BRAZING, SOLDERING, ADHESIVE BONDING, DEFECTS, SAFETY ASPECTS & NON DESTRUCITVE TESTING AT A GLANCE

By

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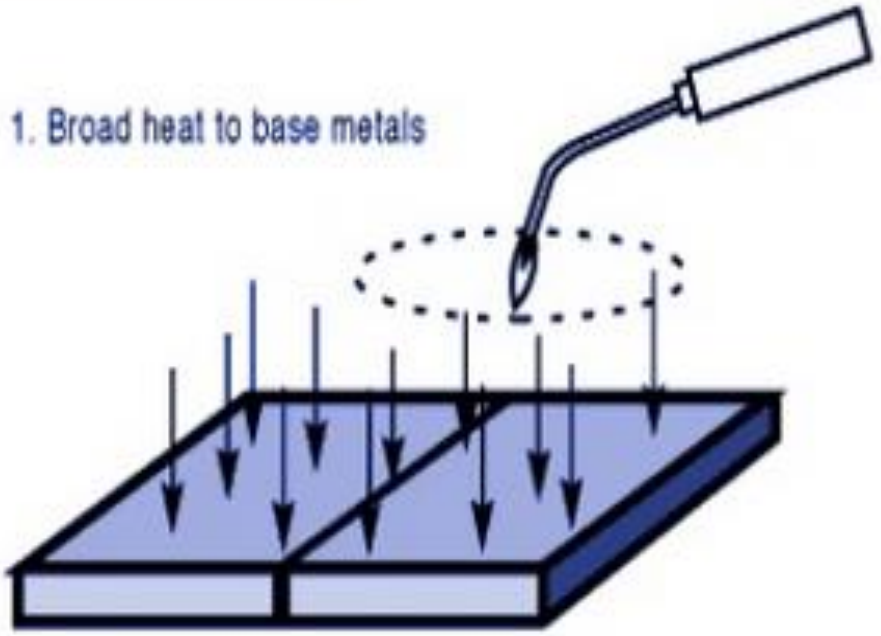
Brazing & soldering

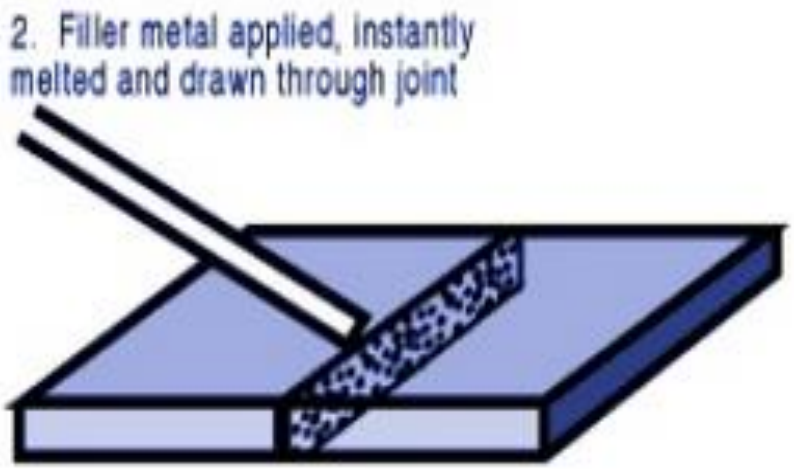
- **Brazing** is when a filler metal or alloy is heated to its melting temperature above 450 ℃.
- In this case only filler metal melts, there is no melting of workpiece metal.

Brazing Process:

1. In a brazing operation, you apply heat broadly to the base metals.



2. The filler metal is drawn through the joint to create this bond is capillary action.



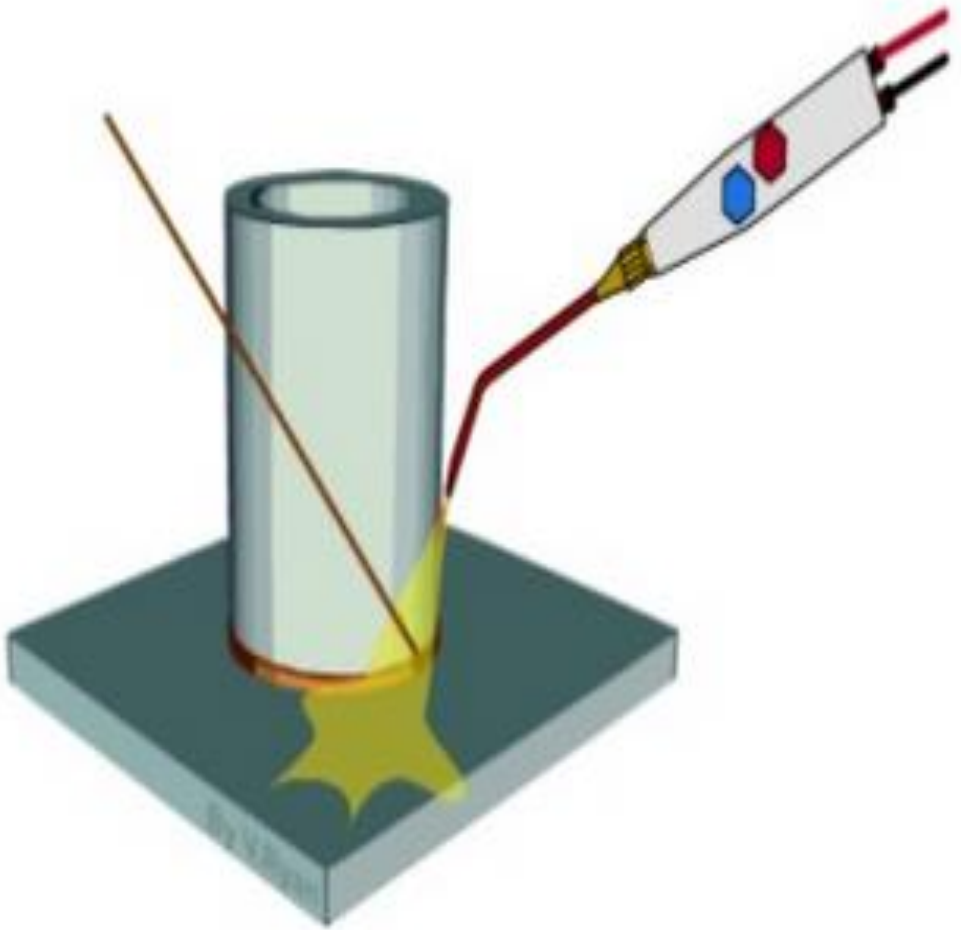
3. Flux

- Flux must be used with all non-fusion welding processes.
- Three purposes of flux.
  1. Chemically clean the metal
  2. Shield from oxidation and atmospheric contamination
  3. Promote wetting
- Flux must be appropriate for the metal and filler material.
- Flux is available in three (3) forms.
  1. Paste
  2. Powder
  3. Liquid

Brazing Methods:

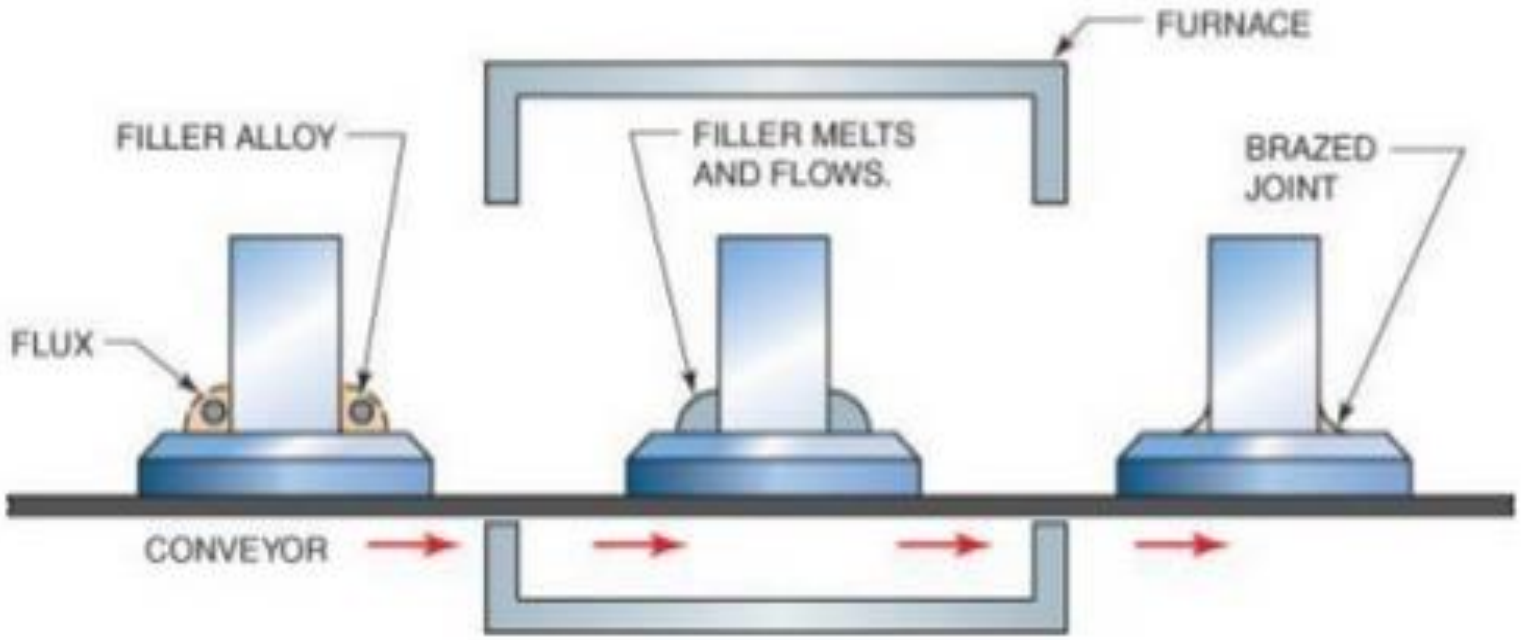
- **Torch Brazing:-**

flux is applied to the part surfaces and a torch is used to focus flame against the work at the joint. A reducing flame is used to prevent the oxidation.



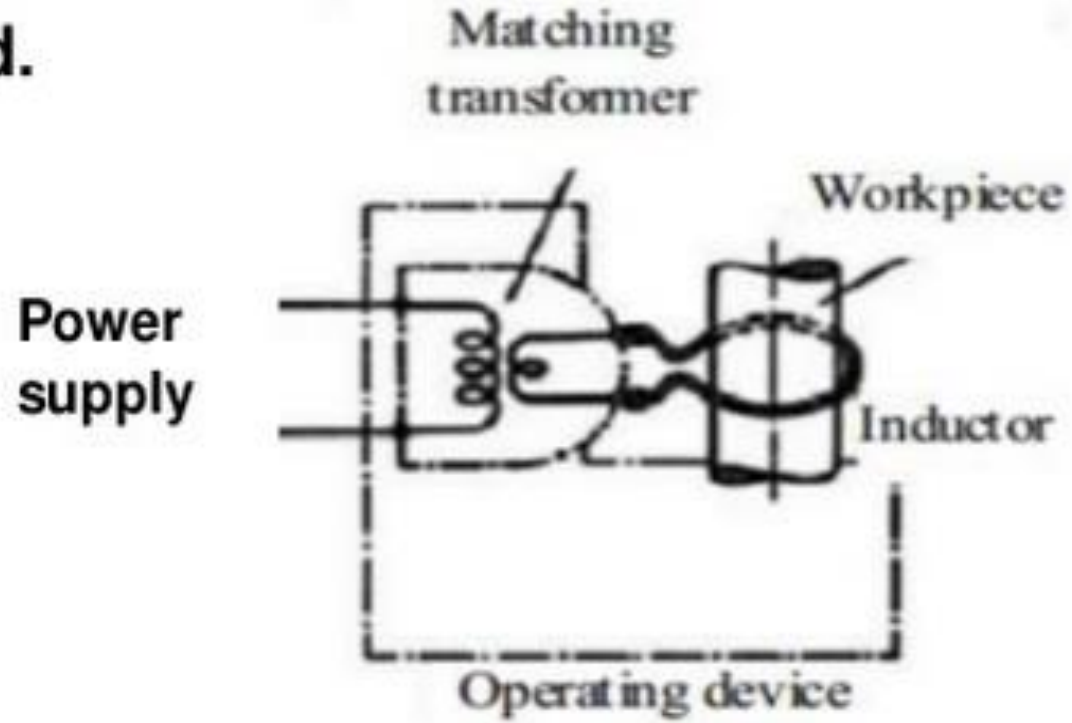
- **Furnace Brazing :**

Furnace Brazing used to heat the workpieces to be joined by brazing operation. The component parts and brazing metal are loaded into a furnace, heated to brazing temperature, and then cooled and removed.



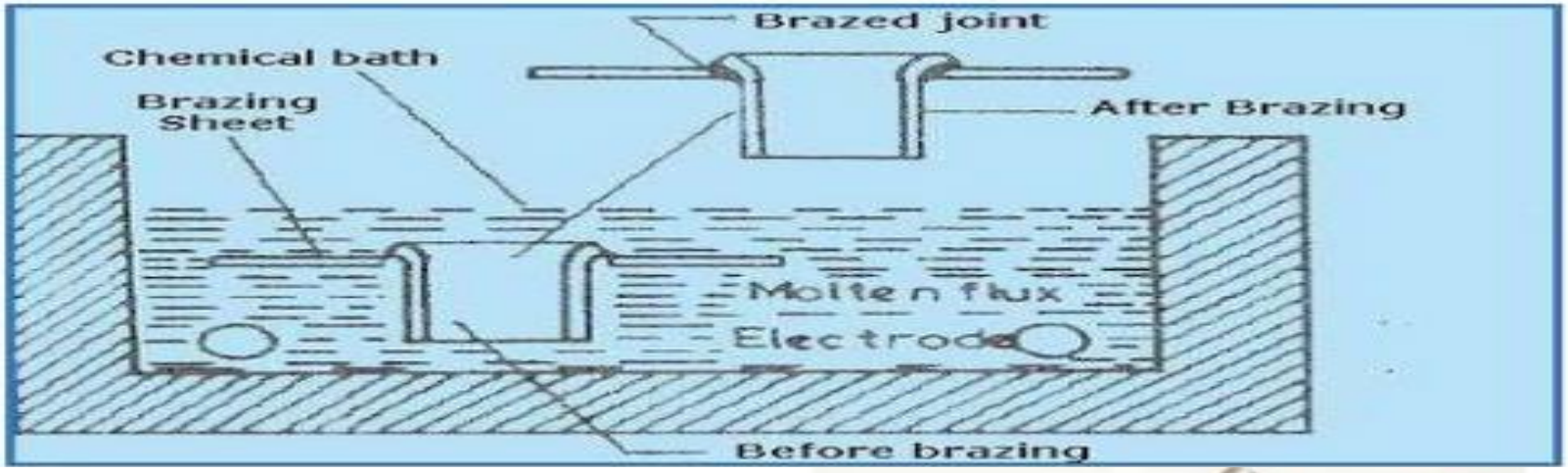
- **Induction Brazing:-**

A process that uses electrical resistance of workpiece and high frequency current induced into the same as a source of heat generation. The parts are pre-loaded with filler metal and placed in a high frequency AC field.



- **Dip Brazing:**

Assembled parts are typically dipped in a heated chemical bath which serve as both fluxing agent and heat source to melt pre-applied filler material.



Brazing Welds:

Advantages of Brazing:

1. Any metals can be joined including dissimilar metals.

2. Certain brazing methods can be performed quickly.

3. Brazing can be applied to join thin-walled parts that can't be welded.

4. In general, less heat and power are required than in fusion welding.

Disadvantages of Brazing:

1. Joint strenght is generally less than that of a welded joint.

2. Although strenght of a good brazed joint is greater than that of the filler metal it is likely to be less than that of the base metals.

3. High service temperatures may weaken a brazed joint

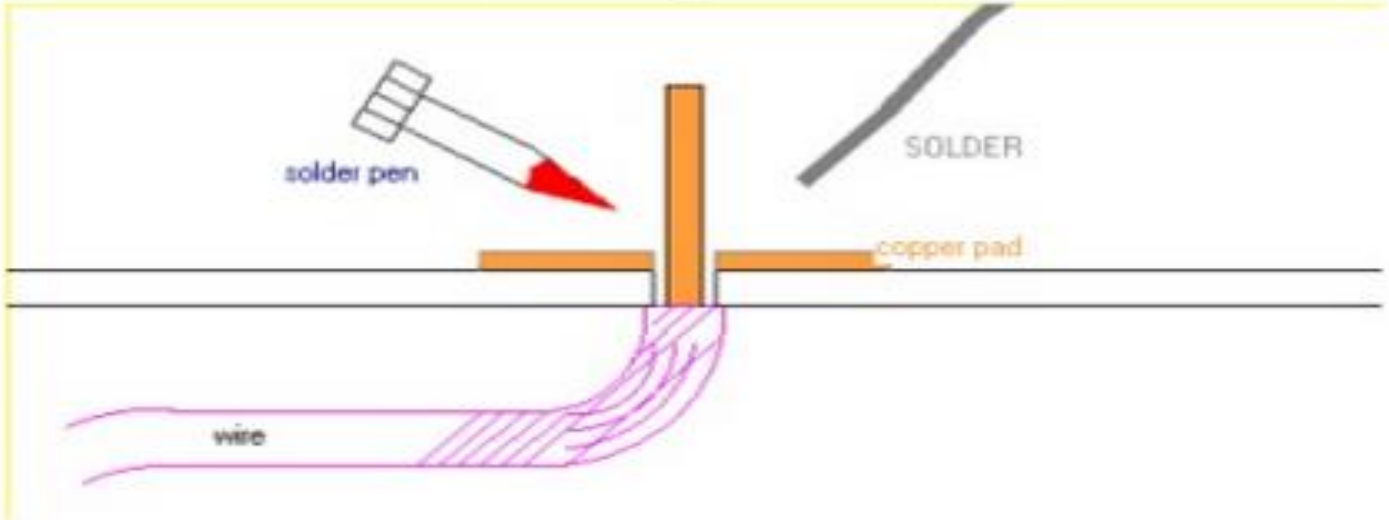
4. The colour of the metal in brazed joint may not match the colour of the base metal parts

Soldering

- **Soldering is very much similar to brazing.**

- **The major difference lies with the filler metal, the filler metal used in case of soldering should have the melting temperature lower than 450°C.**

- **The joining of metals using a filler material of a lower melting point than that of the parent metals to be joined.**



Solder:

- **Solder** is an alloy of Tin and Lead.
- The solder used for electronics is frequently called 60/40 solder because it is made of 63% tin and 37% lead.
- 60/40 solder melts at 361° F.

