1. INTRODUCTION
2. DESIGN
3. INSPECTION
4. MAINTENANCE

LEMBAGA JURUTERA MALAYSIA

API American Petroleum Institute

Australian Government
Civil Aviation Safety Authority

NIOSH
National Institute of Occupational Safety and Health

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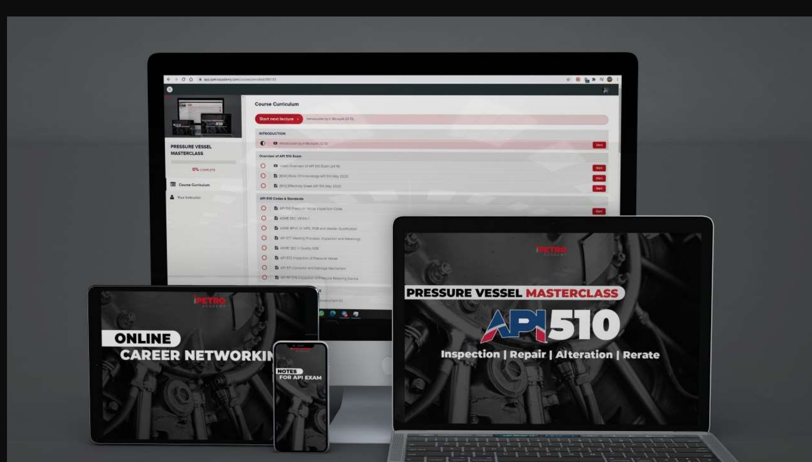
Ir Mursyidi | Creator of API Master Class | Career Strategist

MODULE 1: INTRODUCTION



Piper Alpha - North Sea – 1988

Deep Water Horizon / Macondo – Gulf of Mexico – 2010

Amuay Refinery - Venezuela - 2012

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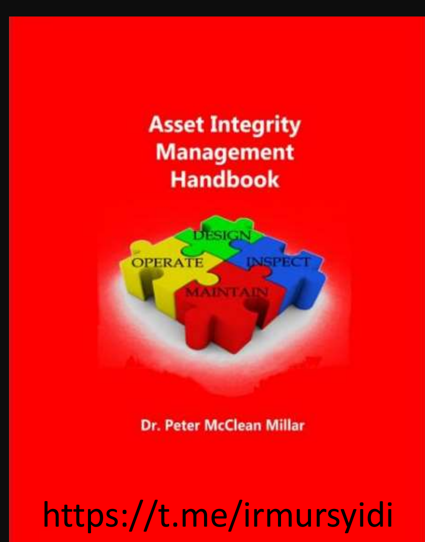
ASSET INTEGRITY MANAGEMENT



DEFINITION

In 2007, the U.K.'s Health and Safety Executive defined:

- **ASSET INTEGRITY** as "*the ability of an asset to perform its required function effectively and efficiently whilst protecting health, safety and the environment*."
- **ASSET INTEGRITY MANAGEMENT** as "*the means of ensuring that the people, systems, processes and resources which deliver the integrity, are in place, in use and fit for purpose over the whole lifecycle of the asset*."
- ***ASSET INTEGRITY MANAGEMENT (AIM) PROGRAM*** *ensures that mechanical integrity is being evaluated and maintained over an asset's entire lifecycle.*

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ASSET'S LIFECYCLE ELEMENTS & ASSET INTEGRITY

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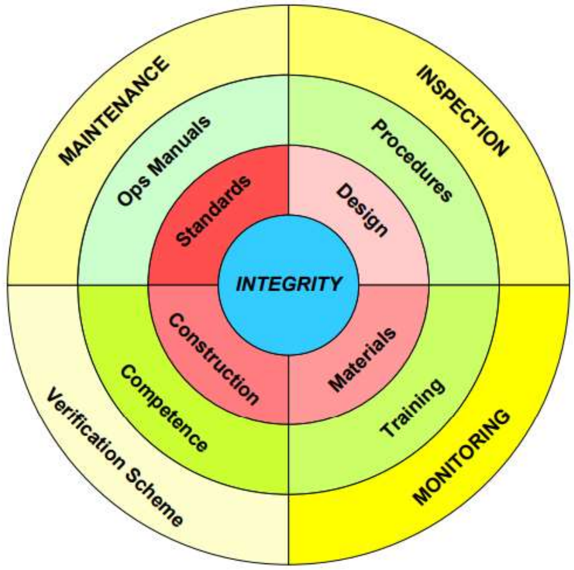
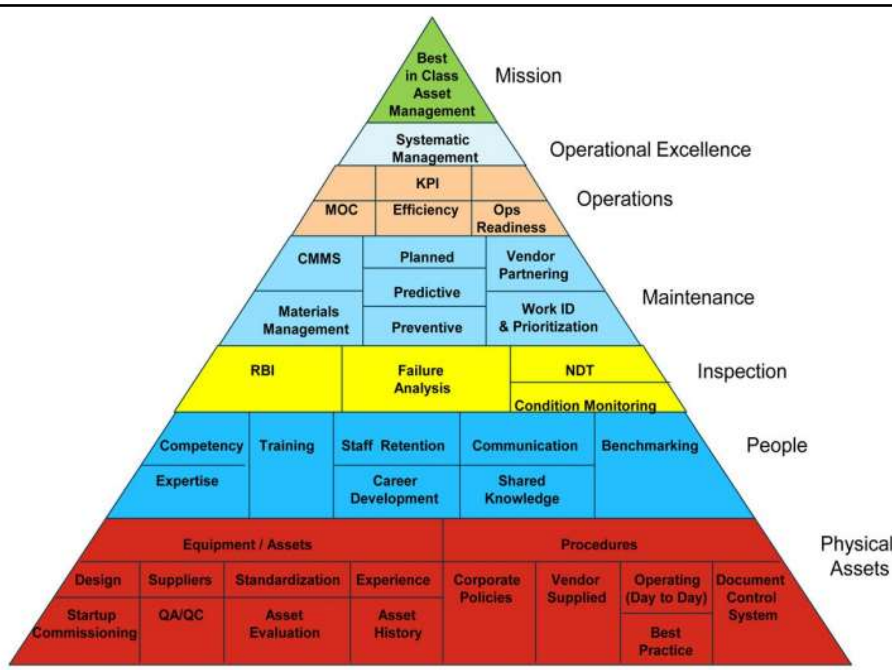


Contributors to Asset Integrity



Asset Management Triangle

GlobeNewswire

FIORMARKETS

Global Asset Integrity Management Market is Expected to Reach USD 48.35 Billion by 2025 : Fior Markets

Global Asset Integrity Management Market by Service Type (Risk-Based Inspection (RBI), Pipeline Integrity Management, Corrosion Management And Others), Industry, Region, Global Industry Analysis, Market Size, Share, Growth, Trends, and Forecast 2018 to 2025

Email | Print Friendly | Share

January 29, 2020 10:00 ET | **Source:** Fior Markets

Newark, NJ, Jan. 29, 2020 (GLOBE NEWSWIRE) -- As per the report published by Fior Markets, the **global asset integrity management market** is expected to grow from USD 20.34 Billion in 2017 to USD 48.35 Billion by 2025 at a CAGR of 11.40% during the forecast period 2018-2025.

Profile
Fior Markets

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Nondestructive Testing (NDT) Inspection segment held largest market share of 21.50% in 2017

- **SERVICE TYPE SEGMENT** is classified into:
  1. Risk-Based Inspection (RBI),
  2. Pipeline integrity management,
  3. Corrosion management,
  4. Structural integrity management,
  5. Nondestructive testing (NDT) inspection,
  6. Reliability-availability-maintainability (RAM) study,
  7. Hazard identification (HAZID) study
- Nondestructive testing (NDT) segment is anticipated to grow with the highest CAGR over the forecast period.

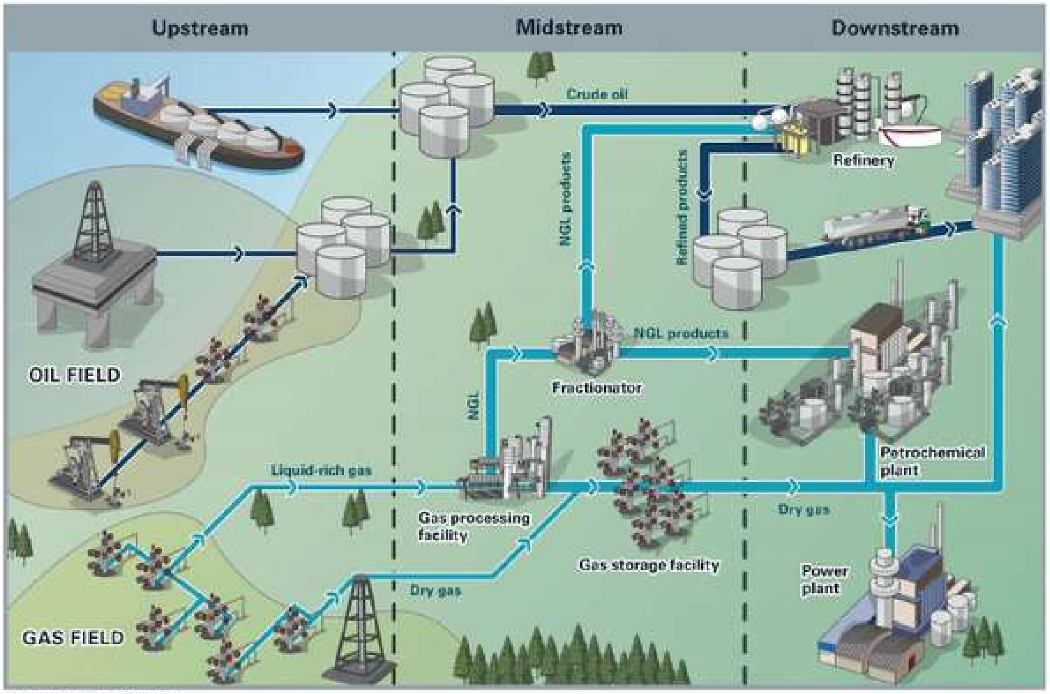
Oil and gas segment valued around USD 3.98 Billion in 2017

- **Industry segment** includes
  - oil and gas,
  - power,
  - mining,
  - marine,
  - aerospace
- Oil and gas has highest market share in 2017 and is playing a chief role in shaping business growth.
- This industry services helps to control risk and operating costs and maintains safe environment which drives the demand of the oil and gas segment

Upstream
- Finding, lifting, processing oil & gas from subsurface into surface and ready for transportation.
- Also known as Exploration & Production (E&P)

Midstream
- Transportation and storage of crude oil and natural gas from E&P plant for further processing by pipeline, railway, road or tanker

Downstream
- Further processing of crude oil ad natural gas into useful final product or raw material for other industry

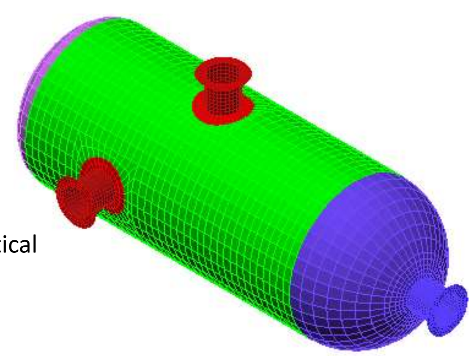


Source: Tortoise Capital

What is Pressure Vessel?

- Pressure Vessel is a container for the containment of pressure, either internal or external.
- This pressure may be obtained from an external source, or by the application of heat from a direct or indirect source, or any combination thereof.

- Classification based on:
  - Function
    - Storage Tank, Process vessel, Heat Exchanger
  - Geometry
    - Cylindrical, Spherical, Conical, Non-circular, Horizontal/vertical
  - Construction
    - Monowall, Forged,
  - Service
    - Cryogenic, Steam, Lethal, Vacuum, Fired/Unfired, Stationary/Mobile



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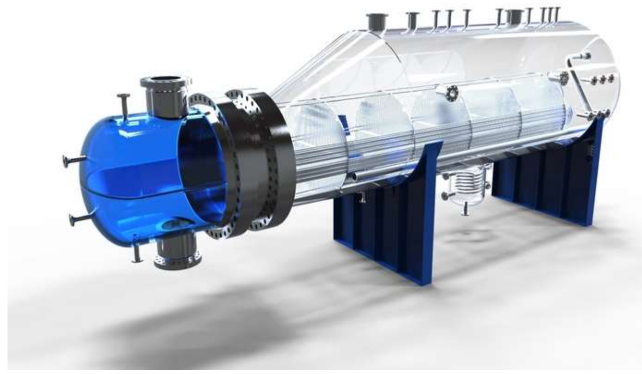
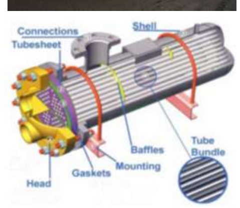
Use of Pressure Vessel

- Pressure Vessels are used in variety of industries:
  - ✓Petroleum Refining
  - ✓Oil & Gas
  - ✓Chemical
  - ✓Power
  - ✓Fertilizer
  - ✓Food
  - ✓Nuclear



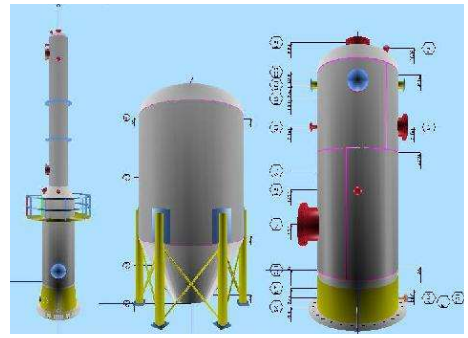
Types of Pressure Vessel

1. Column, tower
2. Reactor
3. Condenser
4. Bullet
5. Sphere
6. Accumulator
7. Heat exchanger
8. Air cooler

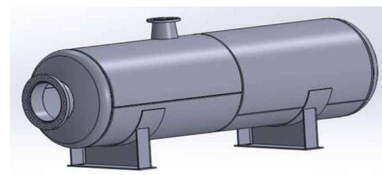


Types of Pressure Vessel

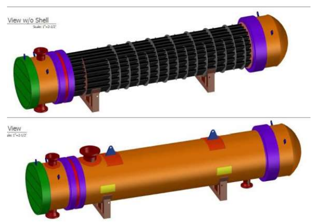
1. Vertical Vessel/Reactor/Column
   - ➢ Supported on legs/Skirt

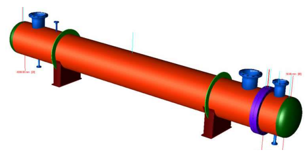


2. Horizontal/Spherical Vessel
   - ➢ Supported on Saddles/Legs



3. Heat Exchanger





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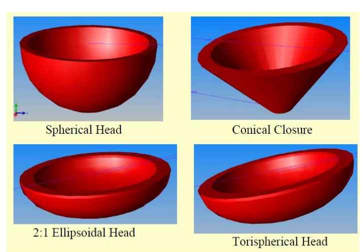
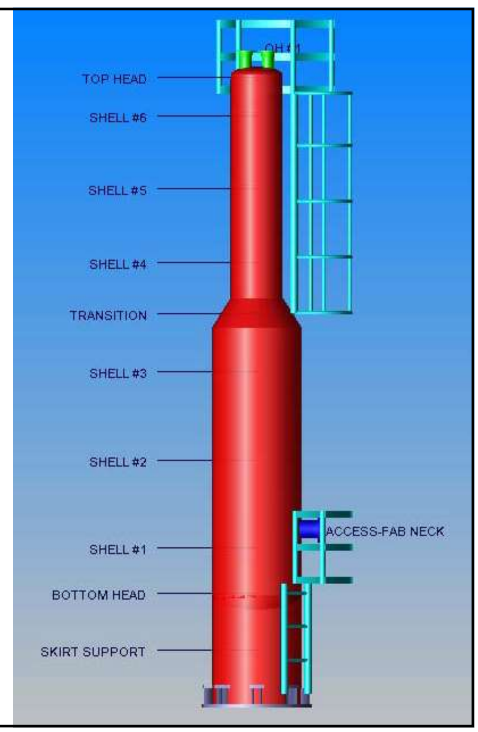
Components of Pressure Vessel

- DISH END
  - Spherical,
  - Conical
  - Elliptical
  - Tori spherical
- SHELL
- NOZZLE (Forged, Fabricated)
- NOZZLE REINFORCEMENT PADS

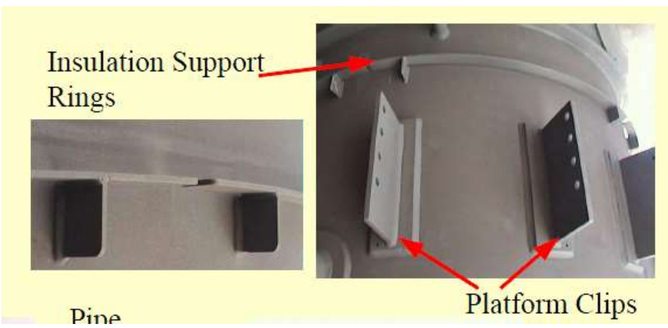


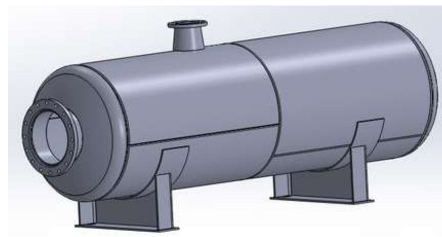


Components of Pressure Vessel

- EXTERNAL ATTACHMENTS (Ladder, Pipe cleats)
- LUGS (for Earthing, Lifting, Tailing)
- SADDLE SUPPORT / SKIRT SUPPORT

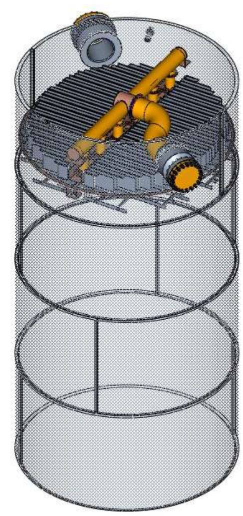


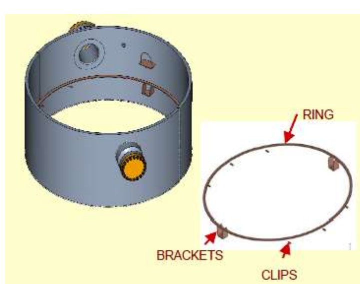


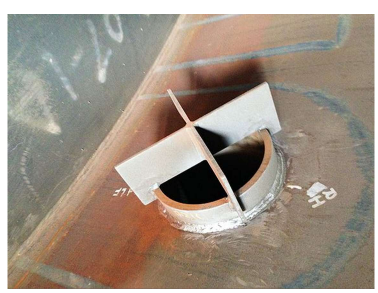


Components of Pressure Vessel

- PIPE or MANWAY DAVIT
- LADDER RUNGS
- INTERNALS (Demister, Vortex breaker, Deflector etc)
- NAME PLATE & ASME STAMPS (U, U2, U3, S)







