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Weld Imperfections and Preventive Measures

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The *Weld Imperfections and Preventive Measures* provides information to assist welding personnel study the arc welding technologies applied in steel fabrication.

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Introduction

In the construction of such steel structures as buildings and bridges and the fabrication of such machinery as ships, autos, rolling stock, and pressure vessels, arc welding is the indispensable method for joining metals. Therefore, the reliability of steel structures and machinery depends on the quality of the welds as well as the quality of the steel materials. In order to produce satisfactory weldments which fulfill the requirements of quality, the integrity of quality control is very important. For integral quality control, all the personnel (including managers, engineers, inspectors, supervisors, foremen, welders, and welding operators) who are involved in arc welding should have adequate knowledge of weld imperfections and preventive measures. This booklet, *Weld Imperfections and Preventive Measures*, is prepared to provide the information of common weld imperfections, causes, and preventive measures.

The weld imperfections contained in this textbook are categorized into surface irregularities and weld discontinuities. Surface irregularities can be defined as "weld surface conditions that contain notches or abrupt changes in thickness or appearance." Surface irregularities include uneven weld bead ripples, excessive weld reinforcement, excessively concave or convex fillet welds, uneven-leg fillet welds, undercut, overlap, herringbone, pockmarks, mouse footmarks, and underfill. Weld discontinuities can be defined as "an interruption of the typical structure of a weld, such as a lack of homogeneity in the mechanical, metallurgical or physical characteristics of the weld." Weld discontinuities include porosity, slag inclusions, incomplete fusion, incomplete joint penetration, excessive melt-through, cold cracks, and hot cracks. However, a surface irregularity or weld discontinuity is not a rejectable defect when it is within the permissible range of extent according to the relevant specification.

This textbook has been edited by employing as many photographs and drawings as possible in order to help the learners fully understand specific technologies of arc welding and related weld imperfections. The information contained in this textbook includes those derived from the reference books listed below.

References

(1) Kobe Steel, Ltd., "Welding Electrode Handbook," 1964

(2) Japan Welding Engineering Society, "Typical Weld Photographs," 1967, Sanpo Publications Inc.

(3) Japan Cultural and Industrial Promotion Co. Ltd., "Photographic Welding," 1961

(4) Overseas Vocational Training Association, "Arc Welding," 1985

(5) American Welding Society, "Welding Handbook," 8th Edition, Vol. 1, 1987

(6) American Welding Society, "Jefferson's Welding Encyclopedia," 18th Edition, 1997

(7) American Welding Society, "Weld and Base Metal Discontinuities," 1986

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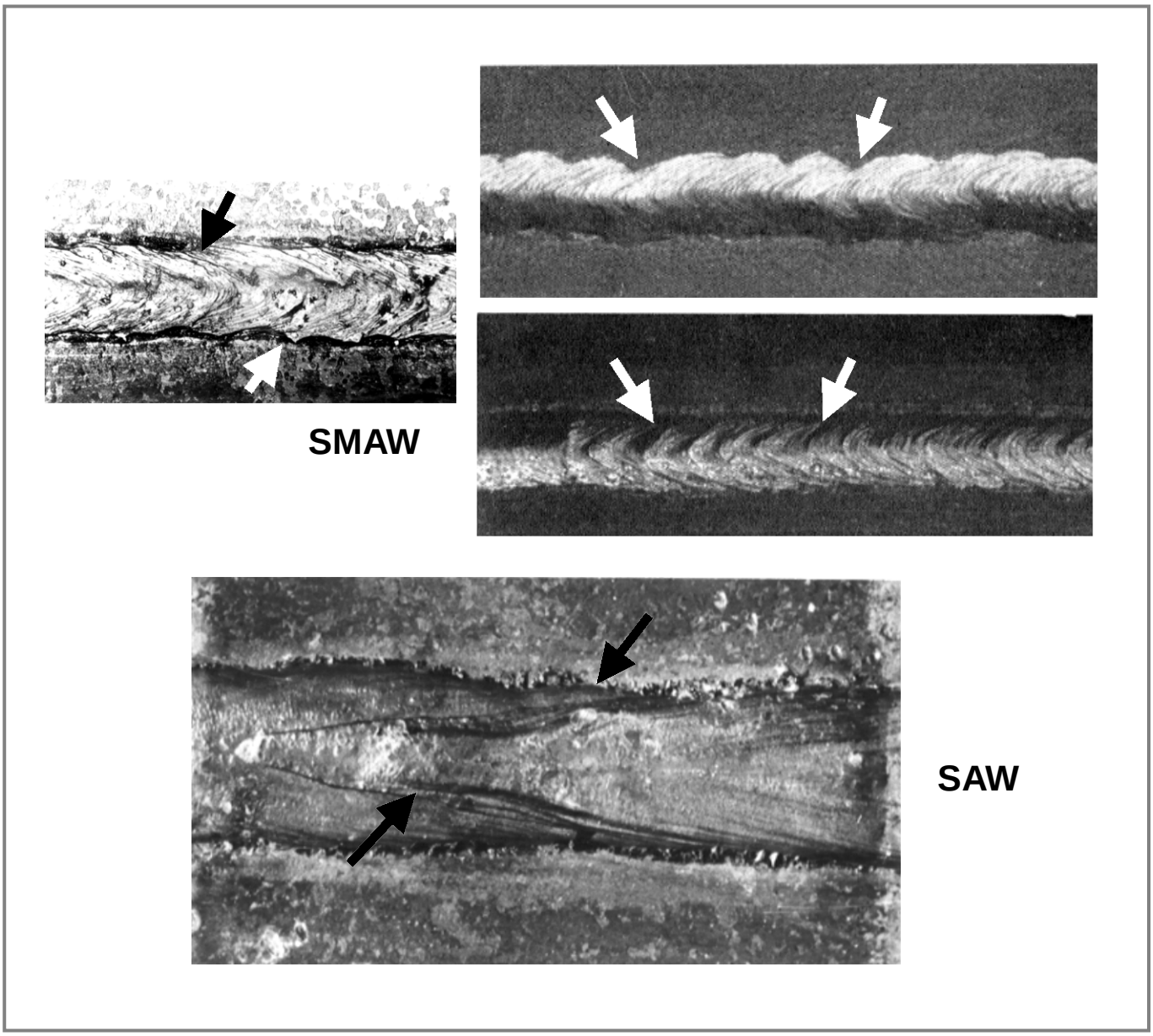
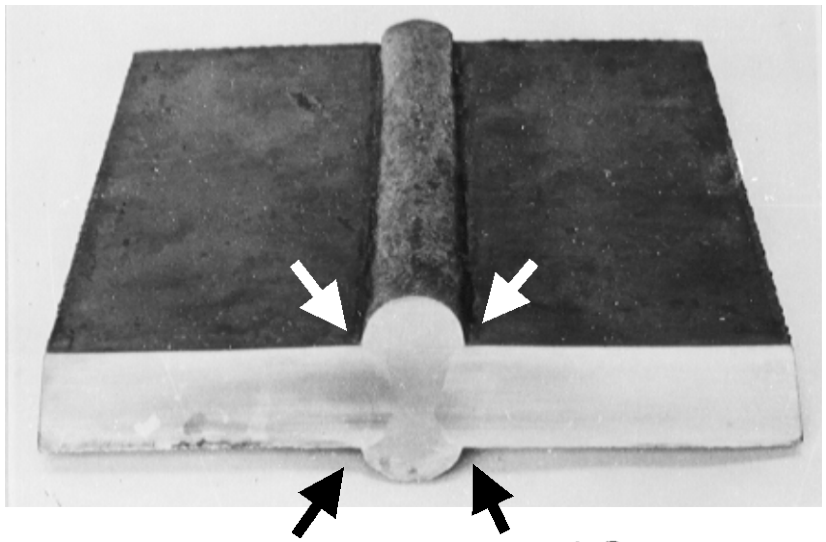


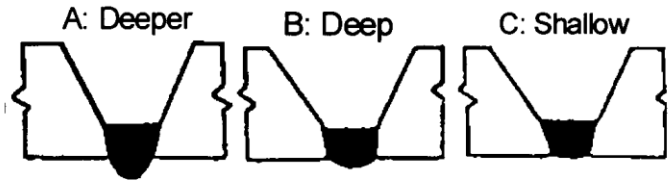
Fig. 1 UNEVEN WELD BEAD RIPPLES

Definition: Abrupt changes in the profiles of weld bead ripples
Main Causes:
(1) Too low or high welding amperage or voltage
(2) Inappropriate electrode manipulation (irregular, too fast, or too slow)
(3) Too much moisture in coatings (SMAW) or fluxes (SAW)
(4) Too much flux-burden height (SAW)

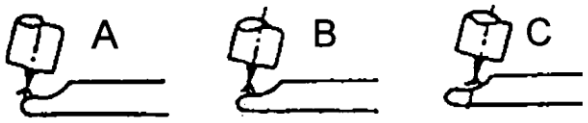
Preventive Measures:
(1) Use proper welding amperages and voltages.
(2) Manipulate electrodes at appropriate speeds.
(3) Redry coatings and fluxes.
(4) Use a proper flux-burden height.



