FFS STATUS AND ISSUES FOR WELDMENTS IN PRESSURE EQUIPMENT UNDER API579

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ABSTRACT
An overview of a Joint API/ASME fitness-for-service standard for application to pressurized equipment is presented in this paper. This new standard is based on API 579 *Recommended Practice for Fitness-For-Service* [1]; however, many modifications to API 579 are being made to address the special needs of other industries such as the fossil electric power industry, and the pulp and paper industry. API 579 was initially released in January of 2000, and since that time has become the de facto international fitness-for-service standard for the refining and petrochemical industry. Insights into the driving force to create the first edition of API 579, a detailed overview of the second edition of API 579, and plans for the establishment of the first edition of a new Joint API/ASME 579 Standard are provided. An overview of the treatment of weld joints in the new Joint API/ASME 579 also is provided.
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INTRODUCTION
The ASME and API design 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 do not provide assessment procedures to evaluate degradation due to in-service environmentally-induced damage or from original fabrication that may be found during subsequent inspections. Fitness-For-Service (FFS) assessments are quantitative engineering evaluations that are performed to demonstrate the structural integrity of an in-service component containing a flaw or damage. API 579 has been developed to provide guidance for conducting FFS assessments of flaws commonly encountered in the refining and petrochemical industry that occur in pressure vessels, piping, and tankage. However, the assessment procedures have been used to evaluate flaws encountered in other industries such as the pulp and paper industry, fossil electric power industry, and nuclear industry. The guidelines provided in API 579 can be used to make run-repair-replace decisions to ensure that pressurized equipment containing flaws that have been identified during an inspection can continue to be operated safely.

API 579 is intended to supplement the requirements in API 510 [2], API 570 [3], API 653 [4], and NB-23 [5]: to ensure safety of plant personnel and the public while older equipment continues to operate; to provide technically sound FFS assessment procedures: to ensure that different service providers furnish consistent remaining life predictions; and to help optimize maintenance and operation of existing facilities to maintain availability of older plants and enhance long-term economic viability. In addition, API 579 will be used in conjunction with API 580 *Recommended Practice For Risk-Based Inspection* [6] to provide guidelines for risk assessment, and prioritization for inspection and maintenance planning for pressure-containing equipment.

API 579 DEVELOPMENT BACKGROUND
The initial impetus to develop a new FFS standard that could be referenced from the API inspection codes was provided by a Joint Industry Project (JIP) administered by the Material Properties Council (MPC). The driving force behind this development was plant safety. The methodology provided in the new FFS standard, together with the appropriate API inspection code, had to ensure that equipment integrity could be safely maintained when operating equipment with flaws or damage and could also be used to demonstrate compliance with US OSHA 1910 PSM Legislation.

A review of the existing international FFS standards by the members of the MPC JIP was undertaken in 1991 as the starting point for the development of a new FFS standard. Based on the results of this review, it was determined that a comprehensive FFS standard covering many of the typical flaw types and damage mechanisms found in the refining and petrochemical industry did not exist. In addition, the existence of many company-based FFS methods, the complexity of the technology that no single company can solve on its own, and the need to gain acceptance by local jurisdictions in the US further indicated the need for a new standard. Therefore, the JIP decided to start the development of the required FFS technology that would be needed to write a comprehensive

FFS standard for the refining and petrochemical industry. The results of this work were documented in a MPC FFS JIP Consultant's Report [7], and this document was subsequently turned over to the API CRE (Committee on Refinery Equipment) FFS Task Force charged with development of the FFS standard.

In terms adopted by the API CRE FFS Task Group developing API 579, a FFS assessment is an engineering analysis of equipment to determine whether it is fit for continued service. The equipment may contain flaws, may not meet current design standards, or may be subjected to more severe operating conditions than the original or current design. The product of a FFS assessment is a decision to operate the equipment as is or to alter, repair, monitor, or replace; guidance on an inspection interval is also provided. FFS assessments consist of analytical methods to assess flaws and damage and usually require an interdisciplinary approach consisting of the following:

- Knowledge of damage mechanisms/material behavior,
- Knowledge of past and future operating conditions & interaction with operations personnel,
- NDE (flaw location and sizing),
- Material properties (environmental effects),
- Stress analysis (often finite element analysis), and
- Data analysis (engineering reliability models).

Based on this definition, the API CRE FFS Task Group modified and greatly enhanced the initial efforts of the MPC JIP to produce the first edition of API 579. The MPC JIP continued to provide valuable technical contributions throughout this development effort and became the technical development arm of the API Task Group. The MPC FFS JIP is still in existence and continues to provide FFS technology development while working closely with the needs of the API CRE FFS Task Group.