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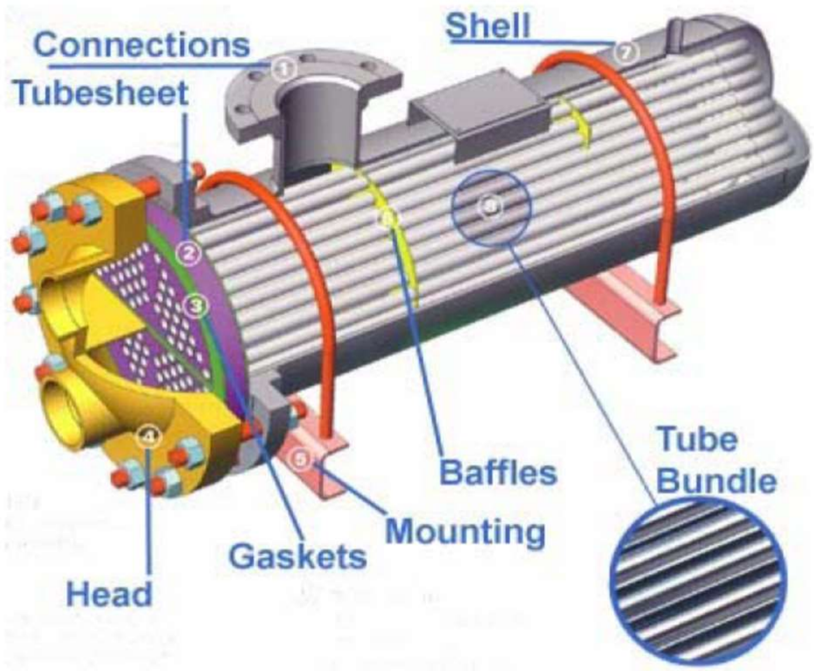
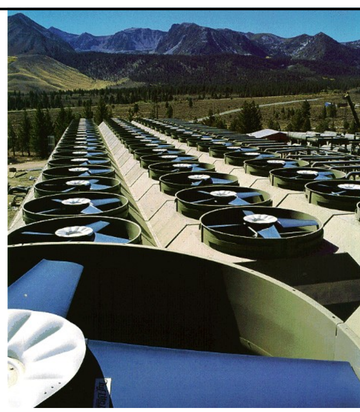
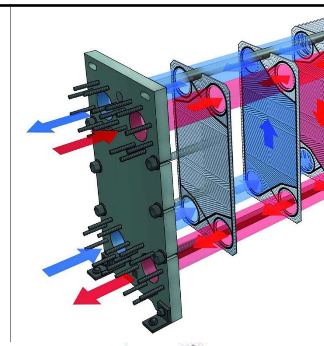
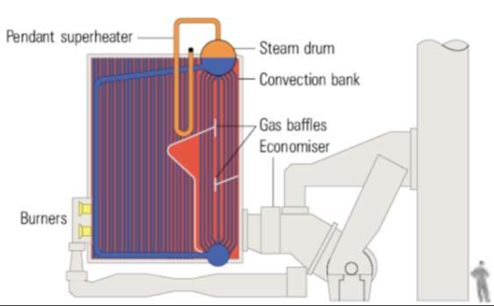
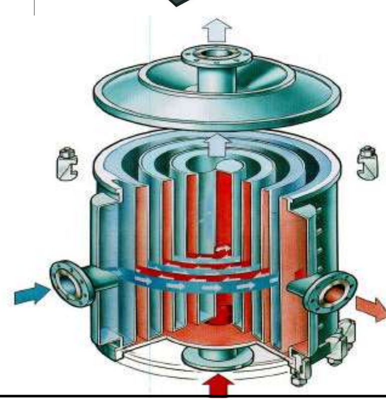

Connections
Shell
Tubesheet
Baffles
Tube Bundle
Mounting
Gaskets
Head

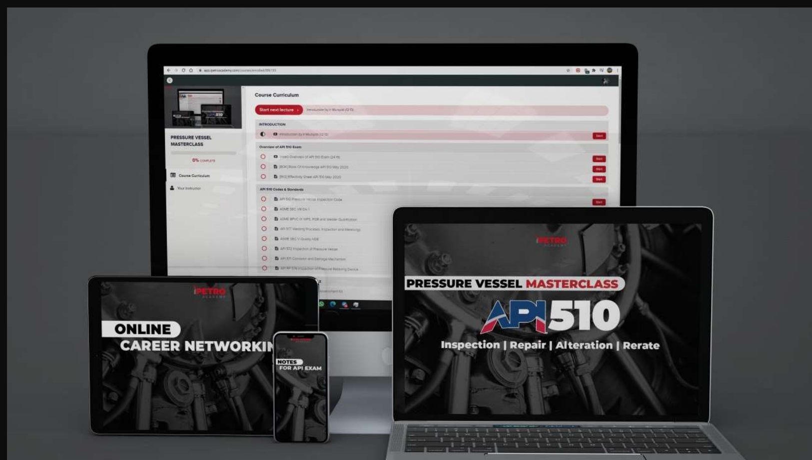


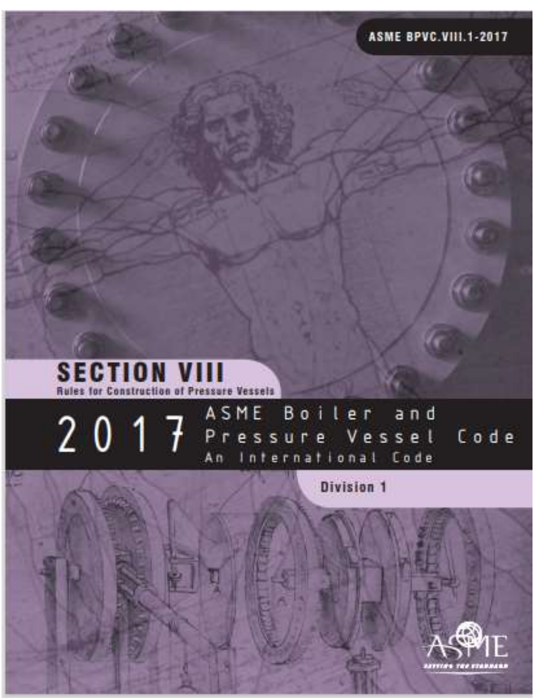



Pendant superheater
Steam drum
Convection bank
Gas baffles
Economiser
Burners



MODULE 2: DESIGN

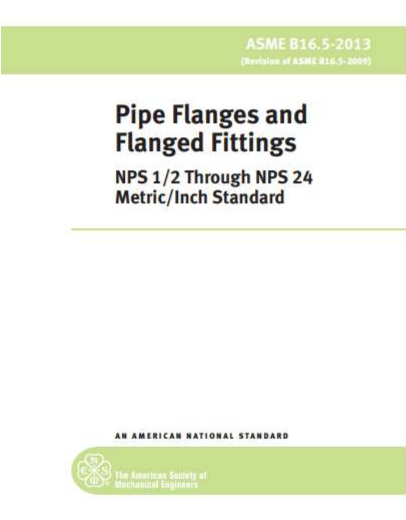




DESIGN CODES

- **USA**
  - ASME Boiler & Pressure Vessel code (Sec I, VIII)
  - TEMA Standards
  - API Pressure Vessel Code
- **United Kingdom**
  - Pressure Vessel code (PD 5500)
- **Germany**
  - AD Merkblatt code
- **Japan**
  - Japanese pressure vessel code
- **Australia**
  - Code for boilers & pressure vessels (AS 1200)
- **India**
  - Pressure vessel standard (IS 2825)
- **France**
  - Construction code for pressure vessels (SNCT)

DESIGN STANDARDS



1. ASME B16.5 - Pipe flanges and flanged fittings
2. ASME B16.47 - Large Diameter Steel Flanges
3. ASME B16.20 - Metallic gaskets for pipe flanges
4. ASME B16.21 - Non metallic gaskets for pipe flanges
5. ASME B36.10 - Welded and Seamless Wrought Steel Pipe
6. ASME B36.19 - Stainless Steel Pipe
7. ASME B16.9 - Factory made Wrought Steel Butt Welding Fittings
8. ASME B16.11 - Forged Fittings, Socket Welding & Threaded

BOILER AND PRESSURE VESSEL CODE

SECTIONS

I Rules for Construction of Power Boilers

II Materials

- Part A - Ferrous Material Specifications
- Part B - Nonferrous Material Specifications
- Part C - Specifications for Welding Rods, Electrodes, and Filler Metals
- Part D - Properties (Customary)
- Part D - Properties (Metric)

IV Rules for Construction of Heating Boilers

V Nondestructive Examination

VI Recommended Rules for the Care and Operation of Heating Boilers.

VII Recommended Guidelines for the Care of Power Boilers

VIII Rules for Construction of Pressure Vessels

- Division 1
- Division 2 - Alternative Rules
- Division 3 - Alternative Rules for Construction of High Pressure Vessels.

IX. Welding and Brazing Qualifications

X. Fiber-Reinforced Plastic Pressure Vessels.

XI. Rules for In service Inspection of Nuclear Power Plant Components

XII Rules for Construction and Continued Service of Transport Tanks.

AMERICAN PETROLEUM INSTITUTE | Individual Certification Programs: ICP Body of Knowledge

BODY OF KNOWLEDGE
API-510 PRESSURE VESSEL INSPECTOR
CERTIFICATION EXAMINATION

May 2020, September 2020 and January 2021 (Replaces Sept 2019)

REFERENCE PUBLICATIONS:

A. API Publications:

API 510, Pressure Vessel Inspection Code
API RP 571, Damage Mechanisms Affecting Equipment in Refining Industry
API RP 572, Inspection of Pressure Vessels including Annex B, (all other Annexes are excluded)
API RP 576, Inspection of Pressure-Relieving Devices
API RP 577, Welding Inspection and Metallurgy

B. ASME Publications:

Section V, Nondestructive Examination
Section VIII, Division 1, Rules for Constructing Pressure Vessels
Section IX, Qualification Standard for Welding, Brazing and Fusion Procedures; Welders; Brazers; and Welding, Brazing and Fusing Operators

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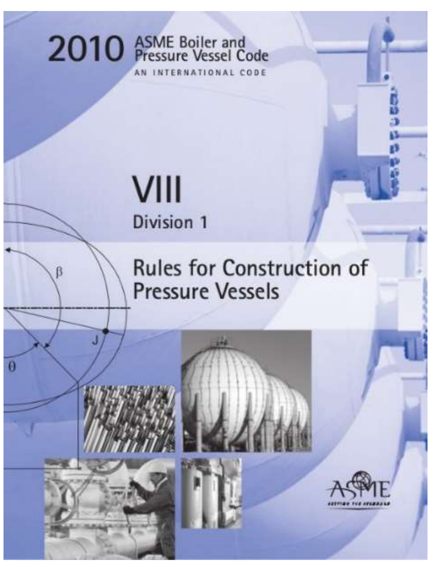

ASME VIII: PURPOSE

- Set of established rules deemed necessary for the **new construction** of pressure vessels
  - that will perform in a safe and reliable manner
- **Construction:** Material selection, design, fabrication, examination, inspection, testing, certification and pressure relief

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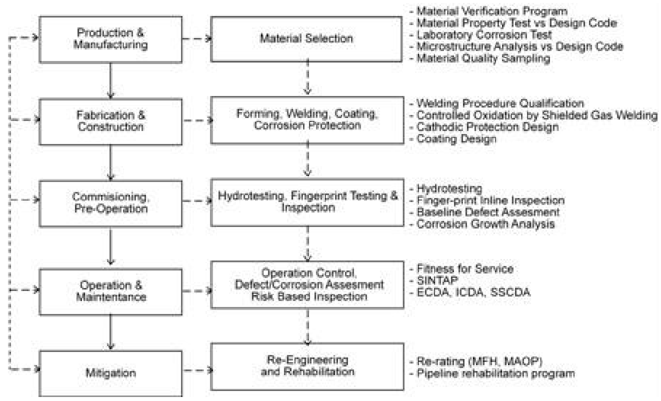
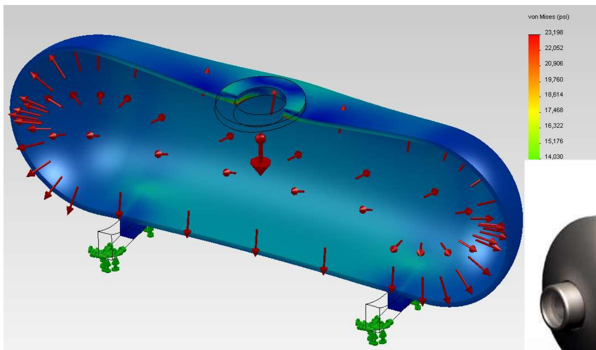
Engineering Integrity Approach



Material Selection

	Design Temperature, °F	Material	Plate	Pipe	Forgings	Fittings	Bolting
Cryogenic	−425 to −321	Stainless steel	SA-240-304, 304L, 347, 316, 316L	SA-312-304, 304L, 347, 316, 316L	SA-182-304, 304L, 347, 316, 316L	SA-403-304, 304L, 347, 316, 316L	SA-320-B8 with SA-194-8
	−320 to −151	9 nickel	SA-353	SA-333-8	SA-522-1	SA-420-WPL8	
Low temperature	−150 to −76	3½ nickel	SA-203-D	SA-333-3	SA-350-LF63	SA-420-WPL3	SA-320-L7 with SA-194-4
	−75 to −51	2½ nickel	SA-203-A				
	−50 to −21	Carbon steel	SA-516-55, 60 to SA-20	SA-333-6	SA-350-LF2	SA-420-WPL6	
	−20 to 4		SA-516-All	SA-333-1 or 6			SA-193-B7 with SA-194-2H
	5 to 32		SA-285-C	SA-53-B SA-106-B	SA-105 SA-181-60,70	SA-234-WPB	
Intermediate	33 to 60 61 to 775		SA-516-All SA-515-All SA-455-II				
Elevated Temperature	776 to 875	C-½Mo	SA-204-B	SA-335-P1	SA-182-F1	SA-234-WP1	
	876 to 1000	1Cr-½Mo	SA-387-12-1	SA-335-P12	SA-182-F12	SA-234-WP12	
		1Cr-½Mo	SA-387-11-2	SA-335-P11	SA-182-F11	SA-234-WP11	
	1001 to 1100	2¼Cr-1Mo	SA-387-22-1	SA-335-P22	SA-182-F22	SA-234-WP22	with SA-193-B5 SA-194-3
	1101 to 1500	Stainless steel	SA-240-347H	SA-312-347H	SA-182-347H	SA-403-347H	SA-193-B8 with SA-194-B
		Incoloy	SB-424	SB-423	SB-425	SB-366	
	Above 1500	Inconel	SB-443	SB-444	SB-446	SB-366	

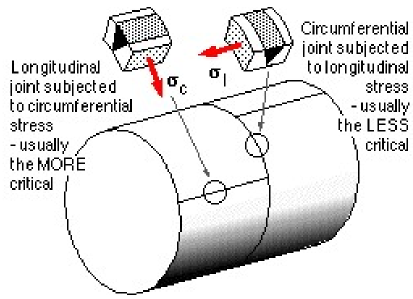
Basic Pressure Vessels Design



STRESS

- **Tension or Compression.**
- **Calculated as;** $S = \dfrac{Load\ (lbs)}{Sectional\ area\ (in2)}$
- **Measured in psi (pounds per in^2).**
- **Ultimate tensile strength:** The maximum stress a material can withstand. SA-516 gr70, S_{ult} = 70,000psi.
- **Allowable stress:** The maximum stress the code allows the designer to use. SA-516 gr70 = 20,000psi.

STRESS ON WELDS



- **Circumferential stress affects _________________ welds?**
- **Longitudinal stress affects ___________________ welds?**

- *Circum stress is usually **twice as large** as the longitudinal stress*

ALLOWABLE STRESS

- Allowable stress is the level the **designer is allowed to use** and is generally determined by **dividing the ultimate tensile strength (UTS)** by the **code's safety factor**.
- The allowable stress for section VIII pressure vessels is provided in the B&PV code, section II.
- The safety factor for section VIII vessels is:

    4 to 1 for pre 2000 vessels.

    3.5 to 1 for post 2000 vessels.

STATIC HEAD

- Water, 1 foot high, will exert 0.433psi at the bottom of the container.

$$\frac{62.4\ \text{lbs}}{144\ in^2} = 0.433\text{psi } \textit{per foot of water}$$

- What is the pressure at the bottom of 10’ of water?
- The formula for calculating static head pressure is:

$$P_{SHead} = 0.433 \text{ x liquid height.}$$

Quiz – STATIC HEAD PRESSURE

1. A 50’ diameter vessel is filled with water. What is the pressure at the bottom of the vessel?

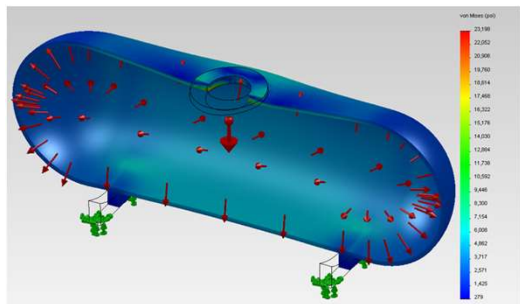
2. A vertical vessel is 60’ high, the pressure at the bottom is 210 psi. What is the pressure at the top?

Ans:
1. 50 X 0.433 = 21.65 psig
2. 210 - 60 x 0.433 = 184.02 psig

DESIGN PRESSURE

- 'The pressure used in the design of a vessel component together with the coincident design metal temperature for the purpose of **determining the minimum permissible thickness**. (Static head shall be added to the design pressure).'

  [Appendix 3-2]



MAXIMUM ALLOWABLE WORKING PRESSURE (MAWP)

- "The maximum allowable working pressure for a vessel part is the **maximum pressure, including static head**, based upon the rules and formulas in this division **excluding** any metal thickness specified as **corrosion allowance**." UG-98(b)

- Vessel individual component MAWP is determined from the design formula in the Code. For example, the MAWP for a shell is calculated with the following formula:

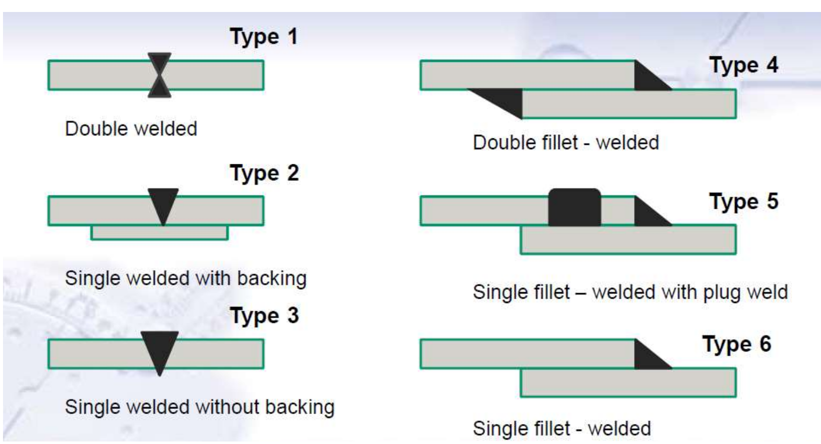
$$P = \frac{SEt}{R + 0.6t}$$

JOINT EFFICIENCY (E)

- **What is joint efficiency E?**
  - A safety factor for welds.
  - Compensation for possible weld defects.
- **What factors affect E?**
  - Type of joint, location of joint, amount of RT.
- **How does joint efficiency affect t_{min}?**
  - As E decreases, required thickness increases.
- **How is joint efficiency determined?**
  - The code, section VIII – Table UW-12.
  - There are a few exceptions also listed in UW-12.

