DI04019041: Fabrication Technology - Unit 4

GTU Course Presentation

July 24, 2026

Course Contents I

Course Contents II

Discontinuities vs. Defects I

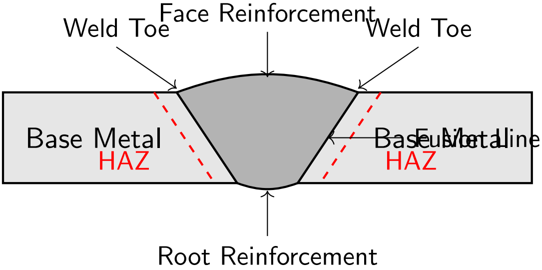
In welding metallurgy and fabrication engineering, a discontinuity and a defect are not synonymous. The transition from a discontinuity to a defect is defined strictly by the governing design code and the component's service conditions.

Discontinuities vs. Defects II

Key Points

- Discontinuity: Any local interruption in the typical physical structure or configuration of a weldment (e.g., porosity, slag, micro-cracks). It is a deviation from homogeneity.
- Defect: A discontinuity whose size, shape, orientation, or location compromises the intended performance of the weldment or fails to meet code acceptance criteria.
- Code Compliance: All defects are discontinuities, but not all discontinuities are defects. A discontinuity only becomes a defect when it exceeds the limits of the applicable standard (e.g., ASME Section VIII).
- Engineering Consequence: Defects require mandatory reject, repair, or scrap procedures, whereas acceptable discontinuities are allowed to remain in service.

Butt Weld Geometry Terminology I



Butt Weld Geometry Terminology II

Key Points

- Weld Face & Root Reinforcement: The weld metal that exceeds the base metal thickness. Excess reinforcement (>3mm in many codes) creates notches and stress risers.
- Weld Toe: The junction between the weld face and the base metal. This area has high stress concentration and is susceptible to fatigue cracking.
- Fusion Line: The boundary between the weld metal and the unmelted base metal, defining the limit of the weld pool.
- Heat-Affected Zone (HAZ): The portion of base metal that has not melted, but has experienced microstructural and mechanical property alterations due to the weld heat cycle.

Fillet Weld Terminology and Mechanics I

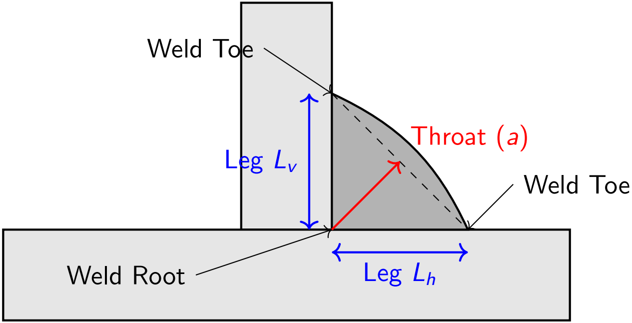
Fillet welds are used to join surfaces that intersect at approximately right angles, such as T-joints, lap joints, and corner joints. Designing and inspecting fillet welds requires precise knowledge of their cross-sectional dimensions.

Fillet Weld Terminology and Mechanics II

Key Points

- Leg Size: The distance from the joint root to the weld toe. Fillet welds are typically sized by their leg length (e.g., a 6mm fillet weld has 6mm legs).
- Theoretical Throat: The perpendicular distance from the hypotenuse of the largest right triangle that can be inscribed within the fillet weld cross-section.
- Effective Throat (a): The minimum distance from the joint root to the weld face, minus any reinforcement. For equal-leg fillet welds, Effective Throat = Leg Size * 0.707.
- Actual Throat: The shortest distance from the root to the weld face. It includes the theoretical throat plus the weld reinforcement (convexity).
- Design Strength: The shear stress of a fillet weld is calculated based on its effective throat, not its leg size

Fillet Weld Cross-Sectional Geometry I



Fillet Weld Cross-Sectional Geometry II

Key Points

- Leg Length (L_v, L_h): Vertical and horizontal legs are generally designed to be equal, though process variables can cause asymmetry.
- Effective Throat (a): Calculated as $a = 0.707 ×L$*forequal* − *legfilletwelds*, *representingthestructuralshearplane*.
- Weld Convexity: The maximum perpendicular distance from the weld face to the line joining the weld toes. Excessive convexity is a defect because it wastes material and concentrates stresses.
- Joint Root: The base intersection where fusion must be fully achieved to prevent root cracks and cold laps.

Classification of Weld Imperfections I

Industrial welding codes classify weld imperfections into standardized groups to streamline non-destructive testing (NDT) and visual inspection workflows (e.g., ISO 6520-1).

Classification of Weld Imperfections II

Key Points

- Group 1 - Cracks: Linear discontinuities caused by high localized stress, thermal contraction, or hydrogen embrittlement. They have zero tolerance in all structural and pressure vessel codes.
- Group 2 - Cavities: Void spaces within the weld, including uniformly distributed porosity, cluster porosity, linear porosity, and shrinkage cavities (piping).
- Group 3 - Solid Inclusions: Entrapped foreign materials, primarily slag inclusions (entrapped flux from SMAW/FCAW), oxide inclusions, or metallic inclusions (tungsten from GTAW).
- Group 4 - Lack of Fusion and Penetration: Incomplete fusion between weld beads or weld-to-base metal (lack of sidewall fusion), and incomplete joint penetration at the weld root.

To guarantee weld quality, fabricators employ testing methods to identify surface and volumetric discontinuities. These methods are divided into Non-Destructive Testing (NDT) and Destructive Testing (DT).

Weld Quality Evaluation: Inspection & NDT II

Key Points

- Visual Testing (VT): The primary and most cost-effective method. VT checks joint fit-up before welding, bead profile during welding, and surface defects post-welding.
- Liquid Penetrant (PT) & Magnetic Particle (MT) Testing: Surface NDT methods. PT uses capillary action for non-porous materials; MT uses magnetic fields to detect surface/near-surface flaws in ferromagnetic steels.
- Ultrasonic (UT) & Radiographic (RT) Testing: Volumetric NDT methods. UT uses high-frequency sound waves to locate depth-specific flaws, while RT uses X-rays or Gamma rays to produce a density-based internal image.
- Destructive Testing (DT): Destructive bend tests (root,

Codes, Standards, and Quality Levels I

Welding is a highly regulated activity. Codes and standards establish the minimum quality level, procedure qualifications, and human performance metrics to ensure structural integrity and public safety.

Codes, Standards, and Quality Levels II

Key Points

- ASME Section IX: Focuses on the qualification of welding procedures (WPS), procedure qualification records (PQR), and welder performance qualifications (WPQ).
- AWS D1.1: The structural steel welding code, detailing weld profiles, allowable tolerances for discontinuities, and visual testing acceptance levels.
- ISO 5817: Quality levels for imperfections in fusion-welded joints. It classifies quality into three levels: Level B (stringent/nuclear), Level C (intermediate), and Level D (moderate/structural).
- Procedure Qualification: A weld must be performed using a qualified Welding Procedure Specification (WPS) that lists essential variables (current, voltage, travel speed, preheat) to guarantee repeatable weld

Weld Defects: Overview and Classification I

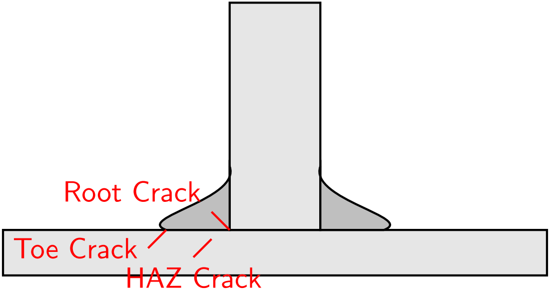
Weld defects are deviations in weld geometry, size, or material soundness exceeding the allowable limits of applicable codes (e.g., ASME Section IX, AWS D1.1). They are classified into dimensional, structural (internal/surface), and chemical/metallurgical defects.

Weld Defects: Overview and Classification II

Key Points

- Dimensional defects: Excess reinforcement, underfill, weld size deviations, distortion, and misalignment.
- Structural defects: Cracks (hot, cold), porosity (scattered, cluster, piping), slag inclusions, undercut, lack of fusion, and incomplete penetration.
- Metallurgical defects: Decarburization, grain growth, and unfavorable phase transformation in the Heat Affected Zone (HAZ).
- Impact: Defects serve as local stress concentrators, drastically reducing fatigue life and load-bearing capacity under dynamic loading.

