CBIA Conference 2017

API 579 Fitness For Service Overview

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Agenda

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  - Joint API/ASME FFS Standard (2000 edition)
- **Jurisdictional Requirements**
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- **Example Problems**
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  - Section 6 – Pitting Corrosion
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- **Overview of 2007 FFS Edition**
- **Technical Basis and Validation of 2007 Edition**
- **API 579-1/ASME FFS-1 2016 Edition**

Fitness for Service Introduction

- ASME and API codes and standards provide guidelines for design, fabrication, inspection and testing.
- These codes do not provide guidelines for evaluating equipment that have been in service.
- ASME formed Post Construction Main Committee (PCC) in late 1990s to develop standards for in-service fixed equipment
- API CRE Task Group continued to develop API 579, many committee members served on both committees.

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Fitness for Service Introduction

- The first edition of API 579 Fitness-For-Service (FFS) produced by API CRE FFS Task Group was issued in 2000 and became the de facto international Fitness-For-Service (FFS) Standard for pressure containing equipment in the refining and petrochemical industries

- In order to streamline development efforts, pool resources, and promote widespread regulatory acceptance, API and ASME agree to form a joint committee to produce a single FFS standard that can be used for pressure-containing.

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Joint API/ASME FFS Standards Committee

- Joint API/ASME Committee formed, first meeting takes place on February 5, 2002
- Polices and procedures manual developed covering
  - Charter
  - Organization
  - Officers
  - Membership
  - Meetings
  - Committee Actions (Voting and Balloting)
  - Public Review and Submittal to ANSI
  - Interpretations
  - Appeals
  - Records
- Polices and procedures manual approved by API CRE and ASME BPTCS

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Jurisdictional Requirement

- CCR Title 8, Chapter 4, Subchapter 15 Petroleum Safety Orders, Article 18 – Unfired Pressure Vessels, Boilers and Fired Pressure Vessels, §6857(c)(3):

"A written fitness-for-service program, as described in API 510-2003 and API 579-2000, may be used to evaluate pressure vessels for continued service when found to have degradation that could affect load-carrying capability, provided it is reviewed and accepted by the Division before the program is implemented, and every three years thereafter. Any revisions made to the accepted fitness-for-service program must also be submitted, reviewed and accepted by the Division prior to implementation of these revisions.

- Program to include (summary):
  - Acceptance by signature of the plant management
  - The type of vessels covered
  - Documentation
  - Involvement of Operations, Engineering, Inspection, and maintenance
  - Procedure for notifying the Division.

Fitness for Service Overview

Scope

- Supplement and augment requirements of API
- Evaluation of both the present integrity of an equipment – given present state of damage – and projected remaining life.
- Evaluate equipment constructed and designed to;
  - ASME Section VIII D1/D2, Section I, B31.3 and B31.1
  - API 650 and 620
  - International and Internal Corporate standards

- Assessment techniques include, but not limited to;
  - Brittle fracture, local & general metal loss, crack-like flaws, pitting, blistering, fire damage, etc.
- Provide in-service monitoring and NDE guidelines
- Documentation

Fitness for Service Overview

Application

- Equipment constructed and designed to;
  - ASME Section VIII D1/D2, Section I, B31.3 and B31.1
  - API 650 and 620
  - International and Internal Corporate standards
- Determine if an equipment may be operated at the original Maximum Allowable Working Pressure (MAWP).
- Determine the minimum required thickness
- Reduced temporary MAWP based on the found damage/flaw.
- Evaluate equipment that is discovered to be lacking appropriate docs
- Evaluate equipment found to have not been designed or constructed to original design criteria

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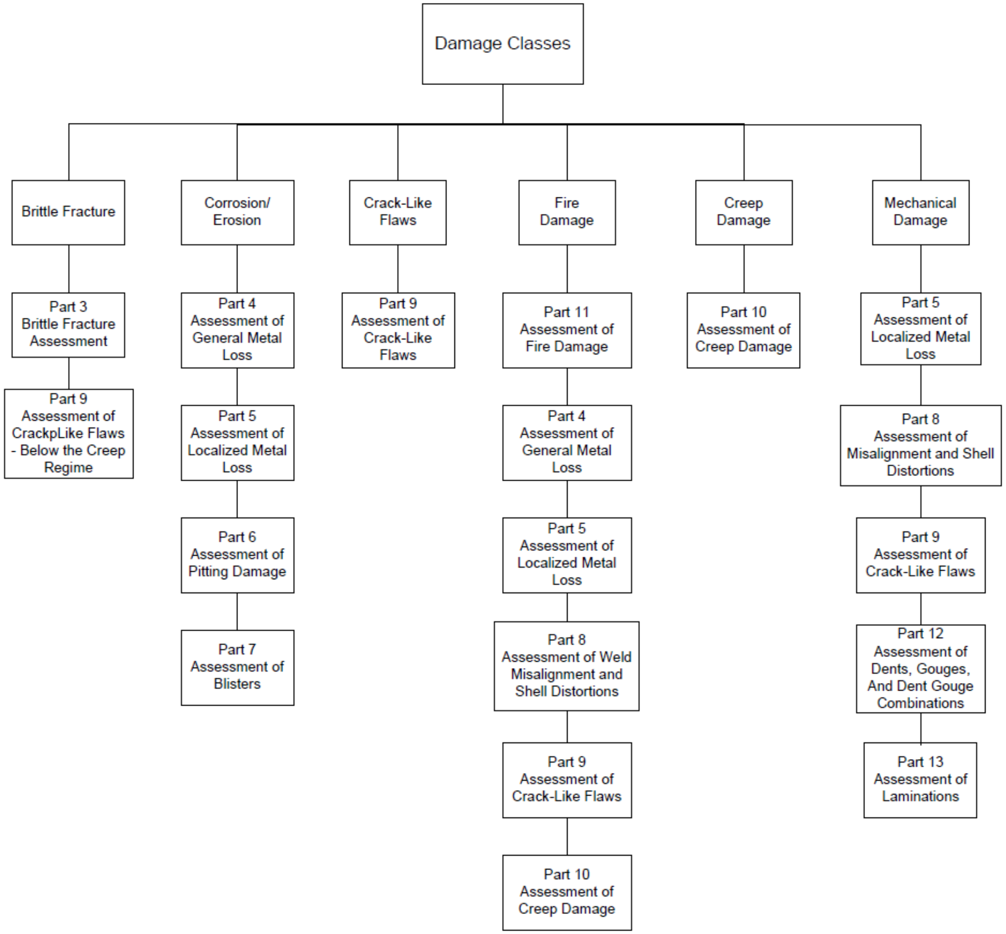
Fitness for Service Overview

Procedure

- Step 1 – Flaw or Damage Mechanism Identification



Fitness for Service Overview

Procedure (cont.)

