Welding defects

ISO 6520 Welding and allied processes — Classification of geometric imperfections in metallic materials

ISO 5817 Welding — Fusion-welded joints in steel, nickel, titanium and their alloys (beam welding excluded) — Quality levels for imperfections

ISO 10042:2018 Welding — Arc-welded joints in aluminium and its alloys — Quality levels for imperfections

DISCONTINUITY

An interruption of the typical structure of a material, such as a lack of homogeneity in its mechanical, metallurgical, or physical characteristics. A discontinuity is not necessarily a defect. See also defect and flaw.

DEFECT

A discontinuity or discontinuities that by nature or accumulated effect render a part or product unable to meet minimum applicable acceptance standards or specifications. The term designates rejectability. See also discontinuity and flaw.

FLAW

An undesirable discontinuity. See also defect

ISO 6520-1:2007(en)

Welding and allied processes — Classification of geometric imperfections in metallic materials — Part 1: Fusion welding

ISO 6520-2

Welding and allied processes — Classification of geometric imperfections in metallic materials — Part 2: Welding with pressure

2.1 imperfection <fusion welding>

discontinuity in the weld or a deviation from the intended geometry

2.2 defect <fusion welding>

unacceptable imperfection

https://www.iso.org/obp/ui/#iso:std:iso:6520:-1:ed-2:v1:en
https://www.iso.org/obp/ui/#iso:std:iso:6520:-2:ed-2:v1:en,fr

http://www.weldguru.com/welding-terminology.html#d-f
http://www.weldguru.com/mechanical-properties-of-metals.html#at_pco=smlwn-1.0&at_si=57ea3ac48f1d62f1&at_ab=per-2&at_pos=0&at_tot=1

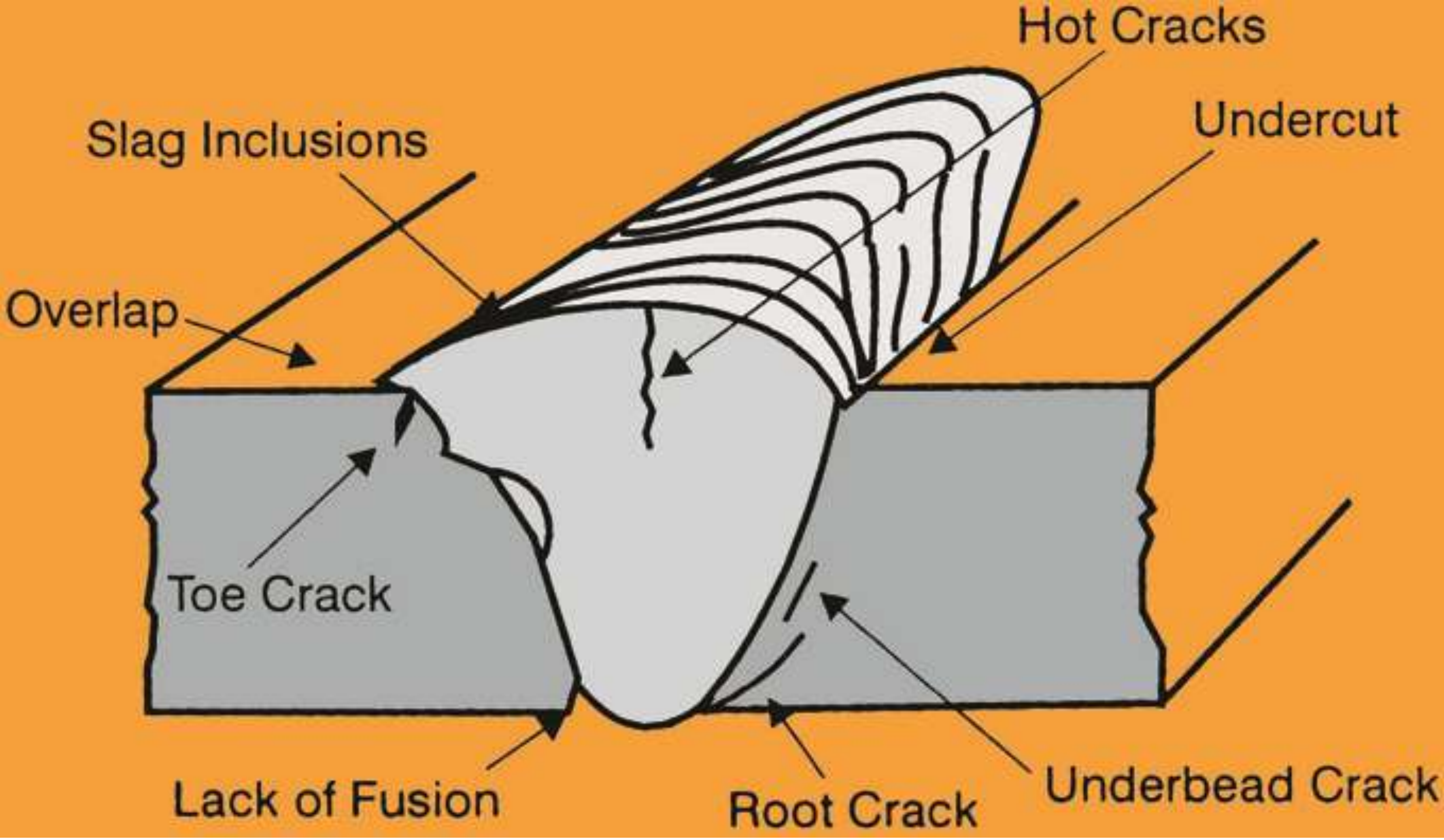
ISO/TR 25901-1:2016(en)

Welding and allied processes — Vocabulary — Part 1: General terms
https://www.iso.org/obp/ui/#iso:std:iso:tr:25901:-1:ed-1:v1:en
check this link for imperfection terms 2.1.3

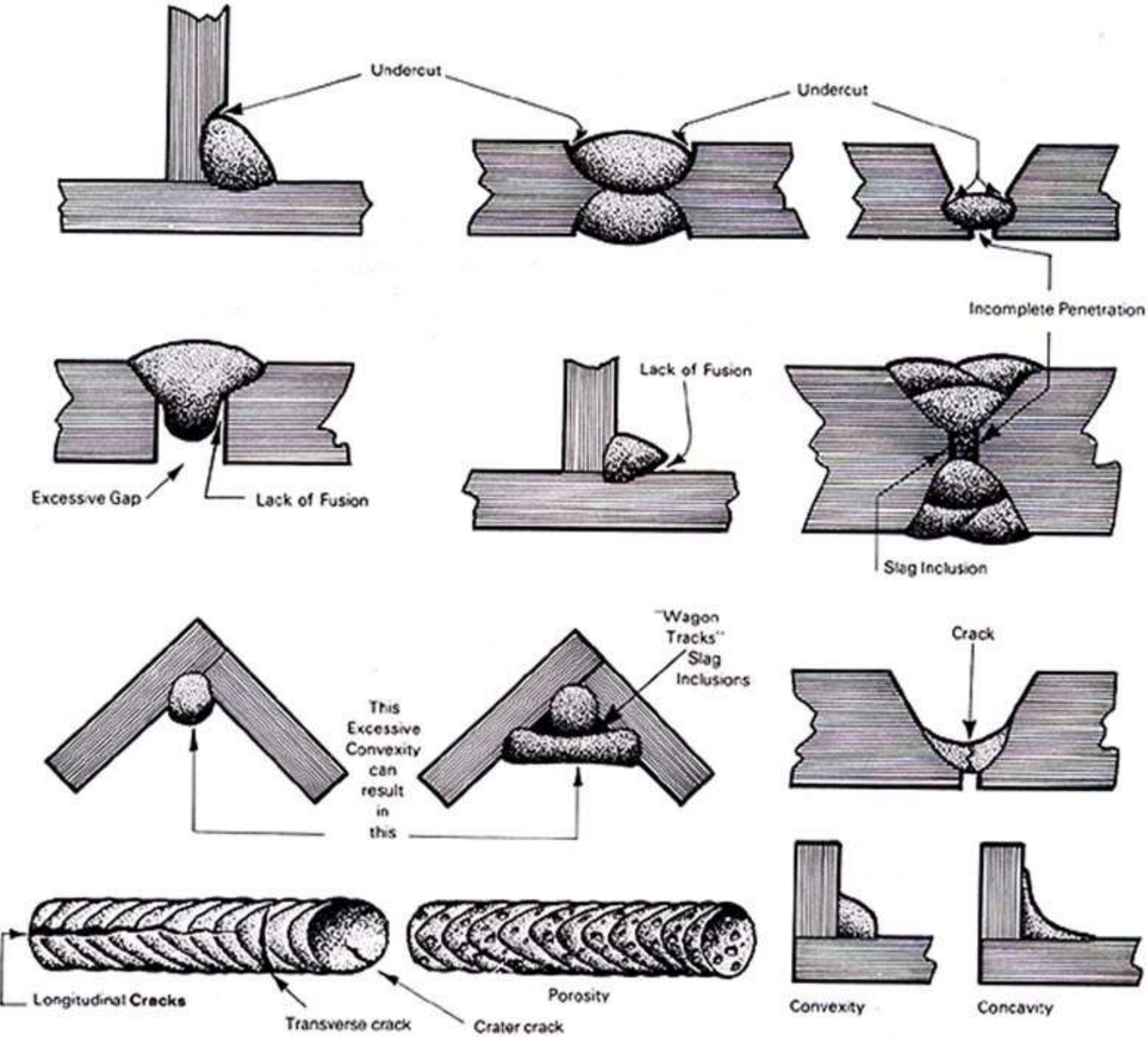
ISO 6520-1:2007(en)

This standard classifies defects onto 6 groups:

- ✓ **cracks**,
- ✓ **gas cavities**,
- ✓ **solid inclusion**,
- ✓ **lack of fusion or lack of penetration**,
- ✓ **imperfect shape**,
- ✓ **miscellaneous imperfections**



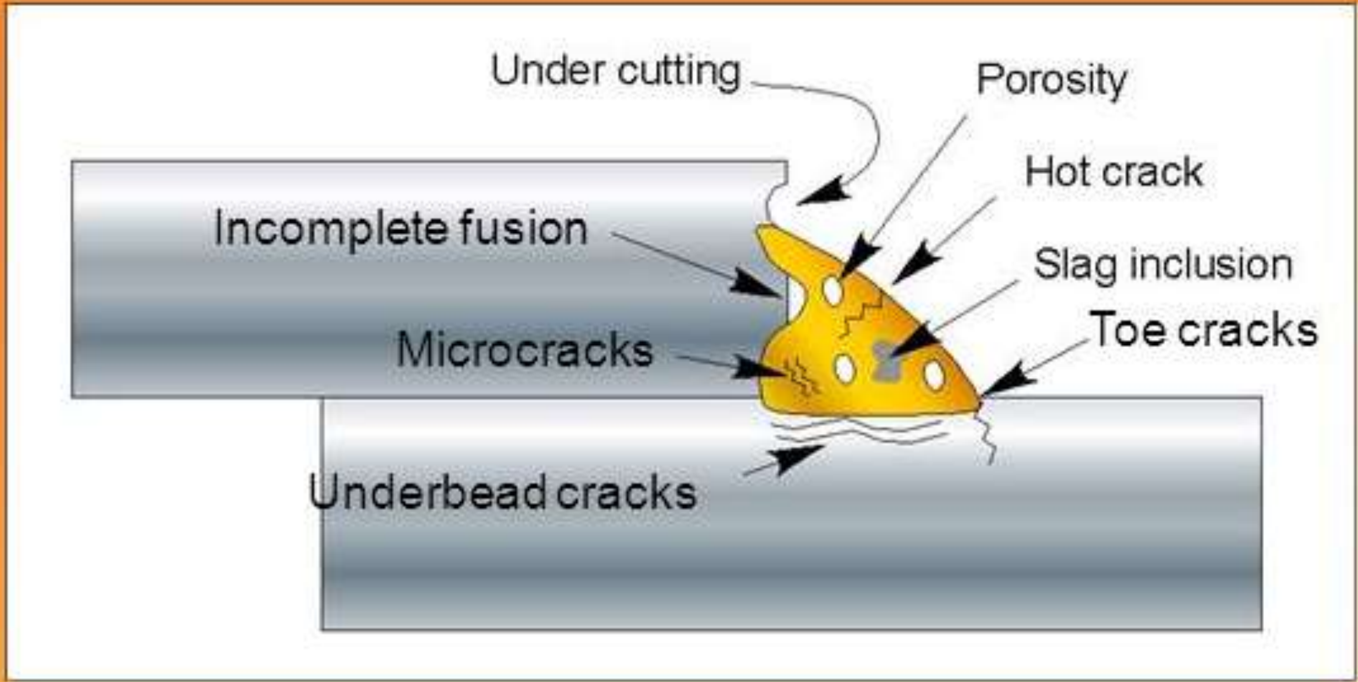
Typical weld defects



DCU

Welding defects

SMAW Weld Defects-cont.



- Toe Cracks
  - Excessive heat and rapid cooling.
- Underbead cracks
  - Excessive hydrogen in weld pool
- Microcracks
  - Caused by stresses as weld cools.
- Incomplete fusion
  - Incorrect welding parameters or welding techniques.

CRACKS

CRACK. A fracture-type discontinuity characterized by a sharp tip and high ratio of length and width to opening displacement. See Figure B.33.

AWS A3.0M/A3.0:2010

- ✓ Longitudinal cracks
- ✓ Transversal cracks
- ✓ Radiating Cracks
- ✓ Disconected cracks
- ✓ Brancing cracks

Cracks are the most dangerous welding defects, which can lead to the almost instantaneous destruction of welded structures with the most tragic consequences. Cracks vary in size (micro- and macro-cracks) and time of occurrence (during or after welding).