Structural Defects: Weld Cracks I

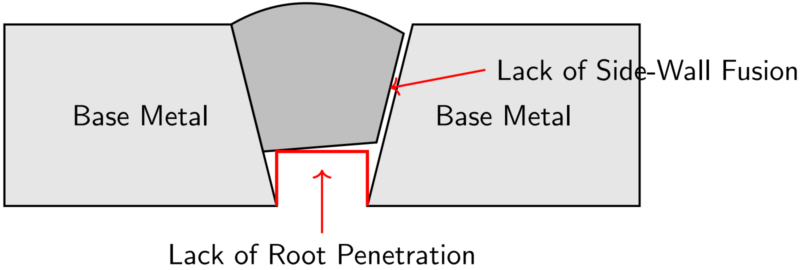


Structural Defects: Weld Cracks II

Key Points

- Cracks are the most severe defects because they act as sharp stress risers and can lead to sudden, catastrophic brittle fracture.
- Hot Cracking (Solidification Cracking): Occurs at elevated temperatures (>900°C) during solidification, typically along the centerline, driven by low-melting segregates (P, S).
- Cold Cracking (Hydrogen-Induced Cracking): Occurs below 150°C, often hours or days after welding. Triggered by a susceptible microstructure (martensite), tensile stress, and diffusible hydrogen.
- Mitigation: Preheat the base metal, control heat input, utilize low-hydrogen electrodes (e.g., E7018), and perform Post-Weld Heat Treatment (PWHT).

Incomplete Fusion and Lack of Penetration I



Incomplete Fusion and Lack of Penetration II

Key Points

- Incomplete Penetration: The weld metal fails to extend through the full thickness of the joint root, leaving an unfused root face that acts as a notch.
- Incomplete Fusion: Failure to fuse the weld metal with the base metal or preceding weld beads (inter-run lack of fusion).
- Causes: Low welding current, excessive travel speed, incorrect electrode angle, or improper joint design (too small root gap/groove angle).
- Consequences: Drastically decreases the effective throat thickness of the weld, reducing tensile and fatigue strength under cyclic loading.

Volumetric and Surface Defects I

Volumetric defects (like porosity and slag inclusions) occupy a three-dimensional volume in the weld, whereas surface defects (like undercut and overlap) compromise the weld profile and transition zone.

Volumetric and Surface Defects II

Key Points

- Porosity: Entrapped gas bubbles (usually hydrogen, nitrogen, or oxygen) that fail to escape before solidification. Can be spherical, clustered, or elongated (piping/wormholes).
- Slag Inclusions: Non-metallic solid material entrapped in the weld metal or between weld runs. Caused by incomplete slag removal in multi-pass welding or low heat input.
- Undercut: A groove melted into the base metal adjacent to the toe of the weld and left unfilled by weld metal. Caused by excessive current or improper electrode manipulation.
- Overlap: Weld metal spilling over the base metal surface without fusing to it, creating a sharp mechanical notch. Caused by low heat input or high deposition rate.

Stages of Weld Inspection I

Quality control is a continuous process divided into three distinct stages: Pre-weld, In-process, and Post-weld inspection. Ensuring quality at each stage minimizes repair costs and project delays.

Stages of Weld Inspection II

Key Points

- Stage 1: Pre-Weld (Before Welding) - Check material certificates, weld groove geometry, root gap, alignment, preheat temperature, tack weld quality, and welder qualifications.
- Stage 2: In-Process (During Welding) - Monitor interpass temperature, welding parameters (voltage, current, travel speed), cleaning between passes, electrode storage/baking, and shielding gas flow rate.
- Stage 3: Post-Weld (After Welding) - Visual inspection of final weld bead profile, checking dimensions (reinforcement height, fillet leg length), and executing NDT/DT as per code requirements.

Destructive Testing (DT) I

Destructive testing involves physically destroying the weldment to evaluate its mechanical properties (strength, ductility, toughness) and structural integrity, crucial for Procedure Qualification Records (PQR).

Key Points

- Tensile Testing: Determines the ultimate tensile strength, yield strength, and elongation of the joint. Transverse tensile tests confirm if the weld is stronger than the base metal.
- Bend Testing: Evaluates the ductility and soundness of the weld. Guided bend tests (face, root, or side bend) reveal internal defects like lack of fusion or cracking when bent 180 degrees.
- Charpy V-Notch Impact Testing: Measures notch toughness and ductile-to-brittle transition temperature, critical for low-temperature applications (ASME Sec VIII).
- Hardness & Macrotech Examination: Hardness traverses (Vickers or Rockwell) map the HAZ to check for brittle martensite phases. Macro-etching reveals weld bead

Non-Destructive Testing (NDT) I

Non-Destructive Testing (NDT) assesses weld soundness without damaging the structure, allowing 100% inspection of critical components in industries like aerospace, pressure vessels, and piping.

Non-Destructive Testing (NDT) II

Key Points

- Visual Testing (VT): The primary, most cost-effective NDT method. Evaluates surface profile, undercut, cracks, and dimensional accuracy using gauges.
- Liquid Penetrant Testing (PT) & Magnetic Particle Testing (MT): PT detects surface-breaking defects via capillary action. MT detects surface and near-surface defects in ferromagnetic materials using magnetic flux leakage.
- Ultrasonic Testing (UT) & Phased Array UT (PAUT): Uses high-frequency sound waves to detect, locate, and size internal planar defects (cracks, lack of fusion). Excellent depth and accuracy.
- Radiographic Testing (RT): Uses X-rays or Gamma rays to produce a volumetric shadowgraph of internal defects (porosity, slag, incomplete penetration) on film or

Inspection vs. Testing I

Understanding the technical distinction between inspection and testing processes in manufacturing quality control.

Inspection vs. Testing II

Key Points

- Inspection is the process of examining a product design, product, service, or process and determining its conformity with specific requirements.
- Testing is the determination of one or more characteristics of an object of conformity assessment according to a specified engineering procedure.
- Inspection is primarily qualitative or involves simple gauge checks (e.g., weld size gauges, thread check, visual checks for surface defects).
- Testing is quantitative and evaluates structural, physical, or chemical performance under applied conditions (e.g., hydrostatic pressure, tensile loads).
- Inspection is often continuous throughout the fabrication workflow; testing is typically a final gatekeeping or procedure qualification activity.

Classifications of Testing I

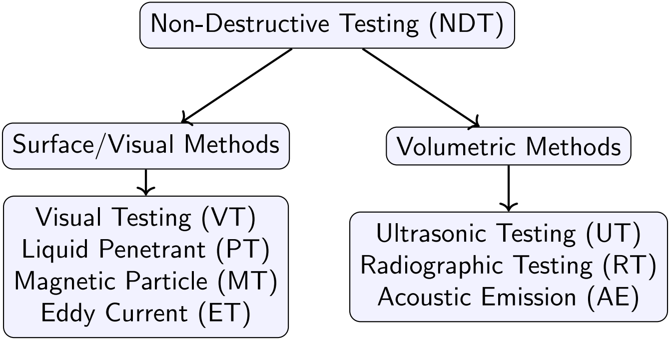
Engineering tests are broadly divided based on whether the test specimen is preserved or damaged during the evaluation process.

Classifications of Testing II

Key Points

- Destructive Testing (DT): Specimens are subjected to mechanical loading until failure to determine material limits and mechanical properties.
- Non-Destructive Testing (NDT): Components are evaluated using physical phenomena (sound, radiation, magnetism) without altering their future serviceability.
- Proof Testing: Applying a safety-factored load to verify structural integrity without causing permanent damage (e.g., proof load test on cranes).
- Leak/Pressure Testing: Verifying joint tightness and pressure-containment integrity using liquid or gas mediums (e.g., vacuum box or hydro-test).
- The selection of testing methods is strictly governed by fabrication codes such as ASME BPVC, AWS D1.1, and ASTM standards.

Non-Destructive Testing (NDT) Methods I



Non-Destructive Testing (NDT) Methods II

Key Points

- Visual Testing (VT) is the most fundamental surface method, detecting gross dimensional variations, misalignment, and open undercut.
- Liquid Penetrant Testing (PT) utilizes capillary action to draw dye into surface-breaking discontinuities on non-porous materials.
- Magnetic Particle Testing (MT) detects surface and near-surface defects in ferromagnetic materials by identifying magnetic flux leakage fields.
- Ultrasonic Testing (UT) uses high-frequency sound waves to scan the internal volume of a weldment for volumetric and planar flaws.
- Radiographic Testing (RT) uses differential absorption of penetrating radiation (X-rays or gamma rays) to image internal defects.

Destructive Testing (DT) of Welds I

Destructive test methods are used to qualify Welding Procedure Specifications (WPS) and welder performance, validating structural design limits.

