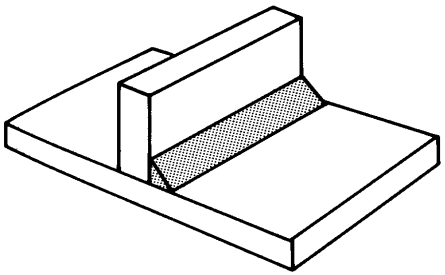
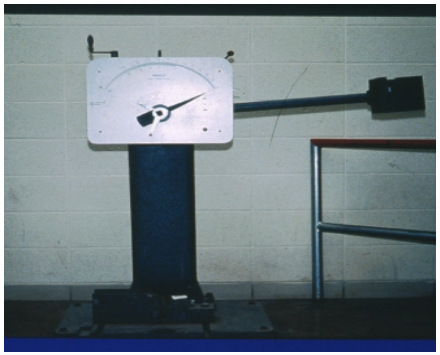
Welding Design Overview

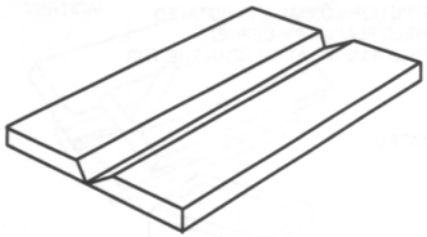
Module 1C

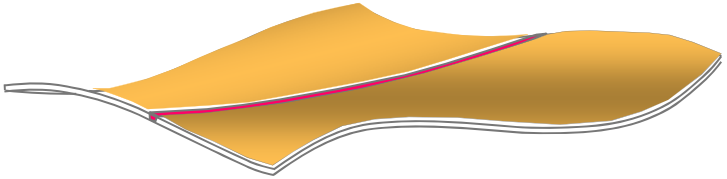
Welding Design and Testing

- Understand the basic principals pertaining to weld design with emphasis on the following
  - The basic types of weld joints
  - The basic types of welds and their symbols
  - Residual stress and weld distortion
  - Mechanical property testing
  - Fitness-for-service



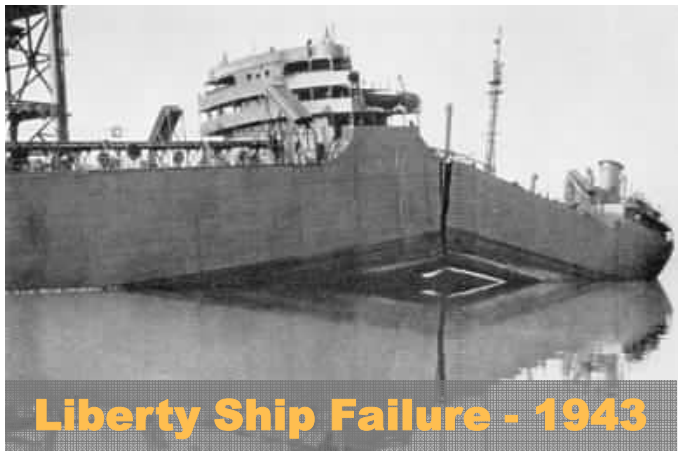






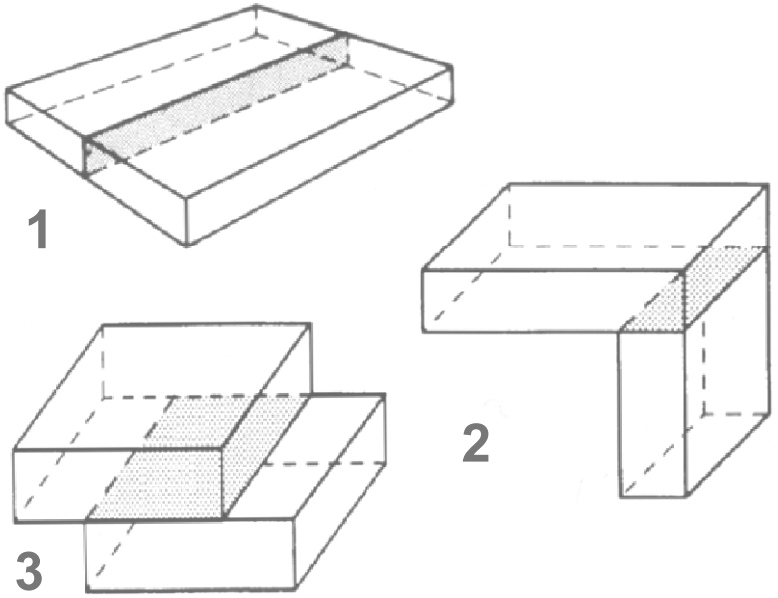
Importance of Weld Design

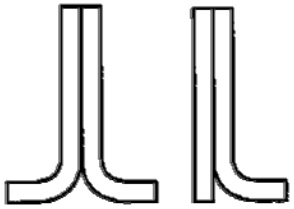
- Proper weld design and testing ensures that welds do not fail under their intended load and environmental conditions
  - The proper base materials must be chosen (and filler metals when applicable)
  - Appropriate weld strength requirements must be met
  - Weld toughness and ductility targets must be established
  - Fatigue resistance against cyclic loading has to be considered



Basics of Joint Design

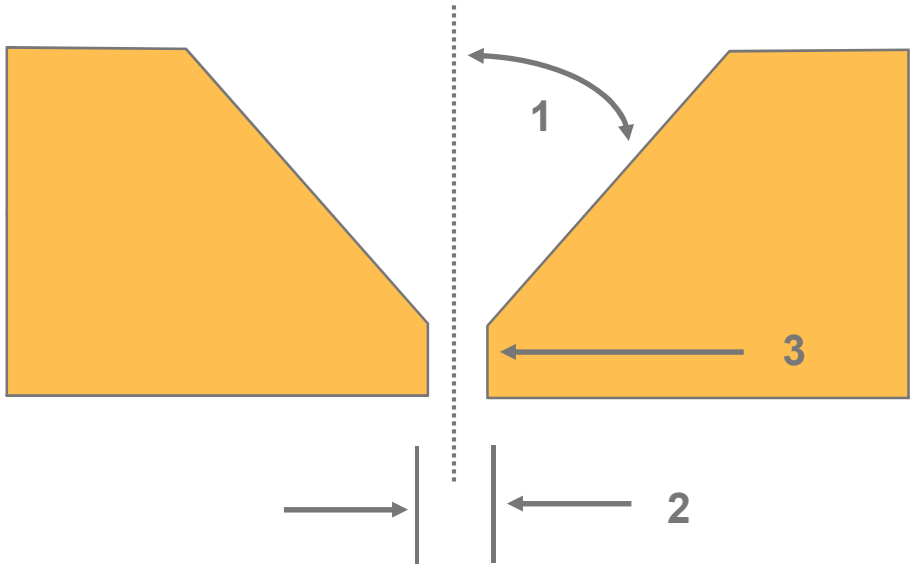
- The shape, dimensions, and configuration of the joint(s) are specified by the applicable welding code and designer
- Five basic joint types
  - Butt (1)
  - Corner (2)
  - Lap (3)
  - Tee (4)
  - Edge (5)
- Several variations of each type





Flange Edge Joints

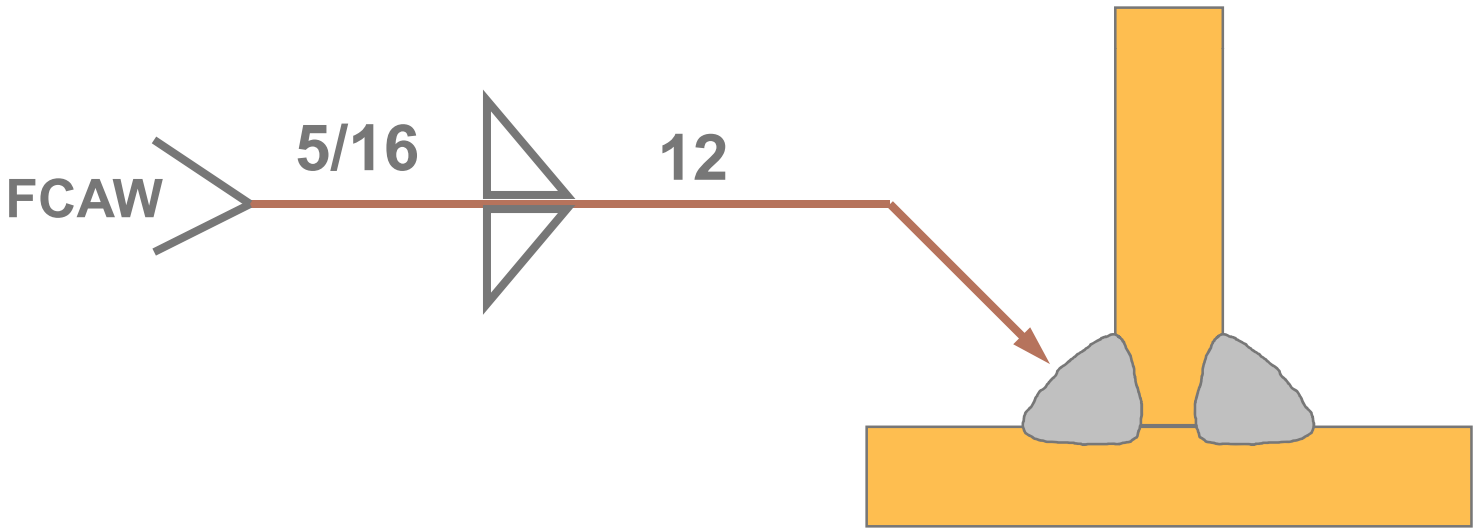
Joint Design Variables



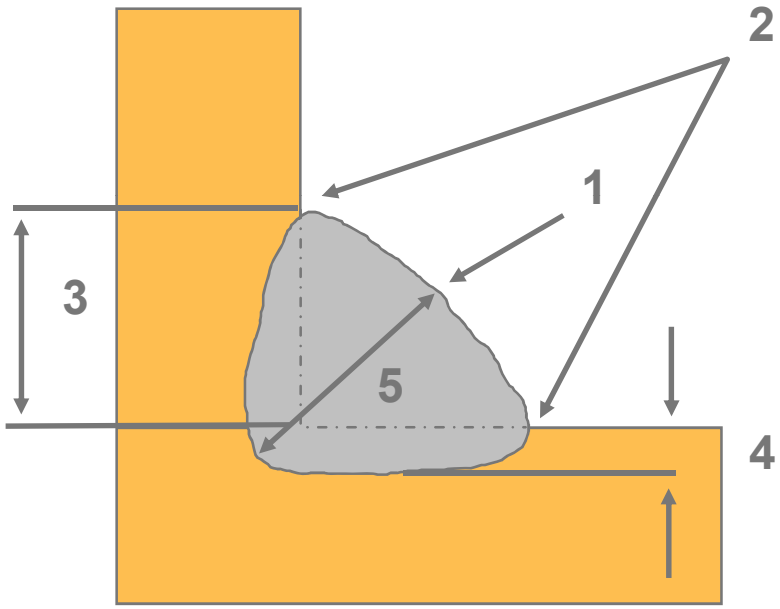
1. Bevel angle
2. Root opening (root gap)
3. Root face (land)

Welding Symbol Example

- Basic example of a welding symbol for fillet weld



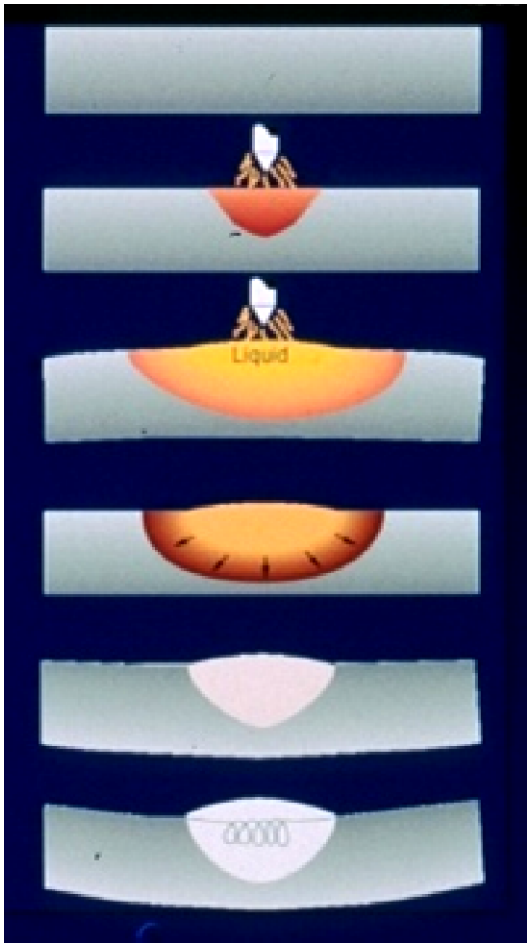
Weld Nomenclature



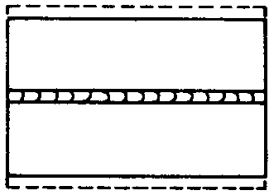
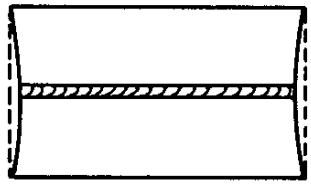
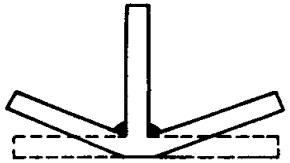
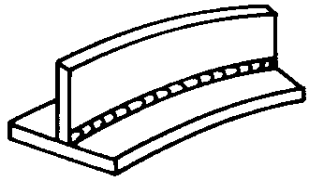
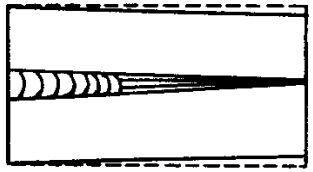
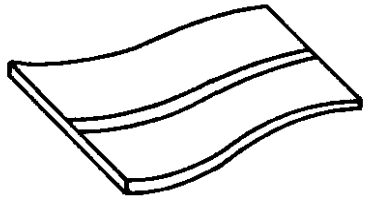
1. Weld face
2. Weld toes
3. Leg length
4. Depth-of-fusion
5. Actual throat

Residual Stress Concept

- Residual stress is the result of structural and metallurgical changes that take place during the welding process
  - Rapid localized heating (melting) and cooling (solidifying)
  - Stresses can be high enough to surpass the yield strength of the base metal
- Two major effects:
  - Distortion
  - Premature failure



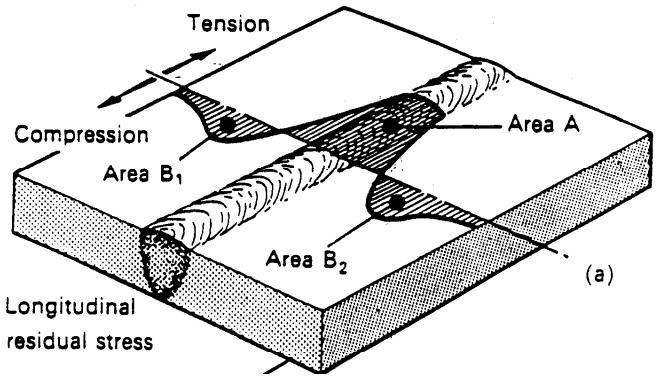
Types of Weld Distortion

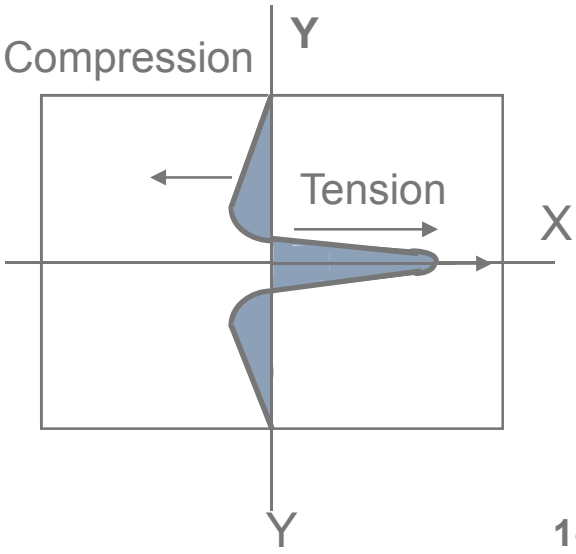
(a) Transverse Shrinkage 	(d) Longitudinal Shrinkage 
(b) Angular Change 	(e) Longitudinal Bending 
(c) Rotation Distortion 	(f) Buckling Distortion 

Reference: *Welding Handbook,* Volume 1, AWS, 1991

What is the Significance?