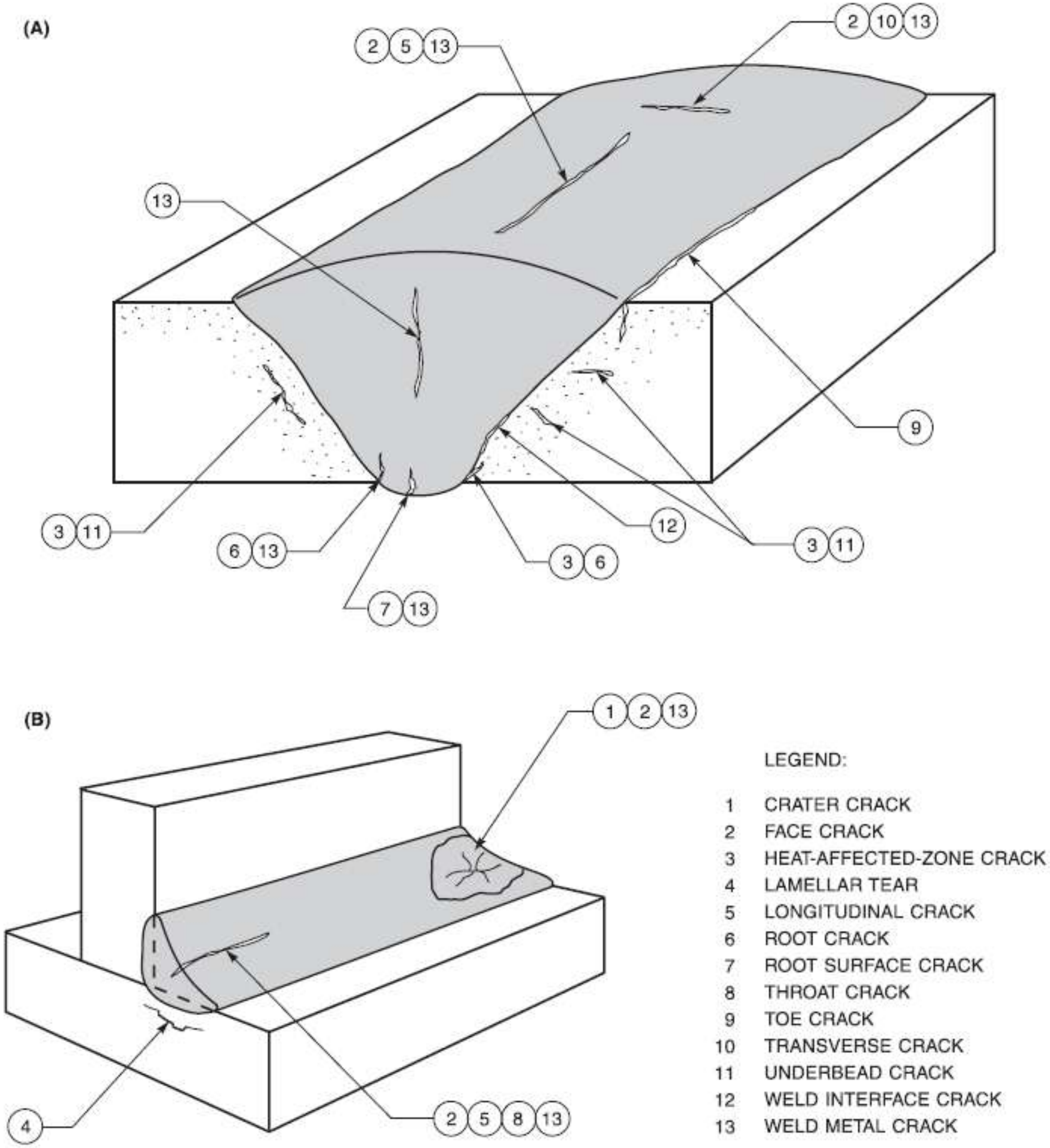


Figure B.33—Crack Types

2.1.3 Imperfections

2.1.3.1 imperfection

discontinuity in the weld (2.1.1.3) or a deviation from the intended geometry

Note 1 to entry: Imperfections are cracks, lack of penetration, porosity, slag (2.1.10.9), inclusions.

2.1.10.9 slag

non-metallic substance that results from fusion of an electrode (2.3.8) covering or a flux (2.1.10.8), and which, after solidification, partly or totally covers the weld metal (2.1.2.1)

2.1.3.2 internal imperfection

imperfection (2.1.3.1) that is not open to a surface or not directly accessible

2.1.3.3 systematic imperfection

imperfections (2.1.3.1) that are repeatedly distributed in the weld (2.1.1.3) over the weld lengths to be examined

2.1.3.4 projected area

area where imperfections (2.1.3.1) distributed along the volume of the weld (2.1.1.3) under consideration are imaged two-dimensionally

2.1.3.5 hot crack(s)

material separations occurring at high temperatures along the grain boundaries (dendrite boundaries) when the level of strain and the strain rate exceed a certain level

> *Note 1 to entry*: Small cracks visible only at magnifications greater than 50×, are often described as microcracks.

2.1.3.6 solidification crack

hot crack (2.1.3.5) formed during solidification from the liquid phase of weld metals (2.1.2.1)

Note 1 to entry: It usually extends up to the surface of the weld metal, but sometimes can be subsurface.

2.1.3.7 liquation crack

hot crack (2.1.3.5) formed by liquation in the heat-affected zone (2.1.2.2) of the parent material (2.1.1.5) or in multirun welds where weld metal (2.1.2.1) is reheated by subsequent runs (2.1.8.4)

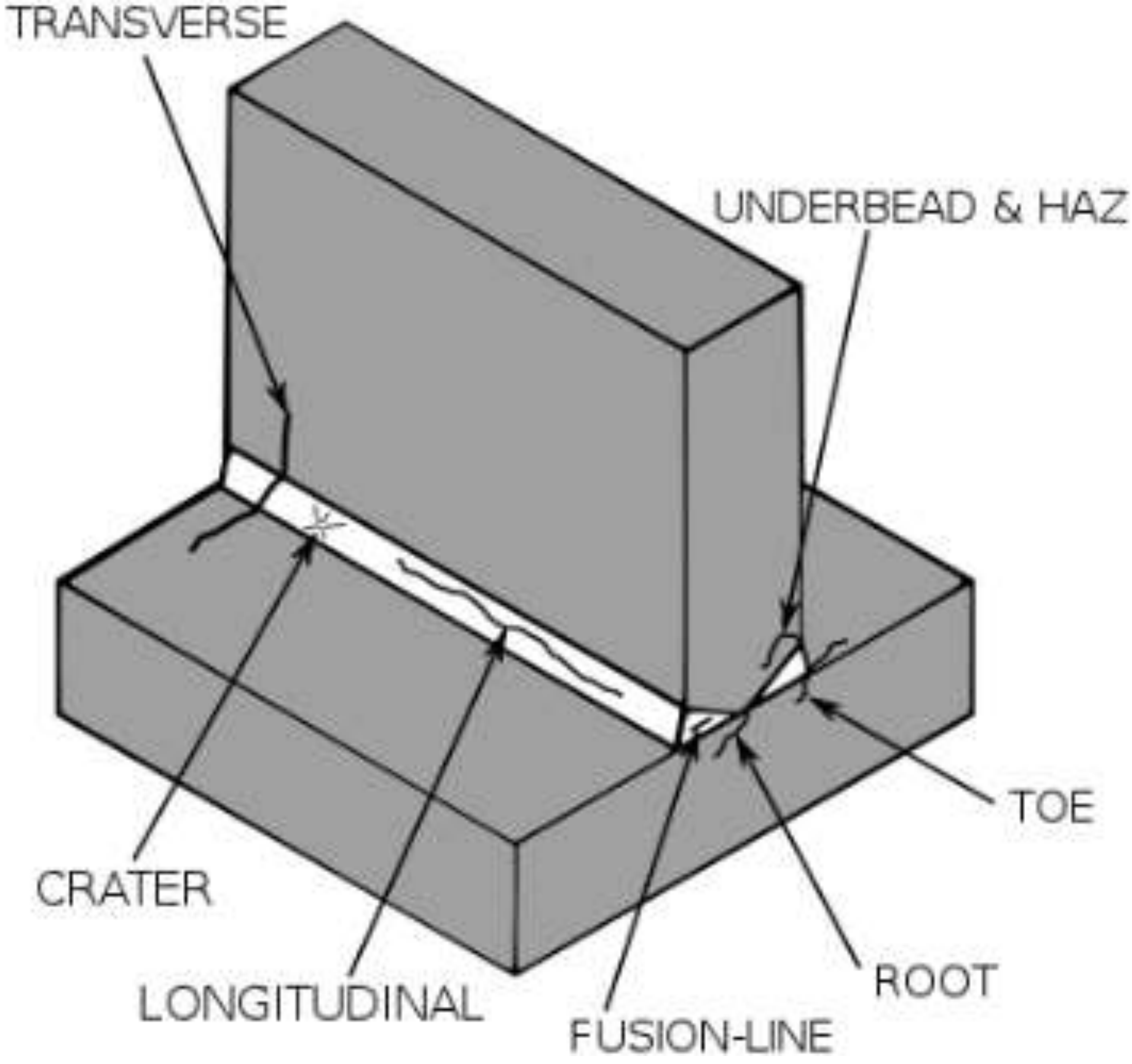
2.1.3.8 ductility dip crack

hot crack (2.1.3.5) formed during welding (2.1.1.1) by a reduction in hot ductility

Note 1 to entry: As with a liquation crack (2.1.3.7), it can occur in the heat-affected zone (2.1.2.2) of the parent material (2.1.1.5) or in multirun welds.

2.1.3.9 cold crack(s)

local rupture (intergranular or transgranular) appearing in a weld (2.1.1.3) as a result of a critical combination of microstructure, stress and hydrogen content


TRANSVERSE
UNDERBEAD & HAZ
TOE
CRATER
ROOT
LONGITUDINAL
FUSION-LINE

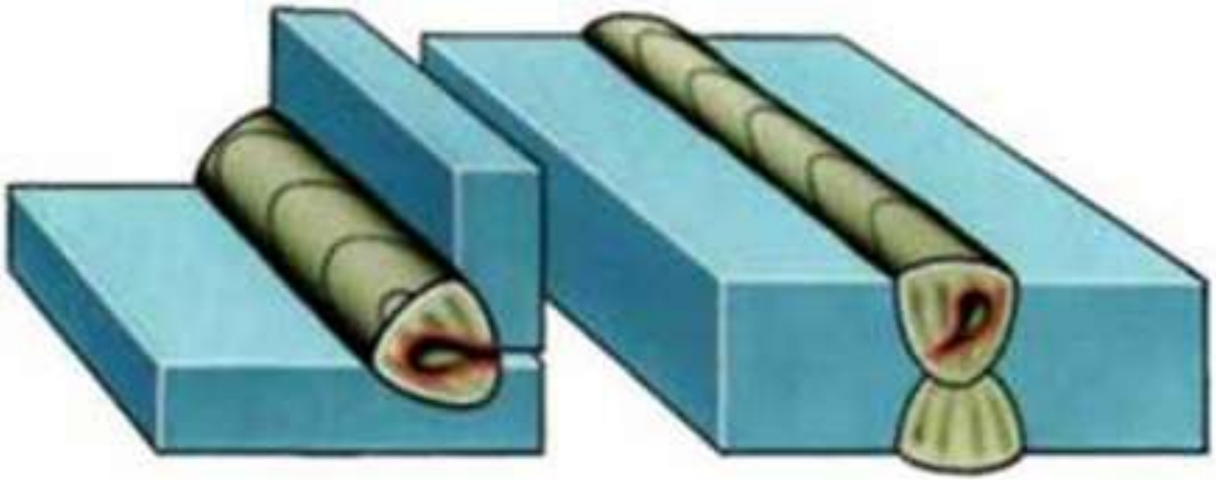
GAS CAVITIES

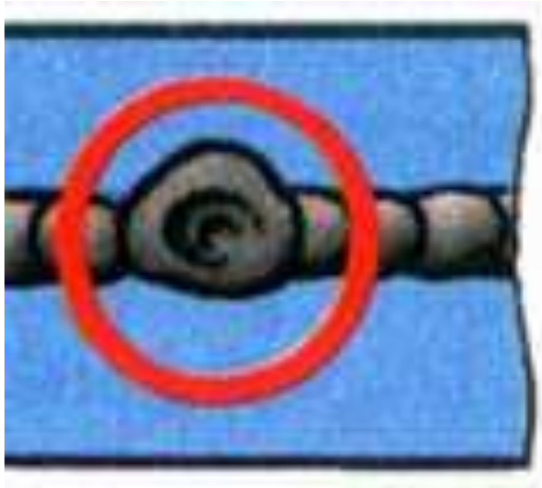
POROSITY. Cavity-type discontinuities formed by gas entrapment during solidification or in a thermal spray deposit.

WORMHOLE POROSITY. A nonstandard term when used for piping porosity.

PIPING POROSITY. A form of porosity having a length greater than its width that lies approximately perpendicular to the weld face.

CRATER. A depression in the weld face at the termination of a weld bead.





http://tool-land.ru/defekty-svarnykh-shvov.php

Crater in weld

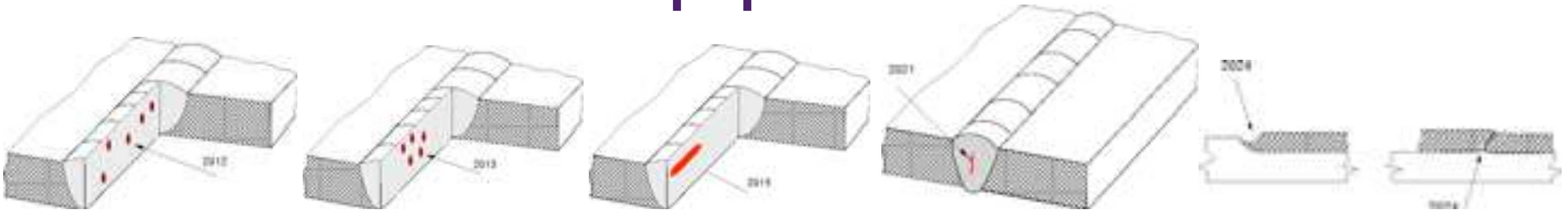
Craters are defects in the form of a recess that arises as a result of breaking the welding arc. Craters reduce the strength of the seam due to a reduction in its cross-section. They may contain shrinkage friability, promoting the formation of cracks.

Porosity is a cavity filled with gases. They arise because of intense gas generation inside the metal, at which gas bubbles remain in the metal after it solidifies. The pore sizes can be microscopic or can reach several millimeters. Often there is an entire accumulation of pores in combination with craters

Worm holes are the defects of the joints in the form of a cavity. Like craters, they reduce the strength of the seam and contribute to the development of cracks.

The standard distinguishes such types of porosities

- ✓ Uniformly distributed porosity
- ✓ Clustered (localized) porosity
- ✓ Linear porosity
- ✓ Elongated cavity
- ✓ Worm-hole
- ✓ Surface pore
- ✓ Interdendritic shrinkage
- ✓ Crater pipe



SOLID INCLUSION

The standard distinguishes such types of solid inclusion

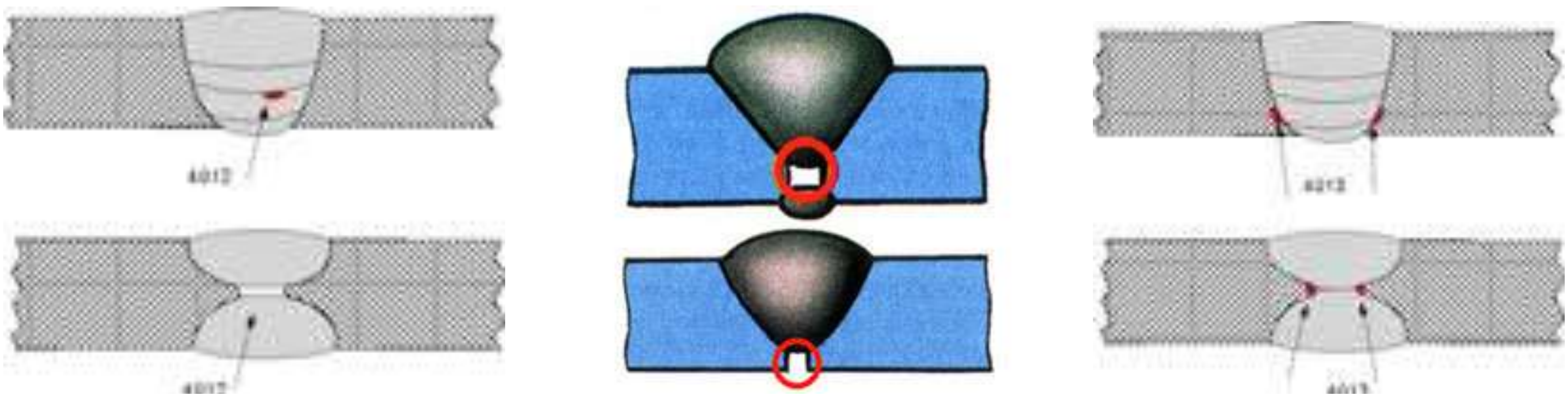
- ✓ slag inclusion
- ✓ flux inclusion
- ✓ oxide inclusion
- ✓ metallic inclusion (tungsten, copper, etc.)