Destructive Testing (DT) of Welds II

Key Points

- Tensile Testing: Verifies that the transverse weld joint strength meets or exceeds the minimum specified tensile strength of the base metal.
- Guided Bend Testing (Root, Face, Side): Evaluates weld and heat-affected zone (HAZ) ductility, exposing internal fusion defects and slag inclusions.
- Charpy V-Notch Impact Testing: Determines the energy absorbed during fracture, indicating notch toughness and ductile-to-brittle transition temperature.
- Hardness Testing (Vickers HV10 / Rockwell): Maps localized mechanical variations across the weld, HAZ, and base metal to detect brittle microstructures.
- Macro-Etch Examination: Acid-etching of the joint cross-section reveals weld penetration, heat-affected zone boundary, and fusion profile.

Industrial Standards & Testing Codes I

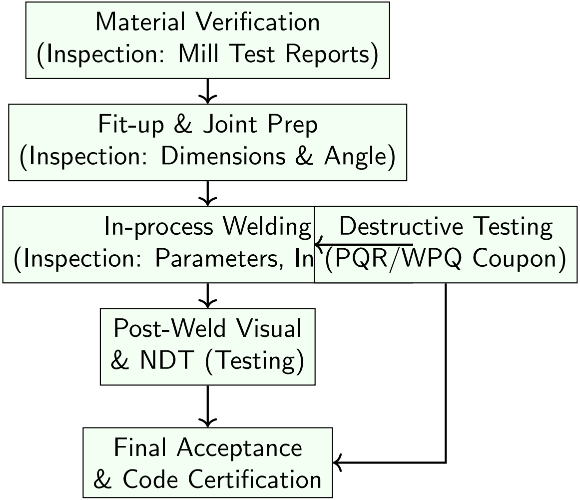
Fabrication testing must be executed in accordance with global regulatory codes to ensure structural safety and legal compliance.

Industrial Standards & Testing Codes II

Key Points

- ASME BPVC Section V: Standard rules for non-destructive examination, specifying procedure controls, calibration blocks, and equipment requirements.
- ASME BPVC Section IX: Standard for welding, brazing, and fusing qualifications, detailing mechanical testing for WPS and welder qualification.
- AWS D1.1: Structural Welding Code for steel, defining ultrasonic, radiographic, visual, and mechanical testing requirements for structural joints.
- ASTM E8/E8M: Standard test methods for tension testing of metallic materials, detailing specimen dimensions and strain rates.
- EN ISO 15614-1: Specification and qualification of welding procedures for metallic materials, defining

Quality Flow in Welded Fabrication I



Quality Flow in Welded Fabrication II

Key Points

- Material Verification ensures that incoming plate and pipe match mill test reports (MTRs) before cutting or preparation begins.
- Fit-up and Joint Preparation inspection verifies root gap, bevel angles, and fit alignment to prevent root-pass weld defects.
- In-process Inspection checks essential variables: preheat temperature, voltage, amperage, shielding gas flow, and interpass cleaning.
- Destructive Testing of test coupons (PQR) is done prior to production to establish that weld metallurgy achieves specified properties.
- Final Acceptance combines NDT reports, visual checks, and dimensional reports into a Manufacturer's Record Book (MRB) for client sign off.

Quality Assurance vs. Quality Control I

Analyzing how inspection and testing act as the enforcement tools within a broader quality management system.

Quality Assurance vs. Quality Control II

Key Points

- Quality Control (QC) is product-focused and reactive; it includes physical inspection and testing to detect defects in the fabricated part.
- Quality Assurance (QA) is process-focused and proactive; it includes creating work procedures, welder audits, and calibration schedules.
- Inspection and testing verify that specific parameters and parameters established during QA planning are strictly adhered to on the shop floor.
- Early stage in-process inspection minimizes weld repairs, significantly reducing overall fabrication cost and scheduling delays.
- Code stamp verification (e.g., ASME U stamp, CE mark) requires complete alignment of both the QA system and QC testing documentation.

Overview of Destructive Testing I

Destructive testing (DT) is a quality control methodology where materials are loaded to failure to directly measure their mechanical limits. Unlike NDE methods governed by ASME Section V, DT provides quantitative stress-strain data required for design and procedure qualification.

Overview of Destructive Testing II

Key Points

- Evaluates fundamental properties: yield strength, tensile strength, ductility, toughness, and compressive limits.
- Primary role in fabrication: Qualification of welding procedures (WPS/PQR) and welder performance per ASME Section IX.
- Crucial for pressure vessel design verification under ASME Section VIII Division 1.
- Ensures welded joints and base materials meet the minimum mechanical design thresholds established in ASME Section II.

Tensile Testing Standards & Procedures (ASTM E8/E8M) I

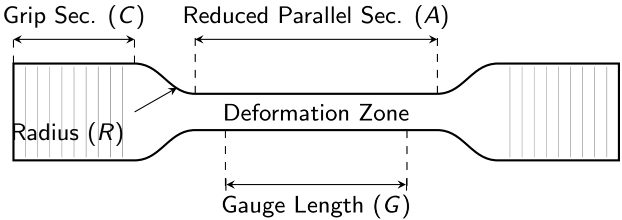
ASTM E8/E8M standardizes the tension testing of metallic materials to determine yield strength, yield point elongation, tensile strength, elongation, and reduction of area.

Tensile Testing Standards & Procedures (ASTM E8/E8M) II

Key Points

- Specimen configuration: Machined plate-type (flat) or round-bar geometries with defined parallel reduced sections.
- Loading control: Conducted using universal testing machines (UTM) with precise rate of straining (0.005 to 0.05 in/in/min).
- Ductility indicators: Percentage elongation measured over a standard 2-inch (50 mm) or 8-inch (200 mm) gauge length.
- Weldment testing: Transverse tension tests per ASME Section IX assess the joint strength relative to the base metal.

Standard Tensile Specimen Geometry I



Standard Tensile Specimen Geometry II

Key Points

- Grip Ends (C): Designed for secure clamping in the UTM wedge grips.
- Transition Fillet (R): Generous radius prevents stress concentrations at the grips.
- Parallel Reduced Section (A): Ensures uniaxial stress state in the target zone.
- Gauge Length (G): Standardized area for strain and elongation measurements.

ASME Tensile Acceptance Criteria I

Welding procedure qualifications (PQR) under ASME Section IX (QW-150) dictate strict tensile acceptance thresholds for pressure vessel fabrications under ASME Section VIII Division 1.

ASME Tensile Acceptance Criteria II

Key Points

- QW-153.1: Weldment tensile strength must not be less than the minimum specified tensile strength of the base metal (S_u).
- Lower Strength Metals: If welding two different base metals, the limit is the lower of the two specified tensile strengths.
- Out-of-Weld Failures: If the specimen breaks in the base metal outside the weld, the test is accepted if strength is ≥ 95

- Weld Metal Failures: If the break occurs in the weld metal, it must meet or exceed 100

Compressive Testing Procedures (ASTM E9) I

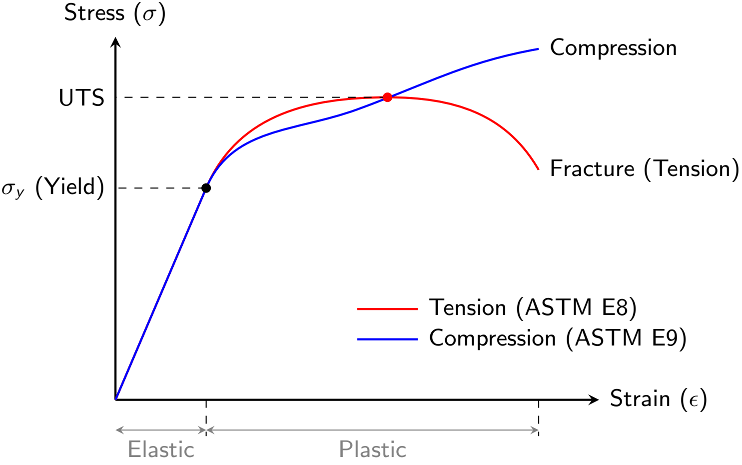
ASTM E9 details the compressive testing of metallic materials. Compression testing evaluates load-bearing capacity under uniaxial compressive forces, vital for heavy support structures.

Compressive Testing Procedures (ASTM E9) II

Key Points

- Specimen design: Cylindrical geometry with length-to-diameter (L/D) ratio of 1.5 to 3 for standard metallic evaluations.
- Buckling mitigation: Low slenderness ratios are maintained to prevent lateral instability and premature column buckling.
- Platen alignment: Loading surfaces must be flat to 0.0002 in/in and perpendicular to the axis within 0.1 degrees.
- Frictional effects: Platen-specimen interfaces are polished and lubricated to minimize radial constraint and subsequent barreling.

Tensile and Compressive Stress-Strain Behavior I



Tensile and Compressive Stress-Strain Behavior II

Key Points

- Elastic Modulus (E): Initial linear slope representing identical atomic bond stiffness in tension and compression.
- Yield Strength ($σ_y$) : *Thepointoftransitionfromelasticdeformationtopermanentplastic*
- Ultimate Tensile Strength (UTS): Maximum nominal tensile stress supported before localized necking begins.
- Strain Hardening: Continued resistance to deformation in compression due to increasing cross-sectional contact area.