Filler Metals

- **Brazing** : Aluminum-silicon ,Copper, Copper-phosphorus, Magnesium, Silver, Nickel alloys.
- **Soldering** : combinations of tin-lead, tin-silver-lead, tin-zinc, silver-copper-zinc and zinc-aluminum alloys.

- A soldering iron must be coated with a thin coat of solder. This will allow for the transfer of heat to the work piece.
- This procedure is called tinning.
- The tip must be kept coated with a shiny layer of solder by occasional wiping and applying solder directly to the tip.

What is Flux?

- ✓ **Flux** is a chemical compound.
- ✓ Is applied and shields the joint surface from air and prevents oxide formation.
- ✓ Although flux will dissolve and absorb oxides.

Soldering Methods

- **Iron soldering** - The **oldest** and **simplest** soldering method and is still **widely used today**. Soldering irons have **copper tips** which **easily** stores and transfers heat to the joint.

- **Wave soldering** -A specific method used in the fabrication of electronic components and printed circuit boards (**PCB**). In this method, continually circulating fountains or waves of solder are **lifted** into contact with the joints.

Advantages of Soldering:

1. Low power is required.
2. Low process temperature.
3. Microstructure is not affected by heat.
4. Easily automated process.
5. Dissimilar materials may be joined.
6. High variety of materials may be joined.
7. Thin wall parts may be joined.

Disadvantages of soldering:

1. Large sections cannot be joined.
2. Fluxes may contain toxic components.
3. Soldering joints can not be used in high temperature applications.
4. Low strength of joints.
5. Careful removal of the flux residuals is required in order to prevent corrosion.

- A process that uses a metal alloy that melts above 840 °F, but less than the melding point of the base metal.
- Braze welding is the same process as brazing except it does not use capillary action and a visible bead is formed.

- Three common processes:
  - ❖ Soldering
  - ❖ Brazing
  - ❖ Braze welding

The filler metal is added to the joint.

The filler metal adheres to both surfaces forming a bead.

➢ The puddle must be heated until the key hole collapses.

The heat source is removed and the filler metal solidifies, bonding the surfaces together.

Braze Welding Joints

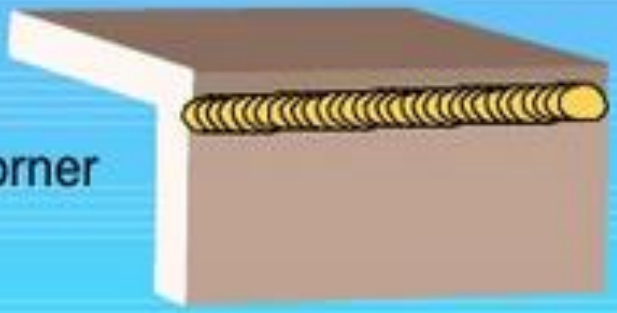
The five (5) standard joints can be used for braze welding.

Butt

Lap

Edge

Corner



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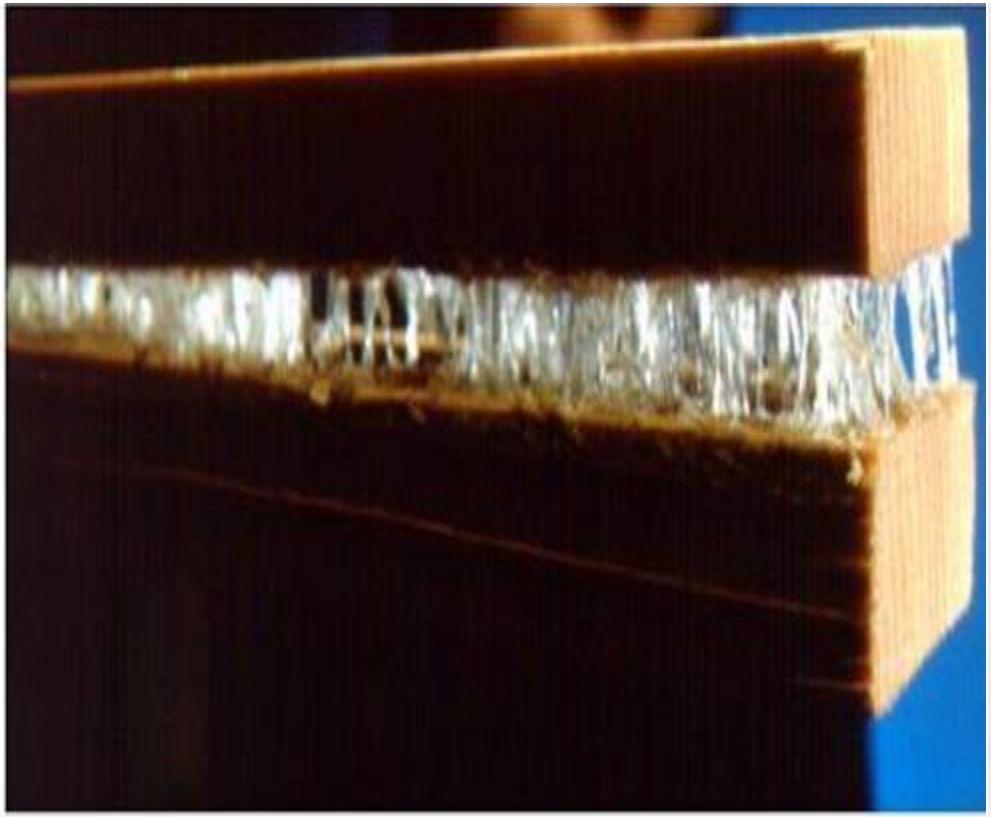
Adhesive Bonding

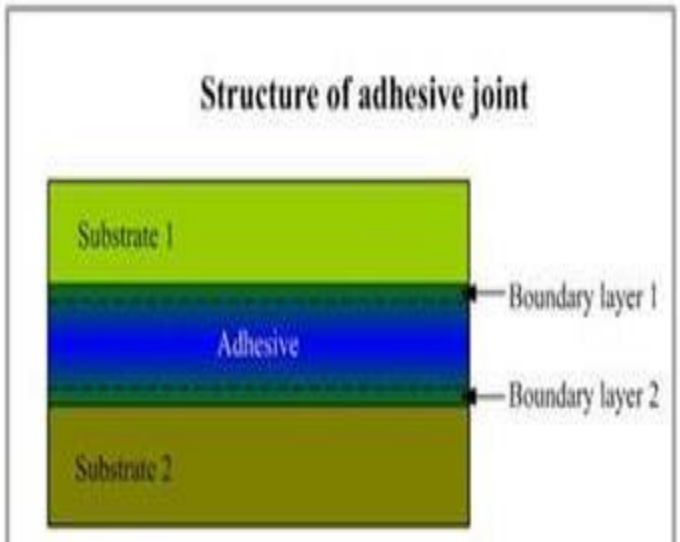
Joining process in which a filler material is used to hold two (or more) closely-spaced parts together by surface attachment

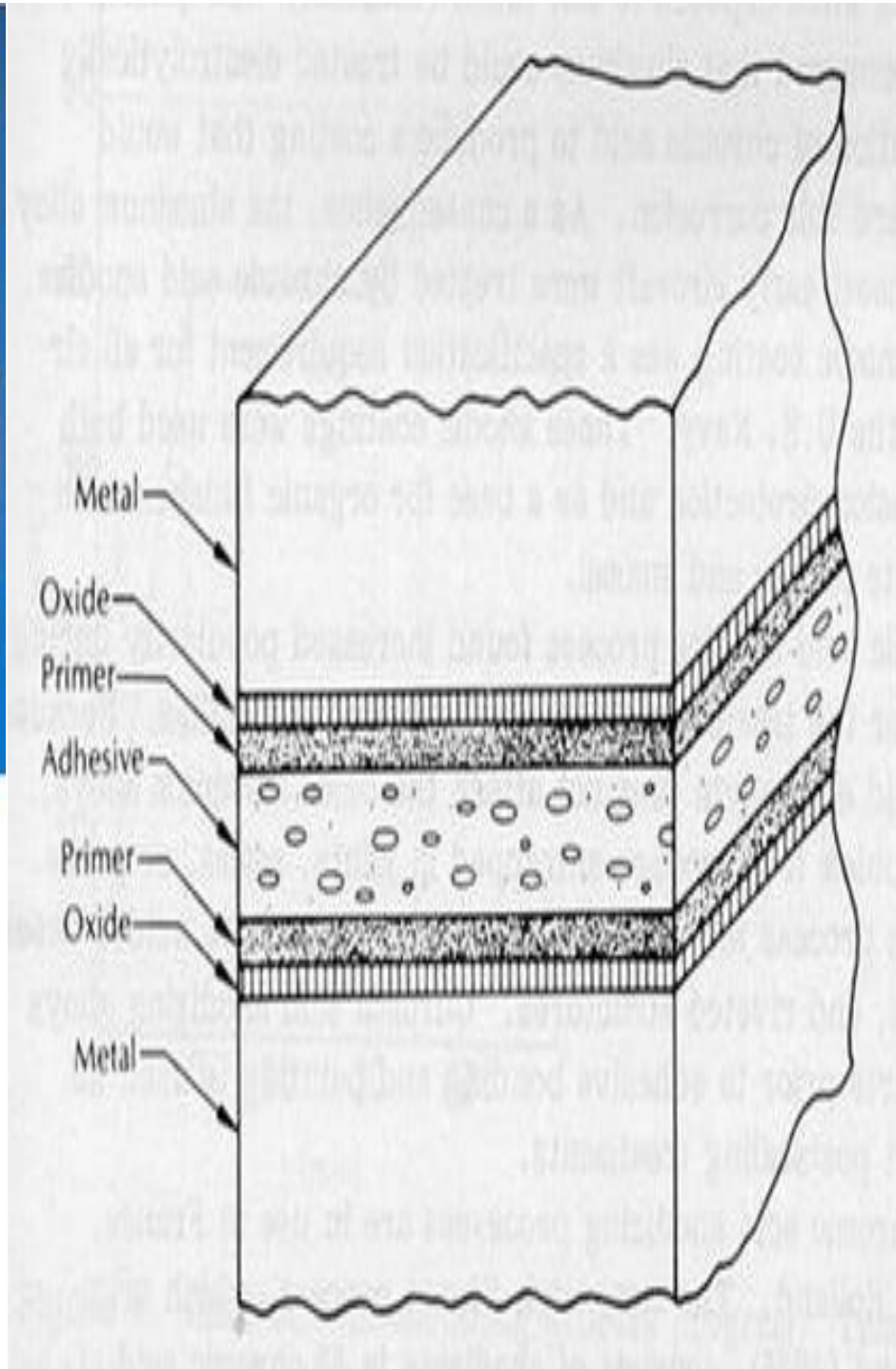
- Used in a wide range of bonding and sealing applications for joining similar and dissimilar materials such as metals, plastics, ceramics, wood, paper, and cardboard
- Considered a growth area because of opportunities for increased applications

Terminology in Adhesive Bonding

- *Adhesive* = filler material, nonmetallic, usually a polymer
- *Adherends* = parts being joined
- *Structural adhesives* – of greatest interest in engineering, capable of forming strong, permanent joints between strong, rigid adherends

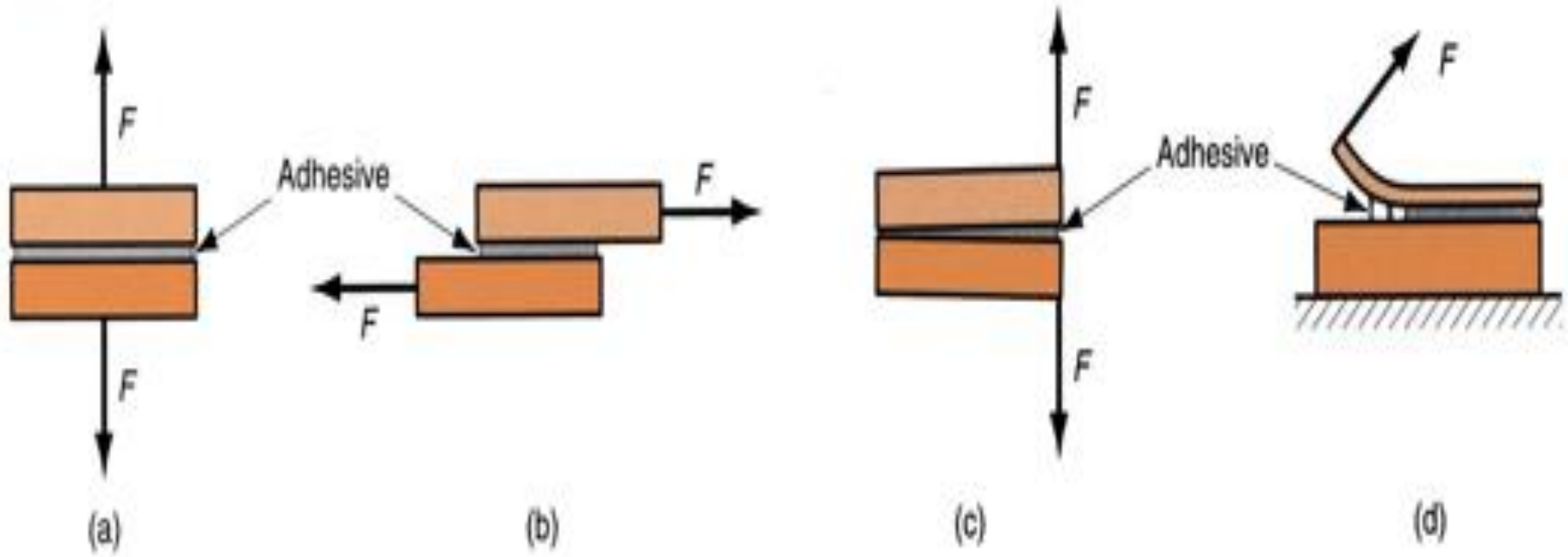



Structure of adhesive joint
Substrate 1
Boundary layer 1
Adhesive
Boundary layer 2
Substrate 2


Metal
Oxide
Primer
Adhesive
Primer
Oxide
Metal

Types of Stresses in Adhesive Bonding

Figure 32.10 Types of stresses that must be considered in adhesive bonded joints: (a) tension, (b) shear, (c) cleavage, and (d) peeling.



Adhesive Types

- Natural adhesives - derived from natural sources, including gums, starch, dextrin, soya flour, collagen
  - Low-stress applications: cardboard cartons, furniture, bookbinding, plywood
- Inorganic - based principally on sodium silicate and magnesium oxychloride
  - Low cost, low strength
- Synthetic adhesives - various thermoplastic and thermosetting polymers

Synthetic Adhesives

- Most important category in manufacturing
- Synthetic adhesives cured by various mechanisms:
  - Mixing catalyst or reactive ingredient with polymer prior to applying
  - Heating to initiate chemical reaction
  - Radiation curing, such as UV light
  - Curing by evaporation of water
  - Application as films or pressure-sensitive coatings on surface of adherend

Applications of Adhesives

- Automotive, aircraft, building products, shipbuilding
- Packaging industries
- Footwear
- Furniture
- Bookbinding
- Electrical and electronics

Application Methods

- Manual brushing and rolling
- Silk screening
- Flowing, using manually operated dispensers
- Spraying
- Automatic applicators
- Roll coating

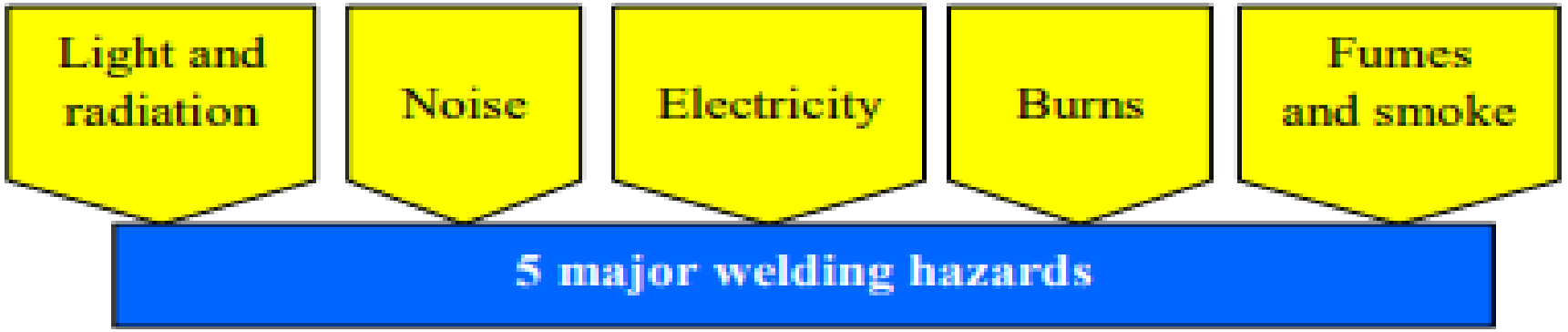
Advantages of Adhesive Bonding

- Applicable to a wide variety of materials
- Bonding occurs over entire surface area of joint
- Low temperature curing avoids damage to parts being joined
- Sealing as well as bonding
- Joint design is often simplified, e.g., two flat surfaces can be joined without providing special part features such as screw holes