Solid inclusions. Inclusions can consist of various substances - slag, tungsten, metal oxides, etc. Slag inclusions are formed when the slag does not manage to float to the surface of the metal and remains inside it. This occurs when the welding mode is incorrect (excessive speed, for example), poorly scraping the weld metal or the previous layer in multi-layer welding.

Tungsten inclusions occur when welding with a tungsten electrode, oxide inclusions occur due to poor solubility of oxides and excessively rapid cooling.

All kinds of inclusions reduce the section of the weld and form a focus of stress concentration, thereby reducing the strength of the joint

LACK OF FUSION/ PENETRATION



lack of fusion (incomplete fusion) -absence of connection between the weld metal and basic metal or between separate welded rollers seam.

lack of penetration - non-fusion of the main metal along the entire length of the seam or on the site arising due to the inability of the molten metal penetrate to the root of the weld

Lacks of fusion/penetration are local non-fusions of welded metal with the base metal, or the multy-pass seam layers between themselves.

This defect is also attributed to the failure to fill the joint section.

Lacks of fusion/penetration significantly reduces the strength of the seam and can cause the destruction of the structure. This defect may arise from the poor welding current, improper preparation of the edges, excessively high welding speed, the presence of foreign substances (flux, rust, slag) and contaminants on the edges of the welded parts.

IMPERFECT SHAPE

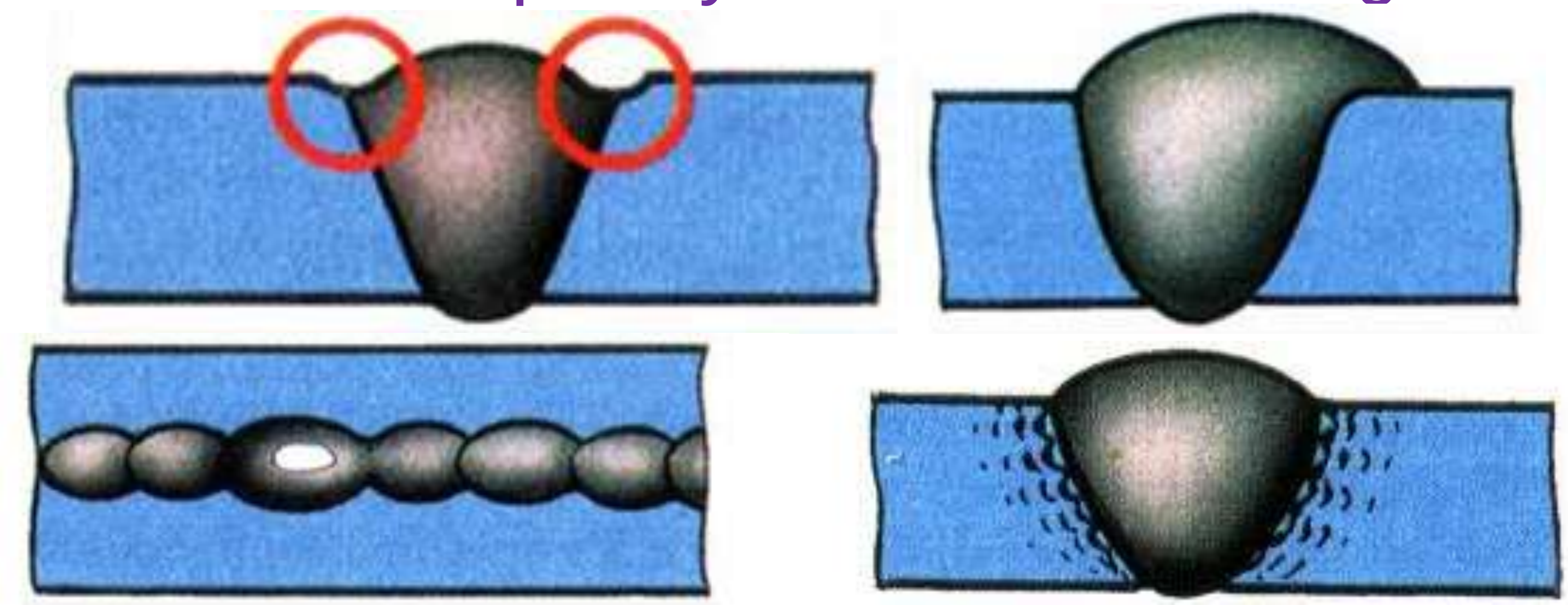
They are undercuts, shrinkage grooves, excesses of metal, misalignments, overlaps, so on.

The **undercuts** are grooves (grooves) at the toe point "basic metal-welded seam". Their negative effect is the reduction of the cross-section of the seam and the appearance of a focus of stress concentration. Both are weakening the seam. Undercuts are caused by an increased welding current. Most often this defect is formed in horizontal seams.

The **overlap** occurs when the molten metal flows onto the main metal, but does not form a homogeneous compound with it. Seam defect occurs for various reasons - with insufficient heating of the base metal due to low current, due to the presence of slag on the welded edges what prevents welding, excessive amount of filler material.

Overheating and **metal burning**. Overheating and burning are caused by an excessively large welding current or a low welding speed. In case of overheating, the dimensions of the metal grains in the seam and the HAZ are increased, resulting in reducing the strength characteristics of the weld joint, mainly impact strength. Overheating is eliminated by thermal treatment of the product.

Metal burning is a more dangerous defect than overheating. The annealed metal becomes fragile because of the presence of oxidized grains, which have small mutual cohesion. The causes of the burning are the same as overheating, and besides this, there is also insufficient protection of the molten metal from nitrogen and oxygen in the air. The burnt metal must be completely cut and welded again.



The standard distinguishes such types of imperfect shapes

- ✓ continious undercut
- ✓ shrinkage groove
- ✓ excess weld metal
- ✓ excessive convexity
- ✓ excessive penetration
- ✓ incorrect weld profile
- ✓ overlap
- ✓ linear misalignment
- ✓ angular misalignment
- ✓ sagging

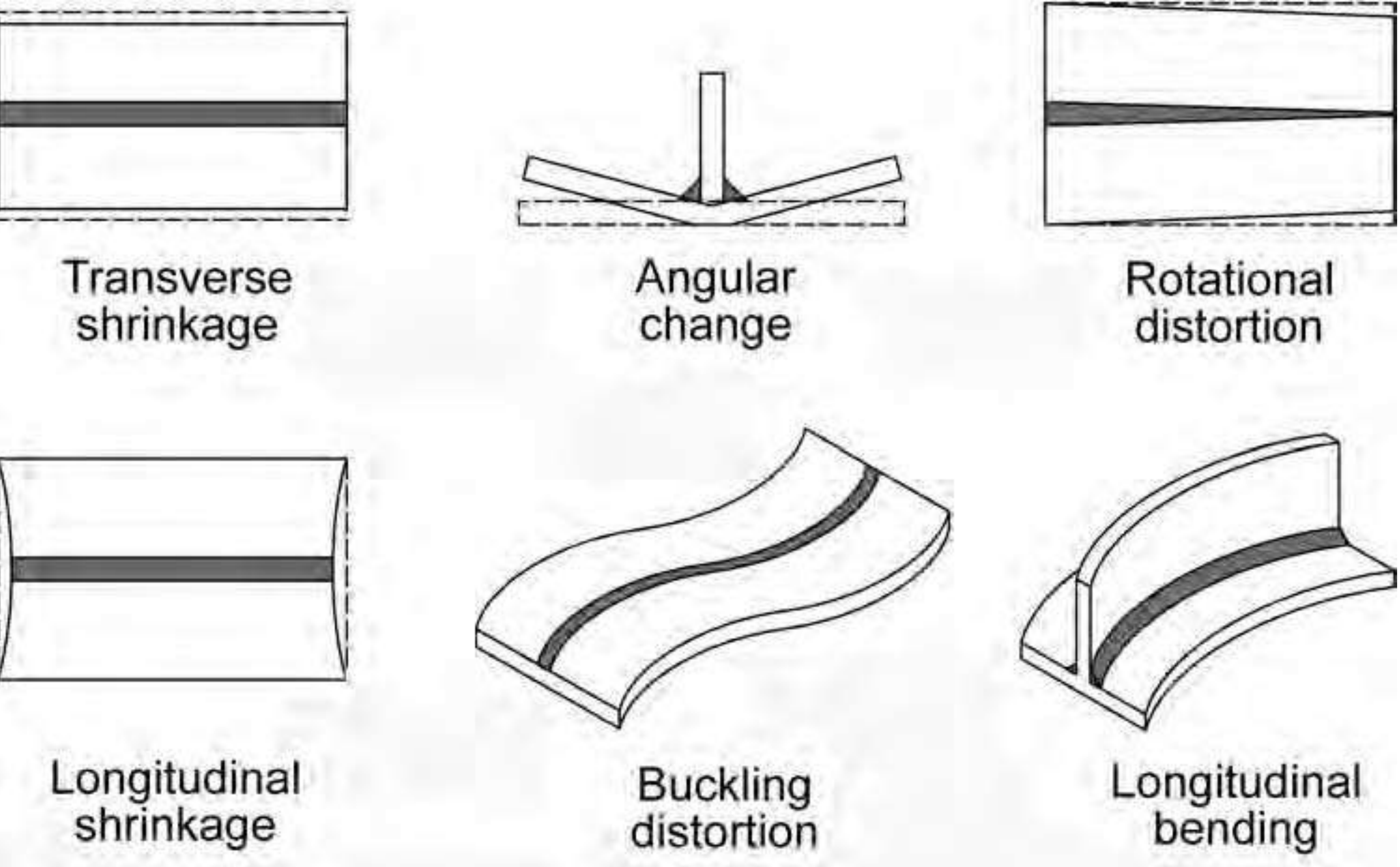


Fig. 16 Types of welding distortion. Source: Ref 62

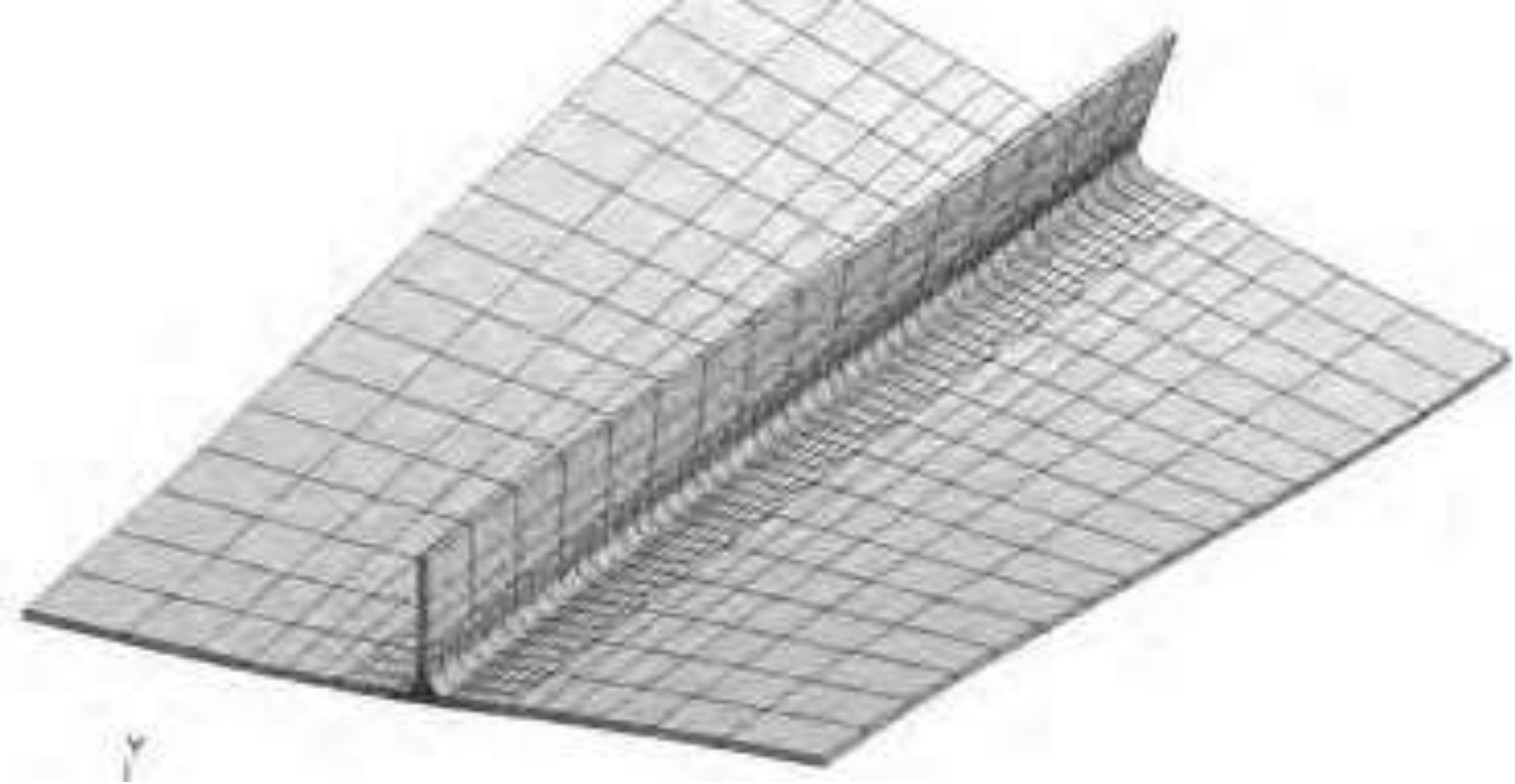
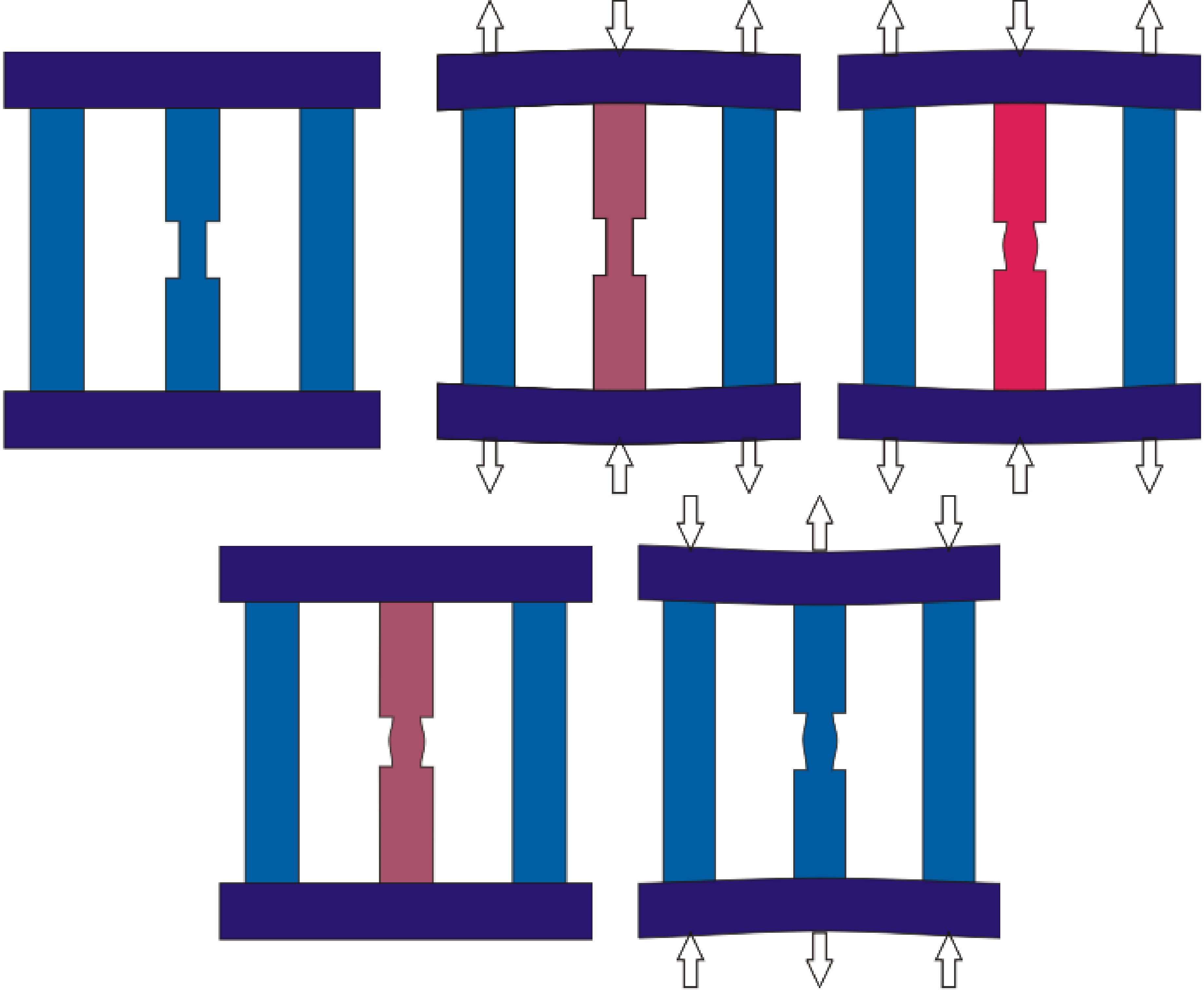
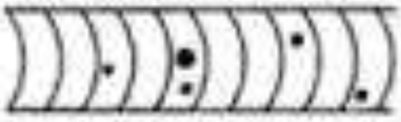
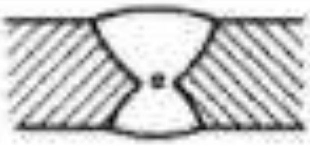
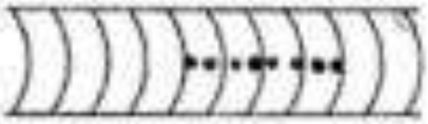
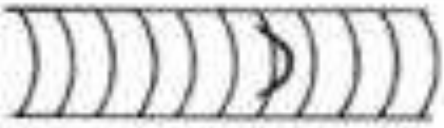
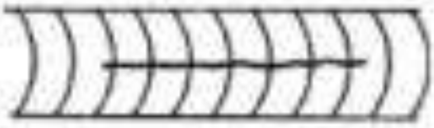
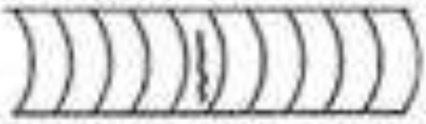