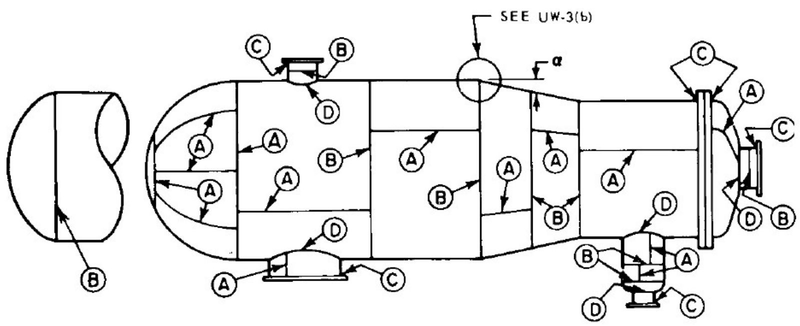
TYPES OF JOINTS

Table UW - 12

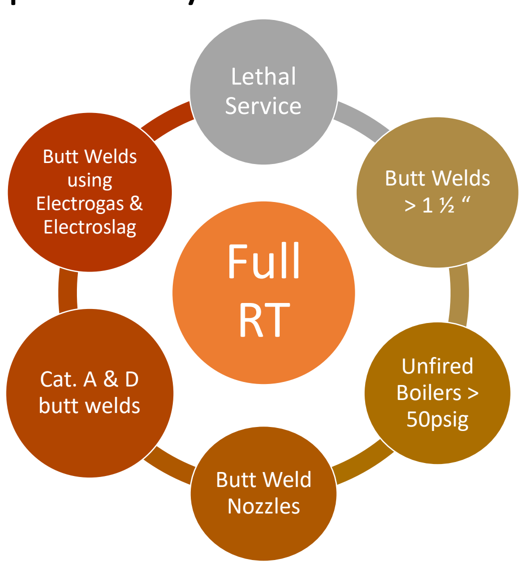


WELD JOINT CATEGORIES

- Category used here defines the location of a joint in a vessel not the type. **UW-3**



FULL RT – Required by Code



Ref: UW – 11(a)

CALCULATION - t_{min}

The formula, UG-27(c)(1) – internal pressure.

- **R is the inside radius:**
  - Radius is ½ of the diameter.
- **P is the design pressure:**
  - the pressure on the part.
  - includes static head.
- **The P formula calculates the shell MAWP:**
  - Part MAWP.
  - Not the vessel MAWP.

$$t_{min} = \frac{PR}{SE - 0.6P}$$

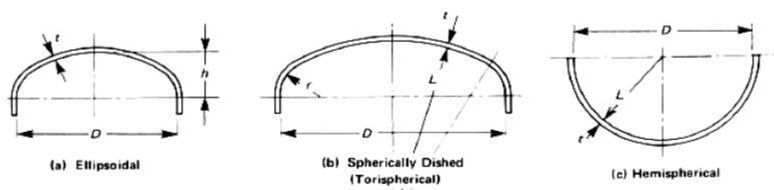
CALCULATION EXAMPLE- t_{min}

A vessel shell has an internal radius of 35.0”. At the design temperature, the material’s allowable stress is 15,000psi. The pressure on the shell (including static head) is 185psi. Nameplate states RT-1. Determine the minimum required thickness.

Given values	P = 185psi R = 35.0”	S = 15,000psi E = 1.0
Formula	$t_{min} = \frac{PR}{SE - 0.6P}$	
Enter values	$t_{min} = \frac{185 \ x \ 35}{15{,}000x1.0 - 0.6x185}$	
Solution	t_{min} = 0.435”	

ROUNDED HEAD - t_{min}

- Heads with pressure on the concave side are designed in accordance with UG-32 and UG-34. The formula, UG-32(d),(e),(f) (Highlight these formulas. Don't highlight formula #4)



$$t = \frac{PD}{2SE - 0.2P}$$

$$t = \frac{0.885PL}{SE - 0.1P}$$

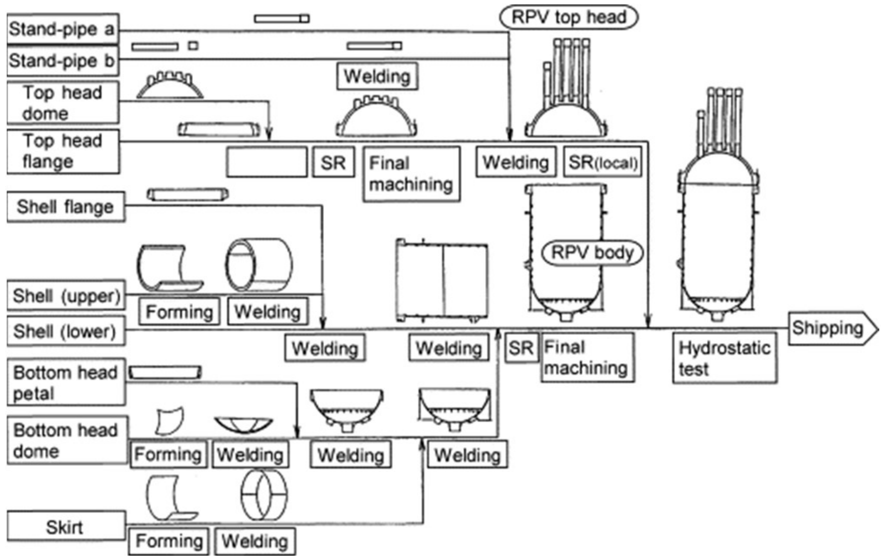
$$t = \frac{PL}{2SE - 0.2P}$$

DESIGN CALCULATION – THICKNESS FORMULAE

Part	Thickness, t_p, in.	Pressure, P, psi	Stress, S, psi
Cylindrical shell	$\frac{Pr}{SE_1 - 0.6P}$	$\frac{SE_1 t}{r + 0.6t}$	$\frac{P(r + 0.6t)}{tE_1}$
Spherical shell	$\frac{Pr}{2SE_1 - 0.2P}$	$\frac{2SEt}{r + 0.2t}$	$\frac{P(r + 0.2t)}{2tE}$
2:1 Semi -Elliptical head	$\frac{PD}{2SE - 0.2P}$	$\frac{2SEt}{D + 0.2t}$	$\frac{P(D + 0.2t)}{2tE}$
Torispherical head with 6% knuckle	$\frac{0.885PL}{SE - 0.1P}$	$\frac{SEt}{0.885L + 0.1t}$	$\frac{P(0.885L + 0.1t)}{tE}$
Conical Section (α = 30°)	$\frac{PD}{2\cos\alpha(SE - 0.6P)}$	$\frac{2SEt\cos\alpha}{D + 1.2t\cos\alpha}$	$\frac{P(D + 1.2t\cos\alpha)}{2tE\cos\alpha}$

Summary of ASME Code Equations

Pressure Vessel Fabrication Flow Chart



ASME IX

A Quality Weld:

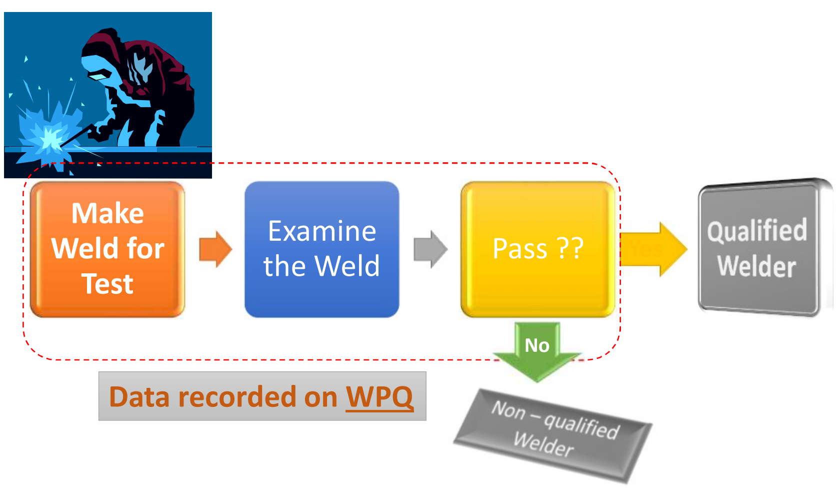
A qualified welder using a qualified weld procedure with appropriate environment; results in a **GOOD WELD**.

Practical Definition:

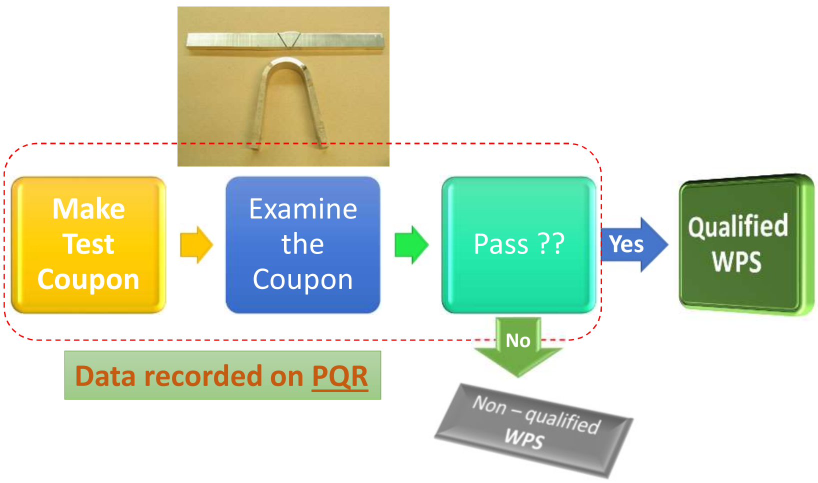
Qualified: *one who has been approved by test(s)*

Good: *One which meets the weld procedure*

QUALIFYING A WELDER (WPQ)



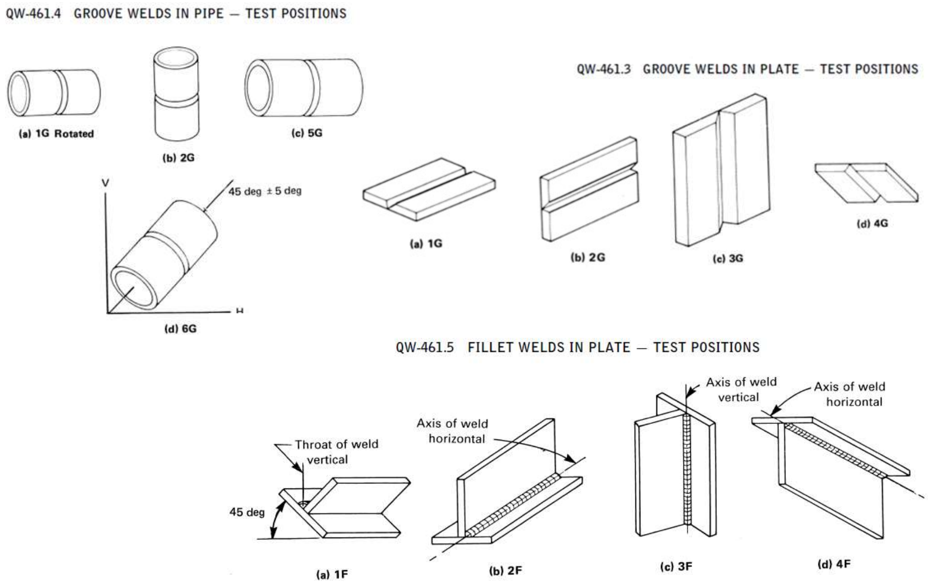
QUALIFYING A WELD PROCEDURE (WPS)



TEST POSITIONS

- Test positions are used during the Welder's Qualification Testing.
- Test positions are designated by symbols life 1G, 2G… 1F, 2F..
  - *Component – either Plate or Pipe*
  - *Orientation (1, 2, 3, 4, 5, 6)*
  - *Groove (G) or Fillet (F)*

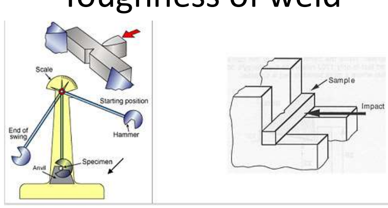
TEST POSITIONS



TESTINGS

- **Tension Test**
  - Strength of HAZ

- **Impact Test**
  - Toughness of weld



- **Bend Test**
  - Soundness of weld

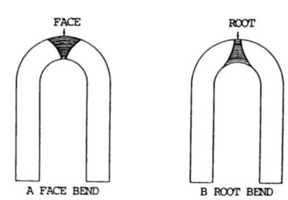
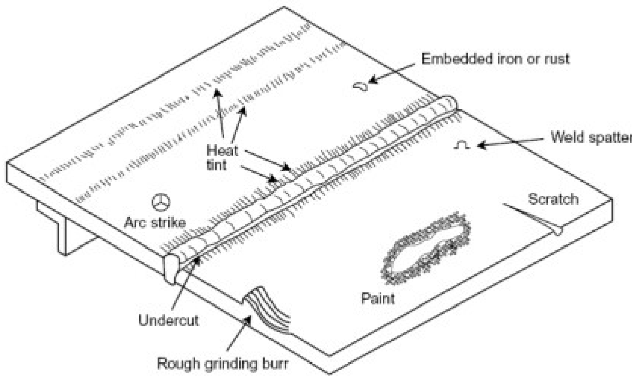


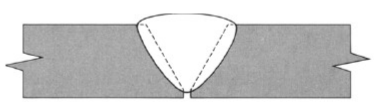
Figure 13-2. Guided bend test specimens.

- **Visual, Radiography & UT;**
  - Surface & Internal weld defects

Typical Welding Related Defect

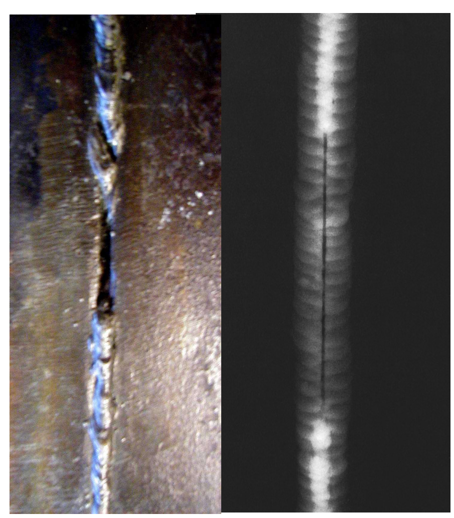


Incomplete Root Penetration (IP)

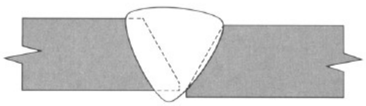


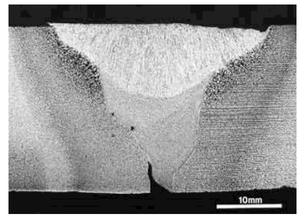
Causes

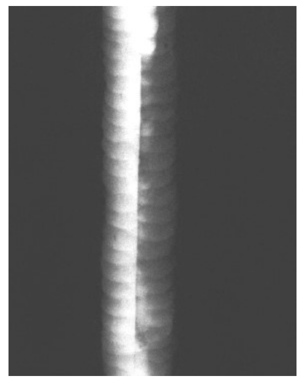
- Too small a root gap
- Arc too long
- Wrong polarity
- Electrode too large for joint preparation
- Incorrect electrode angle
- Too fast a speed of travel for current



Incomplete Root Fusion



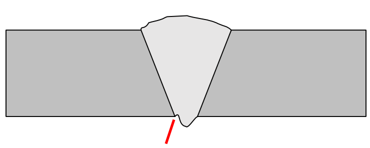


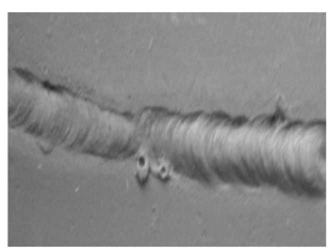


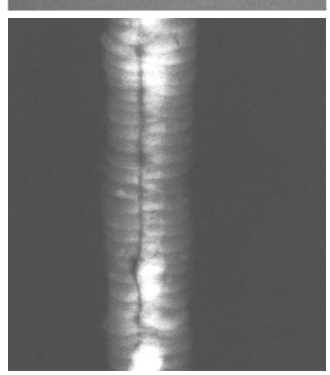
Causes

- Too small a root gap
- Arc too long
- Wrong polarity
- Electrode too large for joint preparation
- Incorrect electrode angle
- Too fast a speed of travel for current
- Misalignment

Root Undercut



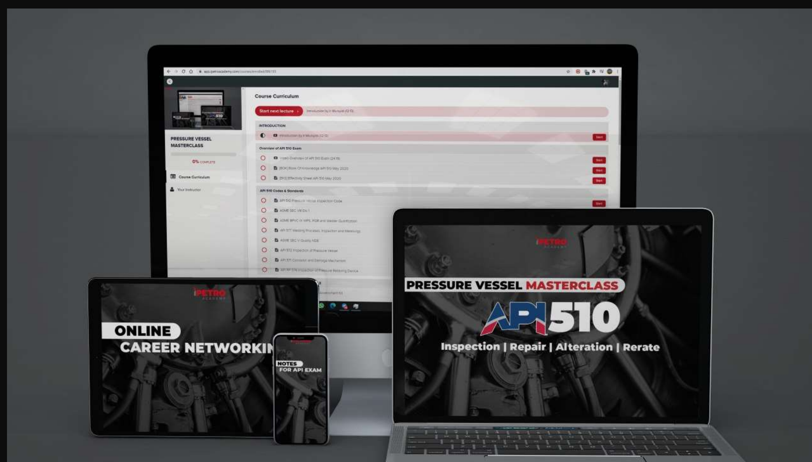


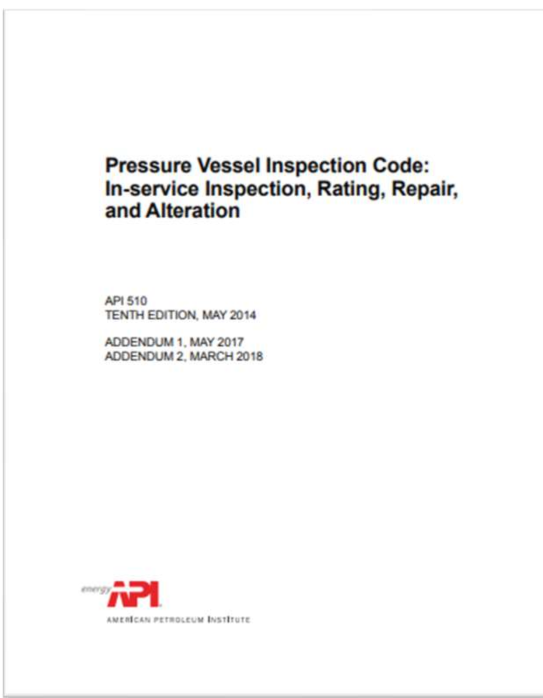


Causes

- Root gap too large
- Excessive arc energy
- Small or no root face

MODULE 3:
INSPECTION, EXAMINATION, TESTING





Pressure Vessel Inspection Code: In-service Inspection, Rating, Repair, and Alteration

API 510
TENTH EDITION, MAY 2014

ADDENDUM 1, MAY 2017
ADDENDUM 2, MARCH 2018

API
AMERICAN PETROLEUM INSTITUTE

API 510 PV Inspection Code

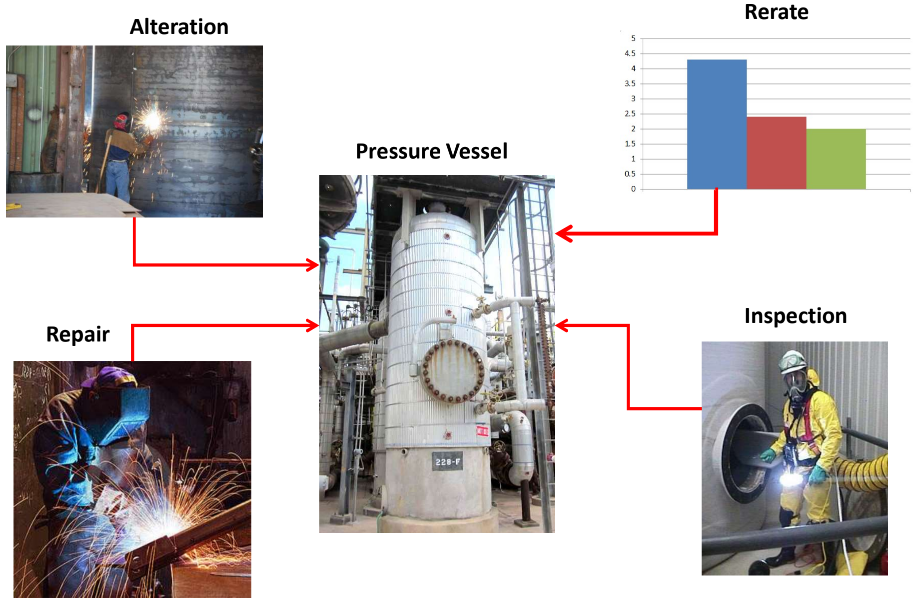
- **PURPOSE:**

To cost effectively safeguard pressure Equipment for Safe and Reliable operating condition in a specific period of time.