Limitations of Adhesive Bonding

- Joints generally not as strong as other joining methods
- Adhesive must be compatible with materials being joined
- Service temperatures are limited
- Cleanliness and surface preparation prior to application of adhesive are important
- Curing times can limit production rates
- Inspection of bonded joint is difficult

SAFETY ASPECTS IN WELDING



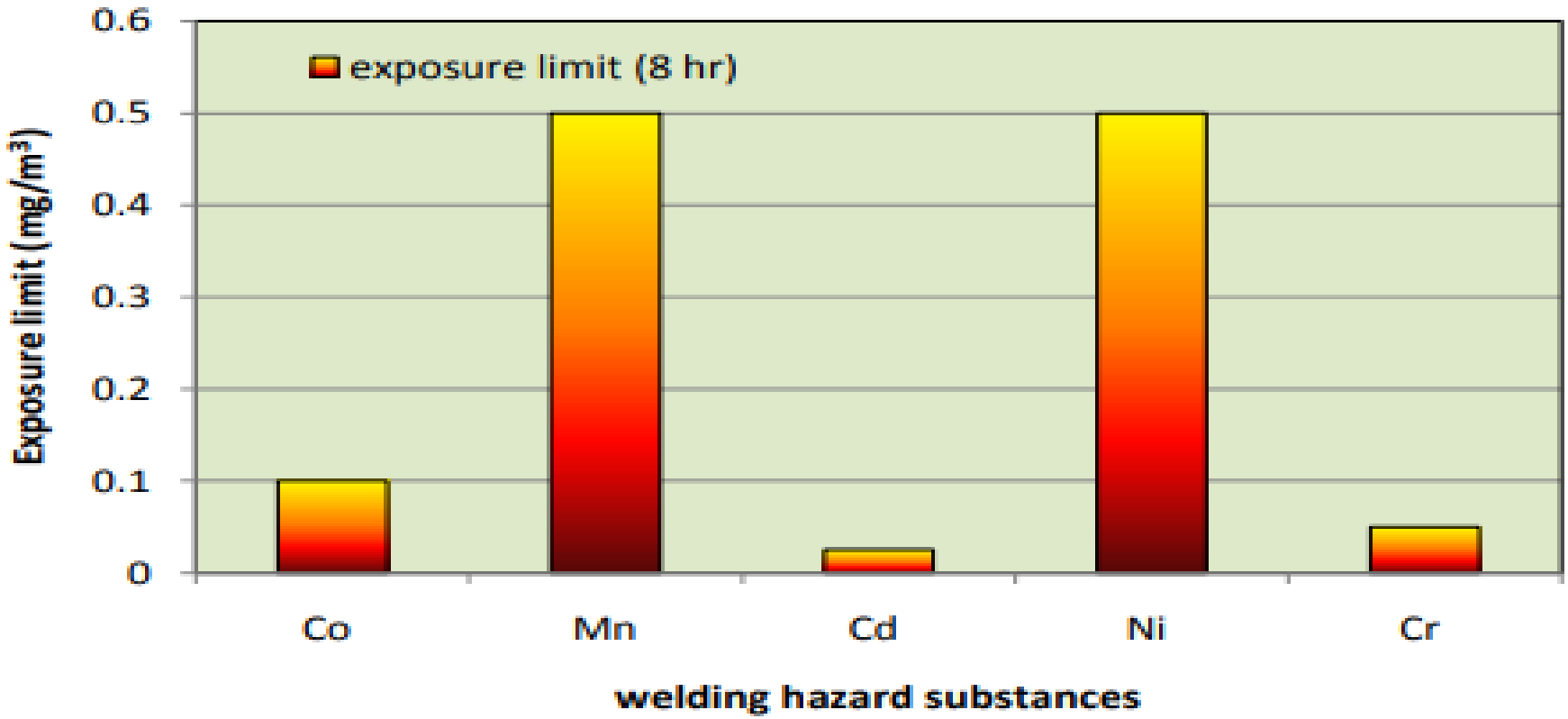
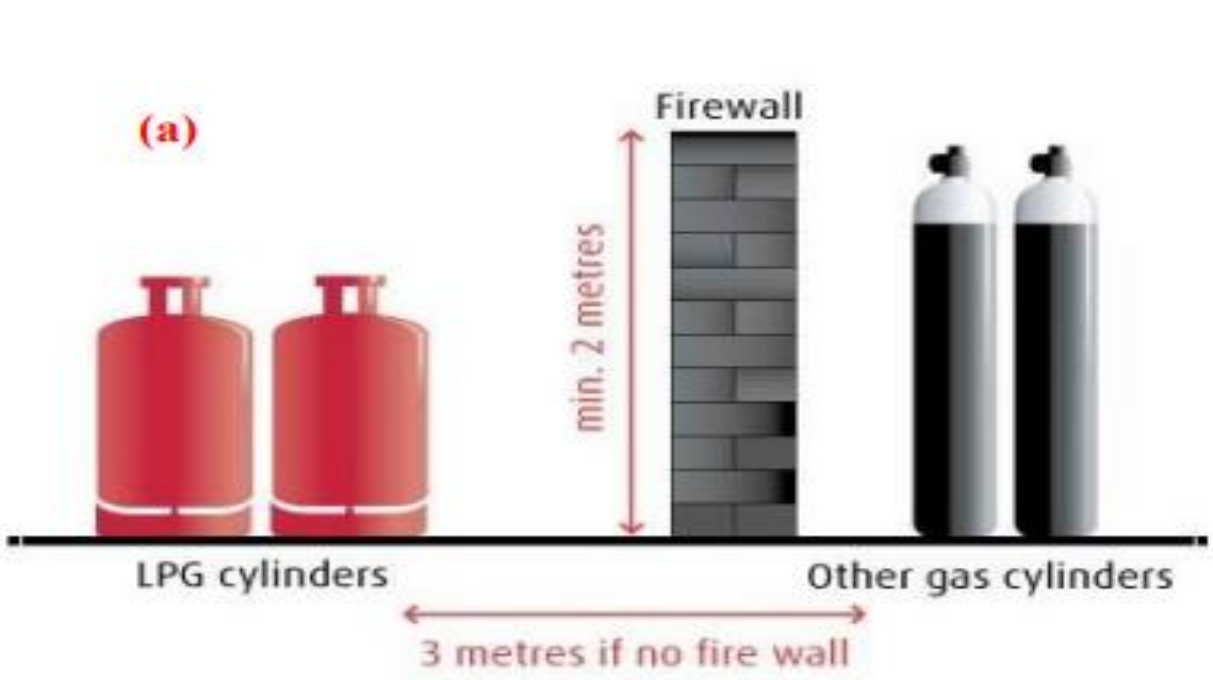
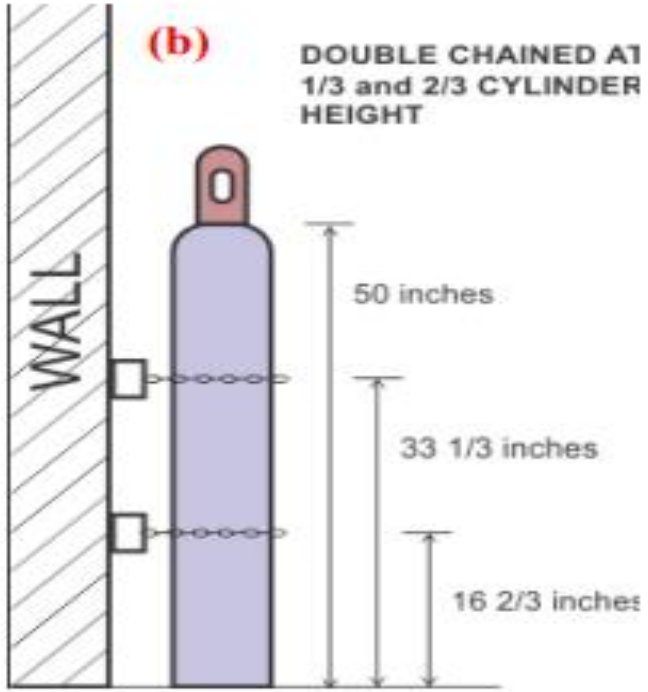
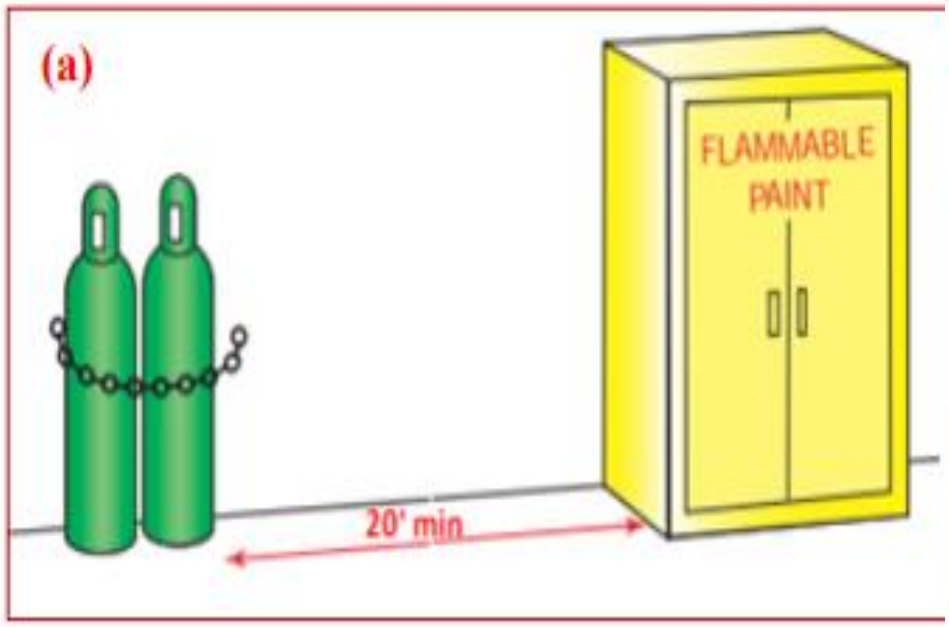


Table 2: Health effects due to chemical agents

Agents	Type	Source	Health effects
Cadmium oxide	Fumes	Cadmium related materials, electroplating	Respiratory problems, muscle aches, carcinogen, head ache, pulmonary edema, fever, lung damage, death
Co	Gas	Co_2 welding, coating	Nausea, dizziness, head ache, cardiovascular symptoms
Phosphine, Phosgene	Vapour	Metal coated, incomplete combustion	Eyes irritation, kidney damage
ZnO_2	Fumes	Painted and galvanized metals	Metal fume fever, zinc poisoning, death
O3	Gas	Formed in welding arc	Lung issue, pulmonary disorders
Nitrogen oxide	Gas	Formed in welding arc	Chronic bronchitis, emphysema, pulmonary fibrosis, pneumonitis
Ni	Fumes	Nickel containing metals	Lung cancer, respiratory tract irritation, dermatitis, renal dysfunction
Mn	Fumes	Welding, high tensile steel	Metal fume fever, kidney damage, insomnia, nervous system disorders.
Magnesium oxides	Fumes	Magnesium alloys, base metal	Eyes and nose irritation, cough, Fever, chest pain, fire or burn.
Iron oxide	Fumes	All ferrous metals, base metal Gas welding	Siderosis, lung irritation, nose irritation, pneumoconiosis
Compressed gases	Gases	Beryllium alloys	Asphyxiation and respiratory problems, fainting
Beryllium	Fume	Lead alloys, Coatings, paints.	Lung inflammation
Lead	fume		Damage to liver, heart, kidney.


(a)
Firewall
min. 2 metres
LPG cylinders
Other gas cylinders
3 metres if no fire wall


(b)
DOUBLE CHAINED AT
1/3 and 2/3 CYLINDER
HEIGHT
WALL
50 inches
33 1/3 inches
16 2/3 inches


(a)
FLAMMABLE
PAINT
20' min

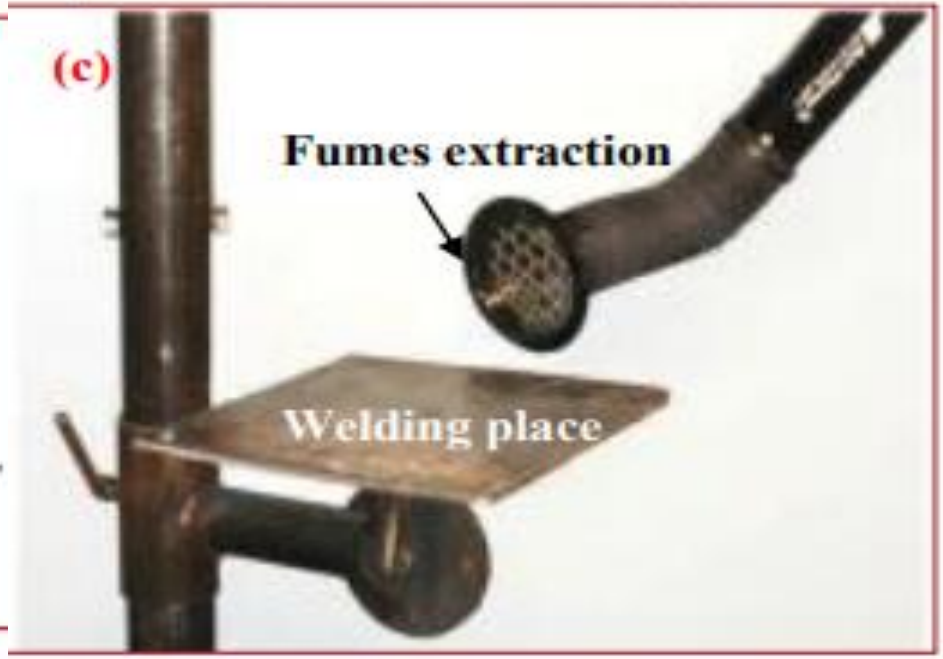

(c)
Fumes extraction
Welding place

Table 4: Arc welding electric shock hazard and health issue at high and low voltage

Fault/hazard	Health issue
▪ Lack of welding machine earthing	Shock, severe burns, fatal
▪ Poor insulation and damaged cable	Fire, property damage, shock, fatal,
▪ Oversize fuse	Shock, burn
▪ Inadequate connection	Fire, overheating

Table 5: Causes of accidents and health effects

Factor	Causes of accidents/ Risk/Hazard	Health effect and control
Environmental	Inadequate lighting in working area, rainy season, presence of dusts, Electrocution, improper ventilation, poor housekeeping, uneasiness due to room temperature, heat & radiation.	Possibility for serious accidents and fatal, lungs damage, over strain, suffocation, arc eye. It can be controlled by good housekeeping, right time usages.
Human	Working in welding machines without proper PPEs with respect to the machines, lack of knowledge on the usage of welding machines and its parameters, fatigue due to overtime work, psychological factors of welders, , working in hot surfaces, smoky region, Electrocution, poor housekeeping, ergonomics aspects.	Fatal due to improper usage of welding machines, minor and serious injuries, pain in neck, burns, eye and nose irritation, over stress, Dehydration. Health and mental fitness, using PPEs, knowledge in the machine usage can control such accidents,
Mechanical	Poorly maintained unsafe welding equipments, over speed in solid state welding machines, materials breakage, over heat, unfamiliarity with the machines and operation.	Fatal, serious and minor injuries, electrical shock. Burns due to hot surfaces of machines and materials. Proper machine maintenance, welding machines with guarding set-up can control risks.

Table 6: Safety precautions to be followed in Arc and gas welding

Arc welding	Gas welding
• Arc welding produces bright light and IR & UV rays, so everyone who is working with arc welding machine must use eye and face protection equipment.	• A special attention must be given to the materials, which are for welding, with toxic materials.
• Proper PPEs should be used and switch off welding machines when not in use.	• The hoses of the gas cylinder should be followed as per safety standard.
• Ear plug can be used for avoiding arc sound which may disturb the welder mind.	• Proper PPEs should be used while joining process.
• Welding materials must be cleaned to remove rusts and area maintained neat.	• Protection against workers skin contact with hot surfaces, fluxes etc…
• Proper insulation of welding torch, cables and welding machine must be ensured	• Care handling for acetylene should be given.
• Usage of wood or rubber is recommended to avoid electrical shock by standing on them while doing welding.	• It is better to clean the weld surfaces with acetone and removing coatings on weld materials.
• Welders not to use wet clothes and gloves and precautions must be taken against dangerous fumes to be inhaled by welders	• The gas cylinders to be used need to be guarded and kept safe during the transfer.

Table 7: First aid precautions for various hazards during welding

Hazard	First-aid precautions
Electric shock	First we have to cut off the power supply and should not touch the casualty body with our bare hands. We have to wear a sturdy non-conducting clothes and gloves. A proper set up should be made around the casualty to open the airway and do the first-aid by trained people.
Burns	Burns should be cooled with water for 10 minutes or more and covered by dressing, and the burns need medical aid depending on its intensity like internal damage, deep burns, and radio frequency burn (1^{st}, 2^{nd} and 3^{rd} degree burns).
Eye injuries	If dust or fumes enters into eye, immediate eye washing with proper liquid is necessary. After washing, if anything stuck, eye check is advisable. Goggles must be worn during the gouging, etching and chipping of weldment. While welding, face shield can be used for short time welding and face helmet with hood can be used for long time welding. It the UV rays are caught by the eyes over a period of time, an eye specialist consultation should be sought.