SAW



GTAW



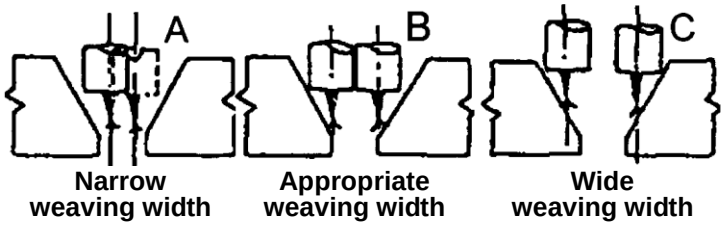


Fig. 2 EXCESSIVE WELD REINFORCEMENT

Definition: The face or root reinforcement that has a larger height than that specified

Main Causes:

(1) Too slow electrode manipulation
(2) Too much root opening (root reinforcement)
(3) Too much welding amperage (root reinforcement)

Preventive Measures:

(1) Manipulate electrodes at appropriate speeds.
(2) Adjust root opening.
(3) Use appropriate welding amperages.
(4) Control the electrode displacement (see the above drawings).

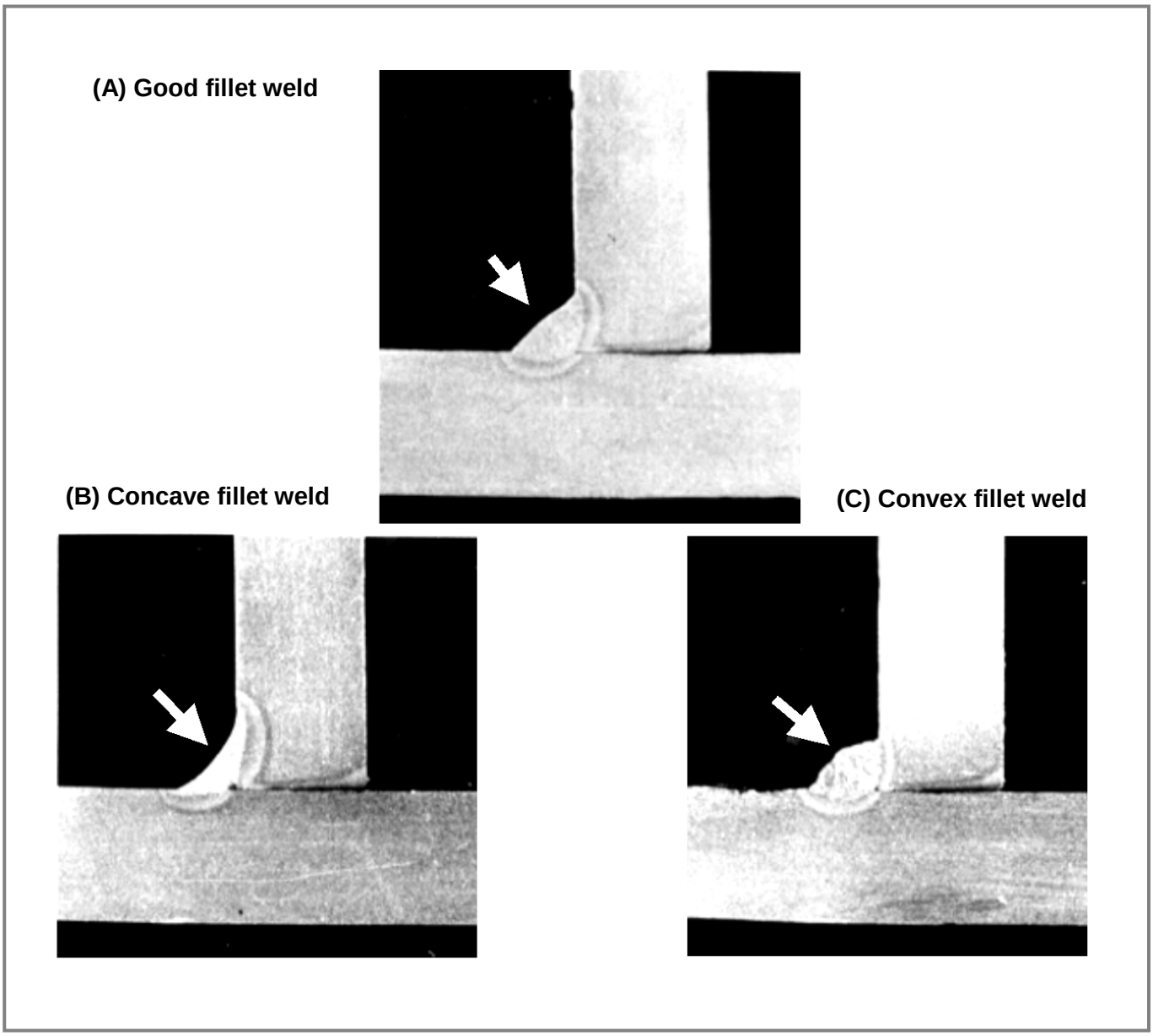


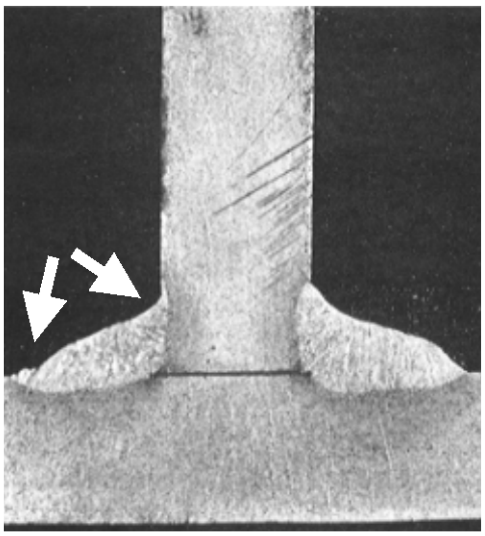
Fig. 3 CONCAVE FILLET WELD, CONVEX FILLET WELD

Definition: A fillet weld that has excessive concavity or convexity
Main Causes:

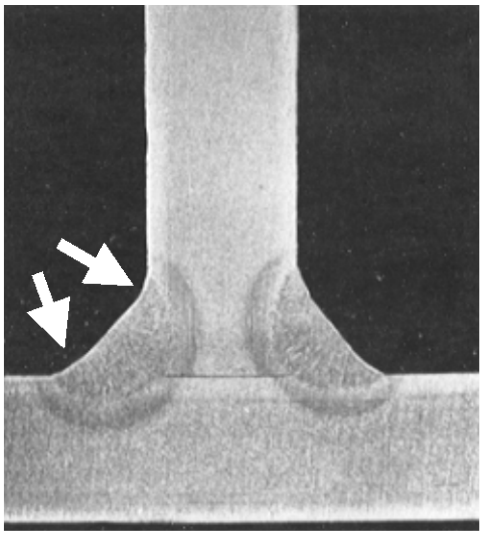
(1) Too fast electrode manipulation, using too high welding amperage (Concave fillet weld)
(2) Too low welding amperage or too slow electrode manipulation (Convex fillet weld)
(3) Electrode travel angle is inappropriate.

Preventive Measures:

Use appropriate welding amperages and electrode manipulation speeds with an appropriate travel angle.



(A) Uneven-leg fillet weld in horizontal position



(B) Even-leg fillet weld in horizontal position

Appropriate electrode work angle

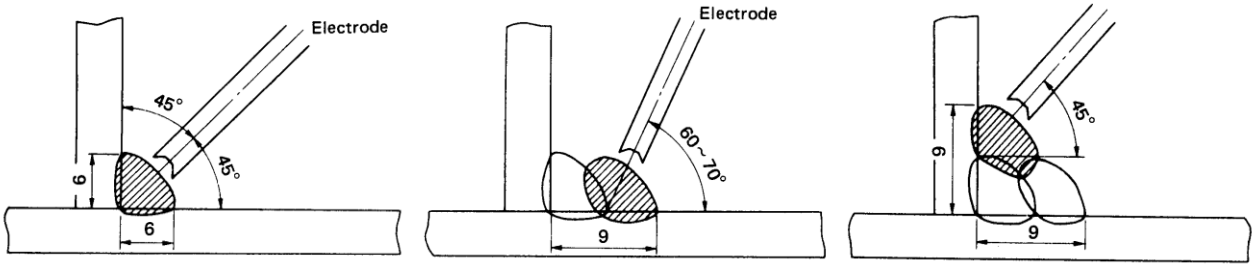
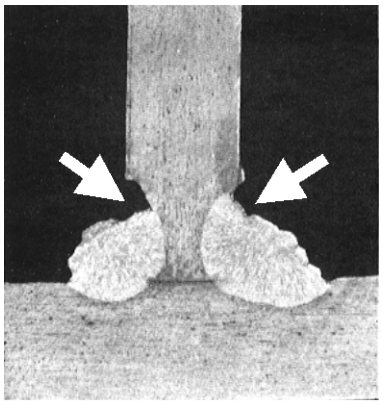
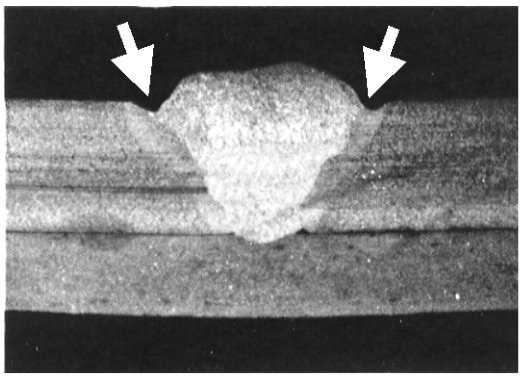


