

NDT

WELD DEFECTS

CLASSIFICATION OF DEFECTS

PLANER DEFECTS (TWO DIMENSIONAL DEFECTS)

Defects such as Crack, lack of fusion, lack of penetration, severe undercuts.

VOLUMINAR DEFECTS (THREE DIMENSIONAL DEFECTS)

Defects such as slag inclusion, cavities, pores etc.

TYPES OF DEFECTS

I. DEFECTS INVOLVING INADEQUATE BONDING

- LACK OF FUSION
- INCOMPLETE PENETRATION

II. FOREIGN INCLUSIONS

- SLAG.
- OXIDE FILMS
- TUNGSTEN.

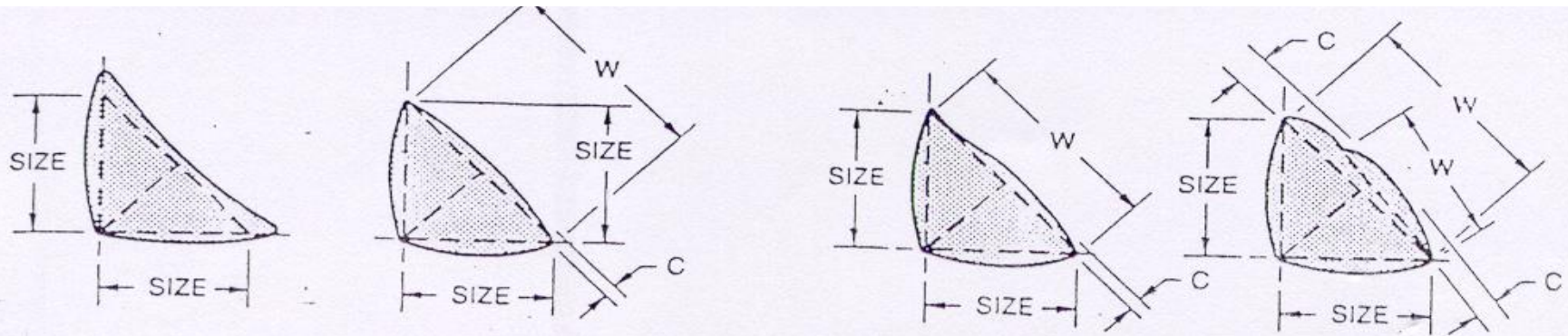
III. GEOMETRIC DEFECTS

- UNDERCUT
- EXCESSIVE REINFORCEMENT
- BURN THROUGH OR EXCESSIVE PENETRATION
- DISTORTION
- IMPROPER WELD PROFILE.

IV. METALLURGICAL DEFECTS

- CRACKS
- GAS POROSITY
- ARC STRIKES
- EMBRITTLEMENT
- STRUCTURAL NOTCHES

WELD PROFILES

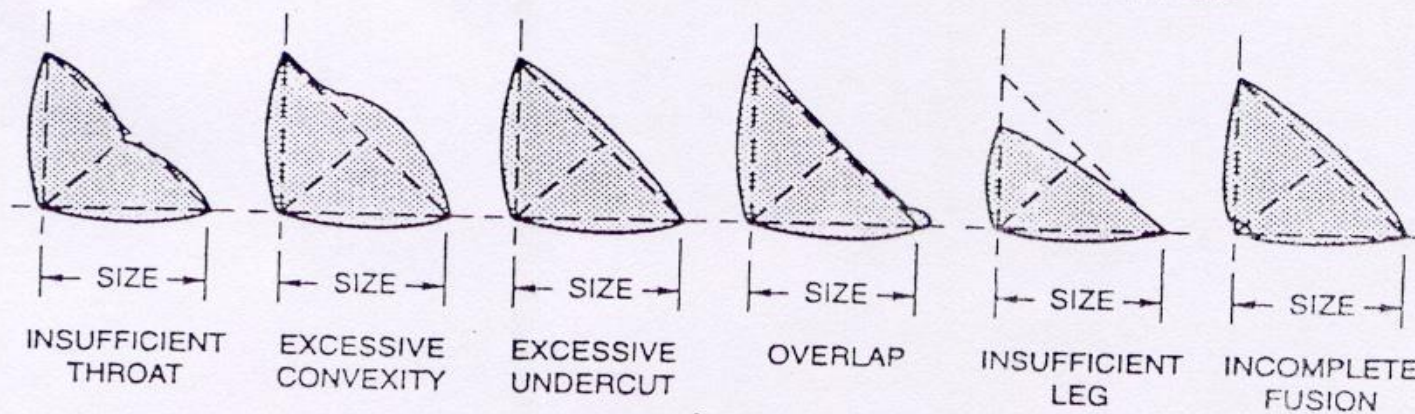


(A) DESIRABLE FILLET WELD PROFILES

(B) ACCEPTABLE FILLET WELD PROFILES

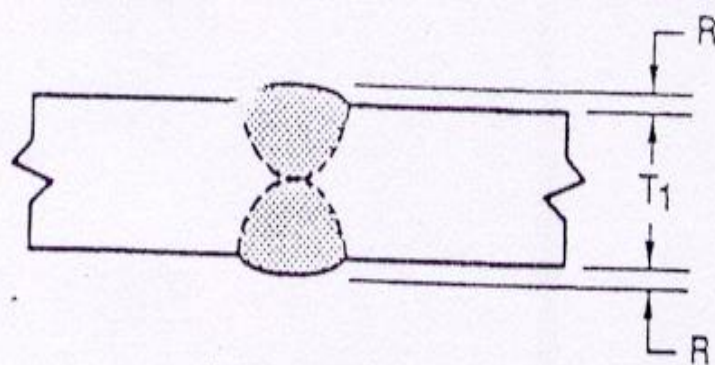
NOTE: CONVEXITY, C, OF A WELD OR INDIVIDUAL SURFACE BEAD WITH DIMENSION W SHALL NOT EXCEED THE VALUE OF THE FOLLOWING TABLE:

WIDTH OF WELD FACE OR INDIVIDUAL SURFACE BEAD, W	MAX CONVEXITY, C
$W \leq 5/16$ in. (8 mm)	1/16 in. (1.6 mm)
$W > 5/16$ in. TO $W < 1$ in. (25 mm)	1/8 in. (3 mm)
$W \geq 1$ in.	3/16 in. (5 mm)

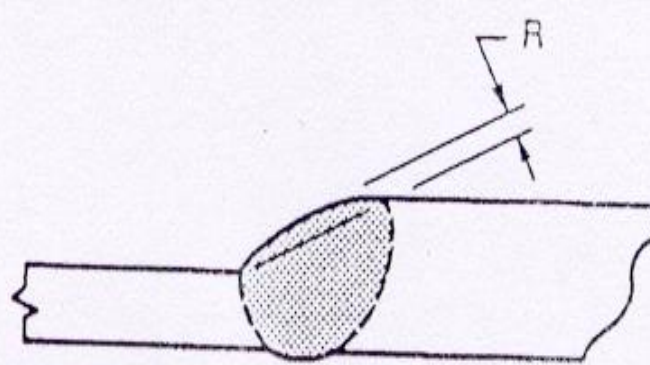


(C) UNACCEPTABLE FILLET WELD PROFILES

Contd.