Destructive testing serves as the ultimate mechanical qualification for pressure vessels, storage tanks, and high-performance welded fabrications built under code standards.

Industrial Applications & Quality Assurance II

Key Points

- ASME Section VIII Div 1 compliance: Ensures vessel plate materials and welded seams resist operating stresses without brittle failure.
- Welder qualification (WPQ): Verifies the welder's ability to deposit sound, defect-free weld metal with required mechanical traits.
- Complementary nature: While NDT (ASME Sec. V) detects flaws, DT (ASTM standard) defines actual margins of safety and yield limits.
- Failure analysis: Post-test fractography of tensile/compression specimens assists in evaluating weld fatigue and microstructural defects.

Introduction to Impact Testing I

Impact testing evaluates the behavior of materials under high-rate loading. It is critical for assessing brittle transition behavior in welded fabrications and structural steels.

Introduction to Impact Testing II

Key Points

- Charpy V-Notch (CVN) test (ASTM E23) uses a horizontal beam specimen supported at both ends.
- Izod test uses a vertical cantilever specimen clamped at one end.
- The test measures the energy absorbed (in Joules or ft-lbs) during fracture by a swinging pendulum.
- Key fabrication codes like ASME Section VIII Div 1 require impact testing for low-temperature service vessels.

Charpy Impact Test Setup I

begintikzpicture[scale=0.8, every node/.style=transform shape]
fill[gray!40] (-2,0) rectangle (-1.2,1);
fill[gray!40] (1.2,0) rectangle (2,1);
draw[thick] (-2,0) – (-1.2,0) – (-1.2,1) – (-2,1);
draw[thick] (2,0) – (1.2,0) – (1.2,1) – (2,1);
draw[fill=blue!20, thick] (-1.5,1) – (-0.1,1) – (-0.1,0.6) – (0,0.5) –
(0.1,0.6) – (1.5,1) – (1.5,1.4) – (-1.5,1.4) – cycle;
node at (0,0.1) V-Notch;
draw[-¿, thick] (0,0.3) – (0,0.5);
node at (-1.6,0.5) Support;
node at (1.6,0.5) Support;
draw[red, ultra thick, -¿] (0,2.5) – (0,1.6);
node[red, above] at (0,2.5) Striker (Impact);
endtikzpicture

Charpy Impact Test Setup II

Key Points

- The specimen is 10x10x55 mm with a 2 mm deep V-notch (45-degree angle).
- Striker hits the specimen directly opposite to the V-notch.
- Initial height (h) determines potential energy; final height (h') after fracture determines absorbed energy.
- Allows determination of Ductile-to-Brittle Transition Temperature (DBTT).

Ductile-to-Brittle Transition Temperature (DBTT) I

The transition of ferritic steels from ductile behavior at high temperatures to brittle behavior at low temperatures is a critical design constraint for cold climates.

Ductile-to-Brittle Transition Temperature (DBTT) II

Key Points

- DBTT is the temperature at which the fracture mode shifts from shear (ductile) to cleavage (brittle).
- Determined by plotting absorbed energy or lateral expansion against temperature.
- FCC metals (e.g., austenitic stainless steels, copper) do not exhibit DBTT and remain tough at cryogenic temperatures.
- BCC metals (e.g., structural carbon steels) exhibit a sharp DBTT, demanding strict control of welding heat input.

Hardness Testing: Brinell & Vickers I

Hardness testing measures a material's resistance to localized plastic deformation, acting as a non-destructive indicator of tensile strength and heat treatment efficacy.

Hardness Testing: Brinell & Vickers II

Key Points

- Brinell Hardness Test (ASTM E10) uses a 10 mm tungsten carbide ball indentor under 3000 kgf load.
- Vickers Hardness Test (ASTM E92) uses a square-based pyramid diamond indentor (136 degree angle).
- Brinell is suited for coarse microstructures (castings/forgings) due to large indentation area.
- Vickers is highly versatile, applicable from micro-indentation (weld HAZ profiling) to macro-hardness.

Rockwell Hardness Testing I

begintikzpicture[scale=0.9, every node/.style=transform shape]
fill[gray!20] (-2.5,0) rectangle (2.5,-1.5);
draw[thick] (-2.5,0) – (2.5,0);
draw[thick] (-2.5,-1.5) – (2.5,-1.5);
draw[dashed, red, thick] (-0.5,0) – (0,-0.3) – (0.5,0);
draw[blue, thick] (-1.0,0) – (0,-0.8) – (1.0,0);
draw[fill=yellow!30, thick] (-0.8,1.5) – (0.8,1.5) – (0,-0.8) – cycle;
draw[¡-] (1.5,-0.3) – (1.5,0) node[midway, right] h0 (Minor Depth);
draw[¡-] (2.0,-0.8) – (2.0,0) node[midway, right] h1 (Total Depth);
draw[-¿, thick, red] (0,2.2) – (0,1.6) node[midway, left] F0 (Minor);
draw[-¿, thick, blue] (-0.3,2.2) – (-0.3,1.6);
draw[-¿, thick, blue] (0.3,2.2) – (0.3,1.6) node[midway, right] F1 (Major);
endtikzpicture

Rockwell Hardness Testing II

Key Points

- Rockwell Hardness Test (ASTM E18) measures the depth of indentation rather than the surface area.
- Utilizes a preliminary test force (minor load of 10 kgf) followed by an additional test force (major load).
- Indentors include a 120-degree diamond cone (Brale) or steel balls (e.g., 1/16 inch).
- Common scales in fabrication are HRC (hardened steels, welds) and HRB (softer alloys).

Hardness Testing in Weldments (HAZ Profiling) I

Weld hardness testing is critical for assessing susceptibility to Hydrogen-Induced Cracking (HIC) in the Heat Affected Zone (HAZ).

Hardness Testing in Weldments (HAZ Profiling) II

Key Points

- NACE MR0175/ISO 15156 limits weldment hardness to 22 HRC (250 HV) for sour gas service.
- Vickers microhardness testing (HV0.5 or HV1) is used to perform traverses across the Weld Metal, Fusion Line (FL), HAZ, and Base Metal.
- High cooling rates in structural steels form brittle martensite, leading to high hardness values.
- Preheating and Post-Weld Heat Treatment (PWHT) are employed to temper the HAZ and reduce hardness below limits.

Comparison of Impact & Hardness Testing in QA/QC I

Both tests serve as primary quality assurance gates in metal fabrication, verifying material processing and welding procedure qualifications (WPQ/PQR).

Comparison of Impact & Hardness Testing in QA/QC II

Key Points

- Impact testing confirms resistance to catastrophic brittle fracture (crucial for bridges, pressure vessels, pipelines).
- Hardness testing provides localized, non-destructive estimation of yield strength and microstructural phase validation.
- ASTM and ISO standards govern the execution and calibration of testing machines to ensure global consistency.
- Weld procedure qualification (e.g., ASME Section IX) mandates these tests based on service conditions and material group.

Weld Bend Testing: Mechanical Principles & Configurations I

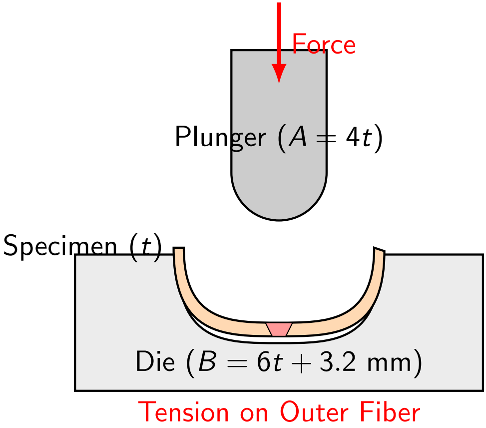
A qualitative destructive mechanical test used to evaluate the ductility of the weld metal, heat-affected zone (HAZ), and fusion line, while revealing soundness by forcing defects to propagate under severe tensile strain.

Weld Bend Testing: Mechanical Principles & Configurations II

Key Points

- Primary objective is checking for planar flaws like lack of side-wall fusion, incomplete root penetration, and macro-inclusions.
- Face Bend: Specimen is bent such that the weld face (wider side of joint) becomes the convex surface, putting the cap area in tension.
- Root Bend: Weld root (narrower side/first pass) is placed in tension on the outer convex surface to evaluate penetration soundness.
- Side Bend: A transverse slice of the weldment is bent, placing the entire cross-section (face to root) under tensile strain.
- Side bend testing is mandatory under ASME Section IX

Guided Bend Test Apparatus & Fixture Geometry I



Guided Bend Test Apparatus & Fixture Geometry II

Key Points

- The guided bend fixture enforces a precise bend radius based on specimen thickness (t) and base material elongation properties.
- Plunger diameter A = 4t and die opening width B = 6t + 3.2 mm (for standard P-No. 1 to P-No. 11 steels under ASME Section IX).
- A wrap-around bending jig may also be used to maintain continuous, uniform contact between the specimen and the plunger.
- The outer fiber strain (e) induced during bending is approximately $e = t / (2R + t)$, where R is the plunger radius.