TYPES OF DEFECTS

- Slag Inclusion
- Undercut
- Porosity
- Incomplete fusion
- Overlap
- Underfill
- Spatter
- Excessive Convexity
- Excessive Weld Reinforcement
- Incomplete Penetration
- Excessive Penetration

SLAG INCLUSION

Cause:- Low amperage, improper techniques, slow travel rate

Prevention:- Increase amperage, increase travel rate

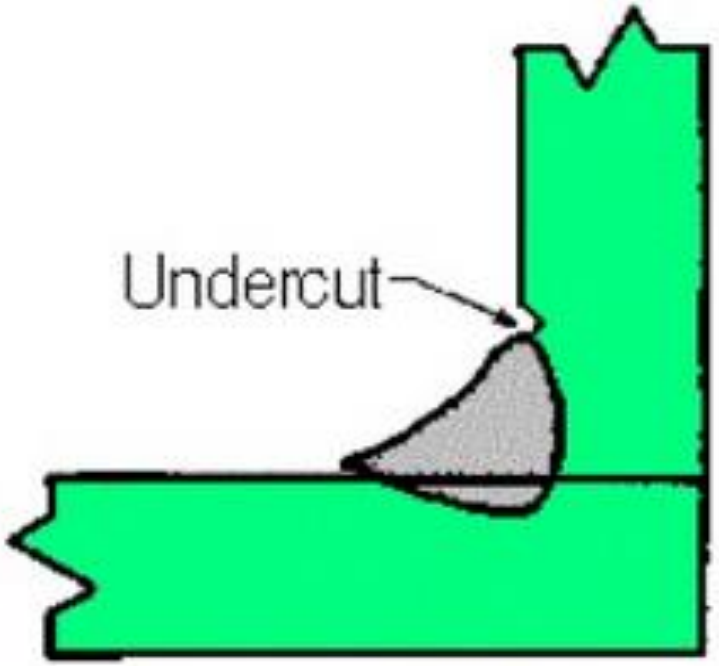
Repair:- Remove by grinding or other mechanical process

UNDERCUT

Cause:- High amperage, wrong electrode angle, long arc length, rust

Prevention:- Set machine on scrap metal to correct parameters, clean metal before welding

Repair:- Weld with smaller electrode, sometimes must be low hydrogen with preheat.

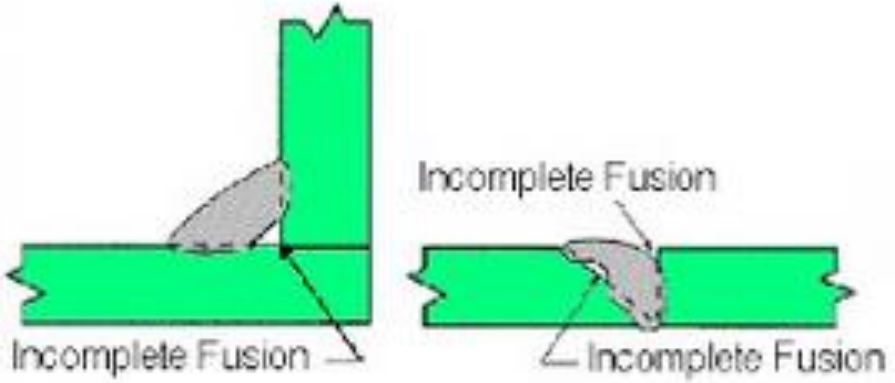


INCOMPLETE FUSION

Cause:- Low amperage, steep electrode angle, fast travel speed, short arc gap, lack of preheat, electrode too small, unclean base metal, arc off seam

Prevention:- Eliminate the potential causes

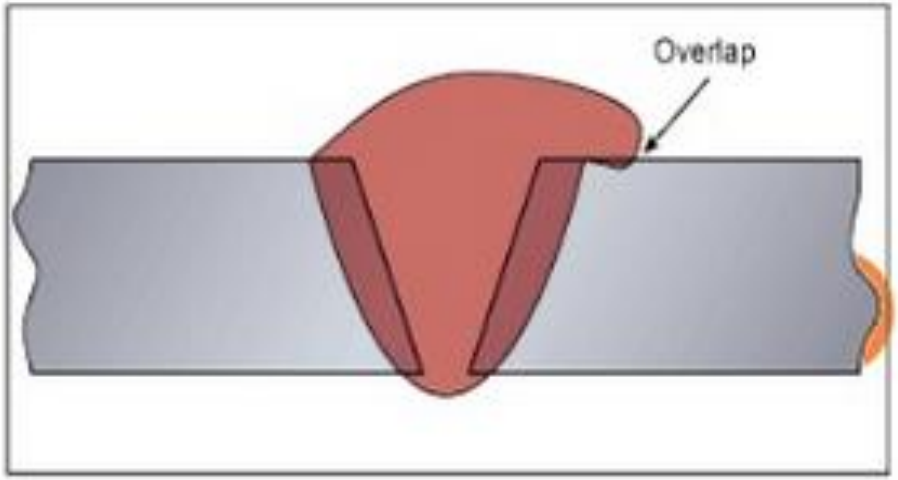
Repair:- Remove & reweld, being careful to completely remove the defective area.



OVERLAP

Cause:- Improper welding technique, steep electrode angle, fast travel speed

Prevention:- Overlap is a contour problem. Proper welding technique will prevent this problem

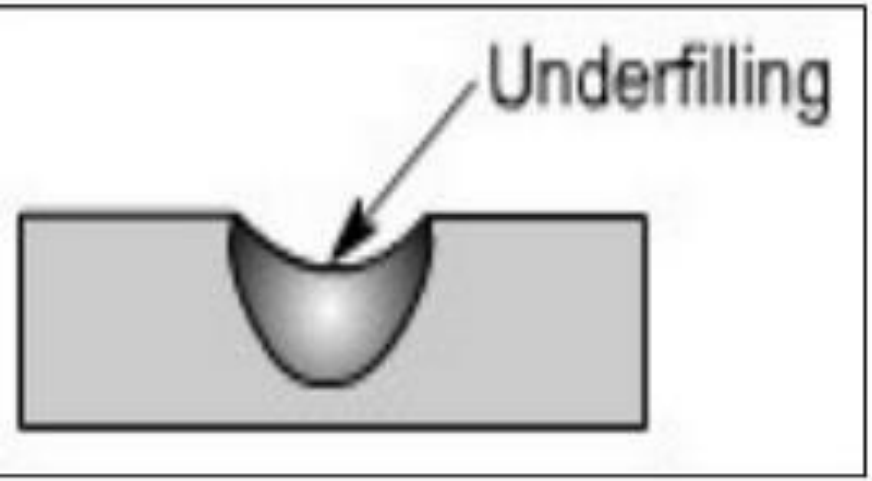


UNDERFILL

Cause:- Improper welding techniques

Prevention:- Apply proper welding techniques for the weld type & position. Use stripper beads before the cover pass.

Repair:- Simply weld to fill. May require preparation by grinding.

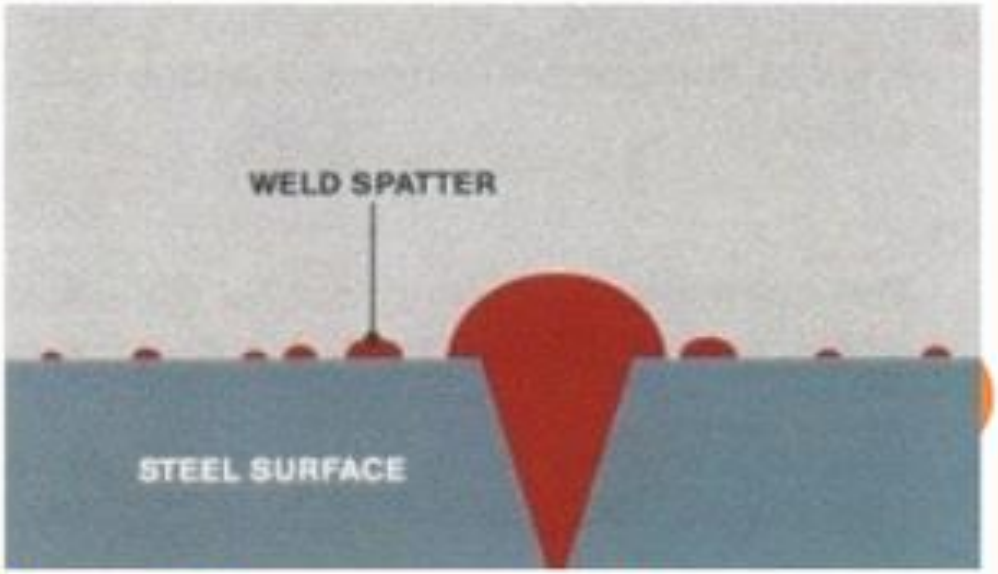


SPATTER

Cause:- High arc power, magnetic arc blow, Damp electrodes

Prevention:- Reduce arc power, reduce arc length, use dry electrodes

Repair:- Remove by mechanical process

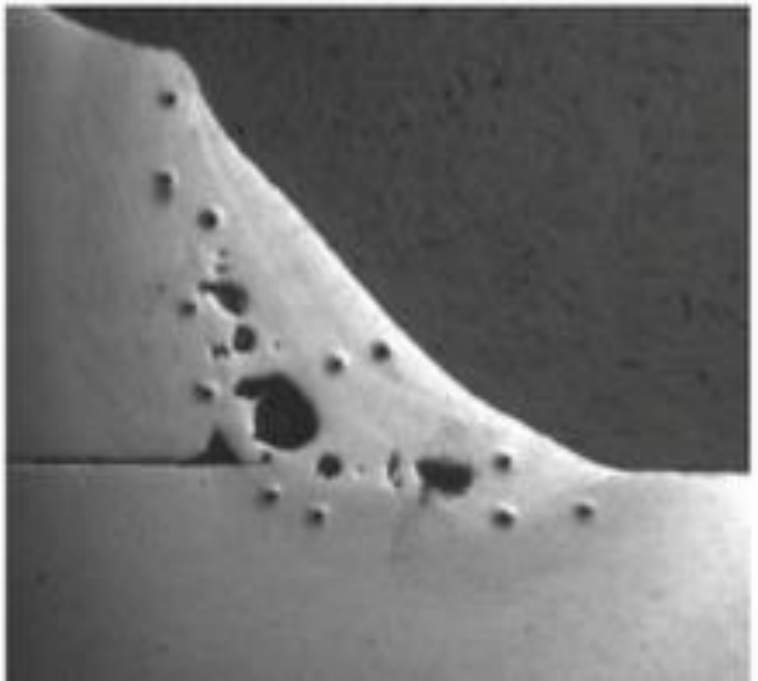


POROSITY

In this defect, air bubbles or gases are present in the weld zone

Cause:- inclusion of atmospheric gases, sulfur in weld metal, or surface contaminants

Prevention:- slower speed to allow gases time to escape

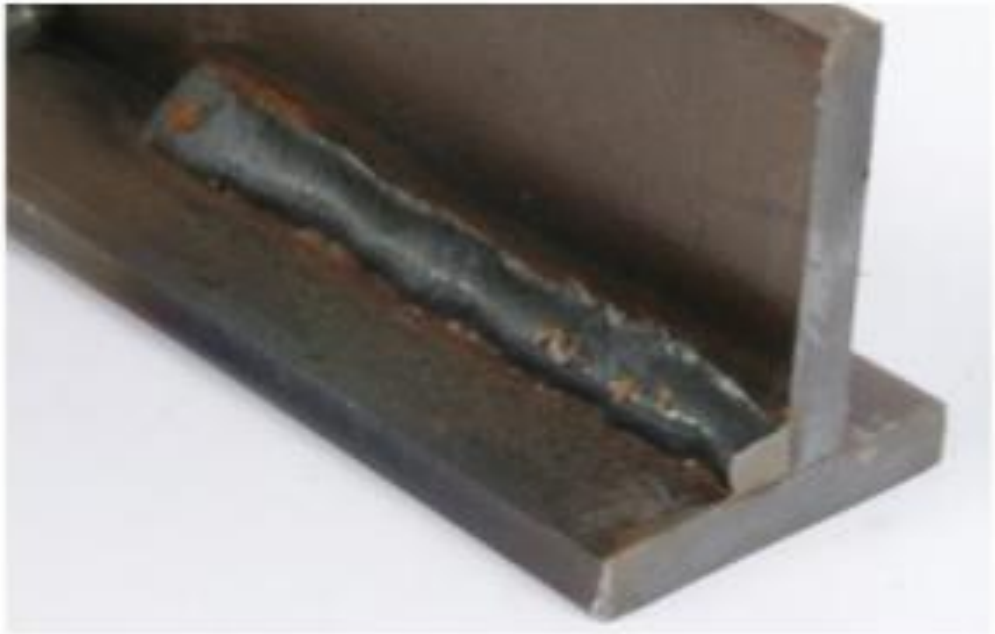


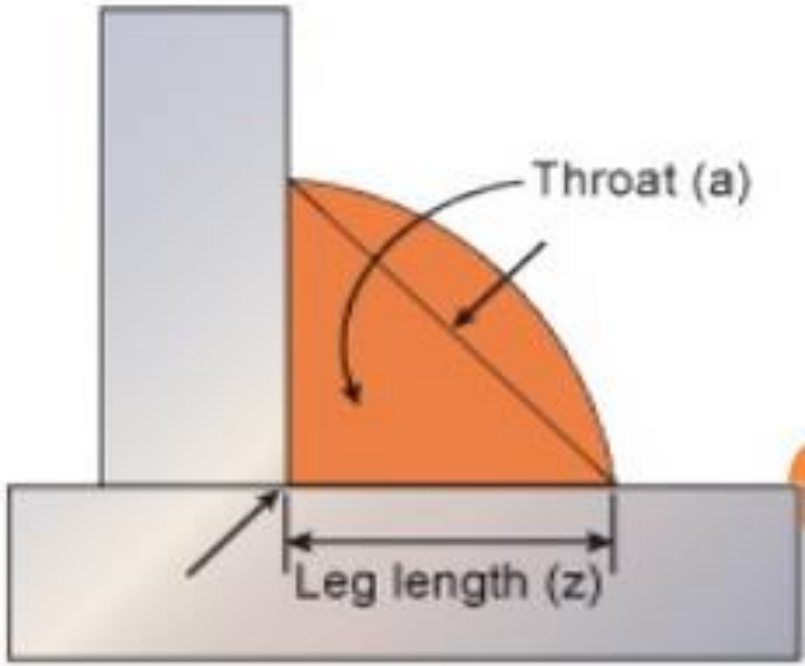
EXCESSIVE CONVEXITY

Cause:- Amperage & travel speed

Prevention:- Observe proper parameters & techniques

Repair:- Must blend smoothly into the base metal



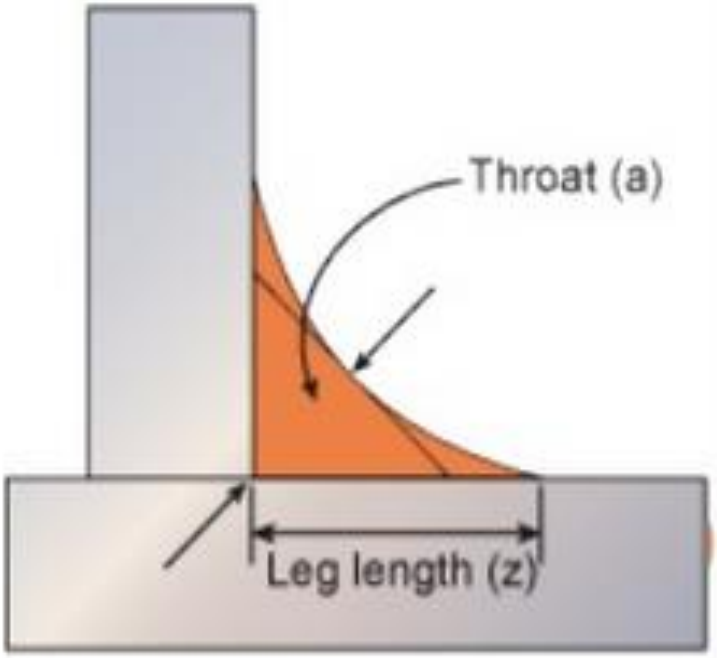


EXCESSIVE CONCAVITY

Cause:- Amperage & travel speed

Prevention:- Observe proper parameters & techniques

Repair:- Must blend smoothly into the base metal

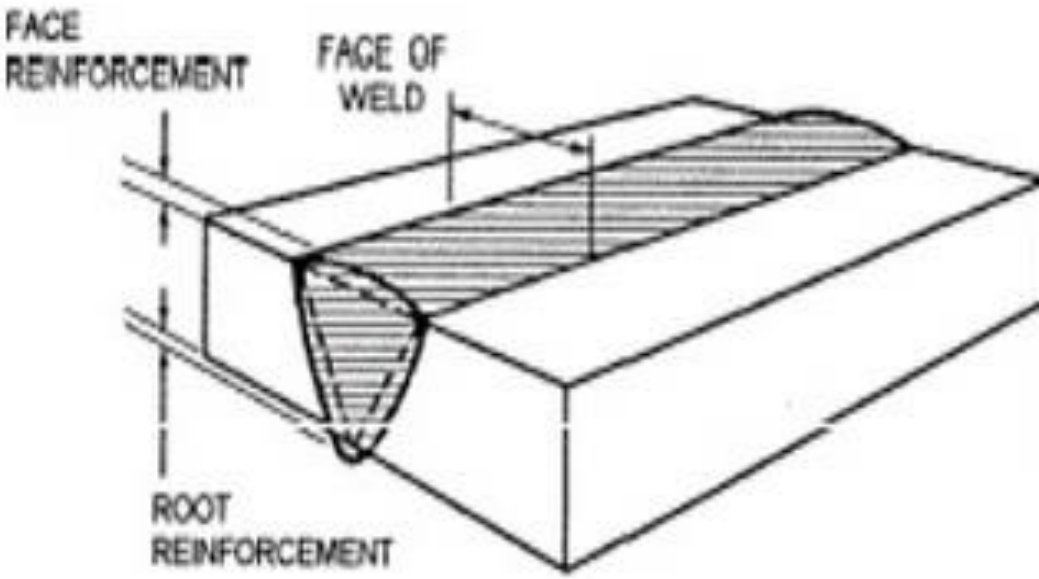


EXCESSIVE WELD REINFORCEMENT

Cause:- Travel speed too slow, amperage too low

Prevention:- Set travel speed & amperage on scrap plate

Repair:- Remove excessive reinforcement and feather the weld toes to a smooth transition to the base plate.