- Step 2 – Applicability and Limitations

- Step 3 – Data Requirements
  - See Table 2.2 in API 579 for overview of data required
  - Examples; Thickness profiles, pitting depth, dimensions of crack-like flaws, etc.
  - Extent of information and data required depends on level of assessment and damage mechanism being valuated.

- Step 4 – Assessment Techniques and Acceptance Criteria
  - Level 1, 2 and 3 assessments

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Fitness for Service Overview

Procedure (cont.)

- Step 5 – Remaining Life Calculation
  - Use to establish inspection plan, intervals and any remediation
  - Estimates with adequate safety factor

- Step 6 – Remediation
  - Coating/lining to isolate the environment
  - Drilling of blisters, monitoring, repair, etc.
  - Changes to the process stream

- Step 7 – In-Service Monitoring
  - Increase confidence in the remaining life assessment

- Step 8 – Documentation
  - All calculations and documentation used to perform the analysis.

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Example Problems

Example #1 – General Metal Loss

- Result from corrosion, erosion or both.
- Based on thickness averaging approach.

Applicability And Limitations

- Uniform or local
- Can calculate reduced MAWP if acceptance criteria are not satisfied
- Some limitations depending on level of assessment (level 1, 2 or 3):
  - No crack-like flaws .
  - No notches i.e. local stress concentrations
  - Not in creep regime
  - Not in cyclic service

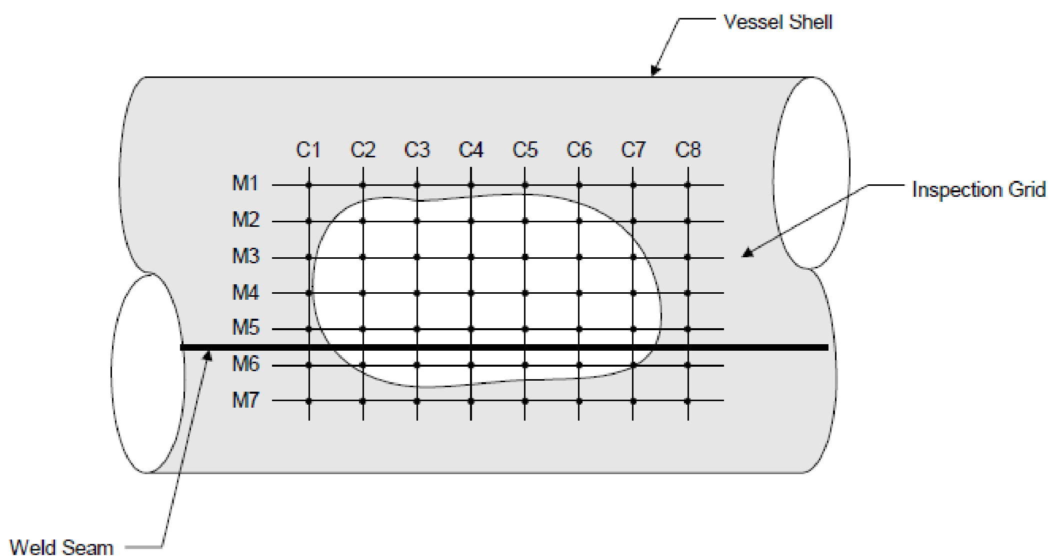
Example Problems

Example #1 – General Metal Loss (PART 4)

Pressure Vessel Information

Design Conditions	=	300 psig @ 350°F
Inside Diameter	=	48 inches
Nominal Thickness	=	0.75 inches
Uniform metal loss	=	0.0 inches
Future Corrosion Allowance	=	0.10 inches
Material	=	SA 516 Grade 70
Weld Joint Efficiency	=	0.85

Inspection Data



Example Problems

Example #1 – General Metal Loss (cont.)

Inspection Data (inches)

Longitudinal Inspection Planes	Circumferential Inspection Planes								Circumferential CTP
	C1	C2	C3	C4	C5	C6	C7	C8	
M1	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
M2	0.75	0.48	0.52	0.57	0.56	0.58	0.60	0.75	0.48
M3	0.75	0.57	0.59	0.55	0.59	0.60	0.66	0.75	0.55
M4	0.75	0.61	0.47	0.58	0.36	0.58	0.64	0.75	0.36
M5	0.75	0.62	0.59	0.58	0.57	0.48	0.62	0.75	0.48
M6	0.75	0.57	0.59	0.61	0.57	0.56	0.49	0.75	0.49
M7	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Longitudinal CTP	0.75	0.48	0.47	0.55	0.36	0.48	0.49	0.75	

- Follow assessment techniques and acceptance criteria in Part 4 of API 579 (Level 1 => Level 2 => Level 3, as needed).
  - Failed Level 1 assessment.
  - Passed Level 2 assessment at a reduced MAWP.

- Alternatively, use industry recognized software (Plant Manager, CodeCalc, etc) to complete the assessment.

Example Problems

Example #1 – General Metal Loss (cont.)

Perform a Level 1 Assessment per paragraph 4.4.2

Step 1 – Calculate the minimum required thickness.

$$t_{min}^{C} = \frac{300\,psig(24"+0.10")}{17500\,psi(0.85) - 0.6(300\,psig)} = 0.492"$$

$$t_{min}^{L} = \frac{300\,psig(24"+0.10")}{2(17500\,psi)(0.85) + 0.4(300\,psig)} = 0.242"$$

$$t_{min} = \max[0.492",\ 0.242"] = 0.492"$$

Step 2 – Thickness profiles are provided, the data for thickness readings is in the above table.