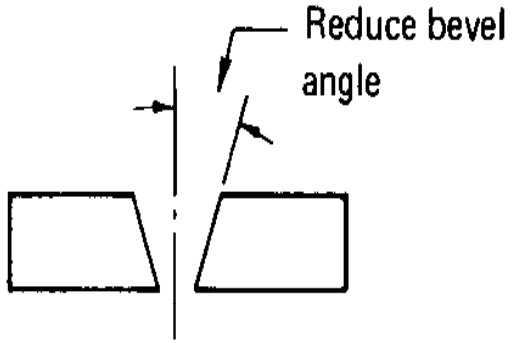
- Residual stress:
  - Degraded structural performance
  - Reduced service life
- Compression
  - Buckling can occur at lower than expected loads
- Tension
  - Can lead to higher than expected local stresses, resulting in cracking

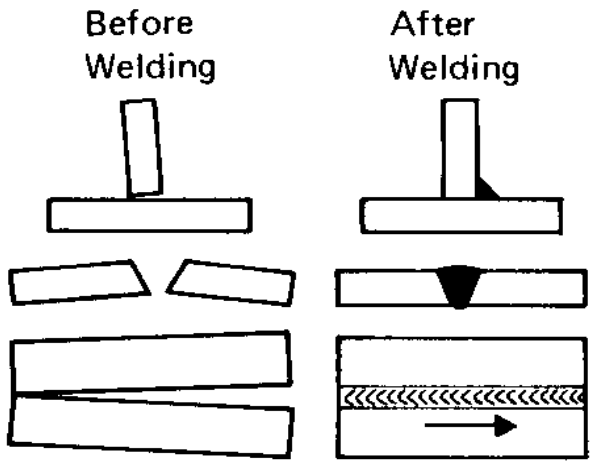




Controlling Stress and Distortion

- Several methods exist for better control of residual stress and distortion
  - Reduce the total volume of weld metal through joint design improvements
  - Pre-set the joint prior to welding
  - Preheat the joint
- Post-weld flame heating can be used to remove distortion





Weld Properties

- From a weld design standpoint, it is important to understand the mechanical properties of welds
- Some of the important properties of a weld include:
  - Strength – the ability to withstand an applied load
  - Ductility – the ability to deform/stretch without failing
  - Hardness – the ability to resist indentation
  - Toughness – the ability to absorb energy
  - Soundness – freedom from imperfections
  - Fatigue strength – resistance to failure under repeated loads

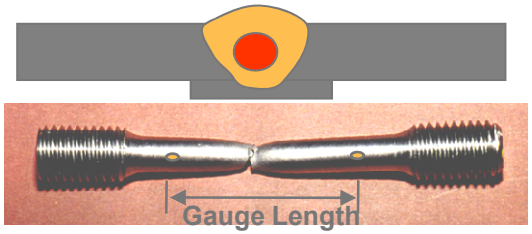
Testing Weld Properties

- There are numerous tests used to determine the various properties of welds
  - Non destructive tests (does not hinder future usage)
  - Destructive tests (render the part useless)
- Module 4 will cover the following destructive test methods used to evaluate properties
  - Tension tests – mechanical properties
  - Hardness tests – mechanical properties
  - Fracture toughness tests – mechanical properties
  - Bend tests – weld soundness

Tension Tests

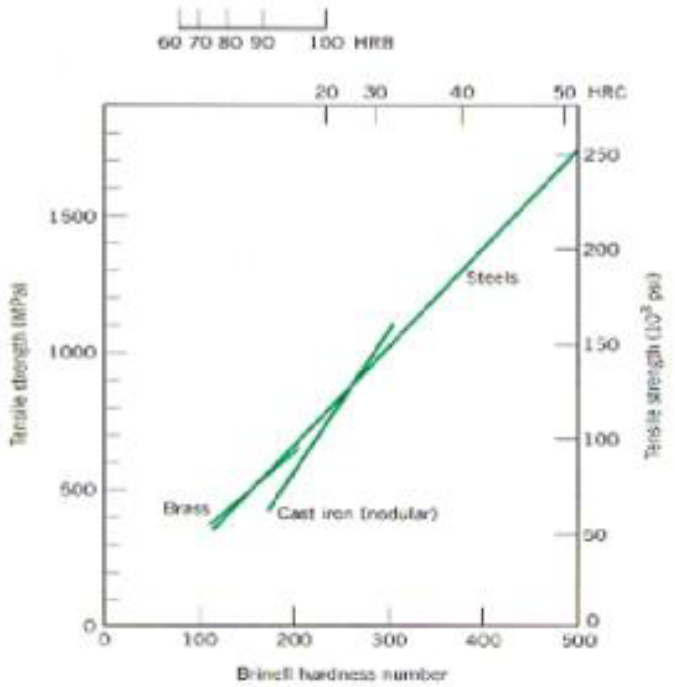
- Several standards and guidelines exist for tensile testing
  - ASTM E8 “Standard Methods of Tension Testing of Metallic Materials”
- Significance
  - Tension tests provide information on many different properties
    - Strength
    - Ductility
    - Toughness
    - Can test the entire weld joint or just the weld metal

All Weld Metal Tensile Test



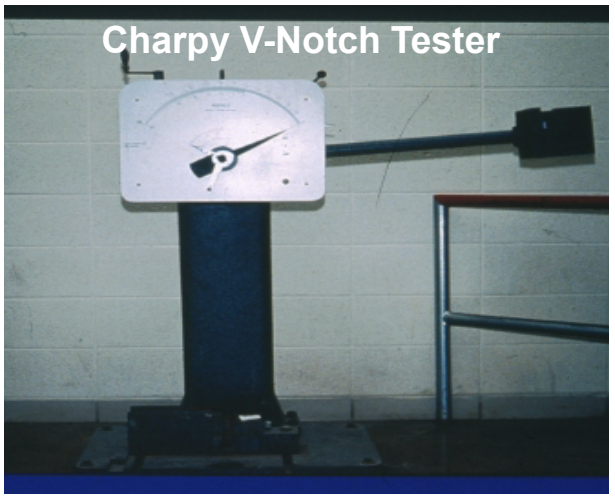
Hardness Tests

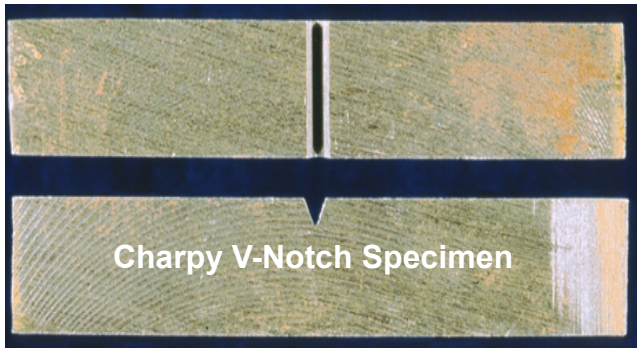
- Several standard techniques
- Significance
  - One of the most commonly and easily measured mechanical properties
  - Hardness and strength are directly related for carbon steels
  - Therefore it is possible to estimate the tensile strength if the hardness is known



Fracture Toughness Tests

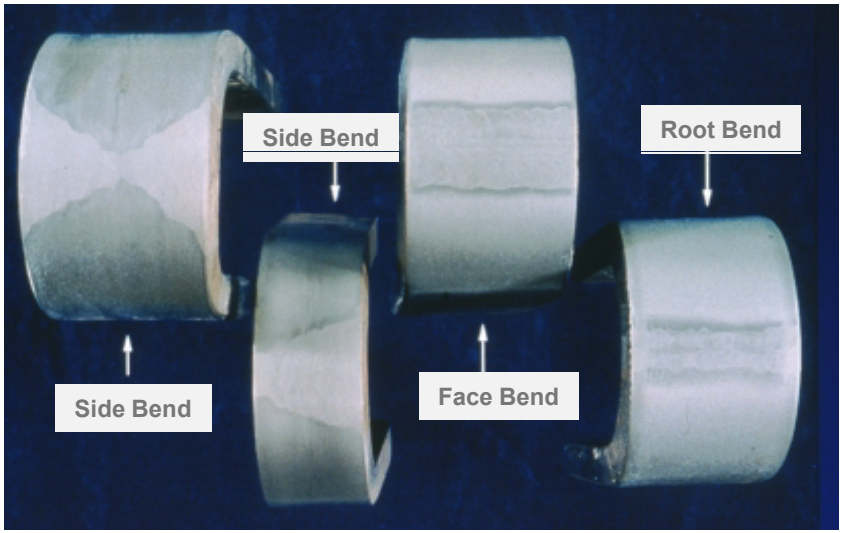
- There are several standard techniques for testing fracture toughness including:
  - Charpy V-notch test
  - Dynamic tear test
  - Plane-strain fracture test
  - Drop weight nil-ductility test
- Significance
  - Provides a measure of resistance to crack initiation or propagation or both
  - The temperature of the specimen has a significant effect on the test results


Charpy V-Notch Tester


Charpy V-Notch Specimen

Bend Tests

- There are three standard techniques for bend testing
  - Guided bend
  - Roller equipped guided bend
  - Wrap-around guided bend
- Significance
  - To assess weld soundness in procedure and performance qualifications
  - The ductility of a weld



Weldability Overview

Module 1D

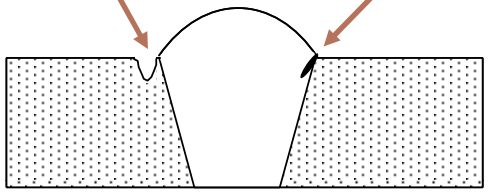
Weld Defects

- Fabrication-related
  - Associated with primary fabrication or repair
  - Can be controlled by combination of metallurgical and welding process factors
  - Use of appropriate inspection techniques is critical
- Service-related
  - Occur upon exposure to service environment
  - Generally mechanically or environmentally induced
  - May result from remnant weld defects or metallurgical phenomena associated with the weld thermal cycle
  - Inspection and design issues are important to control defect formation and monitor propagation

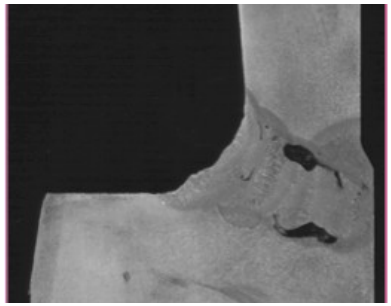
Non-Metallurgical Fabrication Defects

Undercut

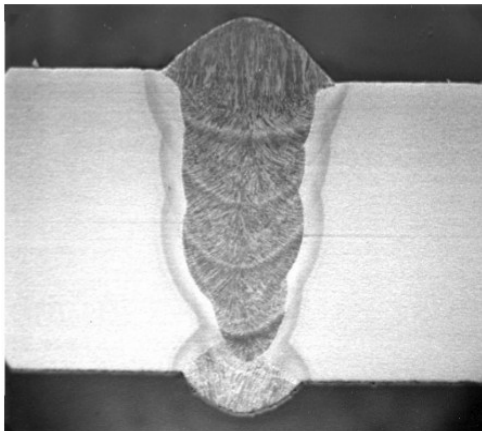
Intrusion



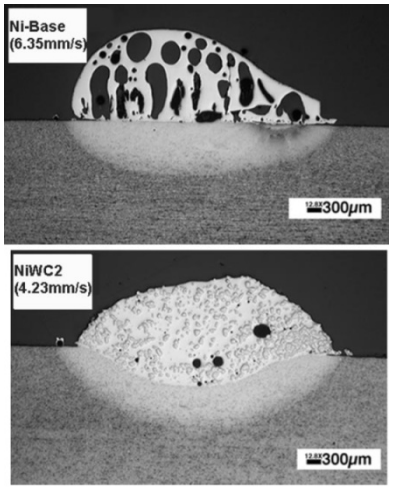
Lack of Fusion (SMAW)



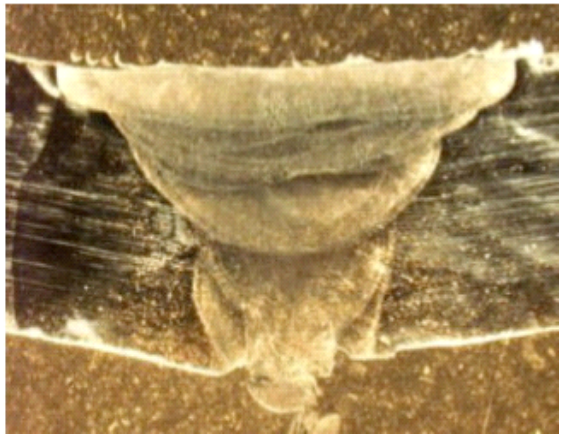
Oxidation



Overbead



Porosity

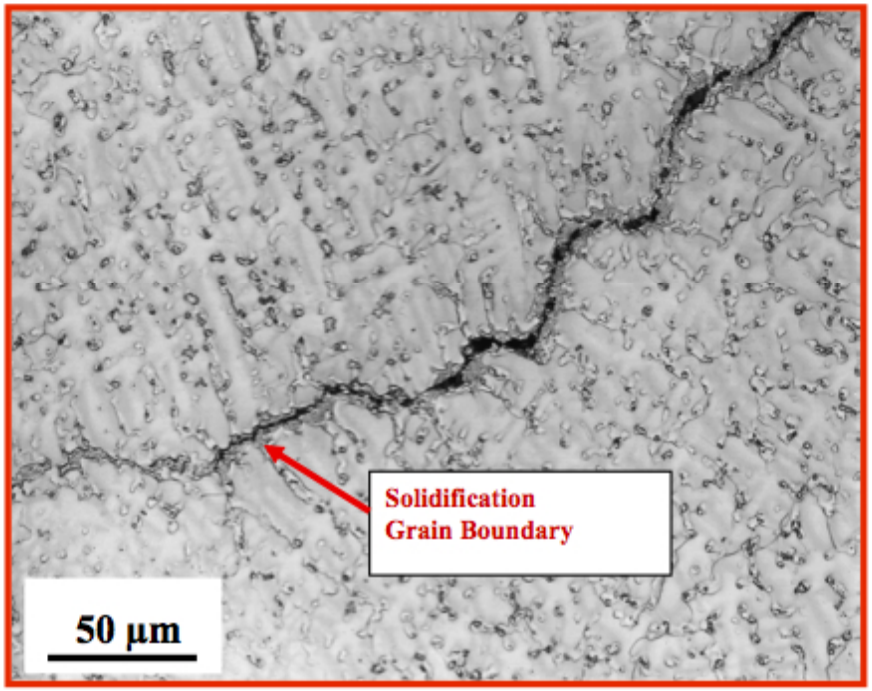


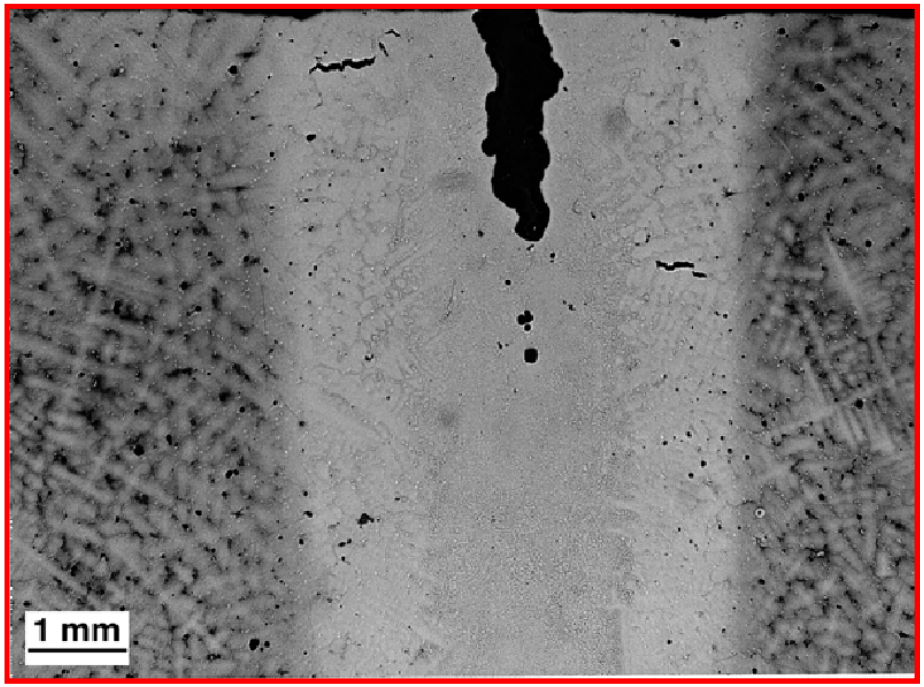
Drop-Through

Cracking Phenomena

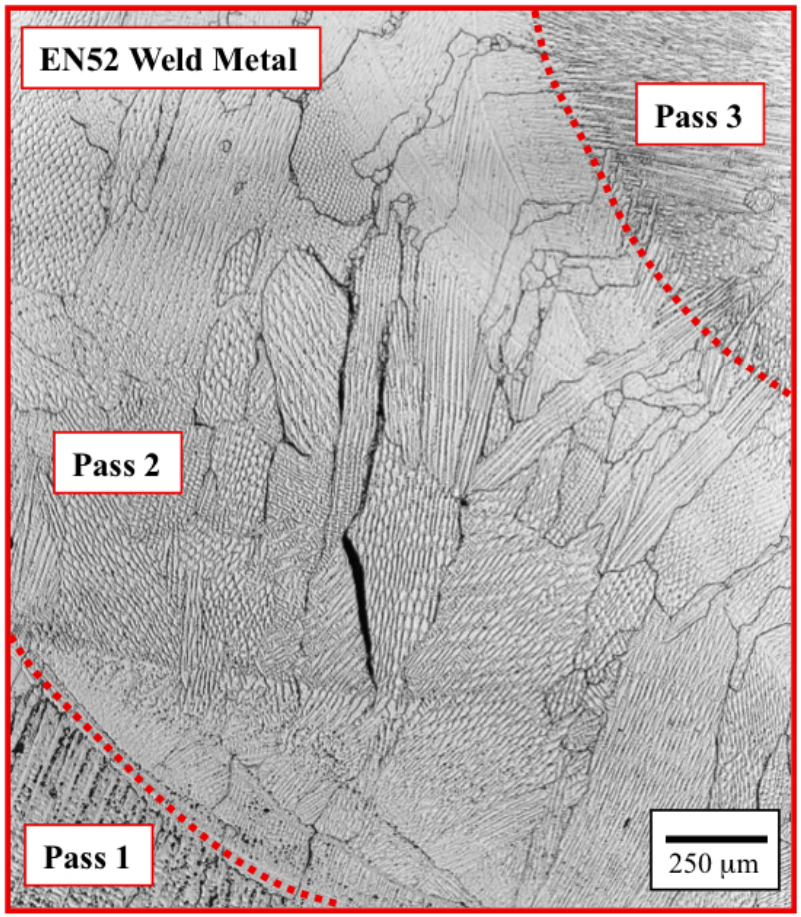
- Solidification Cracking – “Hot Cracking”
  - HAZ/PMZ liquation cracking
  - Weld metal liquation cracking
- Solid-State Cracking – “Warm Cracking”
  - Ductility dip cracking
  - Reheat cracking
  - Strain-age cracking
  - Copper contamination cracking
- Hydrogen-Induced Cracking - “Cold Cracking”