Fig. 4 UNEVEN-LEG FILLET WELD

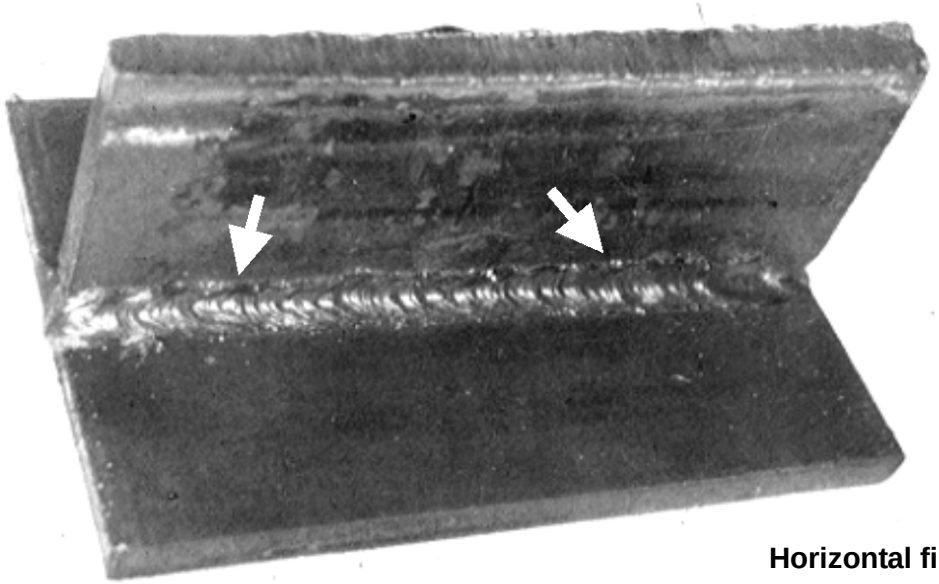
Definition: A fillet weld that has uneven legs
(the upper leg is often smaller than the lower leg)
Main Causes:
Electrode work angle is inappropriate.
Preventive Measures:
Use an appropriate electrode work angle (see the above drawings).



Horizontal fillet weld



Flat-position groove weld



Horizontal fillet weld

Fig. 5 UNDERCUT

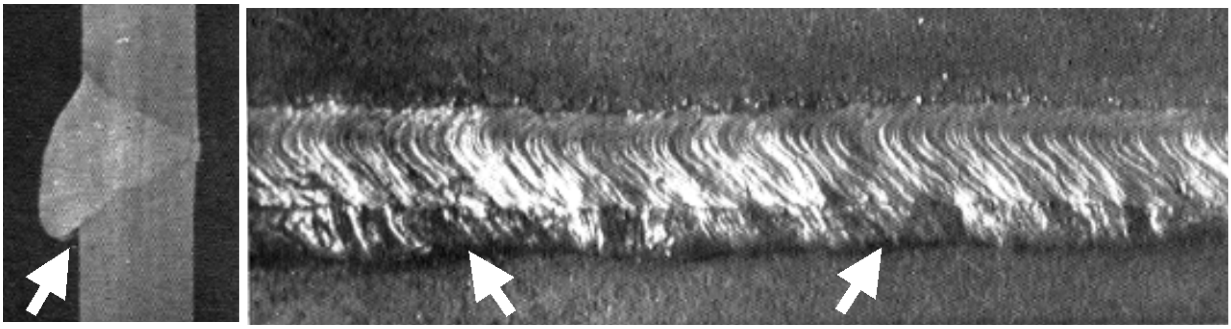
Definition: A groove that is gouged in the base metal adjacent to the weld toe or weld root and is left unfilled by the weld metal

Main Causes:

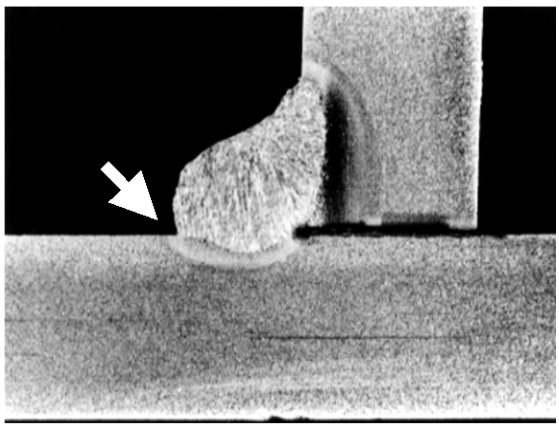
(1) Too high welding amperage
(2) Too fast electrode manipulation
(3) Too long arc length, or too high arc voltage
(4) Electrode travel and work angles are inappropriate.
(5) The wire tracking is too close to the groove face (SAW)

Preventive Measures:

(1)-(4) Use appropriate welding amperages, electrode manipulation speeds, arc lengths (or arc voltages), and electrode travel and work angles.
(5) Adjust the wire tracking location.



Butt weld in horizontal vertical position



Fillet weld in horizontal position

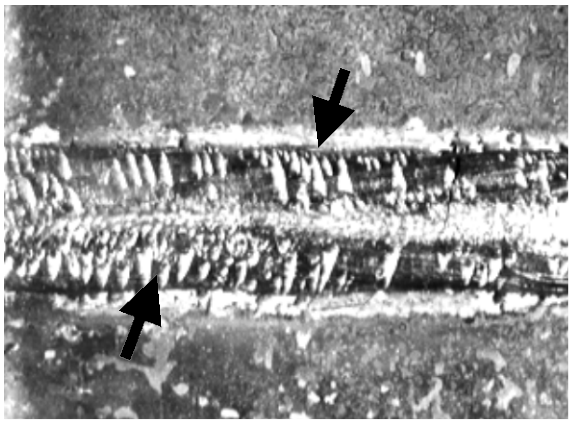
Fig. 6 OVERLAP

Definition: The protrusion of weld metal beyond the weld toe or weld root
Main Causes:

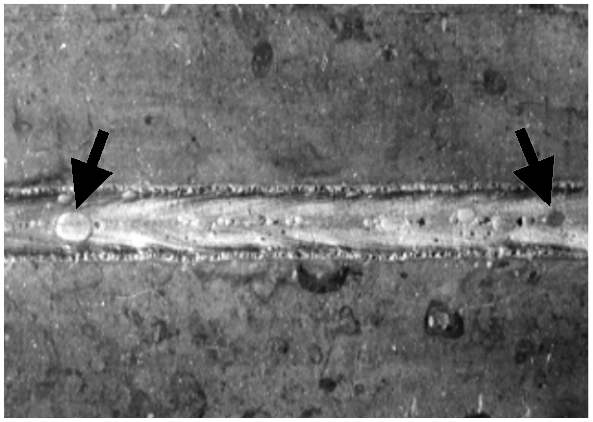
(1) Too low welding amperage
(2) Too slow electrode manipulation
(3) Too short arc length, or too low arc voltage
(4) Electrode travel and work angles are inappropriate.

Preventive Measures:

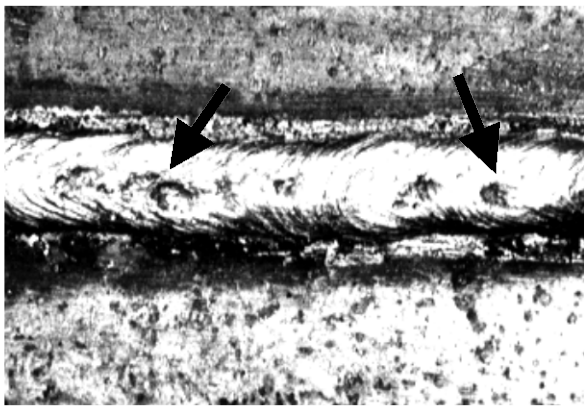
Use appropriate welding amperages, manipulation speeds, arc lengths (arc voltages), and electrode travel and work angles.



Herringbone in SAW weld



Pock mark in SAW weld



Mouse footmark in SMAW weld

Fig. 7 HERRINGBONE, POCK MARK, MOUSE FOOTMARK

Definition: Shallow indentations on the surface of a weld
Main Causes:
(1) Moisture in coatings (SMAW) or fluxes (SAW)
(2) Rust, paint, or moisture on the joint fusion faces
Preventive Measures:
(1) Redry the coatings (SMAW) and fluxes (SAW).
(2) Remove rust, paint, and moisture from the joint fusion faces.