Step 3 – Determine the length for thickness averaging.

Step 3.1 – Determine the minimum thickness and remaining thickness ratio

$$t_{mm} = 0.36"$$

$$R_t = \frac{0.36 - 0.10}{0.492} = 0.528$$

Step 3.2 – Determine the length for thickness averaging.

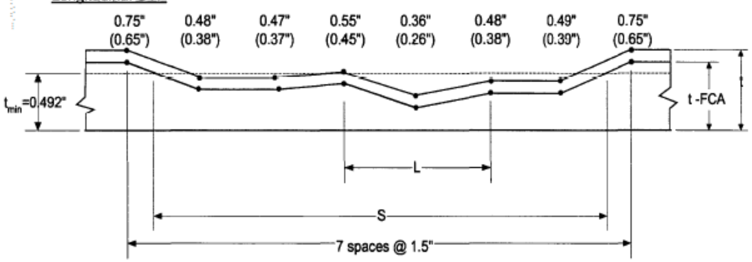
From Table 4.4 with R_t = 0.528 with RSF_a = 0.9 (see Section 2, paragraph 2.4.2.2.d); $Q \approx$ 0.62 or by equation

$$Q = 1.123\left[\left(\frac{1.0 - 0.528}{1.0 - 0.528/0.9}\right)^2 - 1.0\right]^{0.5} = 0.616$$

$$L = (0.616)\sqrt{48"(0.492")} = 3.0"$$

Step 4 – Thickness profiles where taken; therefore, determine the longitudinal and circumferential *CTP's*, (the thickness readings for the critical inspection planes are indicated in the above table and shown in the following figure) and determine the flaw dimensions.

Longitudinal CTP



Note: In this figure, the top number is the wall thickness at the time of the inspection and the number in the parentheses is this wall thickness minus the future corrosion allowance

The flaw dimension is: $s = 5(1.5") + \left(\frac{0.492" - 0.38"}{0.65" - 0.38"}\right)(1.5") + \left(\frac{0.492" - 0.39"}{0.65" - 0.39"}\right)(1.5") = 8.71"$

Circumferential CTP

The circumferential CTP does not need to be determined because the minimum required thickness based on the circumferential plane (longitudinal stress) is less than the average measured thickness (see Step 2). Note that in this example, c is not required because the minimum required thickness for the circumferential direction is less than the minimum measured thickness, or $\left(t_{min}^{L} = 0.242"\right) < \left(t_{mm} - FCA = 0.36" - 0.10" = 0.26"\right)$.

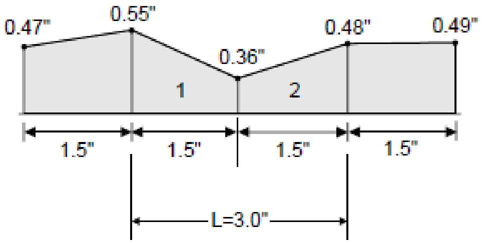
Step 5 – Since $(s = 8.71") > (L = 3.0")$, the evaluation is performed using paragraph 4.4.2.1.e.2. This evaluation can be performed by direct averaging the thickness readings that reside within length L.

$$t_{am} = t_{am}^{s} = \frac{0.55" + 0.36" + 0.48"}{3} = 0.463"$$

Alternatively, the average thickness can be established more accurately using areas. The area method should normally be used to determine the average thickness when there is only a small number of thickness readings which reside within length L. As the number of thickness readings within this length increase, the average thickness determined by the direct averaging method and the area method will converge to the same result.

Example Problems

Example #1 – General Metal Loss (cont.)



$$A_1 = \frac{(0.55"+0.36")}{2}(1.5") = 0.6825\ in^2$$

$$A_2 = \frac{(0.48"+0.36")}{2}(1.5") = 0.63\ in^2$$

$$and \quad \sum_{i=1}^{2} A_i = 1.313\ in^2$$

$$t_{am} = t_{am}^{s} = \frac{\sum_{i=1}^{2} A_i}{L} = \frac{1.313\ in^2}{3.0"} = 0.438"$$

Step 6 – Determine if the component is acceptable for continued operation.

Per paragraph 4.4.2.1.f.1:

$$\left(t_{am} - FCA = 0.438" - 0.10" = 0.338"\right) \geq \left(t_{min}^{C} = 0.492"\right) \qquad False$$

Per paragraph 4.4.2.1.f.2:

$$\left(t_{mm} - FCA = 0.36" - 0.10" = 0.26"\right) \geq \left(\max\left[0.5 t_{min}, 0.10"\right] = 0.246"\right) \qquad True$$

The Level 1 Assessment criteria are not satisfied.

Fitness for Service Overview

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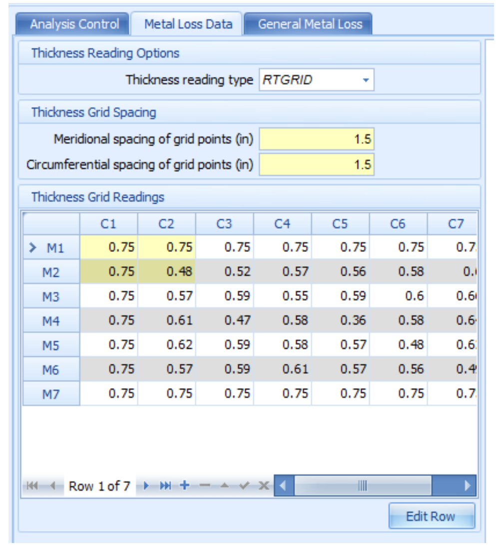
Example #1 – General Metal Loss (cont.)