Solidification Cracking

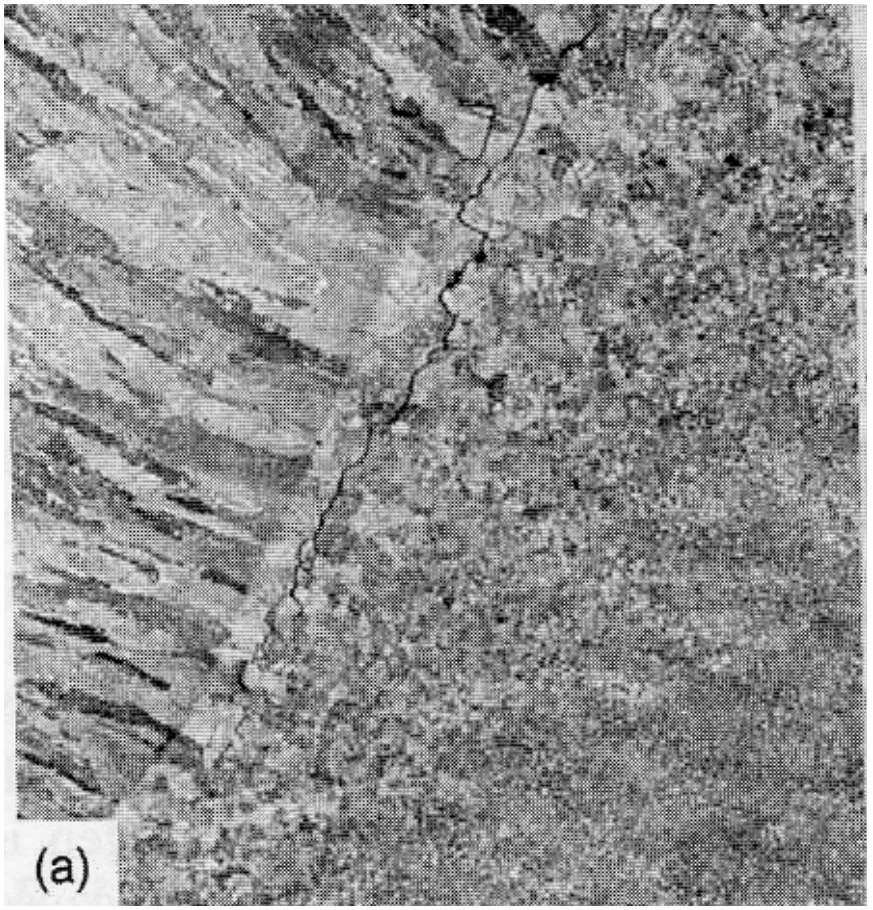




Solid-State Cracking

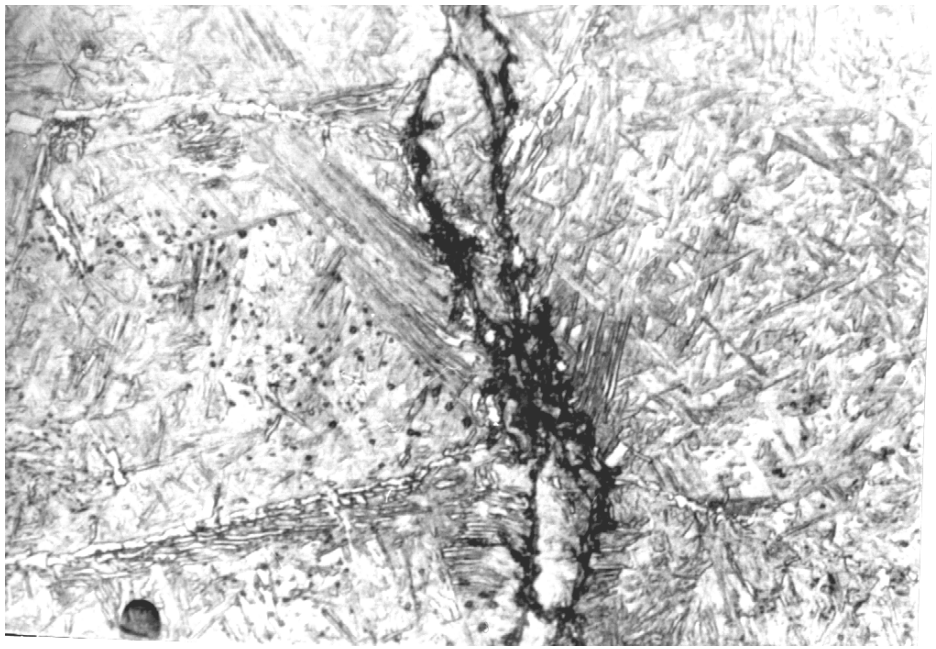


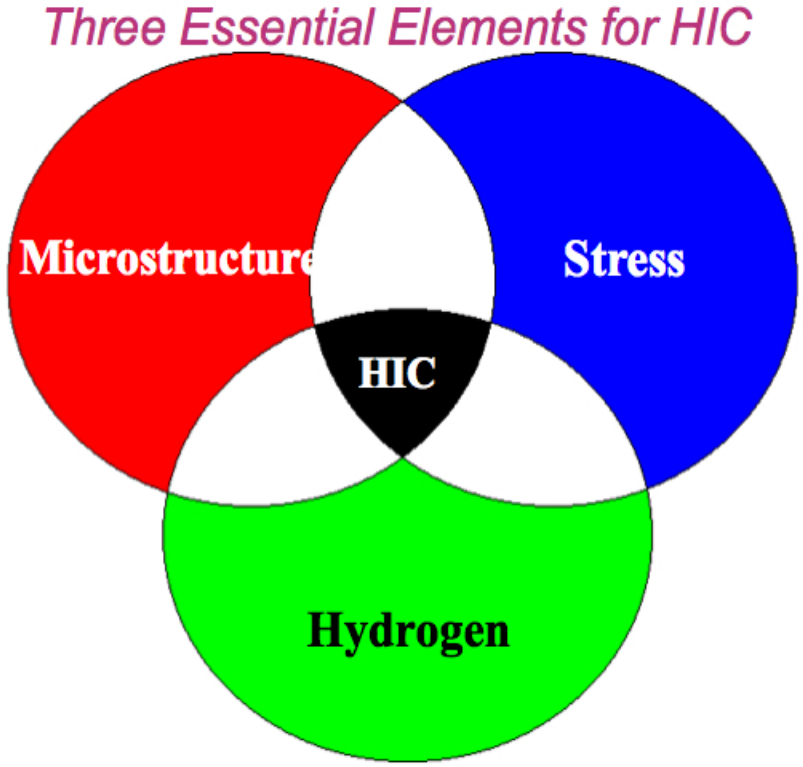
Ductility Dip Cracking



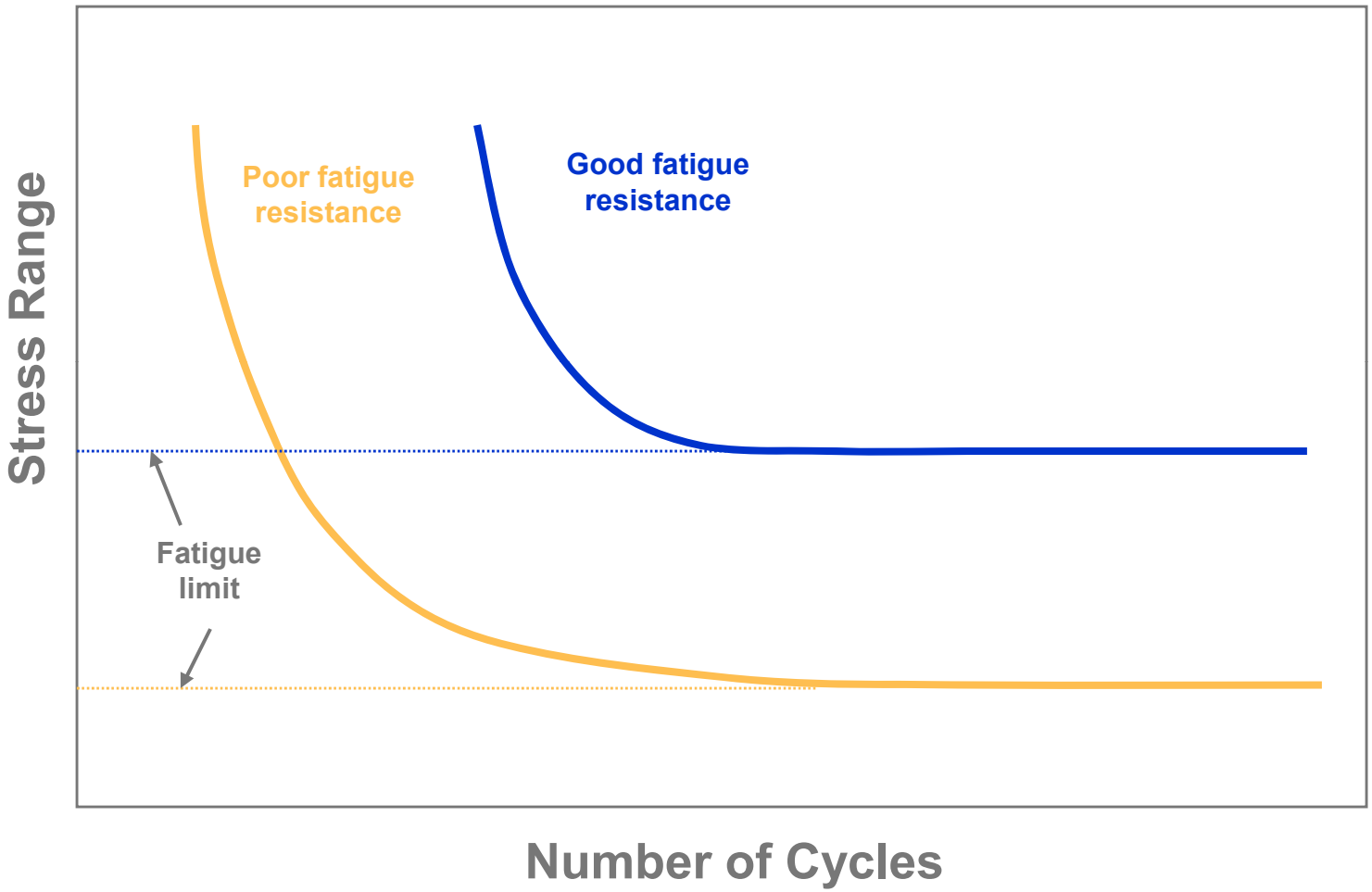
Reheat Cracking

Hydrogen Induced Cracking

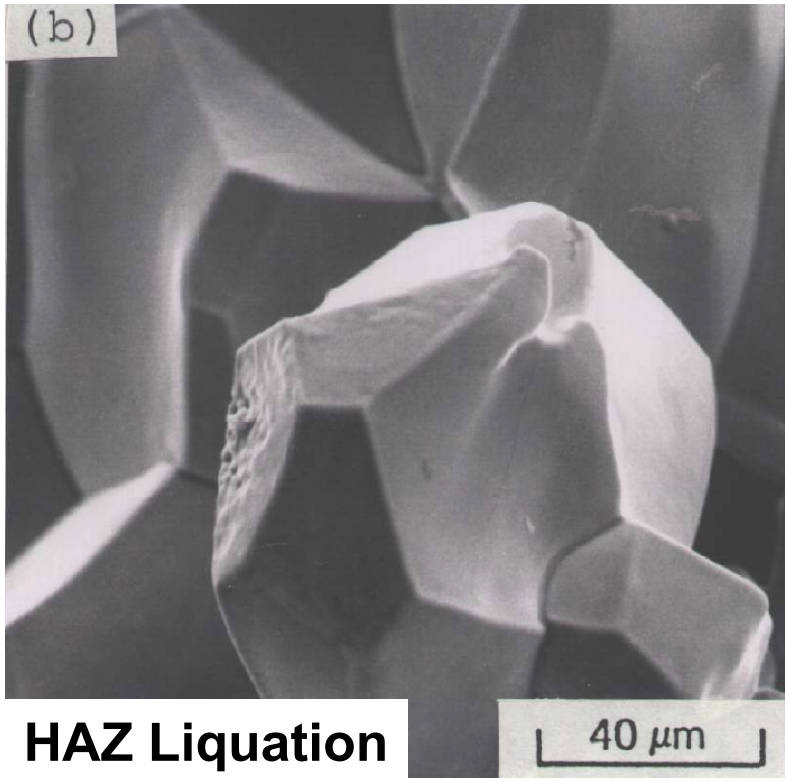




Fatigue and Fracture

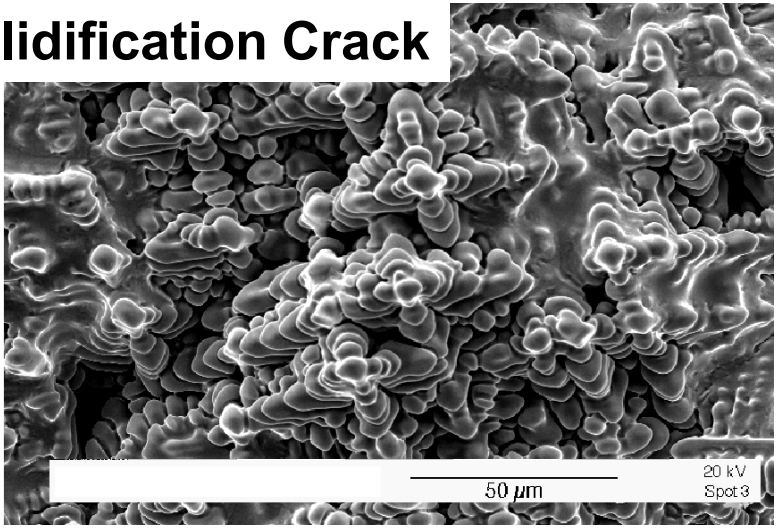


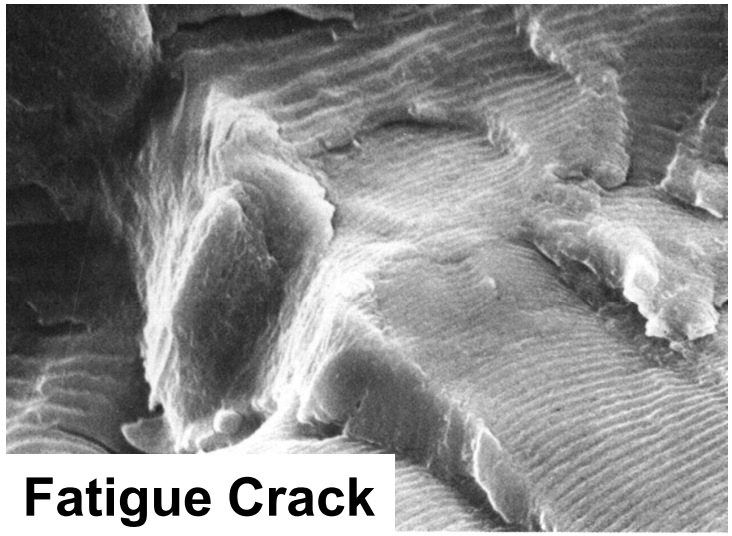
Fractography



HAZ Liquation

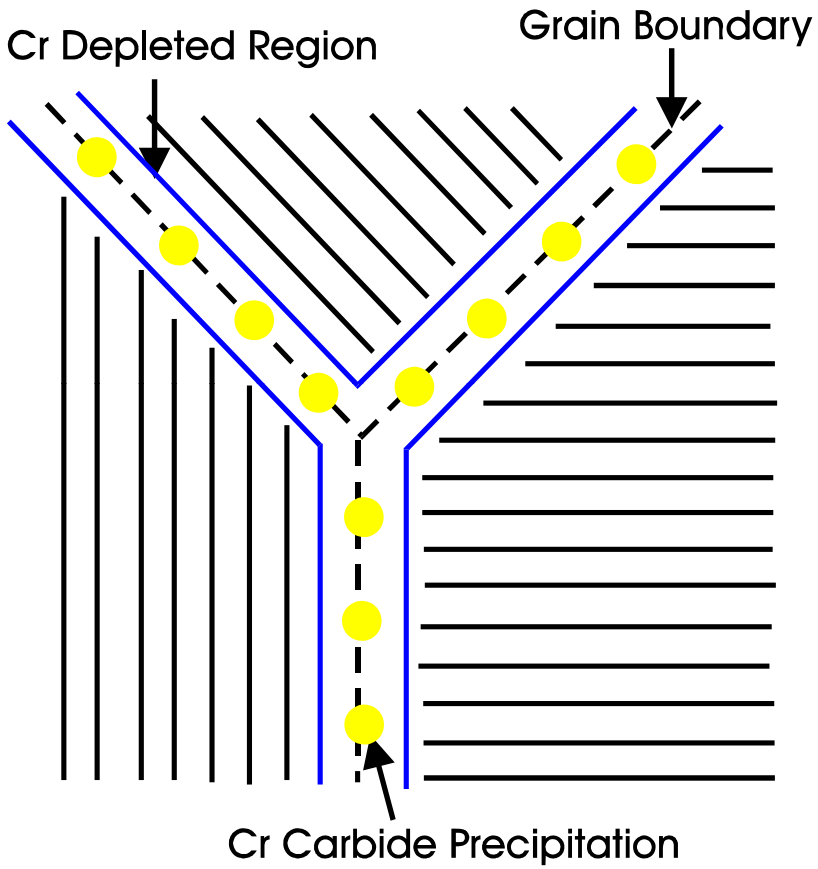
Solidification Crack



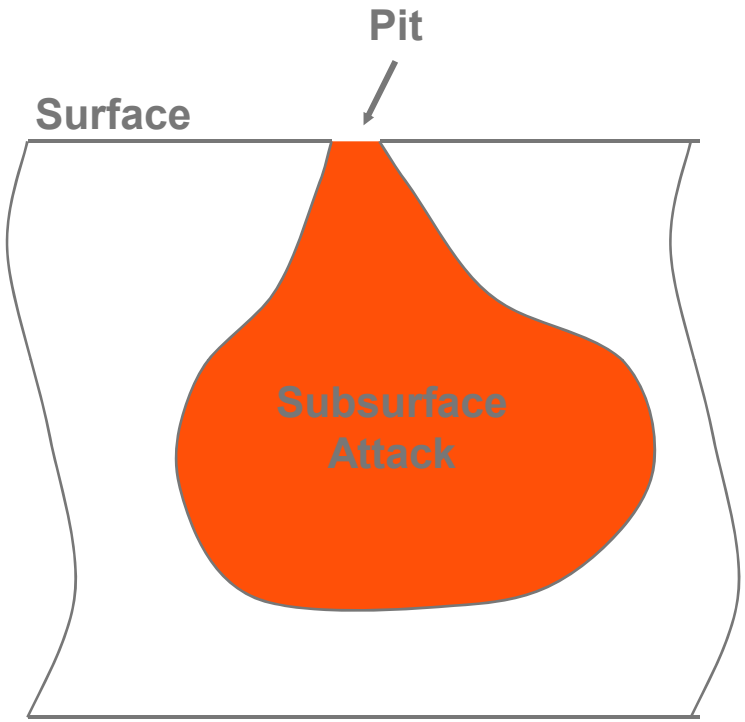


Fatigue Crack

Corrosion



Sensitization of Stainless Steels



Pitting Corrosion

Inspection Overview

Module 1E

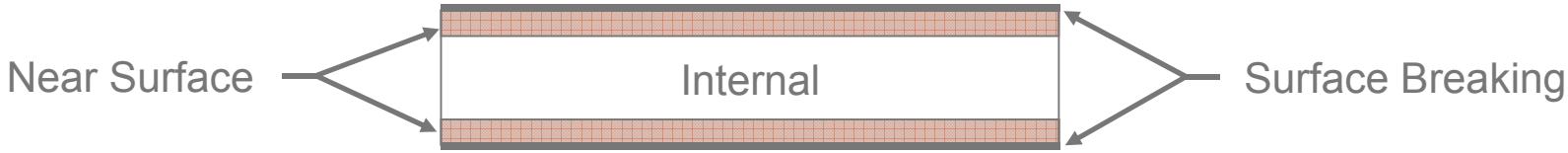
Non-Destructive Examination






Non-Destructive Examination

- Volumetric flaws
  - Surface breaking
    - Visual, liquid penetrant
  - Near surface
    - Magnetic particle and eddy current
  - Internal
    - Ultrasonic testing and radiography
- Planar flaws
  - Surface breaking
    - Visual
  - Near surface
    - Magnetic particle and eddy current
  - Internal
    - Ultrasonic testing