Specimen Preparation & Testing Procedures (ASTM E190) I

Specimen preparation is highly critical to eliminate artificial stress risers that could lead to false failures during deformation.

Specimen Preparation & Testing Procedures (ASTM E190) II

Key Points

- Weld reinforcement must be removed mechanically (grinding or milling) flush with the base metal surface on both sides.
- The width of a standard transverse specimen is typically 1.5 inches (38 mm) for plate welds, with thickness t equal to wall thickness.
- All longitudinal edges of the specimen must be rounded to a radius not exceeding 1/16 inch (1.6 mm) to prevent corner cracks.
- Grinding marks must run longitudinal (parallel to the direction of bending) to avoid transverse stress concentrations.
- The bend is executed at a controlled, slow rate to allow

ASME Code Acceptance Criteria for Bend Tests I

Standards for qualifying welding procedures (WPS) and welder performance (WPQ) under ASME Section IX and ASME Section VIII Div. 1 specify strict limits on weld defects exposed by bending.

ASME Code Acceptance Criteria for Bend Tests II

Key Points

- ASME Section IX QW-163: The weld and HAZ of the bend specimen must be completely examined for open discontinuities on the convex surface.
- No open discontinuity exceeding 1/8 inch (3.2 mm), measured in any direction, is permitted on the convex surface after bending.
- Cracks occurring at the corners of the specimen during bending are generally ignored unless there is clear evidence of slag inclusions or lack of fusion.
- For corrosion-resistant overlay cladding (ASME QW-163), no open discontinuity exceeding 1/16 inch (1.6 mm) is permitted in the cladding.
- Failure of even a single specimen requires re-evaluation of parameters or rejection of the welder/procedure qualification.

Liquid Penetrant Testing (LPT): Principles & Methods I

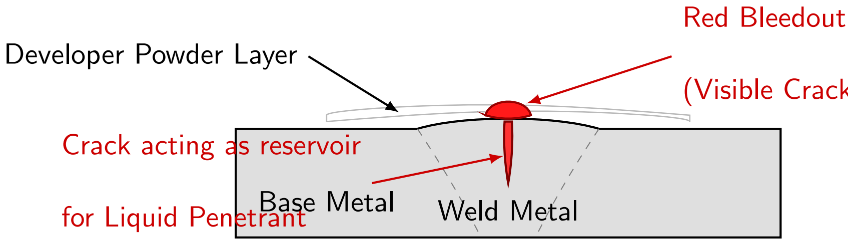
Liquid Penetrant Testing (LPT), governed by ASME Section V Article 6, is a highly sensitive non-destructive testing (NDT) method designed to detect surface-breaking discontinuities.

Liquid Penetrant Testing (LPT): Principles & Methods II

Key Points

- Relies on capillary action: A liquid penetrant with low surface tension and high wetting capability is applied to draw into fine cracks.
- Applicable to non-porous ferrous and non-ferrous materials, making it ideal for checking weld crowns, roots, and heat-affected zones.
- Method Classifications: Type I (Fluorescent penetrant viewed under ultraviolet blacklight) and Type II (Visible dye penetrant viewed under white light).
- Penetrant Systems: Water-washable, Post-emulsifiable (lipophilic or hydrophilic), and Solvent-removable systems.
- Dwell Time: The minimum time the penetrant must

LPT Mechanism: Capillary Action & Bleedout I



LPT Mechanism: Capillary Action & Bleedout II

Key Points

- Initial surface preparation requires thorough degreasing and cleaning; residues will block penetrant entry into surface crack openings.
- Excess surface penetrant must be removed carefully (solvent wipe or water spray) without washing penetrant out of the crack cavity.
- The developer layer provides a contrasting white background and acts as a capillary sponge to draw out the trapped red penetrant.
- Bleedout magnification: The visible surface indication is significantly wider than the physical crack, facilitating visual detection.

LPT ASME Sec. V Art. 6 & Sec. VIII Div. 1 App. 8 Criteria I

Standardized procedure execution is mandated by ASME Section V Article 6, while ASME Section VIII Division 1 Appendix 8 sets the acceptance-rejection criteria for pressure vessels.

LPT ASME Sec. V Art. 6 & Sec. VIII Div. 1 App. 8 Criteria II

Key Points

- Procedure Requirements: Written procedures must detail cleaner/penetrant/developer brand names, dwell times, and surface preparation.
- Temperature Limits: Standard testing must be conducted between 40 degrees F (5 degrees C) and 125 degrees F (52 degrees C).
- Light Intensity: Visible dye testing requires a minimum of 100 foot-candles (1076 lx) on the examination surface; fluorescent requires 1000 $\mu W/cm^2$.
- ASME Sec VIII Div 1 App 8 Acceptance: All surfaces must be free from relevant linear indications (length > 3x width).

Introduction to Magnetic Particle Testing (MPT) I

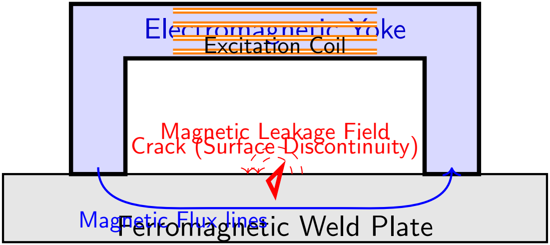
Magnetic Particle Testing is a highly sensitive non-destructive testing method used to detect surface and near-surface discontinuities in ferromagnetic materials by exploiting magnetic leakage fields.

Introduction to Magnetic Particle Testing (MPT) II

Key Points

- Limited to ferromagnetic materials like carbon steel, iron, nickel, and cobalt. Unsuitable for non-magnetic materials (e.g., austenitic stainless steel, aluminum).
- Relies on creating a magnetic field in the component. Surface defects disrupt the magnetic flux lines, forcing them to leak out into the air.
- The resulting magnetic leakage field creates local magnetic poles (North/South) that attract and hold fine magnetic particles.
- Governed by international standards such as ASME Section V Article 7 and ASTM E1444.
- Highly effective for detecting welding defects like surface cracks, seams, lapses, and undercut.

Magnetic Yoke & Leakage Fields I



Magnetic Yoke & Leakage Fields II

Key Points

- The Electromagnetic Yoke creates a local longitudinal magnetic field between its contact poles.
- Alternating Current (AC) yoke excitation provides maximum sensitivity for surface-breaking cracks due to the skin effect.
- Direct Current (DC) or rectified AC excitation provides deeper penetration, allowing detection of sub-surface defects up to 6mm deep.
- The leakage field forms a concentrated bridge of particles, outlining the crack orientation and size.

Selecting the correct inspection medium (dry or wet) and method is critical to optimize contrast, sensitivity, and reliability in industrial environments.

MPT Inspection Media and Procedures II

Key Points

- Dry Method: Employs dry magnetic powders (colored red, black, or yellow for contrast). Best for hot surfaces and coarse weld profiles.
- Wet Method (WMT): Employs micro-sized magnetic particles suspended in a liquid carrier (oil or water). Offers superior sensitivity for fine cracks.
- Fluorescent MPT: Uses fluorescent particles inspected under ultraviolet-A (UV-A) light (365 nm wavelength, minimum intensity of 1000 microWatts per square centimeter).
- ASME Sec V Article 7 mandates that the magnetic field strength must be verified using a Pie-field indicator or Hall-effect gaussmeter.
- Post-cleaning and demagnetization are required to

Principles of Ultrasonic Testing (UT) I

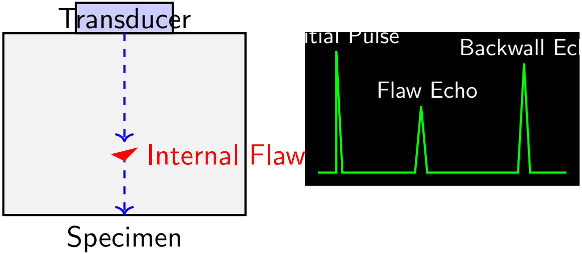
Ultrasonic Testing uses high-frequency sound energy (0.5 to 20 MHz) to detect internal volumetric flaws, map thickness profiles, and conduct material characterization.