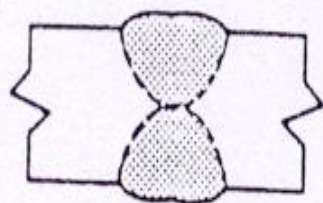
BUTT JOINT—
EQUAL THICKNESS PLATE



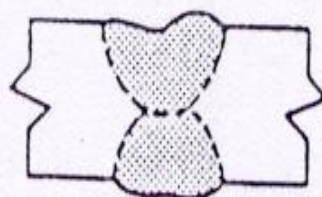
BUTT JOINT (TRANSITION)—
UNEQUAL THICKNESS PLATE

NOTE: REINFORCEMENT R SHALL NOT EXCEED 1/8 in. (3 mm).

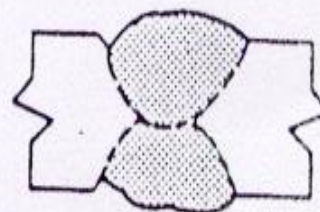
(D) ACCEPTABLE GROOVE WELD PROFILE IN BUTT JOINT



EXCESSIVE
CONVEXITY



INSUFFICIENT
THROAT



EXCESSIVE
UNDERCUT



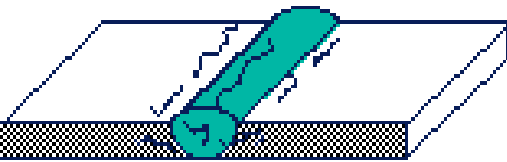
OVERLAP

(E) UNACCEPTABLE GROOVE WELD PROFILES IN BUTT JOINTS

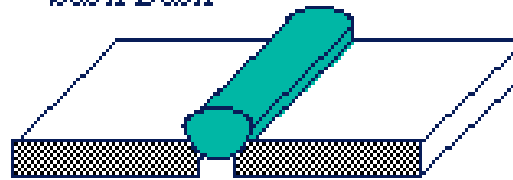
Figure 11 Acceptable and Unacceptable Weld Profiles

WELD DEFECTS

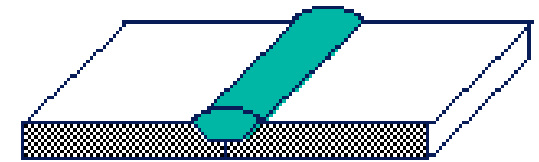
Cracking



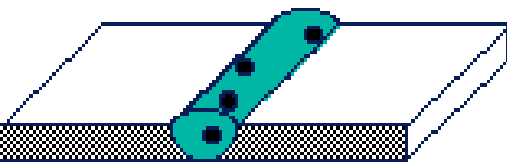
Suck Back



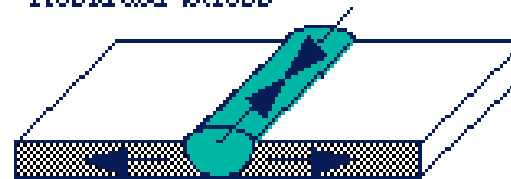
Lack of Penetration



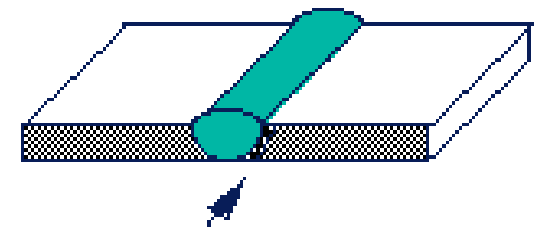
Porosity



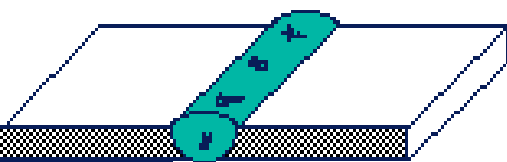
Residual Stress



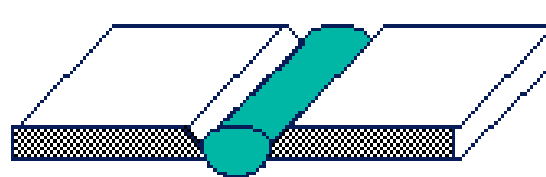
Metallurgical Transformation



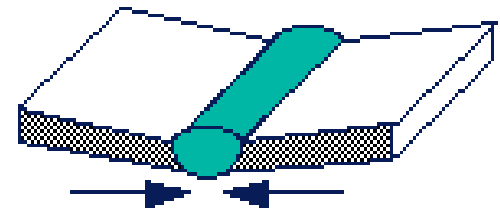
Inclusions



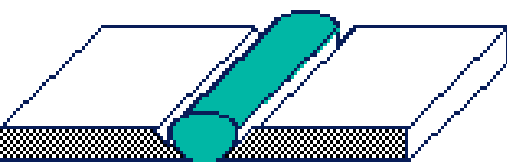
Drop Through



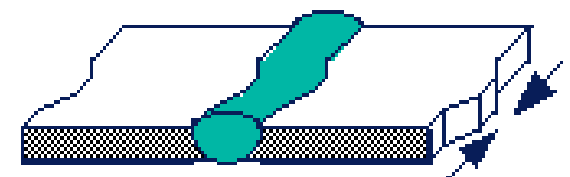
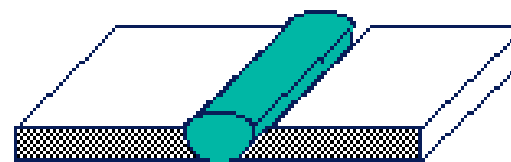
Distortion