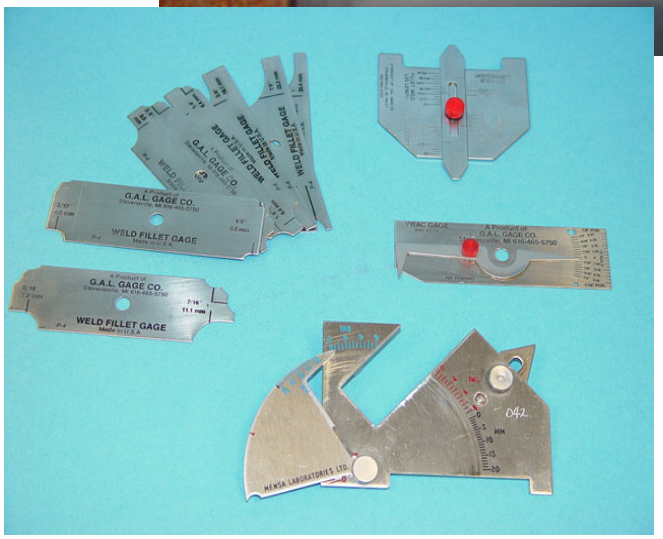
Non-Destructive Examination

- Volumetric flaws
  - Porosity
  - Inclusions
    - Slag
    - Tungsten
  - Shrinkage
  - Holes and voids
  - Corrosion
    - Thinning/loss
    - Pitting
- Planar flaws
  - Seams
  - Lamination
  - Lack of bonding
  - Forging/rolling lap
  - Fatigue cracks
  - Stress corrosion cracks
  - Incomplete fusion
  - Incomplete penetration

Visual Testing (VT)

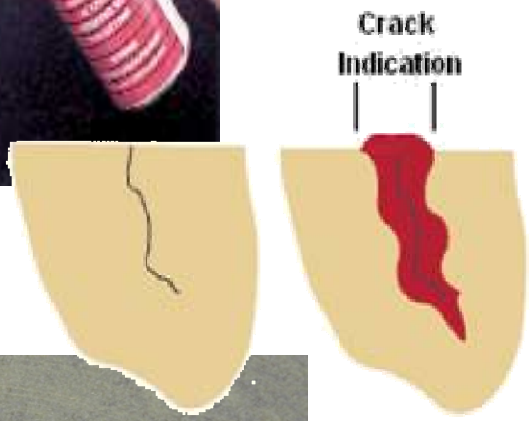
- Rulers
- Tape measures
- Calipers
- Borescopes
- Remote crawlers with cameras

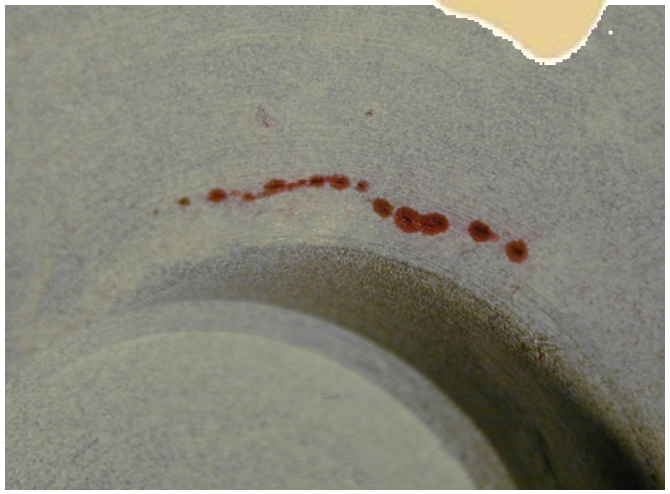
- Dimensional conformance, flaw detection



Liquid Penetrant Testing (PT)

- Steps in an PT procedure
  - Clean & Dry Component
  - Apply penetrant
  - Remove excess
  - Apply developer
  - Visual inspection
  - Post clean component
- Portable, easy to use
- Surface breaking defects only





Magnetic Particle Testing (MT)

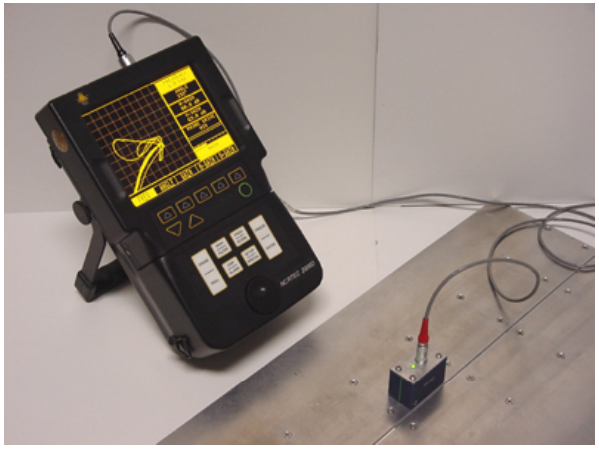
- Steps in a MT procedure
  - Component pre-cleaning
  - Introduction of magnetic field
  - Application of magnetic media
  - Interpretation of magnetic particle indications

- Can detect both surface and VERY NEAR sub-surface defects
- Cannot inspect non-ferrous materials such as aluminum, magnesium or most stainless steels

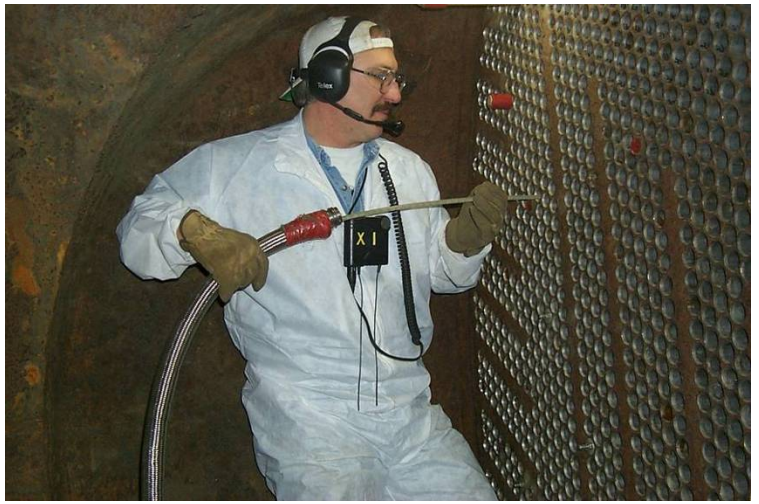
Wet Fluorescent Method

Eddy Current Testing (ECT)

- Uses the principal of "electromagnetism" as the basis for conducting examinations

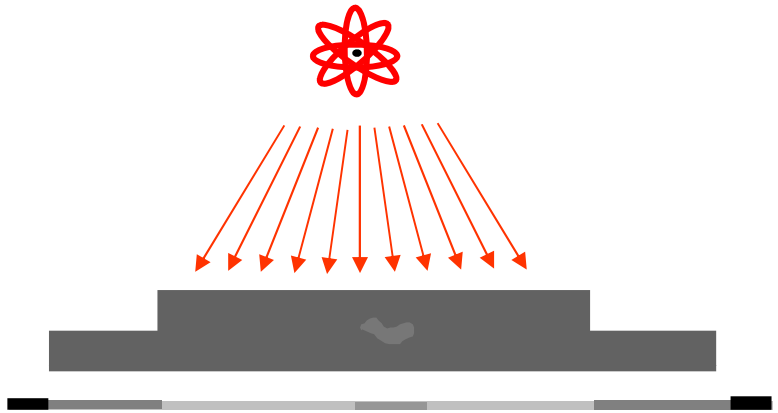


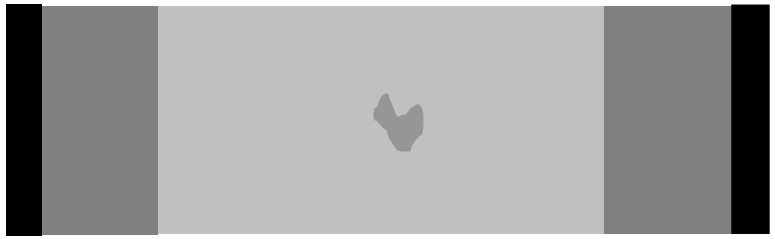
- Surface and slightly subsurface detection capabilities
  - Discontinuities
    - Cracks, pores
  - Geometry
    - Scratches, undercut
  - Material properties
    - Heat treatment, residual stresses, hardness, phase composition, creep, fatigue, corrosion



Radiographic Testing (RT)

- The part is placed between the radiation source and a piece of film
  - Part absorbs some radiation
  - Thicker and more dense area will stop more of the radiation
  - Safety precautions
- Technique is not limited by material type or density
  - Detects both surface and subsurface defects
- Orientation of equipment and flaw can be critical
  - Extensive training





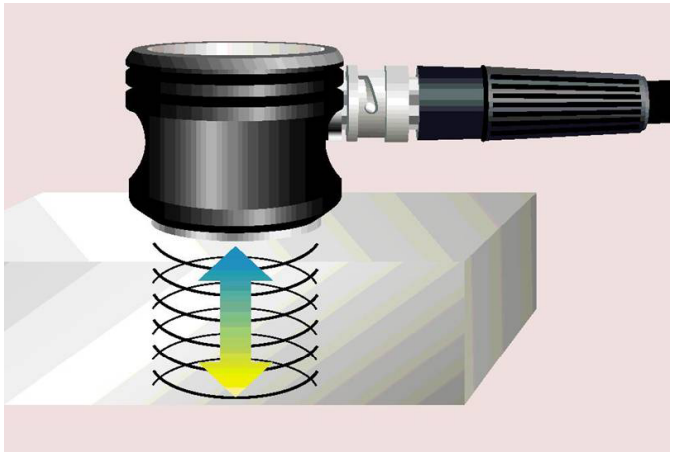
Top view of developed film

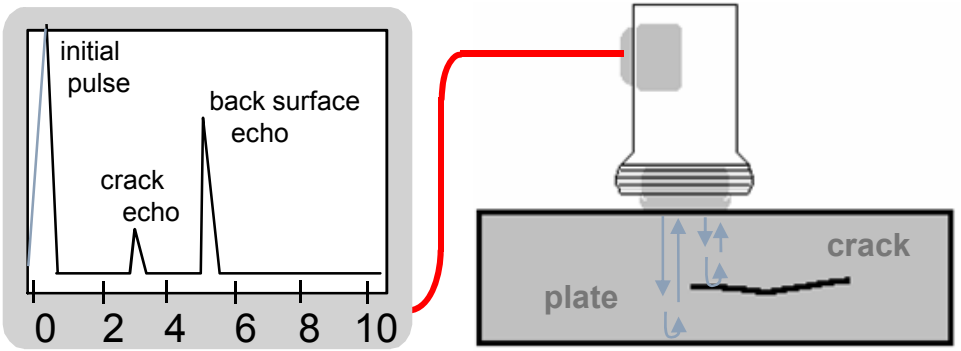
= less exposure

= more exposure

Ultrasonic Testing (UT)

- Sound produced by a vibrating body (transducer) and travels in the form of a wave
  - Similar to light waves, they can be reflected, refracted, and focused
  - Ultrasonic reflections from the presence of discontinuities or geometric features enables detection and location

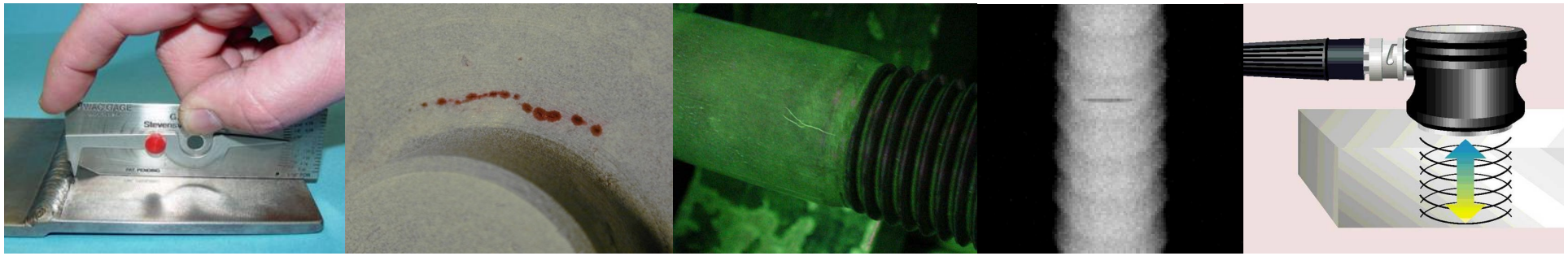




UT Instrument Screen

Summary

- Introduce common non-destructive inspection techniques, procedures, and equipment
- Describe advantages and limitations
- Demonstrate how to select the best process for a given application



Fitness-for-Service Concept

- Definition
  - Quantitative engineering evaluations demonstrating the structural integrity of a flawed or damaged component and their fitness for intended purpose
- Rationale
  - Design/welding codes and standards do not address the fact that structures degrade while in service
- Benefits
  - Make run/repair/replace decisions
  - Reduce unnecessary repairs and avoid unplanned shutdowns
  - Accurately predict structural behaviors in service

What Does FFS Cover?

- Safe operation
  - Present the integrity of the component given current state of damage, operating loads, and environmental conditions
- Safety margin and re-rating
  - The limiting operating condition to avoid failure of equipment containing a known or postulated flaw
- Projected remaining life
  - Run, repair, or replace based on future operation conditions and environmental compatibility

Welding Codes Overview

Module 1F

Products Covered by Standards of Various Organizations

Product	AISC	ASME	ASTM	AWS
Base Metals		X	X	X
Bridges	X			X
Buildings	X			X
Construction equip.				X
Filler metals		X		X
Machine tools				X
Power gen. equip.		X		
Piping		X		X
Presses				X
Pressure vessels, boilers		X		
Ships				X
Storage tanks				X
Structures, general	X			X

American National Standards Institute (ANSI)

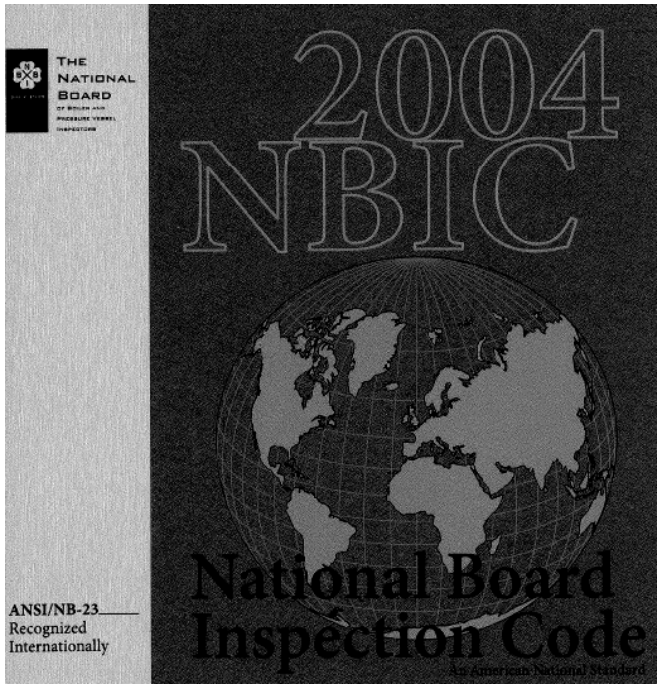
- Coordinating organization for US voluntary standards system
- Does not produce standards, but approves those produced by other organizations
- US member of ISO and International Electrotechnical Commission (IEC)
- Approximately 10,000 ANSI documents currently
- Provide a common language that can be used confidently by industry, suppliers, customers, business, the public, government, and labor

American Society for Testing and Materials (ASTM)

- Develops and publishes specifications for use in the production and testing of materials
  - ASTM E8 – Tensile Testing of Metallic Materials
- Cover virtually all materials used in industry and commerce with exception of welding consumables, which are covered by AWS
- Currently publish 15 sections comprising 65 volumes and an index
- When ASTM specifications adopted by ASME for certain applications, either in its entirety or in a revised form, ASME adds an “S” in front of ASTM letter prefix
  - ASTM A105, Carbon steel forgings for piping applications, is listed as SA-105 in ASME