❖ *We deal with high pressure and high temperature equipment containment, failing which, may contribute to major accident hazards.*

PETRO ACADEMY

API 510 SCOPE



APPENDIX B—INSPECTOR CERTIFICATION

<u>B.1 Examination</u>

- A written examination to certify inspectors within the scope of API 510 shall be based on the current API 510 *Inspector Certification Body of Knowledge as published by API.*

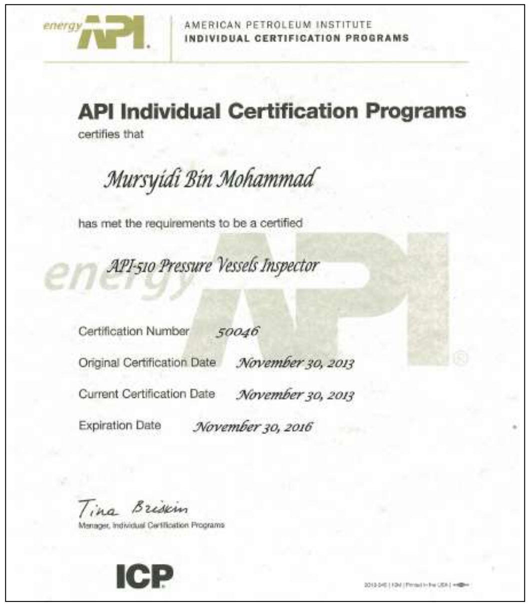
<u>B.2 Certification</u>

B.2.1 To qualify for the certification examination, the applicant's education and experience, when combined, shall be equal to at least one of the following:

- a. A Bachelor of Science degree in engineering or technology, plus one year of experience in supervision of inspection activities or performance of inspection activities as described in API 510.
- b. A two-year degree or certificate in engineering or technology, plus two years of experience in the design, construction, repair, inspection, or operation of pressure vessels, of which one year must be in supervision of inspection activities or performance of inspection activities as described in API 510.
- c. A high school diploma or equivalent, plus three years of experience in the design, construction, repair, inspection, or operation of pressure vessels, of which one year must be in supervision of inspection activities or performance of inspection activities as described in API 510.
- d. A minimum of five years of experience in the design, construction, repair, inspection, or operation of pressure vessels, of which one year must be in supervision of inspection activities or performance of inspection activities as describe in API 510.

B.2.2 An API 510 authorized pressure vessel inspector certificate may be issued when an applicant provides documented evidence of passing the <u>National Board of Boiler and Pressure Vessel Inspectors</u> examination and meets all requirements for education and experience of API 510.

APPENDIX B—INSPECTOR CERTIFICATION



AMERICAN PETROLEUM INSTITUTE
INDIVIDUAL CERTIFICATION PROGRAMS

API Individual Certification Programs
certifies that

Mursyidi Bin Mohammad

has met the requirements to be a certified

API-510 Pressure Vessels Inspector

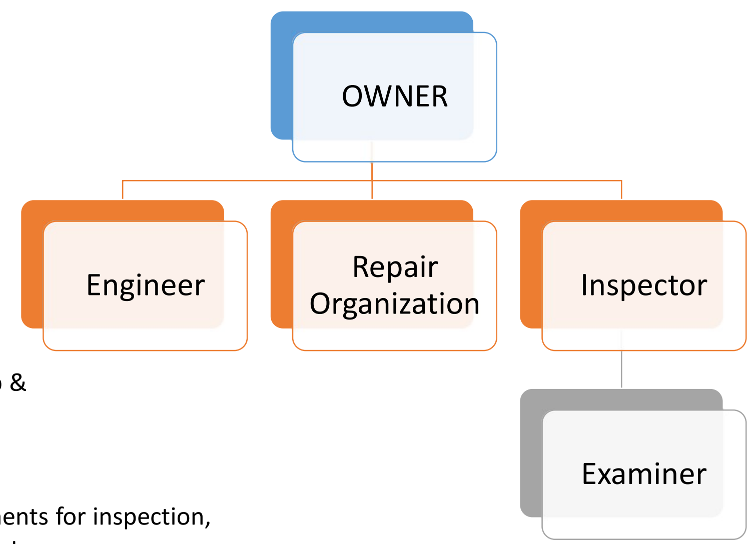
Certification Number *50046*
Original Certification Date *November 30, 2013*
Current Certification Date *November 30, 2013*
Expiration Date *November 30, 2016*

Tina Briskin
Manager, Individual Certification Programs

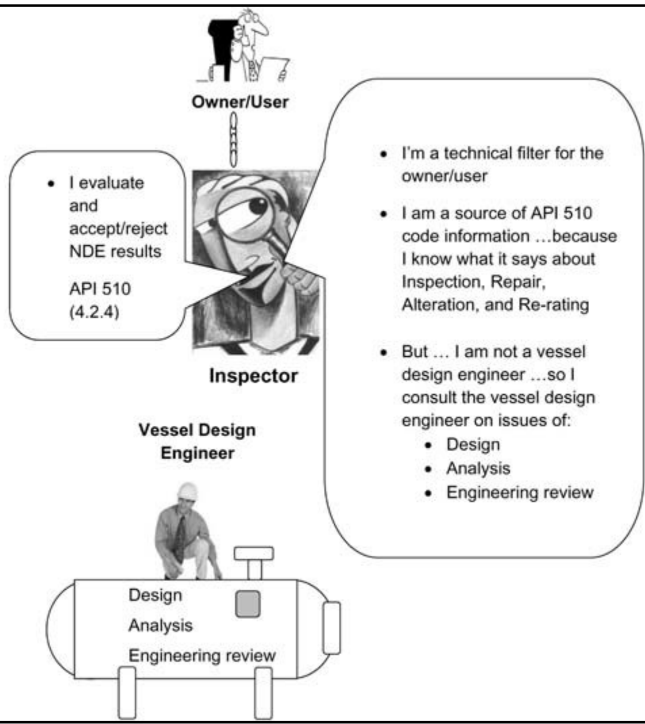
ICP

API 510 PLAYER

- **Owner/user**
  - Overall responsibility for compliance with the code.
- **Engineer**
  - Design and analysis.
- **Repair organization**
  - Responsible for workmanship & materials and QC!!!

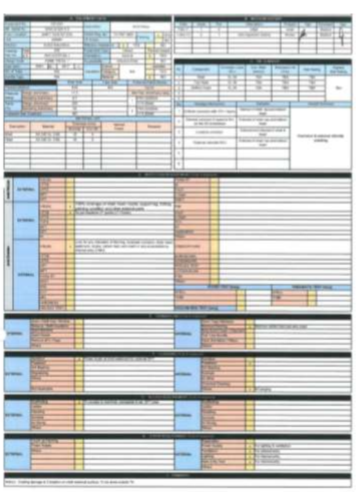


- **Authorized inspector**
  – Ensure that the Code requirements for inspection, examination and testing are met.
- **Examiner**
  – NDE and Welding Inspector.



API INSPECTOR VS ENGINEER

INSPECTION PLAN



- Required for **all vessels and relief devices.**
- **Developed** by either **inspector or engineer**.
- To consult with corrosion specialist when needed.
  - ❑i.e. for elevated temperature (above 750°F or 400°C)
- Should be readily available.

- **Data to develop plan**
  - a. Damage mechanism/s.
  - b. Damage rate (s).
  - c. Effectiveness of NDE.
- **Contents of the plan**
  - a. Type of inspections needed.
  - b. Next inspection date.
  - c. NDE methods to used.
  - d. Extent & location of NDE.
  - e. Surface cleanliness.
  - f. Required repairs.

INSPECTION TYPES

- **Internal:**
  - Check inside of vessel from inside.
  - Damage hard to find from outside.
  - By authorized inspector.
- **On-stream:**
  - Check inside of vessel from outside.
  - By an authorized inspector or examiner.
- **External:**
  - Check outside of vessel from outside
  - By an authorized Inspector or qualified others
- **Thickness readings:**
  - By an Authorized inspector or examiner
- **Corrosion under insulation (CUI).**

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INSPECTION INTERVALS

- **Internal or on-stream lesser of:**
  - **10 years**
  - **1/2 remaining life**
- **If remaining life is less than 4 years, Interval is lesser of:**
  - **2 years, or**
  - **Full remaining life**
- **External, lesser of:**
  - **5 years**
  - **At Internal Interval**
- **CUI and thickness inspection**
  - Not specified
  - Intervals set by the inspector or engineer

Determine Inspection Interval

Remaining Life	Internal Inspection	External Inspection
24	**10** or 12	**5** or 10

Determine Inspection Interval

Remaining Life	Internal Inspection	External Inspection
24	**10** or 12	**5** or 10
12	10 or **6**	**5** or 6

Determine Inspection Interval

Remaining Life	Internal Inspection	External Inspection
24	**10** or 12	**5** or 10
12	10 or **6**	**5** or 6
3	**2** or 3	5 or **2**

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Determine Inspection Interval

Remaining Life	Internal Inspection	External Inspection
24	**10** or 12	**5** or 10
12	10 or **6**	**5** or 6
3	**2** or 3	5 or **2**
1	2 or **1**	5 or **1**

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THICKNESS INSPECTION

- **Condition monitoring locations (CML)** number and location is ***based on the vessel damage mechanisms and consequence of failure***.
- CMLs are usually known as locations for UT thickness readings, but ***can also be locations for non-wall loss types of damage e.g. SCC, HTHA*** using methods such as UT, RT, replication, etc.
- CMLs **can be reduced** or eliminated ***if risk is low*****.**
  - ✓Low likelihood or consequence of failure
  - ✓Needs agreement with a corrosion specialist
- CMLs should be recorded either by marking the vessel or on the drawing.

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CORROSION RATES

- The long-term (LT) corrosion rate is calculated from the following formula:

$$\text{Corrosion rate}(\mathbf{LT}) = \frac{t_{initial} - tactual}{Year@t_{initial} - Year@tactual}$$

- The short-term (ST) corrosion rate is calculated from the following formula:

$$\text{Corrosion rate}(\mathbf{ST}) = \frac{t_{previous} - tactual}{Year@t_{previous} - Year@tactual}$$

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REMAINING LIFE CALCULATION

Remaining life = $\frac{t_{actual} - trequire}{corrosion\ rate}$

Where:

- t_{actual} = the actual CML ***thickness from most recent inspection***.
- $t_{required}$ = ***required thickness*** calculated from design equations **not including corrosion allowance** or manufacturers.

Determine Corrosion Rate, Remaining Life & Next Inspection Date

T min	0.24”
2010	0.375”
2015	0.325”
2020	0.300”

- Inspection records contains the following information for a condition monitoring location (CML) at vessel shell
- Determine the
  - Corrosion Rate
  - Remaining Life
  - Next Inspection Date

STEP1: Determine Corrosion Rate

T min	0.24”
2010	0.375”
2015	0.325”
2020	0.300”

LT (2010–2020)

ST (2015–2020)

- CR ST
  = (0.325 - 0.3) / (2020-2015)
  = (0.025) / 5 = 0.005 ipy

- CR LT
  = (0.375 - 0.3) / (2020-2010)
  = (0.075) / 10 = **0.0075 ipy**

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STEP 2: Determine Remaining Life

T min	0.24”
2010	0.375”
2015	0.325”
2020	0.300”

LT (2010–2020)

ST (2015–2020)

- RL
  = (0.30 - 0.24) / (0.0075)
  = (0.06) / 0.0075
  = **8 years**

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STEP 3: Next Inspection Date

RL = **8 years**

Remaining Life	Internal Inspection	External Inspection
8	10 or **4**	5 or **4**

Next Inspection Date
Internal Inspection = 2020 + 4 = 2024
External Inspection = 2020 + 4 = 2024

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QUIZ

- When remaining safe operating life of vessel is 3 years, the internal inspection interval may be a maximum of:
  a) 1 year
  b) 1.5 years
  c) 2 years
  d) 3 years

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QUIZ

- When remaining safe operating life of vessel is 3 years, the internal inspection interval may be a maximum of:
  a) 1 year
  b) 1.5 years
  c) <u>2 years</u>
  d) 3 years

Remaining Life	Internal Inspection	External Inspection
3	**2** or 3	5 or **2**

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COMPARISON OF NDTs

Flaw Type / Inspection Method	Visual	Liquid Penetrant	Magnetic Particle (A)	Ultrasonic Straight Beam	Ultrasonic Angle Beam	Eddy Current (B)	X-Ray
Surface Breaking Linear	1	3	3	1	2	3	1
Surface Breaking Volumetric Defect	3	3	3	3	3	3	3
Near-Surface Linear & Normal to Surface	0	0	2	1	2	3	1
Near-Surface, Linear & Parallel to Surface	0	0	0	3	3	0	0
Near-Surface, Volumetric	0	0	2	3	3	3	3
Subsurface, Linear & Normal to Surface	0	0	0	1	2	0	1
Subsurface, Linear & Parallel to Surface	0	0	0	3	3	0	1
Subsurface, Volumetric	0	0	0	3	3	0	3
Thickness Measurement of Thin Materials	0	0	0	3	3	3	3
Thickness Measurement of Thick Materials	0	0	0	3	3	0	3
Non-Conductive Coating Thickness Measurements	0	0	0	2	2	3	1

" Surface" refers to the surface most suitable for the inspection given the various options

(A) Ferromagnetic materials only (B) Conductive materials only

(0) Will not detect (1) Not well suited (2) Fairly well suited (3) Ideal Application

Center for NDE
Iowa State University

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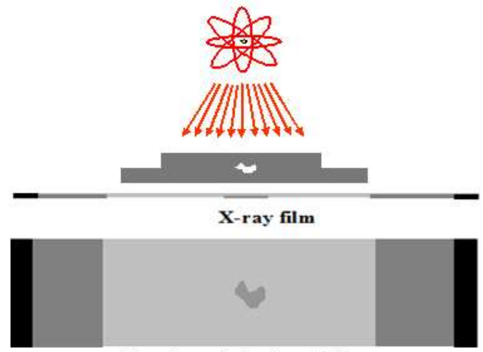
RADIOGRAPHY TESTING (RT)

Principles of Radiation

- Radiation penetrates matter
- Radiation that strikes film, exposes the film
- When developed, the more "exposed", the darker the film
- "Mass" of object absorbs or reflects some of the radiation.
- Factors of Mass
  - Thickness
  - Material Density



Top view of developed film

The film darkness (density) will vary with the amount of radiation reaching the film through the test object

= less exposure

= more exposure

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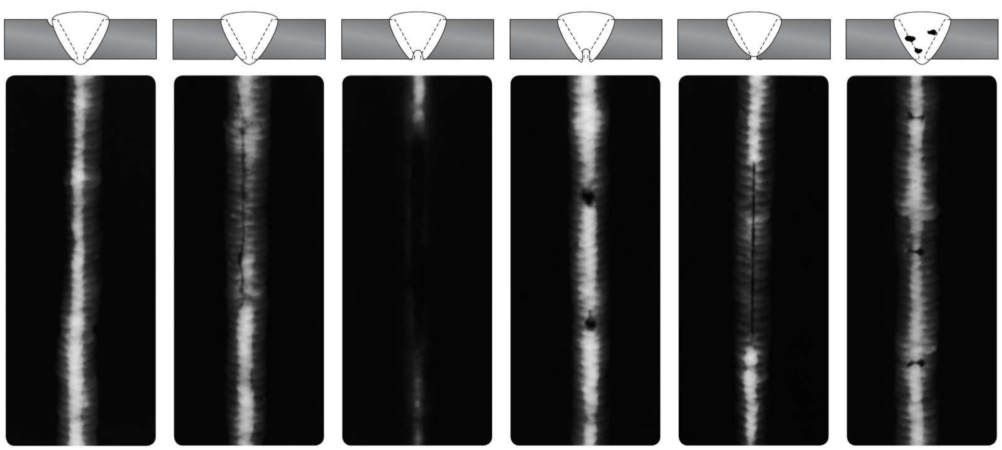
WELD QUALITY INDICATIONS



External undercut.
An irregular darker density along the edge of the weld image. The density will always be darker than the density of the pieces being welded.

Internal (root) undercut.
An irregular darker density near the centre of the width of the weld image and along the edge of the root pass image.

Internal concavity (suck back).
An elongated irregular darker density with fuzzy edges, in the vcentre of the width of the weld image.

