engineer may perform both a Level 1 Assessment and Level 2 Assessment and typically has certain knowledge of the engineering disciplines, or access to personnel with the necessary engineering disciplines knowledge required for the FFS Assessment to be performed, described in paragraph 1.4.3.2.

1.5 Qualifications

1.5.1 Education and Experience

The level or amount of education and experience of all participants shall be commensurate with the complexity, rigor, requirements and significance of the overall assessment. All individuals involved shall be able to demonstrate their proficiency to the satisfaction of the Owner-User.

1.5.2 Owner-User

The Owner-User shall understand the overall process, the importance of each piece of equipment to that process, and the failure consequences of each piece of equipment such that the Owner-User can assume overall responsibility for the results of the FFS Assessment performed (see paragraph 1.4.1). The Owner-User shall have the ability and experience to recognize potentially damaging operations or equipment conditions and to take remedial steps.

1.5.3 Inspector

The Inspector shall be qualified and certified in accordance with the applicable post-construction Code, API 510, API 570, API 653, NB-23, or other post-construction code or standard required by the jurisdiction (see paragraph 1.4.2). Nondestructive examination personnel responsible for data used in an FFS Assessment shall be certified to at least Level II in accordance with industry standards such as the American Society for Nondestructive Testing (ASNT) SNT-TC-1A, CP-189, ACCP, or equivalent. The Inspector shall have experience in the inspection, examination, or both, of the type of equipment and associated process that is the subject of the FFS Assessment.

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1.5.4 Engineer

The Engineer shall be competent to perform the level of assessment required (see paragraph 1.4.3). The Engineer shall meet all required qualifications to perform engineering work within the applicable jurisdiction and any supplemental requirements stipulated by the Owner-User.

1.6 Definition of Terms

Definitions of common technical terms used throughout this Standard may be found in Annex 1A.

1.7 References

1.7.1 Types

Throughout this Standard, references are made to various international codes, standards, recommended practices, and technical reports that cover:

a) Design, fabrication, inspection, and testing of pressure vessels, piping, and tankage.

b) In-service inspection of pressure vessels, piping, and tankage.

c) FFS standards applicable to welded components.

d) Materials selection and behavior in process plants or other industrial environments.

1.7.2 Code, Standards and Recommended Practices

Rules for the use of these codes, standards, recommended practices and technical reports are stated in each Part and Annex of this Standard. The referenced codes, standards, and recommended practices in this Standard are listed in Table 1.1. The edition of the codes, standards, and recommended practices used in the FFS Assessment shall be either the latest edition, the edition used for the design and fabrication of the component, or a combination thereof. The Engineer responsible for the assessment shall determine the edition(s) to be used. The principles cited in paragraph 1.2.3 and Annex 2C, paragraph 2C.3 should be considered when making this determination.

1.7.3 Technical reports and Other Publications

References to other publications that provide background and other pertinent information to the assessment procedures used in this Standard are included in each Part and Annex, as applicable.

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1.8 Tables

Table 1.1 – Codes, Standards and Recommended Practices

Title	Identification
Pressure Vessel Inspection Code: In-Service Inspection, Rating, Repair and Alteration	API 510
Calculation of Heater-Tube Thickness in Petroleum Refineries	API Std 530
Piping Inspection Code: In-Service Inspection, Repair, and Alteration of Piping Systems	API 570
Damage Mechanisms Affecting Fixed Equipment in the Refining Industry	API RP 571
Inspection of Pressure Vessels	API RP 572
Inspection of Fired Boilers and Heaters	API RP 573
Inspection Practices for Piping System Components	API RP 574
Inspection Practices for Atmospheric and Low-pressure Storage Tanks	API RP 575
Inspection of Pressure-Relieving Devices	API RP 576
Welding Processes, Inspection, and Metallurgy	API RP 577
Material Verification Program for New and Existing Alloy Piping Systems	API RP 578
Risk-Based Inspection	API RP 580
Risk-Based Inspection Methodology	API RP 581
Design and Construction of Large, Welded, Low-Pressure Storage Tanks	API Std 620
Welded Tanks for Oil Storage	API Std 650
Tank Inspection, Repair, Alteration, and Reconstruction	API Std 653
Materials and Fabrication of 2-1/4Cr-1Mo, 2 1/4Cr-1Mo-1/4V, 3Cr-1Mo, and 3Cr-1Mo-1/4V Steel Heavy Wall Pressure Vessels for High-temperature, High Pressure Hydrogen Service	API RP 934–A
Materials and Fabrication of 1 1/4Cr-1/2 Mo Steel Heavy Wall Pressure Vessels for High-pressure Hydrogen Service Operating at or Below 825 Degrees F (440 Degrees C)	API RP 934–C
Closed Recommended Practice for Materials and Fabrication of 1 1/4 CR-1/2 Mo Steel Pressure Vessels for Service Above 825 degrees F (440 C)	API RP 934–E
Steels for Hydrogen Service at Elevated Temperatures and Pressures in Petroleum Refineries and Petrochemical Plants	API RP 941
Avoiding Environmental Cracking in Amine Units	API RP 945
Assessment and Management of Cracking in Pipelines	API RP 1176
Assessment and Management of Dents in Pipelines	API RP 1183