Undercut



Lack of Fusion



NORMAL



EXCESS



REINFORCEMENT

LONGITUDINAL



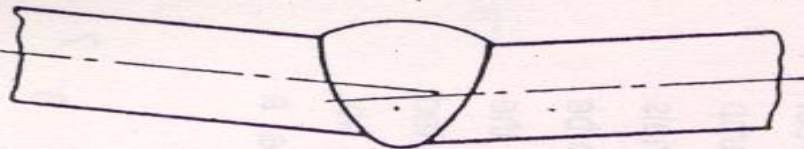
CRATER

TRANSVERSE

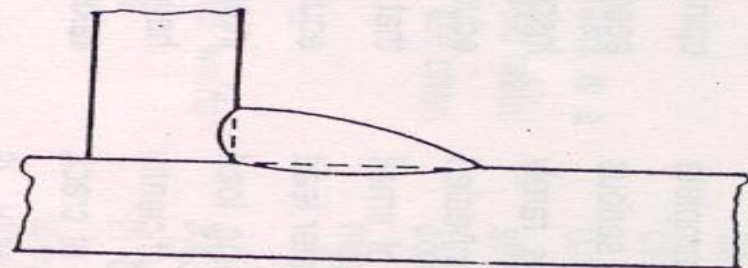
CRACKS



BURN THROUGH



DISTORTION



IMPROPER WELD PROFILE



INCOMPLETE PENETRATIONS



EXCESSIVE PENETRATION



SLAG INCLUSIONS



LACK OF FUSION



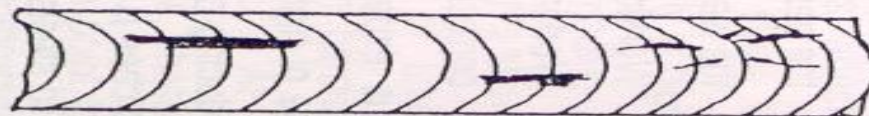
UNDER CUT



DISTRIBUTED POROSITIES



LINER PORES



WORM HOLES
GAS POROSITY

COMMON WELDING DEFECTS

Trouble	Possible Causes	How to Correct
Incomplete Penetration	1. Faulty joint design 2. Welding speed too rapid 3. Insufficient welding current 4. Electrode size too large	1. Check root opening root face and included angle 2. Reduce welding speed 3. Increase welding current 4. Use smaller electrode
Poor Appearance	1. Current too high or too low 2. Improper technique 3. Faulty electrode	1. Adjust current 2. Check welding procedure 3. Dry electrode to remove moisture change electrode
Undercutting	1. Current too high 2. Arc length too long 3. Improper manipulation of the electrode 4. Welding speed too rapid	1. Reduce current 2. Shorten arc length 3. Change electrode angle so that arc force will help fill undercut 4. Reduce electrode travel speed
Excessive Spatter	1. Current too high 2. Arc length too long 3. Excessive arc blow 4. Faulty electrode	1. Reduce current 2. Shorten arc length 3. See remedies for arc blow 4. Replace electrode
Arc Blow	1. Magnetic field created when using DC.. causes the arc to wander	1. Use AC welder 2. Counter blow by adjusting electrode angle 3. Rearrange or split ground clamp 4. Replace magnetic work bench 5. Use brass or copper back-up bar
Pin-Holes	1. Foreign matter in joint	1. Remove rust, scale and other foreign matter from weld area base metal
Slag in Weld	1. Joint design: sharp V-Shaped recess 2. High viscosity of molten metal,	1. Avoid contours that are difficult to penetrate with arc 2. Use Preheat and higher weld heat input
Porous Welds	1. High rate of weld freezing 2. Excessive moisture in electrode <i>oil, paint or Rust on base metal</i>	1. Reduce welding speed 2. Raise current setting 3. Use low-hydrogen electrodes 4. Dry electrodes to remove moisture; use fresh electrodes
Cracked Welds	1. Faulty electrode 2. Joint too rigid: stressed weld 3. Shape of bead 4. Craters 5. Fast cooling rate	1. Use low-hydrogen electrodes 2. Redesign joint: use pre-heat and post-heat; weave 3. Use slower travel or faster-freezing electrode to give a more convex bead 4. Back step to fill craters 5. Preheat or post-heat or both
Distortion	1. Improper weld design 2. Overheating 3. Welding speed too slow 4. Improper welding sequence 5. Faulty clamping	1. Redesign to allow for expansion and contraction 2. Use lower current and more efficient chill bars 3. Increase travel speed 4. Improve welding sequence - weld heavy sections first 5. Clamp properly to chill bar
Brittle Welds	1. Wrong electrode 2. Incorrect heat treatment 3. Air-hardening deposit 4. Base metal pick-up	1. Use low-hydrogen or austenite electrode 2. Use proper preheat and post-heat cycles 3. Reduce penetration by directing arc on weld puddle

NDT METHODS

- **LIQUID PENETRANT TESTING**
- **MAGNETIC PARTICLE TESTING**
- **ULTRASONIC TESTING**
- **RADIOGRAPHIC TESTING**

LIQUID PENETRANT TESTING

This is a simple method of surface flaws such as cracks, laps, porosity etc. to be detected. The flaw must reach the surface to be tested.

Penetrant testing is one step up from visual inspection and offers many advantages such as speed, large area, coverage, and low cost.

Penetrant testing is usually six-stage process :

- A. Surface Cleaning (Degreasing etc.)
- B. Application of Penetrant (Dipping, Spraying or by brush)
- C. Removal of Excess Penetrant (Solvent or water)
- D. Application of Developer
- E. Inspection of Test Surface
- F. Post- Inspection Cleaning

There are three major groups of Penetrant process :

- 1. Water - Soluble
- 2. Post - Emulsifiable with water rinsing
- 3. Solvent Removable

The different being in the method used to remove the excess penetrant.

In each of the three groups the penetrant solution can contain a dye to make the indication visible under a white light or a fluorescent material which fluoresces under suitable ultra-violet light.

The principle of Liquid Penetrant Testing is that the Liquid Penetrant is drawn into the surface flaw by capillary action and excess surface penetrant is then removed. A Developer (typically a dry powder) is then applied to the surface to draw out the penetrant in the flaw and produce a surface indication. Cracks as narrow as 150 nanometers can be detected. The indications produced are much broader than the actual flaw and are therefore, more easily visible.

Liquid Penetrant Testing can be applied to any non-porous clean material, metallic or non-metallic, but is unsuitable for the dirty or very rough surfaces. Surface cleaning is a vital part of LP testing technique.

MAGNETIC PARTICLE INSPECTION

This method is used for the detection of surface and near surface flaws in ferromagnetic materials and is primarily used for crack detection.

This testing is based on the fact that the magnetic reluctance of a ferromagnetic material by any flaw in it.

The specimen is magnetized either locally or overall and if the material is sound the magnetic flux is predominantly inside the material. If however, there is surface breaking flaw, the magnetic field is distorted, causing local magnetic flux leakage around the flaw. This leakage flux is displayed by covering the surface with very fine iron particles applied either dry or suspended in a liquid. The particles accumulate at the regions of flux leakage producing a build up, which can be seen visually even when the crack opening is very narrow. Thus, the crack is indicated a line of powder particles on the surface.