Analysis Control | Metal Loss Data | General Metal Loss

Thickness Reading Options

Thickness reading type: RTGRID

Thickness Grid Spacing

Meridional spacing of grid points (in): 1.5

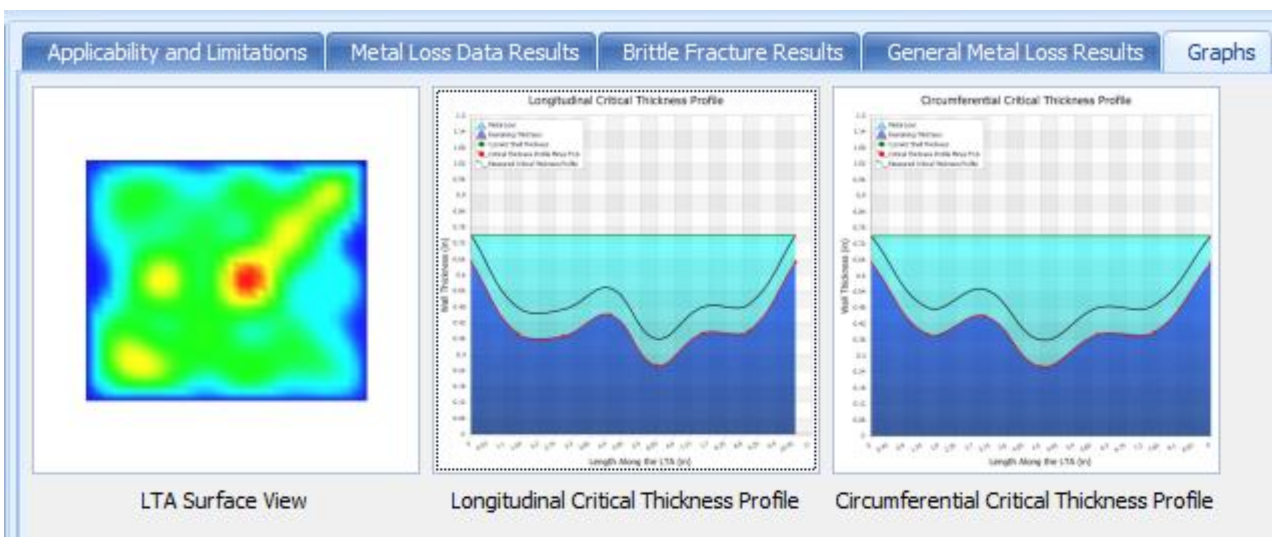
Circumferential spacing of grid points (in): 1.5

Thickness Grid Readings

	C1	C2	C3	C4	C5	C6	C7
M1	0.75	0.75	0.75	0.75	0.75	0.75	0.7
M2	0.75	0.48	0.52	0.57	0.56	0.58	0.
M3	0.75	0.57	0.59	0.55	0.59	0.6	0.6
M4	0.75	0.61	0.47	0.58	0.36	0.58	0.6
M5	0.75	0.62	0.59	0.58	0.57	0.48	0.6
M6	0.75	0.57	0.59	0.61	0.57	0.56	0.4
M7	0.75	0.75	0.75	0.75	0.75	0.75	0.7

Row 1 of 7

Edit Row



LTA Surface View

Longitudinal Critical Thickness Profile

Circumferential Critical Thickness Profile

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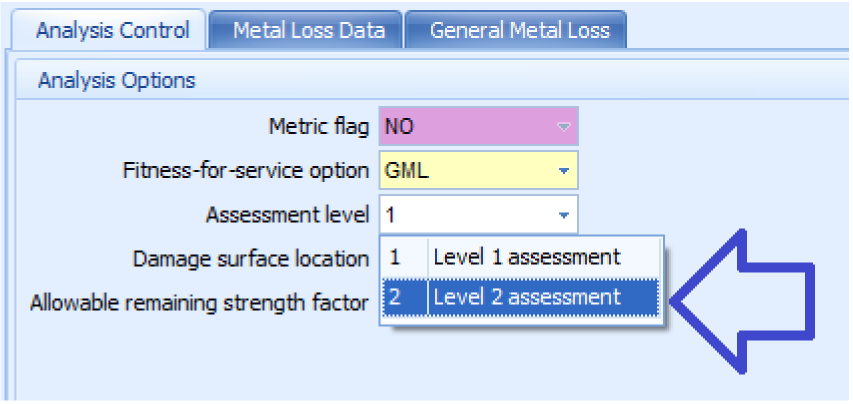
Example #1 – General Metal Loss (cont.)

```
              -- General Metal Loss Messages --

==> The average thickness of the longitudinal plane is
less than the required thickness.

==> The component is not fit for service at the specified
operating conditions. A Level 2 assessment should be
performed to determine the reduced MAWP.

==> If the region of corrosion is within an area that has
additional thickness requirement criteria (i.e. nozzle or
cone reinforcement, flanges, etc.) then those additional
criteria must also be satisfied in addition to this
analysis.

          *** APIFFS Module Analysis Complete ***
             *** CPU Time: 0.3120 Seconds ***
```



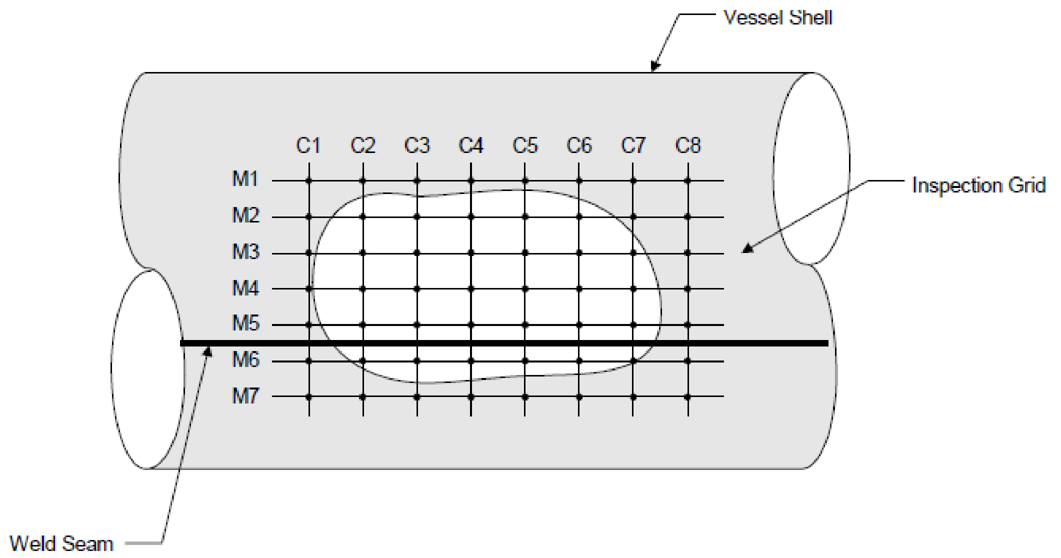
Example Problems

Example #2 – Local Metal Loss (PART 5)