Burn through.
Localized darker density with fuzzy edges in the centre of the width of the weld image. It may be wider than the width of the root pass image.

Incomplete - or Lack of Penetration (LoP).
A darker density band, with very straight parallel edges, in the center of the width of the weld image.

Interpass slag inclusions.
Irregularly-shaped darker density spot, usually slightly elongated and randomly spaced.

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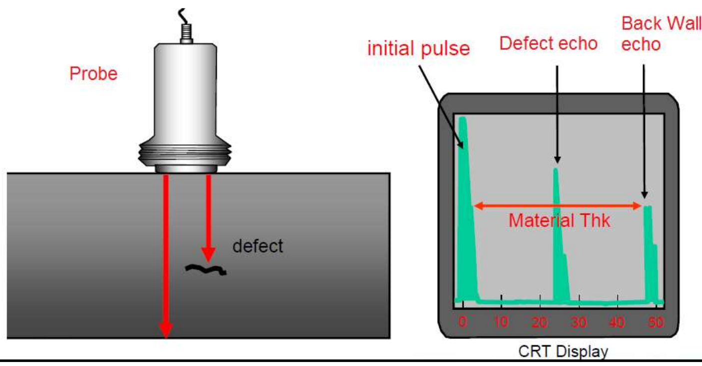
ULTRASONIC TESTING - UT

- High frequency sound waves are introduced into a material and reflected back from surfaces or flaws.
- Reflected sound energy is displayed verses time, and the inspector can visualize in a cross-section of the specimen showing the depth of features that reflect sound.



ASME Section V, Article 23, SE-797 Scope

Suitable Defects: porosity, lack of fusion, incomplete penetration, slag inclusions, toe cracks, root cracks

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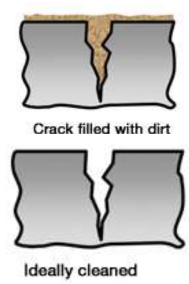
DYE PENETRANT TEST (DPT)

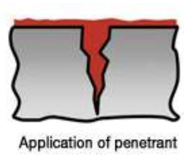
Step 1. Pre-Cleaning

Clean the surface normally with the use of a solvent. Surface preparation is the most important stage for Penetrant testing. For welds, the weld volume and 25mm either side should be free from Dirt, Grease, Lint, Scale, welding flux, weld spatter, paint, oil.



Step 2. Apply penetrant

Apply the penetrant, and leave on the components surface for approximately 15 minutes (dwell time). The penetrant enters any defects that may be present by capillary action



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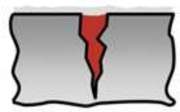
DYE PENETRANT TEST (DPT)

Step 3. Clean off penetrant

The penetrant is then removed, and care must be taken not to wash any Penetrant out off any defects present

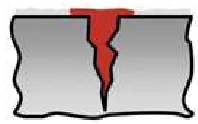
Step 4. Apply developer

A thin even layer of developer is then applied. The developer acts as a contrast against the penetrant and allows for reverse capillary action to take place



Step 5. Inspection / development time

Inspection should take place immediately after the developer has been applied any defects present will show as a 'bleed out' during development time. After full inspection has been carried out post cleaning is generally required.



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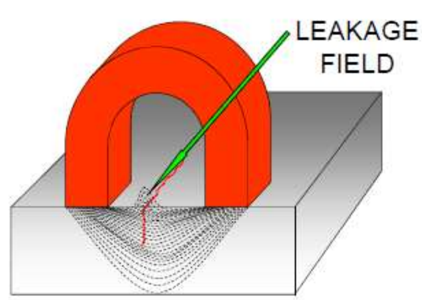
MAGNETIC PARTICLE TESTING - MPT

T-720 General

- Magnetizing an area to be examined
- Applying ferromagnetic particles to the surface
- Particles form patterns on surface / discontinuities cause distorsions in nominal magnetic field.



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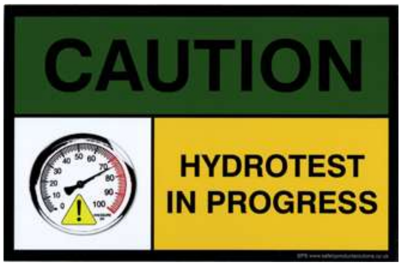
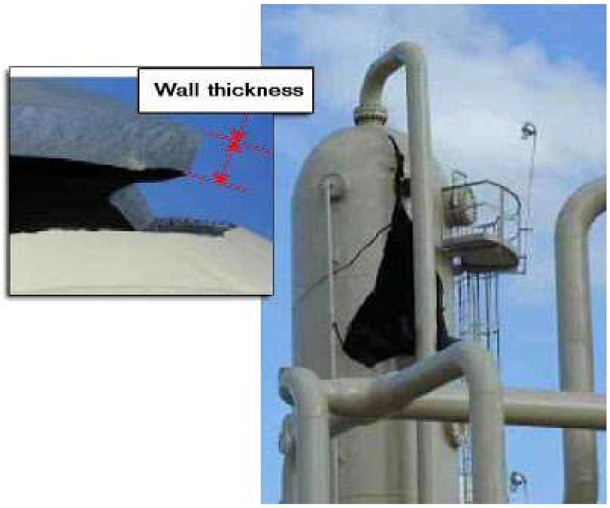
PRESSURE TESTING





Brittle failure during hydrotesting

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PRESSURE TESTING (HYDROTEST)

- Hydro-test requirements – **UG – 99**
- Test pressure formula:

$$P_t = 1.3 \text{ MAWP } \times \left(S_t / S_d \right)$$

P_t = Test Pressure
*S_t = Absolute stress at **hydrotest temperature***
*S_d = Allowable stress at **design temperature***
❖ ***$S_t / S_d > 1$ ….. always***

NOTE: It is recommended that the metal temperature during hydrostatic testing be maintained at least 30ºF above the minimum design metal temperature, but need not exceed 120ºF, to minimize the risk of brittle fracture.

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PRESSURE TESTING

- Normally required **after alterations.**
- **After repairs?** If inspector decides to.
- **Test pressure** as per **rating code formula**
- **Minimum metal temperature**
  - **If thickness exceeds 2", MDMT + 30ºF**
  - **If thickness less than or equal to 2", MDMT + 10ºF**
  - **Most brittle fracture occur during 1st hydrotest**

PRESSURE TESTING

- **Hydrotest** of **SS vessels** (avoid CL SCC)
  - Use low chloride water (<50ppm)
  - Drain and dry
- **Pneumatic Test**
  - follow precautions in ASME VIII

- **DO NOT perform inspection, until pressure is lowered to MAWP!**

PNEUMATIC TESTING

- **The formula for determining test pressure for pneumatic test is:**

$$P_t = 1.1\ MAWP\ x\ (S_t / S_d)$$

*S_t = Absolute stress at **hydrotest temperature***
*S_d = Allowable stress at **design temperature***

- Unlike hydrostatic testing, the temperature given in UG-100(c) is not a recommendation. UG-100(c) says, ***'The metal temperature during pneumatic test shall be maintained at least 30°F above the minimum design metal temperature (MDMT)'***

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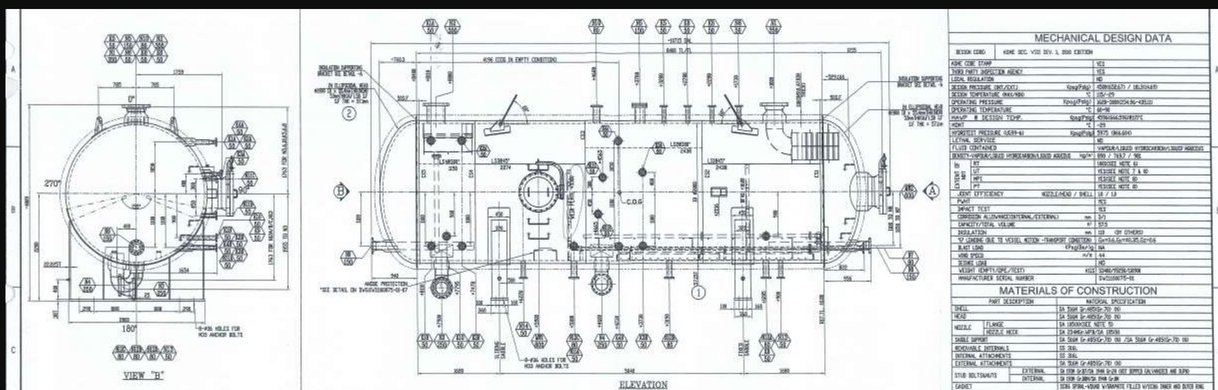
5 BEST PRACTICES IN INSPECTION & REPORTING

1. DRAWING & RECORD
2. INSPECTION PRACTICES STANDARDS
3. LOCATE & DIMENSION
4. EVALUATION / ACCEPTANCE CRITERIA
5. CONCISE & UNDERSTANDABLE

1: DRAWING & RECORDS REVIEW



1: DRAWING & RECORDS REVIEW

MANUFACTURER

S&W

PROJECT:

PRODUCTION SYSTEM DEVELOPMENT

TITLE:

GENERAL ARRANGEMENT DRAWING (TAG NO:
QTY-01 OFF

CLIENT:	CONTRACTOR:	CAD FILE NAME:	SHT.
JOINT OPERATING COMPANY	SERVICES CORPORATION	DRAWING NO.:	1 OF 1
			REV. H

MECHANICAL DESIGN DATA

DESIGN CODE:		ASME SEC. VIII DIV. 1, 2010 EDITION
ASME CODE STAMP		YES
THIRD PARTY INSPECTION AGENCY		YES
LOCAL REGULATION		NO
DESIGN PRESSURE (INT./EXT.)	Kpag(Psig)	4500(652.67) / 101.3(14.69)
DESIGN TEMPERATURE (MAX/MIN)	°C	115/-29
OPERATING PRESSURE	Kpag(Psig)	1620-3000(234.96-435.11)
OPERATING TEMPERATURE	°C	60-90
MAWP @ DESIGN TEMP.	Kpag(Psig)	4596(666.596)@115°C
MDMT	°C	-29
HYDROTEST PRESSURE (UG99-b)	Kpag(Psig)	5975 (866.604)
LETHAL SERVICE		NO
FLUID CONTAINED		VAPOUR/LIQUID HYDROCARBON/LIQUID AQUEOUS
DENSITY-VAPOUR/LIQUID HYDROCARBON/LIQUID AQUEOUS	kg/m³	890 / 769.7 / 981
EXTENT OF NDT	RT	100%(SEE NOTE 6)
	UT	YES(SEE NOTE 7 & 8)
	MPI	YES(SEE NOTE 8)
	PT	YES(SEE NOTE 8)
JOINT EFFICIENCY	NOZZLE/HEAD / SHELL	1.0 / 1.0
PWHT		YES
IMPACT TEST		YES
CORROSION ALLOWANCE(INTERNAL/EXTERNAL)	mm	3/1
CAPACITY/TOTAL VOLUME	m³	57.5
INSULATION	mm	110 (BY OTHERS)
'G' LOADING (DUE TO VESSEL MOTION -TRANSPORT CONDITION)		Gx=0.6,Gy=±0.35,Gz=0.6
BLAST LOAD	KPag(Bar)g	NA
WIND SPEED	m/s	44
SEISMIC LOAD		NO
WEIGHT (EMPTY/OPE./TEST)	KGS	53400/95250/110900
MANUFACTURER SERIAL NUMBER		SWI1100075-01

MATERIALS OF CONSTRUCTION

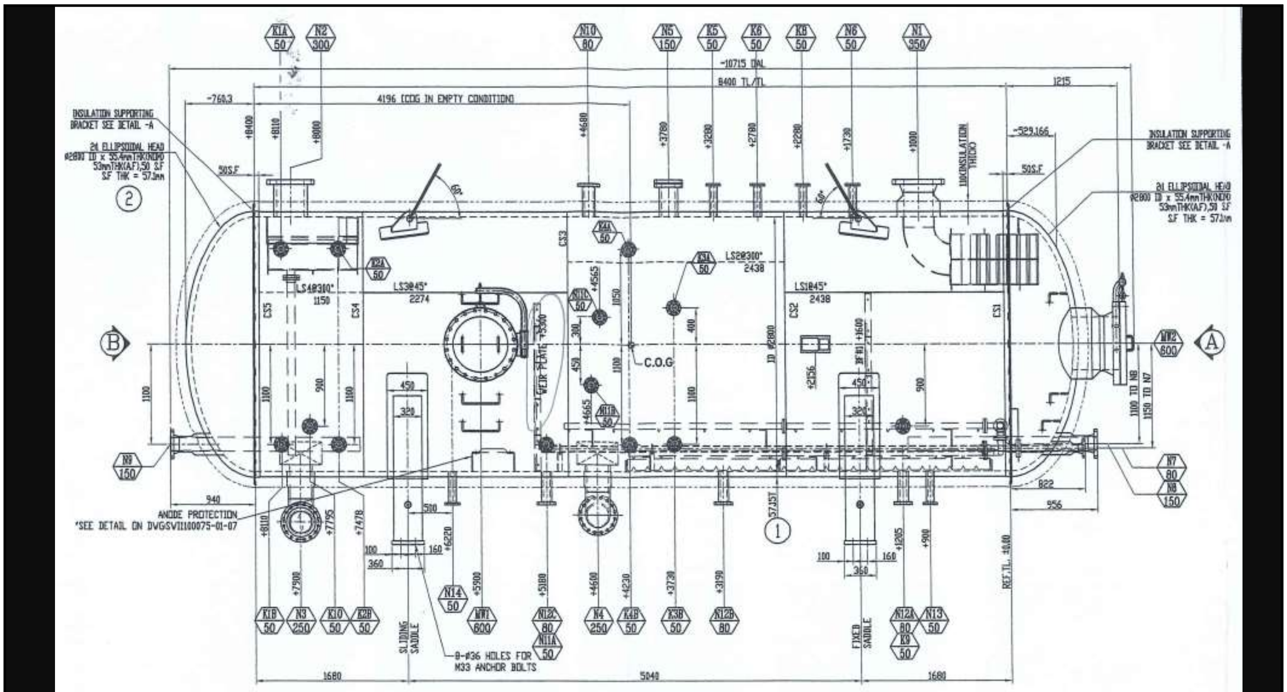
PART DESCRIPTION		MATERIAL SPECIFICATION
SHELL		SA 516M Gr.485(Gr.70) (N)
HEAD		SA 516M Gr.485(Gr.70) (N)
NOZZLE	FLANGE	SA 105(N)(SEE NOTE 5)
	NOZZLE NECK	SA 234MGr.WPB/SA 105(N)
SADDLE SUPPORT		SA 516M Gr.485(Gr.70) (N) /SA 516M Gr.485(Gr.70) (N)
REMOVABLE INTERNALS		SS 316L
INTERNAL ATTACHMENTS		SS 316L
EXTERNAL ATTACHMENTS		SA 516M Gr.485(Gr.70) (N)
STUD BOLTS&NUTS	EXTERNAL	SA 193M Gr.B7/SA 194M Gr.2H (HOT DIPPED GALVANIZED AND SUPN)
	INTERNAL	SA 193M Gr.B8M/SA 194M Gr.8M
GASKET		SS316 SPIRAL-WOUND W/GRAPHITE FILLED W/SS316 INNER AND OUTER RING

NOZZLE SCHEDULE

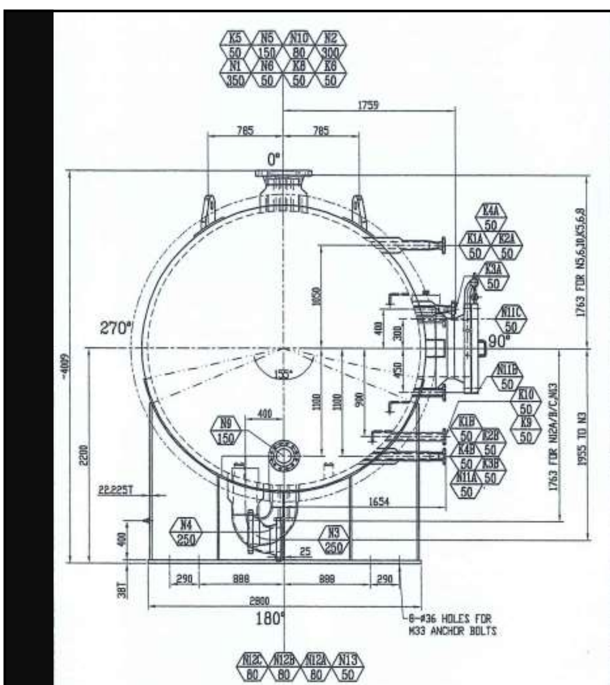
MARK	NO.	SIZE	SERVICE	RATING (FLANGE AS PER ASME B16.5)	FACE	TYPE	THK OR SCH.	NOZZ. PROJ CL/TL	REMARKS
MW1&MW2	2	DN600(24")	MANWAY	ASME CL.300	RF	WN	15T	SEE DRAWING	WITH BF/DAVIT
K9/10	2	DN50(2")	PRESSURE TRANSMITTER	ASME CL.300	RF	LWN	16.67T	SEE DRAWING	-
K6/8	2	DN50(2")	PRESSURE TRANSMITTER	ASME CL.300	RF	LWN	16.67T	1763	-
K5	1	DN50(2")	PRESSURE GAUGE	ASME CL.300	RF	LWN	16.67T	1763	-
K4A/B	2	DN80 x DN50	LEVEL TRANSMITTER	ASME CL.300	RF	WN	SCH.XXS	SEE DRAWING	-
K3A/B	2	DN80 x DN50	INTERFACE LEVEL GAUGE/TRANSMITTER	ASME CL.600	RF	WN	SCH.XXS	SEE DRAWING	-
K2A/B	2	DN80 x DN50	LEVEL TRANSMITTER	ASME CL.300	RF	WN	SCH.XXS	SEE DRAWING	-
K1A/B	2	DN80 x DN50	LEVEL GAUGE/LEVEL TRANSMITTER	ASME CL.600	RF	WN	SCH.XXS	SEE DRAWING	-
N14	1	DN50(2")	DRAIN	ASME CL.300	RF	LWN	16.67T	1763	
N13	1	DN50(2")	SPARE	ASME CL.300	RF	LWN	16.67T	1763	-
N12A/B/C	3	DN80(3")	SAND DRAIN	ASME CL.300	RF	LWN	20.637T	1763	-
N11A/B/C	3	DN50(2")	SAMPLING CONNECTION	ASME CL.300	RF	LWN	16.67T	1654	-
N10	1	DN80(3")	PSV	ASME CL.300	RF	LWN	20.637T	1763	-
N9	1	DN150(6")	ELECTRIC HEATER ELEMENT	ASME CL.300	RF	WN	12T	SEE DRAWING	-
N8	1	DN150(6")	ELECTRIC HEATER ELEMENT	ASME CL.300	RF	WN	12T	SEE DRAWING	-
N7	1	DN80(3")	SAND JETTING	ASME CL.300	RF	WN	12T	SEE DRAWING	w/INT.PIPE
N6	1	DN50(2")	VENT/PURGE	ASME CL.300	RF	LWN	16.67T	1763	-
N5	1	DN150(6")	SAND MEASUREMENT	ASME CL.300	RF	LWN	26.924T	1763	WITH BF
N4	1	DN250(10")	WATER OUTLET	ASME CL.300	RF	WN	SCH.80	1876	WITH VORTEX BREAKER
N3	1	DN250(10")	OIL OUTLET	ASME CL.300	RF	WN	SCH.80	1955	WITH VORTEX BREAKER
N2	1	DN300(12")	GAS OUTLET	ASME CL.300	RF	LWN	34.925T	1809	w/VANE PACK & CYCLONE PACK DEVICE
N1	1	DN350(14")	FLUID INLET	ASME CL.300	RF	WN	15T	1809	w/INLET DEVICE