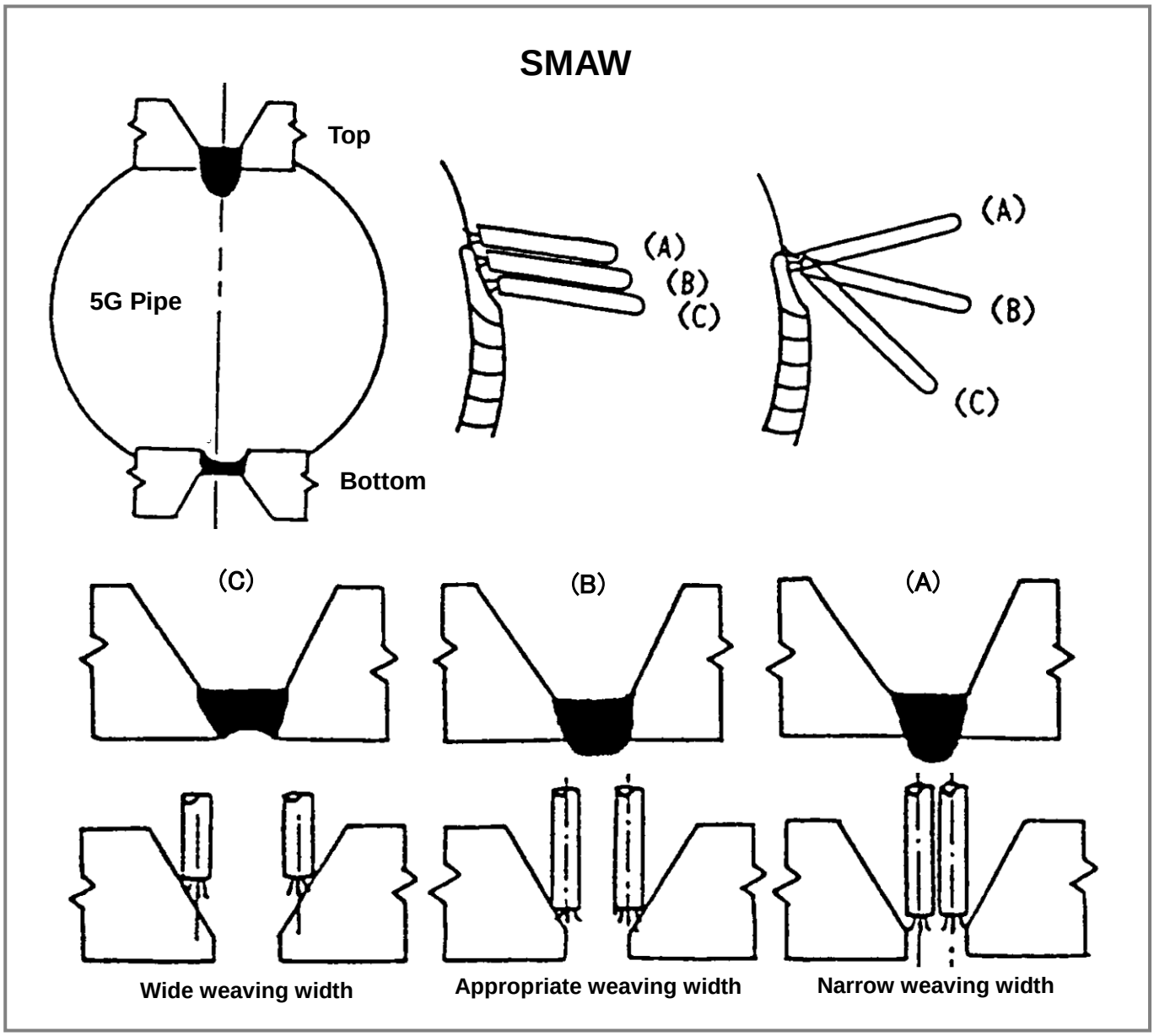


Fig. 8 UNDERFILL (INTERNAL CONCAVITY)

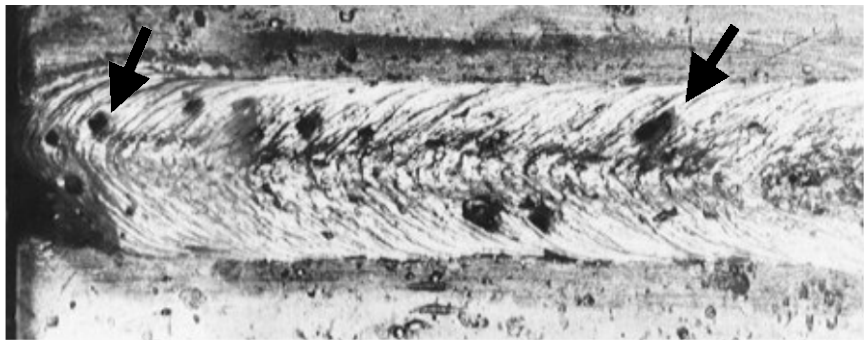
Definition: A depression on the weld face or root surface extending below the adjacent surface of the base metal

Main Causes:

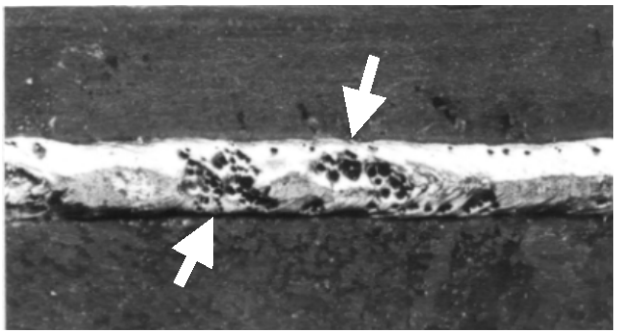
(1) Too small root opening, groove angle, or too much root face
(2) Too low amperage, or too long arc
(3) Inappropriate electrode manipulation

Preventive Measures:

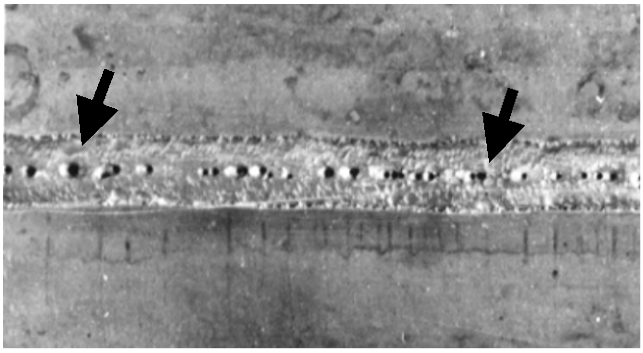
(1) Adjust the root opening, groove angle, and root face.
(2) Use appropriate welding amperages and keep the arc length short.
(3) Use the suitable electrode manipulation as shown in the above drawings.



SMAW



GMAW



SAW

Fig. 9 POROSITY (PIT)

Definition: Cavity type discontinuities formed by gas entrapment during solidification of weld metal

Main Causes:

(1) Rust, oil, paint, or moisture on the joint fusion faces and high sulfur content of the base metal
(2) Moisture in coatings (SMAW), fluxes (SAW), or shielding gases (GMAW)
(3) Too little shielding gas (GMAW) or flux-burden height (SAW)
(4) Strong wind (SMAW, GMAW)
(5) Too much welding amperage, arc length, or arc voltage

Preventive Measures:

(1) Clean the joint fusion faces.
(2) Redry coatings (SMAW) and fluxes (SAW) and use suitable shielding gases (GMAW).
(3) Use proper amounts of shielding gas (GMAW) and flux-burden height (SAW).
(4) Use a wind screen (SMAW, GMAW).
(5) Use appropriate welding amperages, arc lengths, and arc voltages.

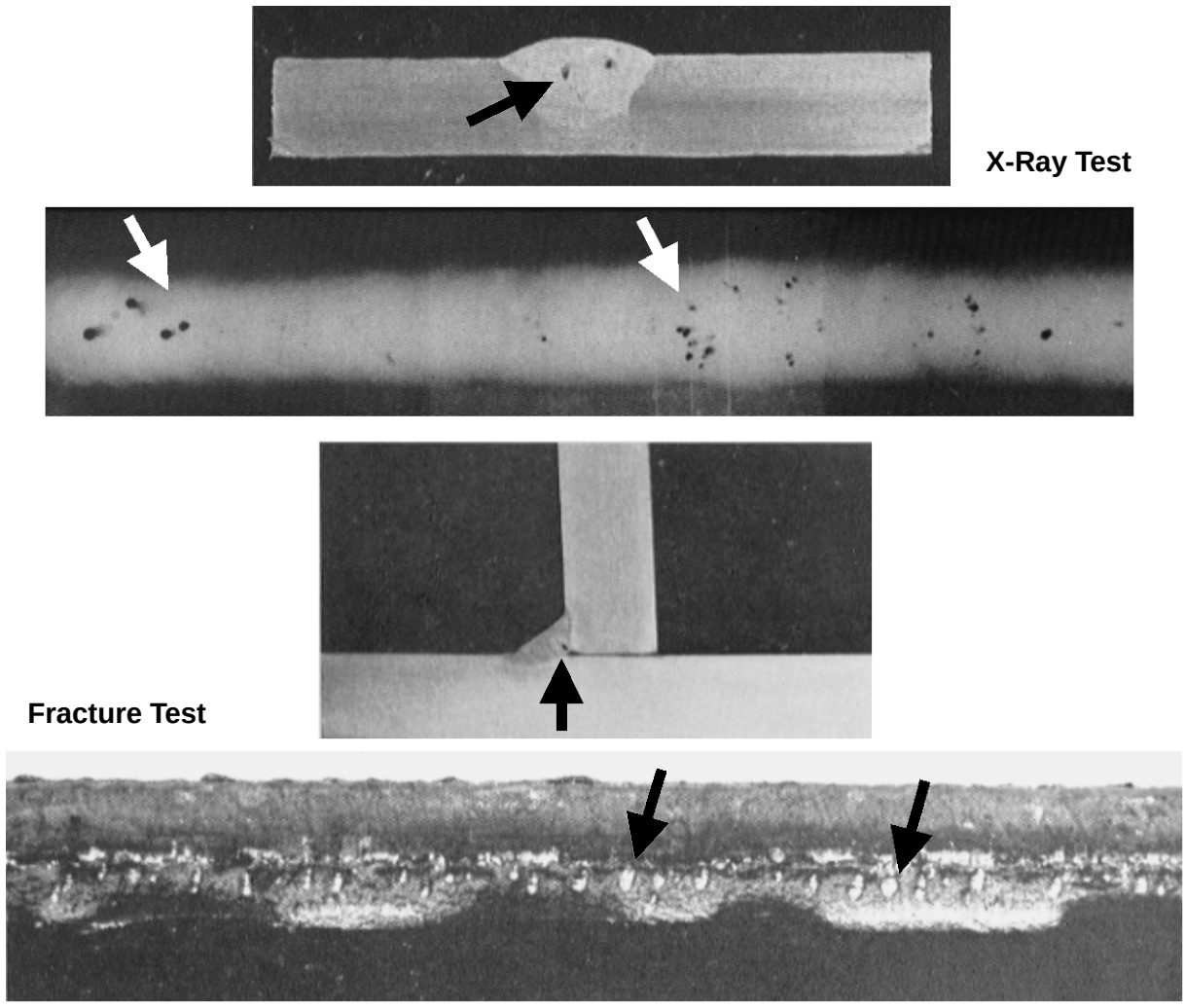


Fig. 10 POROSITY (BLOWHOLE)

Definition: Cavity type discontinuities formed by gas entrapment during solidification of weld metal

Main Causes:

(1) Rust, oil, paint, or moisture on the joint fusion faces and high sulfur content of the base metal
(2) Moisture in coatings (SMAW), fluxes (SAW), or shielding gases (GMAW)
(3) Too little shielding gas (GMAW) or flux-burden height (SAW)
(4) Strong wind
(5) Too much welding amperage, arc length, or arc voltage

Preventive Measures:

(1) Clean the joint fusion faces.
(2) Redry coatings (SMAW) and fluxes (SAW) and use suitable shielding gases (GMAW).
(3) Use proper amounts of shielding gas (GMAW) and flux-burden height (SAW).
(4) Use a wind screen (SMAW, GMAW).
(5) Use appropriate welding amperages, arc lengths, and arc voltages.

