



Introduction to API 579-ASME FFS-1 Fitness for Service with Case Study

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Introduction

The operation of industrial equipment will inevitably lead to situations where equipment becomes damaged, and the operational condition of that equipment must be assessed. Similarly, for reliability's sake, equipment must be assessed for various in-service damage mechanisms. In either case, a procedure has been developed to determine if the equipment is fit for the intended service and can continue to operate, or it needs to be rerated, repaired, replaced, or continually monitored.

API published the *Recommended Practice 579, Fitness-For-Service (FFS)*, in January 2000. The standard provided engineers, operators, owners, etc., with a compilation of methods to make reliable assessments regarding the integrity and of various equipment with known damage that could possibly result in unsafe and/or unsatisfactory operation of equipment. The FFS procedure was written to be used in conjunction with existing codes and standards for pressure vessels, piping, and aboveground storage tanks (API 510, API 570, and API 653, respectively). Following the FFS procedures will help ensure that aging equipment continues to operate safely, can aid in optimizing maintenance and operational practices, and help maintain positive economic conditions of plant equipment.

The American Society of Mechanical Engineers (ASME) was simultaneously designing procedures targeted at operational integrity issues relating to plant equipment. In order to avoid redundancies and possible conflicts, a joint API/ASME committee was formed to develop and maintain the FFS procedure covering a wide range of industries.

The design, fabrication, inspection, and testing of new pressure vessels, piping, and storage tanks are dictated by ASME and API new construction codes. However, these codes do not readily provide guidelines to evaluate equipment for fabrication defects, in-service degradation, and/or deficiencies resulting from degradation. It should

be noted that various codes and standards such as API 510, API 570, API 653, and NB-23 that cover the inspection, repair, alteration, and rerating of equipment do address the fact that equipment degrades while in service.

FFS guidelines provide a methodology to perform qualitative engineering evaluations to determine the structural integrity of equipment containing a flaw, or that has been damaged, or equipment that may be operating under conditions that may result in failure (i.e., high-temperature operation causing creep damage). The guidelines for performing an FFS assessment are provided for pressure containing equipment and can be used to aid in making run-repair-replace decisions for equipment containing flaws identified during the inspection, and if said equipment can continue safe operation. FFS assessments are referenced by several API codes such as API 510, 570, 653, and NB-23 as acceptable methods for evaluating equipment for degradation and flaws.

The FFS assessment procedures can be used for the rerating of equipment designed and constructed to the following codes:

- 1) ASME B&PV Code, Section VIII, Division 1
- 2) ASME B&PV Code, Section VIII, Division 2
- 3) ASME B&PV Code, Section I
- 4) ASME B31.1 Piping Code
- 5) ASME B31.3 Piping Code
- 6) ASME B31.4 Piping Code
- 7) ASME B31.8 Piping Code
- 8) ASME B31.12 Piping Code
- 9) API Std 650
- 10) API Std 620
- 11) API Std 530

The assessment procedures in the FFS manual cover the present integrity of the component at its current state of damage and the projected remaining life. Provisions for both qualitative and quantitative guidance for determining remaining life and in-service operational margins for continued operation are provided. Additionally, the FFS guidelines provide assessment methods, material properties, NDE guidelines, and documentation

requirements needed to evaluate a number of different types of flaws such as 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.

General FFS Assessment Procedure

The FFS assessment procedures are organized by flaw type and/or damage mechanism. A list of the flaw types and damage mechanisms and the corresponding section of the FFS manual that references the said flaw is illustrated in the table below. If multiple flaws or damage mechanisms are suspected, the assessment may require referencing multiple sections of the FFS guidelines. An example of this may be the discovery of pitting and/or cracking within regions of general corrosion.

The table below provides an overview of the various damage classes. The figure shows how a full FFS assessment of equipment may require the assessment of multiple flaw types. Fortunately, the FFS guidelines provide insights on how to handle the assessment of multiple damage mechanisms that are present.

The general FFS procedure for all flaw types and damage mechanisms will be described below. The procedure will be outlined in the following eight (8) steps.

- 1) Flaw Types and Damage Mechanism Identification
- 2) Applicability and Limitations
- 3) Data Requirements
- 4) Assessment Techniques and Acceptance Criteria
- 5) Remaining Life Evaluation
- 6) Remediation
- 7) In-Service Monitoring
- 8) Documentation

Specific procedures for a flaw type or damage mechanism can be found in the section of the standard that references that flaw type or damage mechanism.