National Board of Boiler and Pressure Vessel Inspectors (NBBPVI)

- Often referred to as the National Board, represents the enforcement agencies empowered to assure adherence to ASME B&PVC
- Involved in boiler and pressure vessel registration and investigation of possible Code violations
- Publishes National Board Inspection Code (NBIC) that describes maintenance, inspection and repair requirements
- Boiler and pressure vessel repair, governed by the “R” stamp is also under their jurisdiction

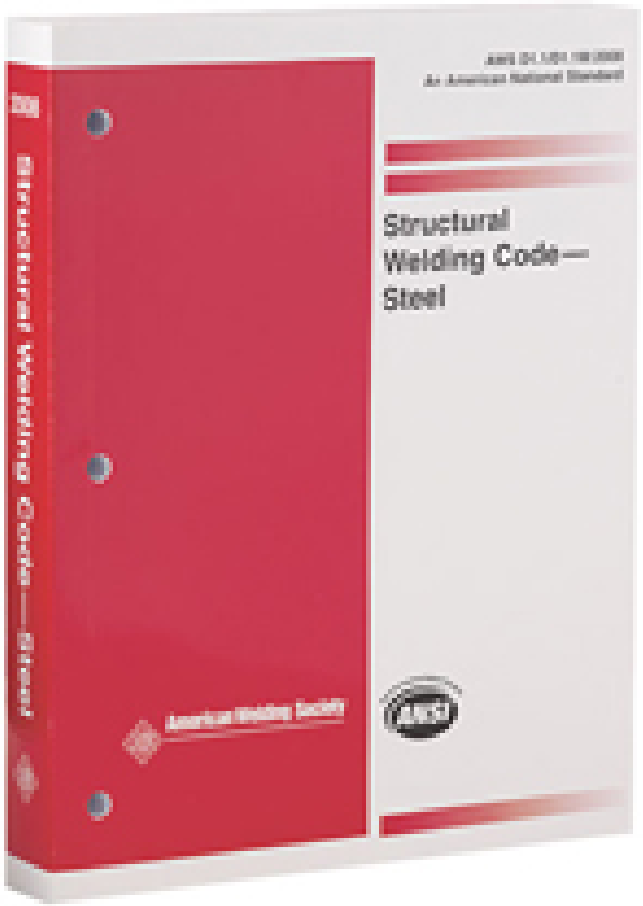


American Welding Society (AWS)

- Publishes numerous documents covering welding and welding related activities
- AWS produces codes, specifications, recommended practices, classifications, methods, and guides related to welding
- General subject areas
  - Definitions and symbols, filler metals, qualification and testing, welding processes, welding applications, safety

Overview of AWS D1.1 – Structural Welding Code

- General Requirements
- Design of Welded Connections
- Prequalification of WPSs
- Qualification
- Fabrication
- Inspection
- Stud Welding
- Strengthening & Repairing Existing Structures
- Annexes (Mandatory): A – J
- Annexes (Informative): K – V
- Commentary
- Index



Overview of AWS D1.1 – Structural Welding Code

- Chapter 1, General Requirements
  - Basic information on the scope and limitations of the code
  - Limitations - NOT intended to be used for the following
    - Yield stress > 100-ksi (690-Mpa)
    - Thickness < 1/8-in (3.2-mm)
    - Pressure vessels, pressure piping, bridges
    - Base metal other than carbon or low-alloy steels
  - Definitions conform to AWS A3.0, supplemented by Annex K
  - Welding symbols conform to AWS A2.4
  - Engineer's, contractor's and inspector's responsibilities
  - Safety references, standard units of measurement and references

Overview of AWS D1.1 – Structural Welding Code

- Chapter 2, Design of Welded Connections
  - Requirements for the design of welded connections composed of tubular, or nontubular, product form members
    - Part A – Common Requirements for Design of Welded Connections (Nontubular and Tubular Members)
    - Part B – Specific Requirements for Design of Nontubular Connections (Statically or Cyclically Loaded)
    - Part C – Specific Requirements for Design of Nontubular Connections (Cyclically Loaded)
    - Part D – Specific Requirements for Design of Tubular Connections (Statically or Cyclically Loaded)

Overview of AWS D1.1 – Structural Welding Code

- Chapter 3, Prequalification of WPSs
  - Prequalified WPSs (SWPSs), such as those found in AWS B2.1, may be used without qualification
    - Limitations apply
    - Welder performance still needs to be qualified in accordance with Section 4
  - Welding Processes
    - Prequalified processes
      - SMAW, SAW, FCAW, and GMAW (except GMAW-S)
        - FCAW and GMAW must use CV power supplies
    - Code approved processes
      - ESW, EGW, GMAW-S, and GTAW
      - WPSs must be qualified in accordance with Section 4

Overview of AWS D1.1 – Structural Welding Code

- Chapter 4, Qualification
  - Requirements for qualification testing of WPSs and welding personnel
    - Part A – General Requirements
    - Part B – Welding Procedure Specification
      - Multiple positions, material shapes, and weld types can be qualified by a single WPS or welder performance qualification test
      - Changes beyond the limitations of the PQR essential variables warrant requalification
    - Part C – Performance Qualification
    - Part D – Requirements for CVN Testing

Overview of AWS D1.1 – Structural Welding Code

- Chapter 5, Fabrication
  - Requirements for fabrication and erection of welded assemblies and structures produced by any process acceptable under AWS D1.1
  - Contains 31 sections which cover numerous topics
    - Base metal
    - Welding consumables
    - Preheat & interpass temperature
    - Backing, backing gas, or inserts
    - Preparation of base metal
    - Tack welds & construction aids
    - Control of distortion & shrinkage
    - Repairs
    - Minimum fillet weld size
    - Etc.

Overview of AWS D1.1 – Structural Welding Code

- Chapter 6, Inspection
  - Contains all of the requirements for the Inspector's qualifications and responsibilities, acceptance criteria for discontinuities, and procedures for NDT
    - Part A – General Requirements
    - Part B – Contractor Responsibilities
    - Part C – Acceptance Criteria
    - Part D – NDT Procedures
    - Part E – Radiographic Testing (RT)
    - Part F – Ultrasonic Testing (UT) of Groove Welds
    - Part G – Other Examination Methods

American Society of Mechanical Engineers (ASME)

- Two standing ASME committees actively involved in the formulation, revision, and interpretation of standards covering products that may be fabricated by welding
- Documents
  - ASME Boiler and Pressure Vessel Code
    - Provide minimum requirements for the design, materials, fabrication, erection, testing, and inspection of boilers and pressure vessels
    - Twelve (12) sections
  - Code for Pressure Piping
    - Provide minimum requirements for the design, materials, fabrication, erection, testing, and inspection of piping systems
    - Twelve (12) sections

ASME Boiler and Pressure Vessel Code Sections

- ASME Boiler and Pressure Vessel Code
  - Five sections cover the design and construction of boilers and pressure vessels
    - I – Rules for Construction of Power Boilers
    - **III – Rules for Construction of Nuclear Facility Components**
      - **Division I – Rules for Construction of Nuclear Facility Components**
        - Subsection **NB**, NC, ND, NE, NF, NG, NH, and appendices
      - Division II – Code for Concrete Reactor Vessels and Containments
      - Division III – Containment Systems and Transport Packaging for Spent Fuel and High-Level Radioactive Waste
    - IV – Rules for Construction of Heating Boilers
    - VIII – Rules for Construction of Pressure Vessels
      - Division 1
      - Division 2 – Alternative Rules
    - X – Fiber-Reinforced Plastic Pressure Vessels

ASME Boiler and Pressure Vessel Code Sections

- ASME Boiler and Pressure Vessel Code
  - Sections cover material specifications, nondestructive examination, and welding and brazing qualifications
    - **II – Materials**
      - Part A: Ferrous Material Specifications
      - Part B: Nonferrous Material Specifications
      - Part C: Specifications for Welding Rods, Electrodes, and Filler Materials
      - Part D: Properties
    - **V – Nondestructive Examination**
    - **IX – Welding and Brazing Qualifications**
      - Part QW: Welding
      - Part QB: Brazing

ASME Boiler and Pressure Vessel Code Sections

- ASME Boiler and Pressure Vessel Code
  - Three sections cover the care and operation of boilers or nuclear power plant components
    - VI – Recommended Rules for the Care and Operation of Heating Boilers
    - VII – Recommended Guidelines for the Care of Power Boilers
    - **XI – Rules for In-service Inspection of Nuclear Power Plant Components**
  - One section covers the construction and continued service of transport tanks
    - XII – Rules for Construction and Continued Service of Transport Tanks

ASME B31 Code for Pressure Piping Sections

- Provides minimum requirements for different piping systems
  - **B31.1 – Power Piping**
  - B31.2 – Fuel Gas Piping
  - B31.3 – Process Piping
  - B31.4 – Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids
  - B31.5 – Refrigeration Piping and Heat Transfer Components
  - B31.8 – Gas Transmission and Distribution Piping Systems
  - B31.8S – Managing System Integrity of Gas Pipelines
  - B31.9 – Building Services Piping
  - B31.11 – Slurry Transportation Piping Systems
  - B31G – Manual for Determining Remaining Strength of Corroded Pipelines
  - B31J – Standard Test Method for Determining Stress Intensification Factors for Metallic Piping Components
  - B31Q – Pipeline Personnel Qualification

Overview of ASME Section III – Rules for Construction of Nuclear Facility Components

- ASME Section III is separated into three divisions
  - Subsection NCA – General Requirements for Division 1 and Division 2
  - Division I – Rules for Construction of Nuclear Facility Components
  - Division II – Code for Concrete Reactor Vessels and Containments
  - Division III – Containment Systems and Transport Packaging for Spent Fuel and High-Level Radioactive Waste
- Division 1 is separated into seven subsections
  - **Subsection NB**, NC, ND, NE, NF, NG, and NH
  - Subsections are separated by the application and design requirements

Overview of ASME Section III – Rules for Construction of Nuclear Facility Components

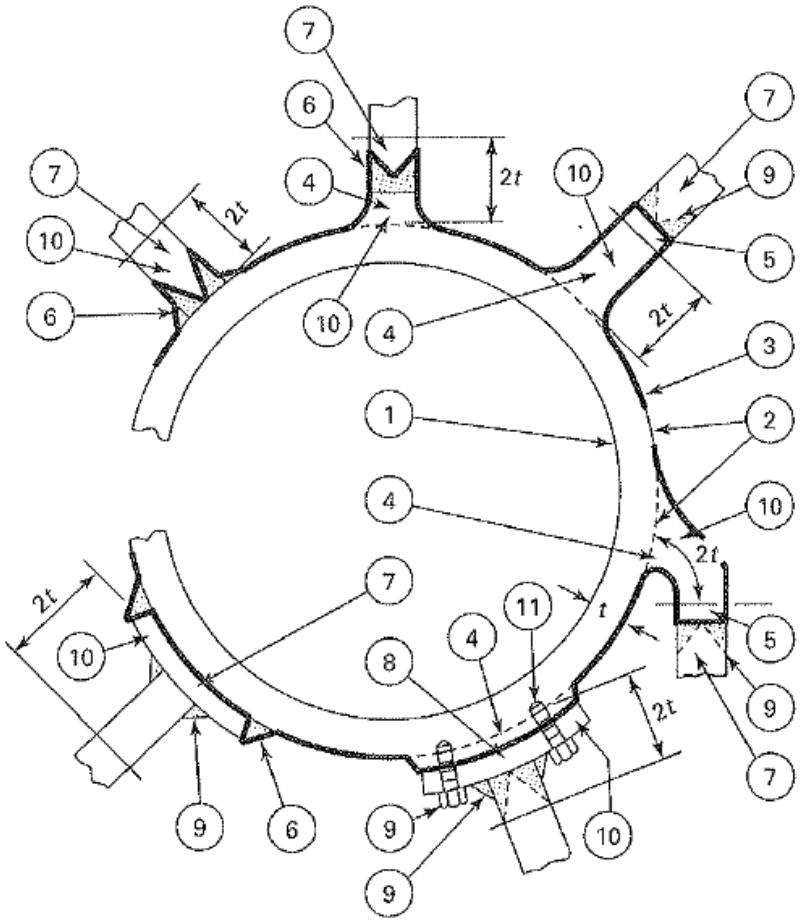
- Subsection NCA applies to both Division 1 and Division 2 vessels
  - Article NCA-1000, Scope of Section III
    - List general material and design requirements
      - Refers to ASME and ASTM specifications for materials
      - Refers to ASME and AWS specifications for welding materials
  - Article NCA-2000, Classification of Components and Supports
    - Provides general requirements such as design loads, service loads and test loads
    - The class of component is based on the engineering design of the vessel
      - Class 1 items are constructed in accordance with subsection NB
      - Class 2 items are constructed in accordance with subsection NC
      - Class 3 items are constructed in accordance with subsection ND
      - Class MC items are constructed in accordance with subsection NE
        - Metal containment vessels
      - Class CS items are constructed in accordance with subsection NG
        - Core support structures

Overview of ASME Section III – Rules for Construction of Nuclear Facility Components

- Subsection NCA applies to both Division 1 and Division 2 vessels
  - Article NCA-3000, Responsibilities and Duties
    - Outlines the responsibilities and duties of the construction contractors, owners, designers, etc
      - All welding curing Code construction shall be done by a Certificate Holder
      - Welding procedures have been properly qualified by the Certificate Holder
      - References ASME Section IX
  - Article NCA-4000, Quality Assurance
    - Describes the requirements for a quality assurance programs
    - N-Type Certificate Holders shall comply with NQA-1-1994, “Quality Assurance Program Requirements for Nuclear Facilities”
  - Article NCA-5000, Authorized Inspector
    - Describes the duties of the authorized inspector
  - Article NCA-8000, Certificates, Nameplates, Code Symbol Stamping, and Data Reports
    - Describes the different ASME certificates and their applicability

Overview of ASME Section III – Rules for Construction of Nuclear Facility Components

- Division 1, Subsection NB applies to Class 1 Components
  - Article NB-1000, Introduction
    - Covers strength and pressure integrity of items included in the pressure containing boundary
  - Article NB-2000, Material
    - Refers to ASME Section II for welding and base material properties
      - Mechanical and chemical analysis requirements for the base material and welds
  - Article NB-3000, Design
    - Outlines all the design criteria that needs to be addressed



Overview of ASME Section III – Rules for Construction of Nuclear Facility Components

- Division 1, Subsection NB applies to Class 1 Components
  - Article ND-4000, Fabrication and Installation
    - Refers to ASME Section IX for qualifications
      - Stud and capacitor discharge welding is limited to temporary attachments
      - Inertia and continuous drive friction welding is prohibited when welding pipe
    - Lists preheat, PWHT and toughness testing requirements if required
  - Article ND-5000, Examination
    - Refers to Section V for examination methods
    - Defines the inspection requirements depending on the weld category
    - Provides construction acceptance criteria
    - Defines the qualification requirements for examination personnel
      - Refers to ASNT Guidelines SNT-TC-1A

Overview of ASME Section III – Rules for Construction of Nuclear Facility Components

- Division 1, Subsection ND applies to Class 3 Components
  - Article ND-6000, Testing
    - Outlines the requirements for pneumatic or hydrostatic pressure testing
  - Article ND-7000, Overpressure Protection
    - Describes the components of the pressure relief system
  - Article ND-8000, Nameplates, Stamping, and Reports
    - Refers to Subsection NCA

Overview of ASME Section II – Materials

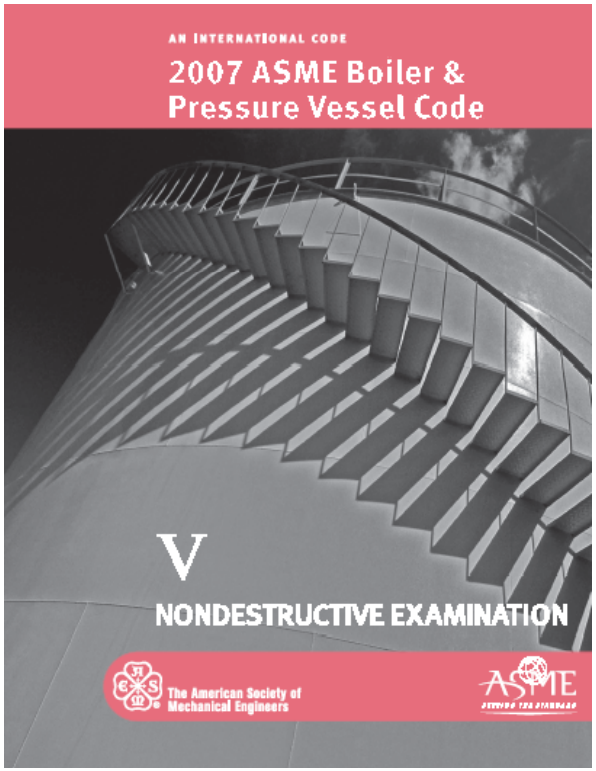
- Part A, Ferrous Material Specifications
  - These specifications contain requirements and mechanical properties, test specimens, and methods of testing for ferrous materials
  - They are designated by SA numbers and are derived from ASTM "A" specifications
- Part B, Nonferrous Material Specifications
  - These specifications contain requirements for heat treatment, manufacture, chemical composition, heat and product analyses, mechanical test requirements and mechanical properties, test specimens, and methods of testing for nonferrous materials
  - They are designated by SB numbers and are derived from ASTM "B" specifications

Overview of ASME Section II – Materials

- Part C, Specifications for Welding Rods, Electrodes, and Filler Metals
  - These material specifications contain requirements for the manufacture, acceptability, chemical composition, mechanical usability, surfacing, testing requirements and procedures, operating characteristics, and intended uses for welding rods, electrodes and filler metals
  - These specifications are designated by SFA numbers and are derived from AWS specifications
- Part D, Properties
  - This part provides tables of design stress values, tensile and yield strength values, and tables and charts of material properties
    - Maximum material stress at temperature
    - Design stress intensity factors

Overview of ASME Section V – Nondestructive Evaluation

- Subsection A, Nondestructive Methods of Examination
  - Many of the inspection methods reference mandatory appendices which apply to specific inspection techniques or applications
    - The requirements may change depending on the appendix used
- Subsection B, Documents Adopted by Section V
  - ASME have adopted several ASTM standards which are included in Section V
- **Acceptance criteria is found in the code of construction not in Section V**



Overview of ASME Section V – Nondestructive Evaluation

- Subsection A, Nondestructive Methods of Examination
  - Article 2, Radiographic Examination
  - Article 4, Ultrasonic Examination Methods for Welds
  - Article 5, Ultrasonic Examination Methods for Materials
  - Article 6, Liquid Penetrant Examination
  - Article 7, Magnetic Particle Examination
  - Article 8, Eddy Current Examination of Tubular Products
  - Article 9, Visual Examination

Overview of ASME Section V – Nondestructive Evaluation

TABLE A-110
IMPERFECTION VS TYPE OF NDE METHOD

	Surface [Note (1)]		Sub-surf. [Note (2)]		Volumetric [Note (3)]				
	VT	PT	MT	ET	RT	UTA	UTS	AE	UTT
Service-Induced Imperfections									
Abrasive Wear (Localized)	●	◑	◑	...	●	◑	◑	...	◑
Baffle Wear (Heat Exchangers)	●	...	...	◑	...	...	...	...	...
Corrosion-Assisted Fatigue Cracks	○	◑	●	...	○	●	...	●	...
Corrosion -Crevice	●	...	...	...	...	...	...	...	○
-General / Uniform	...	...	...	○	◑	...	◑	...	●
-Pitting	●	●	○	...	●	○	○	◑	○
-Selective	●	●	○	...	...	...	...	...	○
Creep (Primary) [Note (4)]	...	...	...	...	...	...	...	...	...
Erosion	●	...	...	...	●	○	◑	...	◑
Fatigue Cracks	○	●	●	◑	◑	●	...	●	...
Fretting (Heat Exchanger Tubing)	◑	...	...	◑	...	...	...	...	◑
Hot Cracking	...	◑	◑	...	◑	○	...	◑	
Hydrogen-Induced Cracking	...	◑	◑	...	○	◑	...	◑	...
Intergranular Stress-Corrosion Cracks	...	...	...	...	...	○	...	...	...
Stress-Corrosion Cracks (Transgranular)	○	◑	●	○	◑	◑	...	◑	...