Pressure Vessel Information

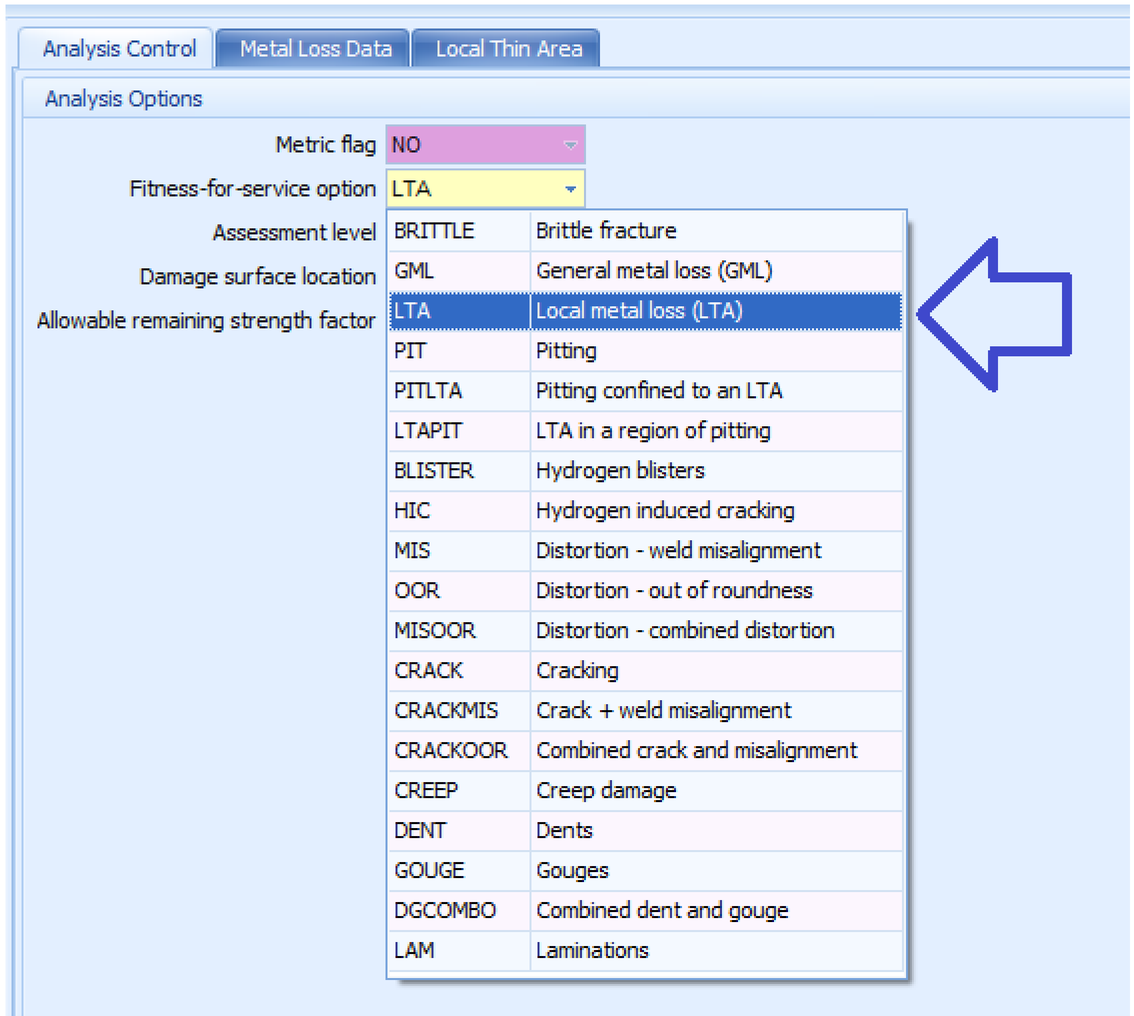
Design Conditions	=	300 psig @ 350°F
Inside Diameter	=	48 inches
Nominal Thickness	=	0.75 inches
Uniform metal loss	=	0.0 inches
Future Corrosion Allowance	=	0.10 inches
Material	=	SA 516 Grade 70
Weld Joint Efficiency	=	0.85

Inspection Data



Example Problems

Example #2 – Local Metal Loss



Example Problems

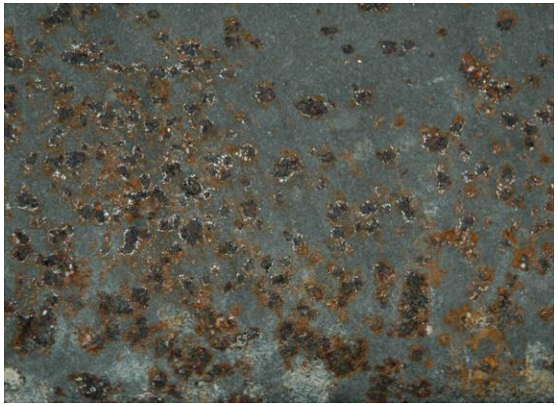
Example #2 – Local Metal Loss (cont.)

```
-- Local Thin Area Messages --

==> The component is fit for service for a pressure of
289.89 (psi) at 350.00 (F).


==> If the region of corrosion is within 10.08 (in) of a
local discontinuity, the above calculated MAWP is not
valid and the component is not fit for service under a
Level 1 or 2 assessment.
```

- Passed Level 1 Assessment slightly reduced MAWP (Original Design Pressure = 300psig)

Example Problems

Example #3 – Pitting (PART 6)



Applicability and Limitations

- Can be used to evaluate general and localized pitting.
- Can calculate reduced MAWP if acceptance criteria are not satisfied
- For Level 1 and 2, some rules in PART 5 may apply.
- Level 2 assessment if pitting damage is on both sides.
- NOTE: Precise measurement of pitting is difficult.

