Weld Quality

WELD DISCONTINUITIES

Lecture Scope

- Nature & causes of discontinuities in steel fusion welds
- Significance for weld fitness-for-service
- Preventive measures

Weld Discontinuities

- Weld discontinuities are interruptions of the typical structure of a weldment such as a lack of continuity in its physical, metallurgical or mechanical characteristics
- Discontinuities may be found in the weld metal, the heat affected zone and the base metal.
- Discontinuities that exceed established acceptance standards are termed "defects"

Causes of Weld Discontinuity

- Discontinuities can be thought of as originating in two sets of causes:
  1. ***Technological***: related to metallurgy and welding process
  2. ***Execution:*** related to welding operator skill in implementing procedures etc.

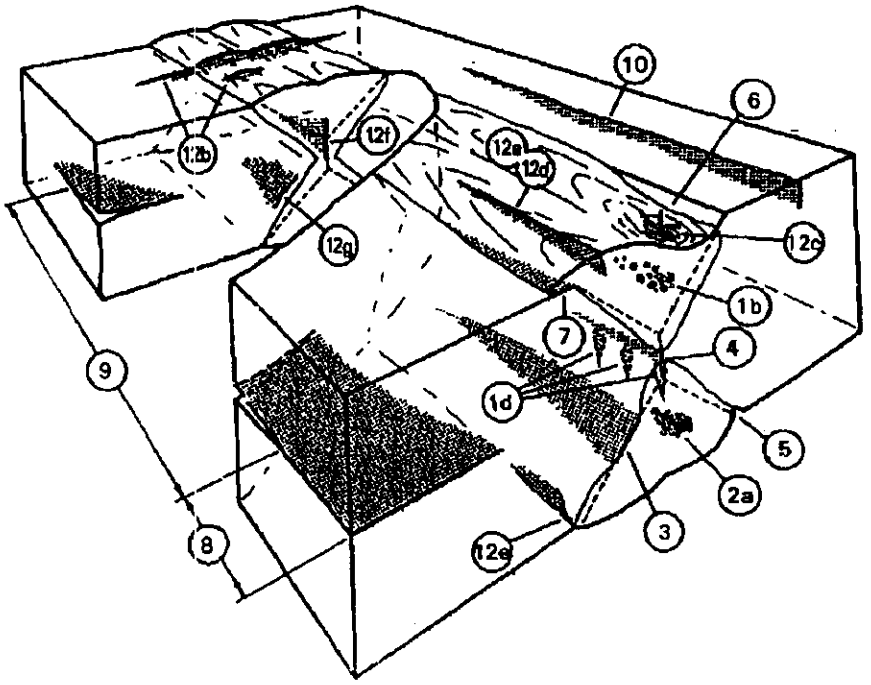
Types of Weld Discontinuity

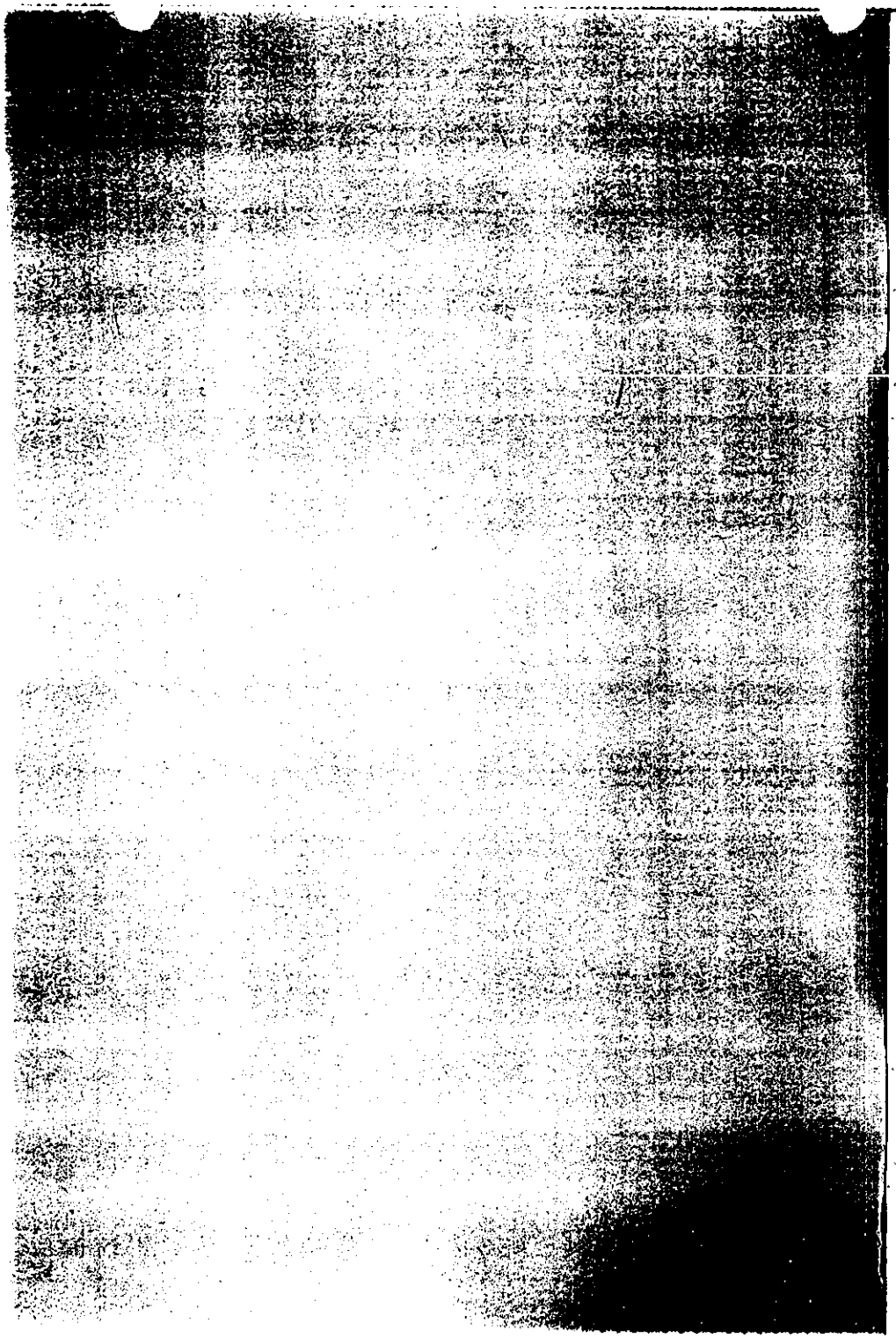
- Discontinuities are usually classified according to their physical characteristics

Type	Location	Fig Ref
Cracks	W, HAZ	12
Laminations, seams and laps	BM	8,9,10
Lamellar tears	BM	11
Porosity/Cavities	W	1
Inclusions	W	2
Lack of fusion or penetration	W	3,4
Imperfect shape: undercut, overfill, overlap	BM, W, W	5, 6, 7

W= weld
HAZ=heat affected zone
BM=base metal

Weld Defects: Groove Weld





lecture 12

FAULTS IN FUSION WELDS IN CONSTRUCTIONAL STEELS

Edited by Norman Bailey

Slide set number 2

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This set of photographs illustrates the main faults found in fusion welds in constructional steels. The notes in this booklet provide a brief identification and description of the faults illustrated; they do not attempt to provide a comprehensive text.

Terms relating to weld imperfections are defined in British Standard BS 499: Part 1: 1983. The examples have been chosen to illustrate the defects, and do not indicate acceptance levels, for which see the appropriate product standards.