● – All or most standard techniques will detect this imperfection under all or most conditions.
◑ – One or more standard technique(s) will detect this imperfection under certain conditions.
○ – Special techniques, conditions, and/or personnel qualifications are required to detect this imperfection.

NOTES:
(1) Methods capable of detecting imperfections that are open to the surface only.
(2) Methods capable of detecting imperfections that are either open to the surface or slightly subsurface.
(3) Methods capable of detecting imperfections that may be located anywhere within the examined volume.

Overview of ASME Section V – Nondestructive Evaluation

TABLE A-110
IMPERFECTION VS TYPE OF NDE METHOD

	Surface [Note (1)]		Sub-surf. [Note (2)]		Volumetric [Note (3)]				
	VT	PT	MT	ET	RT	UTA	UTS	AE	UTT
Welding Imperfections									
Burn Through	●	...	...	...	●	◑	...	...	○
Cracks	○	●	●	◑	◑	●	○	●	...
Excessive/Inadequate Reinforcement	●	...	...	...	●	◑	○	...	○
Inclusions (Slag/Tungsten)	...	...	◑	◑	●	◑	○	○	...
Incomplete Fusion	◑	...	◑	◑	◑	●	◑	◑	...
Incomplete Penetration	◑	●	●	◑	●	●	◑	◑	...
Misalignment	●	...	...	...	●	◑	...	...	...
Overlap	◑	●	●	○	...	○	...	...	...
Porosity	●	●	○	...	●	◑	○	○	...
Root Concavity	●	...	...	...	●	◑	○	○	○
Undercut	●	◑	◑	○	●	◑	○	○	...

● – All or most standard techniques will detect this imperfection under all or most conditions.
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Overview of ASME Section V – Nondestructive Evaluation

TABLE A-110
IMPERFECTION VS TYPE OF NDE METHOD

	Surface [Note (1)]		Sub-surf. [Note (2)]		Volumetric [Note (3)]				
	VT	PT	MT	ET	RT	UTA	UTS	AE	UTT
Product Form Imperfections									
Bursts (Forgings)	○	●	●	◑	◑	◑	◑	●	...
Cold Shuts (Castings)	○	●	●	○	●	◑	◑	○	...
Cracks (All Product Forms)	○	●	●	◑	◑	◑	○	●	
Hot Tear (Castings)	○	●	●	◑	◑	◑	○	○	...
Inclusions (All Product Forms)	...	...	◑	◑	●	◑	○	○	...
Lamination (Plate, Pipe)	○	◑	◑	...	...	○	●	○	●
Laps (Forgings)	○	●	●	○	◑	...	○	○	
Porosity (Castings)	●	●	○	...	●	○	○	○	...
Seams (Bar, Pipe)	○	●	●	◑	○	◑	◑	○	...

● – All or most standard techniques will detect this imperfection under all or most conditions.
◑ – One or more standard technique(s) will detect this imperfection under certain conditions.
○ – Special techniques, conditions, and/or personnel qualifications are required to detect this imperfection.

NOTES:
(1) Methods capable of detecting imperfections that are open to the surface only.
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(3) Methods capable of detecting imperfections that may be located anywhere within the examined volume.

Overview of ASME Section V – Nondestructive Evaluation

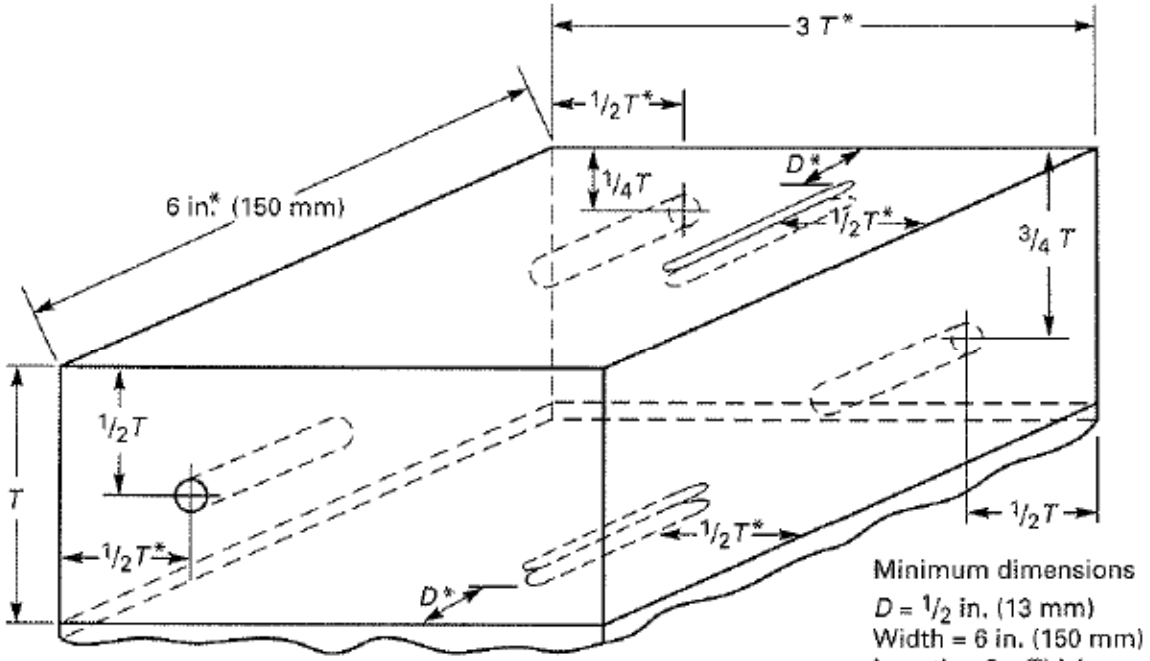
- Each nondestructive evaluation article is generally broken into several subsections which vary depending on applicability
  - Scope
  - General
    - States that a written procedure shall be included and gives requirements that should be included in the procedure
  - Equipment and Materials
    - Provides minimum requirements for the equipment and materials
    - Refers to other ASME and industry documents
  - Miscellaneous Requirements
  - Techniques
    - Describes different techniques of applying the examination method
      - For radiographic examination, the technique could be single-wall or double-wall
      - For ultrasonic examination, the technique could be straight beam or angle beam

Overview of ASME Section V – Nondestructive Evaluation

- Calibration
  - Describes the calibration requirements for the examination method
    - For radiographic examination, the calibration should include verifying the source size and the requirements for either a densitometer or a step wedge comparison
    - For ultrasonic examination, the calibration includes instrument linearity checks and requirement for the calibration block depending on the application
- Examination
  - Includes the steps that should be followed when performing an examination
- Evaluation
  - Describes how to evaluate the evaluation
    - For radiographic examination, the evaluation includes making the sure the film is free from blemishes that may mask indications
    - For ultrasonic examination, the evaluation includes determining what flaws require addition evaluation
      - **Not all ultrasonic reflectors indicate flaws, since certain conditions may produce indications that are not relevant**
- Documentation
  - Defines what should be included in the nondestructive evaluation report

Overview of ASME Section V – Nondestructive Evaluation

FIG. T-434.2.1 NON-PIPING CALIBRATION BLOCKS

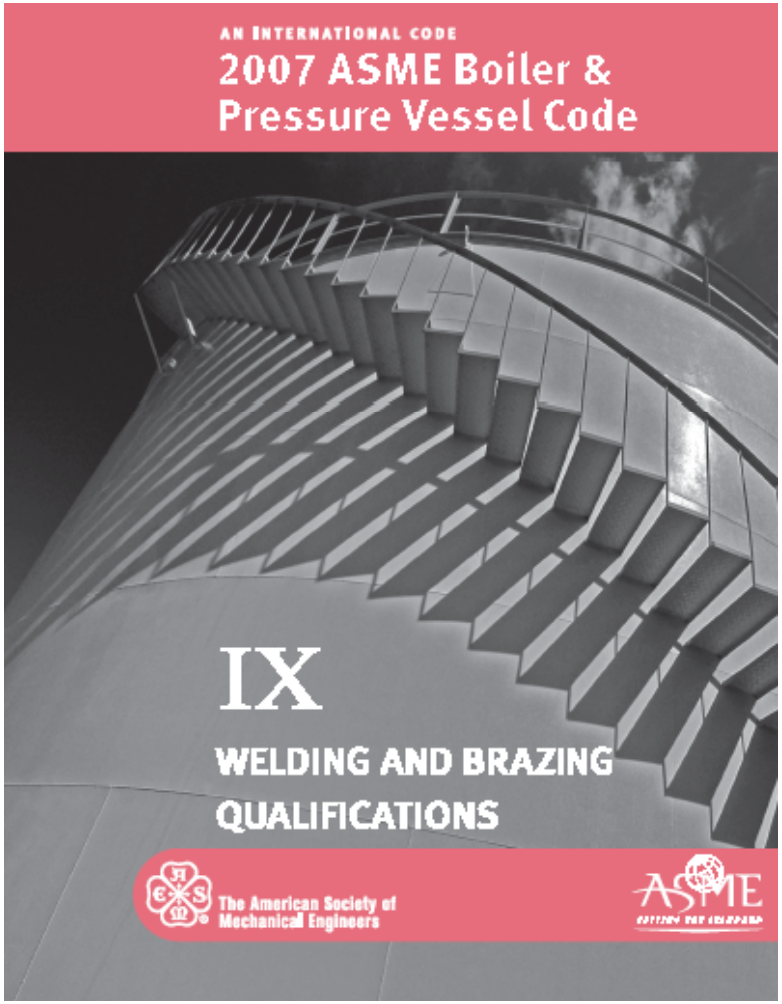


Weld Thickness (t), in. (mm)	Calibration Block Thickness (T), in. (mm)	Hole Diameter, in. (mm)
Up to 1 (25)	3/4 (19) or t	3/32 (2.5)
Over 1 (25) through 2 (50)	1 1/2 (38) or t	1/8 (3)
Over 2 (50) through 4 (100)	3 (75) or t	3/16 (5)
Over 4 (100)	$t \pm 1$ (25)	[Note (1)]

Notch Dimensions, in. (mm)
Notch depth = 2% T
Notch width = 1/4 (6) max.
Notch length = 1 (25) min.

Overview of ASME Section IX – Welding and Brazing Qualifications

- Scope
  - Covers the qualification of welders, welding operators, brazers, and brazing operators, and the procedures employed in welding or brazing
    - Referenced by ASME B&PV Code and ASME B31 Code for Pressure Piping
- Part QW – Welding
  - Article I, II, III, IV, V
- Part QB – Brazing
  - Articles XI, XII, XIII, XIV
- Appendices



Overview of ASME Section IX – Welding and Brazing Qualifications

- Primary purpose for procedure qualification
  - To verify compatibility of materials and techniques to result in a sound weld with acceptable properties
    - WPS qualified by mechanical testing
    - PQR documentation
  - **To qualify a welding procedure the weld must me destructively tested**
- Primary purpose for performance qualification (i.e. welder qualifications)
  - To verify the ability of an individual to execute a qualified welding procedure specification to produce a sound weld
    - Can be qualified by mechanical test or NDE

Overview of ASME Section IX – Welding and Brazing Qualifications

- Part QW Welding
  - Article I, Welding General Requirements
  - Article II, Welding Procedure Qualifications
  - Article III, Welding Performance Qualifications
  - Article IV, Welding Data
  - Article V, Standard Welding Procedure Specifications (SWPS)
- Part QB Brazing
  - Article XI, Brazing General Requirements
  - Article XII, Brazing Procedure Qualifications
  - Article XIII, Brazing Performance Qualifications
  - Article XIV, Brazing Data

Overview of ASME Section IX – Welding Qualifications

- Article I, Welding General Requirements
  - QW-100, General
    - Describes a welding procedure specification (WPS) and procedure qualification record (PQR)
      - WPS defines the way a weld should be made
      - PQR is the documentation that a weld made using the WPS is acceptable
  - QW-110, Weld Orientation
    - Defines flat, horizontal, overhead and vertical
  - QW-120, Test Positions for Groove Welds
  - QW-130, Test Positions for Fillet Welds

Typical PQR format

QW-483 SUGGESTED FORMAT FOR PROCEDURE QUALIFICATION RECORD (PQR)
(See QW-201.2, Section IX, ASME Boiler and Pressure Vessel Code)
Record Actual Conditions Used to Weld Test Coupon.

Company Name _____
Procedure Qualification Record No. _____ Date _____
WPS No. _____
Welding Process(es) _____
Types (Manual, Automatic, Semi-Auto.) _____

JOINTS (QW-402)

Groove Design of Test Coupon
(For combination qualifications, the deposited weld metal thickness shall be recorded for each filler metal or process used.)

BASE METALS (QW-403)
Material Spec. _____
Type or Grade _____
P-No. _____ to P-No. _____
Thickness of Test Coupon _____
Diameter of Test Coupon _____
Other _____

POSTWELD HEAT TREATMENT (QW-407)
Temperature _____
Time _____
Other _____

GAS (QW-408)

	Percent Composition (Gas(es))	(Mixture)	Flow Rate
Shielding			
Trailing			
Backing			

FILLER METALS (QW-404)
SFA Specification _____
AWS Classification _____
Filler Metal F-No. _____
Weld Metal Analysis A-No. _____
Size of Filler Metal _____
Other _____
Deposited Weld Metal _____

ELECTRICAL CHARACTERISTICS (QW-409)
Current _____
Polarity _____
Amps. _____ Volts _____
Tungsten Electrode Size _____
Other _____

POSITION (QW-405)
Position of Groove _____
Weld Progression (Uphill, Downhill) _____
Other _____

TECHNIQUE (QW-410)
Travel Speed _____
String or Weave Bead _____
Oscillation _____
Multipass or Single Pass (per side) _____
Single or Multiple Electrodes _____
Other _____

PREHEAT (QW-406)
Preheat Temp. _____
Interpass Temp. _____
Other _____

(12/86) This form (E00007) may be obtained from the Order Dept., ASME, 345 E. 47th St., New York, N.Y. 10017

QW-483 (Back)

PQR No. _____

Tensile Test (QW-150)

Specimen No.	Width	Thickness	Area	Ultimate Total Load lb	Ultimate Unit Stress psi	Type of Failure & Location

Guided-Bend Tests (QW-160)

Type and Figure No.	Result

Toughness Tests (QW-170)

Specimen No.	Notch Location	Notch Type	Test Temp.	Impact Values	Lateral Exp.		Drop Weight	
					% Shear	Mils	Break	No Break

Fillet-Weld Test (QW-180)

Result — Satisfactory: Yes _____ No _____ Penetration into Parent Metal: Yes _____ No _____
Macro—Results _____

Other Tests

Type of Test _____
Deposit Analysis _____
Other _____

Welder's Name _____ Clock No. _____ Stamp No. _____
Tests conducted by: _____ Laboratory Test No. _____
We certify that the statements in this record are correct and that the test welds were prepared, welded, and tested in accordance with the requirements of Section IX of the ASME Code.

Manufacturer _____

Date _____ By _____
(Detail of record of tests are illustrative only and may be modified to conform to the type and number of tests required by the Code.)

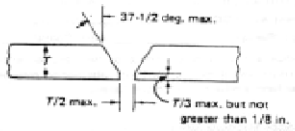
Typical WPS format

QW-482 SUGGESTED FORMAT FOR WELDING PROCEDURE SPECIFICATION (WPS)
(See QW-201.1, Section IX, ASME Boiler and Pressure Vessel Code)

Company Name _____ By _____
Welding Procedure Specification No. _____ Date _____ Supporting PQR No.(s) _____
Revision No. _____ Date _____
Welding Process(es) _____ Type(s) _____
(Automatic, Manual, Machine, or Semi-Auto.)

JOINTS (QW-402) Details
Joint Design _____
Backing (Yes) _____ (No) _____
Backing Material (Type) _____
(Refer to both backing and retainers.)
☐ Metal ☐ Nonfusing Metal
☐ Nonmetallic ☐ Other

Sketches, Production Drawings, Weld Symbols or Written Description should show the general arrangement of the parts to be welded. Where applicable, the root spacing and the details of weld groove may be specified.



(At the option of the Mfgr., sketches may be attached to illustrate joint design, weld layers and bead sequence, e.g. for notch toughness procedures, for multiple process procedures, etc.)