Example Problems

Example #3 – Pitting (cont.)

Table 6.1
Required Data For Assessment Of Pitting

Use this form to summarize the data obtained from a field inspection.

Equipment Identification: ____________________
Equipment Type: _____ Pressure Vessel _____ Storage Tank _____ Piping Component
Component Type & Location: ____________________

Data Required for Level 1:

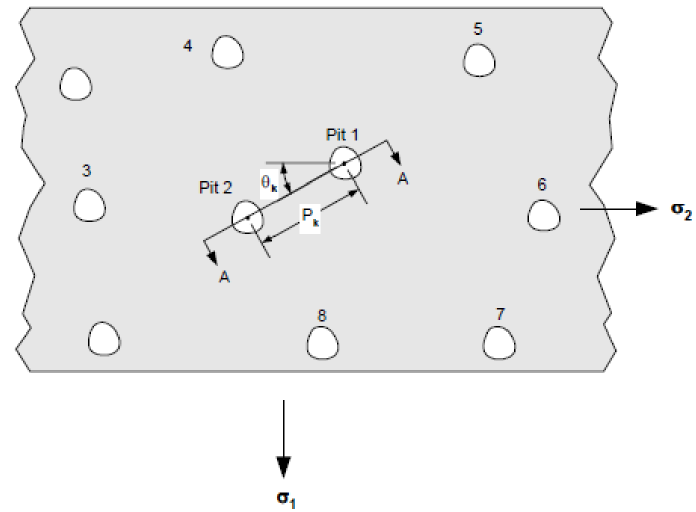
Average Pit Diameter, d_{avg}: ____________________

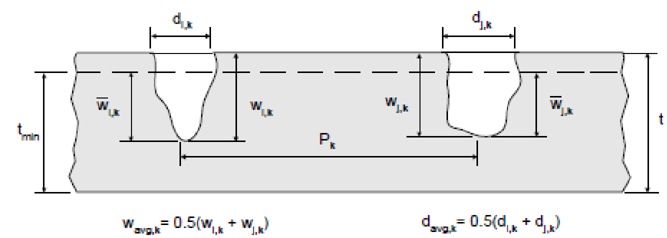
Average Pit Spacing, P_{avg}: ____________________

Average Pit Depth, w_{avg}: ____________________

Data Required for Level 1 and Level 2:

Pit-Couple	P_k	θ_k	$d_{i,k}$	$w_{i,k}$	$d_{j,k}$	$w_{j,k}$

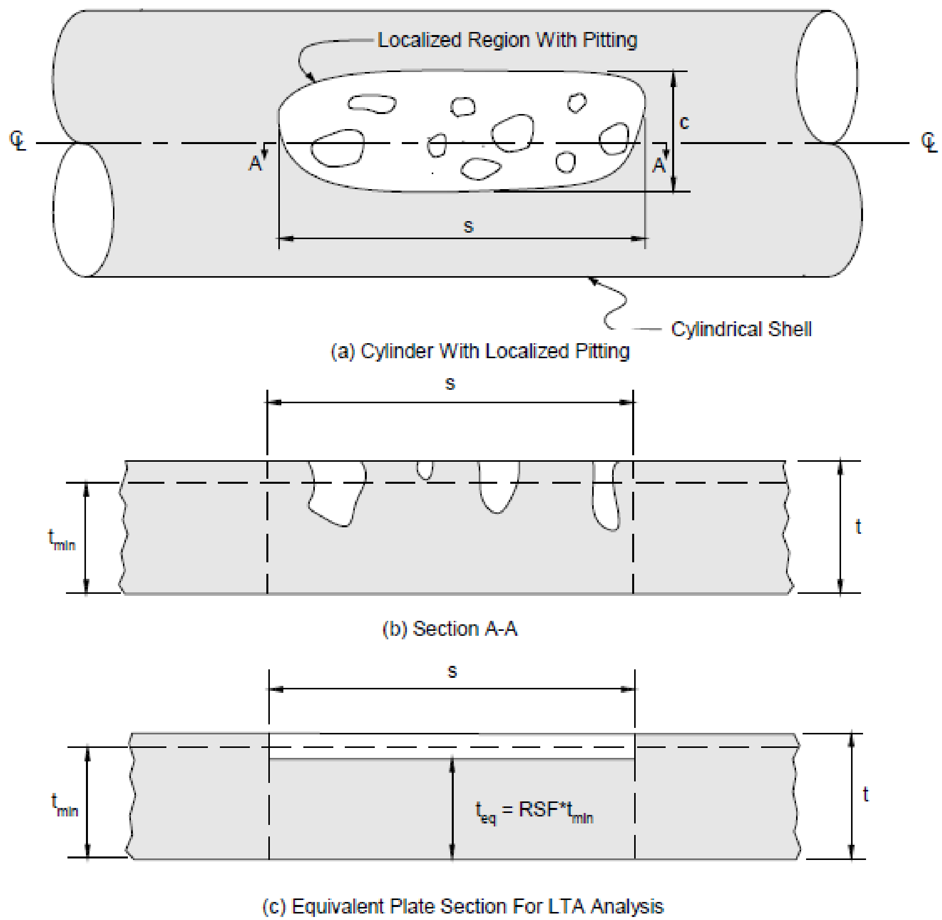




Example Problems

Example #3 – Pitting (cont.)

Figure 6.5
Additional Parameters For The Analysis Of A Localized Region Of Pits



Example Problems

Example #3 – Pitting (cont.)

Example Problem 1 – Widely scattered pitting has been discovered on the cylindrical section of a pressure vessel during an inspection. The vessel and inspection data are shown below. The vessel was designed and constructed to the ASME B&PV Code, Section VIII, Division 1. Determine if the vessel is acceptable for continued operation at the current $MAWP$ and temperature.