Fig. 18 Computed distortion by three-dimensional large-deformation analysis of a 310 _ 610 mm (12 _ 24 in.) panel. Original magnification: 2_. Source: Ref 15

Thermomechanical Effects of Fusion Welding
Residual Stresses and Distortion



Description	Cross-section of weld	Radiogram
Worm hole		
Linear Slag Inclusion -|		
Gas Pore		
Porosity (Linear)		
Lack of side-wall fusion - (lack of root fusion)		
Lack of inter-run fusion		
Longitudinal Crack		
Traverse Crack		
Radiating Cracks		

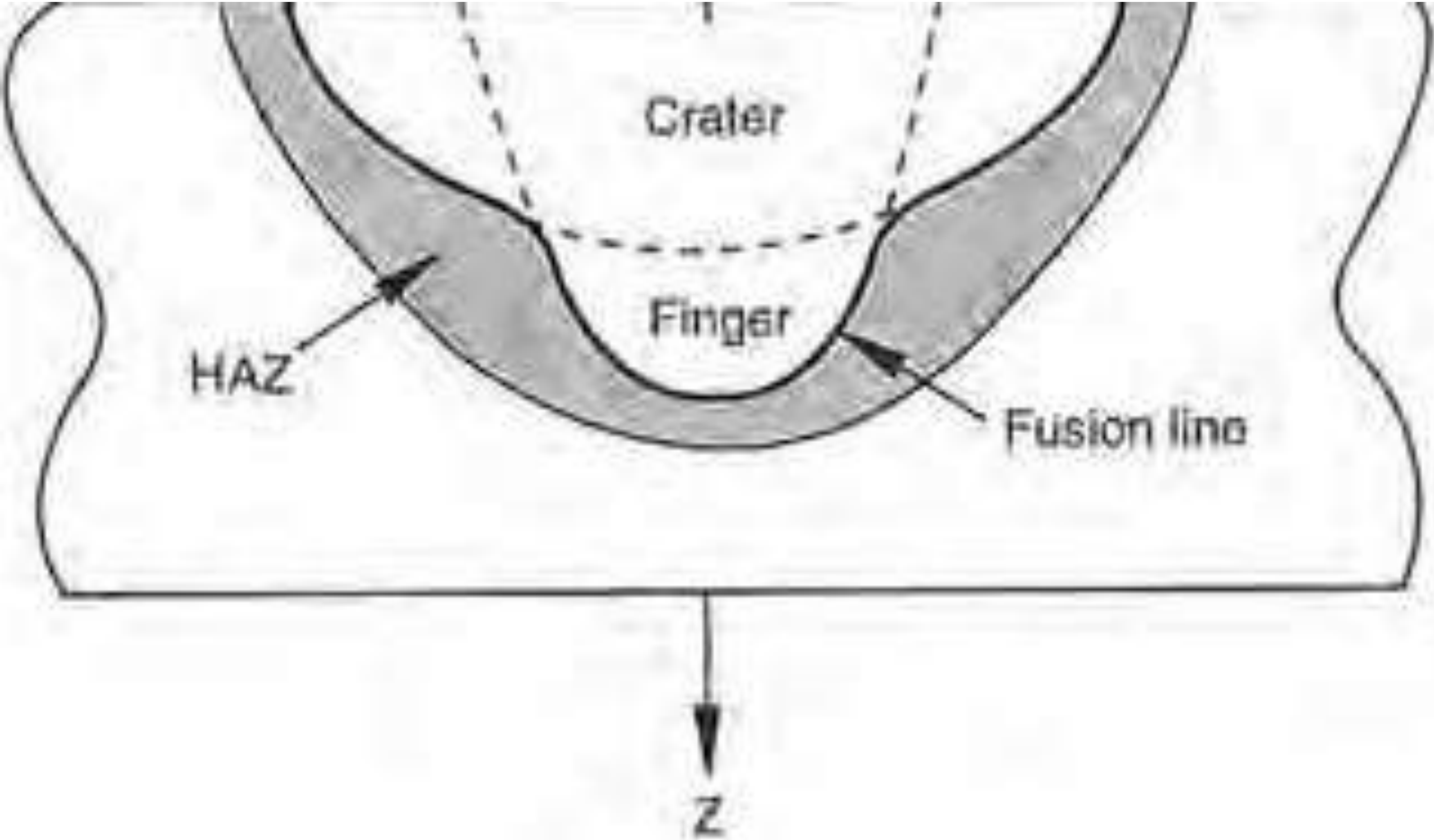


Fig. 11 Schematic diagram showing the weld crater/weld finger formation during stringer bead welding. HAZ, heat-affected zone. Source: Ref 1

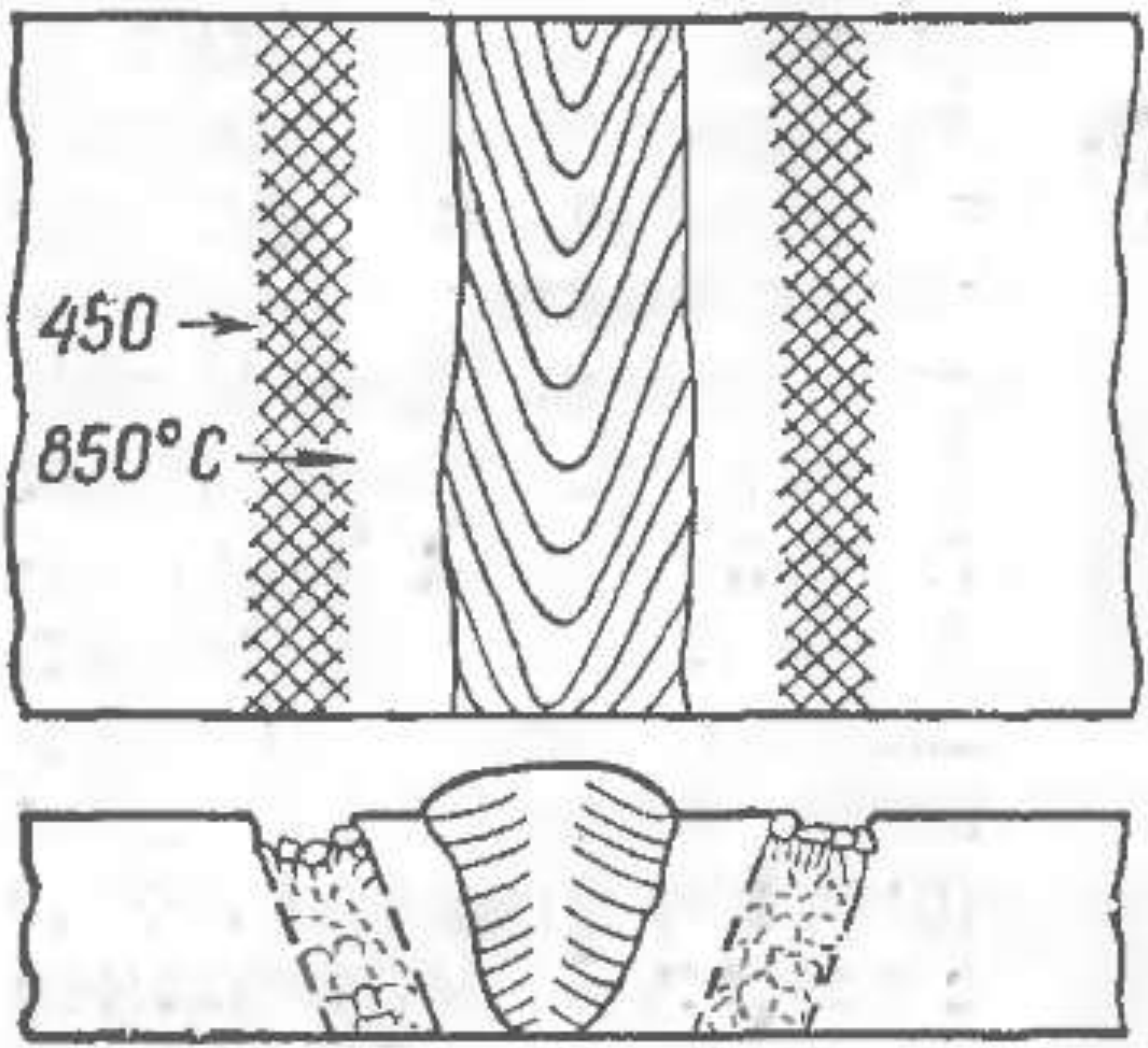
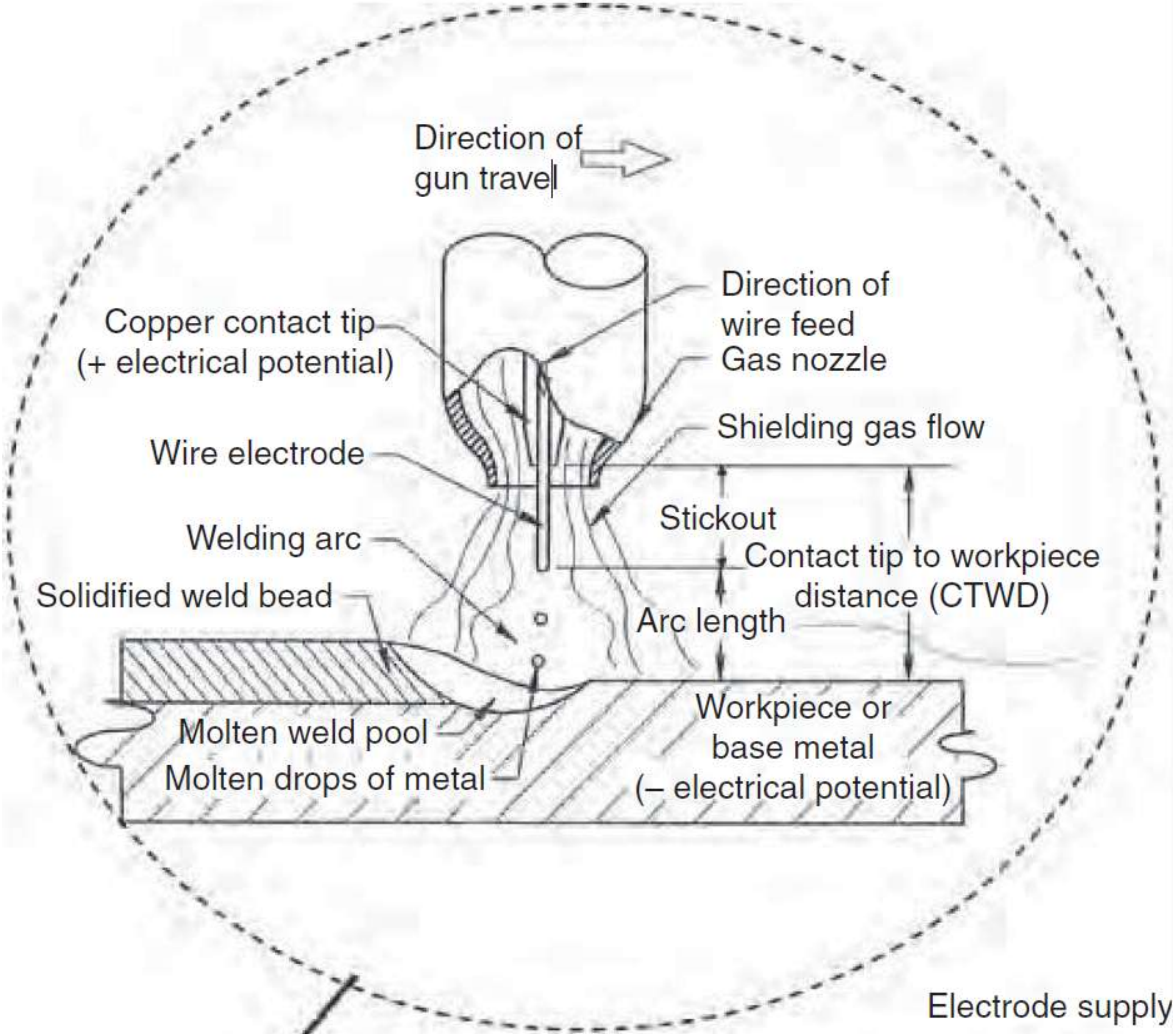


Рис. 204. Схема межкристаллитной коррозии в основном металле под воздействием сварочного нагрева.