The method is applicable to all metals which can be strongly magnetized ferrite steels and irons but not generally austenitic stainless steels. The method of magnetization must produce a magnetic field with lines of force at a large angle to the expected direction of the cracks to be detected, so that it is usual to apply magnetization more than once in different directions. For examples two directions mutually at right angles, but methods of swinging the field direction during magnetization are available.

The magnetization may be produced by any one of the following methods.

- a) Applying a permanent or electro - magnet to the surface (magnetic flow).
- b) Passing a large current through the specimen or locally by means of current productions (current flow).
- c) Putting the specimen inside a current coil or forming a coil around the specimen.

The electric current used may be DC or AC of any wave form. It is most important to ensure that the current used is correct for the specimen size and shape and also that the direction of the magnetic flux produced is suitable for the cracks expected.

By using a combination of two magnetic fields a swinging or rotating magnetic flux can be produced which will detect a crack in any orientation.

Usually the iron particles dry powdered or suspended in a liquid (magnetic ink) are applied while the magnetizing current is still flowing, but residual magnetization is sometimes used when the particles are applied after magnetization.

Magnetic inks (particles suspended in a liquid) are used more widely than dry powder. They are applied by low-pressure spray, dipping or brushing. It is important to use plenty of ink and to allow time for the particles to flow over the surface and migrate to any cracks. On dark surfaces a very thin layer of white paint can be applied to give a height contrast indication.

ULTRASONIC TESTING :

Ultrasonic testing for detection of discontinuities, flaws in welds are generally carried out by pulse -echo method using straight and angular beam waves. If the material being tested contains a flaw, the vibrations are reflected. The presence of the flaw can be indicated either by noting the reduction in the strength of the transmitted vibrations or by monitoring the reflections.

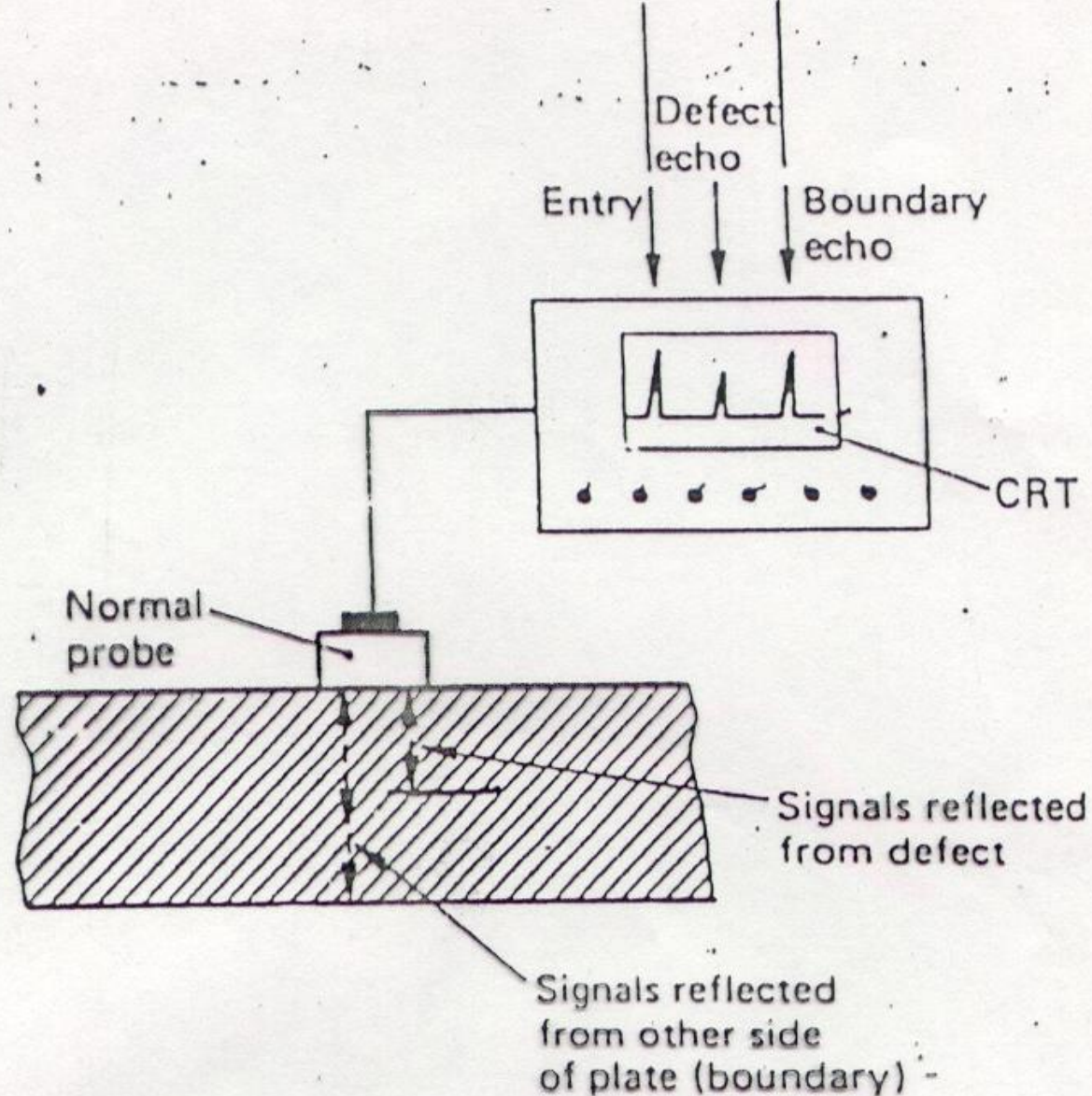
Surface shall be free from dirt, grit, spatter, rust, and scale for proper probe contact. Weld crown to be ground flush to enable the probe to travel across. In the ultrasonic testing of the metals, frequencies between 0.5 and 10MHz are used, and the vibrations are measured by using the piezo-electrical characteristics of a crystal.

In UT pulsed beams of ultra sound are used and in the simplest instruments a single probe, hand-held is placed on the specimen surface.

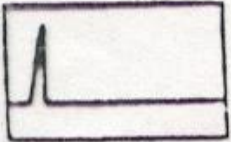
A transmitter probe is used for the method and access is required to only one surface.

With a normal probe the signal is transmitted at right angles to the surface. In the absence of a defect, the ultrasonic waves travel through the thickness of the plate, are reflected on the other surface and return to the probe. They are displayed on the cathode ray tube (CRT) as a boundary echo. The CRT also records the entry of the waves into the plate as the transmitter signal. When there is a defect in the path of the waves, some of the signal is reflected and having a shorter distance to travel appears on the CRT before the boundary echo. The depth of the defect below the surface can be deduced from its position relative to the transmitter and boundary indications.