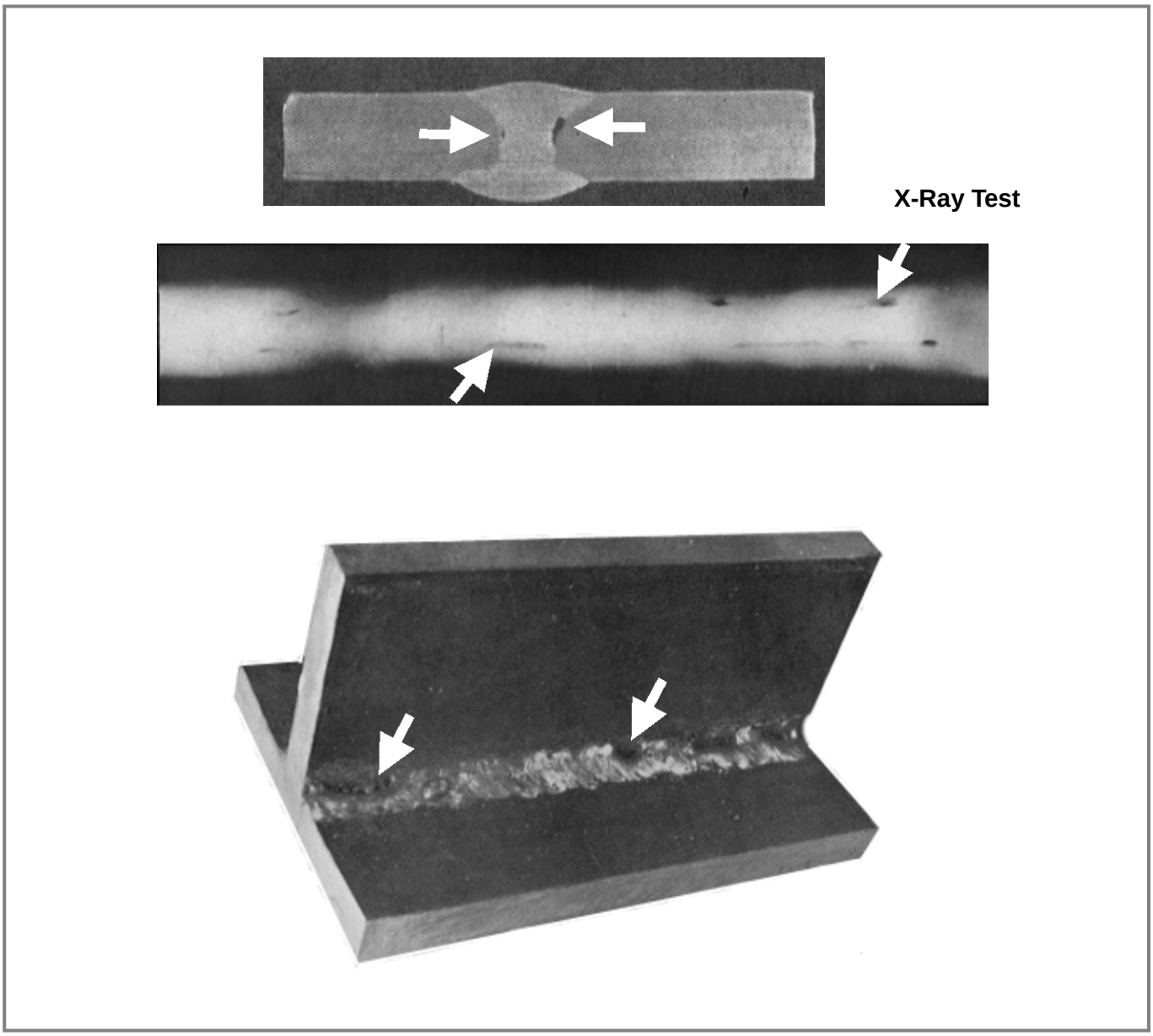


Fig. 11 SLAG INCLUSIONS

Definition: Nonmetallic solid materials entrapped in weld metals or between weld metal and base metal

Main Causes:

(1) Too low welding amperage
(2) Too much arc length
(3) Too much weaving width
(4) Too narrow groove
(5) Slag that remains on the preceding layer
(6) Inclined weld axis downward to the welding direction in the flat position

Preventive Measures:

(1)-(4) Use appropriate welding parameters and groove angles.
(5) Remove slag of the preceding layer completely.
(6) Keep the weld axis in horizontal by positioning.

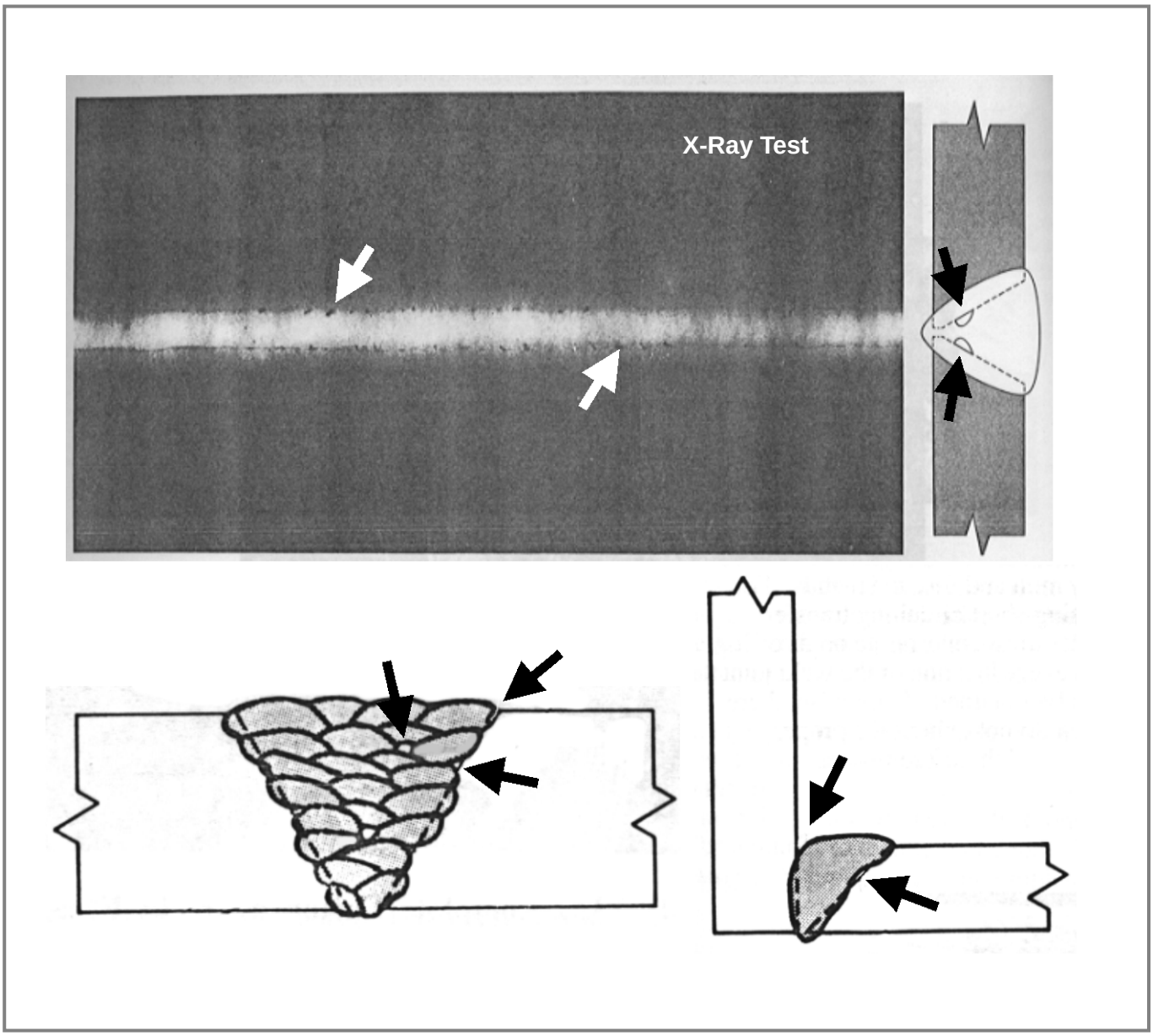


Fig. 12 INCOMPLETE FUSION

Definition: A weld discontinuity in which fusion did not occur between weld metal and joint fusion face or between adjoining weld beads.