Principles of Ultrasonic Testing (UT) II

Key Points

- A piezoelectric transducer generates ultrasonic waves upon electrical excitation and detects returning echo pulses.
- Acoustic Impedance (Z = density * velocity) controls sound reflection. Refractory reflection occurs at boundaries with impedance mismatches.
- The sound velocity depends on the material properties: longitudinal waves travel at 5900 m/s in carbon steel, while shear waves travel at 3200 m/s.
- Couplants like gel, water, or oil are used to eliminate the air interface, maximizing acoustic energy transmission into the test piece.
- Commonly implemented per ASME Section V Article 4 (weld examination) and ASTM E164.

Pulse-Echo UT & A-Scan Display I



Pulse-Echo UT & A-Scan Display II

Key Points

- A-Scan: A one-dimensional representation showing signal amplitude on the Y-axis and time-of-flight (depth) on the X-axis.
- Initial Pulse represents the entry point of sound into the specimen at the transducer interface.
- Flaw Echo indicates a signal reflection from an internal discontinuity before the backwall is reached.
- Backwall Echo represents the reflection from the opposite surface of the test specimen.
- Depth is calculated using the formula: Depth = (Sound Velocity * Time of Flight) / 2.

Angle Beam UT for Weldments I

In structural fabrication, weld geometries block straight-beam access. Angle beam transducers are used to launch shear waves at precise angles into the weld volume.

Angle Beam UT for Weldments II

Key Points

- Snell's Law: Dictates refraction angles at interfaces: sin(theta1)/V1 = sin(theta2)/V2. Used to design the transducer wedge angle.
- Angled wedges (commonly 45, 60, and 70 degrees) redirect the acoustic beam to inspect the weld root, face, and fusion line.
- Skip Distance: The path length along the surface between the source and the point where the beam reflects off the backwall and returns to the top.
- Weld defects like lack of side-wall fusion, incomplete root penetration, slag inclusions, and HAZ cracking are easily sized.
- Calibration is performed using IIW type 1 or V1/V2 blocks to verify index point, angle of refraction, and time base linearity.

Comparative Analysis: MPT vs. UT I

Choosing the appropriate NDT method depends on material type, defect location, wall thickness, and manufacturing specifications.

Comparative Analysis: MPT vs. UT II

Key Points

- Detection Depth: MPT is strictly for surface and near-surface flaws. UT is a volumetric method capable of scanning very thick sections.
- Material Constraints: MPT is restricted to ferromagnetic materials. UT can inspect almost all engineering metals, plastics, and composites.
- Orientation Sensitivity: MPT is highly sensitive to cracks perpendicular to the magnetic field. UT requires the beam to hit defects at near-normal incidence.
- Interpretation & Record: MPT provides direct visual indications. UT requires skilled operators for signal analysis, but Phased Array UT (PAUT) provides digital mapping.

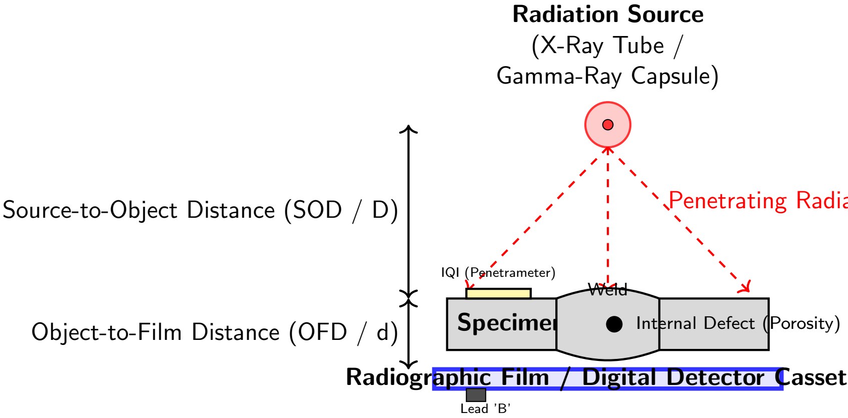
Radiographic Testing (RT): Principles and Physics I

Radiographic Testing (RT) is a volumetric nondestructive testing method utilizing short-wavelength electromagnetic radiation (X-rays or gamma-rays) to penetrate materials and detect internal volumetric flaws.

Radiographic Testing (RT): Principles and Physics II

Key Points

- Differential Absorption: The fundamental physical principle. Denser areas (or thicker sections) absorb more radiation, resulting in lighter regions on the film, while voids, gas pockets, or cracks absorb less radiation and appear as dark regions.
- Industrial Radiation Sources: X-ray machines (electrically generated, adjustable energy for various thicknesses) and Gamma-ray isotopes (Cobalt-60 for steel thickness of 50-150 mm; Iridium-192 for 10-75 mm; Selenium-75 for thin-walled components).
- Geometric Unsharpness (Ug): The fuzziness at the edges of the radiographic image, governed by the formula $Ug = f * d / D$, where 'f' is the source focal spot size, 'd' is the specimen-to-film distance, and 'D' is the source-to-specimen distance.


Radiation Source
(X-Ray Tube /
Gamma-Ray Capsule)
Penetrating Radia
Source-to-Object Distance (SOD / D)
Object-to-Film Distance (OFD / d)
IQI (Penetrameter)
Weld
Specimen
Internal Defect (Porosity)
Radiographic Film / Digital Detector Casset
Lead 'B'

Radiographic Testing: Equipment & Exposure Setup II

Key Points

- ASME Section V Article 2: Specifies standard procedures for RT, including geometric unsharpness limits (maximum 0.51 mm for material thickness $t < 50$ mm, up to 1.1 mm for thick sections).
- Image Quality Indicators (IQIs): Wire-type or hole-type penetrameters must be placed on the source side to verify that the sensitivity of the radiograph is at least 2% of the specimen thickness.
- Double-Wall Double-Image (DWDI) technique: Applied to small-diameter piping (OD $<=$ 3.5 inches) where both the front and back wall welds are projected and resolved on the film in a single exposure.
- Backscatter Protection: A lead letter 'B' must be attached to the back of the film cassette. If a light

RT Quality Standards, Interpretation, & ASME Code Compliance I

Interpretation of industrial radiographs requires certified ASNT Level II/III personnel to assess weld quality against the acceptance criteria of codes like ASME Section VIII Div 1 (pressure vessels) and API 1104 (pipelines).

RT Quality Standards, Interpretation, & ASME Code Compliance II

Key Points

- Radiographic Density Limits: ASME Section V Article 2 requires a density range between 1.8 and 4.0 for X-rays, and 2.0 to 4.0 for Gamma-rays to ensure proper contrast and detail visibility.
- Identifying Weld Defects: Slag inclusions show up as dark, irregular, elongated shapes; porosity appears as dark, circular spots; lack of fusion appears as a sharp, straight line along the weld bevel; cracks appear as jagged, fine dark lines.
- ASME Sec VIII Div 1 UW-51 & Appendix 4: Defines strict acceptance criteria where any type of crack, zone of incomplete penetration, or lack of fusion is unacceptable, regardless of size.
- Radiation Safety Protocols: Adherence to ALARA

Eddy Current Testing (ECT): Principles and Electromagnetic Theory I

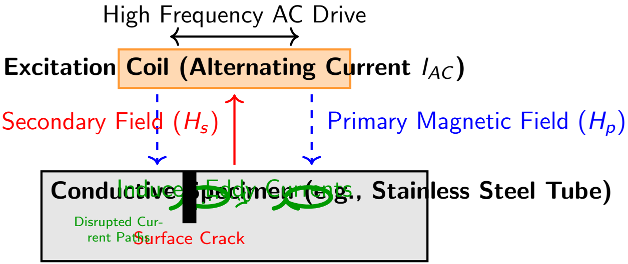
Eddy Current Testing (ECT) is an electromagnetic nondestructive testing method used for detecting surface and near-surface defects in conductive materials, material sorting, and coating thickness measurement.

Eddy Current Testing (ECT): Principles and Electromagnetic Theory II

Key Points

- Electromagnetic Induction: An alternating current flowing through a coil creates a dynamic primary magnetic field. When the coil is placed near a conductor, eddy currents are induced in the material (Faraday's Law).
- Secondary Field Generation: The induced eddy currents flow in closed loops perpendicular to the magnetic field. They generate their own secondary magnetic field that opposes the primary field (Lenz's Law).
- Impedance Plane Analysis: Defect detection is achieved by measuring the change in the coil's electrical impedance (resistance and inductive reactance) when eddy currents are disrupted by cracks, material variations, or corrosion.

Eddy Current Testing: Coil and Field Interaction I



Eddy Current Testing: Coil and Field Interaction II

Key Points

- Skin Effect & Penetration: Eddy currents are concentrated on the outer surface of conductive materials and decay exponentially with depth. High frequencies restrict inspection to the surface; lower frequencies penetrate deeper.
- Lift-off Effect: The change in coil impedance that occurs when the distance between the probe and the test specimen is varied. It is minimized using electronic balancing but utilized directly in coating thickness gauges.
- Edge Effect: The distortion of the eddy current field when a probe approaches a structural boundary, weld joint, or geometry change, requiring specialized shielded probes to minimize false indications.
- Phase-Angle Discrimination: Essential for isolating

ECT Applications: Tube Inspection & ASME Code Compliance I

ECT is widely used in power generation, oil gas, and chemical industries for high-speed, automated inspection of heat exchanger tubes, condenser tubing, and aircraft structural airframes.