*BASE METALS (QW-403)
P-No. _____ Group No. _____ to P-No. _____ Group No. _____
OR
Specification type and grade _____
to Specification type and grade _____
OR
Chem. Analysis and Mech. Prop. _____
to Chem. Analysis and Mech. Prop. _____
Thickness Range:
Base Metal: Groove _____ Fillet _____
Pipe Dia. Range: Groove _____ Fillet _____
Other _____

*FILLER METALS (QW-404)

Spec. No. (SFA)		
AWS No. (Class)		
F-No.		
A-No.		
Size of Filler Metals		
Deposited Weld Metal		
Thickness Range:		
Groove		
Fillet		
Electrode-Flux (Class)		
Flux Trade Name		
Consumable Insert		
Other		

*Each base metal-filler metal combination should be recorded individually.

(12/86) This form (E00006) may be obtained from the ASME Order Dept., 22 Law Drive, Box 2300, Fairfield, NJ 07007-2300

QW-482 (Back)
WPS No. _____ Rev. _____

POSITIONS (QW-405)
Position(s) of Groove _____
Welding Progression: Up _____ Down _____
Position(s) of Fillet _____

POSTWELD HEAT TREATMENT (QW-407)
Temperature Range _____
Time Range _____

PREHEAT (QW-406)
Preheat Temp. Min. _____
Interpass Temp. Max. _____
Preheat Maintenance _____
(Continuous or special heating where applicable should be recorded)

GAS (QW-408)

	Percent Composition		
	Gas(es)	(Mixture)	Flow Rate
Shielding			
Trailing			
Backing			

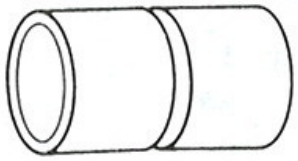
ELECTRICAL CHARACTERISTICS (QW-409)
Current AC or DC _____ Polarity _____
Amps (Range) _____ Volts (Range) _____
(Amps and volts range should be recorded for each electrode size, position, and thickness, etc. This information may be listed in a tabular form similar to that shown below.)
Tungsten Electrode Size and Type _____
(Pure Tungsten, 2% Thoriated, etc.)
Mode of Metal Transfer for GMAW _____
(Spray arc, short circuiting arc, etc.)
Electrode Wire feed speed range _____

TECHNIQUE (QW-410)
String or Weave Bead _____
Orifice or Gas Cup Size _____
Initial and Interpass Cleaning (Brushing, Grinding, etc.) _____
Method of Back Gouging _____
Oscillation _____
Contact Tube to Work Distance _____
Multiple or Single Pass (per side) _____
Multiple or Single Electrodes _____
Travel Speed (Range) _____
Peening _____
Other _____

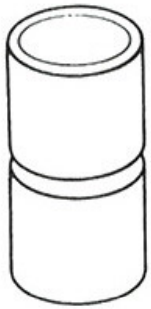
Weld Layer(s)	Process	Filler Metal Class	Filler Metal Dia.	Current Type Polar.	Current Amp. Range	Volt Range	Travel Speed Range	Other (e.g., Remarks, Comments, Hot Wire Addition, Technique, Torch Angle, Etc.)

Test Positions for Groove Welds in Pipe

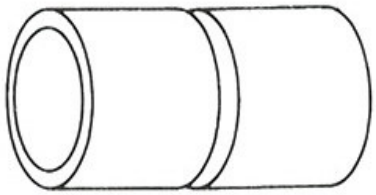
QW-461.4 GROOVE WELDS IN PIPE — TEST POSITIONS



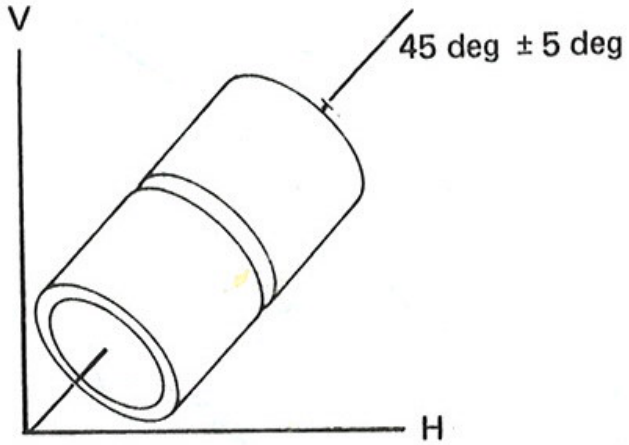
(a) 1G Rotated



(b) 2G



(c) 5G



(d) 6G

Overview of ASME Section IX – Welding Qualifications

- Article I, Welding General Requirements
  - QW-140, Types and Purposes of Tests & Examinations
    - Describes the types of tests that are used to qualify welding procedures including acceptance criteria
  - QW-150, Tension Tests
  - QW-160, Guided-Bend Tests
  - QW-170, Notch-Toughness Tests
  - QW-180, Fillet-Weld Tests
  - QW-190, Other Tests and Examinations
    - Describes NDE inspection methods including acceptance criteria for qualifying procedures and welder qualification
    - References back to Section V
      - QW-191 Radiographic Examination
      - QW-194 Visual Examination
      - QW-195 Liquid Penetrant Examination

Overview of ASME Section IX – Welding Qualifications

- Article II, Welding Procedure Qualifications
  - QW-200, General
    - Describes what the information belong in the WPS and PQR
    - Changes to the WPS
      - Changes can be made to nonessential variables without requalification
      - Changes to essential variables or supplementary essential variable (when required) require requalification
    - Manufacturer's and Contractor's responsibility
    - Processes covered
      - Oxy-fuel, SMAW, SAW, GMAW, FCAW, GTAW, PAW, ESW, EGW, EBW, Stud, Inertia & Cont. Drive Friction Welding, Resistance Welding, LBW, Flash Welding
    - Type and number of tests required for procedure qualification

Overview of ASME Section IX – Welding Qualifications

QW-451.1
GROOVE-WELD TENSION TESTS AND TRANSVERSE-BEND TESTS

Thickness T of Test Coupon, Welded, in. (mm)	Range of Thickness T of Base Metal, Qualified, in. (mm) [Notes (1) and (2)]		Maximum Thickness t of Deposited Weld Metal, Qualified, in. (mm) [Notes (1) and (2)]	Type and Number of Tests Required (Tension and Guided-Bend Tests) [Note (2)]			
	Min.	Max.		Tension, QW-150	Side Bend, QW-160	Face Bend, QW-160	Root Bend, QW-160
Less than 1/16 (1.5)	T	$2T$	$2t$	2	...	2	2
1/16 to 3/8 (1.5 to 10), incl.	1/16 (1.5)	$2T$	$2t$	2	Note (5)	2	2
Over 3/8 (10), but less than 3/4 (19)	3/16 (5)	$2T$	$2t$	2	Note (5)	2	2
3/4 (19) to less than 1 1/2 (38)	3/16 (5)	$2T$	$2t$ when $t < 3/4$ (19)	2 [Note (4)]	4	...	...
3/4 (19) to less than 1 1/2 (38)	3/16 (5)	$2T$	$2T$ when $t \geq 3/4$ (19)	2 [Note (4)]	4	...	...
1 1/2 (38) to 6 (150), incl.	3/16 (5)	8 (200) [Note (3)]	$2t$ when $t < 3/4$ (19)	2 [Note (4)]	4	...	...
1 1/2 (38) to 6 (150), incl.	3/16 (5)	8 (200) [Note (3)]	8 (200) [Note (3)] when $t \geq 3/4$ (19)	2 [Note (4)]	4	...	...
Over 6 (150)	3/16 (5)	1.33T [Note (3)]	$2t$ when $t < 3/4$ (19)	2 [Note (4)]	4	...	...
Over 6 (150)	3/16 (5)	1.33T [Note (3)]	1.33T [Note (3)] when $t \geq 3/4$ (19)	2 [Note (4)]	4	...	...

NOTES:
(1) The following variables further restrict the limits shown in this table when they are referenced in QW-250 for the process under consideration: QW-403.9, QW-403.10, QW-404.32, and QW-407.4. Also, QW-202.2, QW-202.3, and QW-202.4 provide exemptions that supersede the limits of this table.
(2) For combination of welding procedures, see QW-200.4.
(3) For the SMAW, SAW, GMAW, and GTAW welding processes only; otherwise per Note (1) or $2T$, or $2t$, whichever is applicable.
(4) See QW-151.1, QW-151.2, and QW-151.3 for details on multiple specimens when coupon thicknesses are over 1 in. (25 mm).
(5) Four side-bend tests may be substituted for the required face- and root-bend tests, when thickness T is 3/8 in. (10 mm) and over.

Overview of ASME Section IX – Welding Qualifications

- Article II, Welding Procedure Qualifications
  - QW-250, Welding Variables
    - Lists the essential, nonessential, and supplementary essential variables for each welding process in Section IX
    - Essential variables
      - Those in which a change is considered to affect the mechanical properties of the weldment, and shall require requalification
    - Nonessential variables
      - Those in which a change may be made in the WPS without requalification
    - Supplementary essential variables
      - When notch-toughness is required, supplementary essential variables become essential variables

- **The procedure variables cover all aspects of the weld quality**

Overview of ASME Section IX – Welding Qualifications

QW-255
WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS)
Gas Metal-Arc Welding (GMAW and FCAW)

Paragraph		Brief of Variables	Essential	Supplementary Essential	Nonessential
QW-402 Joints	.1	ϕ Groove design			X
	.4	– Backing			X
	.10	ϕ Root spacing			X
	.11	± Retainers			X
QW-403 Base Metals	.5	ϕ Group Number		X	
	.6	*T* Limits		X	
	.8	ϕ *T* Qualified	X		
	.9	*t* Pass > 1/2 in. (13 mm)	X		
	.10	*T* limits (S. cir. arc)	X		
	.11	ϕ P-No. qualified	X		
	.13	ϕ P-No. 5/9/10	X		
QW-404 Filler Metals	.4	ϕ F-Number	X		
	.5	ϕ A-Number	X		
	.6	ϕ Diameter			X
	.12	ϕ Classification		X	
	.23	ϕ Filler metal product form	X		
	.24	± Supplemental ϕ	X		
	.27	ϕ Alloy elements	X		
	.30	ϕ *t*	X		
	.32	*t* Limits (S. cir. arc)	X		
	.33	ϕ Classification			X
QW-405 Positions	.1	+ Position			X
	.2	ϕ Position		X	
	.3	ϕ ↑↓ Vertical welding			X
QW-406 Preheat	.1	Decrease > 100°F (55°C)	X		
	.2	ϕ Preheat maint.			X
	.3	Increase > 100°F (55°C) (IP)		X	
QW-407 PWHT	.1	ϕ PWHT	X		
	.2	ϕ PWHT (T & T range)		X	
	.4	*T* Limits	X		

QW-255
WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS) (CONT'D)
Gas Metal-Arc Welding (GMAW and FCAW)

Paragraph		Brief of Variables	Essential	Supplementary Essential	Nonessential
QW-408 Gas	.1	± Trail or ϕ comp.			X
	.2	ϕ Single, mixture, or %	X		
	.3	ϕ Flow rate			X
	.5	± or ϕ Backing flow			X
	.9	– Backing or ϕ comp.	X		
	.10	ϕ Shielding or trailing	X		
QW-409 Electrical Characteristics	.1	> Heat input		X	
	.2	ϕ Transfer mode	X		
	.4	ϕ Current or polarity		X	X
	.8	ϕ I & E range			X
QW-410 Technique	.1	ϕ String/weave			X
	.3	ϕ Orifice, cup, or nozzle size			X
	.5	ϕ Method cleaning			X
	.6	ϕ Method back gouge			X
	.7	ϕ Oscillation			X
	.8	ϕ Tube-work distance			X
	.9	ϕ Multiple to single pass/side		X	X
	.10	ϕ Single to multiple electrodes		X	X
	.15	ϕ Electrode spacing			X
	.25	ϕ Manual or automatic			X
	.26	± Peening			X
	.64	Use of thermal processes	X		

Legend:
+ Addition – Deletion > Increase/greater than < Decrease/less than ↑ Uphill ↓ Downhill ← Forehand → Backhand ϕ Change

Overview of ASME Section IX – Welding Qualifications

Paragraph		Brief of Variables	Essential	Supplementary Essential	Nonessential
QW-406 Preheat	.1	Decrease > 100°F (55°C)	X		
	.2	ϕ Preheat maint.			X
	.3	Increase > 100°F (55°C) (IP)		X	

QW-406.1 A decrease of more than 100°F (55°C) in the preheat temperature qualified. The minimum temperature for welding shall be specified in the WPS.

Overview of ASME Section IX – Welding Qualifications

- Article III, Welding Performance Qualifications
  - QW-300, General
    - Welders or welding operators may be qualified by mechanical bending tests, radiography of a test plate, or radiography of the initial production weld
    - **Welders are qualified to weld with a process not a specific WPS**
  - QW-320, Retests and Renewal of Qualifications
  - QW-350, Welding Variables for Welders
  - QW-360, Welding Variables for Welding Operators

Overview of ASME Section IX – Welding Qualifications

QW-355
SEMIAUTOMATIC GAS METAL-ARC WELDING (GMAW)
[This Includes Flux-Cored Arc Welding (FCAW)]
Essential Variables

Paragraph		Brief of Variables
QW-402 Joints	.4	– Backing
QW-403 Base Metals	.16	ϕ Pipe diameter
	.18	ϕ P-Number
QW-404 Filler Metals	.15	ϕ F-Number
	.30	ϕ *t* Weld deposit
	.32	*t* Limit (S. Cir. Arc.)
QW-405 Positions	.1	+ Position
	.3	ϕ ↑↓ Vertical welding
QW-408 Gas	.8	– Inert backing
QW-409 Electrical	.2	ϕ Transfer mode

Overview of ASME Section IX – Welding Qualifications

- Article IV, Welding Data
  - QW-400, Variables
    - QW-410, Technique
    - QW-420, Material Groupings
      - P-Numbers
    - QW-430, F-Numbers
    - QW-440, Weld Metal Chemical Composition
    - QW-450, Specimens
    - QW-460, Graphics
    - QW-490, Definitions
  - Variables are grouped into categories
    - Some variables apply to all process
      - Preheat, Base Metal Thickness, etc.
    - Some variables apply to one or two processes
      - Shielding gas, Shielding Flux, etc.

Overview of ASME Section IX – Welding Qualifications

A08/07

QW/QB-422 FERROUS/NONFERROUS P-NUMBERS AND S-NUMBERS (CONT'D)

Grouping of Base Metals for Qualification

Ferrous (CONT'D)											
				Welding				Brazing			
Spec. No.	Type or Grade	UNS No.	Minimum Specified Tensile, ksi (MPa)	P-No.	Group No.	S-No.	Group No.	P-No.	S-No.	Nominal Composition	Product Form
SA-249	TP316L	S31603	70 (485)	8	1	...	...	102	...	16Cr–12Ni–2Mo	Welded tube
SA-249	TP316H	S31609	75 (515)	8	1	...	...	102	...	16Cr–12Ni–2Mo	Welded tube
SA-249	TP316N	S31651	80 (550)	8	1	...	...	102	...	16Cr–12Ni–2Mo–N	Welded tube
SA-249	TP316LN	S31653	75 (515)	8	1	...	...	102	...	16Cr–12Ni–2Mo–N	Welded tube
SA-249	TP317	S31700	75 (515)	8	1	...	...	102	...	18Cr–13Ni–3Mo	Welded tube
SA-249	TP317L	S31703	75 (515)	8	1	...	...	102	...	18Cr–13Ni–3Mo	Welded tube
SA-249	S31725	S31725	75 (515)	8	4	...	...	102	...	19Cr–15Ni–4Mo	Welded tube
SA-249	S31726	S31726	80 (550)	8	4	...	...	102	...	19Cr–15.5Ni–4Mo	Welded tube
SA-249	TP321	S32100	75 (515)	8	1	...	...	102	...	18Cr–10Ni–Ti	Welded tube
SA-249	TP321H	S32109	75 (515)	8	1	...	...	102	...	18Cr–10Ni–Ti	Welded tube
SA-249	TP347	S34700	75 (515)	8	1	...	...	102	...	18Cr–10Ni–Cb	Welded tube
SA-249	TP347H	S34709	75 (515)	8	1	...	...	102	...	18Cr–10Ni–Cb	Welded tube
SA-249	TP348	S34800	75 (515)	8	1	...	...	102	...	18Cr–10Ni–Cb	Welded tube
SA-249	TP348H	S34809	75 (515)	8	1	...	...	102	...	18Cr–10Ni–Cb	Welded tube
SA-249	TPXM-15	S38100	75 (515)	8	1	...	...	102	...	18Cr–18Ni–2Si	Welded tube
SA-250	T1b	K11422	53 (365)	3	1	...	...	101	...	C–0.5Mo	E.R.W. tube
SA-250	T1	K11522	55 (380)	3	1	...	...	101	...	C–0.5Mo	E.R.W. tube
SA-250	T2	K11547	60 (415)	3	1	...	...	101	...	0.5Cr–0.5Mo	E.R.W. tube
SA-250	T11	K11597	60 (415)	4	1	...	...	102	...	1.25Cr–0.5Mo–Si	E.R.W. tube
SA-250	T1a	K12023	60 (415)	3	1	...	...	101	...	C–0.5Mo	E.R.W. tube
SA-250	T12	K11562	60 (415)	4	1	...	...	102	...	1Cr–0.5Mo	E.R.W. tube
SA-250	T22	K21590	60 (415)	5A	1	...	...	102	...	2.25Cr–1Mo	E.R.W. tube
A 254	Cl.1	K01001	42 (290)	...	...	...	...	...	101	C	Cu brazed tube
A 254	Cl.2	K01001	42 (290)	...	...	...	...	...	101	C	Cu brazed tube
SA-266	4	K03017	70 (485)	1	2	...	...	101	...	C–Mn–Si	Forgings
SA-266	1	K03506	60 (415)	1	1	...	...	101	...	C–Si	Forgings
SA-266	2	K03506	70 (485)	1	2	...	...	101	...	C–Si	Forgings
SA-266	3	K05001	75 (515)	1	2	...	...	101	...	C–Si	Forgings
SA-268	TP405	S40500	60 (415)	7	1	...	...	102	...	12Cr–1Al	Smls. & welded tube
SA-268	S40800	S40800	55 (380)	7	1	...	...	102	...	12Cr–Ti	Smls. & welded tube
SA-268	TP409	S40900	55 (380)	7	1	...	...	102	...	11Cr–Ti	Smls. & welded tube
SA-268	TP410	S41000	60 (415)	6	1	...	...	102	...	13Cr	Smls. & welded tube
SA-268	S41500	S41500	115 (795)	6	4	...	...	102	...	13Cr–4.5Ni–Mo	Smls. & welded tube
SA-268	TP429	S42900	60 (415)	6	2	...	...	102	...	15Cr	Smls. & welded tube
SA-268	TP430	S43000	60 (415)	7	2	...	...	102	...	17Cr	Smls. & welded tube
SA-268	TP439	S43035	60 (415)	7	2	...	...	102	...	18Cr–Ti	Smls. & welded tube