Each section has notes on causes, and where appropriate, on rectification and on prevention.

Most of the photographs also appear in The Welding Institute wallchart, 'Faults in fusion welds in constructional steels' (Ref. C1-86).

CAUSES
Common causes of faults in welds made by the conventional arc welding processes are briefly described.

RECTIFICATION
Measures to remove the defect, if it exceeds the applicable acceptance criteria, are outlined.

PREVENTION
Preventive measures, where they do not consist simply of an obvious treatment of the cause, are outlined.

Some joints call for considerable welder skill to obtain an acceptable weld; in these cases, preventive measures may involve selection, training, and approval testing of welders.

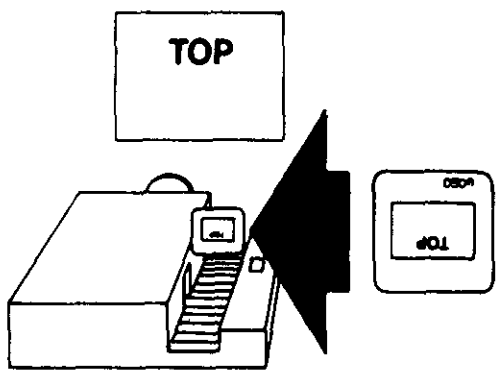
DETECTION

Surface defects are normally detected by visual inspection, penetrant dye or magnetic particle inspection: in some cases it is feasible to use eddy current or potential drop testing.

To detect embedded defects, volumetric methods, principally radiography and ultrasonics, are needed: they also indicate surface defects. The performance of either method depends critically on orientation of the defect to the beam: this must be taken into account when selecting a test procedure.

SLIDE SET 2

The photographs are also available as a slide set, numbered 0240 to 0279. Each slide carries its number in the picture area, repeated on the slide mount and indicating correct orientation.



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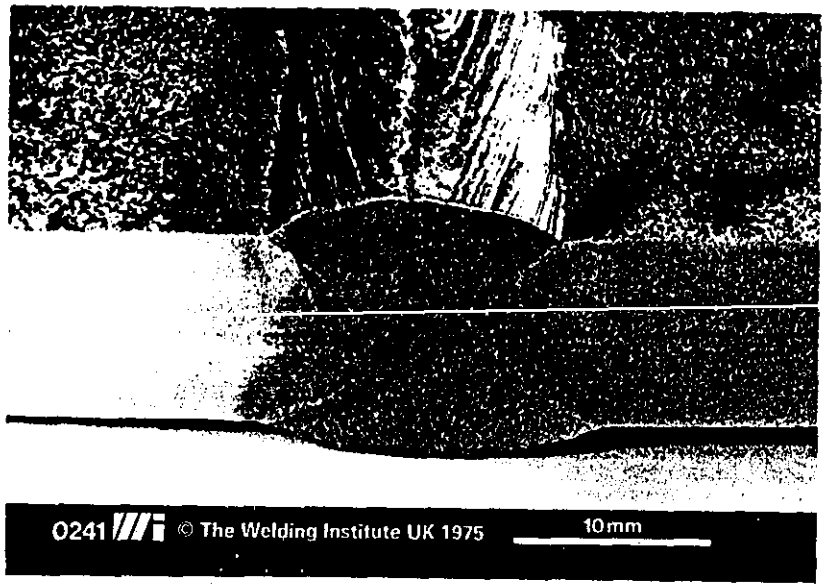
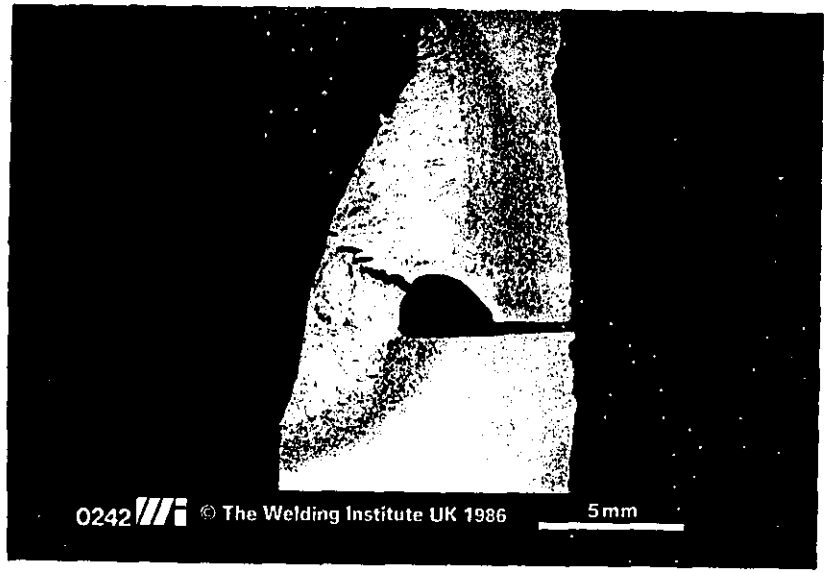
CRACKS

SOLIDIFICATION CRACKING





CAUSES

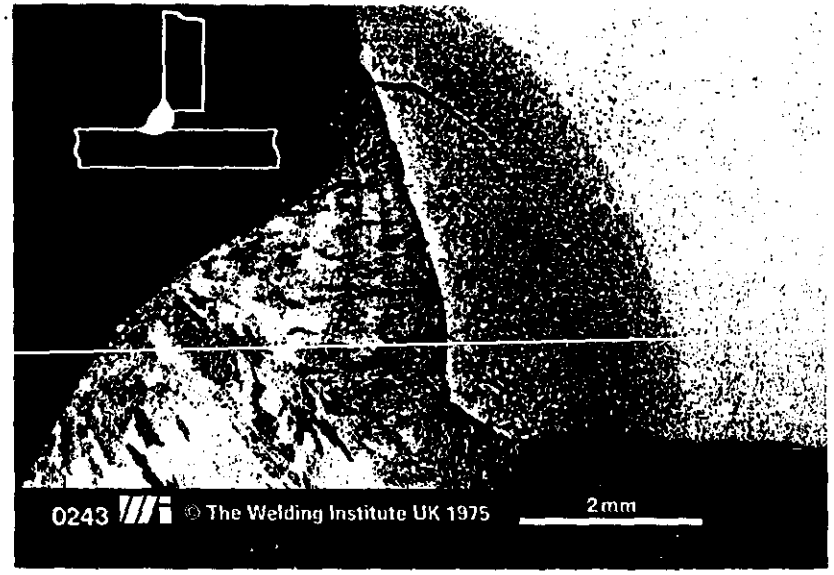
Excessively deep or wide weld bead.
High current and/or welding speed.
Large root gap.
Carbon, sulphur or phosphorus pickup from parent steel.
The risk of cracking is greatest with submerged-arc welding, and reduced with gas-shielded metal-arc, self-shielded metal arc, manual metal arc, to least with gas-shielded tungsten-arc
High strength parent metal increases the risk.

RECTIFICATION

Cut out defective weld length plus 5mm beyond visible end o crack and reweld.

PREVENTION

Plan welding parameters to reduce thermally induced strains.
Adjust weld parameters to obtain weld width between 0.5 an 0.8 of depth.
Avoid parent steels containing more than 0.6% total of sulphu and phosphorus.
Take care if submerged-arc welding steel with more than 0.2% carbon.
Clean off all traces of cutting oils.
Control joint fit-up to reduce gaps.
Reduce weld metal dilution by reducing welding current, by welding with electrode negative, or in the submerged-arc process with metal powder additions.