Direction of
gun travel
Copper contact tip
(+ electrical potential)
Direction of
wire feed
Gas nozzle
Shielding gas flow
Wire electrode
Stickout
Welding arc
Contact tip to workpiece
distance (CTWD)
Solidified weld bead
Arc length
Workpiece or
base metal
(– electrical potential)
Molten weld pool
Molten drops of metal
Electrode supply

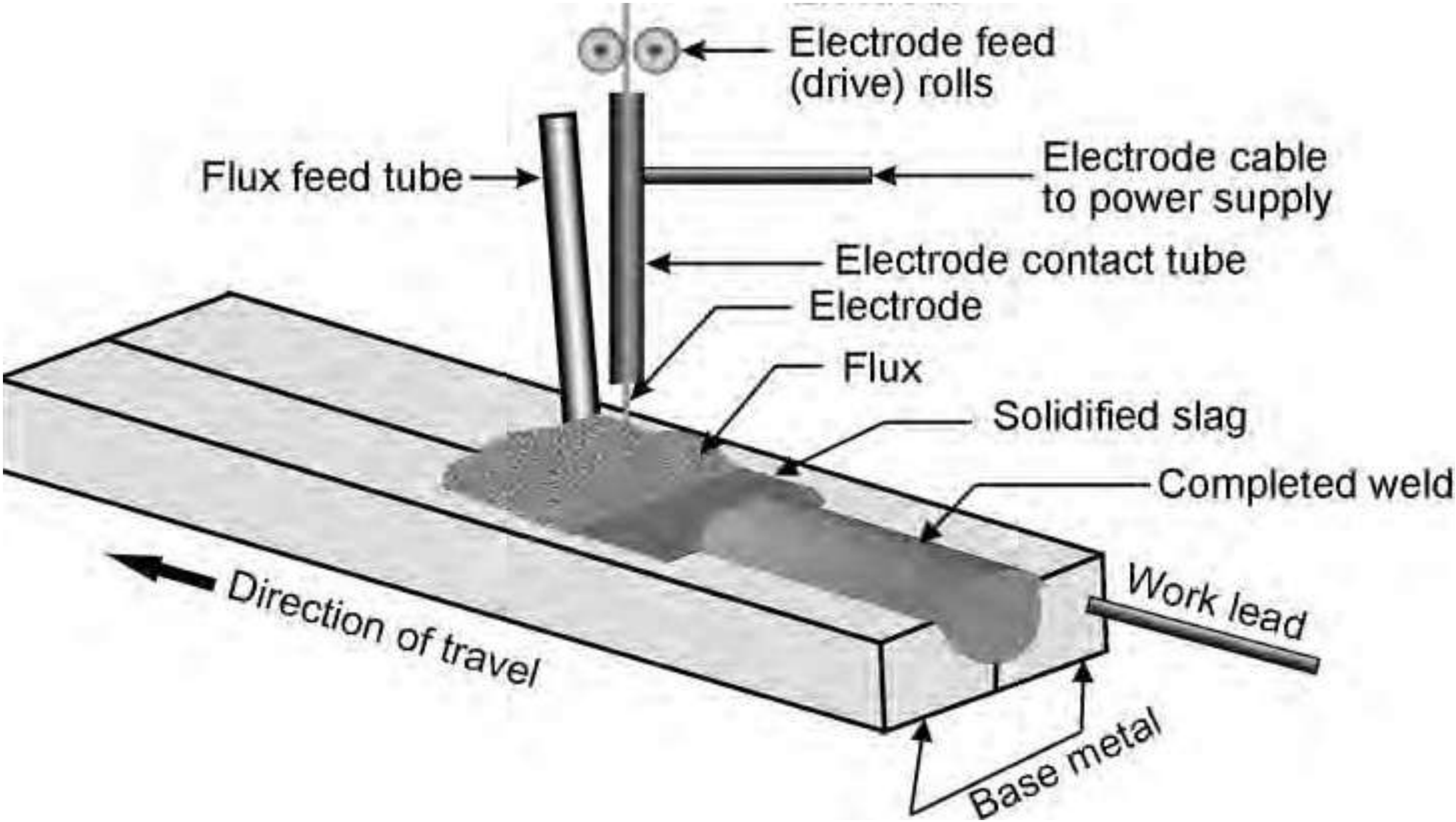


Fig. 1 Schematic of a typical submerged arc weld

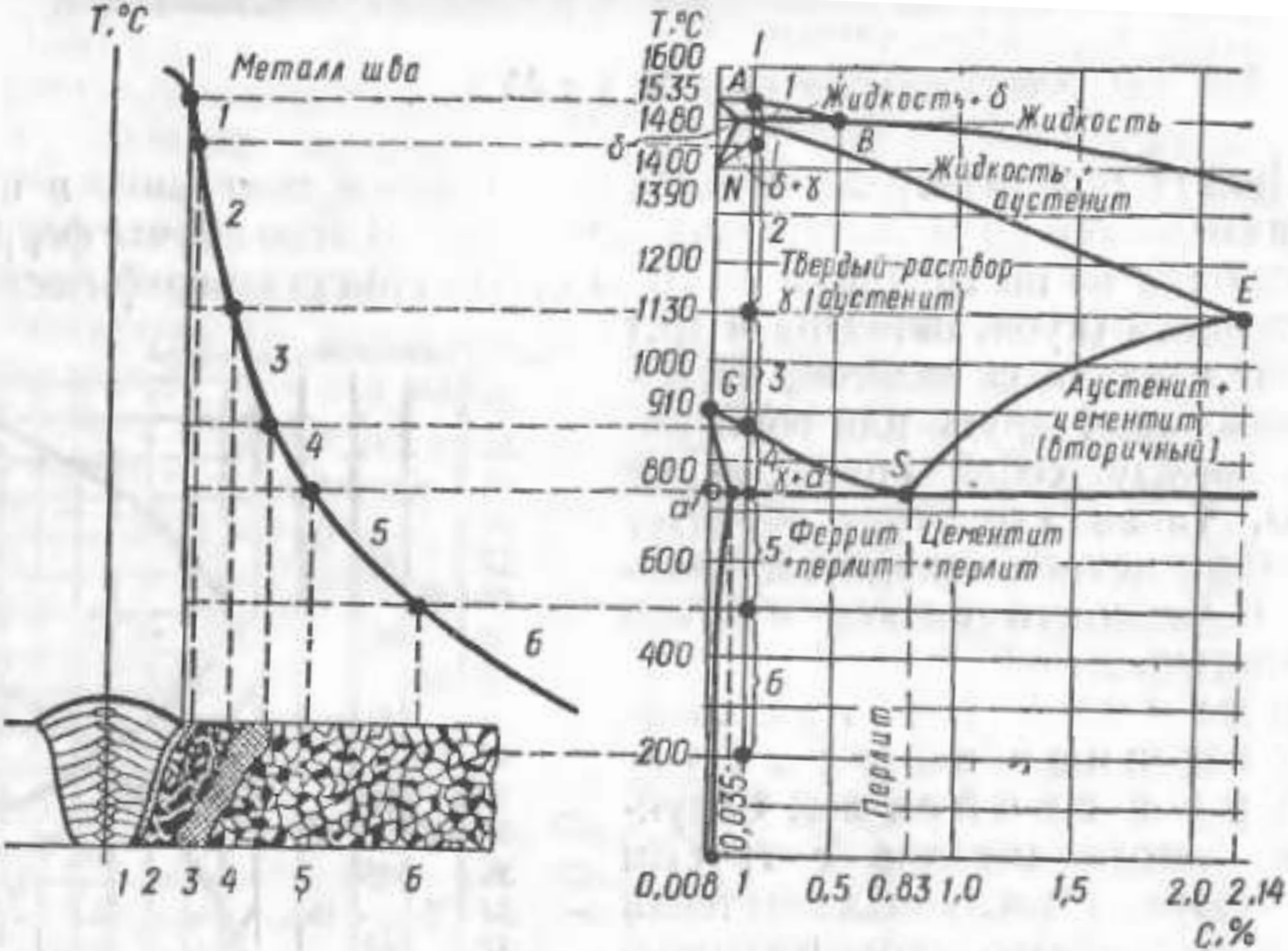


Рис. 155. Строение зоны термического влияния при сварке малоуглеродистой стали.

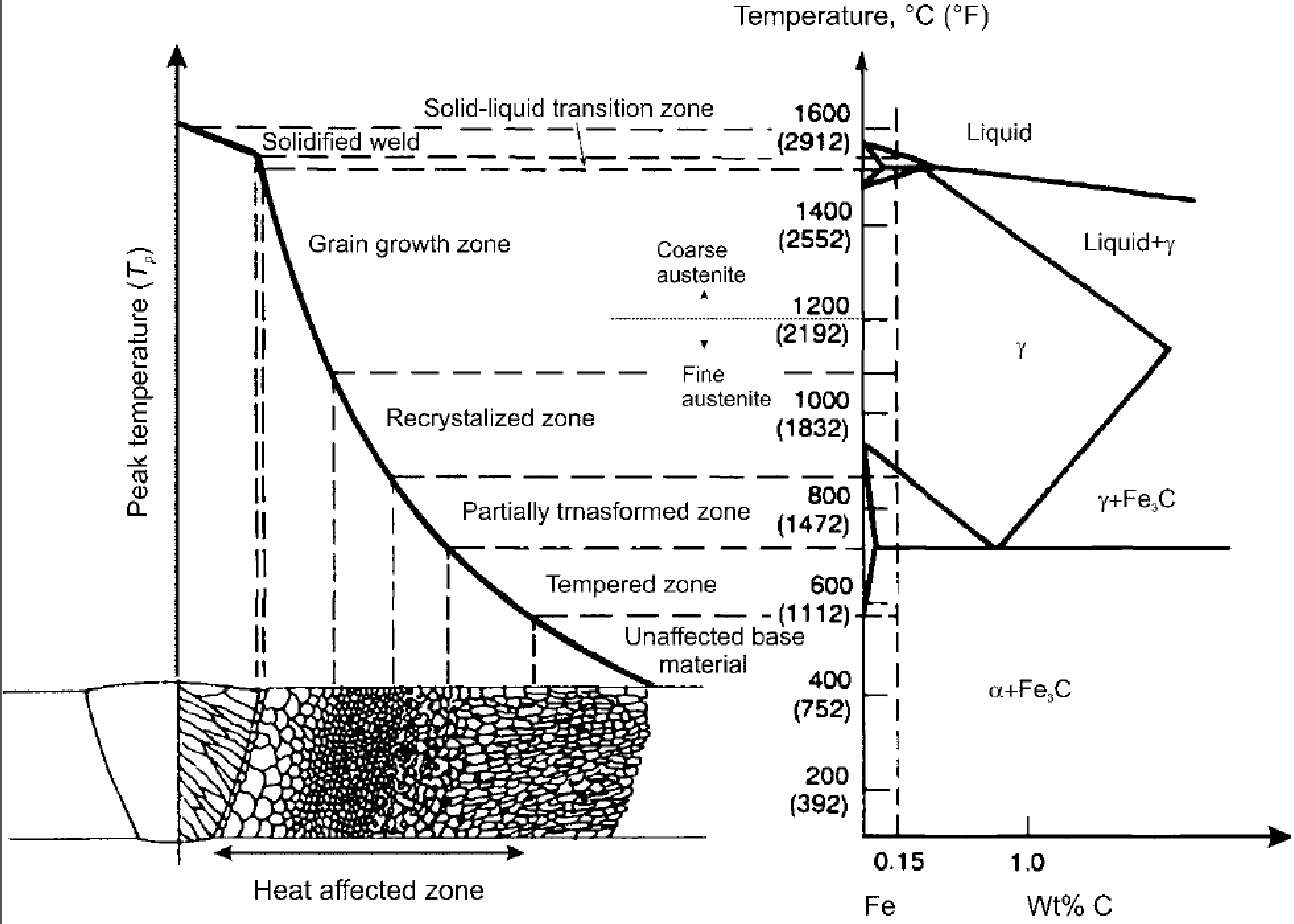
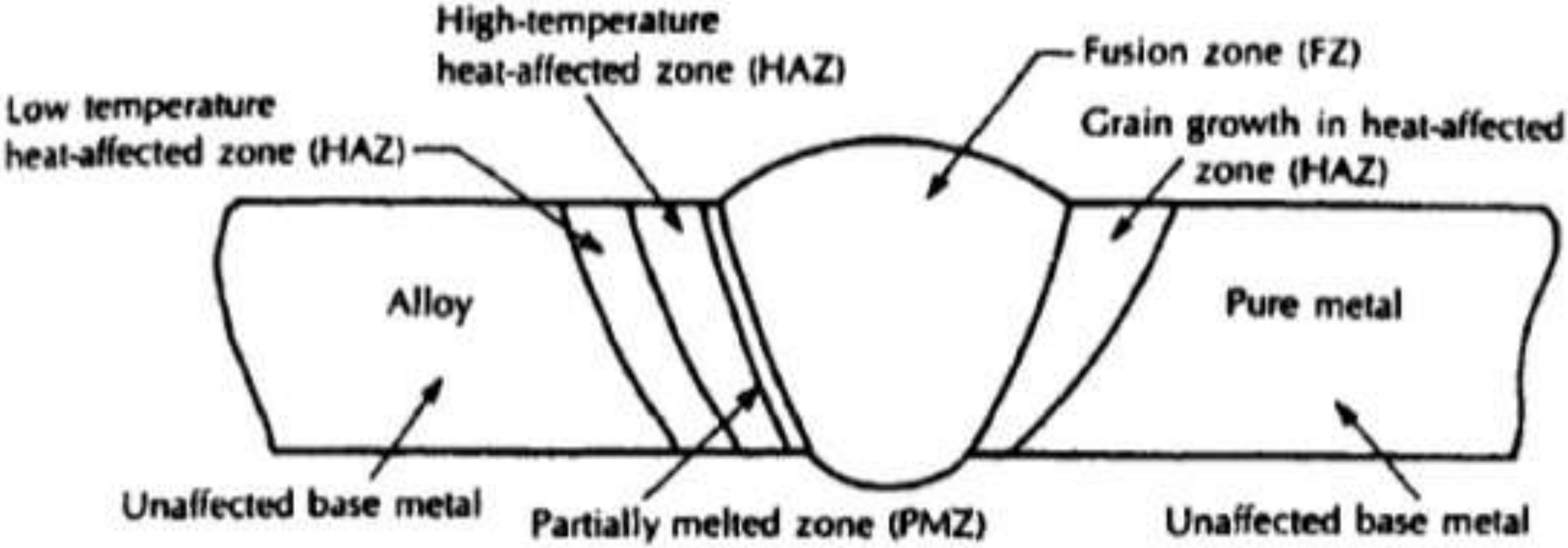