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Overview of ASME Section IX – Welding Qualifications

P-No.	Description
1	C, C-Mn, and C-Mn-Si steels
3	Low-alloy steels [Mo, Mn-Mo, Si-Mo and Cr-Mo (Cr ≤ ¾% and total alloy content < 2%)]
4	Cr-Mo low-alloy steels with Cr between ¾% and 2% and total alloy content < 2 ¾%
5A	Cr-Mo low-alloy steels with Cr ≤ 3% and < 85 ksi minimum tensile strength
5B	Cr-Mo low-alloy steels with Cr > 3% and ≤ 85 ksi minimum tensile strength
5C	Cr-Mo low-alloy steels with Cr between 2 ¼ % and 3% and ≥ 85 ksi minimum tensile strength
6	Martensitic stainless steels
7	Ferritic stainless steels - nonhardneable
8	Austenitic stainless steels

Overview of ASME Section IX – Welding Qualifications

P-No.	Description
9A, 9B, 9C	Nickel alloy steels with 4.5% Ni
10A – 10K	Mn-V and Cr-V steels, 26% Cr-3% Ni-3% Mo, and 29% Cr-4% Mo-2% Ni steels and duplex stainless steels
11A, 11B	Low-alloy quench and tempered steels with > 95 ksi minimum tensile strength
21 – 25	Aluminum and aluminum-base alloys
31 – 35	Copper and copper-base alloys
41 – 47	Nickel and nickel-base alloys
51 – 53	Titanium and titanium-base alloys
61, 62	Zirconium and zirconium-base alloys

Overview of ASME Section IX – Welding Qualifications

- Article V, Standard Welding Procedure Specifications (SWPSs)
  - SWPSs that may be used for Section IX are listed in Appendix E
  - AWS B2.1, Standard Welding Procedure Specifications
    - Each is specific to the combination of base materials, welding process(es), and welding filler metals covered by the scope of each
    - Supported by procedure qualification records (PQRs)
  - If the SWPS, or a similar SWPS hasn't been used by the manufacturer, than they must weld and test one groove weld test coupon following the SWPS
    - Additional SWPSs that are similar may be used without demonstration
      - Limitations apply

Overview of ASME Section XI – Rules for Inservice Inspection of Nuclear Power Plant Components

- ASME Section XI is separated into three divisions depending on application
  - Division 1, Rules for Inspection and Testing of Components of Light-Water Cooled Reactors
    - IWA, General requirements
    - IWB, Requirements for Class 1
    - IWC, Requirements for Class 2
    - IWD, Requirements for Class 3
    - IDE, Requirements for Class MC
    - IWF, Requirements for Supports
    - IWL, Requirements for Concrete Components
    - Mandatory Appendices
    - Non-Mandatory Appendices
  - Division 2, Rules for Inspection and Testing of Components of Gas-Cooled Reactors
  - Division 3, Rules for Inspection and Testing of Components of Liquid Metal Cooled Reactors

Overview of ASME Section XI – Rules for Inservice Inspection of Nuclear Power Plant Components

- Division 1, Rules for Inspection and Testing of Components of Light-Water Cooled Reactors
  - IWA, General Requirements
    - IWA-1000, Scope and Responsibility
    - IWA-2000, Examination and Inspection
      - Includes the qualifications of the examination personnel, the examination methods and inspection programs
    - IWA-3000, Standards for Examination Evaluation
      - Discuss how the evaluate the examination and determine flaws
    - IWA-4000, Repair/Replacement Activities
      - Defines what needs to be repaired, how to make the repair and how to inspect the repair
    - IWA-5000, System Pressure Tests
      - Discuss how to pressure test the system and document the results
    - IWA-6000, Records and Reports
    - IWA-9000, Glossary

Overview of ASME Section XI – Rules for Inservice Inspection of Nuclear Power Plant Components

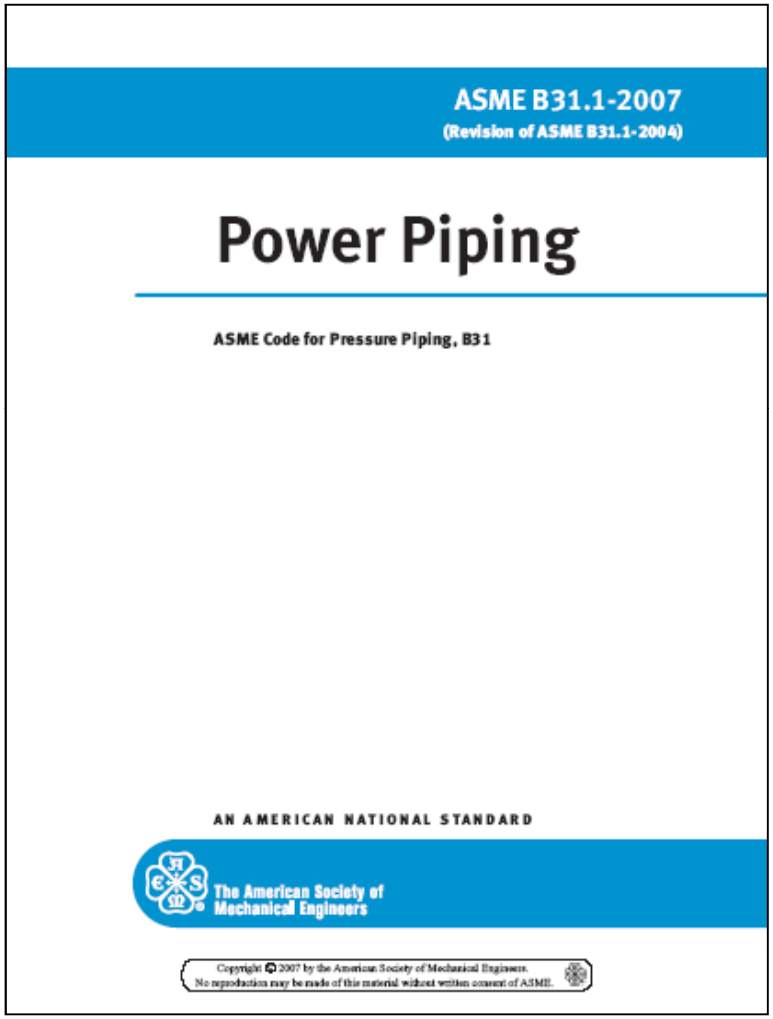
- Division 1, Rules for Inspection and Testing of Components of Light-Water Cooled Reactors
  - IWB, Class 1 Components
    - IWB-1000, Scope and Responsibility
    - IWB-2000, Examination and Inspection
      - Defines how and when to inspect
    - IWB-3000, Acceptance Standards
      - Provides descriptions of acceptable flaws and methods to analysis flaws
    - IWB-5000, System Pressure Tests
      - Discuss how to pressure test the system and document the results
  - IWC-XXXX, Class 2 Components and IWD-XXXX, Class 3 Components
    - Generally IWC and IWD have much less detail than IWB, and IWC and IWD will frequently refer user to IWB

Overview of ASME Section XI – Rules for Inservice Inspection of Nuclear Power Plant Components

- Division 1, Rules for Inspection and Testing of Components of Light-Water Cooled Reactors
  - IWE-XXXX, Requirements for Class MC and Metallic Liners of Class CC Components of Light-Water Cooled Plants
  - IWF-XXXX, Requirements for Class 1, 2, 3 and MC component supports of Light-Water Cooled Plants
  - IWL-XXXX, Requirements for Class CC Concrete Components of Light-Water Cooled Plants
  - Appendices
    - Mandatory (I-X)
    - Nonmandatory (A-R)

Overview of ASME B31.1 – Power Piping

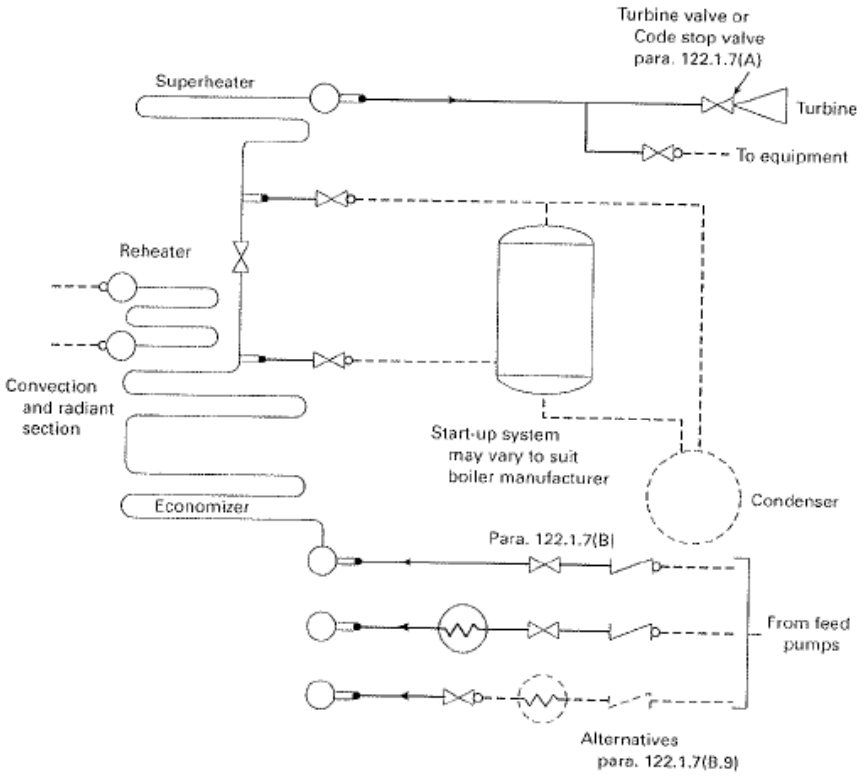
- Chapter I, Scope and Definitions
- Chapter II, Design
- Chapter III, Materials
- Chapter IV, Dimensional Requirements
- Chapter V, Fabrication, Assembly, and Erection
- Chapter VI, Inspection, Examination, and Testing
- Chapter VII, Operation and Maintenance
- Mandatory Appendices
- Nonmandatory Appendices



Overview of ASME B31.1 – Power Piping

- Chapter I, Scope and Definitions
  - The code includes piping found in electric power generating stations, industrial and institutional plants, geothermal heating systems, and central and district heating and cooling systems
    - Includes but not limited to steam, water, oil, gas, and air service
      - Where steam or vapor is generated at a minimum pressure 15 psig
      - Where high temperature water is generated at a minimum pressure of 160 psig and/or a minimum temperature of 250ºF (120ºC)
  - Defines what applications are not covered by B31.1
    - Components covered by Sections of the ASME Boiler and Pressure Vessel Code
    - Steam and condensate piping design for 15 psig or less, or hot water systems designed for 30 psig or less
    - Towers, building frames, tanks, mechanical equipment, instruments, and foundations
    - Many other applications

Overview of ASME B31.1 – Power Piping



Administrative Jurisdiction and Technical Responsibility

——— Boiler Proper — The ASME Boiler and Pressure Vessel Code (ASME BPVC) has total administrative jurisdiction and technical responsibility. Refer to ASME BPVC Section I Preamble.

•——— Boiler External Piping and Joint (BEP) — The ASME BPVC has total administrative jurisdiction (mandatory certification by Code Symbol stamping, ASME Data Forms, and Authorized Inspection) of BEP. The ASME Section Committee B31.1 has been assigned technical responsibility. Refer to ASME BPVC Section I Preamble, fifth, sixth, and seventh paragraphs and ASME B31.1 Scope, para. 100.1.2(A). Applicable ASME B31.1 Editions and Addenda are referenced in ASME BPVC Section I, PG-58.3.

o----- Nonboiler External Piping and Joint (NBEP) — The ASME Code Committee for Pressure Piping, B31, has total administrative and technical responsibility.

Overview of ASME B31.1 – Power Piping

- Chapter II, Design
  - Design conditions are define pressure, temperatures and various forces applicable to the design of power piping systems
    - Design for the most severe conditions
  - Includes design criteria for piping and components in the piping system
    - Temperature-Pressure Ratings
    - Allowable stress
    - Weld joint efficiency factors
    - Reinforcement of branch connections
    - Valve requirements
    - Flange, bolting, facing and gasket requirements
    - Pipe supports

Overview of ASME B31.1 – Power Piping

- Chapter III, Materials
  - Refers to ASME Section II, ASTM Specifications, and numerous other industry standards for the type and product form of materials using in piping systems
  - Refers to tabulated stress values in Appendix A
    - Specifies the difference between listed materials, unlisted materials and unknown materials
  - Describes limitations of different material types
    - Temperature limitations
    - Pressure limitations
- Chapter IV, Dimensional Requirements
  - Refers to other ASME Sections, other ASTM Specifications, and numerous other industry standards for the dimensional tolerances of materials using in piping systems

Overview of ASME B31.1 – Power Piping

- Chapter V, Fabrication, Assembly, and Erection
  - Address specific requirements related to fabrication, assembly, and erection which include welding and brazing
    - The qualification of welding procedures and welder and welding operators shall conform to the requirements of the ASME Section IX
      - Each employer shall be responsible for qualifying any WPS; however a WPS qualified by a technically competent group or agency could be used if approved by the owner
      - Each employer shall be responsible for qualifying all the welders and welding operators employed by him; however the employer can accept qualification from previous employers if accepted by the owner
    - The welding materials shall conform to ASME Section II Part C
    - List visual weld contour criteria including some acceptable fillet weld sizes
    - Preheat and PWHT Requirements
    - Assembly guidance for other then welded joints

Overview of ASME B31.1 – Power Piping

- Chapter VI, Inspection, Examination, and Testing
  - Listed the NDE methods that are allowed
    - Visual Examination
    - Magnetic Particle Examination
    - Liquid Penetrant Examination
    - Radiography
    - Ultrasonic Inspection
  - States each examination method shall be performed in accordance with ASME Section V
  - Gives the construction acceptance criteria for each NDE method
    - The construction acceptance criteria may be different than the qualification acceptance criteria
  - Personnel who perform nondestructive examination of welds shall be qualified and certified for each examination method
    - References ASME Section V for personnel qualification
  - Provides guidance for pressure testing

Overview of ASME B31.1 – Power Piping

Table 136.4 Mandatory Minimum Nondestructive Examinations for Pressure Welds or Welds to Pressure-Retaining Components

	Piping Design Conditions and Nondestructive Examination		
Type Weld	Temperatures Over 750°F (400°C) and at All Pressures	Temperatures Between 350°F (175°C) and 750°F (400°C) Inclusive, With All Pressures Over 1,025 psig [7 100 kPa (gage)]	All Others
Butt welds (girth and longitudinal) [Note (1)]	RT or UT for over NPS 2. MT or PT for NPS 2 and less [Note (2)].	RT or UT for over NPS 2 with thickness over ¾ in. (19.0 mm). VT for all sizes with thickness ¾ in. (19.0 mm) or less.	Visual for all sizes and thicknesses
Welded branch connections (size indicated is branch size) [Notes (3) and (4)]	RT or UT for over NPS 4. MT or PT for NPS 4 and less [Note (2)].	RT or UT for branch over NPS 4 and thickness of branch over ¾ in. (19.0 mm) MT or PT for branch NPS 4 and less with thickness of branch over ¾ in. (19 mm) VT for all sizes with branch thickness ¾ in. (19.0 mm) or less	VT for all sizes and thicknesses
Fillet, socket, attachment, and seal welds	PT or MT for all sizes and thicknesses [Note (5)]	VT for all sizes and thicknesses	VT for all sizes and thicknesses

Overview of ASME B31.1 – Power Piping

- Chapter VI, Inspection, Examination, and Testing

Table 136.4.1 Weld Imperfections Indicated by Various Types of Examination

Imperfection	Visual	Magnetic Particle	Liquid Penetrant	Radiography	Ultrasonic
Crack — surface	X [Note (1)]	X [Note (1)]	X [Note (1)]	X	X
Crack — internal	...	...	...	X	X
Undercut — surface	X [Note (1)]	X [Note (1)]	X [Note (1)]	X	...
Weld reinforcement	X [Note (1)]	...	...	X	...
Porosity	X [Notes (1), (2)]	X [Notes (1), (2)]	X [Notes (1), (2)]	X	...
Slag inclusion	X [Note (2)]	X [Note (2)]	X [Note (2)]	X	X
Lack of fusion (on surface)	X [Notes (1), (2)]	X [Notes (1), (2)]	X [Notes (1), (2)]	X	X
Incomplete penetration	X [Note (3)]	X [Note (3)]	X [Note (3)]	X	X

NOTES:
(1) Applies when the outside surface is accessible for examination and/or when the inside surface is readily accessible.
(2) Discontinuities are detectable when they are open to the surface.
(3) Applies *only* when the inside surface is readily accessible.

Overview of ASME B31.1 – Power Piping

- Chapter VII, Operation and Maintenance
  - The Code does not prescribe detailed operating and maintenance procedures that cover all cases
    - Each Operating Company shall develop operation and maintenance procedures necessary to ensure safe facility operations
    - Some requirements are listed but they do not cover all aspects of operation
  - Company shall perform condition assessments of the piping system at regular intervals as determined by engineering
    - Some requirements are listed but they do not cover all aspects of operation
  - Records shall be maintained and easily accessible for the life of the piping system