CAUSES

Hardened HAZ — heat affected zone of the parent metal — coupled with presence of hydrogen diffused from weld metal, caused by damp electrodes or flux, or contaminated wire.
Susceptibility increases with increasing thickness of section, especially in steels with high carbon equivalent.
Excessively fast cooling, allowing insufficient time for hydrogen to diffuse out at higher temperatures — cracking does not occur above about 200°C.
High restraint, excessive root gaps, stress concentrations.
Risk greatest with manual metal arc welding with cellulosic or rutile electrodes; least with gas-shielded tungsten-arc, solid wire gas-shielded metal-arc and manual metal arc with austenitic or nickel-base or adequately dried and controlled basic electrodes. NOTE: the cracks are fine and difficult to detect; they may not be found until after postweld heat treatment. They grow slowly, so inspection should be delayed.

RECTIFICATION

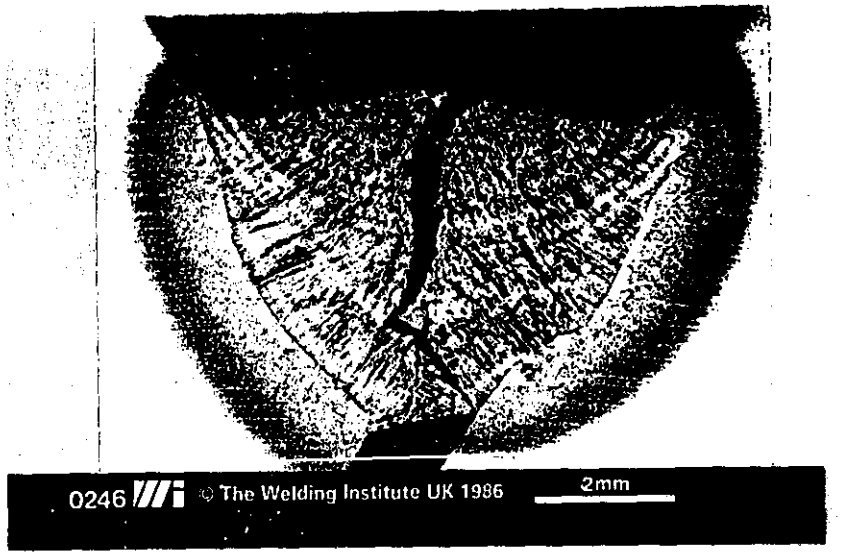
Short isolated lengths of crack, where accessible, can be cut out and rewelded. Extensive or inaccessible cracking may not be possible to rectify. Austenitic or nickel-base electrodes may be helpful if preheat must be limited. Note that any repair weld should use the correct procedures as detailed below.

PREVENTION

Use the appropriate procedures, which may include:
Hydrogen-controlled welding consumables;
Consumables dried and stored in accordance with the manufacturer's instructions;
Preheat and minimum interpass temperatures reaching the specified value in the whole joint;
Heat input as specified, even for tack welds;
Parent metal composition within limits specified for the procedure in use.
Avoid use of excessively strong weld metal.

Weld face, toes at the sides of the photograph

Weld face, toes at top and bottom of photograph



May be transverse (0244), at 90° or 45° to surface (0245), or longitudinal (0246).

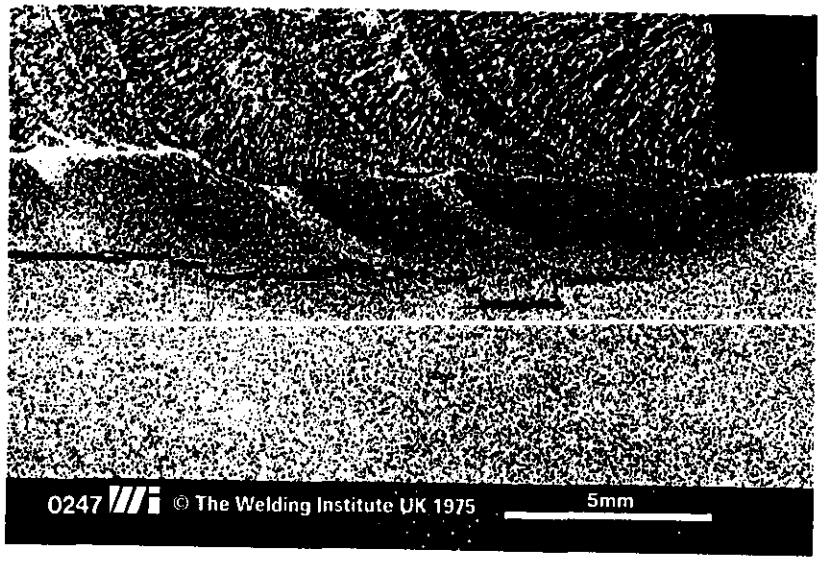
CAUSES

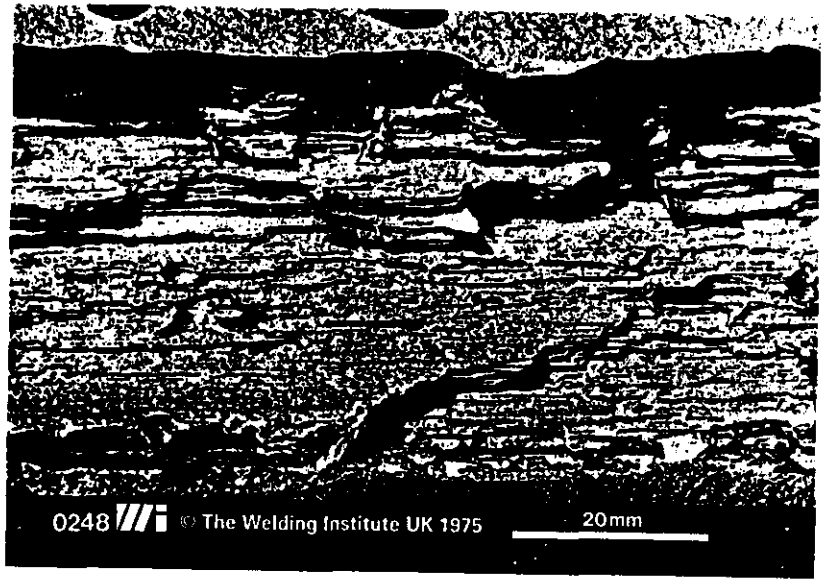
Weld metal alloyed as much as, or more than, parent steel, usually in thick sections with insufficient consumable drying or preheat.
High restraint.
Excessive gap.
Sharp notch in root run.

PREVENTION

As for HAZ cracking.