OVERVIEW OF API RP 579

Applicable Codes

API 579 provides guidelines for performing FFS assessments that can be used in conjunction with the API Inspection Codes (API 510, API 570 and API 653) to determine the suitability for continued operation. The assessment procedures in this recommended practice can be used for fitness-for-service assessments and/or rerating of components designed and constructed to the design codes shown below.

- ASME B&PV Code, Section VIII, Division 1
- ASME B&PV Code, Section VIII, Division 2
- ASME B&PV Code, Section I
- ASME B31.3 Piping Code
- ASME B31.1 Piping Code
- API 650
- API 620

The assessment procedures in API 579 may also be applied to pressure containing equipment constructed to other recognized codes and standards including international and internal corporate standards. API 579 has broad application since the assessment procedures are based on allowable stress methods and plastic collapse loads for non-crack-like flaws and FAD-based strategies for crack-like flaws.

Organization

API 579 is a highly structured document designed to facilitate use by practitioners and to facilitate future enhancements and modifications by the API CRE FFS Task Group. Part 1 of the document covers: introduction and scope; responsibilities of the owner-user, inspector, and engineer; qualification requirements for the inspector and engineer; and references to other codes and standards. An outline of the overall FFS assessment methodology that is common to all assessment procedures included in API 579 is provided in Part 2 of the document. The organization of Part 2 is shown in Table 1. This same organization is utilized in all subsequent parts that contain FFS assessment procedures.

Starting with Part 3, a catalogue of FFS assessment procedures organized by damage mechanism is provided in API 579. A complete listing of the flaw and damage assessment procedures currently covered is shown in Table 2. When assessment procedures are developed for a new damage mechanism, they will be added as a self-contained part to maintain the structure of API 579. A series of appendices is provided which contains technical information that can be used with all parts of API 579 that cover FFS assessment procedures. The majority of the information in the appendices covers stress analysis techniques, material property data, and other pertinent information that is required when performing a FFS assessment. An overview of the appendices is provided in Table 3.

Assessment Levels

Three levels of assessment are provided in API 579 for each flaw and damage type. In general, each assessment level provides a balance between conservatism, the amount of information required for the evaluation, the skill of the practitioner performing the assessment, and the complexity of analysis being performed. Level 1 is the most conservative but the easiest to use. Practitioners usually proceed sequentially from a Level 1 to a Level 3 assessment (unless otherwise directed by the assessment techniques) if the current assessment level does not provide an acceptable result or a clear course of action cannot be determined. It should be noted that the definitions of assessment levels in API 579 are significantly different than those used in other standards.

A general overview of each assessment level and its intended use are described below.

- Level 1 – The assessment procedures included in this level are intended to provide conservative screening criteria that can be utilized with a minimum amount of inspection or component information. The Level 1 assessment procedures may be used by either plant inspection or engineering personnel.
- Level 2 – The assessment procedures included in this level are intended to provide a more detailed evaluation that produces results that are less conservative than those from a Level 1 assessment. In a Level 2 assessment, inspection information similar to that required for a Level 1 assessment is required; however, more detailed calculations are used in the evaluation. Level 2

assessments are typically conducted by plant engineers or engineering specialists experienced and knowledgeable in performing FFS assessments.

- Level 3 – The assessment procedures included in this level are intended to provide the most detailed evaluation that produces results that are less conservative than those from a Level 2 assessment. In a Level 3 assessment, the most detailed inspection and component information is typically required. The recommended analysis is based on numerical techniques such as the finite element method. The Level 3 assessment procedures are primarily intended to be used by engineering specialists experienced and knowledgeable in performing FFS evaluations.

Remaining Life And Rerating

The FFS assessment procedures in API 579 cover both the present integrity of the component given a current state of damage and the projected remaining life. If the results of a FFS assessment indicate that the equipment is suitable for the current operating conditions, the equipment can continue to be operated at these conditions if a suitable inspection program is established. If the results of the FFS assessment indicate that the equipment is not suitable for the current operating conditions, calculation methods are provided in API 579 to rerate the component. For pressurized components (e.g. pressure vessels and piping) these calculation methods can be used to find a reduced Maximum Allowable Working Pressure and/or coincident temperature. For tank components (i.e., shell courses) the calculation methods can be used to determine a reduced Maximum Fill Height. The remaining life calculation in API 579 is not intended to provide a precise estimate of the actual time to failure. Alternatively, the remaining life calculation is used to establish an appropriate inspection interval in conjunction with the governing inspection code and/or in-service monitoring plan, or the need for remediation. API 579 emphasizes the need for remediation where the remaining life cannot be established. Remediation can be in the form of altering the process stream or isolating the stream from the pressurized component. API 579 also emphasizes the need for monitoring and inspection to validate the assumptions made about continuing damage.