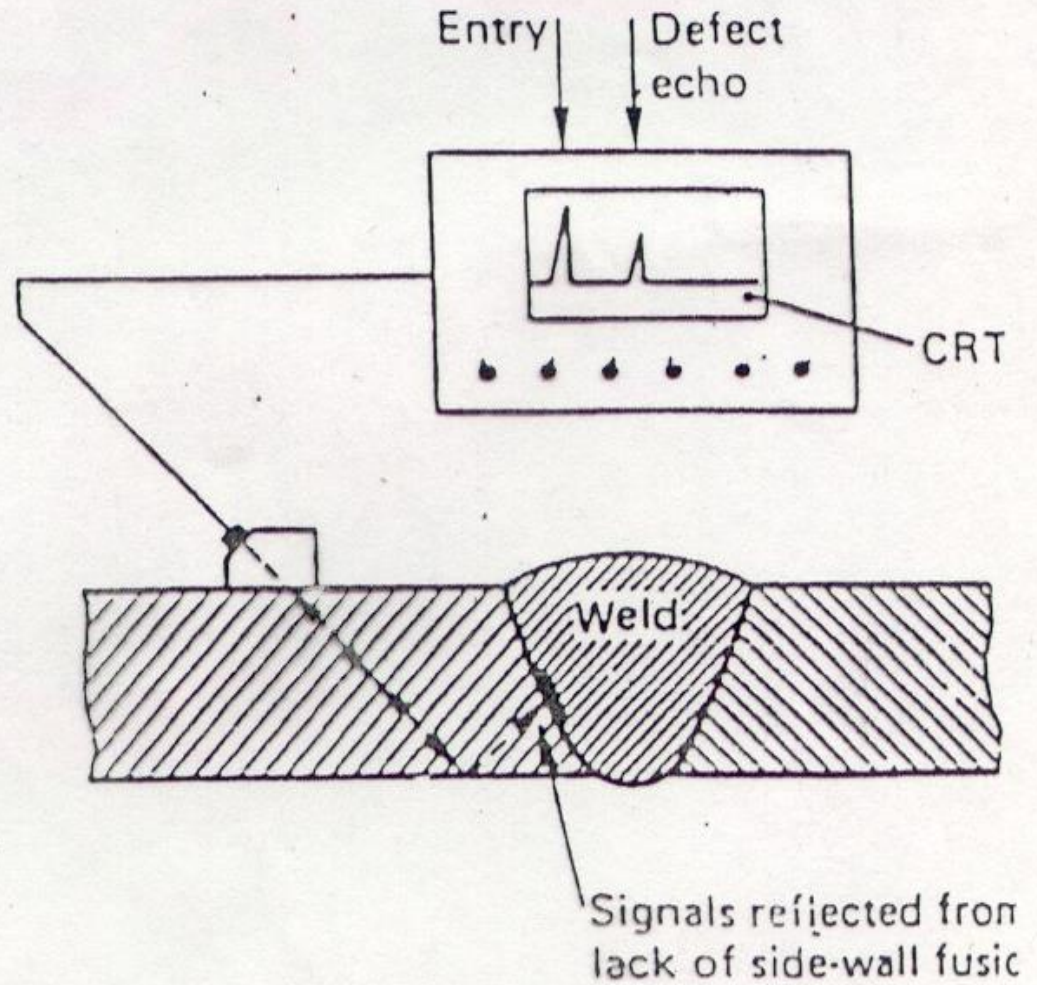
An angle probe fitted with a single crystal is normally used to test welded joints. Pulse echo ultrasonic vibrations are transmitted into the plate at an angle to the surface. This travels to the opposite surface, where it is reflected at an angle equal to the angle of incidence. The vibrations are again reflected from the top surface, and so on. If there is no interface in their path the vibrations continue until they peter out. On the other hand, a defect reflects some or all of the signal, which may then follow the original path or take a new route back to the probe, depending on the orientation of the interface with respect to the beam. A defect echo is displaced in the CRT and again its distance from the transmitter signal will be the measure of distance traveled by the ultrasonic wave. Knowing the geometry of the system the exact location of the defect can be calculated.



Reflection technique using a normal probe which injects ultrasonic vibrations at right angles to the plate surface