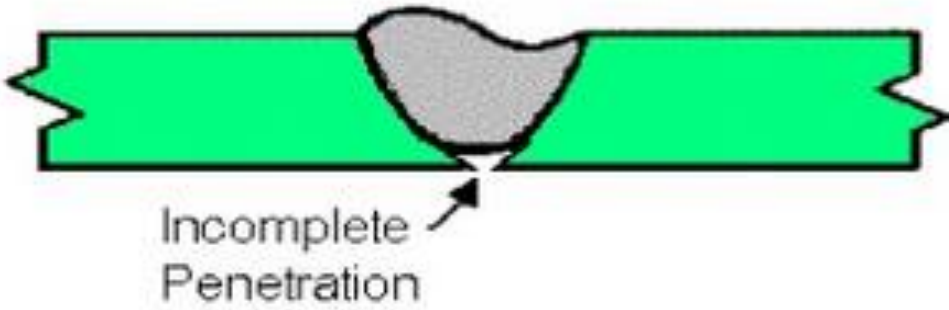


INCOMPLETE PENETRATION

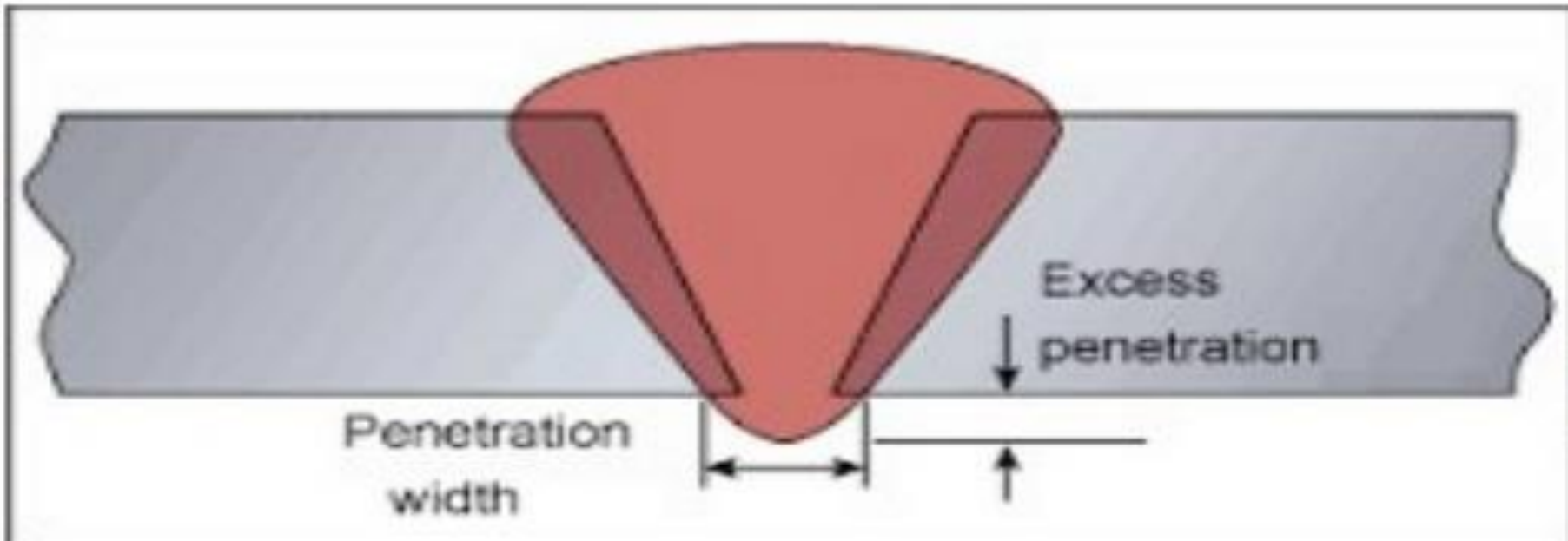
Cause:- Low amperage, low preheat, tight root opening, fast travel speed, short arc length

Prevention:- Correct the contributing factors.

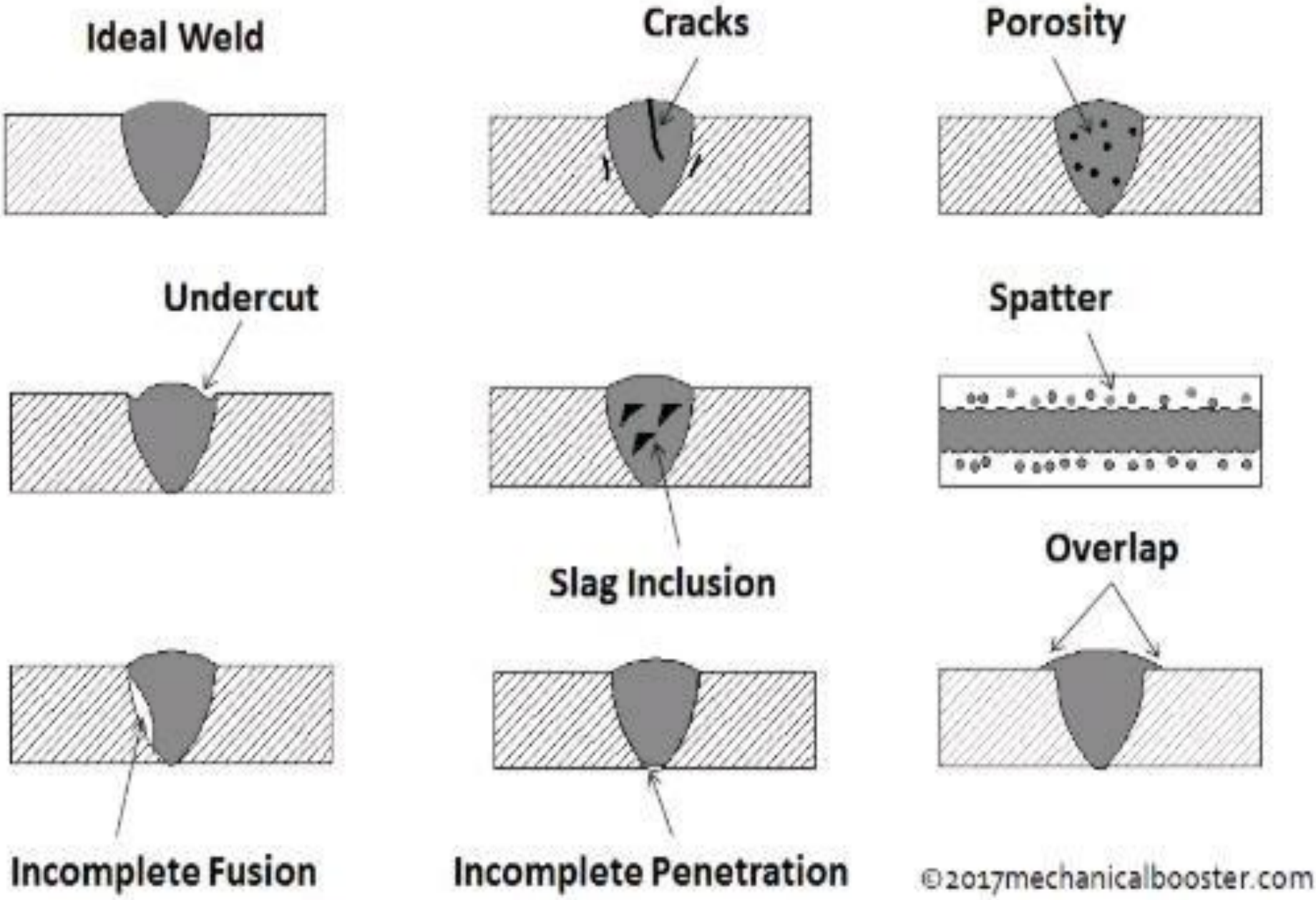
Repair:- Back gauge and back weld



EXCESSIVE PENETRATION



Different Welding Defects



DESTRUCTIVE TESTING

- This test is performed after the completion of welding. In NDT, physical damage is done to the test component.

- PURPOSE:
  - Verifies properties of a material.
  - Determines quality of welds.
  - Helps you to reduce failures, accidents and costs.
  - Ensures compliance with regulations.

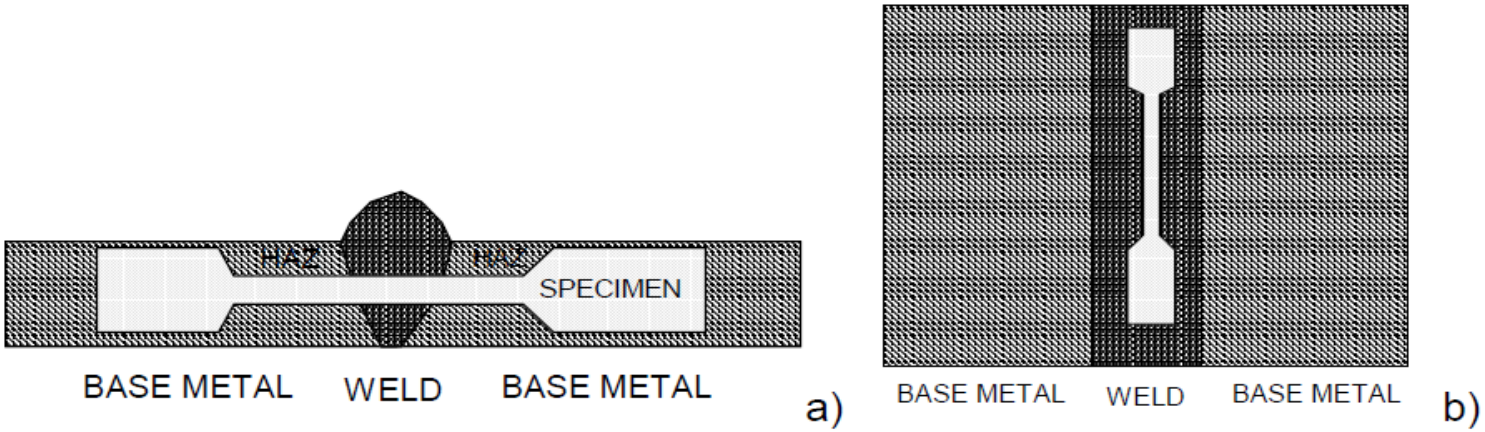
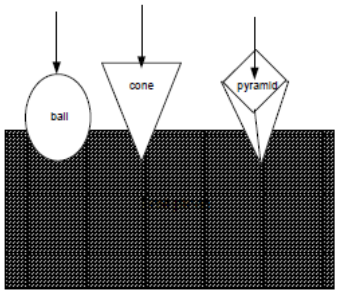


Fig. 31.1 Schematic of tensile specimens from a) transverse section of weld joints and b) all weld specimen

Parameter	Brinell	Rockwell	Knoop	Vickers
Load	500-2000 kg	Minor: 10 kg Major: 60 to 200 kg as dictated by scale to be used (A-C)	10 to 3000 g	
Indenter	Ball	Ball or cone	Cone	Pyramid
Measurement	Diameter	Depth	Diagonal	Diagonal



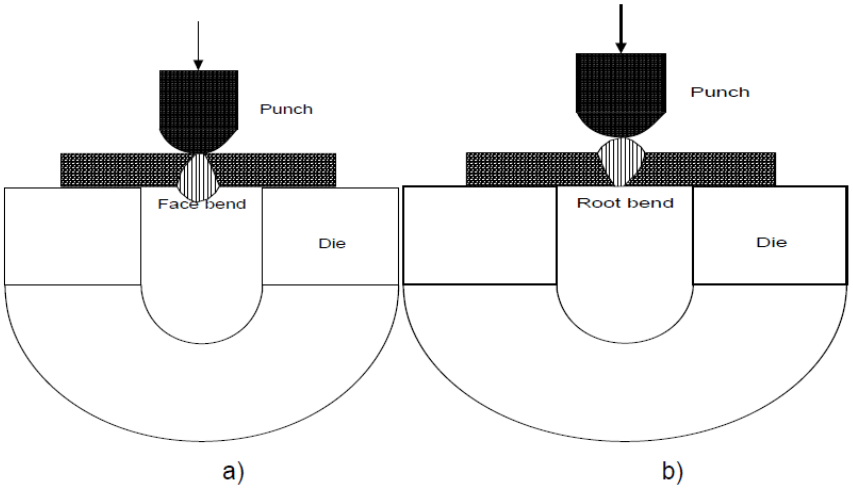
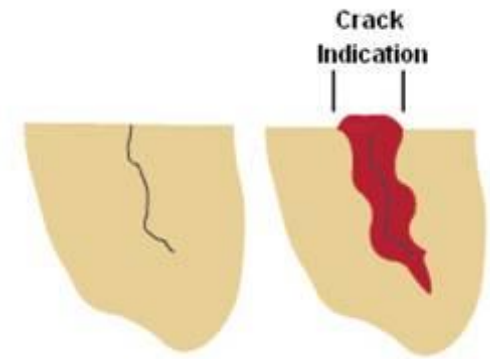


Fig. 31.4 Schematics of guided bend tests a) face bend and b) root bend.

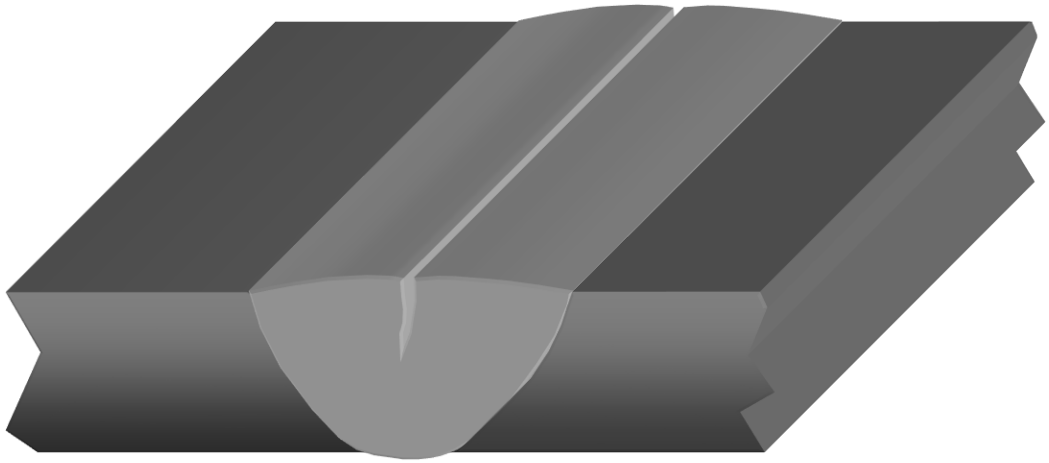
INTRODUCTION

- Liquid Penetrant Testing (PT) is used to verify the Surface defects only.
- It works with the capillary action principle.
- It can be used both for Magnetic and and non magnetic materials.
- It can detect surface defects which is not visible to the naked eye



SURFACE CLEANING

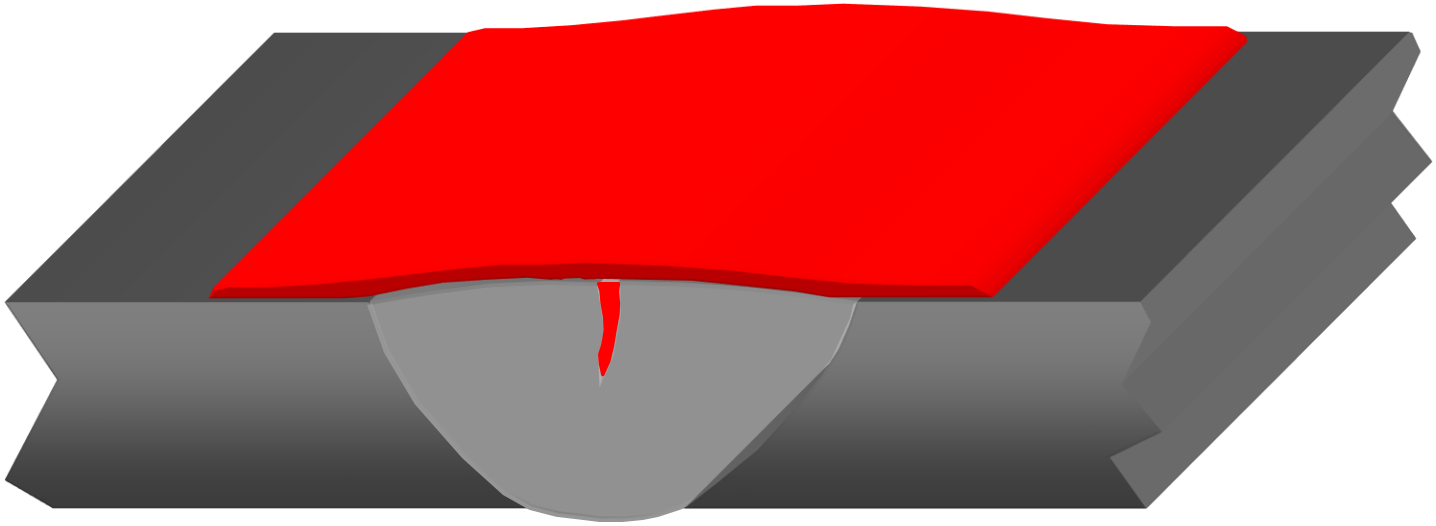
- Parts must be free of dirt, rust, scale, oil, grease, etc. to perform a reliable inspection.
- The cleaning process must remove contaminants from the surfaces of the part and defects, and must not plug any of the defects.