Relationship To Other FFS Standards

As previously discussed, the members of the MPC FFS JIP reviewed existing international FFS standards to determine the suitability for use in the refining and petrochemical industry. Although a single comprehensive standard did not exist, technology contained in these international standards was identified that could be utilized for certain flaw types. Where possible, parts of these methodologies were incorporated into API 579, and in many cases they were significantly enhanced. In some cases, where the technology was not directly incorporated, the API CRE FFS Task Group members felt that alternate approaches may be appropriate for use by more advanced practitioners. Therefore, the Level 3 assessment in API 579 permits the use of alternative FFS assessment methodologies. For example, the Level 3 assessment in Part 9 of API 579 covering crack-like flaws provides references to Nuclear Electric R-6 [8], BS 7910 [9], SAQ/FoU-Report 96/08 [10], WES 2805 [11], EPRI J-Integral Methodology [12], and A16 [13].

NEW JOINT API AND ASME FFS STANDARD

API and ASME have agreed to form a joint committee to produce a single FFS Standard that can be used for pressure-containing equipment. API 579 will form the basis of the new joint API/ASME standard that will be produced by this committee. The initial release of the new joint standard entitled API/ASME 579 will occur simultaneously with or after the release of the second edition of API 579. The new joint standard and second edition of API 579 includes all topics currently contained in API 579 and will also include new parts covering FFS assessment procedures that address the unique damage mechanisms experienced by other industries such as the fossil electric power industry and the pulp and paper industry. The agreement to produce a joint standard on FFS technology is a landmark decision that will focus resources in the US to develop a single document that can be used in all industries. This agreement will help avoid jurisdictional conflicts and promote uniform acceptance of FFS technology. It will also provide an opportunity for pooling of resources of API, ASME, PVRC, and MPC to develop new FFS technology as required by the new joint committee.

NEW DEVELOPMENTS FOR API 579

Many new developments are being completed for the second edition of API 579 and the first release of API/ASME 579. These development activities are summarized in Table 2 and Table 3, and are based on a technical gap analysis performed by the API CRE FFS Committee, feedback from the API 579 user community, and input from the joint API/ASME FFS Standards committee. The most significant changes will be the introduction of four new parts in the document covering assessment procedures for:

- Assessment of HIC/SOHIC Damage,
- Assessment of Creep Damage,
- Assessment of Dent and dent-gouge combinations, and
- Assessment of Laminations.

The second edition of API 579 has been reformatted to comply with ISO standardization requirements. In addition, Sections in API 579 have now been renamed as Parts to avoid confusion when referring to ASME B&PV Codes. An effort is also being undertaken to simplify the existing Level 1 assessment methods. The objective of the assessment procedures included in this level is to provide conservative screening criteria that can be utilized with a minimum amount of inspection or component information. In the initial release of API 579, the degree of difficulty and time requirements to perform Level 1 assessments was not consistent for all forms of damage. In addition to technical changes, the example problems currently provided in each part of API 579 will be removed from the standard and placed in a separate example problems manual. This change is being made because of the space the example problems occupy and the request by the user community for additional example problems. A complete set of example problems is crucial to the deployment of any standard because these problems not only demonstrate proper use of the rules in the document but also provide a means to benchmark computer programs developed to automate assessment procedures.

TECHNICAL BASIS AND VALIDATION OF API 579 FFS ASSESSMENT METHODS

The API CRE FFS Committee is committed to publishing in the public domain the technical background to all FFS assessment procedures utilized in API 579. It is hoped that other FFS standards writing committees adopt the same policy as it is crucial that FFS knowledge remains at the forefront of technology on an international basis to facilitate adoption by jurisdictional authorities. The technical basis and experimental validation of the FFS assessment procedures used in API 579 are published in a series of WRC Bulletins. WRC Bulletins have been published covering the technical areas described below.

- A review of existing fitness-for-service criteria for crack-like flaws [14]
- Technologies for the evaluation of erosion/corrosion, pitting, blisters, shell out-of-roundness, weld misalignment, bulges, and dents in pressurized components [15]
- New stress intensity factor solutions for surface and embedded cracks in cylinders and spheres [16]
- New stress intensity factor and crack opening area solutions for through-wall cracks in cylinders and spheres [17]
- Recommendations for determining residual stresses for use in fitness-for-service assessment of crack-like flaws [18] and [19].
- Fatigue evaluation of welded joints using the structural stress concepts in conjunction with a master S-N curve [20].