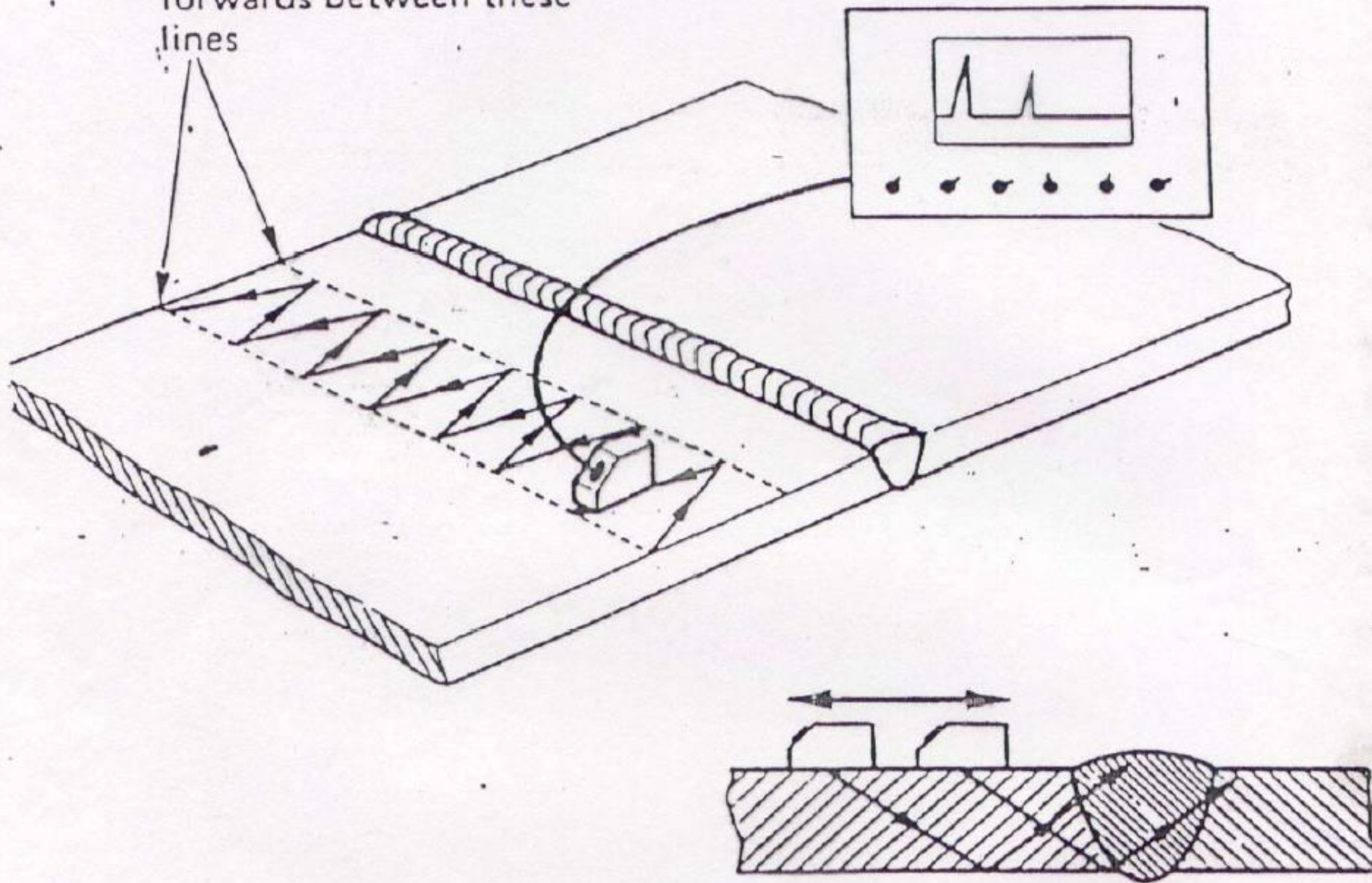


CRT display
with no defect
present



Reflection technique with an angle probe

Probe moved backwards and forwards between these lines



RADIOGRAPHIC INSPECTION:

Radiography is the process for detecting discontinuities in test objects by passing ionizing radiation through them and recording the transmitted radiation pattern on Radiographic films. This is a well-established technique, which gives a permanent record and is widely used to detect internal flaws in a welded specimen, castings, assemblies etc. The radiation sources used for industrial radiography can be Gamma ray sources and X-ray machines.

Characteristics of Gamma Ray Sources :

<u>Source</u>	<u>Half Life</u>
Iridium-192	74d
Cobalt-60	5.26Y
Cesium-137	30Y
Thorium-170	127d

For X-ray sources, it needs electric power and continuous cooling arrangement as it get heated up. Energy and intensity can be controlled by controlling KV and mA. The higher the voltage the greater the penetrating power of the radiation. Industrial X-ray equipment ranges from about 20kV to 20MV and the most powerful equipment can be used to radiograph up to 500mm steel.

Radiation units used to determine radiation hazard :

1. Strength of the source : The old unit is Curies (Ci) and new unit is Bequerel (Bq).

1 Curie = 3.7×10^{10} disintegrations / sec

1 Bequerel = One transmission / second

1 Curie - 37G Bq (G stands for Giga = 10^9)

2. Exposure Rate : Exposure rate gives the radiation level (X and Gamma rays) at any point and place in air.

Exposure ® = Exposure rate (R/hr) x time (hr)

3. Dose : For all types of radiation it gives the energy deposited or absorbed in any medium. Its unit is radian.

4. Dose Equivalent : The dose equivalent gives the biological effect. The unit of dose equivalent is rem.

Radiographic Techniques :

Before starting the radiographic examination of the specimen, test object should be cleaned and inspected to remove any surface gross defects. The lead identification number and image quality indicators should be fixed on the object.

To obtain images with good definition it is desirable to have small diameter radiation sources and the effective source size of typical X-ray and Gamma-ray sources in the range of 1 to 4mm in diameter. Source to film distance to be selected properly and object to be positioned so that central beam of radiation is perpendicular to it. After the radiographic film is exposed, it has to be photographically processed and is then placed on an illuminated screen for visual interpretation of the image. The degree of blackening of processed radiographic film is measured in "Densitometer" and the density range is approx. 1.5-3.0 for industrial purpose.

A. Butt Welded plates : The film is kept in close contact with plate and source is directed.

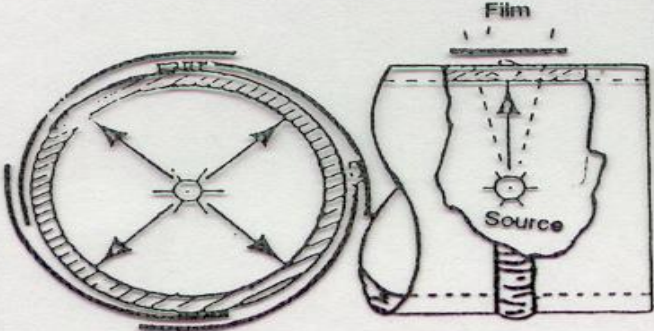
B. Fillet Welded plates : For fillet welds we never do radiographic testing. However, in certain cases if it is required, then the source is directed at $10-15^{\circ}$ angles from the weld with respect to standing leg. For 100% penetration 45° angle is selected.

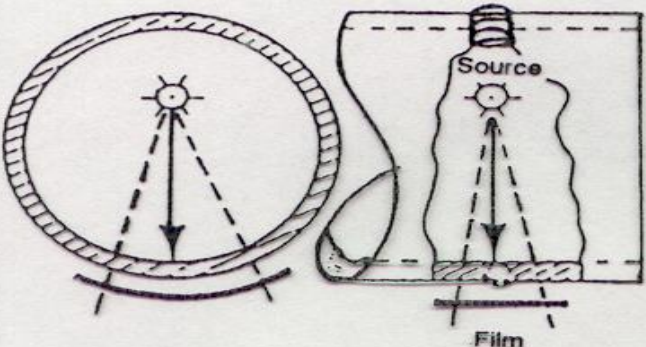
C. Welded joints in pipe and cylindrical objects : The following techniques are adopted depending on the size and accessibility of both sides of pipe.

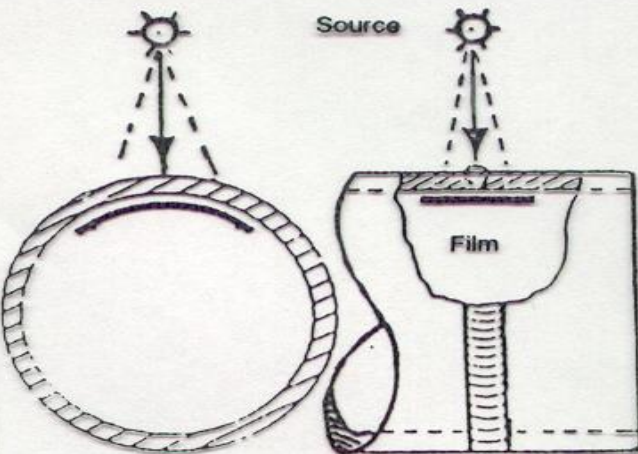
1. Single Wall Penetration : If the center is not accessible or in small diameter pipes, the sources can be off the center and the exposures can be taken. The welds can be divided into several segments and the exposures can be carried out.
2. Double Wall Single Image : If there is no access to the inside of the pipe either to keep film or source, this may be adopted. Sources can be kept on the pipe or away from the pipe depending on the diameter of the pipe, source film distance required and accessibility.
3. Double Wall Double Image : This technique is adopted for smaller size pipes of diameter up to 80mm. The source is kept at an angle with respect to weld so as to avoid the overlap of the top and bottom weld. This is also called as elliptical shot.