Fig. 4 Schematic illustration of the microstructural variation in the heat-affected zone of a carbon steel containing 0.15 wt% C. Source: Adapted from Ref 4

Micro-structural zones in Fusion welding



1) Fusion zone 2) Weld interface/partially melted zone
3) Heat affected zone 4) Unaffected base metal

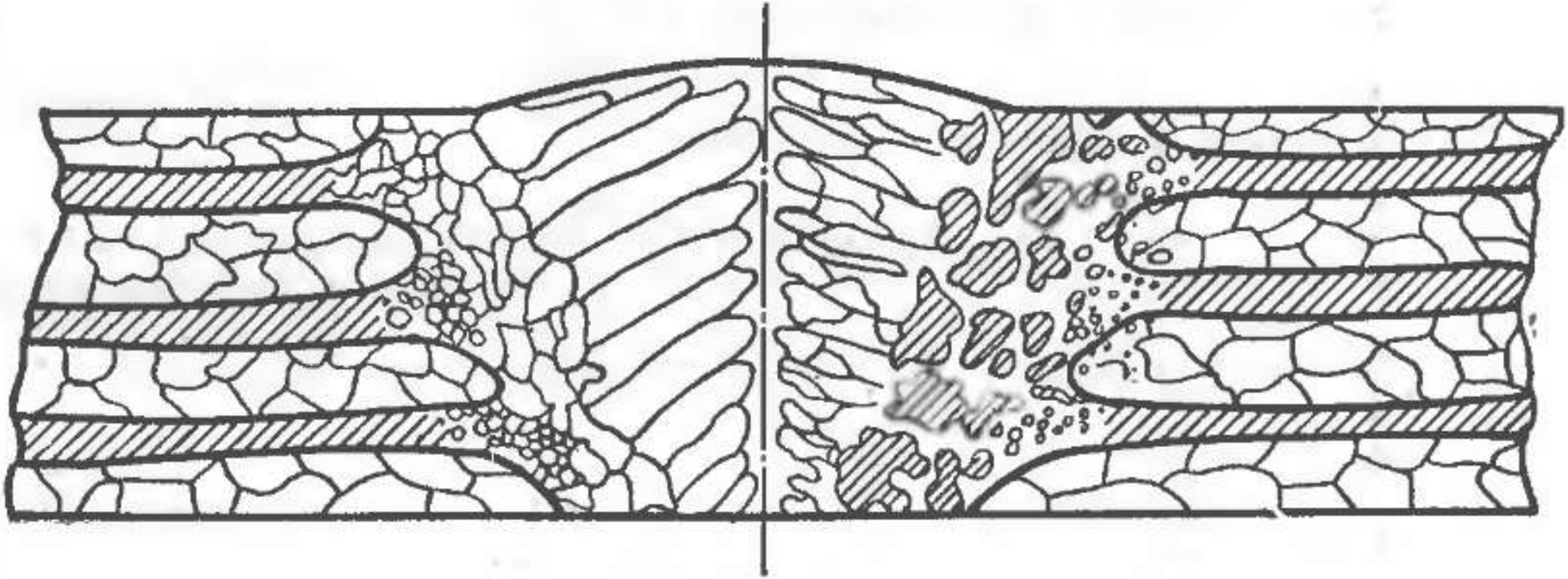


Рис. 157. Схема структуры металла сварного соединения.

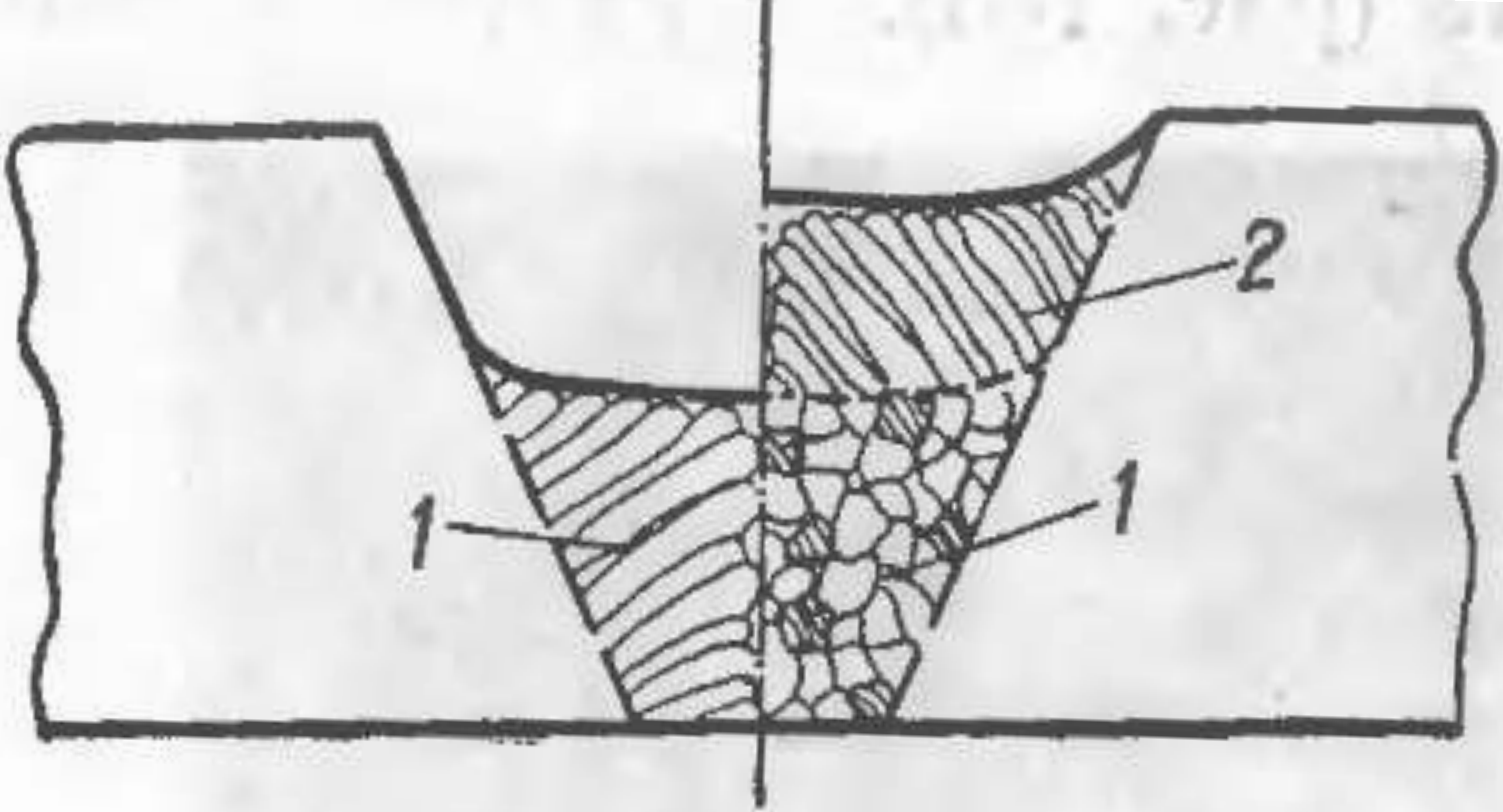


Рис. 154. Схема изменения структуры металла шва при наложении последующих слоев металла.

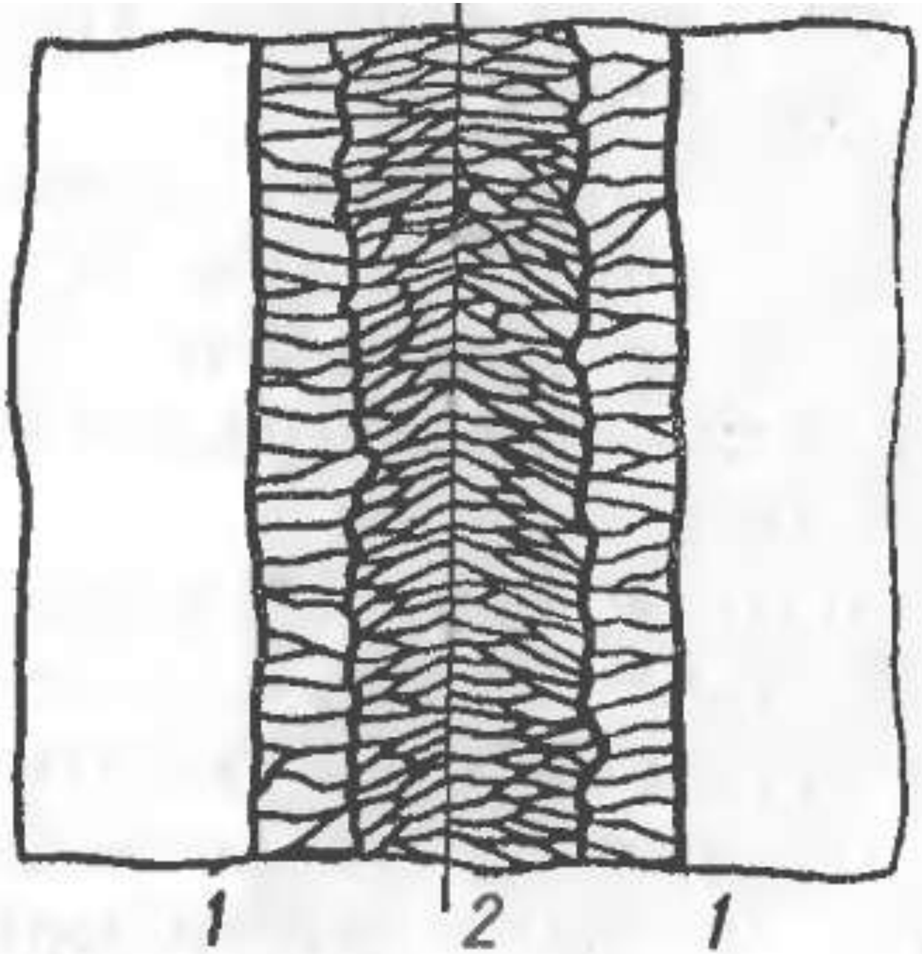


Рис. 141. Зоны столбчатых кристаллов (продольное се-

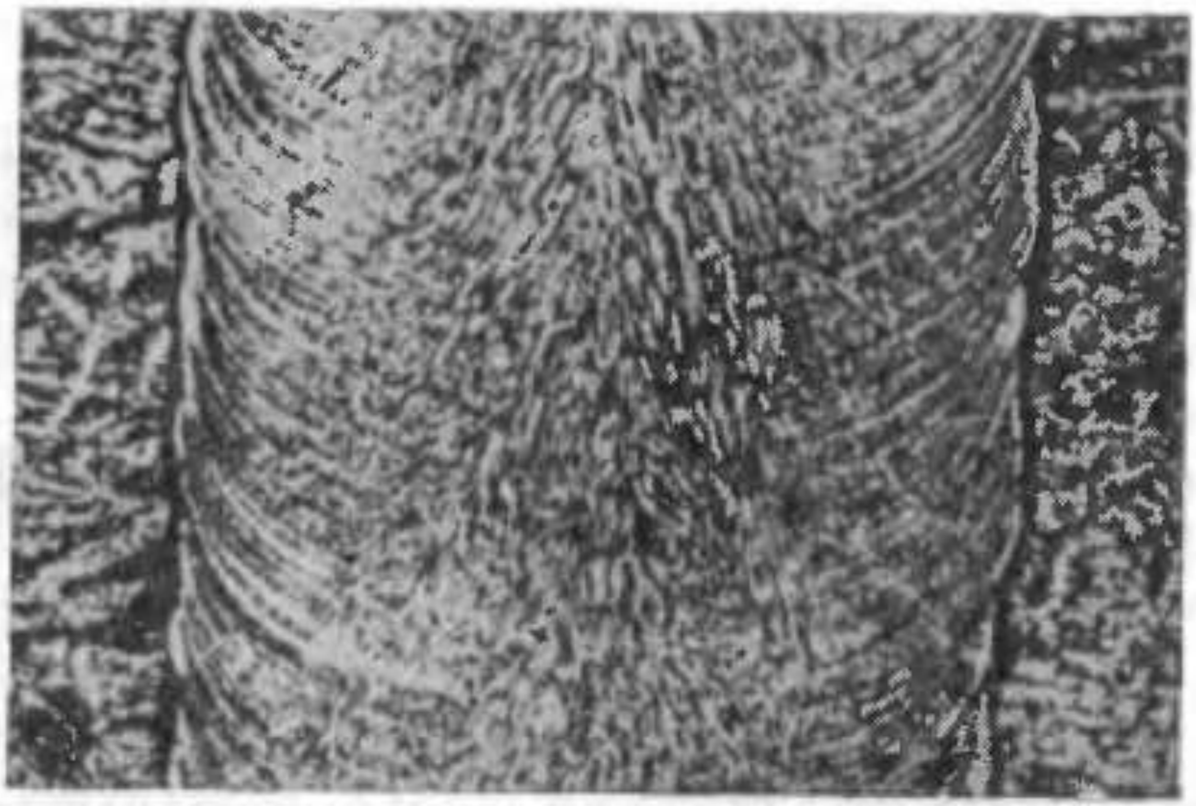


Рис. 142. Кристаллизационные слои в металле шва при электрошлаковой сварке.