Additional WRC Bulletins are in preparation that will provide:

- An overview and validation of the fitness-for-service assessment procedures for locally thin areas in API 579
- An overview of the fitness-for-service assessment procedures for pitting damage in API 579
- An overview of the fitness-for-service assessment procedures for weld misalignment and shell distortions in API 579
- An overview and validation of the fitness-for-service assessment procedures for crack-like flaws in API 579
- An overview and validation of the fitness-for-service assessment procedures for assessment of creep damage in API 579

UNDERSTANDING OF DAMAGE MECHANISMS

The first step in a FFS assessment performed in accordance with API 579 is to identify the flaw type and cause of damage. When conducting a FFS assessment it is important to determine the cause(s) of the damage or deterioration observed and the likelihood and degree of further damage that might occur in the future. In order to assist the practitioner in this step, WRC Bulletins 488 [21], 489 [22], and 490 [23] have been produced to cover damage mechanism in the fossil electric power industry, the pulp and paper industry, and the refining and petrochemical industry, respectively, to provide guidance to the practitioner for the combined considerations of:

- Practical information on damage mechanisms that can affect process equipment,
- Assistance regarding the type, extent, and time-dependency of damage that can be expected, and
- How this knowledge can be applied to the selection of effective inspection methods to detect, size, and characterize the damage.

A factor that complicates a FFS assessment for refining and petrochemical equipment is the diversity and complexity of equipment, materials of construction, and operating environments. Refineries and chemical plants contain many different processing units each having its own combination of numerous aggressive process streams and temperature/pressure conditions. In general, the following types of damage are encountered in petrochemical equipment:

- General and local metal loss due to corrosion and/or erosion,
- Surface connected cracking,
- Subsurface cracking,
- Micro-fissuring/microvoid formation, and
- Metallurgical changes.

The information for each damage mechanism in the WRC Bulletins described above is provided in the standard format shown below. The standard format facilitates use of the information in the development of inspection programs and FFS assessments.

- Description of Damage – a basic description of the damage mechanism.
- Affected Materials – a list of the materials prone to the damage mechanism.
- Critical Factors – a list of factors that affect the damage mechanism (i.e. rate of damage).
- Affected Units or Equipment – a list of the affected equipment and/or units where the damage mechanism occurs is provided; the location of the damage mechanism is shown on process flow diagrams for typical process units.
- Appearance or Morphology of Damage – a description of the damage mechanism, with pictures in some cases, to assist with recognition of the damage.
- Prevention/Mitigation – methods to prevent and/or mitigate damage.

- Inspection and Monitoring – recommendations for NDE for detecting and sizing the flaw types associated with the damage mechanism.
- Related Mechanisms – a discussion of related damage mechanisms is provided
- References – a list of references that provide background and other pertinent information.

TREATMENT OF WELD JOINTS IN FITNESS-FOR-SERVICE ASSESSMENTS

The treatment of weld joints is a critical aspect of most fitness-for-service assessment procedures because the weld joint may be the weak link of the component when subject to the operating environment. An overview of the treatment of weld joints in a fitness-s-for-service assessment performed in accordance with API 579 is shown in Table 4. Considerable progress has been made in understanding the behavior of weld joints; however, additional work is required especially in the areas environmental effects, fatigue and creep-fatigue interaction.

IN-SERVICE INSPECTION CODES AND FITNESS-FOR-SERVICE

The in-service inspection codes in the US for pressure containing equipment comprise of:

- ANSI/API 510 – Pressure Vessels,
- ANSI/API 570 – Piping,
- API 653 – Tankage, and
- ANSI/NB-23 – Pressure Vessels & Piping.

Currently, these inspection codes contain empirical rules that are used to evaluate metal loss and pitting damage. Assessment procedures for crack-like flaws and other damage mechanisms (e.g. blisters, creep, and fire damage) are not provided. In addition, these codes impose an inspection interval based on equipment condition with a maximum inspection interval cap. In the future, the owner-user will be able to evaluate metal loss and pitting damage with technology-based rules that can be used to rerate components with damage if necessary. Crack-like flaws in components may be acceptable pending an FFS assessment. Better guidance on assessment procedures for common types of damage mechanisms found in the refining and petrochemical industry will be provided. Moreover, the in-service inspection codes will permit use of FFS assessments to develop an appropriate inspection interval based on the level of damage at the option of the owner-user.

The first edition of API 579 was published as a recommended practice; jurisdictional acceptance is obtained by reference from an inspection code or standard. API is currently in the process of modifying API 510, API 570, and API 653 to provide this reference. In addition, API is actively working with the National Board to promote the use of API 579 for FFS Assessments; a reference to API 579 has been placed in the Forward to NB-23. Once the rules are adopted by these inspection codes, the existing empirical FFS assessment rules contained in these codes will be phased out over a period of time. The benefits of having a comprehensive FFS document that is tightly integrated with the API inspection codes are:

- Ease of use in assessing flaws and damage mechanisms including jurisdictional acceptance,
- Extended safe operation of damaged equipment based on industry accepted assessment methods (API/ANSI),
- New basis for inspection planning,
- Flexibility in developing tactics for repair and/or replacement of damaged equipment, and
- Turnaround support decision making with a goal to minimize turnaround scope and length.