LAMEL_ .R TEARING





Fracture surface

CAUSES

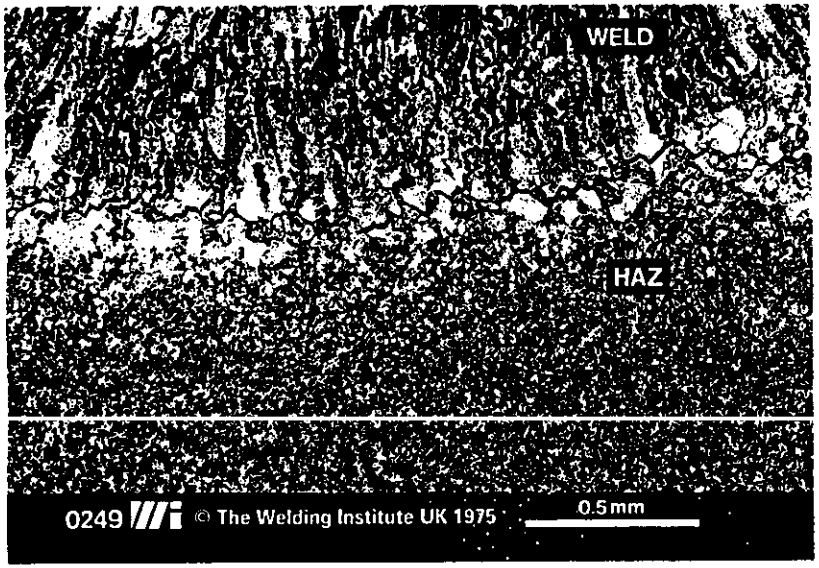
Poor ductility in through-thickness direction because of non-metallic inclusions.
Only found in rolled plate.
Occurs mainly where weld metal is deposited on plate surface, such as T, corner, and cruciform joints, and where restraint is high.

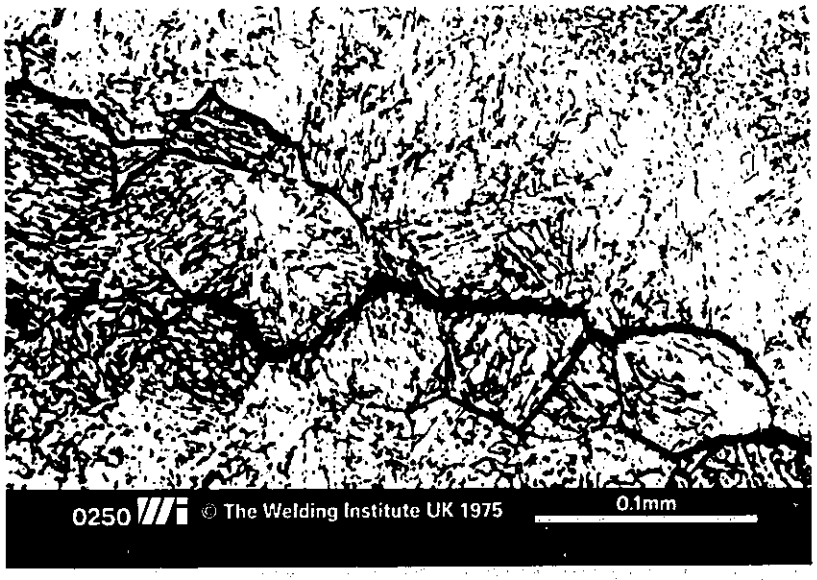
RECTIFICATION

Gouge out cracked area. Butter affected plate with low strength weld metal to spread residual stresses over a large area.

PREVENTION

Design joints to avoid through-thickness tensile stress.
Specify plate with sufficient through-thickness (short transverse) ductility, that is with a low sulphur and oxygen content.
Use forgings or castings instead of plate.





treatment, particularly if they contain chromium, molybdenum and vanadium.

CAUSES

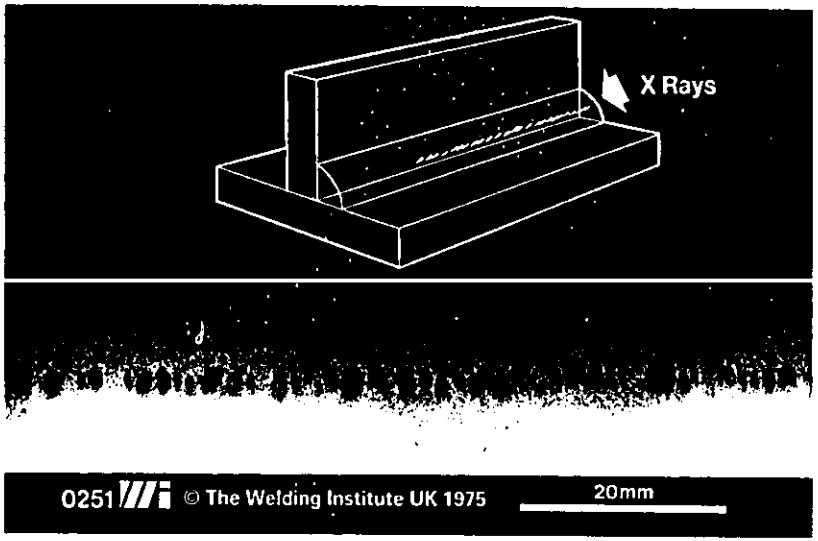
Poor creep ductility in HAZ coupled with thermal stress.
Accentuated by severe notches such as pre-existing cracks, or tears at weld toes, or unfused root of partial penetration weld.

PREVENTION

Heat treatment may need to include low temperature soaking, followed by fairly rapid heating to final temperature.
Grinding or peening of weld toes after welding can be beneficial
Can be avoided by 'two-layer' welding technique to refine the coarse-grained heat affected zone, together with the use of non-susceptible weld metal.

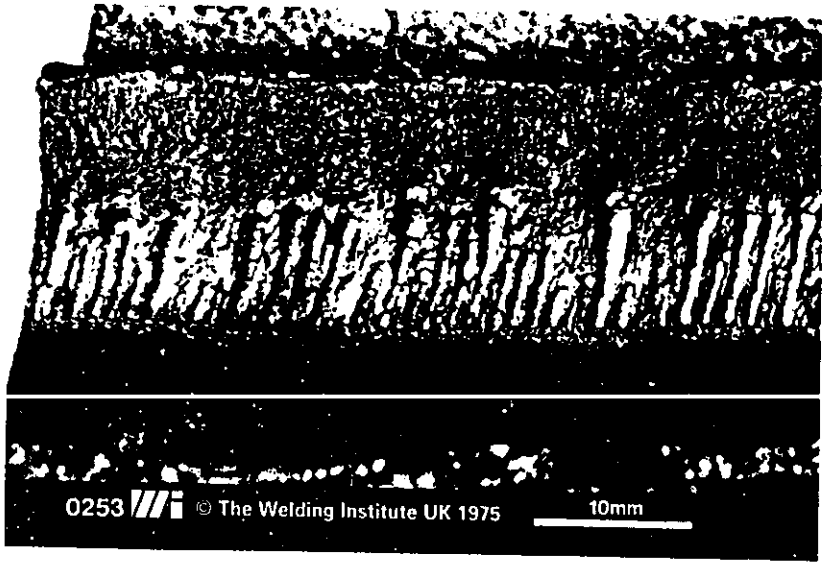
CAV. .ES

WORMHOLES



Radiograph

Radiograph



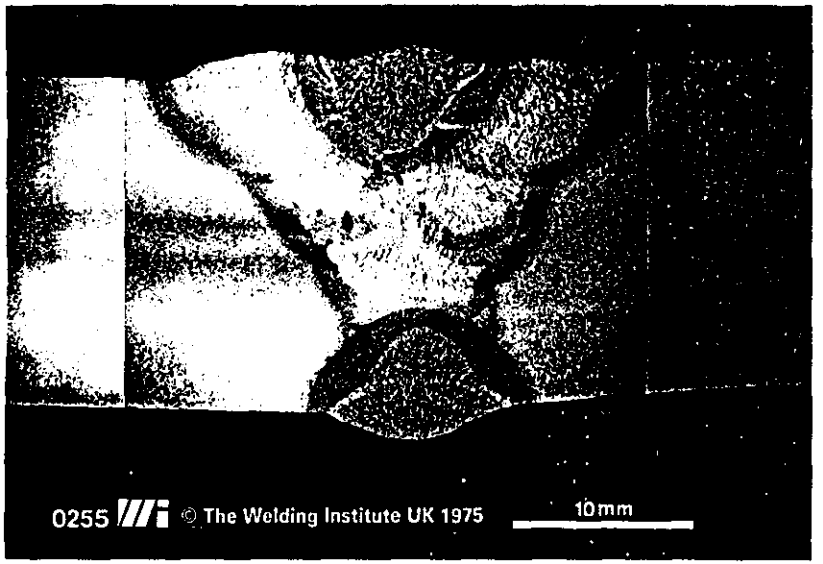
Fracture surface

Resulting from entrapment of gas between solidifying dendrites of weld metal, often showing a 'herring-bone' array, as in radiograph 0252.