ECT Applications: Tube Inspection & ASME Code Compliance II

Key Points

- In-Service Tubing Inspection: Utilizing internal Bobbin probes (for fast detection of volumetric wall thinning and pitting) and Rotating Pancake Probes (RPP) to identify circumferential cracks.
- ASME Section V Article 8: Governs electromagnetic examinations of conductive tubing. Requires calibration reference standards containing EDM notches, flat-bottom holes, and radial drill holes to calibrate instrument amplitude and phase.
- Multi-Frequency Eddy Current: Simultaneous excitation at multiple frequencies allows suppression of unwanted signals from tube support plates, tubesheet expansions, and magnetic copper-rich sludge deposits.
- Material Characterization: Sorting allows checking heat

4.4 Special Testing Methods for Equipment & Piping Operation I

Specialized testing techniques are employed during fabrication, commissioning, or in-service operation of pressure vessels, tanks, and piping networks where standard RT or ECT are insufficient.

4.4 Special Testing Methods for Equipment & Piping Operation II

Key Points

- Helium Leak Testing (Mass Spectrometer Leak Detector): Evaluated under ASME Section V Article 10. High-sensitivity leak testing using Helium as a tracer gas (detects leaks down to $10^{-}12 stdcm3/s)forvacuum, cryogenic, orhigh - pressuregaspiping$.
- Acoustic Emission Testing (AET): Under ASME Section V Article 11. A passive technique monitoring transient elastic waves from active defects (crack growth, plastic deformation) under hydrostatic/pneumatic stress.
- Time of Flight Diffraction (ToFD) & PAUT: Advanced ultrasonic techniques frequently substituted for RT in

Fundamentals of Hydrostatic Testing I

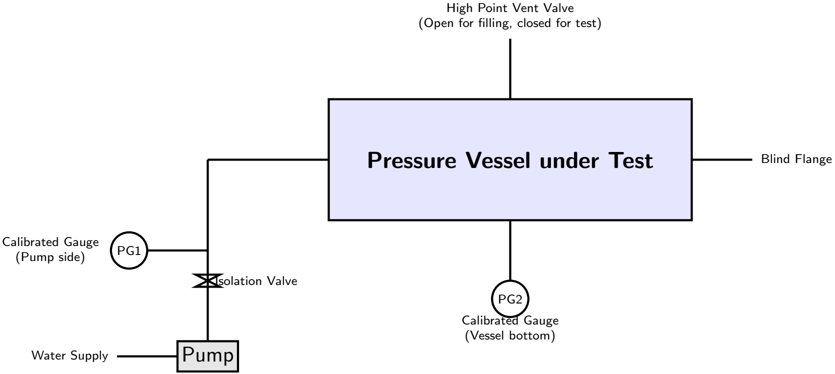
Hydrostatic testing (hydrotest) is the primary method to verify the mechanical integrity of pressure-retaining components like pressure vessels and piping spools.

Fundamentals of Hydrostatic Testing II

Key Points

- Definition and Purpose: Hydrostatic testing is a proof test and leak test in which a system is filled with liquid, vented of air, pressurized, and examined for leaks or deformation.
- Pressure Vessel Code (ASME Sec VIII Div 1 UG-99): Standard hydrostatic test pressure is 1.3 times the Maximum Allowable Working Pressure (MAWP) adjusted for temperature stress ratios.
- Process Piping Code (ASME B31.3 Para 345.4): Standard hydrostatic test pressure is 1.5 times the internal design pressure, adjusted for temperature stress ratios.
- Test Fluid Requirements: Clean water is the typical medium. For austenitic stainless steel systems, strict limits on chlorides (typically < 50 ppm) are enforced to

Hydrostatic Test System Layout I



Hydrostatic Test System Layout II

Key Points

- Air Venting: High point vents must remain open during the filling process. If air is trapped, the test becomes highly hazardous due to energy stored in compressed air.
- Gauge Placement: ASME Sec VIII UG-102 requires a minimum of two gauges connected directly to the vessel or lines. One is usually placed on the pump discharge, the other at the top or bottom of the vessel.
- Gauge Range: The pressure dial must be graduated to about double the test pressure (between 1.5 and 4 times per code) to ensure accurate readings.
- Isolation and Safety: Isolation valves allow locking the pressure during the holding time. Relieving devices must be set at 1.1 to 1.2 times the test pressure to prevent accidental over-pressurization.

Hydrostatic Test Execution Procedure I

Executing a hydrostatic test requires a structured sequence to guarantee safety and compliance with ASME requirements.

Hydrostatic Test Execution Procedure II

Key Points

- Pre-test inspection: Verify that all non-destructive testing (RT, UT, MT, PT) is completed and accepted. Install test gaskets, temporary blinds, and temporary supports if necessary.
- System filling: Pump clean test water into the lowest point of the system. Maintain venting until a continuous stream of water, free of air bubbles, escapes from the vents.
- Thermal stabilization: Let the filled system rest. The metal temperature and water temperature must stabilize. ASME recommends a minimum test fluid and metal temperature of 60°F (16°C) to prevent brittle fracture.
- Step-wise Pressurization: Raise the pressure gradually in stages (e.g., 50% and 90% of test pressure) before

Fundamentals of Pneumatic Testing I

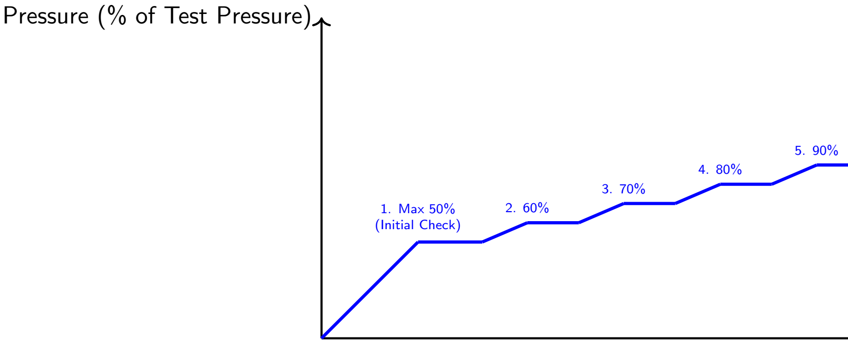
Pneumatic testing uses gases such as dry, oil-free air or nitrogen. Due to the high compressibility of gases, pneumatic tests present high thermodynamic stored energy and are subjected to strict safety criteria.

Fundamentals of Pneumatic Testing II

Key Points

- Criteria for Choice: Performed only when hydrostatic testing is not feasible (e.g. system cannot tolerate moisture, catalyst beds present, structural support cannot handle the weight of water, or cryogenic applications).
- ASME Code Limits: ASME Section VIII Div 1 UG-100 sets the pneumatic test pressure at 1.1 times the MAWP (multiplied by stress ratio). ASME B31.3 Paragraph 345.5 specifies it as 1.1 times the design pressure.
- Extensive NDT Requirement: Because of the high blast risk, code-mandated non-destructive testing (such as radiography of all longitudinal and circumferential welds) is typically required prior to test execution.
- Test Medium Quality: Dry nitrogen or instrument air with a very low dew point to avoid ice formation or

Pneumatic Test Pressure Step-Up Curve I



ASME B31.3 Pneumatic Test Step-Up Sequ

Pneumatic Test Pressure Step-Up Curve II

Key Points

- Safety Exclusion Zone: Personnel must be evacuated to a safe calculated distance (exclusion zone boundary) determined by the stored energy (TNT equivalent energy formula) before pressurization starts.
- Incremental Pressurization: Pressure is raised slowly in steps. An initial hold is done at 50% of the test pressure (or 25 psi, whichever is less) to allow first leak checks on joints.
- Subsequent Stages: Pressure is then increased in increments of 10% of the test pressure, holding at each step to allow thermal and strain stabilization.
- Visual Examination Pressure: Visual inspection for leaks using soapy water or 'snoop' is NEVER performed at 100% test pressure. The pressure must be reduced back to the design pressure or 90% of test pressure before

Comparison: Hydrostatic vs. Pneumatic Testing I

A comparative evaluation of these test methods highlights the critical trade-offs between safety, system contamination, and structural support weight.