Integration of the FFS assessment procedures with the in-service inspection codes also facilitates effective use of the emerging RBI technologies to maximize equipment availability and to improve sustainable maintenance performance. The FFS and RBI relationship depends upon the type of RBI study. In a RBI study using a qualitative evaluation, FFS assessment procedures can be used to alter the risk-ranking of equipment based on the level of damage and the results of the assessment. In a RBI study using a quantitative evaluation, the FFS assessment procedures provide a model for flaw and damage analysis that can be used to establish a probability of failure. The probably of failure can be combined with a consequence of failure model to produce risk that can be subsequently utilized in the RBI study. Work is underway to identify areas to improve API 579 to facilitate use with the API in-service inspection codes and API 580. When work is complete, API 580 can be used to set the scope, method of inspection, and inspection interval for a piece of equipment. If damage is found, the inspection interval can be modified based on the results of a FFS assessment performed in accordance with API 579.

CONCLUSIONS

FFS assessments are quantitative engineering evaluations which are performed to demonstrate the structural integrity of an in-service component containing a flaw or damage. API 579 was developed to provide guidance for conducting FFS assessments of equipment in the refining and petrochemical industry. Since publication, API 579 has become the de facto international standard for FFS assessments in the refining and petrochemical industry. In addition, the FFS assessment procedures in API 579 have also been applied to flaws encountered in other industries such as the fossil electric power industry, the pulp and paper industry, the chemical industry, and the nuclear industry. The assessment procedures provided in this document can be used to make run-repair-replace decisions to ensure that pressurized equipment containing flaws which have been identified by inspection can continue to be operated safely.

API 579 is intended to supplement and augment the requirements in API 510, API 570, API 653, and NB-23. In addition, API 579 will be used in conjunction with API 580 to provide guidelines for risk assessment and prioritization for inspection and maintenance planning for pressure-containing equipment. FFS is a powerful technology that can be used to extend the useful life of aging equipment or allow new equipment with flaws and/or damage to enter service without repairs. In many cases, significant savings can be realized because FFS enables the owner-user to operate equipment until the next scheduled downtime without compromising safety and minimizing unscheduled downtimes. In many cases repair or replacement can be avoided.

The landmark decision by API and ASME to produce a single joint standard will promote jurisdictional acceptance and permit pooling of resources with other technical organizations such as PVRC and MPC which will greatly enhance the ability to develop new FFS technology.

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Table 1 – Organization Of Each Part In The Second Edition Of API 579 And The New Joint API/ASME 579 Standard

Part Subparagraph Number and Title	Overview
1 – General	The scope and overall requirements for an FFS assessment are provided.
2 – Applicability and Limitations of the FFS Assessment Procedures	The applicability and limitations for each FFS assessment procedure are clearly indicated; these limitations are stated in the front of each part for quick reference.
3 – Data Requirements	The data requirements for the FFS assessment are clearly outlined; these data requirements include: • Original equipment design data • Maintenance and operational history • Data/measurements for a FFS assessment • Recommendations for inspection technique and sizing requirements
4 – Assessment Techniques and Acceptance Criteria	Detailed assessment rules are provided for three levels of assessment: Level 1, Level 2, and Level 3. A discussion of these assessment levels is covered in the body of this paper.
5 – Remaining Life Evaluation	Guidelines for performing a remaining life estimate are provided for the purpose of establishing an inspection interval in conjunction with the governing inspection code.
6 – Remediation	Guidelines are presented on methods to mitigate and/or control future damage. In many cases, changes can be made to the component or to the operating conditions to mitigate the progression of damage.
7 – In-Service Monitoring	Guidelines for monitoring damage while the component is in-service are provided. These guidelines are useful if a future damage rate cannot be estimated easily or the estimated remaining life is short. In-service monitoring is one method whereby future damage or conditions leading to future damage can be assessed or confidence in the remaining life estimate can be increased.
8 – Documentation	Guidelines for documentation for an assessment are provided. The general rule is - A practitioner should be able to repeat the analysis from the documentation without consulting an individual originally involved in the FFS assessment.
9 – References	A comprehensive list of technical references used in the development of the FFS assessment procedures is provided. References to codes and standards are provided in this part.
10 – Tables and Figures	Tables and Figures including logic diagrams are used extensively in each part to clarify assessment rules and procedures.
11 – Example Problems	A number of example problems are provided which demonstrate the application of the FFS assessment procedures.