BILL OF MATERIAL

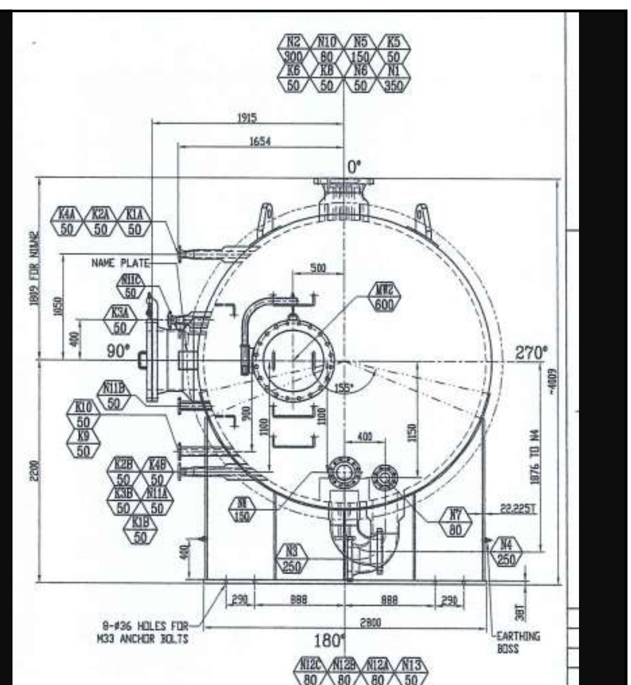
ITEM NO	NO REQD	MATERIAL SPECIFICATION	DESCRIPTION
4	2	SA 36M	INSULATION SUPPORT RING Ø10mm x ~9621mm. LG
3	64	SA 516M Gr.485(Gr.70) (N)	INSULATION SUPPORT BRACKET 90 x 75 x 9.525mmTHK
2	1	SA 516M Gr.485(Gr.70) (N)	SHELL-Ø2800ID x 57.15mmTHK x ~8300mmLG
1	2	SA 516M Gr.485(Gr.70) (N)	2:1 ELLIPSOIDAL HEAD-Ø2800 ID x 55.4mmTHK(NOM),53mmTHK A.F (MIN),50S.F



ELEVATION



VIEW "B"



VIEW "A"

PHOTO (GENERAL)	DESCRIPTION
	Findings: Overall insulation condition on shell and dished head had not shown any major degradation and intact. Recommendations: Nil.
	Findings: Insulation condition on dished head had not shown any major degradation and intact. Recommendations: Nil.
	Findings: Via inspection window. Shell external noted without any sign of corrosion under insulation, CUI. Recommendations: Nil.

RECORDS REVIEW

- HISTORY OF EQUIPMENT
- INSPECTION REPORT
- PRIOR REPAIR
- INSPECTION PLAN
- ENGINEERING EVALUATION

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2: INSPECTION PRACTICES STANDARDS

Inspection Practices for Pressure Vessels

Downstream Segment

RECOMMENDED PRACTICE 572
THIRD EDITION, NOVEMBER 2009

Inspection Practices for Piping System Components

API RECOMMENDED PRACTICE 574
FOURTH EDITION, NOVEMBER 2016

AMERICAN PETROLEUM INSTITUTE

General requirements for internal & external inspection

1. Check the components that contain the pressure
   - Shell & heads
   - Welds & heat affected zone
   - Manways, nozzles, openings
2. Check the components that protect the vessel
   - Insulation
   - Painting / coating
   - Internal lining
3. Check the components that keep the vessel in place
   - Foundation & guy wires

EXTERNAL INSPECTION

COMPONENT	DAMAGE	INSPECTION METHODS
LADDER, STAIRWAYS, PLATFORM, WALKWAYS	CORRODED/BROKEN PARTS, CRACKS, TIGHTNESS OF BOLTS, CONDITION OF PAINTS, WEAR OF LADDER RUNG/STAIR TREADS, SECURITY OF HANDRAILS, CONDITION OF FLOORING	VISUAL, HAMMERING, SCRAPPING, TAPPING WITH SMALL BALL PEEN HAMMER, THICKNESS MEASUREMENT
FOUNDATION , SUPPORTS	SPALLING, CRACKING, SETTLING, CREVICE	SETTLEMENT CHECK
NOZZLES	DISTORTION, CRACKING DUE TO SETTLING, LEAKS, DISCOLORATION, INSULATION/FIREPROOFING/PAINT DAMAGE, WETTING OF INSULATION	FLANGE FACE CHECK WITH FLANGE SQUARE, MT/PT/UT/REPLICA, MEASURE WALL THICKNESS

INTERNAL INSPECTION

COMPONENT	DAMAGE	INSPECTION METHODS
SHELL/HEAD	THINNING & PITTING CRACKING EROSION BLISTERING DEFORMATION	BASED ON DEGRADATION
NOZZLES	CORROSION, CRACKING, DISTORTION EXPOSED GASKET SURFACE – SCORING/CORROSION, RING JOINT FLANGE – CORROSION CRACKING	VISUAL, SCRAPPER, FLASHLIGHT
METALLIC LINING	CORROSION PROPERLY INSTALLED NO HOLES OR CRACKS	

EXTERNAL: GENERAL VIEW

Findings:

- General view. This insulated horizontal equipment was firmly placed with no uneven settling issues observed.

Recommendations:

- Nil.

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NAMEPLATE

Findings:

- Nameplate noted intact and legible.

Recommendations:

- Nil.

INSULATION (SHELL & HEAD)

Findings:

- Overall insulation condition on shell and dished head had not shown any major damage and intact.

Recommendations:

- Nil.

INSULATION (SHELL & HEAD)

Findings:

- Overall insulation condition on shell and dished head had not shown any major damage and intact.

Recommendations:

- Nil.

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NOZZLE

Findings:

- Neither bending, distortion nor leakages observed on shell nozzle orientation

Recommendations:

- Nil.

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EARTHING

Findings:

- Earthing connection found intact and secured in position.

Recommendations:

- Nil.

SADDLE SUPPORT

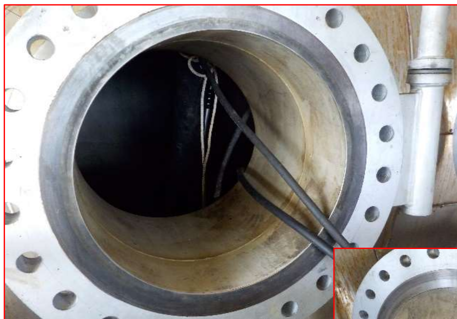
Findings:

- Surface corrosion noted on saddle support and base plate without sign of wall loss.

Recommendations:

- To perform surface preparation & maintenance painting as per approved procedure

INTERNAL: NOZZLE



Findings:

- 24” Manway, MW1 and cover seen free from in-service degradation and gasket active area found free from any defect.

Recommendations:

- Nil

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DISH HEAD

Findings:

- Internal dish head appeared with blackish stain marks.
- Ladder rung in good condition with no sign of crack or damage.

Recommendations:

- Nil

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SHELL

Findings:

- Shell internal appeared with process stain. No sign of deformation or in-service degradation observed.
- Internal L.S and C.S weld found in sound condition without any major defect

Recommendations:

- Nil

SHELL

Findings:

- View of shell bottom section with scattered pitting <0.5mm depth under coating. Coating noted in good condition

Recommendations:

- To be monitored

VORTEX BREAKER

Findings:

- Vortex breaker found intact and free from blockage

Recommendations:

- Nil

HEATER

Findings:

- The heater (thru N8) is free from tube fretting or damages. Tubes external covered by thin layer of blackish deposit.

Recommendations:

- Nil

INTERNAL PIPING

Findings:

- Internal piping and heater arrangement are satisfactory.
- No sign of bending, deformation, weld cracking nor joint leakages.

Recommendations:

- Nil

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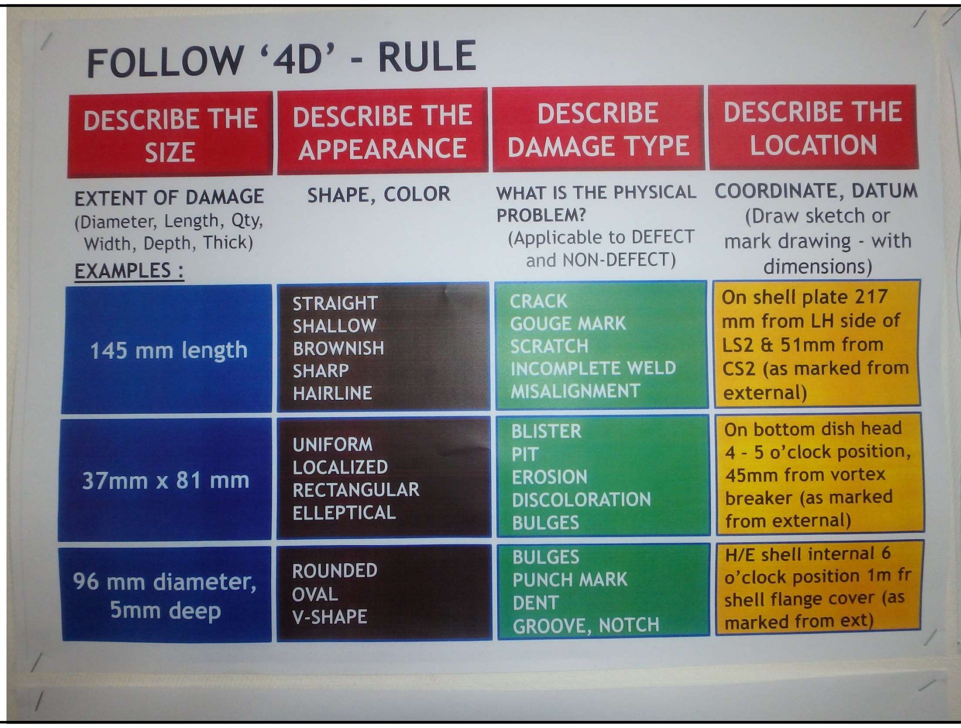
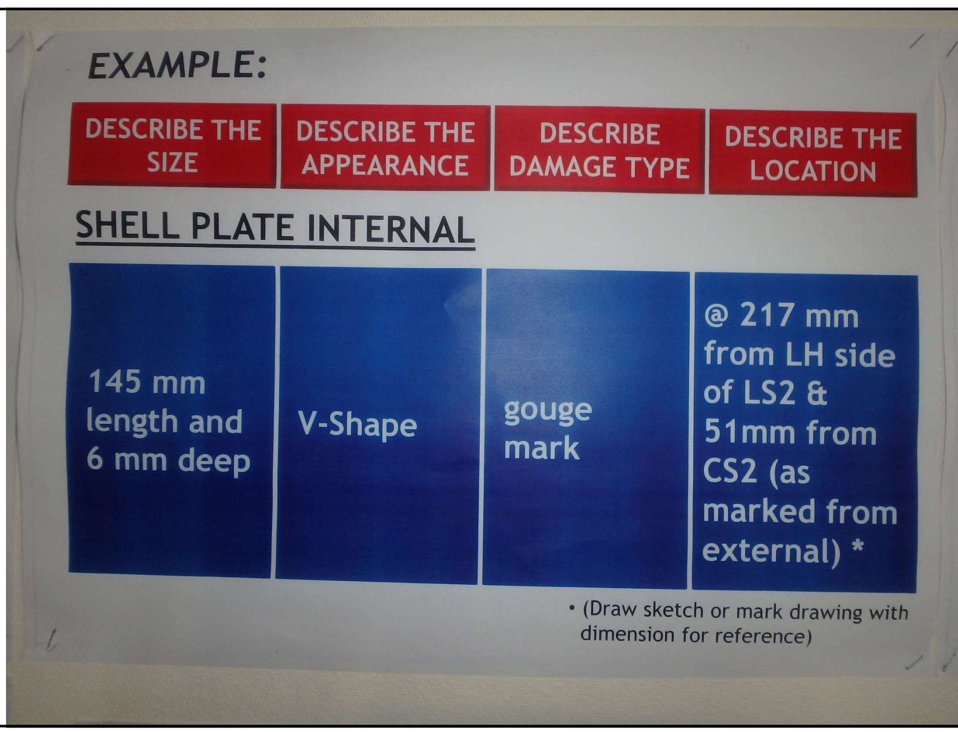
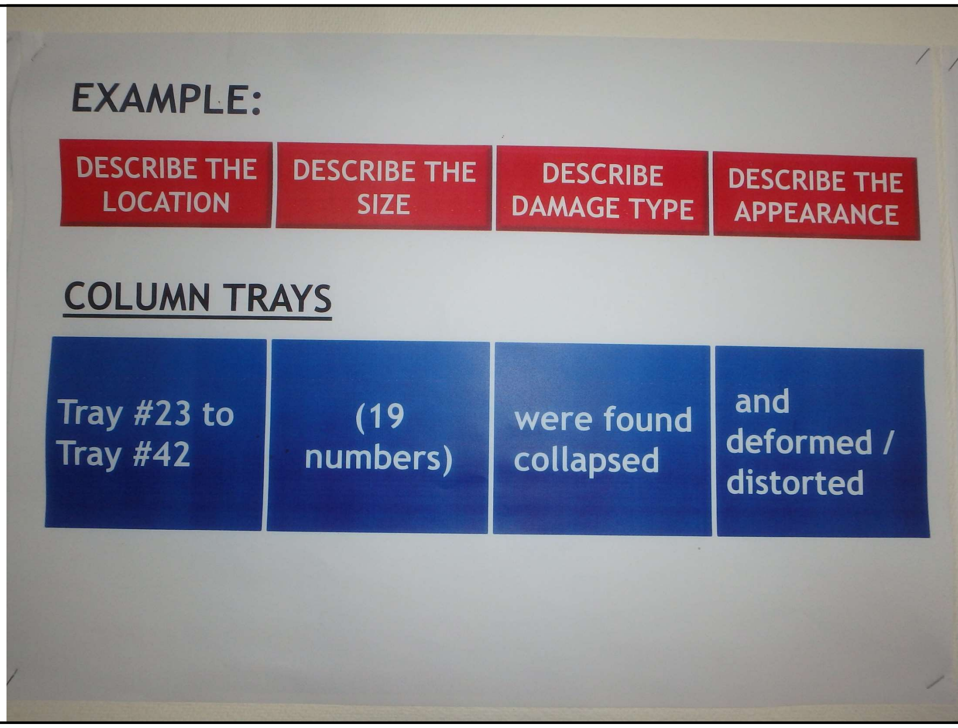
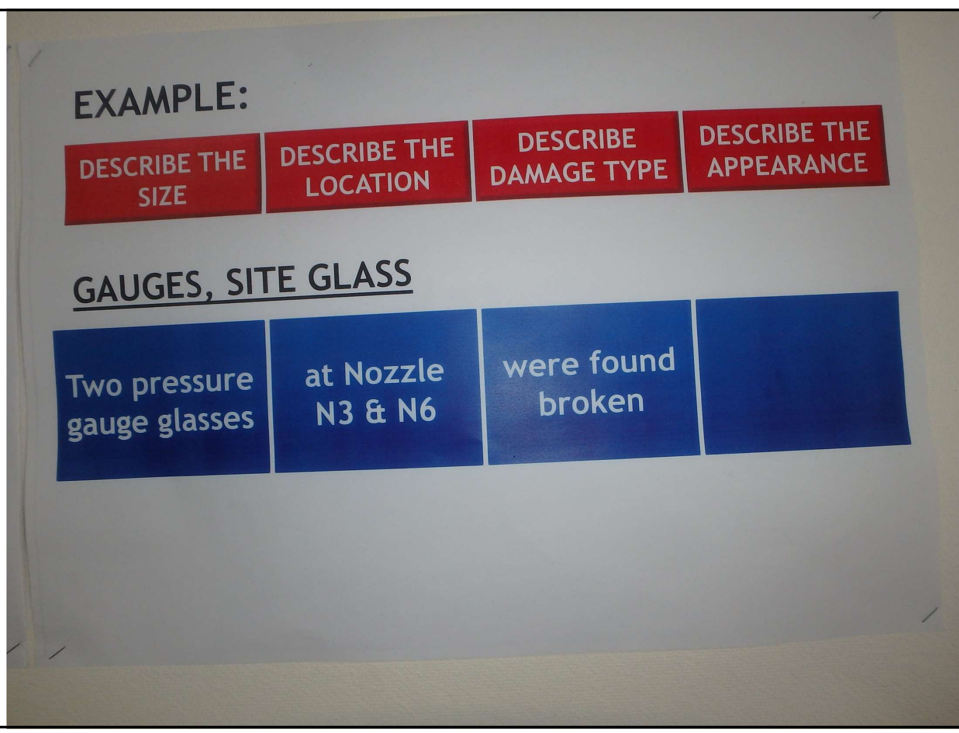
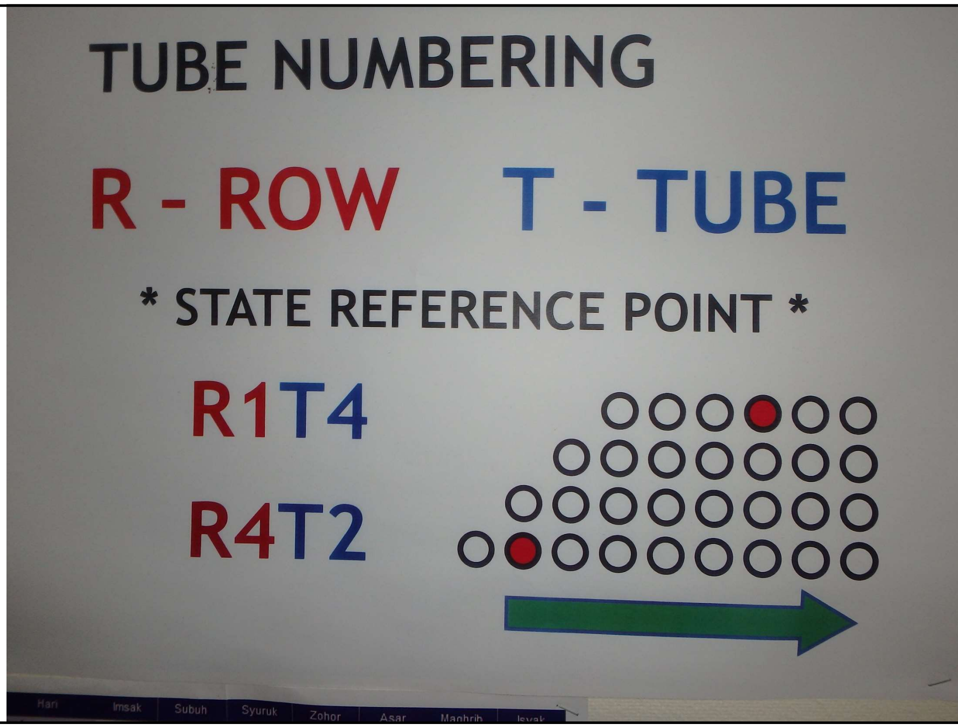
3: LOCATE & DIMENSION