Pre-cleaning is the most important step in the PT process!!!

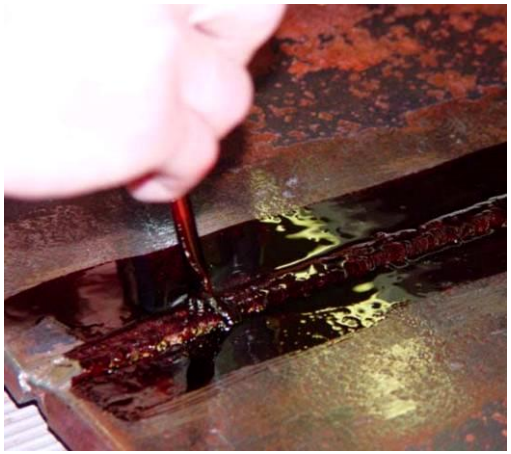
APPLICATION OF PENETRANT

- After Cleaning the surface, Penetrant shall be applied on the Test Surface.
- Soak for 10 to 15 minutes (Dwell Time) to enable Penetrant to enter in to the defective spots by capillary action.



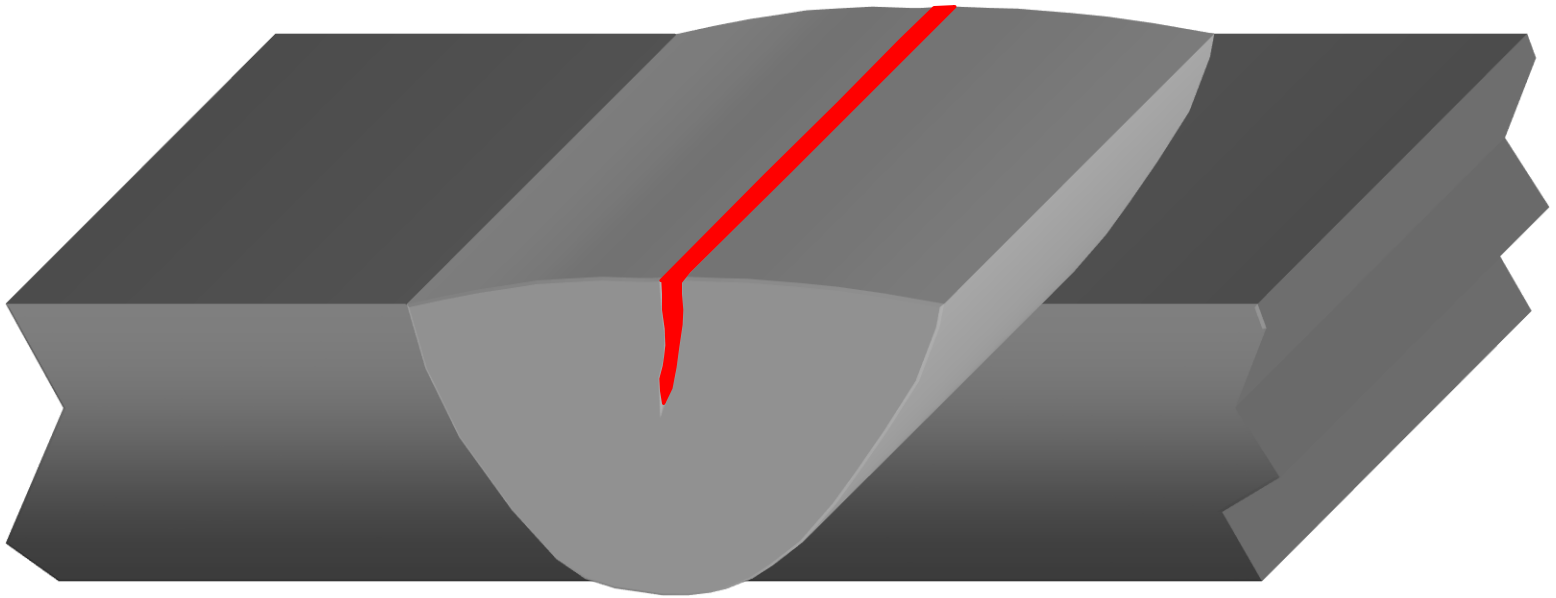
PENETRANT APPLICATION METHOD

- Brushing
- Spraying
- Dipping/ Immersing
- Flow-on
- And more



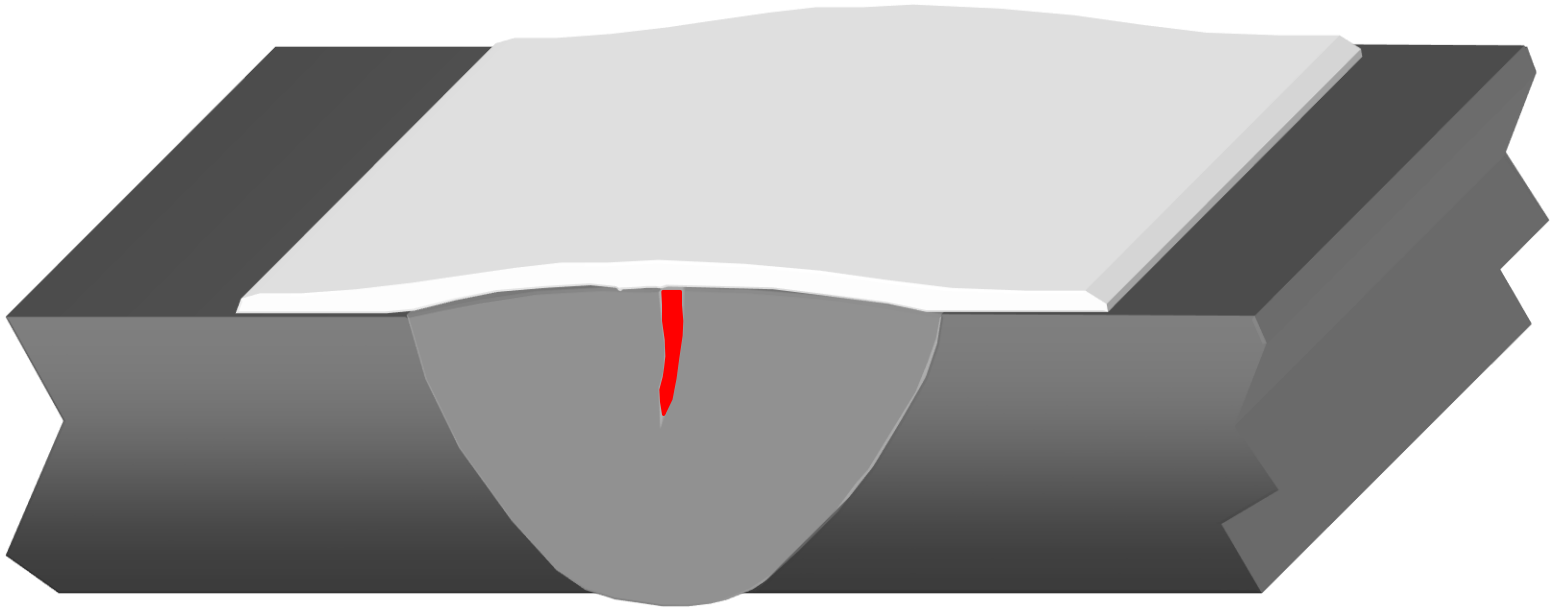
CLEANING OFF PENETRANT

- After sufficient penetration time (dwell time), penetrant must be removed.
- Care must be taken not to wash any penetrant out of defects spot.



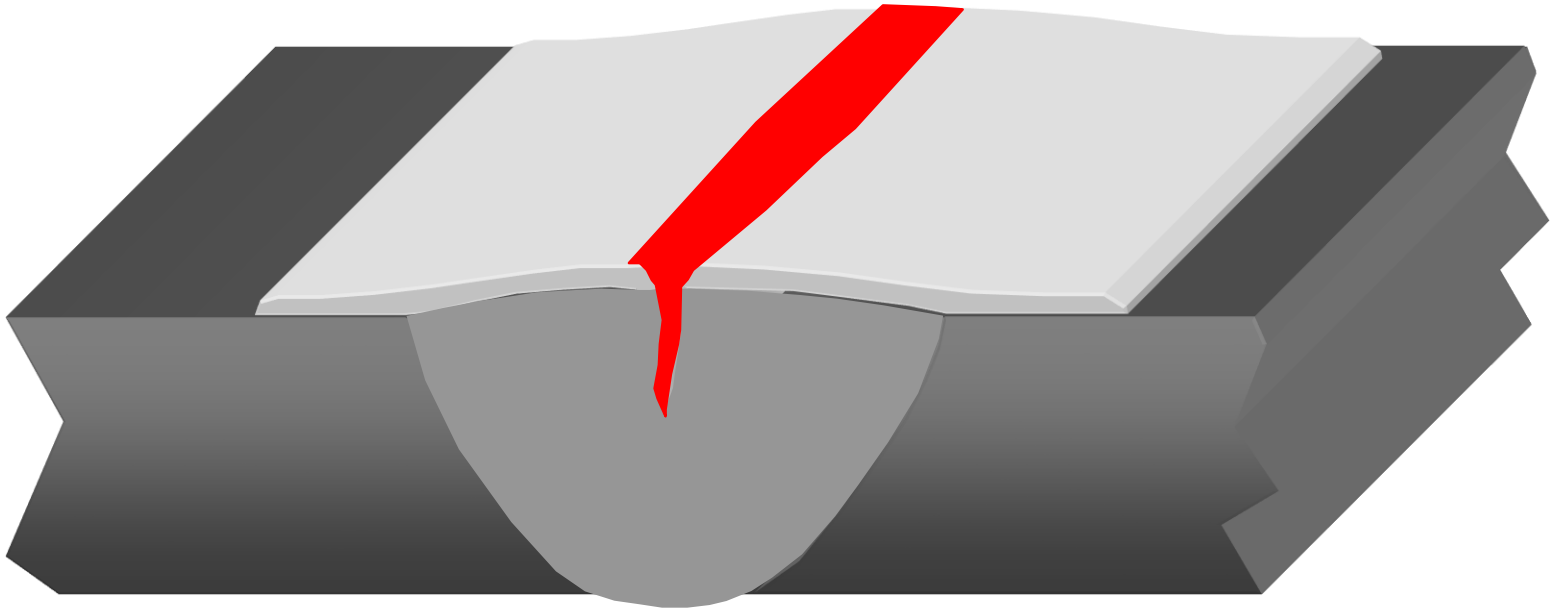
APPLYING DEVELOPER

- After Cleaning the Penetrant, Developer will be applied by spray.
- The developer acts as a contrast against the penetrant and allows for reverse capillary action to take place.
- Developer is in white color for easy visibility.



INSPECTION / DEVELOPMENT TIME

- Inspection should take place immediately after the developer has been applied.
- Any defects present will show as a bleed out during development time.

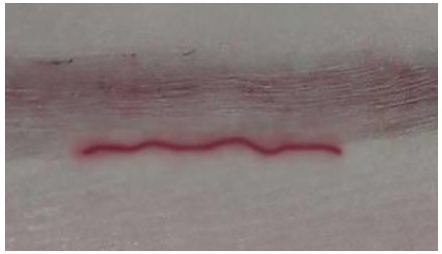


POST CLEANING

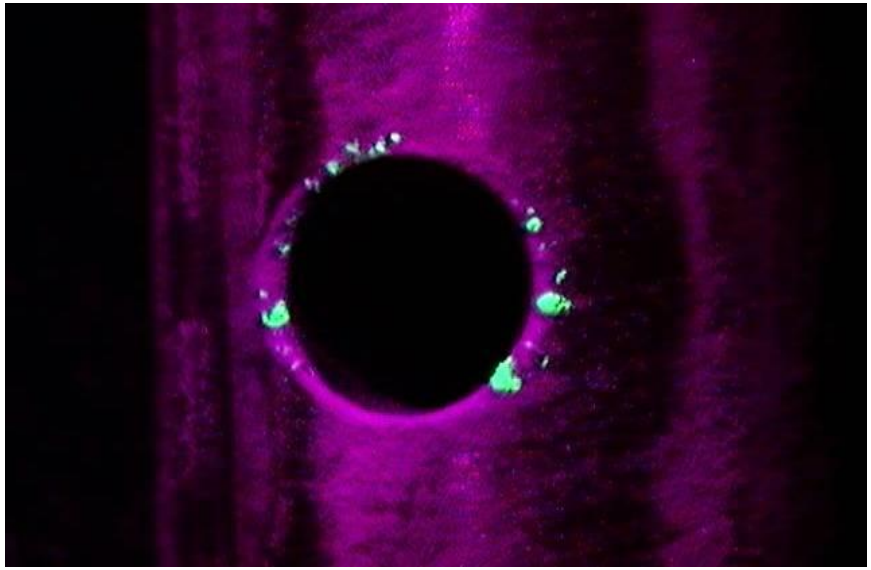
- The final step in the penetrant inspection process is to thoroughly clean the part that has been tested to remove all penetrant processing materials.

- The residual materials could possibly affect the performance of the part or affect its visual appeal.

TYPICAL EXAMPLE OF DEFECTS IDENTIFIED AFTER DEVELOPER APPLICATION



IDENTIFYING THE DEFECT



Relevant crack indications from an abusive drilling process

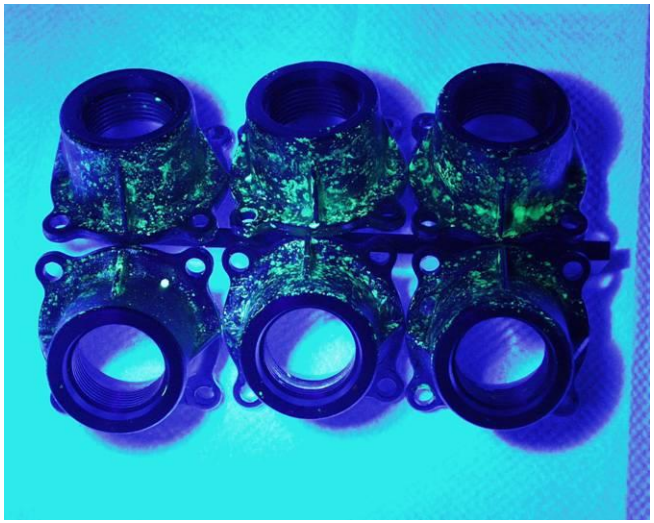
Non-relevant weld geometry indications

WHAT CAN BE INSPECTED BY PT?

Almost any material that has a relatively smooth, non-porous surface can be Verified for defects

WHAT KIND OF OBJECT WHICH CAN NOT BE PT EXAMINED?

- Components with rough surfaces, such as sand castings, that trap and hold penetrant.
- Porous ceramics
- Wood and other fibrous materials.
- Plastic parts that absorb or react with the penetrant materials.
- Components with coatings that prevent penetrants from entering defects.



WHAT TYPES OF DEFECTS DETECTED BY PT?

All Types of defects that are open to the surface can be verified by Penetrant Testing

– Rolled products -- cracks, seams, laminations.

– Castings -- cold shuts, hot tears, porosity, blow holes, shrinkage.

– Forgings – cracks, laps, external bursts.

– Welds – cracks, porosity, undercut, overlap, lack of fusion, lack of penetration.

PENETRANT MATERIALS

Penetrant

Type

1) Fluorescent
2) Normal Visible

Method

1) Water Washable
2) Postemulsifiable - Lipophilic
3) Solvent Removable
4) Postemulsifiable - Hydrophilic

Developer

Form

1) Dry Powder
2) Wet, Water Soluble
3) Wet, Water Suspendable
4) Wet, Non-Aqueous

ADVANTAGES OF PT

- Relatively ease to use.
- PT Can be used on a wide range of material types.
- Large areas or large volumes of parts/materials can be inspected rapidly at low cost.
- Parts with complex geometries are routinely inspected.
- Indications are produced directly on surface of the part providing a visual image of the discontinuity.
- Initial equipment investment is low.
- Aerosol spray cans can make equipment very portable.

DISADVANTAGES OF PT

- Only detects surface breaking defects.
- Requires relatively smooth nonporous material.
- Precleaning is critical. Contaminants can mask defects.
- Requires multiple operations under controlled conditions.
- Chemical handling precautions necessary (toxicity, fire, waste).
- Metal smearing from machining, grinding and other operations inhibits detection. Materials may need to be etched prior to inspection.
- Post cleaning is necessary to remove chemicals.