The larger X-ray equipments are also costly and require costly protective enclosures. Gamma-ray sources are much less expensive and are widely used on site work because of their greater probability. Generally, exposure times in gamma radiography are much longer than with X-rays.

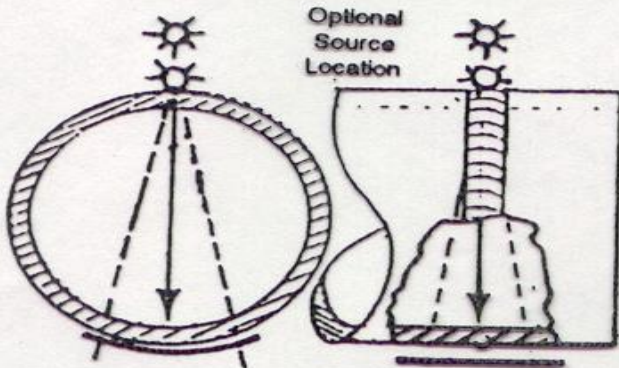
Single-Wall Radiographic Techniques

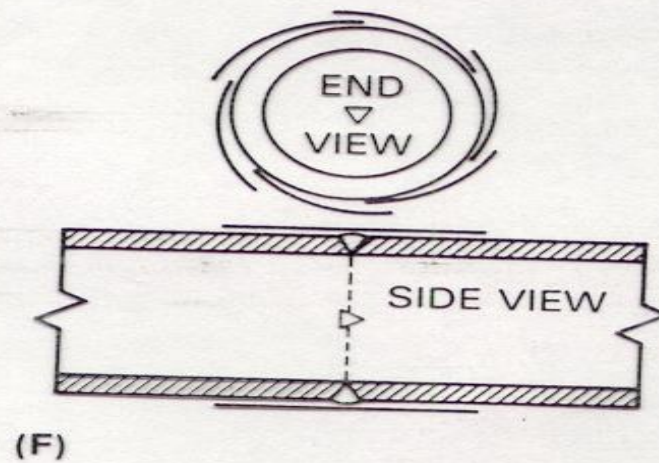
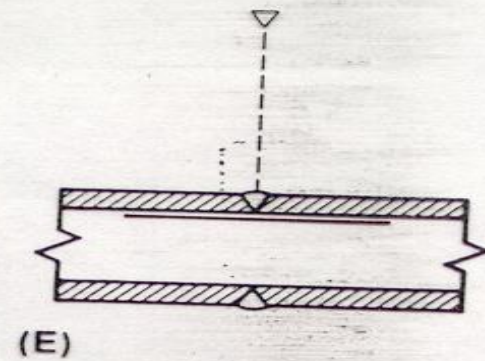
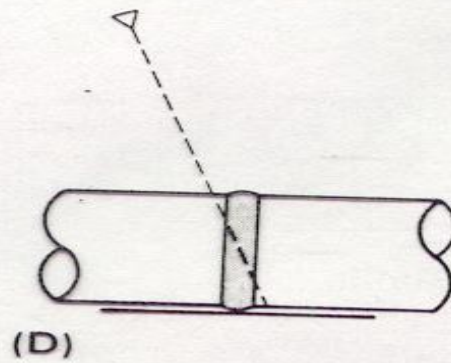
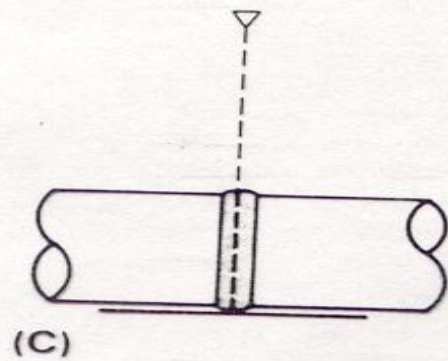
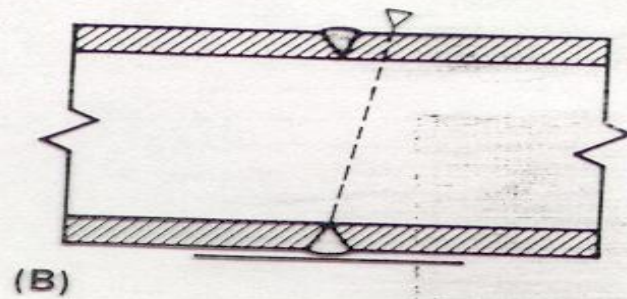
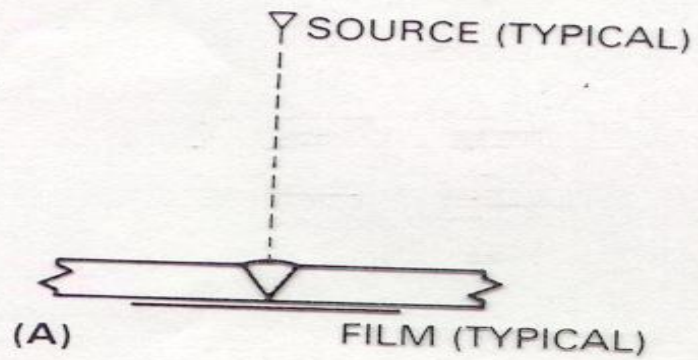
Pipe O.D.	Exposure Technique	Radio- graph Viewing	Source-Weld-Film Arrangement		IQI Penetrameter		Location Marker Placement
			End View	Side View	Selection	Placement	
Any	Single- Wall T-271.1	Single- Wall	 <i>Exposure Arrangement - A</i>		T-276 and Table T-276	Source Side T-277.1(a)	Either Side T-257.3 T-275.1(c)
						Film Side T-277.1(b)	

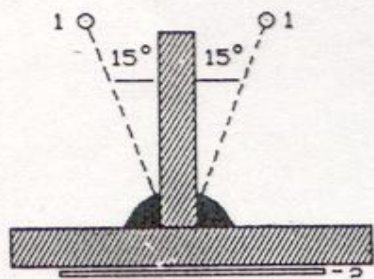
Any	Single- Wall T-271.1	Single- Wall	 <i>Exposure Arrangement - B</i>		T-276 and Table T-276	Source Side T-277.1(a)	film Side T-275.1(b)(1)
						Film Side T-277.1(b)	