FOLLOW '4D' - RULE
DESCRIBE THE SIZE
DESCRIBE THE APPEARANCE
DESCRIBE DAMAGE TYPE
DESCRIBE THE LOCATION
EXTENT OF DAMAGE (Diameter, Length, Qty, Width, Depth, Thick)
SHAPE, COLOR
WHAT IS THE PHYSICAL PROBLEM? (Applicable to DEFECT and NON-DEFECT)
COORDINATE, DATUM (Draw sketch or mark drawing - with dimensions)
EXAMPLES :
145 mm length
STRAIGHT SHALLOW BROWNISH SHARP HAIRLINE
CRACK GOUGE MARK SCRATCH INCOMPLETE WELD MISALIGNMENT
On shell plate 217 mm from LH side of LS2 & 51mm from CS2 (as marked from external)
37mm x 81 mm
UNIFORM LOCALIZED RECTANGULAR ELLEPTICAL
BLISTER PIT EROSION DISCOLORATION BULGES
On bottom dish head 4 - 5 o'clock position, 45mm from vortex breaker (as marked from external)
96 mm diameter, 5mm deep
ROUNDED OVAL V-SHAPE
BULGES PUNCH MARK DENT GROOVE, NOTCH
H/E shell internal 6 o'clock position 1m fr shell flange cover (as marked from ext)


EXAMPLE:
DESCRIBE THE SIZE
DESCRIBE THE APPEARANCE
DESCRIBE DAMAGE TYPE
DESCRIBE THE LOCATION
SHELL PLATE INTERNAL
145 mm length and 6 mm deep
V-Shape
gouge mark
@ 217 mm from LH side of LS2 & 51mm from CS2 (as marked from external) *
• (Draw sketch or mark drawing with dimension for reference)


EXAMPLE:
DESCRIBE THE LOCATION
DESCRIBE THE SIZE
DESCRIBE DAMAGE TYPE
DESCRIBE THE APPEARANCE
COLUMN TRAYS
Tray #23 to Tray #42
(19 numbers)
were found collapsed
and deformed / distorted


EXAMPLE:
DESCRIBE THE SIZE
DESCRIBE THE LOCATION
DESCRIBE DAMAGE TYPE
DESCRIBE THE APPEARANCE
GAUGES, SITE GLASS
Two pressure gauge glasses
at Nozzle N3 & N6
were found broken



4: EVALUATION / ACCEPTANCE CRITERIA

Table D-2M Allowable Defect Depth vs. Width Across Face (Metric)

Measurement	Hard-Faced Gaskets	Soft-Faced Gaskets
$r_d < w/4$	< 0.76 mm	< 1.27 mm
$w/4 < r_d < w/2$	< 0.25 mm	< 0.76 mm
$w/2 < r_d < 3w/4$	Not allowed	< 0.13 mm
$r_d > 3w/4$	Not allowed	Not allowed

GENERAL NOTE: See Figs. D-3 and D-4 for description of defect measurement.

Table D-2 Allowable Defect Depth vs. Width Across Face (U.S. Customary)

Measurement	Hard-Faced Gaskets	Soft-Faced Gaskets
$r_d < w/4$	< 0.030 in.	< 0.050 in.
$w/4 < r_d < w/2$	< 0.010 in.	< 0.030 in.
$w/2 < r_d < 3w/4$	Not allowed	< 0.005 in.
$r_d > 3w/4$	Not allowed	Not allowed

GENERAL NOTE: See Figs. D-3 and D-4 for description of defect measurement.

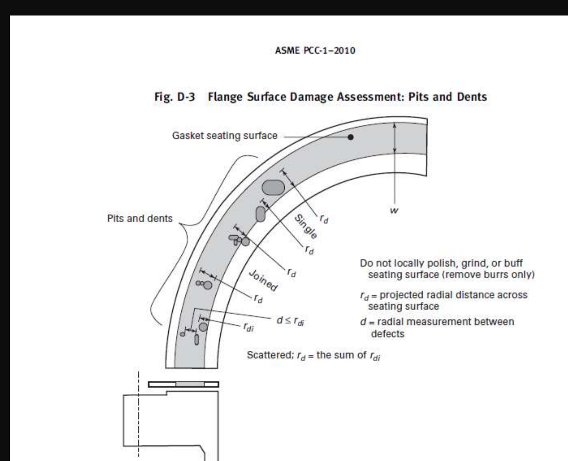


Fig. D-3 Flange Surface Damage Assessment: Pits and Dents

7.4.2 Evaluation of Locally Thinned Areas

7.4.2.1 For a corroded area of considerable size the wall thicknesses may be averaged over a length not exceeding the following:

— for vessels with inside diameters less than or equal to 60 in. (150 cm), one-half the vessel diameter or 20 in. (50 cm), whichever is less;

— for vessels with inside diameters greater than 60 in. (150 cm), one-third the vessel diameter or 40 in. (100 cm), whichever is less.

7.4.2.2 Along the designated length, the thickness readings should be equally spaced. For areas of considerable size, multiple lines in the corroded area may have to be evaluated to determine which length has the lowest average thickness. The following criteria must be met in order to use thickness averaging:

— the region of metal loss has relatively smooth contours without notches (i.e. negligible local stress concentrations),

— the equipment does not operate in the creep range,

— the component is not in cyclic service,

— a minimum of 15 thickness readings should be included in the data set,

— minimum reading must be included in the thickness average;

— lowest individual reading cannot be less than 50 % of $t_{required}$.

7.4.3 Evaluation of Pitting

During the current inspection, widely scattered pits may be ignored as long as all of the following are true:

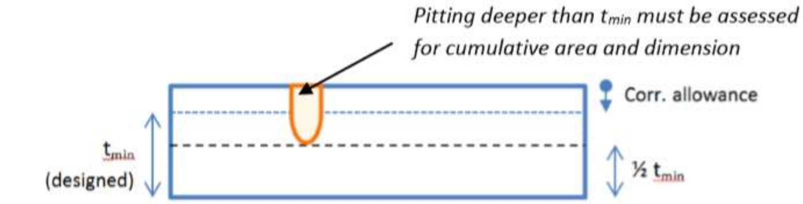
a) the remaining thickness below the pit is greater than one-half the required thickness ($^1/_2\ t_{required}$),

b) the total area of the pitting that is deeper than the corrosion allowance does not exceed 7 in.^{2} (45 cm^2) within any 8-in. (20-cm) diameter circle,

c) the sum of the pit dimensions that is deeper than the corrosion allowance along any straight 8-in. (20-cm) line does not exceed 2 in. (5 cm).

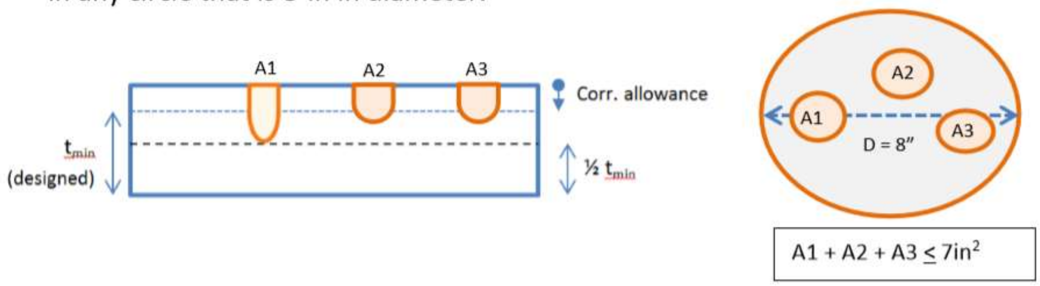
API 579-1/ASME FFS-1, Part 6 may be used to evaluate different pit growth modes, estimate pitting propagation rates, and evaluate the potential problems with pitting remediation versus component replacement. The maximum pit depth and the extent of pitting are related in the API 579-1/ASME FFS-1, Level 1 assessment pitting charts, which may be used to evaluate the extent of pitting allowed before the next inspection.

- The remaining thickness left below any pit is > ½ t_{min}.



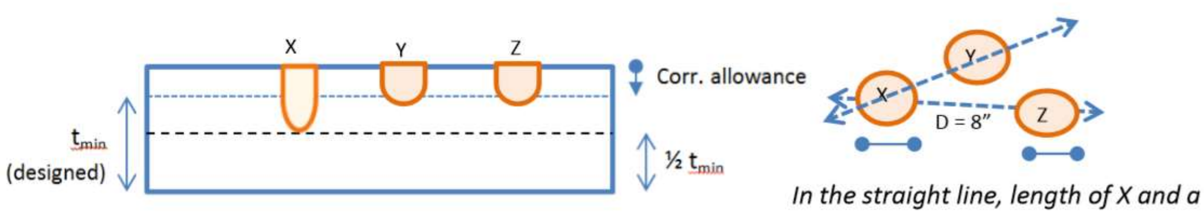
AND;

- The total area of the pits that are deep enough to eat into t_{min} do not exceed $7in^2$ in any circle that is 8-in in diameter.



AND;

- The sum of the dimensions (length) of the pits that eat into t_{min} along any straight line within an 8-in circle do not exceed 2-in.



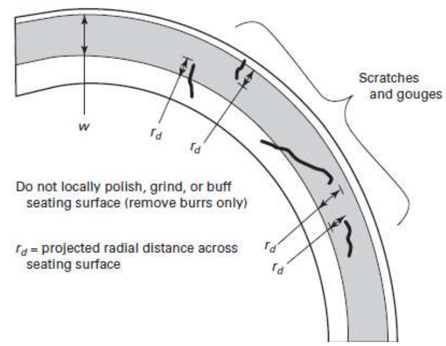
In the straight line, length of X and a bit of Y, or X and Z are considered; must be < 2"

ASME B16.5

Table 3 Permissible Imperfections in Flange Facing Finish for Raised Face and Large Male and Female Flanges

NPS	Maximum Radial Projection of Imperfections Which Are No Deeper Than the Bottom of the Serrations, mm	Maximum Depth and Radial Projection of Imperfections Which Are Deeper Than the Bottom of the Serrations, mm
½	3.0	1.5
¾	3.0	1.5
1	3.0	1.5
1¼	3.0	1.5
1½	3.0	1.5
2	3.0	1.5
2½	3.0	1.5
3	4.5	1.5
3½	6.0	3.0
4	6.0	3.0
5	6.0	3.0
6	6.0	3.0
8	8.0	4.5
10	8.0	4.5
12	8.0	4.5
14	8.0	4.5
16	10.0	4.5
18	12.0	6.0
20	12.0	6.0
24	12.0	6.0

GENERAL NOTE: For permissible imperfections in inch units, refer to Annex F, Table F3.



ASME 16.47

ADDENDA 1998

TABLE 16 PERMISSIBLE IMPERFECTIONS IN FLANGE FACING FINISH (See Para. 6.1.5)

Nominal Pipe Size	Maximum Radial Projection of Imperfections Which Are No Deeper Than the Bottom of the Serration, in.	Maximum Depth and Radial Projection of Imperfections Which Are Deeper Than the Bottom of the Serration, in.
26–36	0.50	0.25
38–48	0.56	0.28
50–60	0.62	0.31

ASME PCC-1

Fig. D-3 Flange Surface Damage Assessment: Pits and Dents

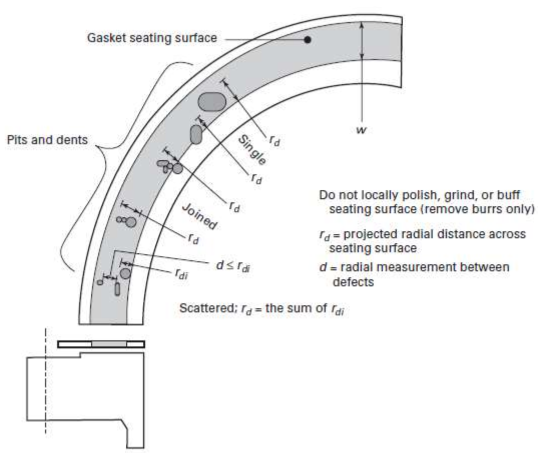
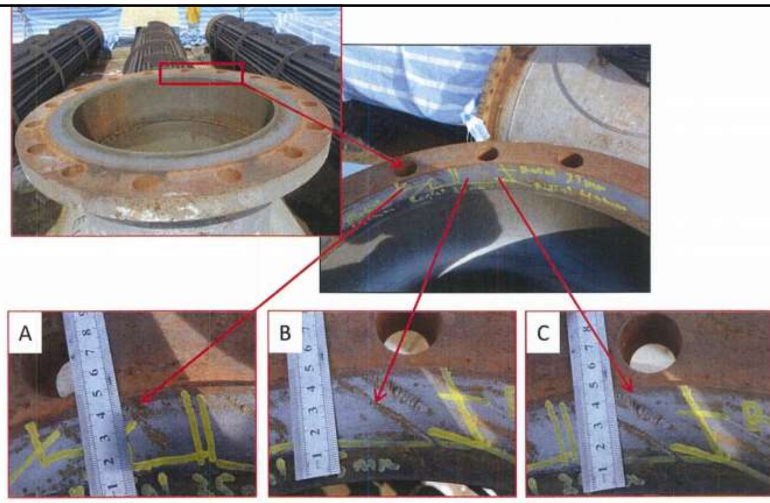


Table D-2M Allowable Defect Depth vs. Width Across Face (Metric)

Measurement	Hard-Faced Gaskets	Soft-Faced Gaskets
$r_d < w/4$	< 0.76 mm	< 1.27 mm
$w/4 < r_d < w/2$	< 0.25 mm	< 0.76 mm
$w/2 < r_d < 3w/4$	Not allowed	< 0.13 mm
$r_d > 3w/4$	Not allowed	Not allowed

GENERAL NOTE: See Figs. D-3 and D-4 for description of defect measurement.

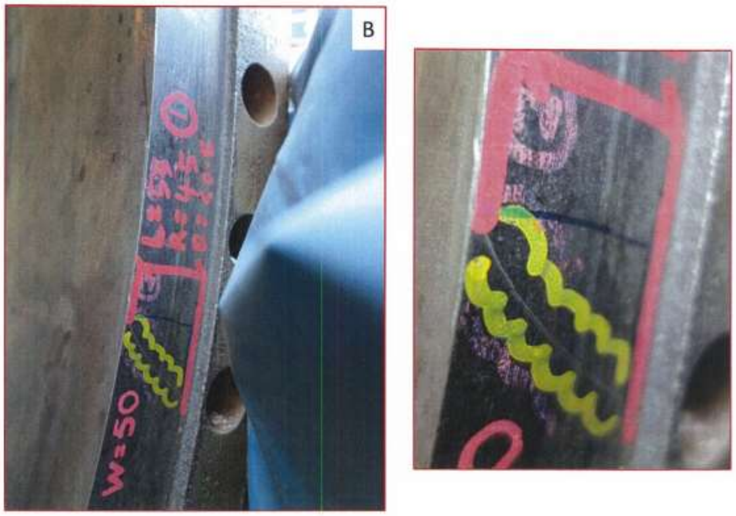


Finding:
- Mechanical scratch marks were found on 3 pointed locations on gasket seating surface of gas inlet nozzle N 81. The scratch marks were deeper than the bottom of serration;
  - A – Radial projection 25mm; depth 0.5mm
  - B – Radial projection 40mm; depth 0.5mm
  - C – Radial projection 22mm; depth 1mm

Recommendation:
- The affected areas on gasket seating surface to be resurfaced as per approved procedure.

Finding:
- Scratch mark was observed on gasket seating surface which is deeper than the bottom of serration.
- Radial projection (32mm) of the imperfection was found out of tolerance as per Table 3 B16.5.

Recommendation:
- Gasket seating surface to be resurfaced as per approved procedure.



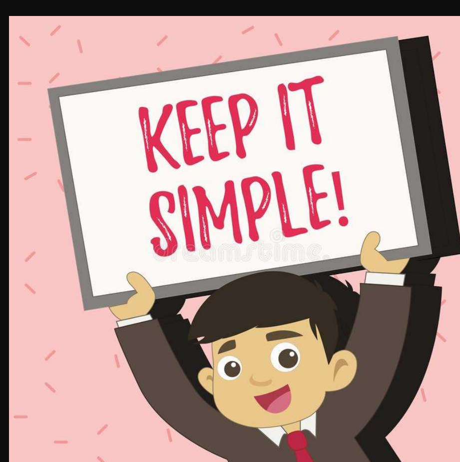
Finding:

- Scratch mark was observed on gasket seating surface which is deeper than the bottom of serration.
- Radial projection (45mm) of the imperfection was found out of tolerance as per Table 3 B16.5.

Recommendation:

- Gasket seating surface to be resurfaced as per approved procedure.