CAUSES

The gas may arise from contamination of surfaces to be welded, or be prevented from escaping from beneath the weld by joint crevices.

Radiograph



CAUSES

Gas may originate from dampness or grease on consumables or workpiece, or by nitrogen contamination from the atmosphere. If the welding wire used contains insufficient deoxidant it is also possible for carbon monoxide to cause porosity.

PREVENTION

Remove the sources of gas by avoiding or removing contamination.
Ensure correct shielding gas flow.
Use consumables with higher levels of deoxidants.
Where porosity is the result of an intentional surface treatment, such as priming paint, remove it locally.

RESTART POROSITY

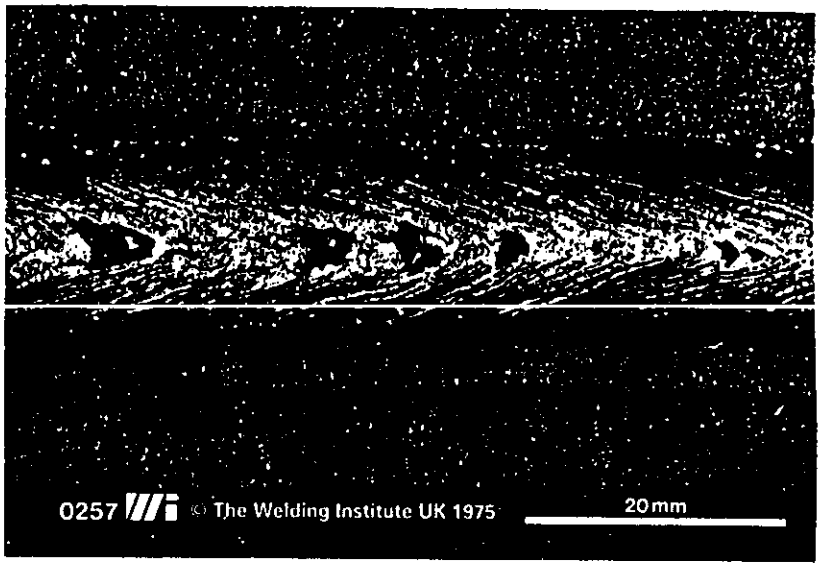
Radiograph

CAUSES
Unstable arc conditions at weld start, where protection may be incomplete and temperature gradients have not had time to equilibrate, coupled with inadequate manipulative technique to allow for this instability.

The radiograph shows internal restart porosity.

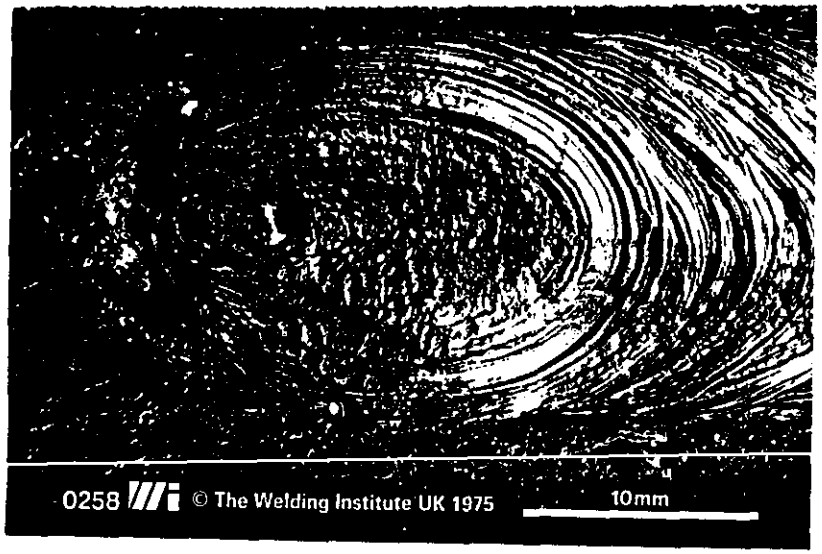
PREVENTION
Improve the welder's restart technique.
Start on a run-on tab if practicable.

SURFACE POROSITY



CAUSES
Excessive contamination from grease, dampness, or atmospheric entrainment.
Occasionally caused by excessive sulphur in consumables or parent metal.

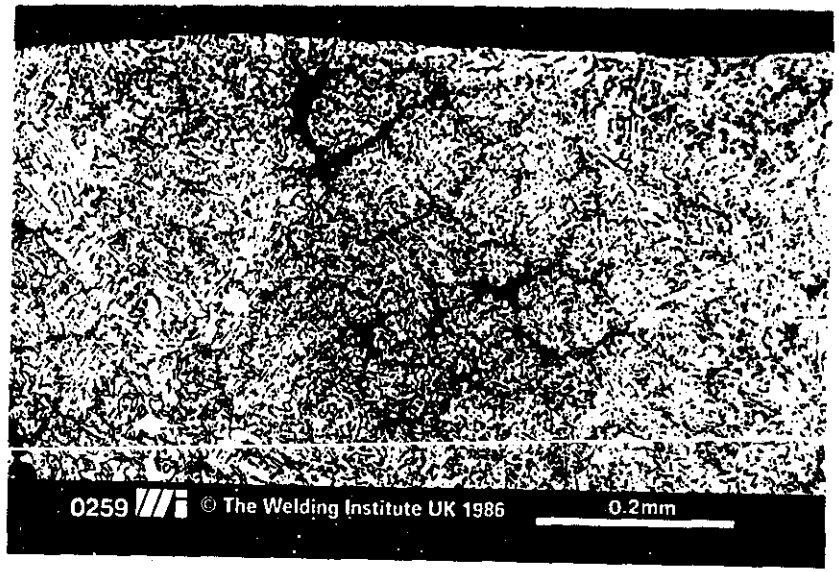
PREVENTION
As for uniform porosity.
Reduce sulphur content where appropriate.



Resulting from shrinkage at the end crater of a weld run.

CAUSES
Incorrect manipulative technique or current decay to allow for crater shrinkage.

PREVENTION
Improve welder's technique.
Use a welding set with a current decay facility.
Use a run-off tab.



Resulting from shrinkage at, or just below, the surface of a submerged-arc weld.