Table 2 – Overview of Flaw and Damage Assessment Procedures In The Second Edition Of API 579 And The New Joint API/ASME 579 Standard

API 579 Part And Damage Mechanism	Overview	Modifications And Development Status For Next Release
3 – Brittle Fracture	Assessment procedures are provided to evaluate the resistance to brittle fracture of in-service carbon and low alloy steel pressure vessels, piping, and storage tanks. Criteria are provided to evaluate normal operating, start-up, upset, and shutdown conditions.	Brittle fracture rules modified to be more consistent with the current ASME Section VIII material toughness rules, and a new screening procedure for shock chilling has been developed.
4 – General Metal Loss	Assessment procedures are provided to evaluate general corrosion. Thickness data used for the assessment can be either point thickness readings or detailed thickness profiles. A methodology is provided to guide the practitioner to the Local Metal Loss assessment procedures based on the type and variability of thickness data recorded during an inspection.	Basic assessment procedures will remain the same. Editorial changes are being introduced to clarify requirements for evaluation of metal loss at structural discontinuities.
5 – Local Metal Loss	Assessment techniques are provided to evaluate single and networks of Local Thin Areas (LTAs), and groove-like flaws in pressurized components. Detailed thickness profiles are required for the assessment. The assessment procedures can also be utilized to evaluate blisters.	New assessment procedures will be introduced to evaluate LTAs in cylinders subject to external pressure and to evaluate the circumferential extent of an LTA in a cylinder subject to pressure and net-section loads.
6 – Pitting Corrosion	Assessment procedures are provided to evaluate widely scattered pitting, localized pitting, pitting which occurs within a region of local metal loss, and a region of localized metal loss located within a region of widely scattered pitting. The assessment procedures can also be utilized to evaluate a network of closely spaced blisters. The assessment procedures utilize the methodology developed for Local Metal Loss.	A new Level 1 Assessment procedure has been developed based on standard pitting charts. These pitting charts can be used by practitioners to perform a visual comparison between damage in the equipment and damage indicated by the chart. An RSF is provided for each chart. Once a chart has been chosen, the RSF can be determined based on the depth of pitting damage.
7 – Assessment Of Hydrogen Blisters And Hydrogen Damage Associated With HIC And SOHIC	Assessment procedures are provided to evaluate either isolated, or networks of blisters and laminations. The assessment guidelines include provisions for blisters located at weld joints and structural discontinuities such as shell transitions, stiffening rings, and nozzles.	Assessment procedures for laminations will be removed and placed in Part 13. New assessment procedures have been developed to evaluate HIC/SOHIC damage. HIC damage will be evaluated using a modified LTA methodology. SOHIC damage will be evaluated using the principals of Part 9.
8 – Weld Misalignment and Shell Distortions	Assessment procedures are provided to evaluate stresses resulting from geometric discontinuities in shell type structures including weld misalignment and shell distortions (e.g. out-of-roundness, bulges, and dents).	The current dents and bulge assessment procedures are being reformulated. The new dent-gouge combination assessment procedures will be placed in Part 12. The new bulge assessment procedure will replace the current procedures in Part 8.

Table 2 – Overview of Flaw and Damage Assessment Procedures In The Second Edition Of API 579 And The New Joint API/ASME 579 Standard

API 579 Part And Damage Mechanism	Overview	Modifications And Development Status For Next Release
9– Crack-Like Flaws	Assessment procedures are provided to evaluate crack-like flaws. Recommendations for evaluating crack growth including environmental concerns are also covered.	The overall assessment procedure will remain the same. However, significant development is currently underway to improve the inputs to the procedures including: • Fracture toughness estimation • New residual stress solutions • New stress intensity factor solutions • New reference stress solutions • New Partial Safety Factors based on flaw size, fracture toughness, primary stress, secondary, and residual stresses • Modification of FAD procedure to evaluate constraint and weld mismatch effects
10 – High Temperature Operation and Creep	Assessment procedures are provided to determine the remaining life of a component operating in the creep regime. The remaining life procedures are limited to the initiation of a crack.	This part is currently being completed based on information received from a PVRC Project on Creep Crack Growth and recent developments in the MPC Project Omega Joint Industry Project. When complete, this part will provide assessment procedures for: • Creep damage • Creep-fatigue damage • Creep-crack growth • Creep-crack growth in combination with fatigue crack growth • Creep buckling Material data will be provided for all assessment methods.
11 – Fire Damage	Assessment procedures are provided to evaluate equipment subject to fire damage using a methodology to rank and screen components for evaluation based on the heat exposure experienced during the fire. The assessment procedures of the other parts of API 579 are utilized to evaluate component damage.	The overall assessment procedure will remain the same. Editorial changes have been made to clarify the assessment procedure.
12 – Dent And Dent-Gouge Combinations	New Part – Assessment procedures will be provided to evaluate dent and dent-gouge combinations in pressure containing components.	Current assessment procedures for dents in Part 8 will be removed. New assessment procedures are currently being developed for dent and dent-gouge combinations.
13 – Laminations	New Part – Assessment procedures will be provided to evaluate laminations in pressure containing components.	Current lamination rules in Part 7 will be removed. Updated rules are currently being developed.