Main Causes:

(1) Too low welding amperage
(2) Too fast or slow electrode manipulation
(3) Too much or too little arc length or arc voltage
(4) Too narrow welding groove

Preventive Measures:

Use appropriate welding parameters and groove angles.

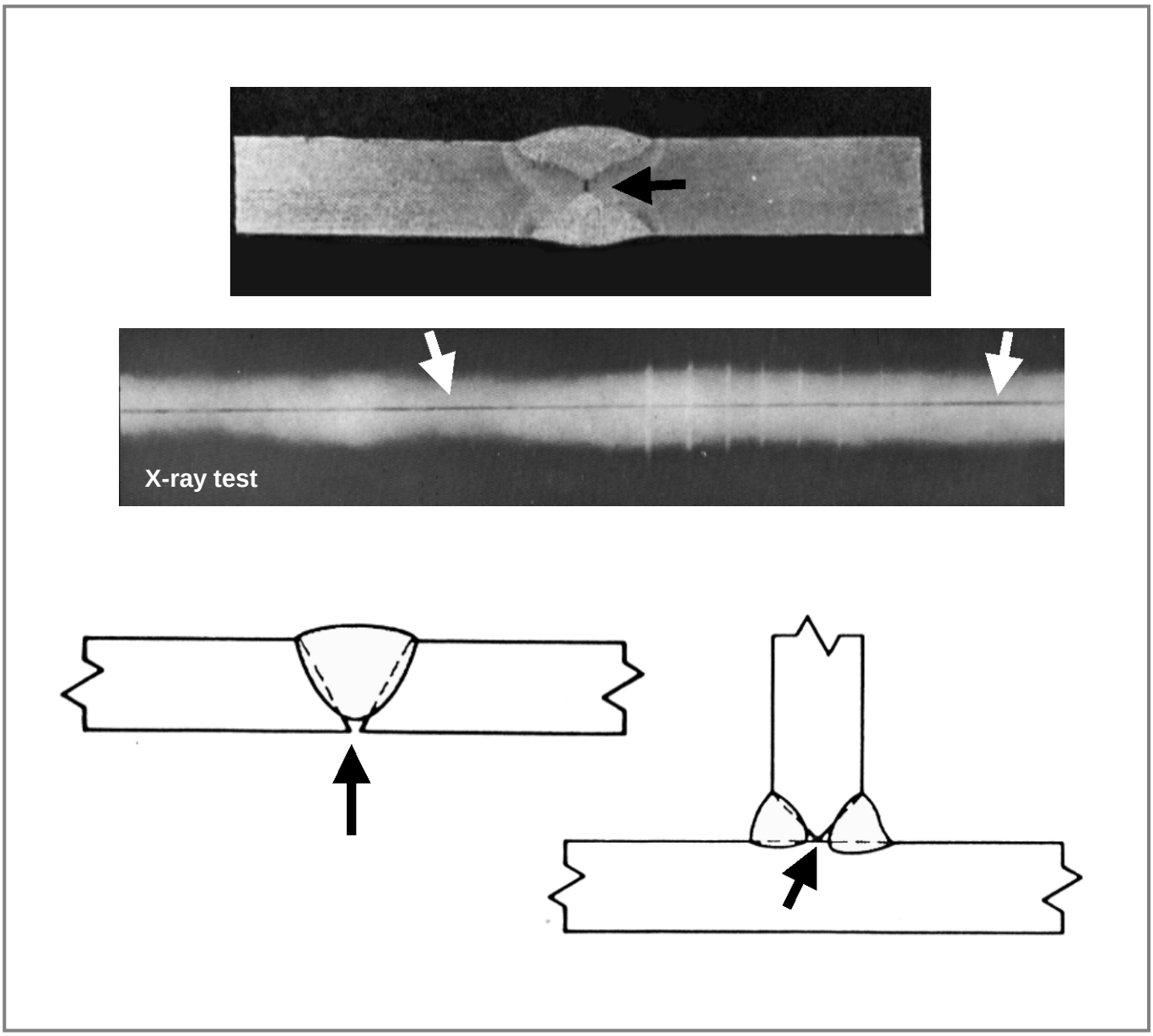


Fig. 13 INCOMPLETE JOINT PENETRATION

Definition: Joint penetration that is unintentionally less than the thickness of the weld joint

Main Causes:

(1) Too narrow welding groove
(2) Too low welding amperage
(3) Too much arc length or arc voltage
(4) Too fast or too slow electrode manipulation

Preventive Measures:

(1) Use an appropriate groove configuration.
(2)-(4) Use appropriate welding amperages, arc lengths (or arc voltages), and electrode manipulation.

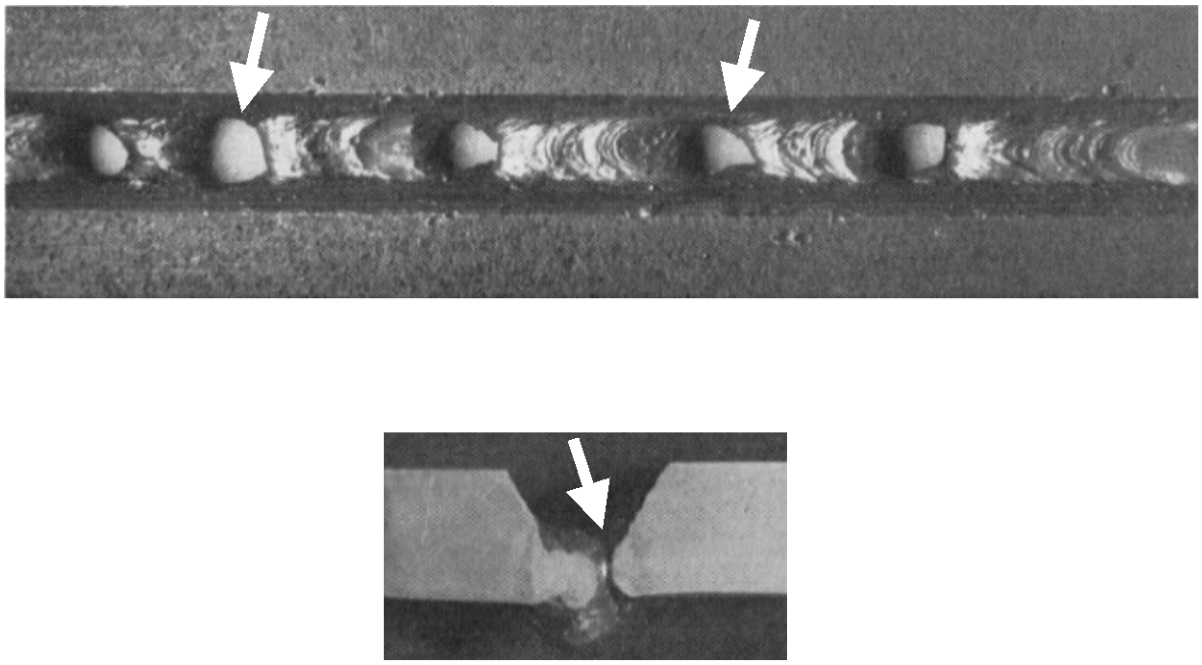


Fig. 14 EXCESSIVE MELT-THROUGH (BURN-THROUGH)

Definition: A hole through the weld metal, usually occurring in the root pass
Main Causes:
(1) Too much root opening
(2) Too high welding amperage
Preventive Measures:
Use appropriate root openings and welding amperages.