Vessel Data

Design Conditions	=	500 psi @ 450°F
Inside Diameter	=	60 inches
Wall Thickness	=	1 – 1/8 inches
Uniform Metal Loss	=	0.03 inches
Future Corrosion Allow.	=	0.05 inches
Material	=	SA516 Grade 70
Weld Joint Efficiency	=	0.85

Inspection Data

Inspection Data

Pit-Couple	P_k *inches*	θ_k *Degrees*	$d_{i,k}$ *inches*	$w_{i,k}$ *inches*	$d_{j,k}$ *inches*	$w_{j,k}$ *inches*
1	3.5	10	0.5	0.5	0.6	0.4
2	4.2	15	1.6	0.6	1.8	0.65
3	2.7	22	0.9	0.5	0.9	0.75
4	2.1	30	1.0	0.7	1.2	0.6
5	4.6	5	0.7	0.6	1.2	0.5
6	3.1	15	1.1	0.5	2.2	0.45
7	2.9	20	0.8	0.65	0.5	0.6
8	3.1	45	0.5	0.4	1.0	0.75
9	2.6	60	1.3	0.5	0.8	0.2
10	2.2	0	0.4	0.55	0.3	0.75
11	1.8	10	1.5	0.4	0.8	0.5
12	2.5	20	0.6	0.75	0.5	0.7
13	3.8	35	2.4	0.5	1.6	0.75
14	1.9	90	0.4	0.25	0.8	0.5
15	1.8	0	1.0	0.7	0.8	0.5
16	1.0	22	0.6	0.75	0.2	0.7
17	2.5	45	0.9	0.3	1.2	0.4
18	1.5	67	0.6	0.5	0.6	0.7
19	1.3	90	0.8	0.4	0.5	0.7

- Follow Level 1 assessment per Part 6
- Perform Level 2 or 3 assessment as needed.

Example Problems

Example #3 – Pitting (cont.)

Perform a Level 1 Assessment per paragraph 6.4.2

Step 1 – Determine the following parameters:

$$D = 60"$$
$$LOSS = 0.03"$$
$$FCA = 0.05"$$
$$RSF_a = 0.9$$
$$t = t_{nom} - LOSS = 1.125" - 0.03" = 1.095"$$

Step 2 – Determine the parameters for each pit couple being evaluated. The pit diameters, pit-couple spacing and orientation are shown in the table of inspection data.

Step 3 – Calculate the minimum required thickness, t_{min}, based on the current design pressure and temperature (see Appendix A).

$$R_c = \frac{60"}{2} + 0.03" + 0.05" = 30.08"$$
$$t_{min}^{C} = \frac{(500\,psig)(30.08")}{(17500\,psi)(0.85) - 0.6(500\,psig)} = 1.032"$$
$$t_{min}^{L} = \frac{(500\,psig)(30.08")}{2(17500\,psi)(0.85) + 0.4(500\,psig)} = 0.501"$$
$$t_{min} = \max[1.032",\ 0.501"] = 1.032"$$

Step 4 – Determine the actual depth of each pit in all pit-couples. For example, the actual and average depths for the first pit-couple are:

$$\overline{w}_{1,1} = 0.50" - (1.095" - 0.05" - 1.032") = 0.487"$$
$$\overline{w}_{2,1} = 0.40" - (1.095" - 0.05" - 1.032") = 0.387"$$
$$\overline{w}_{avg,1} = \frac{(0.487" + 0.387")}{2} = 0.437"$$

The average pit depth for all pits is:

$$\overline{w}_{avg} = 0.5435"$$

Step 5 – Determine the average pit diameter and pit-couple spacing. The average diameter for the first pit-couple is:

$$d_{avg,1} = \frac{(0.50" + 0.60")}{2} = 0.55"$$

The average diameter and pit spacing for all pits is:

$$d_{avg} = 0.9237"$$
$$P_{avg} = 2.5842"$$

Step 6 – Calculate the Remaining Strength Factor, RSF:

$$\mu_{avg} = \frac{2.584 - 0.9237}{2.584} = 0.6426$$
$$E_{avg} = \frac{\sqrt{3}}{2}(0.6426) = 0.5565$$
$$RSF = \min\left[\left\{1.0 - \frac{0.5435"}{1.032"} + \frac{0.5565(1.095" - 0.05" + 0.5435" - 1.032")}{1.032"}\right\}, 1.0\right] = 0.7734$$

Step 7 – Evaluate results based on the type of pitting damage:

Widespread pitting with $(RSF = 0.7734) < (RSF_a = 0.9)$; therefore a rerate is required. The reduced operating pressure for continued operation is:

$$MAWP_r = MAWP\left(\frac{RSF}{RSF_a}\right) = (500\,psig)\left(\frac{0.7734}{0.90}\right) = 430\,psig$$

Step 8 – Check the recommended limitations on the pit dimensions. All pit depths should be checked. In this example problem, only the first pit of pit-couple number one is examined to illustrate the procedure.

Pit Dimensions and Remaining Thickness Ratio:

$$\overline{w} = \overline{w}_{1,1} = 0.487"$$
$$R_t = \frac{1.032" - 0.487" - 0.05"}{1.032"} = 0.48$$
$$\left\{\begin{matrix} R_t = 0.48 \\ RSF_a = 0.9 \end{matrix}\right\} \textit{from Table 4.4};\ Q = 0.55$$
$$(d = 0.5") \le \left(Q\sqrt{Dt_{min}} = 0.55\sqrt{(2 \cdot 30.08")(1.032")} = 4.3"\right) \quad \textit{True}$$

Pit Depth:

$$(R_t = 0.48) \ge 0.20 \quad \textit{True}$$

Example Problems

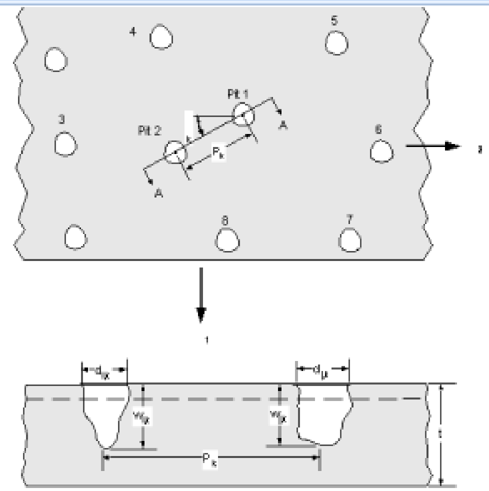
Example #3 – Pitting (cont.)