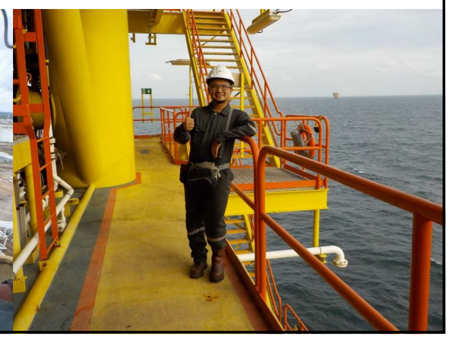
5: CONCISE & UNDERSTANDABLE



FINAL Inspection tips

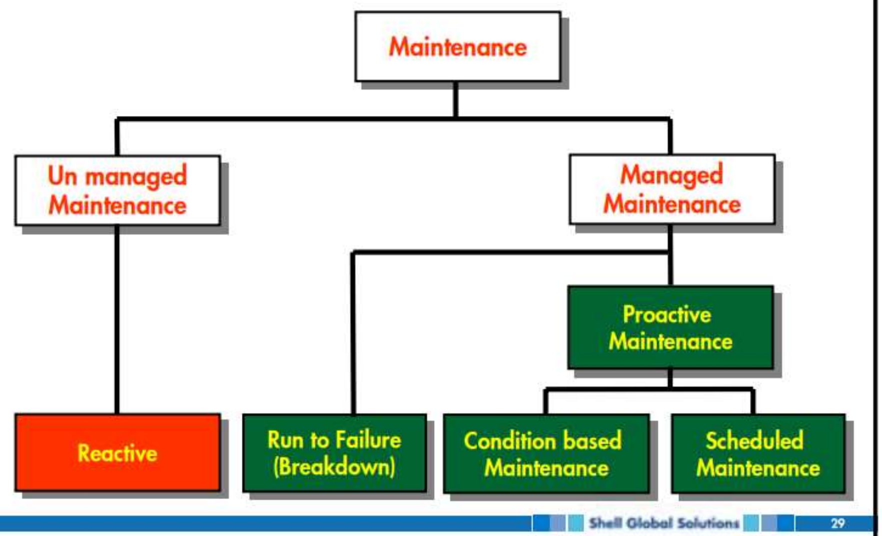
- Telling you how to inspect vessel is like telling you how to drive a car – you need EXPERIENCE
- NO substitute for experience & common sense





MODULE 4: MAINTENANCE & REPAIR

Maintenance Options



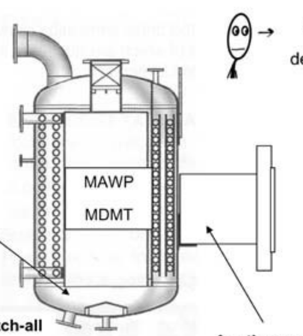
AN ALTERATION IS:

A physical change that has *design implications* that weren't considered when it was originally manufactured

API 510 definition (3.2)

For example

Changing the shape of head from hemispherical to torispherical



Note this additional catch-all

If work results in any change to the MAWP or MDMT, this is an alteration

- MAWP: maximum allowable working pressure
- MDMT: minimum design metal temperature

Another example

Adding a reinforced nozzle larger than what is there already

By default, work that is not considered an alteration is classed as a *repair*

A REPAIR IS:

(Using the 'default principle' logic of API 510)

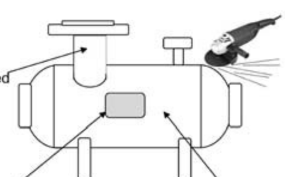
ALMOST ANYTHING THAT DOES NOT QUALIFY AS AN ALTERATION

API 510 definition (3.53)

There must be cutting, grinding or welding going on

Adding an unreinforced nozzle of *any size*

IS A REPAIR



Remember there must be no change to MAWP or MDMT…or it becomes an alteration

- MAWP: maximum allowable working pressure
- MDMT: minimum design metal temperature

Adding a reinforced nozzle the same size or smaller than what is there already….

IS A REPAIR

Do not confuse these API 510 definitions with any other definitions or understanding of the term 'repair'. They may be different (and the exam questions are based on those above)

APPROVAL: Meaning review of *what is to be done* (8.1.2.1)

***APPROVAL* OF METHOD (8.1.2.1)**			
	Repairs	**Alterations**	**Work in progress for either**
Engineer	**ONLY** Fillet welded patches 8.1.5.1.2.1, Lap band repairs 8.1.5.1.3, Repair to SS (only) weld overlay 8.1.5.4.1	**Yes**	**Not required**
Inspector	**Yes**	**Yes**	**Yes**

AUTHORIZATION: Meaning *OK for work to proceed*

***AUTHORIZATION* TO PROCEED (8.1.1)**		
	Repairs	**Alterations**
ASME VIII Div 1	Inspector	Inspector and Engineer
ASME VIII Div 2	Inspector and Engineer	Inspector and Engineer

Inspector may give *prior general* authorization for limited or routine repairs provided that:

- It is for a specific vessel
- The inspector is happy with the repair contractor's competence
- The repair type does not require pressure testing (e.g. weld overlay that does not require PWHT)

Who approves repairs and authorizations?

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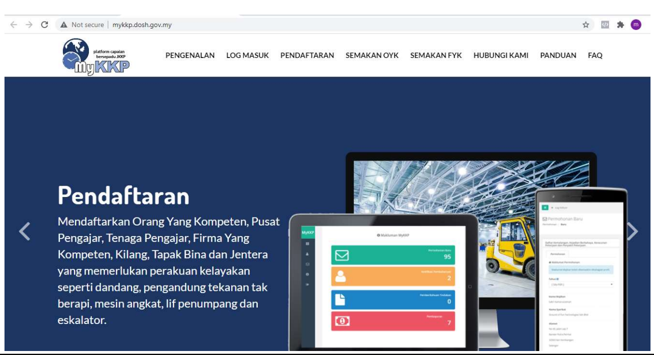
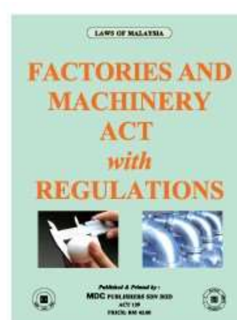
DOSH Equipment Repair

- Jurisdiction of DOSH, normally those involve welding
- DOSH approval required prior to repair activities
- Only DOSH approved repairer can repair the vessel





Regulatory requirement (FMA 1967)
Steam Boiler and UPV Regulation 1970

79. Repairs.

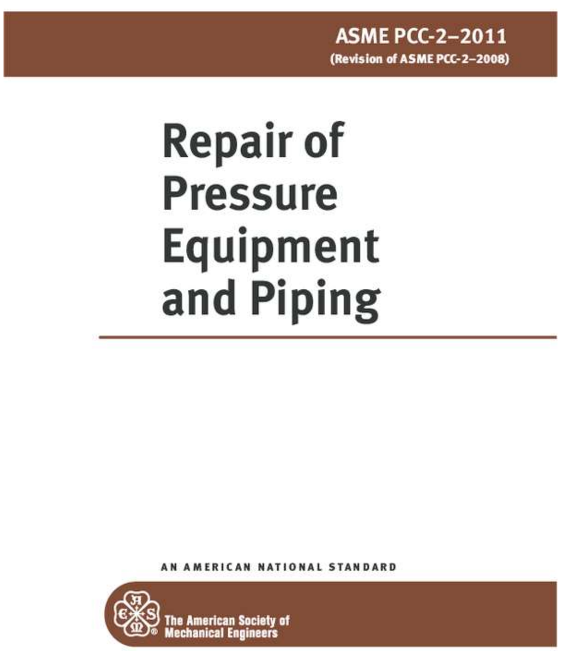
(1) An owner or other person shall not, unless approval has been given by an Inspector, make or cause to be made any repair to any steam boiler or unfired pressure vessel where such repair involves the cutting, welding, patching or riveting of any member thereof which is subject to a stress induced by fluid pressure.

(2) Where any steam boiler or unfired pressure vessel repair necessitates welding, the metallic arc process shall be used.

(3) Welding shall not be used to repair any part of a fitting which is made of cast iron and is subject to fluid pressure.

(4) Where repair has been made to a steam boiler or unfired pressure vessel such boiler or vessel shall not be placed in service except with the approval of an Inspector.

(5) For the purpose of this regulation "repair" does not include normal maintenance work or boiler tube renewals not exceeding ten per centum of the total number of tubes.


ASME PCC-2–2011
(Revision of ASME PCC-2–2008)

Repair of Pressure Equipment and Piping

AN AMERICAN NATIONAL STANDARD

The American Society of Mechanical Engineers

ASME PCC-2

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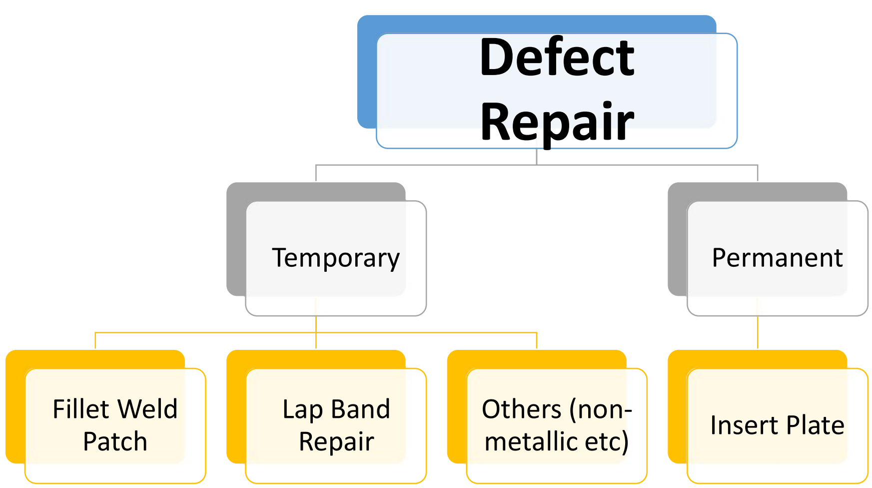
Table 1 Guide for the Selection of Repair Technique

Article Number and Title	General Wall Thinning	Local Wall Thinning	Pitting	Gouges	Blisters	Laminations	Circumferential Cracks	Longitudinal Cracks	Other
2.1 Butt-welded Insert Plates in Pressure Components	Y	Y	Y	Y	Y	Y	Y	Y	Note (1)
2.2 External Weld Overlay to Repair Methods for Internal Thinning	N	Y	Y	Y	N	N	N	N	Note (2)
2.3 Seal-Welded Threaded Connections and Seal Weld Repairs	NA	NA	NA	NA	NA	NA	NA	NA	Note (3)
2.4 Welded Leak Box Repair	N	Y	Y	N	N	N	R	R	Note (4)
2.6 Full Encirclement Steel Reinforcing Sleeves for Piping									
Type A sleeve	Y [Note (5)]	Y [Note (5)]	Y [Note (5)]	R	N	N	N	N	...
Type B sleeve	Y	Y	Y	Y	Y	Y	Y	R	...
2.8 Alternatives to Traditional Welding Preheat	Y	Y	R	Y	R	Y	R	R	Note (6)
2.9 Alternatives to Postweld Heat Treatment	Y	Y	Y	Y	S	Y	Y	Y	Note (7)
2.10 In-Service Welding Onto Carbon Steel Pressure Components or Pipelines	N	N	N	N	N	N	N	N	Note (8)
2.11 Weld Buildup, Weld Overlay, and Clad Restoration	N	Y	S	S	S	N	N	N	...
2.12 Fillet Weld Patches	N	Y	Y	Y	S	N	R	R	...
2.13 Fillet Welded Patches With Reinforcing Plug Welds	N	Y	Y	Y	S	N	R	R	...
2.14 Threaded or Welded Plug Repairs	N	Y	Y	Y	N	N	Y	Y	...
3.1 Replacement of Pressure Components	Y	Y	Y	Y	Y	Y	Y	Y	...
3.2 Freeze Plugs	NA	NA	NA	NA	NA	NA	NA	NA	Note (9)
3.3 Damaged Threads in Tapped Holes	N	N	N	N	N	N	N	N	Note (10)
3.4 Flaw Excavation and Weld Repair	NA	NA	Y	Y	Y	Y	Y	Y	Note (11)
3.5 Flange Refinishing	N	N	Y	Y	S	N	Y	N	Note (12)
3.6 Mechanical Clamp Repair	N	Y	Y	R	N	N	R	R	Notes (2), (13)
3.7 Pipe Straightening or Alignment Bending	N	N	N	N	N	N	N	N	Note (14)
3.8 Damaged Anchors in Concrete	NA	NA	NA	NA	NA	NA	NA	NA	Note (15)
3.11 Hot and Half Bolting Removal Procedures	N	N	N	N	N	N	N	N	...
3.12 Inspection and Repair of Shell and Tube Heat Exchangers	Y	Y	Y	R	Y	N	Y	Y	...
4.1 Nonmetallic Composite Repair Systems: High-Risk Applications	Y	Y	Y	R	Y	Y	R	R	...
4.2 Nonmetallic Composite Repair Systems: Low-Risk Applications	Y	Y	Y	R	Y	Y	Y	R	...
4.3 Nonmetallic Internal Lining for Pipe: Sprayed Form for Buried Pipe	Y	Y	Y	Y	Y	Y	Y	Y	...
5.1 Pressure and Tightness Testing of Piping and Equipment	N	N	N	N	N	N	N	N	Note (16)
5.3 Nondestructive Examination in Lieu of Pressure Testing for Repairs and Alterations	NA	NA	NA	NA	NA	NA	NA	NA	Note (17)

Y = generally appropriate
S = may be acceptable, but is not generally used for this condition
R = may be used, but requires special cautions
N = not generally appropriate
NA = not applicable

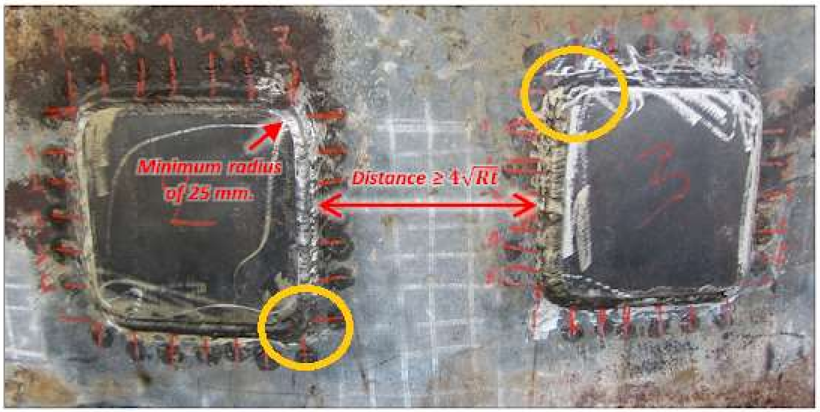
NOTES:
(1) This method may apply to replacement of nozzles, flat spots, and dents.
(2) See Part 2, Article 2.1, Limitations.

ASME PCC-2



Fillet Welded Patch Repair of Vessel

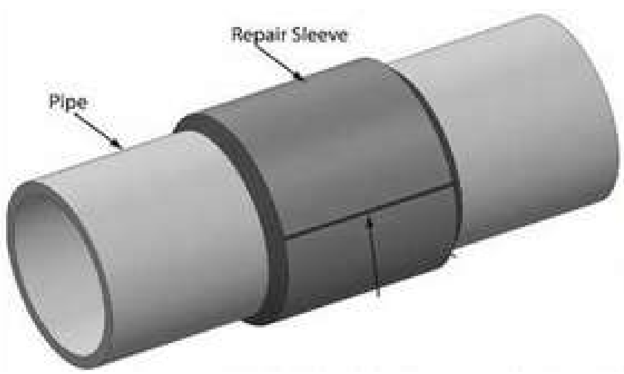
- ***The patch plate shall have rounded corners with minimum radius of 1 in. (25 mm.)***
- ***Distance between the toes of fillet weld ≥ $4\sqrt{Rt}$***
  - Where ***R*** = inside radius of the vessel, ***t*** = thickness of the vessel wall



Credit: API 510

Full encirclement lap band repair

- ➢ Not used for crack repair on pressure vessel
- ➢ Not subject to fatigue



Permanent Repair

1. Excavating the defect & blend-grinding
2. Excavating a defect and repair welding of the excavation.
3. Replacing the defected section or the component.
4. Weld overlay of corroded area
5. Adding strip or plate lining to the interior surface.
6. Insert Plates

Crack repair

- Consult your pressure vessel engineer before repairing any crack
- General steps:
  1. Remove crack
  2. Build up area by welding
  3. Ensure repaired area is free from defect
  4. Perform PWHT, if required
  5. Perform pressure test if required

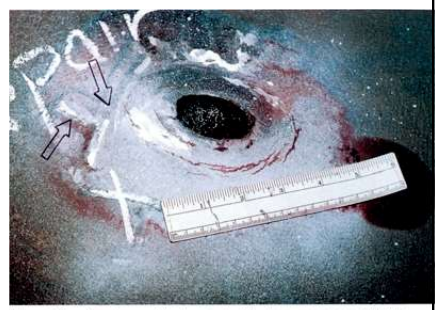


Figure 1: Cracking is generally characterized by the appearance of "stretch marks" around the weld in the base metal. The arrows identify prior weld repairs in the same area.

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WELDING

- **Weld procedures** must be qualified to **ASME Sect. IX**
- **Welders** must be qualified to **ASME Sect. IX**
- **Welding records** shall be available to the **AI**
- **Hot-tapping** (in-service welding) should be as **per API 2201**
- **Pre-heat and PWHT** should follow **ASME Sect VIII**

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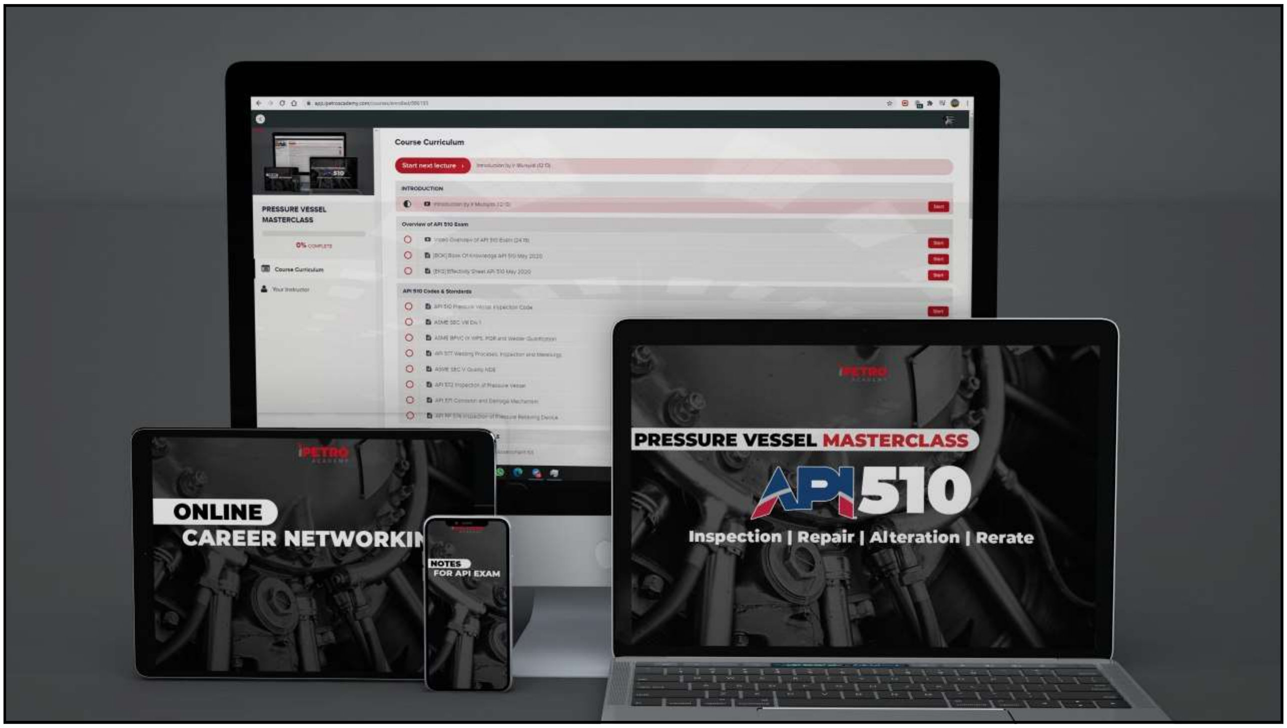
OTHER REQUIREMENTS

- **Materials:**
  - **Meet** requirements of **construction code**
  - **Carbon** of **less than 0.35%**
- **NDE**
  - Before welding – PT or MT
  - After welding – Applicable NDE
  - Meet **RT** requirements of **construction code**.
  - **Acceptance criteria** based on **ASME VIII**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