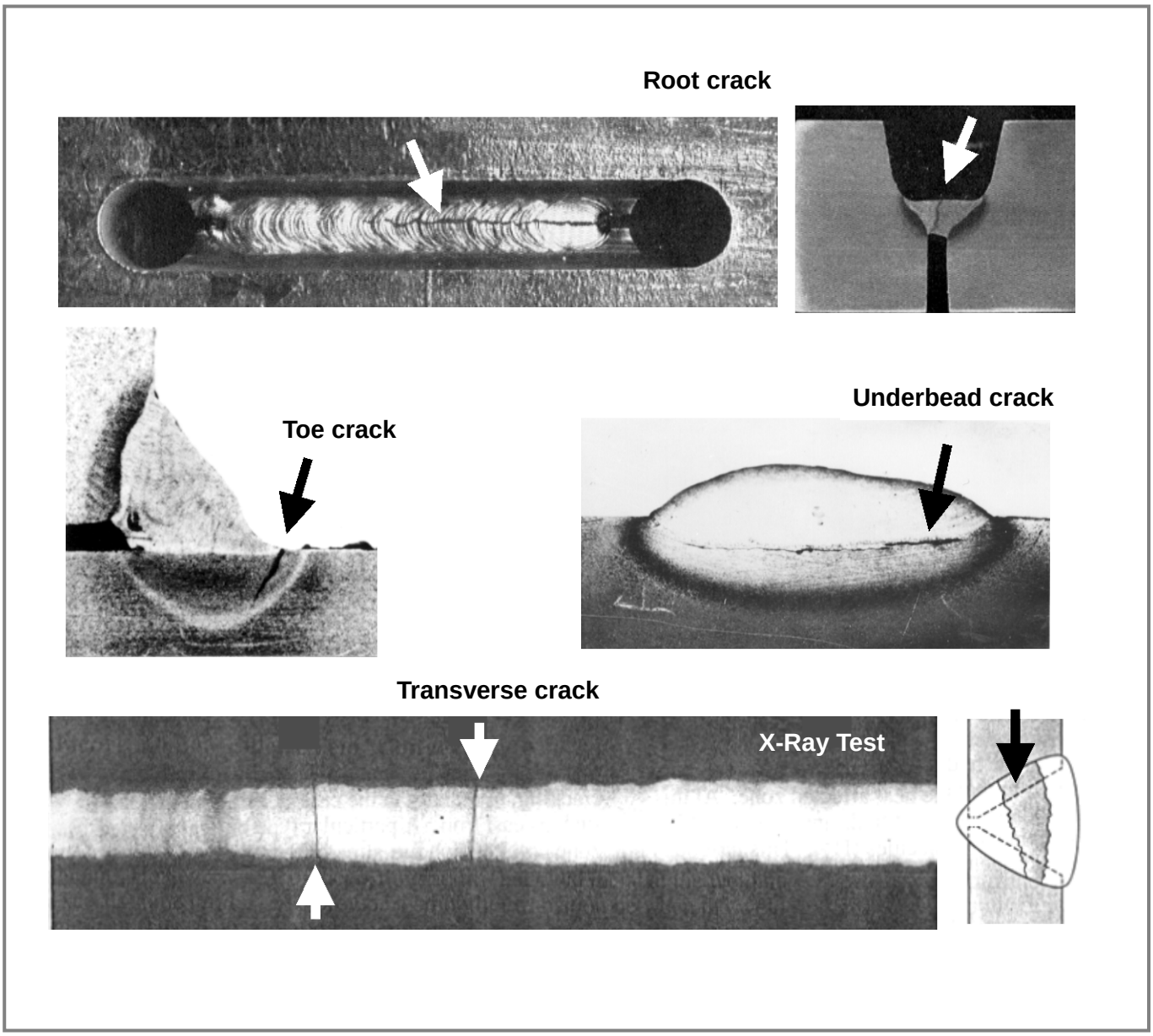


Fig. 15 COLD CRACK (ROOT CRACK, TOE CRACK, UNDERBEAD CRACK, TRANSVERSE CRACK)

Definition: A crack that develops after solidification of weld metal is completed at temperatures lower than approx. 200°C for steel

Main Causes:

(1) Diffusible hydrogen in welds
(2) Brittle structure of weld
(3) Restraint stresses in welds

Preventive Measures:

(1) Redry coatings (SMAW) and fluxes (SAW).
(2) Preheat base metals.

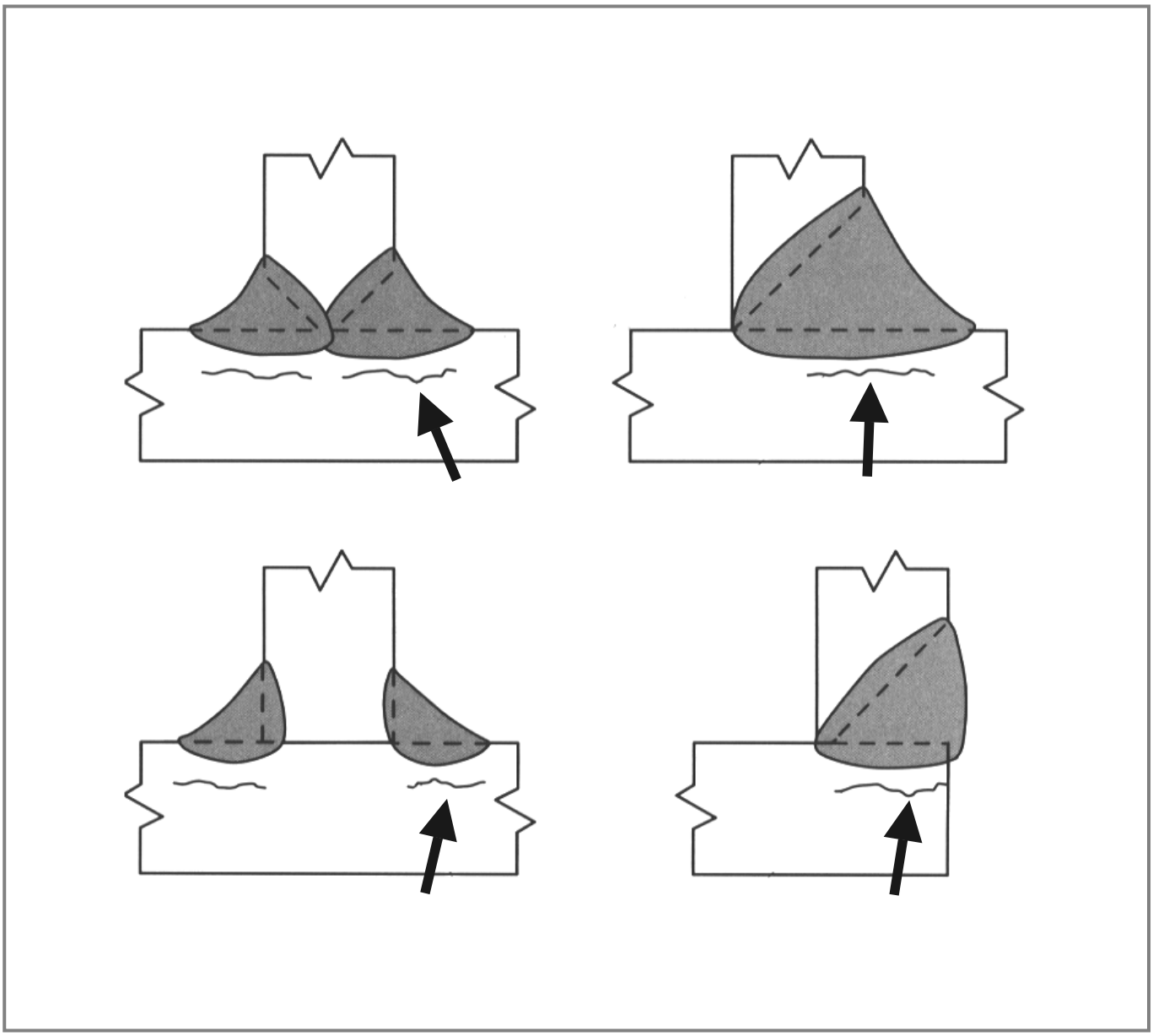


Fig. 16 COLD CRACK (LAMELLAR TEAR)

Definition: A subsurface terrace and step-like fracture in the base metal with a basic orientation parallel to the wrought surface

Main Causes:

(1) Inadequate ductility of the base metal in the thickness direction
(2) High sulfur content of the base metal
(3) Nonmetallic inclusions in the base metal
(4) Hydrogen in the weld
(5) Tensile stresses in the thickness direction of the base metal

Preventive Measures:

(1)-(3) Use a base metal that features higher ductility in the thickness direction, lower sulfur, and lower inclusions.
(4) Use low hydrogen type electrodes.
(5) Modify the joint details and the welding procedures to decrease the stresses.

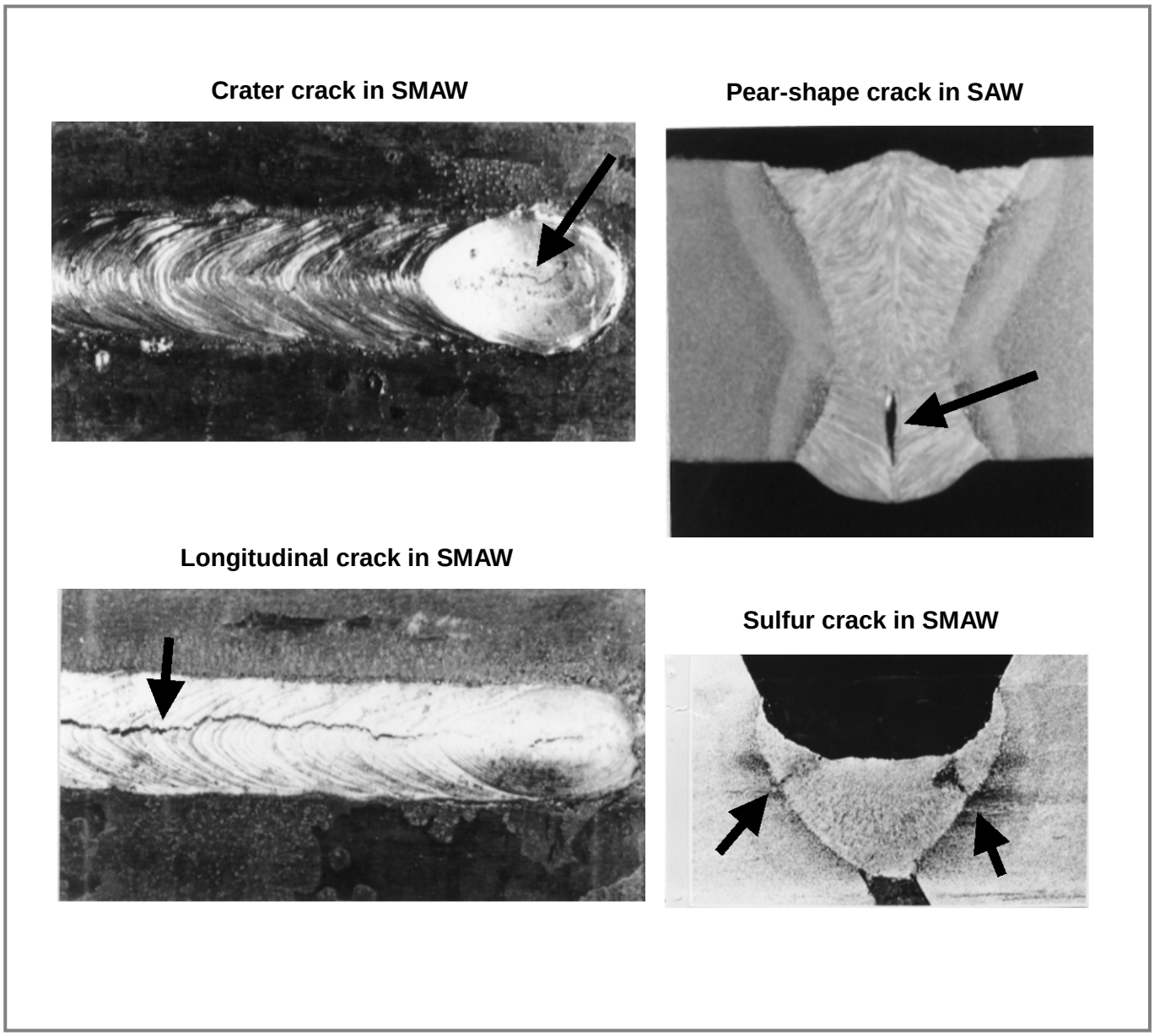


Fig. 17 HOT CRACK (CRATER CRACK, LONGITUDINAL CRACK, PEAR-SHAPE CRACK, SULFUR CRACK)