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Table 1.1 – Codes, Standards and Recommended Practices

Title	Identification
API-ASME Code for the Design, Construction, Inspection and Repair of Unfired Pressure Vessels for Petroleum Liquids and Gases	API-ASME Code 1934-1954
National Board Inspection Code	NBBI NB-23
Minimum Design Loads and Associated Criteria for Buildings and Other Structures	ASCE 7
Section I: Rules for Construction of Power Boilers	ASME B&PV Code Section I
Section II: Materials – Part A: Ferrous Material Specifications	ASME B&PV Code Section II, Part A
Section II: Materials – Part B: Nonferrous Material Specifications	ASME B&PV Code Section II, Part B
Section II: Materials – Part D: Properties (Customary)	ASME B&PV Code Section II, Part D
High Temperature Reactors	ASME B&PV Code Section III, Division 5
Unfired Pressure Vessels	ASME Section VIII, 1950 to 1965 Edition
Unfired Pressure Vessels	ASME Section VIII, prior to the 1950
Boiler and Pressure Vessel Code, Section VIII, Pressure Vessels Division 1	ASME B&PV Code Section VIII, Division 1
Boiler and Pressure Vessel Code, Section VIII, Pressure Vessels Division 2, Alternative Rules	ASME B&PV Code Section VIII, Division 2
Rules for In-Service Inspection of Nuclear Power Plant Components	ASME B&PV Code Section XI
Alternative Method to Area Replacement Rules for Openings Under Internal Pressure, Section VIII, Division 1	ASME B&PV Code Case 2168
Alternative Rules for Determining Allowable External Pressure and Compressive Stresses for Cylinders, Cones, Spheres, and Formed Heads, Section VIII, Divisions 1, and 2	ASME B&PV Code Case 2286
Factory-Made Wrought Buttwelding Fittings	ASME B16.9
Manual for Determining the Remaining Strength of Corroded Pipelines: Supplement to ASME B31 Code for Pressure Piping	ASME B31G
Power Piping	ASME B31.1
Process Piping	ASME B31.3
Pipeline Transportation Systems for Liquids and Slurries	ASME B31.4
Gas Transmission and Distribution Piping System	ASME B31.8
Hydrogen Piping and Pipelines	ASME B31.12
Standard Specification for General Requirements for Steel Plates for Pressure Vessels	ASTM A20
Standard Specification for Electric-Fusion-Welded Austenitic Chromium-Nickel Stainless Steel Pipe for High-Temperature Service and General Applications	ASTM A358

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Table 1.1 – Codes, Standards and Recommended Practices

Title	Identification
Standard Test Methods and Definitions for Mechanical Testing of Steel Products	ASTM A370
Standard Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe	ASTM A530
Standard Specification for Electric-Fusion-Welded Steel Pipe for Atmospheric and Lower Temperatures	ASTM A671
Standard Specification for Electric-Fusion-Welded Steel Pipe for High-Pressure Service at Moderate Temperatures	ASTM A672
Standard Specification for Carbon and Alloy Steel Pipe, Electric-Fusion-Welded for High-Pressure Service at High Temperatures	ASTM A691
Standard Test Methods of Tension Testing of Metallic Materials	ASTM E8
Standard Test Method for Measurement of Fatigue Crack Growth Rates	ASTM E647
Standard Practices for Cycle Counting in Fatigue Analysis	ASTM E1049
Standard Test Method for Measurement of Fracture Toughness	ASTM E1820
Standard Test Method for Determination of Reference Temperature, T_0, for Ferritic Steels in the Transition Range	ASTM E1921
Standard Guide for Examination and Evaluation of Pitting Corrosion	ASTM G46
Specification for Unfired Pressure Vessels	BS PD 5500
Guide to Methods for the Assessment of the Influence of Crack Growth on the Significance of Defects in Components Operating at High Temperatures	BS PD 6539
Method for Determination of K_{IC}, Critical CTOD and Critical J Values of Welds in Metallic Materials	BS 7448: Part 2
Guide to Fatigue Design and Assessment of Steel Products	BS 7608
Guide to Methods for Assessing the Acceptability of Flaws in Metallic Structures	BS 7910
Design of Steel Pressure Pipes	DIN 2413 Part 1
Design of Steel Bends Used in Pressure Pipelines	DIN 2413 Part 2
Unfired pressure vessels	EN 13445
Summary of Average Stress Rupture Properties of Wrought Steels for Boilers and Pressure Vessels	ISO/TR 7468-1981(E)
Guidelines for Detection, Repair, and Mitigation of Cracking of Existing Petroleum Refinery Pressure Vessels in Wet H_2S Environments	NACE Std RP0296
Assessment Procedure for High Temperature Response of Structures	EDF Energy R-5

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Table 1.1 – Codes, Standards and Recommended Practices

Title	Identification
Assessment of the Integrity of Structures Containing Defects	EDF Energy R-6
A combined deterministic and probabilistic procedure for safety assessment of components with cracks – Handbook	SSM Report 2008:01
Method of Assessment for Flaws in Fusion Welded Joints with Respect to Brittle Fracture and Fatigue Crack Growth	JWES 2805

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