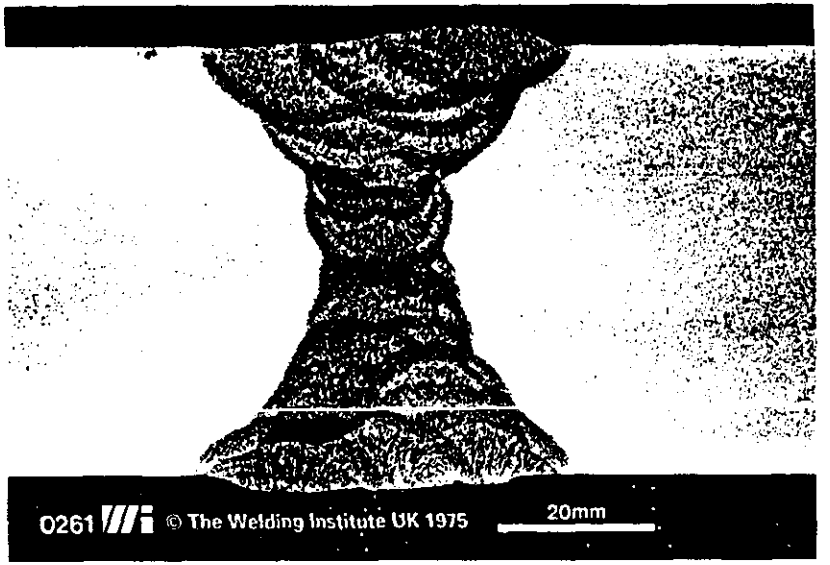
CAUSES
High welding speed with deep weld pool.

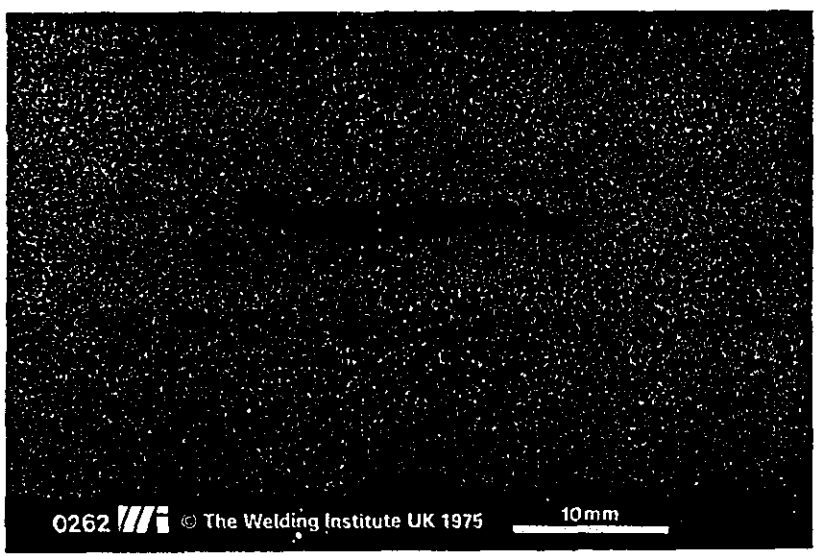
LINEAR INCLUSIONS

Radiograph

CAUSES

Incomplete removal of slag in multipass welds, often associated with the presence of undercut or irregular surfaces in underlying passes. The radiograph in the slide shows two slag lines in a weld root zone.





Radiograph

prepared surfaces, or electrodes with coverings which are cracked or damaged, for example by too rapid drying.
May also arise from isolated undercut in underlying passes of multipass welds.

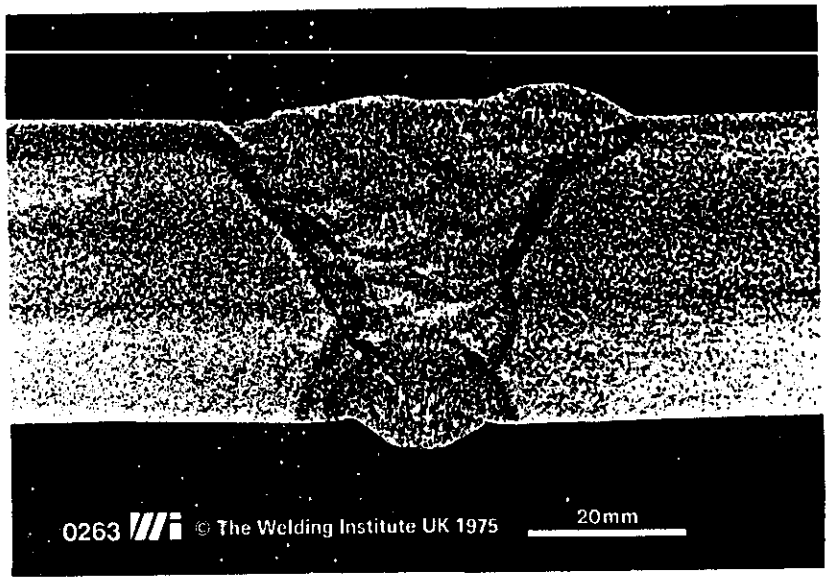
LACK OF FUSION AND PENETRATION

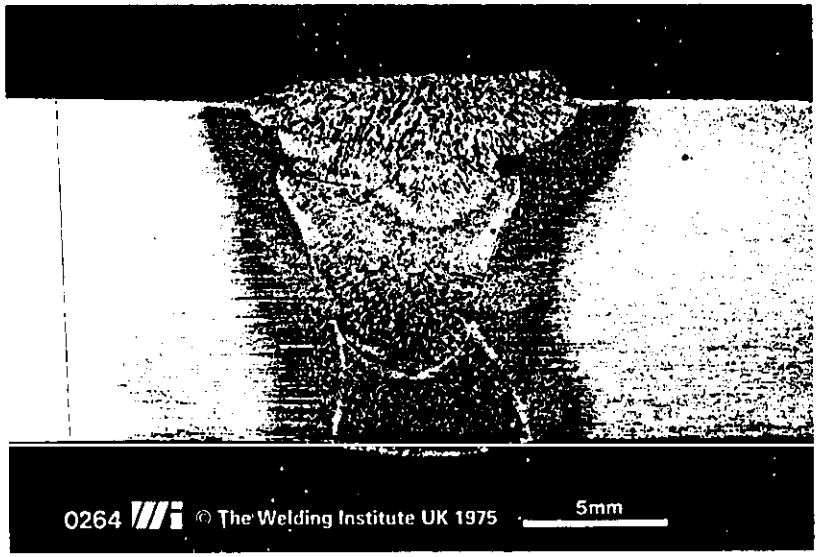
CAUSES

Incorrect welding conditions, such as too low a current, or incorrect torch/gun angle.

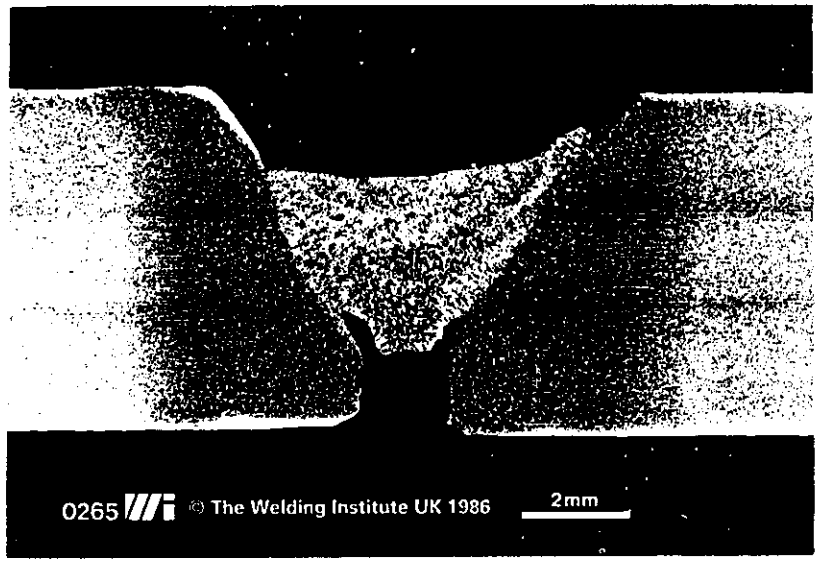
Incorrect edge preparation, for example too large a root face.