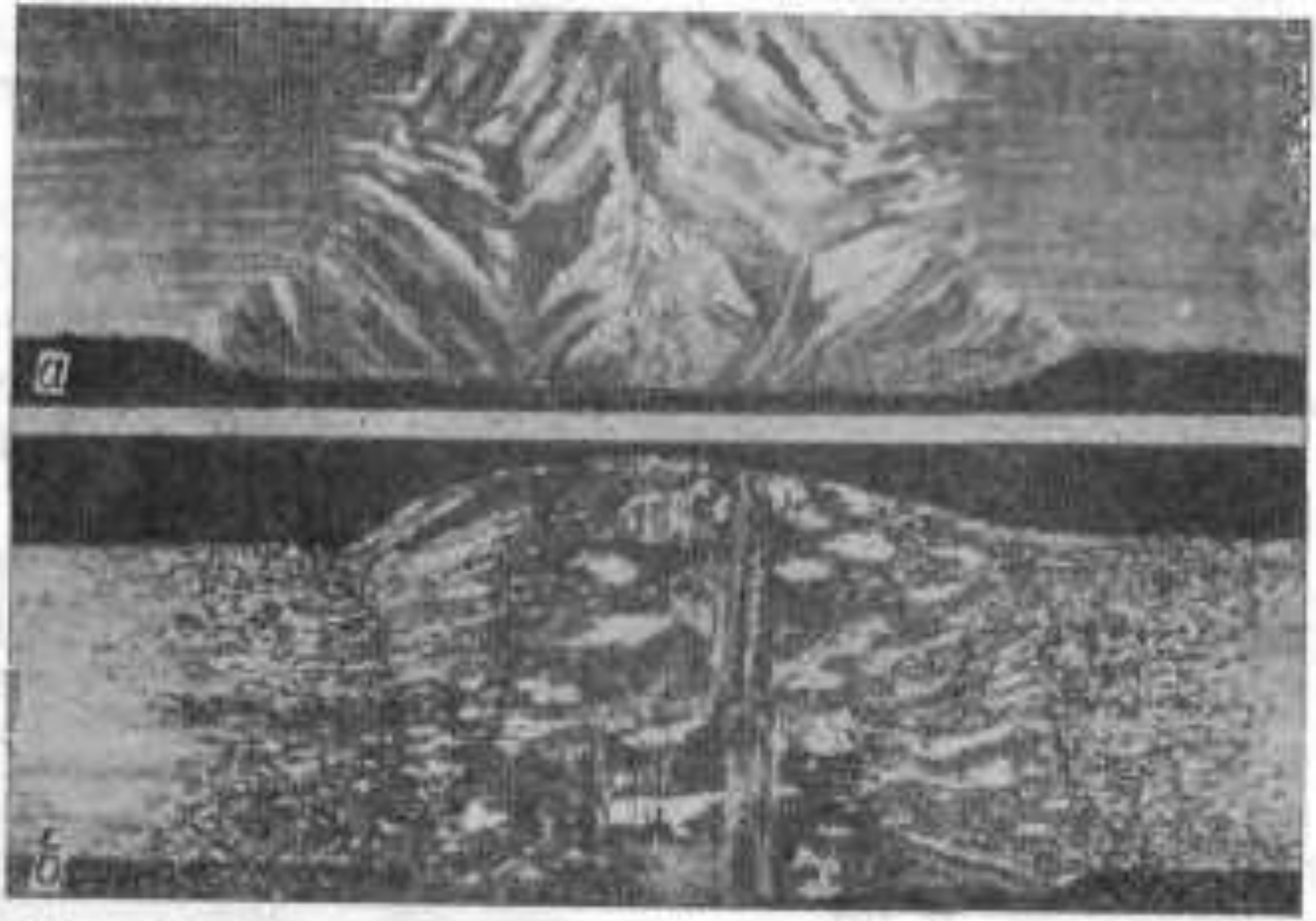


Рис. 226. Макроструктура сварного шва.

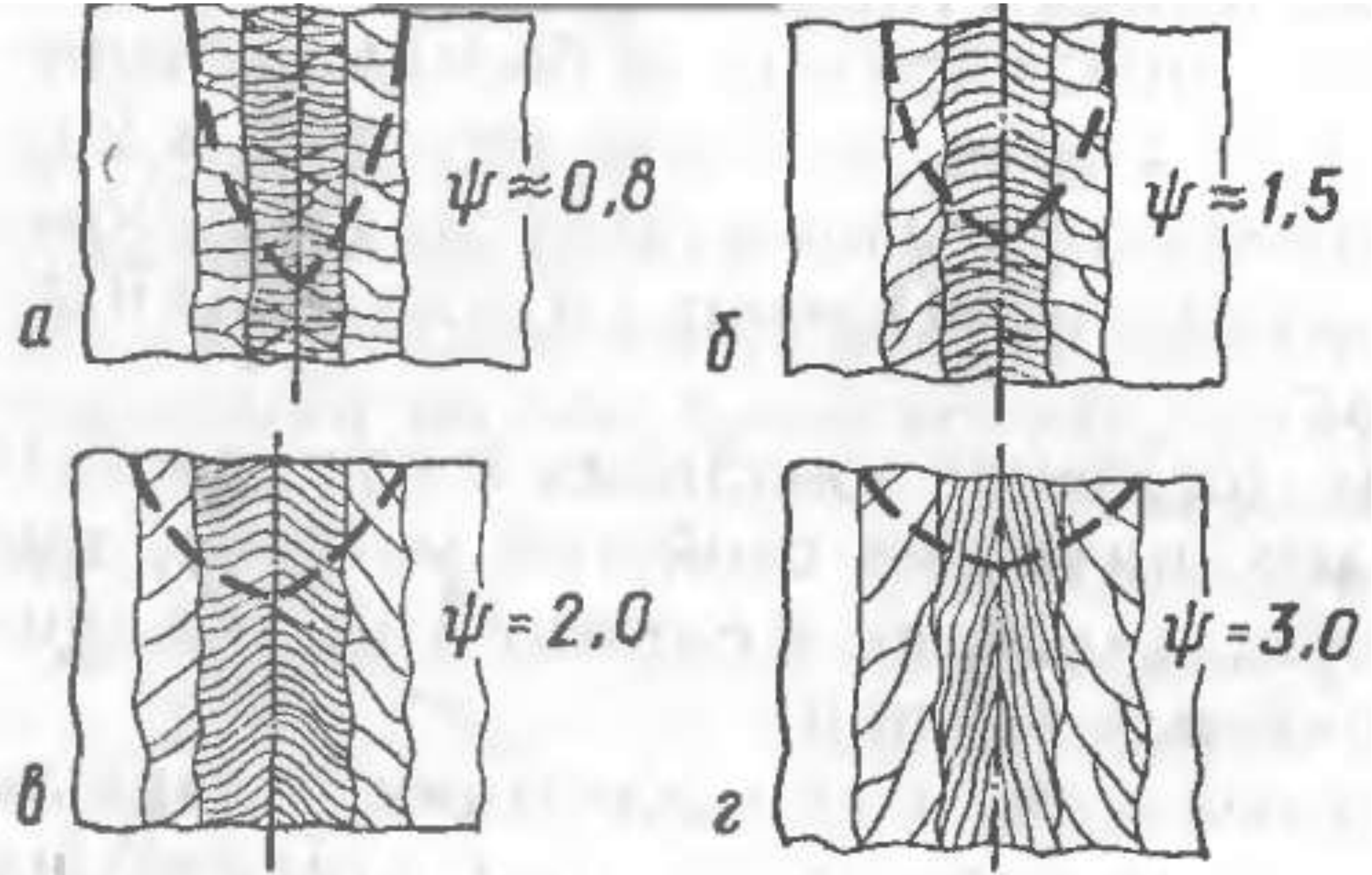
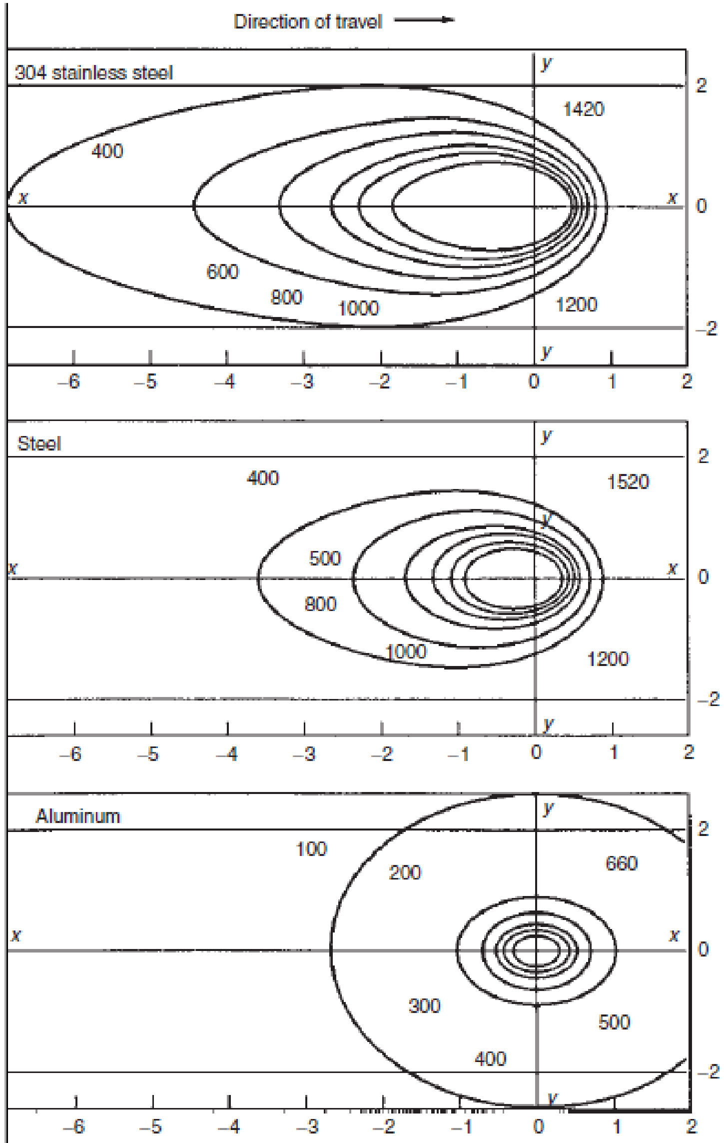


Рис. 150. Изменение направления роста столбчатых кристаллов в зависимости от коэффициента формы сварочной ванны второго типа.



ig. (5a) Effect of thermal property on isotemperature contours for a heat input of 4.2 kJ/s (1 kcal/) at a welding speed, *V*, of 1 mm/s (2 ipm) and the espective thermal conductivities of each material (refer o text for values). Values for *x* and *y* are given in cm, nd temperatures are given in °C.

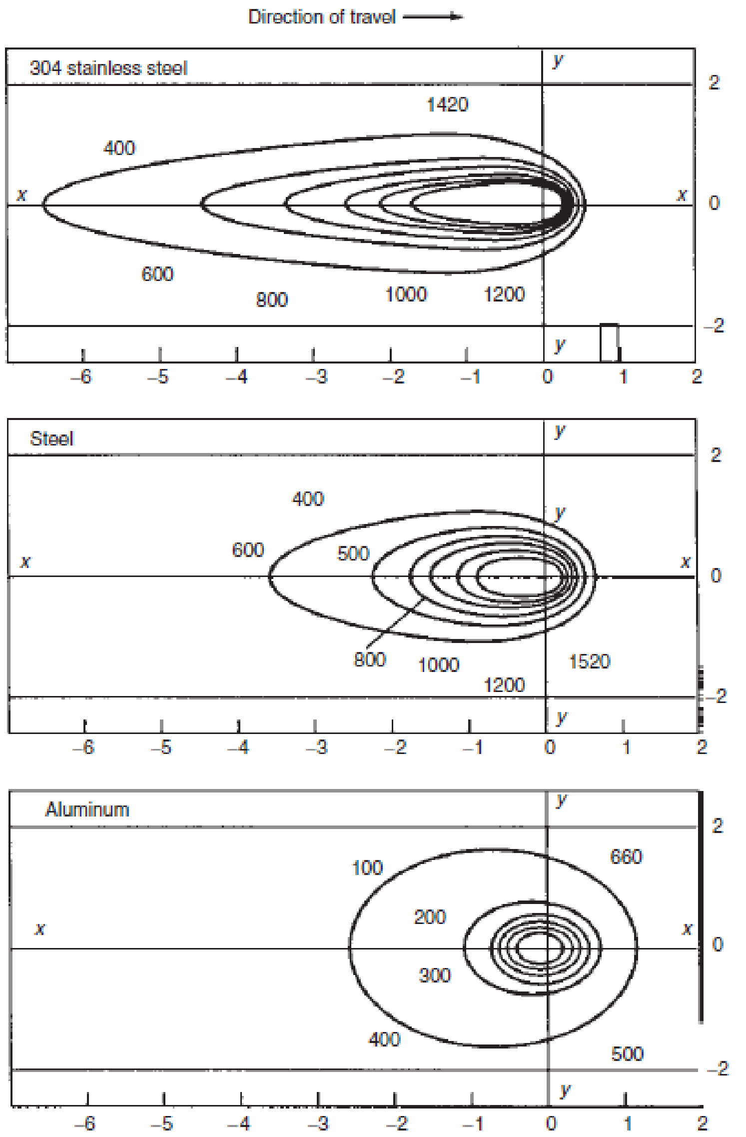


Fig. (5b) Effect of thermal property on isotemperature contours for a heat input of 4.2 kJ/s (1 kcal/s) at a welding speed, *V*, of 5 mm/s (12 ipm) and the respective thermal conductivities of each material (refer to text for values). Values for *x* and *y* are given in cm, and temperatures are given in °C.

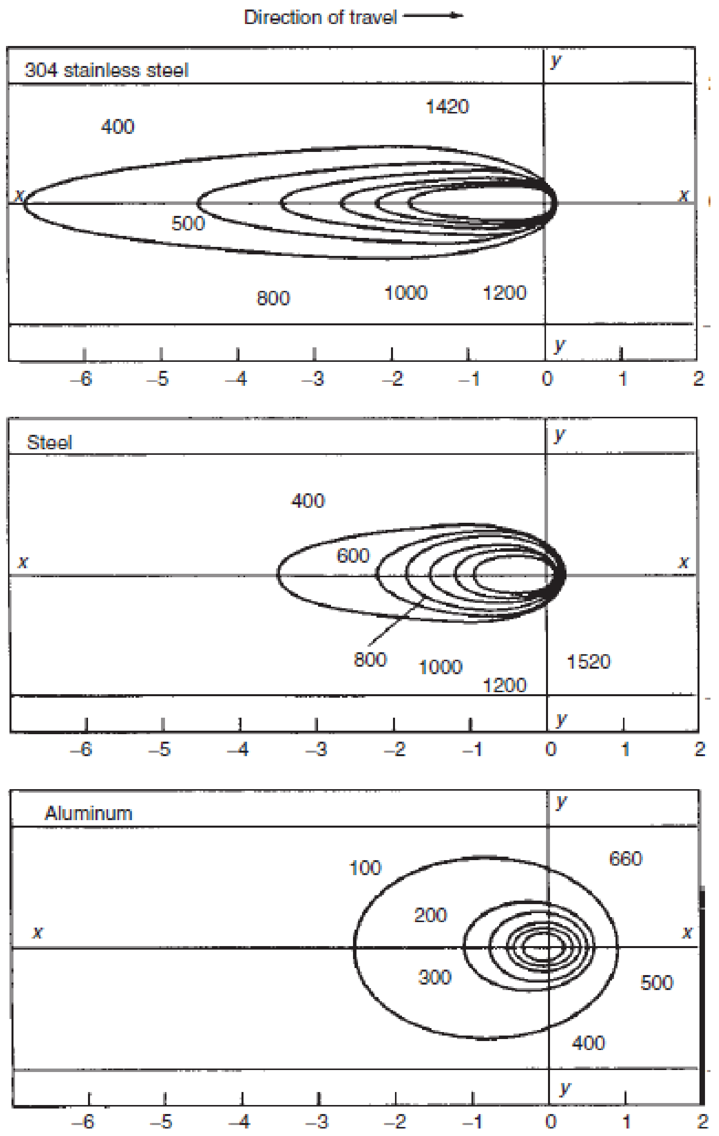


Fig. (5c) Effect of thermal property on isotemperatu contours for a heat input of 4.2 kJ/s (1 kcal at a welding speed, *V*, of 8 mm/s (19 ipm) and tl respective thermal conductivities of each material (refer text for values). Values for *x* and *y* are given in cm, ar temperatures are given in °C.