Table 3 – Appendices In The Second Edition Of API 579 And The New Joint API/ASME 579 Standard

Appendix And Title	Overview	Modifications And Development Status For Next Release
A – Thickness, MAWP And Membrane Stress Equations for a FFS Assessment	Equations for the thickness, MAWP, and membrane stress are given for most of the common pressurized components. These equations are provided to assist international practitioners who may not have access to the ASME Code and who need to determine if the local design code is similar to the ASME Code for which the FFS assessment procedures were primarily designed.	Updates are planned to reflect many of the new advances developed by PVRC for the ASME Div2 Re-Write Project.
B – Stress Analysis Overview for a FFS Assessment	Recommendations for stress analysis techniques that can be used to perform an FFS assessment are provided including guidelines for finite element analysis.	Major modifications are planned to reflect many of the new advances developed by PVRC for the ASME Div2 Re-Write Project. This part will be modified to provide recommendations for analysis techniques used to evaluate protection against: • Plastic collapse • Local failure (strain concentration) • Collapse from buckling • Cyclic loading • Creep damage
C – Compendium of Stress Intensity Factor Solutions	A compendium of stress intensity factor solutions for common pressurized components (i.e. cylinders, spheres, nozzle, etc.) is given. These solutions are used for the assessment of crack like flaws. The solutions presented represent the latest technology and have been re-derived using the finite element method in conjunction with weight functions.	New stress intensity factor solutions will be introduced for thick wall cylinders and through-thickness cracks in cylinders and spheres.
D – Compendium of Reference Stress Solutions	A compendium of reference stress solutions for common pressurized components (i.e. cylinders, spheres, nozzle, etc.) is given. These solutions are used for the assessment of crack-like flaws.	New reference stress solutions based on J-integral analysis are being developed using the techniques described in Appendix B.
E – Residual Stresses in a Fitness-For-Service Evaluation	Procedures to estimate the through-wall residual stress fields for different weld geometries are provided; this information is required for the assessment of crack like flaws.	Major modifications are planned; all residual stress solutions will be updated based on the work being performed under a PVRC Joint Industry Project.

Table 3 – Appendices In The Second Edition Of API 579 And The New Joint API/ASME 579 Standard

Appendix And Title	Overview	Modifications And Development Status For Next Release
F – Material Properties for a FFS Assessment	Material properties required for all FFS assessments are provided including: • Strength parameters (yield and tensile stress) • Physical Properties (i.e. Young's Modulus, etc.) • Fracture Toughness • Data for Fatigue Crack Growth Calculations • Fatigue Curves (Initiation) • Material Data for Creep Analysis including remaining life and creep crack growth	Many modifications and updates are being developed including: • A new universal stress-strain curve model that can be used in elastic-plastic analysis and to generate a FAD • Inclusion of physical property tables as a function of temperature for the elastic modulus, thermal expansion coefficient, thermal conductivity, and thermal diffusivity • New procedures for estimating the fracture toughness of in-service components using material chemistry and NDE techniques
G – Deterioration and Failure Modes	An overview of the types of flaws and damage mechanisms that can occur is provided, concentrating on service-induced degradation mechanisms. This appendix only provides an abridged overview on damage mechanisms; API 571 [16] is currently being developed to provide a definitive reference for damage mechanisms that can be used with API 579 and API 580.	This appendix will be modified to reference WRC Bulletins 488 [20], 489 [21], and 490 [22].
H – Validation	An overview of the studies used to validate the general and local metal loss, and the crack-like flaw assessment procedures are provided.	The results from studies performed by the Materials Properties Council FFS Joint Industry Project will be summarized in this appendix. The major findings of this work will be published as WRC Bulletins.
I – Glossary of Terms and Definitions	Definitions for common terms used throughout the parts and appendices of API 579 are given.	Editorial changes are being made to clarify many of the current definitions.
J – Technical Inquiries	Guidelines for submitting a Technical Inquiry to API are provided. Technical inquires will be forwarded to the API CRE FFS Task Group for resolution.	Changes are currently not planned.
K – Crack Opening Areas	The equations for the Crack Opening Areas (COA) in this appendix have been derived for both elastic and plastic conditions for cylinders and spheres with membrane and/or bending stresses.	Crack opening area solutions are based on reference [16].