Any	Single-Wall T-271.1	Single-Wall	 Exposure Arrangement - C	T-276 and Table T-276	Source Side T-277.1(a)	Source Side T-275.1(a)(3)
					Film Side T-277.1(b)	

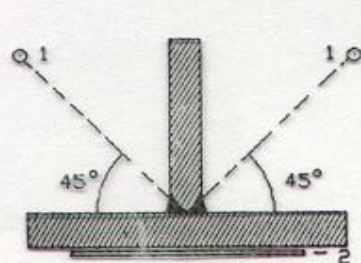
Double-Wall Radiographic Techniques

Pipe O.D.	Exposure Technique	Radio- graph Viewing	Source-Weld-Film Arrangement		IQI Penetrameter		Location Marker Placement
			End View	Side View	Selection	Placement	
Any	Double-Wall T-271.2(a) at Least 3 Exposures 120 deg. to Each Other for Complete Coverage	Single-Wall	 Exposure Arrangement - D		T-276 and Table T-276	Source Side T-277.1(a)	Film Side T-257.1(b)(1)
						Film Side T-277.1(b)	

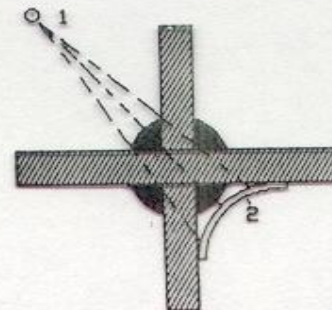




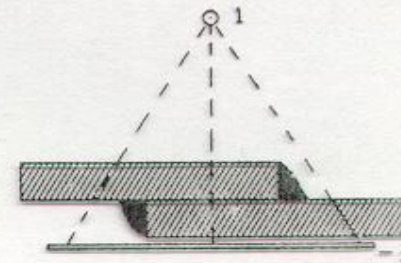
(a) 100% corner penetration



(b) 100% joint penetration



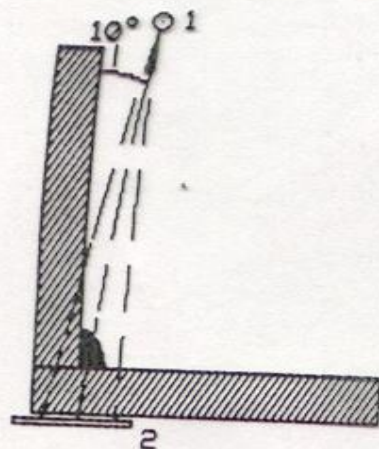
(c) Square joint



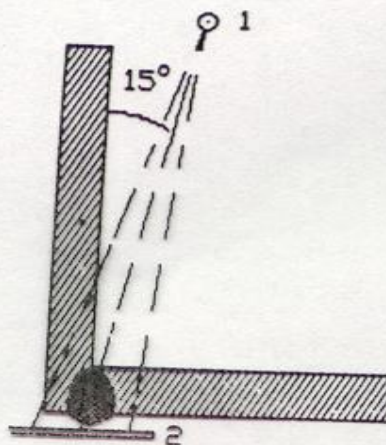
(d) Lap joint

1. Source 2. Film

Radiography techniques for fillet joints

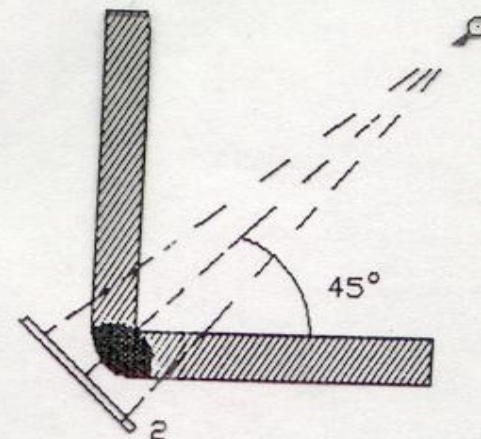


(a) 100% corner penetration



(b) Corner joint with double V

1. Source 2. Film



(c) Plane corner joint with 100% joint penetration

Radiography techniques for corner joints

Advantages and Limitations of Radiation Sources

Radioisotopes

- (1) Small and portable
- (2) No electric power required
- (3) No electrical hazards
- (4) Rugged
- (5) Low initial cost
- (6) High penetrating power
- (7) Access into small cavities
- (8) Low maintenance costs

X-Ray Machines

Advantages

- (1) Radiation can be shut off
- (2) Penetrating power (kV) is adjustable
- (3) Can be used on all metals
- (4) Radiographs have good contrast and sensitivity

Limitations

- (1) Radiation emitted continuously by the isotope
- (2) Radiation hazard if improperly handled
- (3) Penetrating power cannot be adjusted
- (4) Radioisotope decays in strength requiring
- (5) Radiographic contrast generally lower than with x-rays

- (1) High initial cost
- (2) Requires source of electrical power
- (3) Equipment comparatively fragile
- (4) Less portable recalibration and replacement
- (5) Tube head usually large in size
- (6) Electrical hazard from high voltage
- (7) Radiation hazard during operation

SUMMARY OF THE METHODS OF NON - DESTRUCTIVE TESTING WELDS

METHOD	DEFECTS DETECTED	ADVANTAGES	LIMITATIONS
Visual	Inaccuracies in size and shape, Surface cracks and Porosity, Undercut, Overlap, Crater faults	Easy to apply at any stage of fabrication and welding. Low cost both in capital and labour.	Does not provide a permanent record. Provides positive information only for surface defects.
Dye-Penetrant	Surface cracks which may be missed by naked eye.	Easy to use. No equipment required low cost both in materials and labour	Only surface cracks detected with certainty. No permanent record.
Magnetic - Particle	Surface cracks which may be missed by naked eye; may give indications of sub-surface flaws.	Relatively low cost. Portable. Gives clear indication.	Only surface cracks detected with certainty. Can be used only on Ferro-magnetic metals. Can give spurious indications. No permanent record.
Radiography	Porosity, Slag inclusions, cavities and lack of penetration. Cracks and Lack of fusion if correctly oriented with respect to beam.	Can be controlled to give reproducible results. Gives permanent record.	Expensive equipment. Strict safety precautions required. Better suited to butt joints-not very satisfactory with fillet-welded joints. Requires high level of skill in choosing conditions and interpreting results.
Ultrasonic	All sub-surface defects. Laminations.	Very sensitive - can detect defects too small to be discovered by other methods. Equipment is portable. Access required to only on side.	Permanent record is difficult to obtain. Requires high level of skill in interpreting cathode -ray - tube indications

Thank You

Thank You

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