Definition: A crack that develops during solidification of weld metal
Main Causes:
(1) Too high welding amperage
(2) Too narrow welding groove
(3) Much sulfur content of the base metal
Preventive Measures:
(1) Use proper welding amperages and crater treatment.
(2) Use an appropriate groove angle.
(3) Inspect the sulfur segregation of the welding groove before welding.

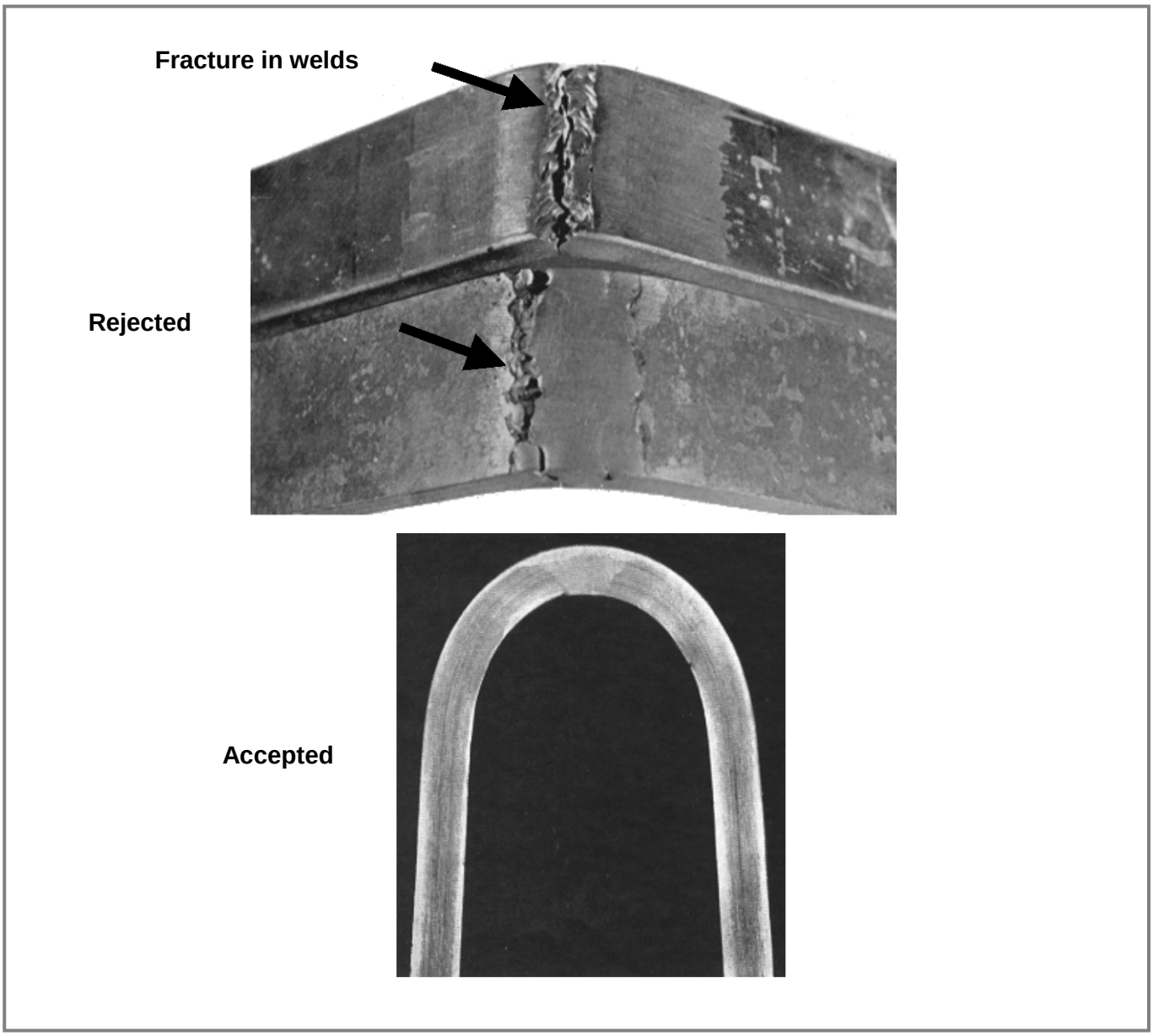


Fig. A-1 Fracture in welds caused by weld imperfections (Bend test results of weld joints)

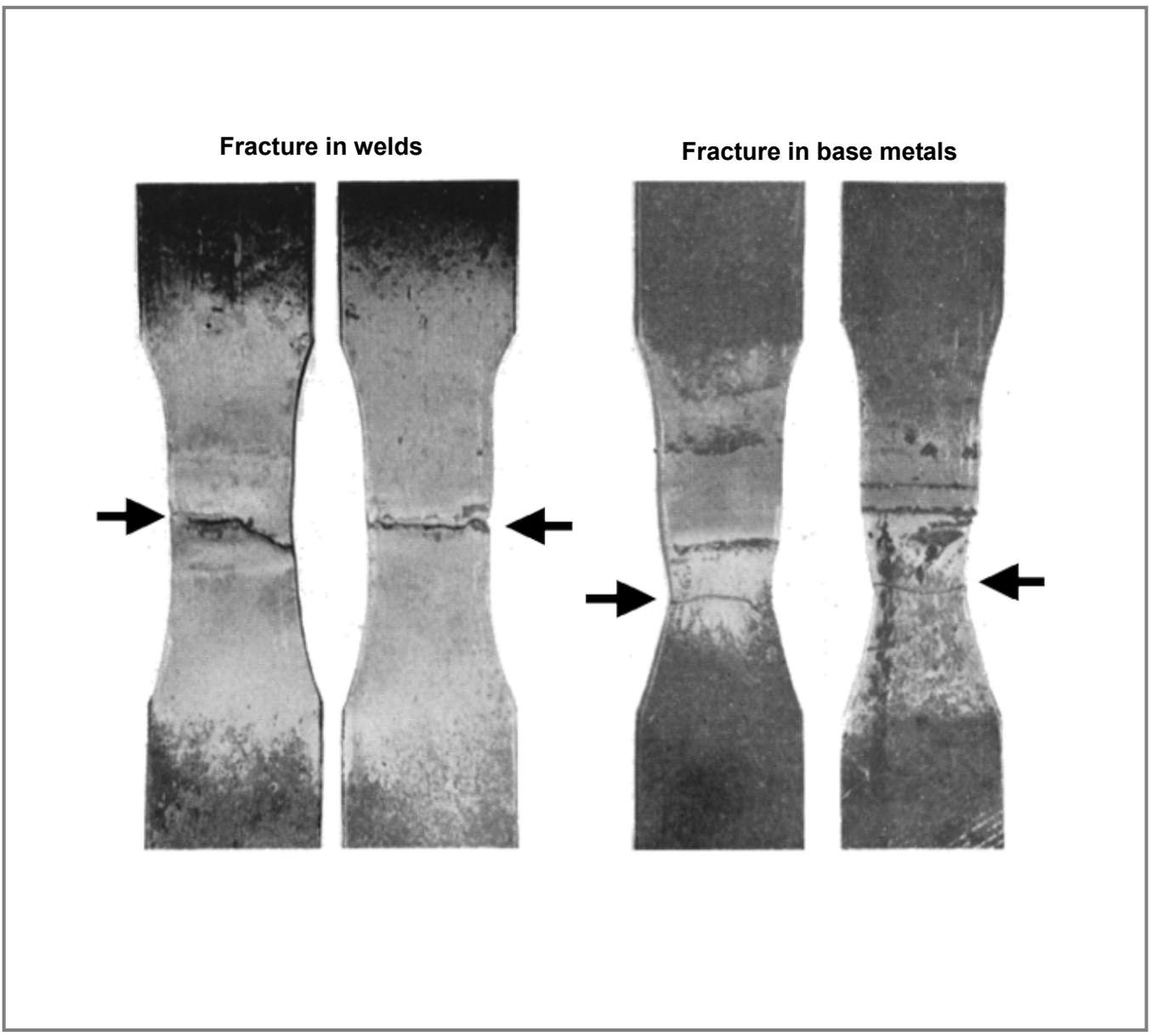


Fig. A-2 Fracture in welds caused by weld imperfections (Tension test results of weld joints)