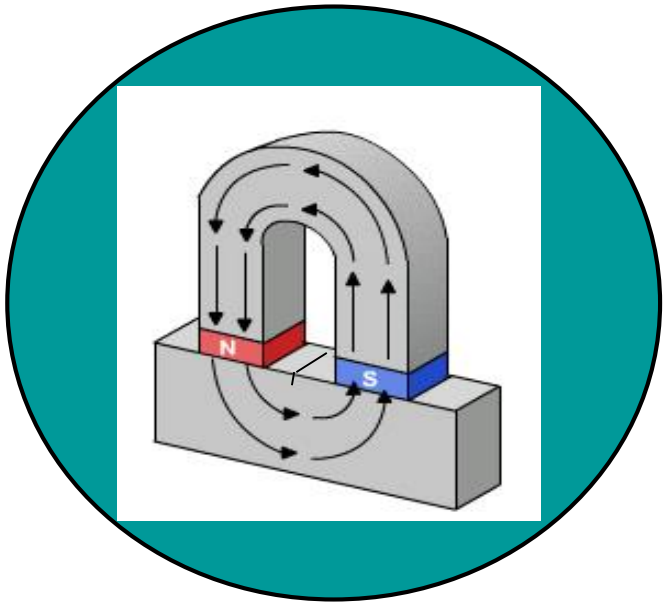
MAGNETIC PARTICLE TESTING (MT)

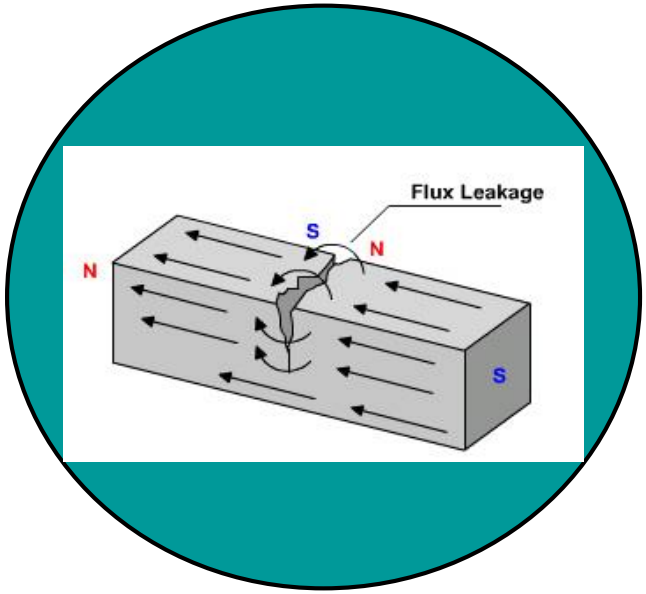
INTRODUCTION

- Widely used method in Fabrication / Construction / Marine Industries.
- MT can detect both production discontinuities (seams, laps, grinding cracks and quenching cracks) and in-service damage (fatigue and overload cracks).
- It can be used only for Ferro Magnetic Materials.
- It reveals Surface and Sub-surface defects.

HOW DOES MT WORKS?

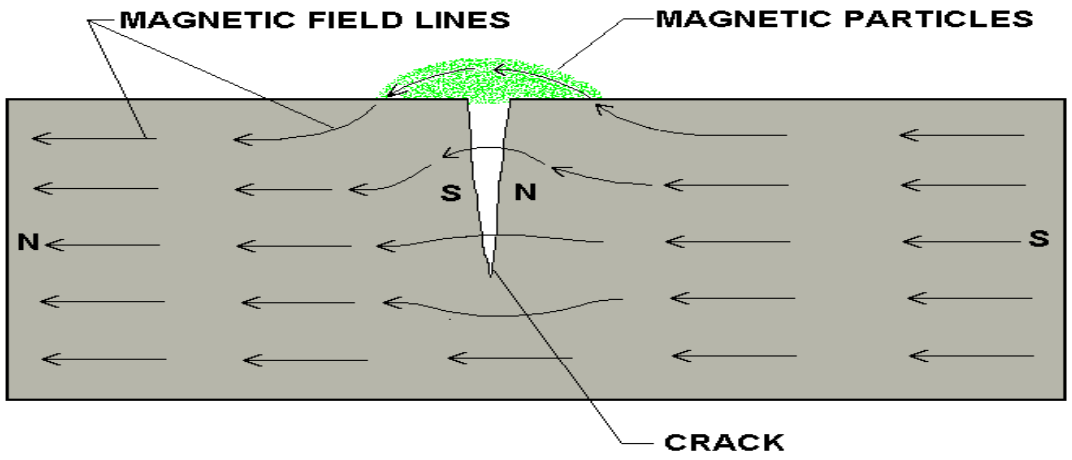
- A ferromagnetic test specimen is magnetized with a strong magnetic field created by a magnet or special equipment.
- If the specimen has a discontinuity, the discontinuity will interrupt the magnetic field flowing through the specimen and a leakage field will occur.





HOW DOES MT WORKS?

- Fine milled iron particles coated with a dye pigment are applied to the test specimen.
- These particles are attracted to leakage fields and will cluster to form an indication directly over the discontinuity.
- This indication can be visually detected under proper lighting conditions.



BASIC STEPS TO CONDUCT MT

1. Component pre-cleaning
2. Introduction of magnetic field
3. Application of magnetic media
4. Interpretation of magnetic particle indications

Magnetic Field

Pre Cleaning

The required magnetic field can be introduced into a component in a number of ways.

1. **Using a permanent magnet or an electromagnet that contacts the test piece**

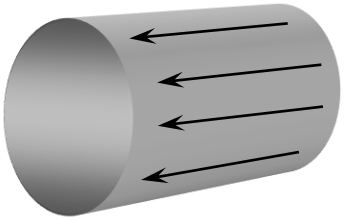
2. **Flowing an electrical current through the specimen**

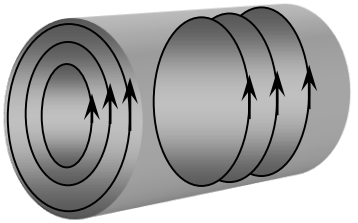
3. **Flowing an electrical current through a coil of wire around the part or through a central conductor running near the part.**

DIRECTION OF MAGNETIC FIELD

Two general types of magnetic fields (longitudinal and circular) may be established within the specimen. The type of magnetic field established is determined by the method used to magnetize the specimen.

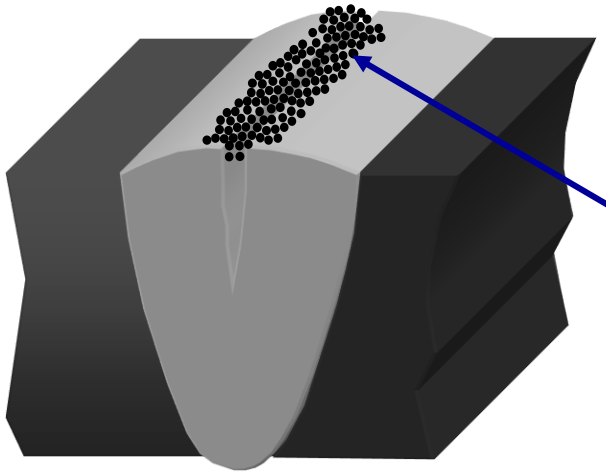
- **A longitudinal magnetic field has magnetic lines of force that run parallel to the long axis of the part.**
- **A circular magnetic field has magnetic lines of force that run circumferentially around the perimeter of a part.**





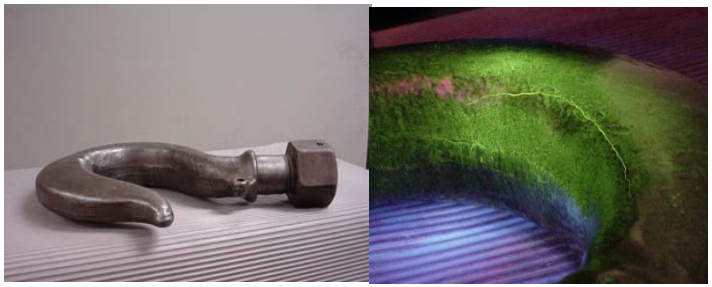
RESULT INTERPRETATION

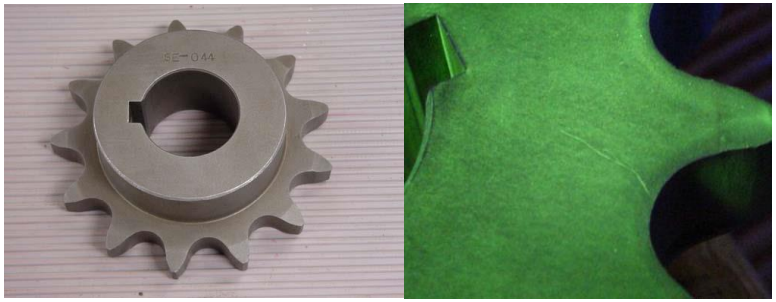
1. After applying the magnetic field, indications that form on the specimen to be interpreted.
2. This process requires that the inspector have knowledge to distinguish between relevant and non-relevant indications.

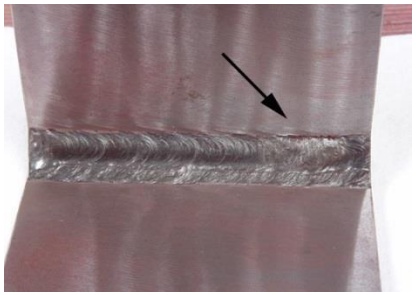


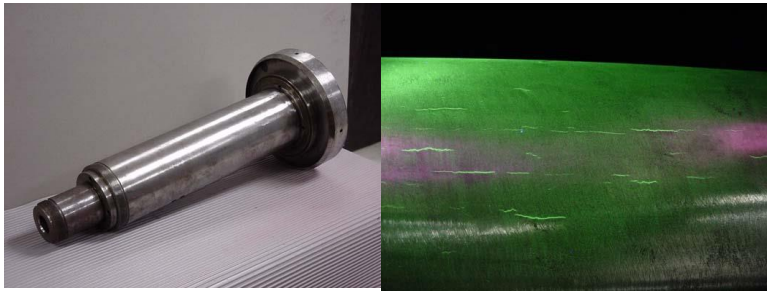
Collection of Magnetic particles due to leakage field

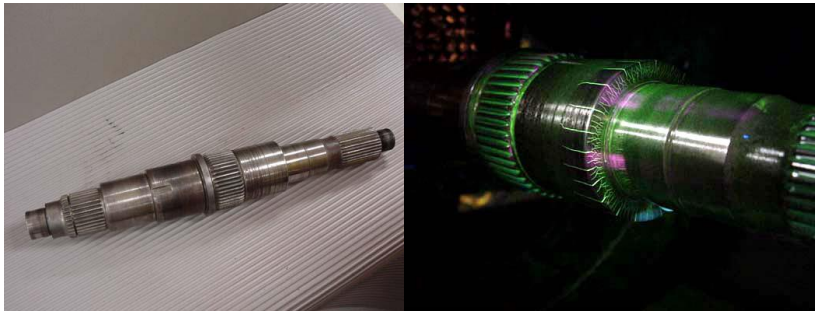
DEFECTS REVEALED BY MT











ADVANTAGES OF MT INSPECTION

- Can detect both surface and near sub-surface defects.
- Can inspect parts with irregular shapes easily.
- Precleaning of components is not as critical as it for some other inspection methods. Most contaminants within a flaw will not hinder flaw detectability.
- Fast method of inspection and indications are visible directly on the specimen surface.
- Considered low cost compared to many other NDT methods.
- Is a very portable inspection method especially when used with battery powered equipment.

DISADVANTAGES OF MT INSPECTION

- Cannot inspect non-ferrous materials such as aluminum, magnesium or most stainless steels.
- Inspection of large parts may require use of equipment with special power requirements.
- Some parts may require removal of coating or plating to achieve desired inspection sensitivity.
- Limited subsurface discontinuity detection capabilities. Maximum depth sensitivity is approximately 0.6” (under ideal conditions).
- Post cleaning, and post demagnetization is often necessary.
- Alignment between magnetic flux and defect is important

ULTRASONIC TESTING

PRINCIPLES OF ULTRASONIC INSPECTION

- Ultrasound waves are introduced into a material where they travel in a straight line and at a constant speed until they encounter a surface.

- At surface interfaces some of the wave energy is reflected and some is transmitted.

- The amount of reflected or transmitted energy can be detected and provides information about the size of the reflector.

- The travel time of the sound can be measured and this provides information on the distance that the sound has traveled.

TEST TECHNIQUES

- Ultrasound testing is a very versatile inspection method, and inspections can be accomplished in a number of different ways.
- Ultrasonic inspection techniques are commonly divided into 3 primary classifications.

1. Pulse-echo and Through Transmission

(Relates to whether reflected or transmitted energy is used)

2. Normal Beam and Angle Beam

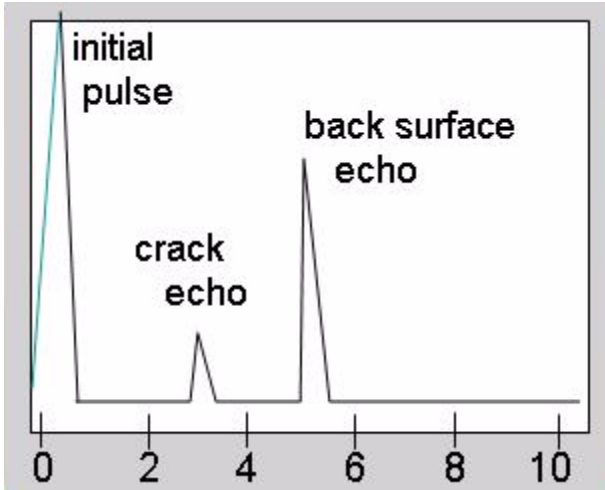
(Relates to the angle that the sound energy enters the test article)

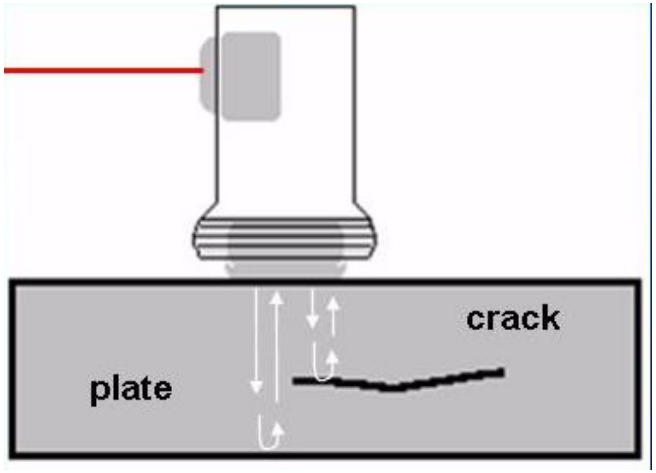
3. Contact and Immersion

(Relates to the method of coupling the transducer to the test article)

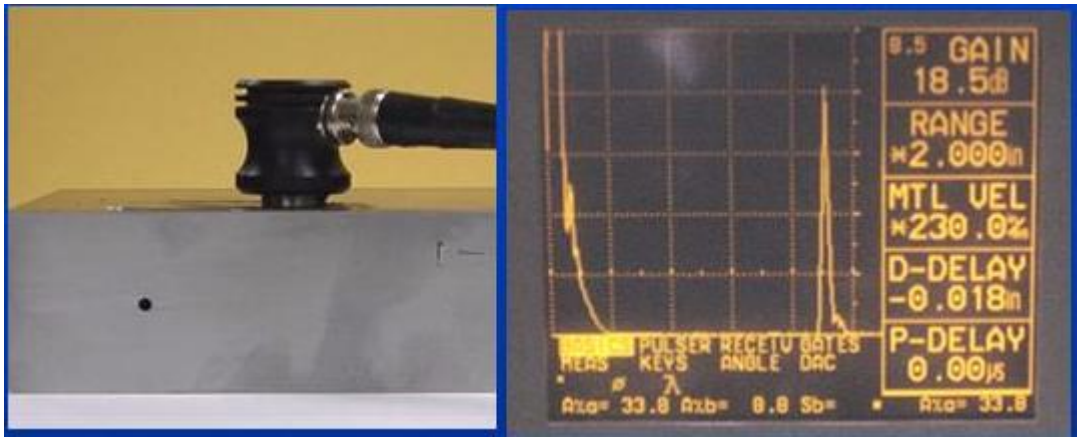
TEST TECHNIQUES - PULSE - ECHO

- In pulse-echo testing, a transducer sends out a pulse of energy and the same or a second transducer listens for reflected energy (an echo).
- Reflections occur due to the presence of discontinuities and the surfaces of the test article.
- The amount of reflected sound energy is displayed versus time, which provides the inspector information about the size and the location of features that reflect the sound.



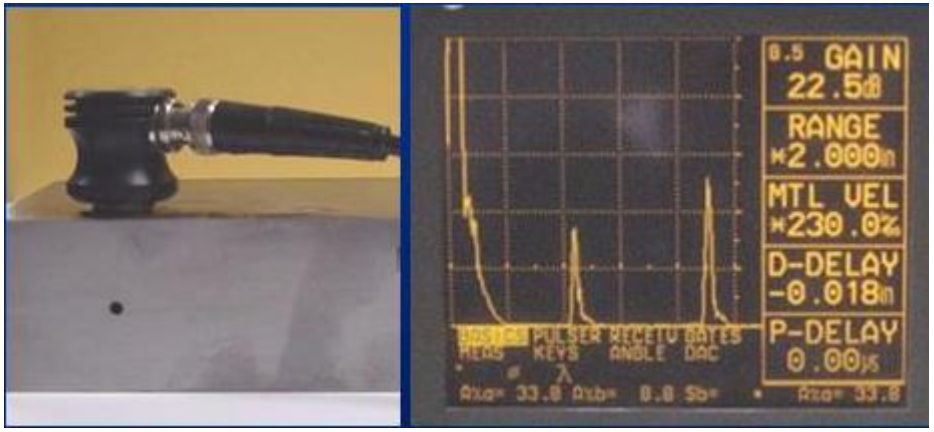


TEST TECHNIQUES - PULSE - ECHO (CONT.)



Digital display showing signal generated from sound reflecting off back surface.

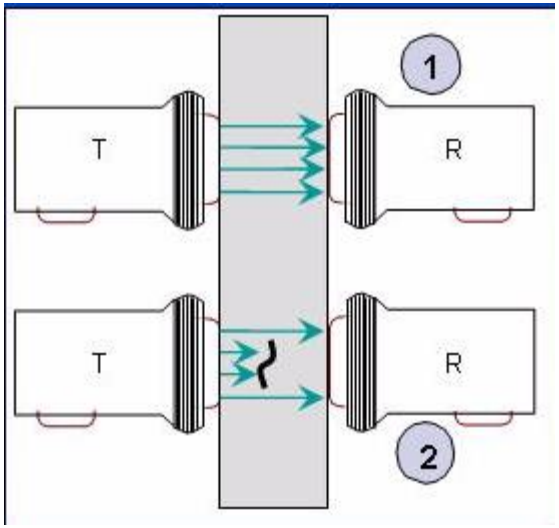
Digital display showing the presence of a reflector midway through material, with lower amplitude back surface reflector.