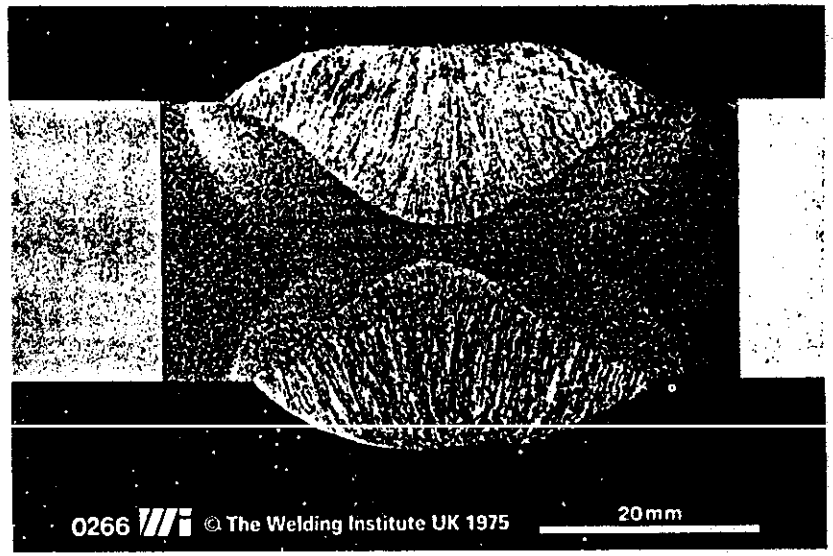
LACK OF SIDE FUSION





LACK OF ROOT FUSION

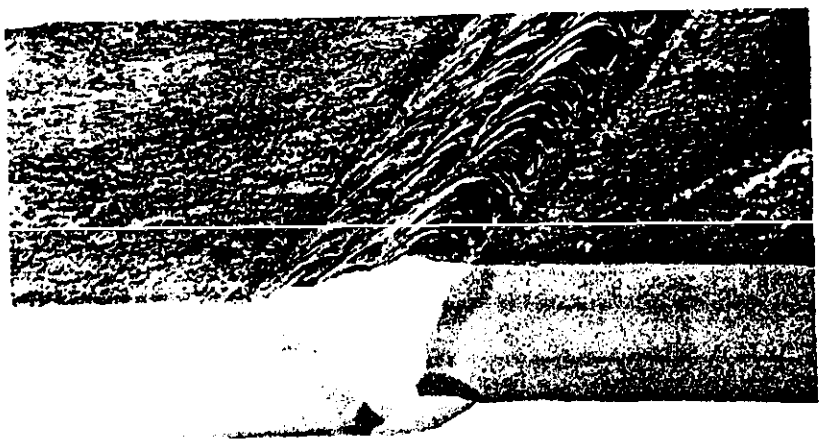




Radiograph

IMPERFECT SHAPE

LINEAR MISALIGNMENT



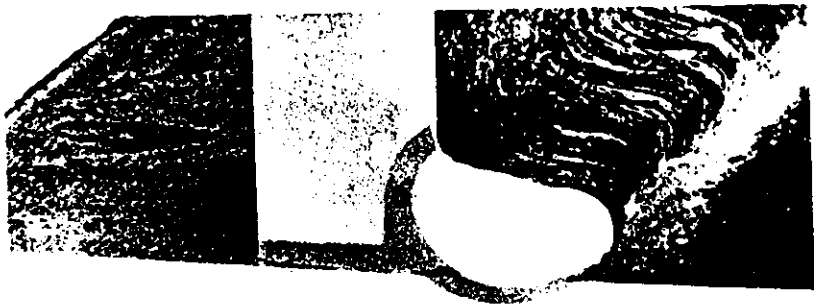
CAUSES
Incorrect assembly and/or distortion during fabrication.

EXCESS WELD METAL

Alternative term — **REINFORCEMENT**

Weld metal normally extends above the parent metal surface: only a fault if exceeding specification.

CAUSES
Deposition of too much weld metal, often associated with unsuitable weld preparation, incorrect welding parameters, or too large an electrode.



0270 © The Welding Institute UK 1975 20mm

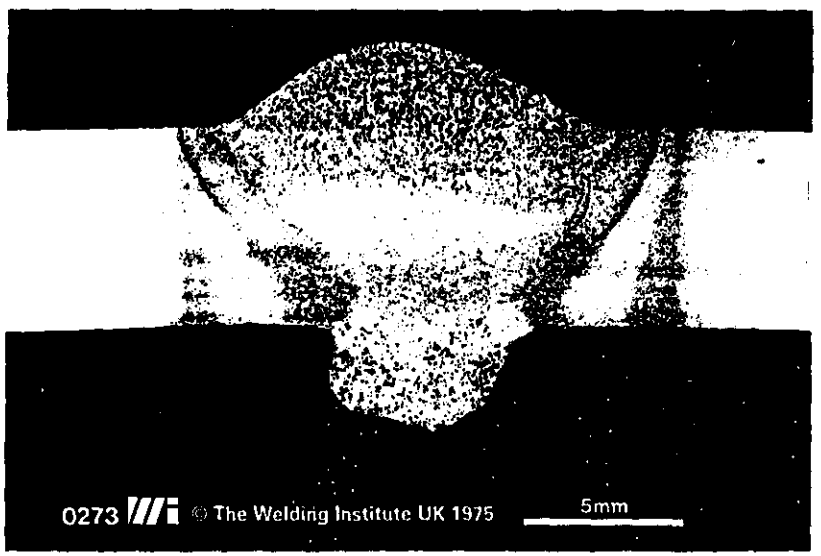
CAUSES
Poor manipulative technique or insufficient heat input, with current or voltage too low.
Depositing too large a fillet weld run in the horizontal-vertical position.

0271 © The Welding Institute UK 1975 20mm

Results from washing away of the edge preparation when molten.

CAUSES
Poor welding technique and/or unbalanced welding conditions.