Comparison: Hydrostatic vs. Pneumatic Testing II

Key Points

- Safety: Hydrostatic testing is low risk because water is virtually incompressible. Pneumatic testing is high risk (equivalent to a kinetic bomb) because gases compress and release massive force in case of a rupture.
- ASME Test Ratios: Hydrostatic tests are higher pressure (ASME Sec VIII: 1.3x MAWP; B31.3: 1.5x design pressure) compared to pneumatic tests (ASME Sec VIII: 1.1x MAWP; B31.3: 1.1x design pressure).
- Structural Weights: Large-diameter gas piping or columns are lightweight but holding water during hydrotest adds massive weight, requiring expensive temporary foundations or structural reinforcing. Pneumatic testing avoids this.
- Post-Test Cleanliness: Hydrotest requires drying and corrosion inhibitor application, which can contaminate

Quality Assurance, Documentation and QA/QC Packages I

Pressure tests are statutory hold points. A completed test must be documented in a structured QA/QC package for code verification.

Quality Assurance, Documentation and QA/QC Packages II

Key Points

- Test Pack Documentation: Includes piping isometric drawings / vessel drawings, P&IDs with test limits highlighted, weld logs showing NDT clearance, valve lists, and blind flange isolation logs.
- Pressure Recorder: A calibrated chart recorder (mechanic/digital) must continuously record system pressure and temperature over the holding duration. The chart serves as legal evidence of the test.
- Calibration Certificates: Test gauges and chart recorders must have valid calibration certificates (typically within the last 6 months) traceable to national standards.
- Inspection Sign-off: The test must be witnessed and signed off by the Manufacturer's QA/QC Inspector, Client Representative, and the Authorized Inspector

Detailed Concept 1 I

Detailed engineering explanation of Helium Leak test.

Key Points

- Fundamental principle 1
- Engineering application 2
- Important consideration 3

Detailed Concept 2 I

Detailed engineering explanation of Helium Leak test.

Key Points

- Fundamental principle 1
- Engineering application 2
- Important consideration 3

Detailed engineering explanation of Helium Leak test.

Key Points

- Fundamental principle 1
- Engineering application 2
- Important consideration 3

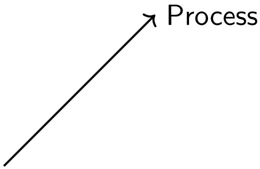
Detailed Concept 4 I

Detailed engineering explanation of Helium Leak test.

Key Points

- Fundamental principle 1
- Engineering application 2
- Important consideration 3

Detailed Concept 5 I



Key Points

- Fundamental principle 1
- Engineering application 2
- Important consideration 3

Detailed Concept 6 I

Detailed engineering explanation of Helium Leak test.

Key Points

- Fundamental principle 1
- Engineering application 2
- Important consideration 3

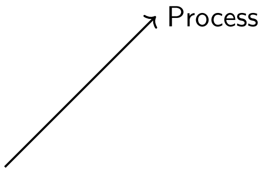
Detailed Concept 7 I

Detailed engineering explanation of Helium Leak test.

Key Points

- Fundamental principle 1
- Engineering application 2
- Important consideration 3

Detailed Concept 8 I



Key Points

- Fundamental principle 1
- Engineering application 2
- Important consideration 3

Sensory Inspection in Fabrication I

Sensory inspection techniques rely on human olfactory, tactile, and auditory feedback to perform primary, real-time quality control checks in metal fabrication and workshop operations.

Sensory Inspection in Fabrication II

Key Points

- First-Line Diagnostics: Immediate detection of workshop anomalies without initial instrument setup or calibration delays.
- Olfactory (Smell): Identifying overheating lubricants, combustion of electrical insulation, and shielding gas leakage.
- Tactile (Touch): Assessing surface roughness, estimating temperature gradients, and detecting high-frequency structural vibration.
- Auditory (Hearing/Earing): Detecting machinery misalignment, cutting tool chatter, structural resonance variations, and pressurized gas leaks.

Olfactory Inspection (by smell) I

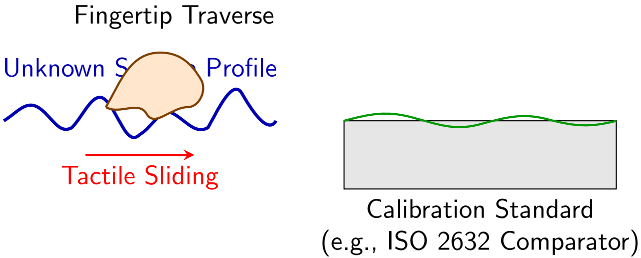
Olfactory inspection identifies volatile organic compounds and gases generated during thermal stress or chemical curing in manufacturing processes.

Olfactory Inspection (by smell) II

Key Points

- Cutting Fluid Degradation: Monitoring sulfurized and chlorinated additives in cutting oils which release distinct odors when overheated during high-rate machining.
- Transformer and Motor Health: Detecting burning phenolic resins, shellac insulation, or PVC jackets indicative of winding overload in welding equipment.
- Fuel Gas Leakage: Identifying mercaptan stenching agents added to odorless fuel gases like LPG or natural gas during oxy-fuel welding and cutting setup.
- Composite Matrix Curing: Monitoring the emission of volatile styrene monomer vapor during hand lay-up of fiber-reinforced polymers to evaluate curing stages.

Tactile Inspection of Surface Finish I



Tactile Inspection of Surface Finish II

Key Points

- Tactile Sensitivity: Fingertip friction and vibration detection can estimate surface roughness down to Ra 0.1 microns.
- Comparative Evaluation: Directly comparing the workpiece tactile feel against standard grit comparator plates (ISO 2632/ANSI B46.1).
- Micro-Asperity Detection: Using fingernail test (perpendicular scratch) to catch localized scratches, steps, and micro-cracks.
- Thermal Gradients: Tactile identification of temperature variations across weldments to monitor preheat and interpass temperatures.

Auditory Inspection (by earing) I

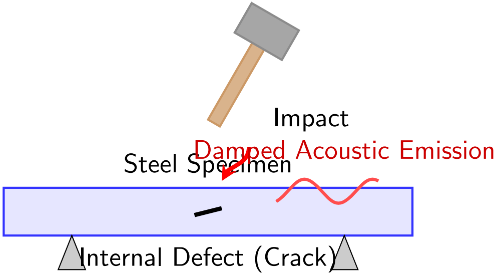
Auditory inspection uses acoustic emissions, resonance, and sound frequency analysis to monitor welding, machining, and structural integrity.

Auditory Inspection (by earing) II

Key Points

- Tapping/Ringing Test: Tapping steel structures or castings to check for internal flaws; defects dampen acoustic energy and reduce frequency.
- Leak Detection: Hearing high-frequency gas discharge or pressure drop from joints, valves, or pipelines under pneumatic testing.
- Machining Sound Signature: Monitoring tool chatter, spindle bearing failure, and blade dullness via real-time acoustic pitch shifts.
- Grinding Spark-Out: Discerning when the wheel has finished cutting based on the fading high-frequency grinding hiss.

Acoustic Ringing Test I



Acoustic Ringing Test II

Key Points

- Acoustic Resonance: A solid, defect-free component acts as a high-Q resonator, maintaining sound waves for several seconds.
- Defect Attenuation: Air-gaps from internal cracks reflect acoustic waves, causing severe sound attenuation (dull sound/thud).
- Frequency Response: Resonant frequency shifts lower in the presence of defects due to local reduction in structural stiffness.
- Application Limit: Highly qualitative; primarily used for swift screening of simple geometries (e.g., cast iron pipes, train wheels).

Comparison of Sensory Testing Methods I

An analysis of the operational capabilities, limits, and environmental parameters for smell, touch, and auditory inspection.

Comparison of Sensory Testing Methods II

Key Points

- Olfactory Method: Highly sensitive to gases and burning insulation, but subjective, vulnerable to olfactory fatigue, and holds toxicity risks.
- Tactile Method: Highly sensitive to sub-micron roughness and vibration, but limited to cold, stationary surfaces and accessible areas.
- Auditory Method: Evaluates internal volume defects through resonance, but heavily masked in high-noise industrial fabrication environments.
- Safety Regulations: OSHA guidelines restrict direct human exposure to chemical odors or loud impact sounds, requiring engineered sensors.

Sensorization of Human Sensory Inspection I

Modern automated manufacturing replaces human sensory checks with calibrated electronic instruments to ensure reproducibility.

Key Points

- Electronic Noses (e-noses): Utilizing metal oxide semiconductor (MOS) sensor arrays to detect and identify volatile organic compounds (VOCs).
- Stylus and Optical Profilometers: Quantifying surface roughness (Ra, Rz parameters) based on laser interferometry or diamond stylus feedback.
- Ultrasonic and Acoustic Emission (AE): Deploying piezoelectric transducers to listen for high-frequency micro-cracking and stress waves.
- Continuous Monitoring: Integrating sensory arrays with machine learning classifiers for automated, real-time welding and machining QC.