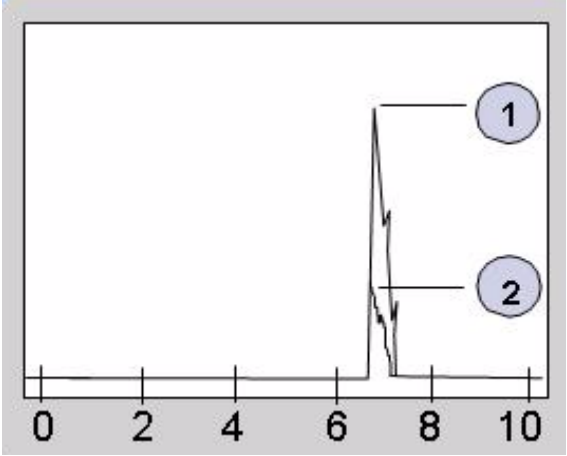


The pulse-echo technique allows testing when access to only one side of the material is possible, and it allows the location of reflectors to be precisely determined.

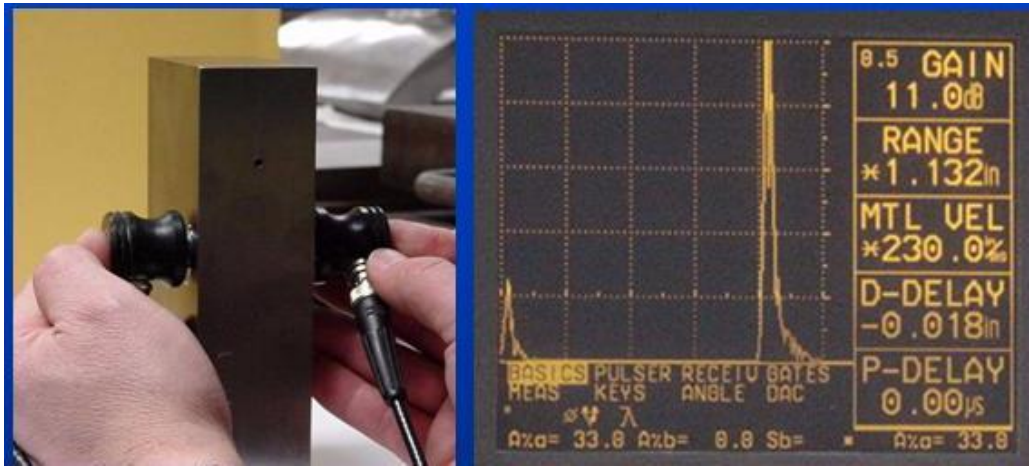
TEST TECHNIQUES - THROUGH - TRANSMISSION

- Two transducers located on opposing sides of the test specimen are used. One transducer acts as a transmitter, the other as a receiver.
- Discontinuities in the sound path will result in a partial or total loss of sound being transmitted and be indicated by a decrease in the received signal amplitude.
- Though transmission is useful in detecting discontinuities that are not good reflectors, and when signal strength is weak. It does not provide dept information.

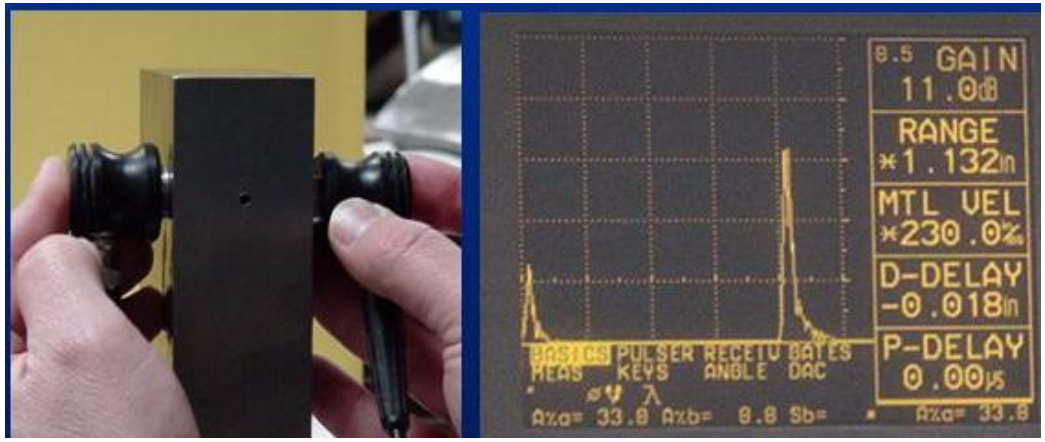




TEST TECHNIQUES - THROUGH - TRANSMISSION

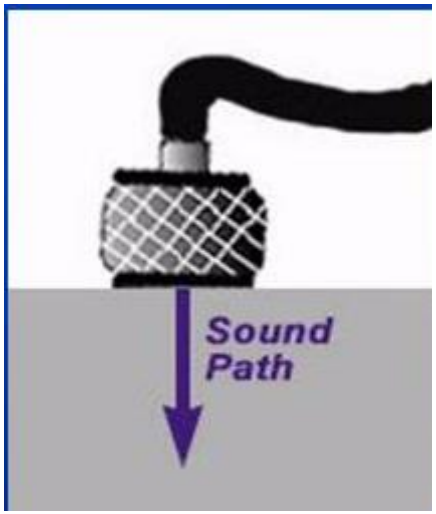


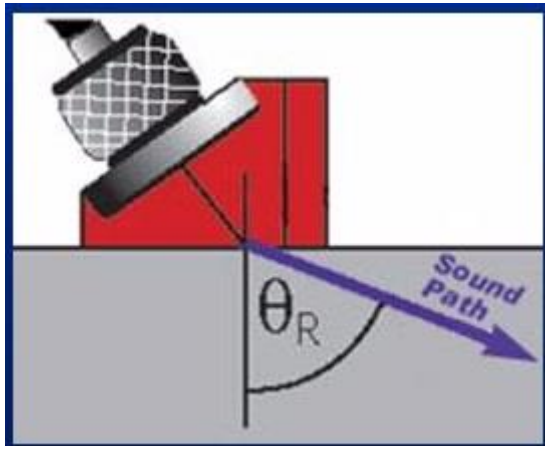
Digital display showing received sound through material thickness.



Digital display showing loss of signal due to presence of a discontinuity in the sound field.

TEST TECHNIQUES - NORMAL AND ANGLE BEAM

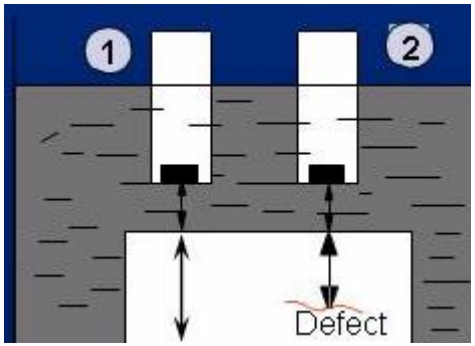


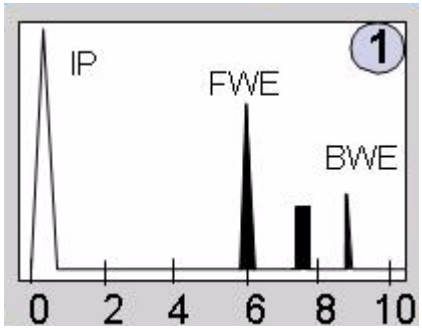


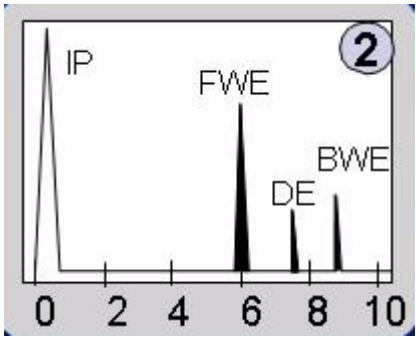
- In normal beam testing, the sound beam is introduced into the test article at 90 degree to the surface.
- In angle beam testing, the sound beam is introduced into the test article at some angle other than 90.
- The choice between normal and angle beam inspection usually depends on two considerations:
  - The orientation of the feature of interest - the sound should be directed to produce the largest reflection from the feature.
  - Obstructions on the surface of the part that must be worked around.

TEST TECHNIQUES - NORMAL AND ANGLE BEAM

- To get useful levels of sound energy into a material, the air between the transducer and the test article must be removed. This is referred to as coupling.
- In contact testing (shown on the previous slides) a couplant such as water, oil or a gel is applied between the transducer and the part.
- In immersion testing, the part and the transducer are place in a water bath. This arrangement allows better movement of the transducer while maintaining consistent coupling.
- With immersion testing, an echo from the front surface of the part is seen in the signal but both otherwise signal interpretation is the same for the 2 techniques.







INSPECTION APPLICATIONS

• Some of the applications for which ultrasonic testing may be employed include:

- Flaw detection (cracks, inclusions, porosity, etc.)
- Erosion & corrosion thickness gauging
- Assessment of bond integrity in adhesively joined and brazed components.
- Estimated of void content in composites and plastics
- Measurement of case hardening depth in steels
- Estimation of grain size in metals

On the following slides are examples of some common applications of ultrasonic inspection.

ADVANTAGES OF ULTRASONIC TESTING

- Sensitive to both surface and subsurface discontinuities.
- Depth of penetration for flaw detection or more measurement is superior to other methods.
- Only single-sided access is needed when pulse-echo technique is used.
- High accuracy in determining reflector position and estimating size and shape.
- Minimal part preparation required.
- Electronic equipment provides instantaneous results.
- Details images can be produced with automated systems.
- Has other uses such as thickness measurements, in addition to flaw detection.

LIMITATION OF ULTRASONIC TESTING

- Surface must be accessible to transmit ultrasound.
- Skill and training is more extensive than with some other methods.
- Normally requires a coupling medium to promote transfer of sound energy into test specimen.
- Materials that are rough, irregular in shape, very small, exceptionally thin or not homogeneous are difficult to inspect.
- Cast iron and other coarse grained materials are difficult to inspect due to low sound transmission and high signal noise.
- Linear defects oriented parallel to the sound beam may go undetected.
- Reference standards are required for both equipment calibration, and characterization of flaws.

RADIOGRAPHIC TESTING (RT)

INTRODUCTION

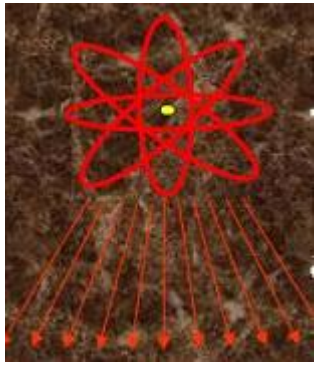
• This module presents information on the NDT method of radiography inspection or radiography.

• Radiography uses penetrating radiation that is directed towards a component.

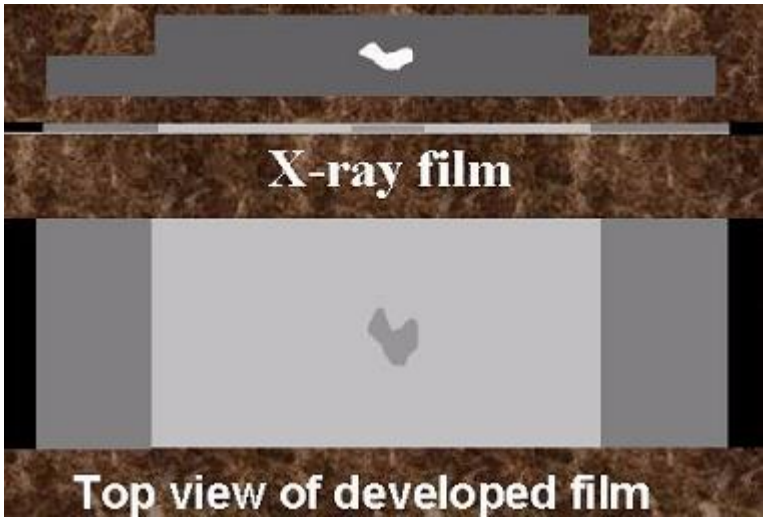
• The component stops some of the radiation. The amount that is stopped or absorbed is affected by material density and thickness differences.

• These differences in “absorption” can be recorded on film, or electronically.

GENERAL PRINCIPLES OF RADIOGRAPHY



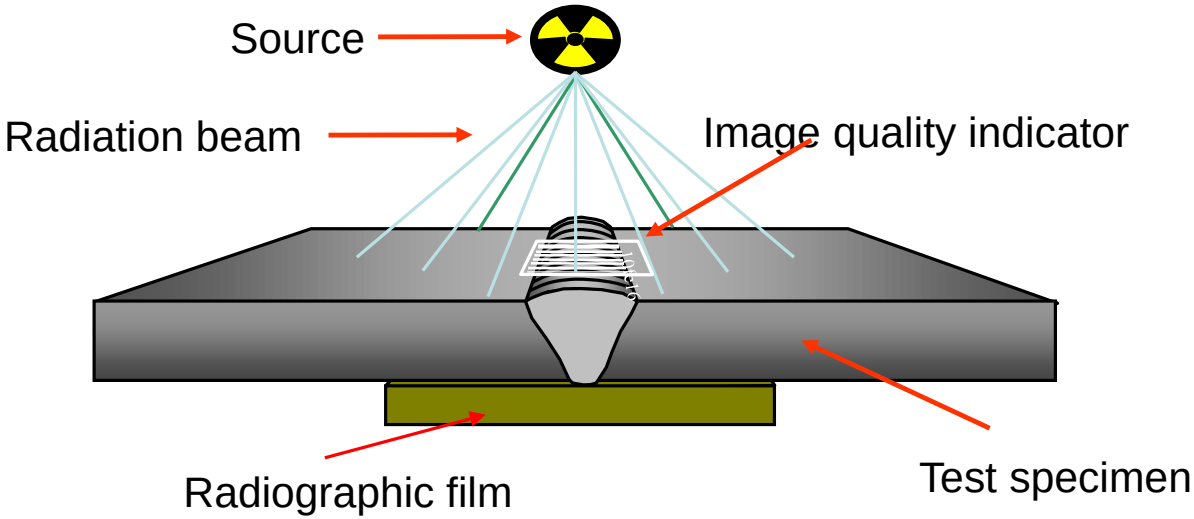
The part is placed between the radiation source and a piece of film. The part will stop some of the radiation. Thicker and more dense area will stop more of the radiation.

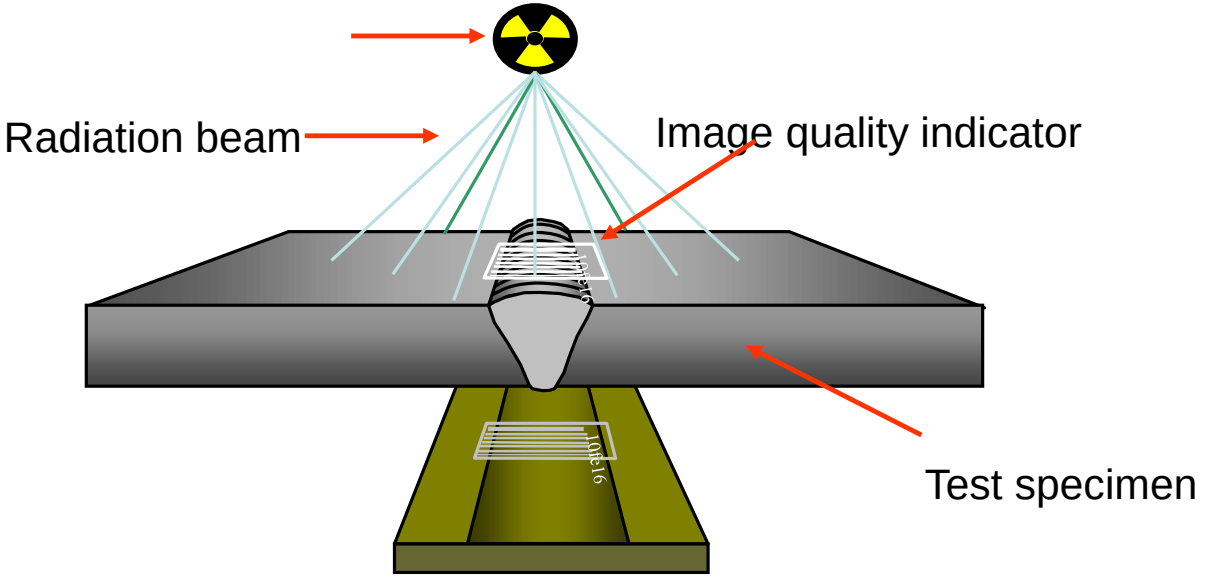


The film darkness (density) will vary with the amount of radiation reaching the film through the test object.

= less exposure

= more exposure


Source
Radiation beam
Image quality indicator
Radiographic film
Test specimen


Radiation beam
Image quality indicator
Test specimen

RADIOGRAPHIC TECHNIQUES

- Single Wall Single Image (SWSI)

  - film inside, source outside

- Single Wall Single Image (SWSI) panoramic

  - film outside, source inside (internal exposure)

- Double Wall Single Image (DWSI)

  - film outside, source outside (external exposure)

- Double Wall Double Image (DWDI)

  - film outside, source outside (elliptical exposure)

ADVANTAGES OF RADIOGRAPHY

- Techniques is not limited by material type or density.
- Can inspect assembled components.
- Minimum surface preparation required.
- Sensitive to changes in thickness, corrosion, voids, cracks, and material density changes.
- Detects both surface and subsurface defects.
- Provides a permanent record of the inspection.

LIMITATIONS OF RADIOGRAPHY

- Many safety precautions for the use of high intensity radiation.
- Many hours of technician training prior to use.
- Access to both sides of sample required.
- Orientation of equipment and flaw can be critical.
- Determining flaw depth is impossible without additional angled exposures.
- Expensive initial equipment cost.