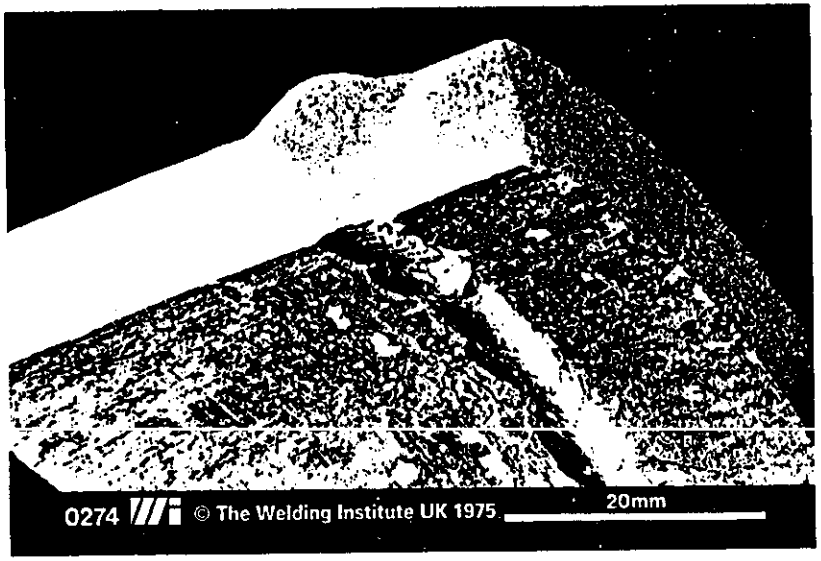
EXCESS PENETRATION BEAD

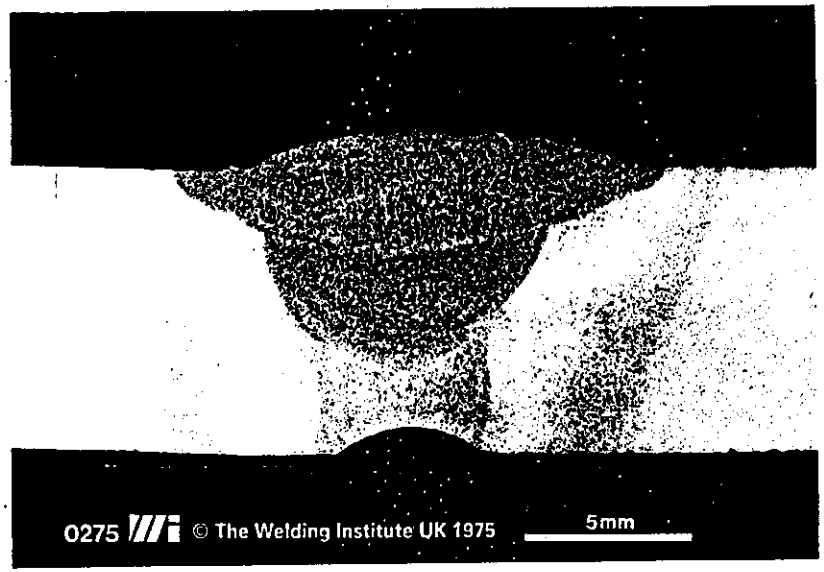


Weld metal normally extends below the parent metal surface: only a fault if exceeding specification.

CAUSES

Incorrect edge preparation providing insufficient support at the root, and/or incorrect welding parameters.

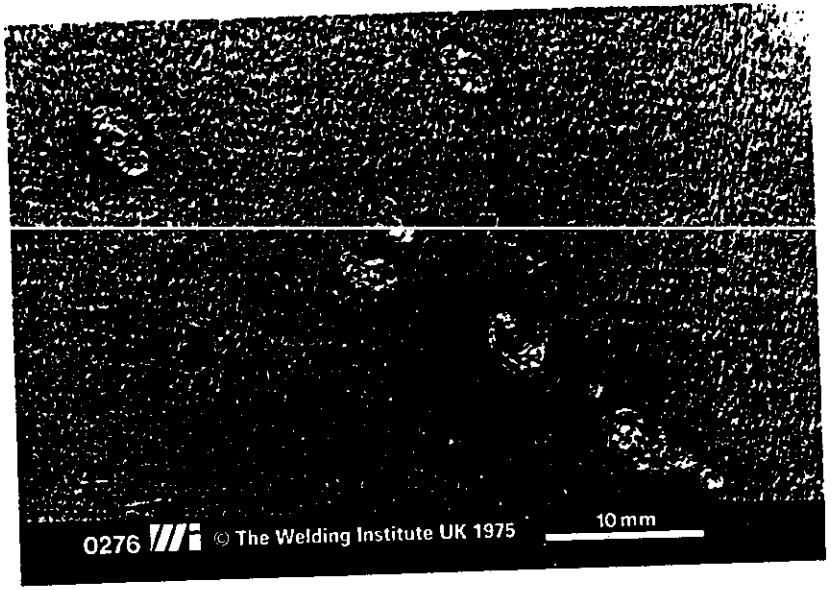




May also be caused by incorrect welding technique, or too high a gas backing pressure.

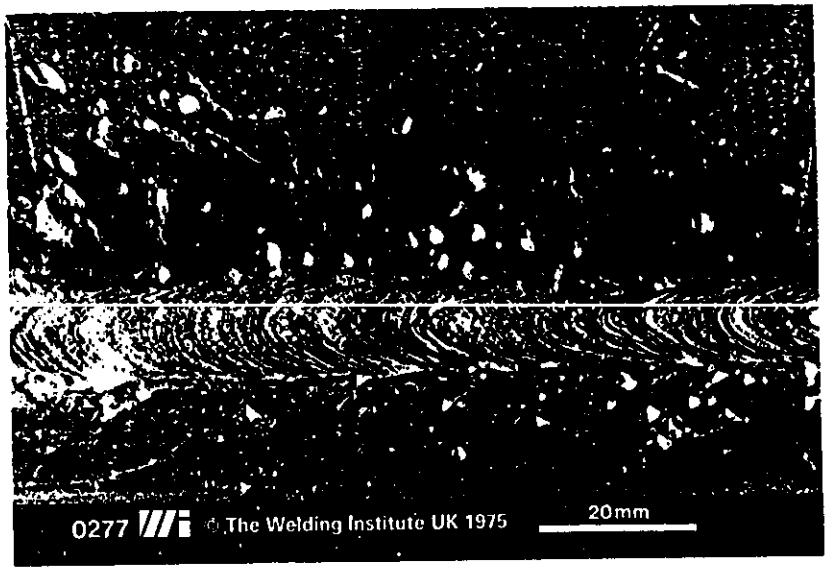
MISCELLANEOUS FAULTS

STRAY ARCING



CAUSES
Accidental contact of electrode or welding torch with plate surface remote from weld. These usually result in small hard spots just beneath the surface which may contain cracks, and are thus to be avoided.

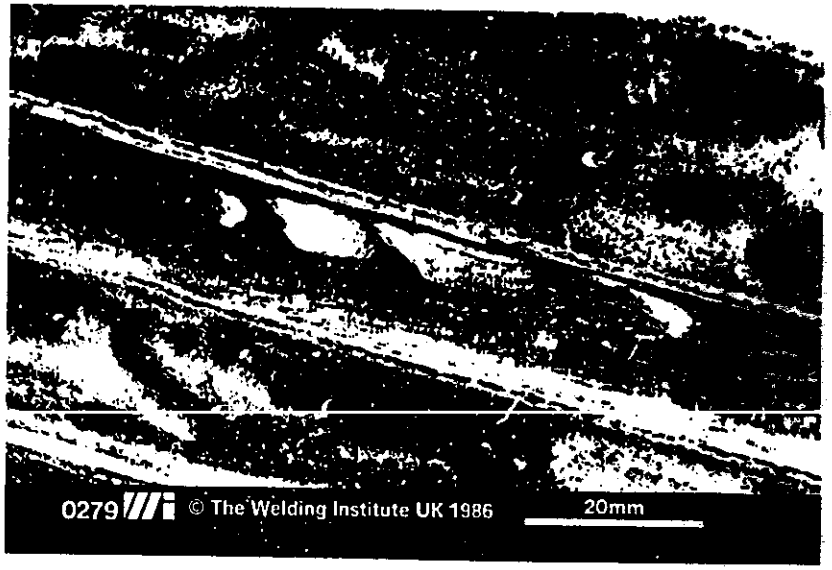
SPATTER



CAUSES
Incorrect welding conditions, such as too high a welding current, and/or contaminated consumables or preparations, giving rise to explosions within the arc and weld pool. Globules of molten metal are thrown out, and adhere to the parent metal remote from the weld.

CAUSES

Melting of copper contact tube in gas-shielded metal-arc welding because of incorrect welding conditions.



Surface depression on face of submerged-arc weld.

CAUSES

Flux inadequately dried or containing insufficient deoxidants.