Table 4 – Treatment of Weld Joints in a Fitness-For-Service Assessment in the New Joint API/ASME 579 Standard

<table>
<tr><th>API 579 Part And Damage Mechanism</th><th>Treatment of Weld Joints in Fitness-For-Service (FFS) Assessments</th></tr>
<tr><td>3 – Brittle Fracture</td><td>The Level 1 and Level 2 assessment are based on the ASME Exemption Curve Approach. This approach has been recently updated and modified for inclusion into the new ASME B&PV Code, Section VIII, and Division 2 Code. Updated exemption curves applicable to weld joints are developed using the FAD approach of Part 9 in conjunction with new Charpy correlations for static and dynamic toughness, an assumed flaw size, and a code allowable design stress.</td></tr>
<tr><td>4 – General Metal Loss</td><td rowspan="3">The assessment procedures of these parts relate to the evaluation of volumetric flaws. For static loading, the fitness-for-service assessment rules are based on limit load or plastic collapse analysis. The integrity of the weld is assumed to be as good as that provided for in the original construction if there is no metal loss at the weld joint. If there is metal loss at the weld joint, then NDE is required to categorize the metal loss and any other defects that may be present. If there is a weld joint efficiency or quality factor associated with the original design, this factor is required to be considered in the assessment. This factor may be modified based on NDE of the welded joint. In a level 3 assessment where a limit load or plastic collapse analysis is performed, the actual material properties of the weldment and based metal should be used.

For cyclic loading a fatigue evaluation is required. The fatigue evaluation may be performed using either welded joint or smooth bar based fatigue curves. The welded joint fatigue curves in the new API/.ASME FFS Standard are based on the Structural Stress and Master Curve Approach developed by Dong [20].</td></tr>
<tr><td>5 – Local Metal Loss</td></tr>
<tr><td>6 – Pitting Corrosion</td></tr>
<tr><td>7 – Assessment Of Hydrogen Blisters And Hydrogen Damage Associated With HIC And SOHIC</td><td>The assessment procedures described for General Metal Loss and Pitting Corrosion are applicable. Spacing requirements are provided in the Level 1 and 2 Assessment procedures to ensure that Blisters and HIC/SOHIC damage are located away from weld joint. A Level 3 assessment is required when damage is located at a weld joint. Key FFS assessment issues are evaluation of HAZ and weld joint toughness, and damage propagation with time in service.</td></tr>
<tr><td>8 – Weld Misalignment and Shell Distortions</td><td>The assessment procedures described for General Metal Loss and Pitting Corrosion are applicable. The Level 1 assessment is based on satisfying the original construction codes fabrication tolerances. In addition to a strength assessment, a fatigue analysis is required in the Level 2 and Level 3 assessment.</td></tr>
<tr><td>9– Crack-Like Flaws</td><td>The assessment procedure is based on the FAD approach. Screening curves are provided for in Level 1. The Level 2 assessment procedure requires stress analysis, NDE for flaw sizing, and material toughness evaluation. The Level 3 assessment includes provisions for crack growth; a loading histogram and associated stresses need to be defined along with material parameters and an appropriate crack growth model. Key FFS assessment issues are the credibility of NDE results, evaluation of residual stress at weld joints, the effects of the environment on the fracture toughness and crack growth models.</td></tr>
<tr><td>10 – High Temperature Operation and Creep</td><td>Assessment procedures are provided for creep damage and creep-crack growth. Assessment procedures are based on the MPC Project Omega Approach; however, the approach is generalized for use with other material models. Screening curves are provided for in the Level 1 Assessment. The Level 2 Assessment required definition of a loading/temperature histogram, stress calculations, and remaining life evaluation; Robinson's life-fraction rules is utilized. Level 3 includes assessment of cyclic effects and creep-crack growth. Weld joints are treated differently than based material. Key FFS assessment issues include development of meaningful load/temperature histogram, material models (base material, HAZ, and weld material) for creep strain rate, creep damage and creep crack growth, and an understanding of the current state of creep damage at the time the FFS assessment.</td></tr>
<tr><td>11 – Fire Damage</td><td>The applicable assessment procedure for general metal loss, crack-like flaws, and creep damage are used. Key FFS assessment issues are evaluation of the effects of overheating on the mechanical and toughness properties of the base material and weldments</td></tr>
<tr><td>12 – Dent And Dent-Gouge Combinations</td><td>The assessment procedures used for general metal loss and crack-like flaws are used. Key FFS assessment issues are an understanding of the material condition (i.e. hardness) and local strain at the dent and the effects on plastic collapse and fatigue damage.</td></tr>
<tr><td>13 – Laminations</td><td>The assessment procedures used for crack-like flaws are used.</td></tr>
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