Analysis Control | Pitting

Pit Couples | Localized Pitting

Pit Corrosion Allowance

Pit depth FCA (in)	0.0
Pit diameter FCA (in)	0.0



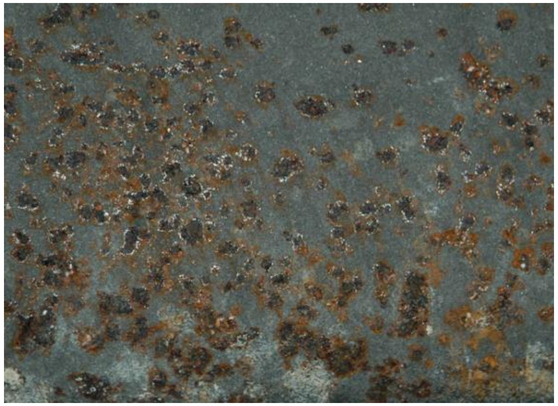
Pit Couple Data

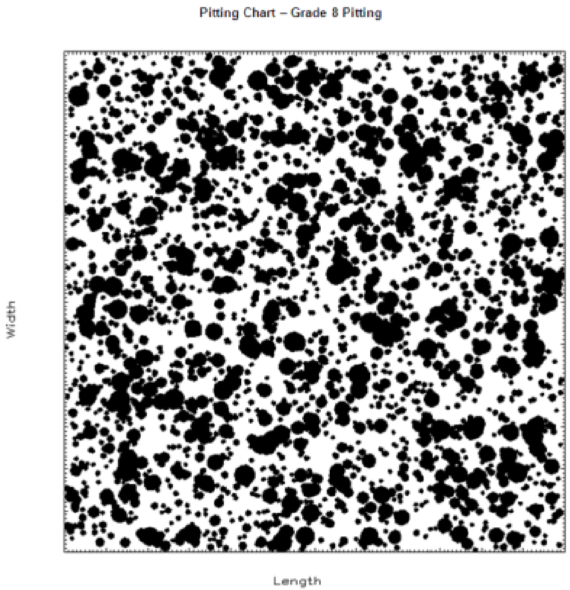
	Pit Couple Pitch (in)	Pit Angle (deg)	Pit 1 Diameter (in)	Pit 1 Depth (in)	Pit 2 Diameter (in)	Pit 2 Depth (in)
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

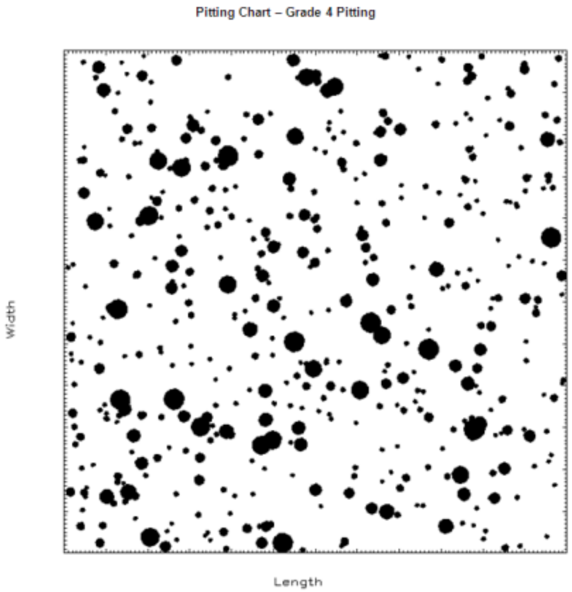
Example Problems

Example #3 – Pitting (cont.)

- 2007 Edition – Pitting Charts







API 579-1/ASME FFS-1, 2007 Edition

Overview

- Released on 2Q2007
- Includes new enhancements and new parts covering FFS assessment procedures that address unique damage mechanism:
  - Part 5 - Assessment of Local Thin Areas
    - Level 1 screening procedure modified
    - Assessment procedures for gouges have been relocated to Part 12
  - Part 7 - Assessment of Blisters and HIC/SOHIC Damage
    - Assessment procedures for HIC/SOHIC damage have been added
    - Assessment of lamination moved to Part 13
  - Part 8 - Assessment of Weld Misalignment and Bulges
    - Assessment procedures for bulges removed
    - Assessment procedures for dents, gouges, and dent-gouge combinations have been relocated to Part 12

API 579-1/ASME FFS-1, 2007 Edition

Overview (cont.)

- Part 10 - Assessment of Equipment Operating in the Creep Range,
  - Assessment procedures for remaining life calculations for components with or without crack-like flaws have been added, New Part
- Part 12 - Assessment of Dents, Gouges, and Dent-Gouge Combinations, New Part
- Part 13 - Assessment of Laminations, New Part

- New enhancements to existing annexes.
- New annexes

- API-1/ASME FFS-1 2007 Edition to supersede API 579-2000 Edition.

API 579-1/ASME FFS-1, 2007 Edition

Technical Basis and Validation

- Joint API/ASME FFS Committee committed to publishing the technical basis to all FFS assessment procedures utilized in API 579-1/ASME FFS-1 2007 in the public domain

- NBIC has supporting language for Fitness for Service in NB-23 Part 2 Inspection.

- Appendix H of API 579-1/ASME FFS-1 2007 provides an overview of technical basis and validation with related references organized by damage type; the references are published in a series of WRC Bulletins and technical papers

- Publication of technical background has been instrumental in obtaining acceptance from regulatory bodies

API 579-1/ASME FFS-1, 2016 Edition

Fitness-For-Service

API 579-1/ASME FFS-1, June, 2016

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