Flaw or Damage Mechanism	Part	Overview
Brittle Fracture	Part 3	Assessment procedures are provided for evaluating the resistance to brittle fracture of existing carbon and low alloy steel pressure vessels, piping, and storage tanks. Criteria are provided to evaluate normal operating, start-up, upset, and shut-down conditions.
General Metal Loss	Part 4	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 utilize the assessment procedures of Part 5 when the thickness data indicates that the metal loss can be treated as localized.
Local Metal Loss	Part 5	Assessment techniques are provided to evaluate single and networks of Local Thin Areas and groove-like flaws in pressurized components. Detailed thickness profiles are required for the assessment. The assessment procedures can also be utilized to evaluate individual pits or blisters as provided for in Part 6 and Part 7 , respectively.
Pitting Corrosion	Part 6	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 as provided for in Part 7 .
Blisters and HIC/SOHIC Damage	Part 7	Assessment procedures are provided to evaluate isolated and networks of blisters and HIC/SOHIC Damage. The assessment guidelines include provisions for blisters and HIC/SOHIC damage located at weld joints and structural discontinuities such as shell transitions, stiffening rings, and nozzles.
Weld Misalignment and Shell Distortions	Part 8	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 and bulges).
Crack-Like Flaws	Part 9	Assessment procedures are provided to evaluate crack-like flaws. Solutions for stress intensity factors and reference stress (limit load) are included in Annex 9B and Annex 9C , respectively. Methods to evaluate residual stress as required by the assessment procedure are described in Annex 9D . Material properties required for the assessment are provided in Annex 9E . Recommendations for evaluating crack growth including environmental concerns are also covered.
High Temperature Operation and Creep	Part 10	Assessment procedures are provided to determine the remaining life of a component operating in the creep regime. Material properties required for the assessment are provided in Annex 10B . Analysis methods for evaluating crack growth including environmental concerns are also covered.
Fire Damage	Part 11	Assessment procedures are provided to evaluate equipment subject to fire damage. A methodology is provided to rank and screen components for evaluation based on the heat exposure experienced during the fire. The assessment procedures of the other Parts of this publication are utilized to evaluate component damage.
Dent, Gouge, and Dent Gouge Combinations	Part 12	Assessment techniques are provided to evaluate dent, gouge, and dent gouge combinations in components.
Laminations	Part 13	Assessment procedures are provided to evaluate laminations. The assessment guidelines include provisions for laminations located at weld joints and structural discontinuities such as shell transitions, stiffening rings, and nozzles.
Fatigue	Part 14	Assessment procedures are provided to evaluate pressurized components subject to cyclic loading. The assessment procedures include specific requirements for welded joints.

Table 2.1 from the API 579/ASME FFS-1 standard.

Flaw Types and Damage Mechanism Identification

Sensibly, the first step in an FFS assessment is to identify the flaw type and/or damage mechanism. Information that may aid in determining the flaw type and/or damage mechanism includes design and fabrication details, construction materials, service history, and operational and environmental conditions that can be used to determine the likely cause of the damage. The beginning of each part provides a general overview of the flaw or damage mechanism.

The standard provides an overview of the damage mechanisms that can assist in identifying the likely cause of damage in Annex 2B of the standard. In general, the information in the annex provides possible pre-service deficiencies (flaws introduced during the production of the raw materials, welding and fabrication flaws, heat treatment flaws, etc.), damage noted during in-service inspection, and service deterioration (metal loss, cracking, voids, and metallurgical changes, etc.). The descriptions provide good general insight and reference additional standards that may be of assistance, such as API RP 571, WRC 489, 488, and 490.

Various useful equations and information for an FFS assessment of pressurized equipment are provided in Annex 2C and 2F of the standard. It is recommended that the reader have a cursory knowledge of these sections, at minimum, with functional knowledge being preferred.

Applicability and Limitations

Each part of the FFS standard describes the applicability and limitations of the standard, whether the assessment can proceed, and when more advanced analysis methods (higher-level assessment) are required, such as FEA.

The FFS procedures were developed to evaluate multiple types of pressurized equipment with a flaw resulting from a known damage mechanism. The methodology may also be used to evaluate a host of non-pressurized components, such as supports.

The assessment procedures have been formulated on the assumption that the component has been designed and constructed in accordance with a known code or standard. If the component has not been built to a recognized code or standard, FFS procedures may still be used to evaluate the in-service damage and as-built condition

relative to the intended design. FFS requires that the assessment of components that have not been built to a known code or standard are to be performed by an engineer with knowledge and experience in the relevant code or standard. For the sake of clarity, FFS defines a component as any part designed or fabricated to a recognized code or standard, and equipment is defined as an assembly of components.

Data Requirements

The flaw type or damage mechanism determines the data required for the FFS evaluation. Data requirements may include operational data such as original design data, maintenance, operational history (corrosion allowance, hydrotests, pressure and temperature histograms, upset history, MAWP, repair history, NDT records, etc.), and anticipated service changes. Additional data specific to the FFS will be required, such as flaw dimensions, component stress state in the vicinity of the flaw, and material properties. Data requirements specific to the damage mechanism are covered in the Part of the FFS that covers that damage mechanism. Data requirements can be extensive, and it is recommended that the assessor be aware of them prior to beginning an assessment. For any number of reasons (personnel, equipment, etc.), all the required information may not be available. The assessor should request measurements to be taken, and as a last resort, to make educated assumptions.

Assessment Techniques

Three levels of assessment are defined in the FFS standard. A Level 1 assessment is the easiest to perform. The assessor is to proceed sequentially through the assessment until a component level fails or a clear course of action can be determined.

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