1 mm/s **5 mm/s** **8 mm/s**

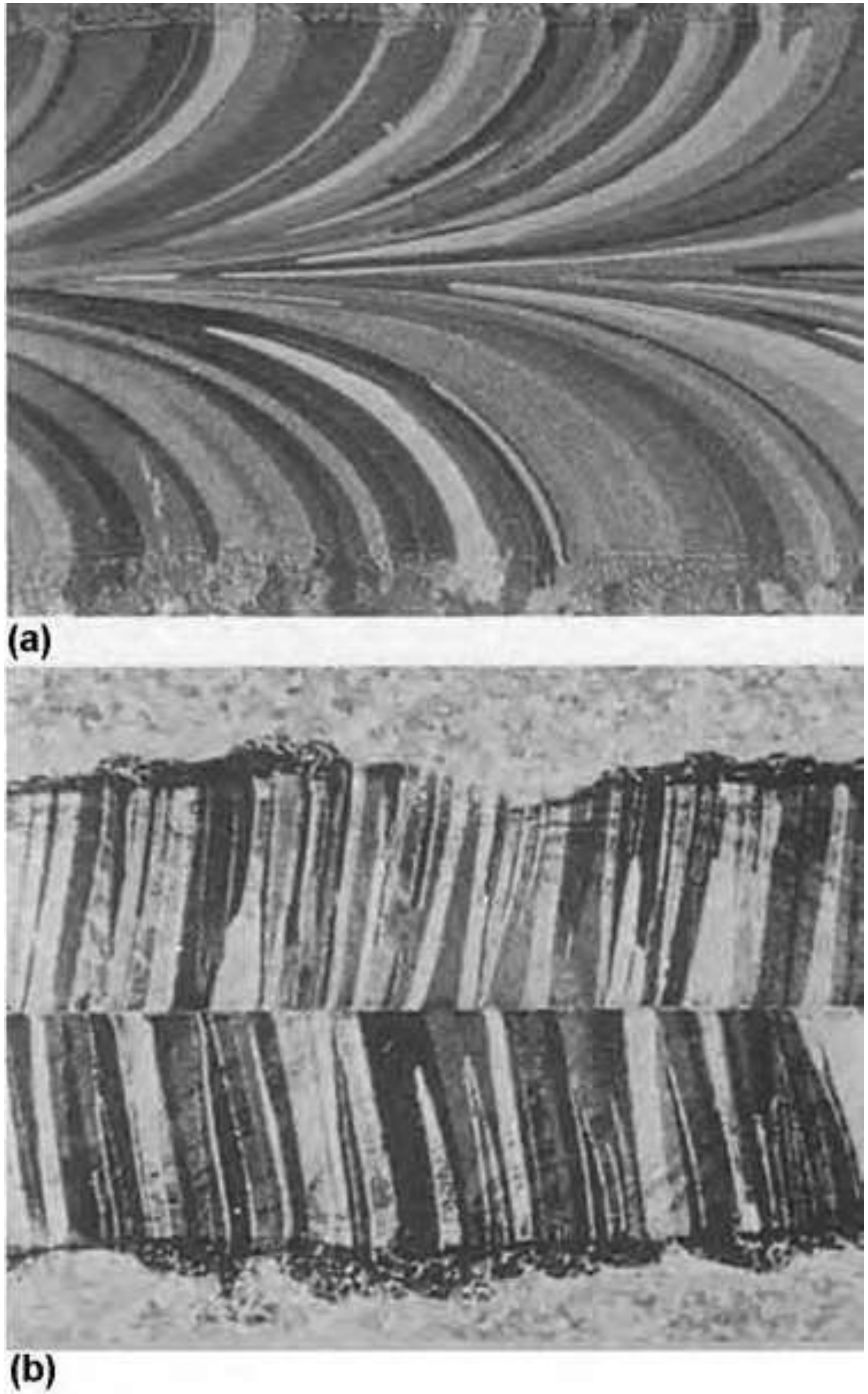
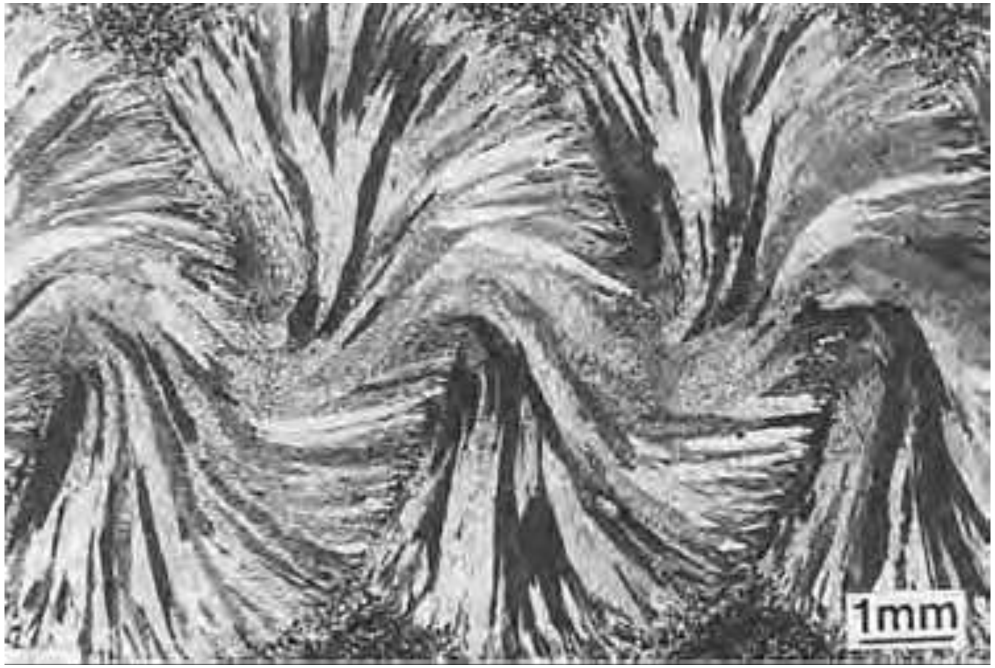


Fig. 11 Examples of (a) competitive grain growth and (b) a centerline grain boundary forming on a weld in 99.96 % Al. The weld in (a) was made at a welding speed of 250 mm/min (10 in./min). The weld in (b) was made at a welding speed of 1000 mm/min (40 in./min). Source: Ref 7

Fig. 13 Grain structure in a fusion weld of alloy 2014 made with transverse arc oscillation. Source: Ref 8



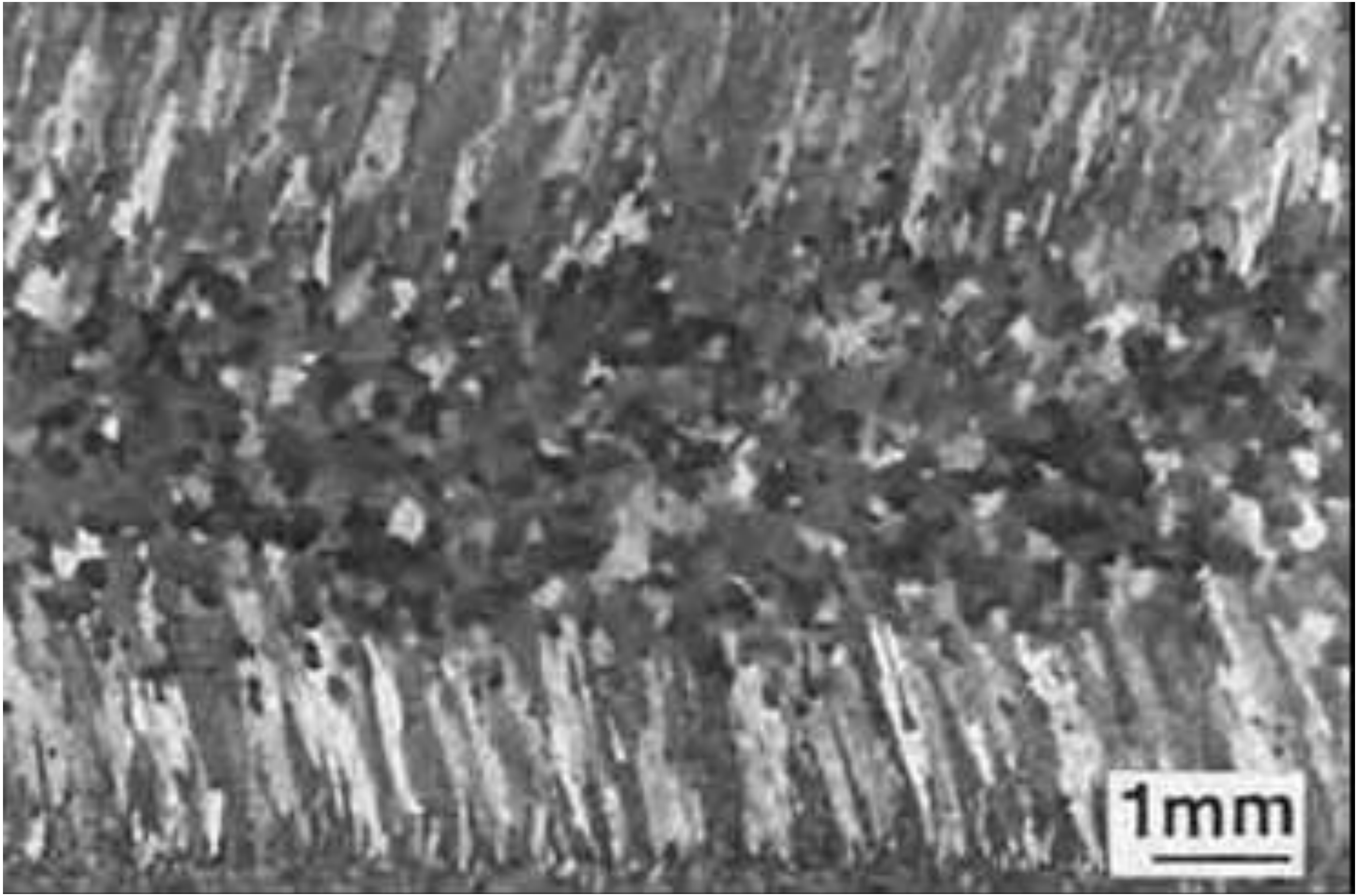


Fig. 18 Example of equiaxed zone in the centerline of a weld made with the gas tungsten arc welding process on 6061 aluminum. Source: Ref 2

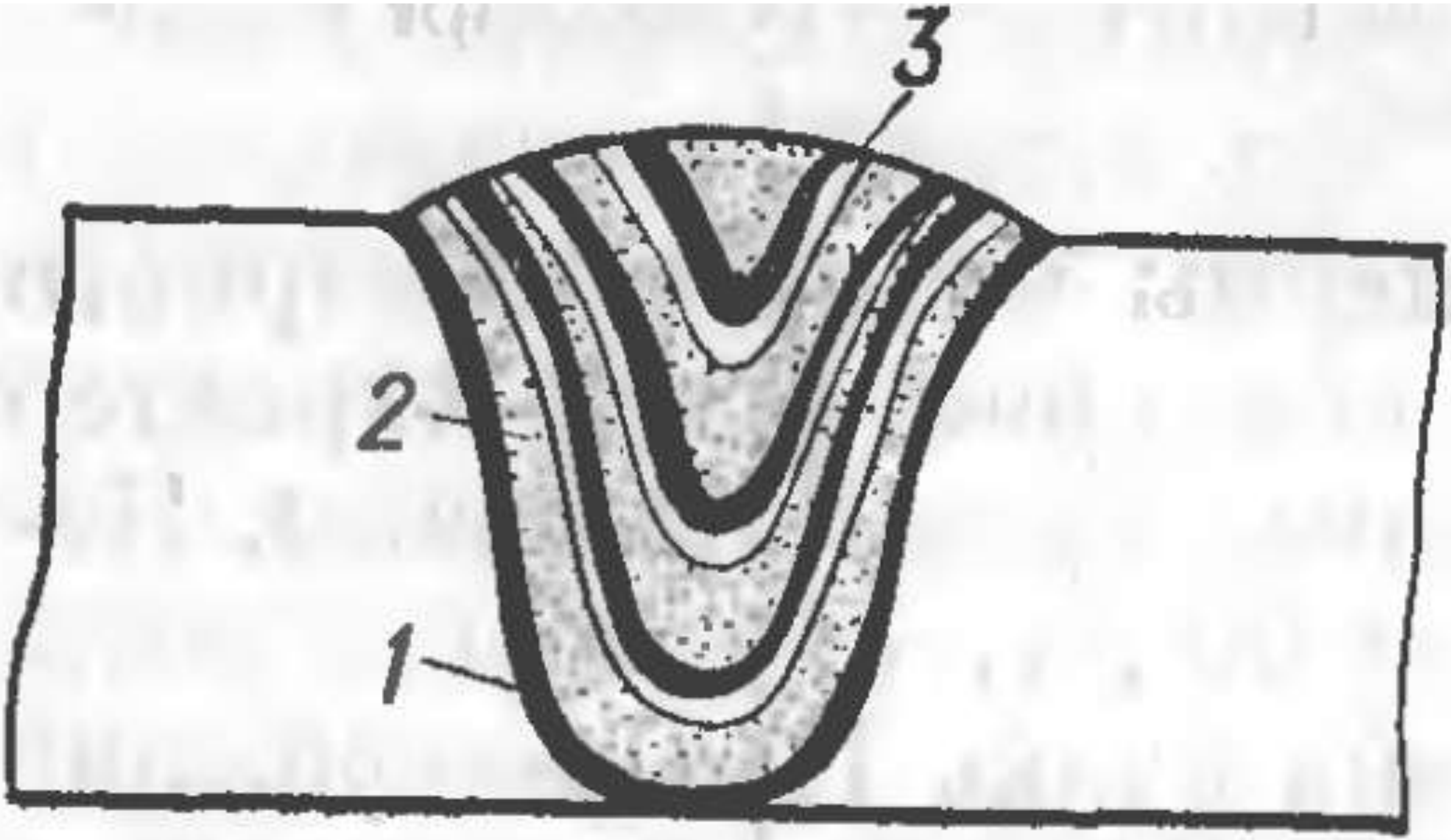


Рис. 140. Схема химической неоднородности по слоям кристаллизации в сварных швах.

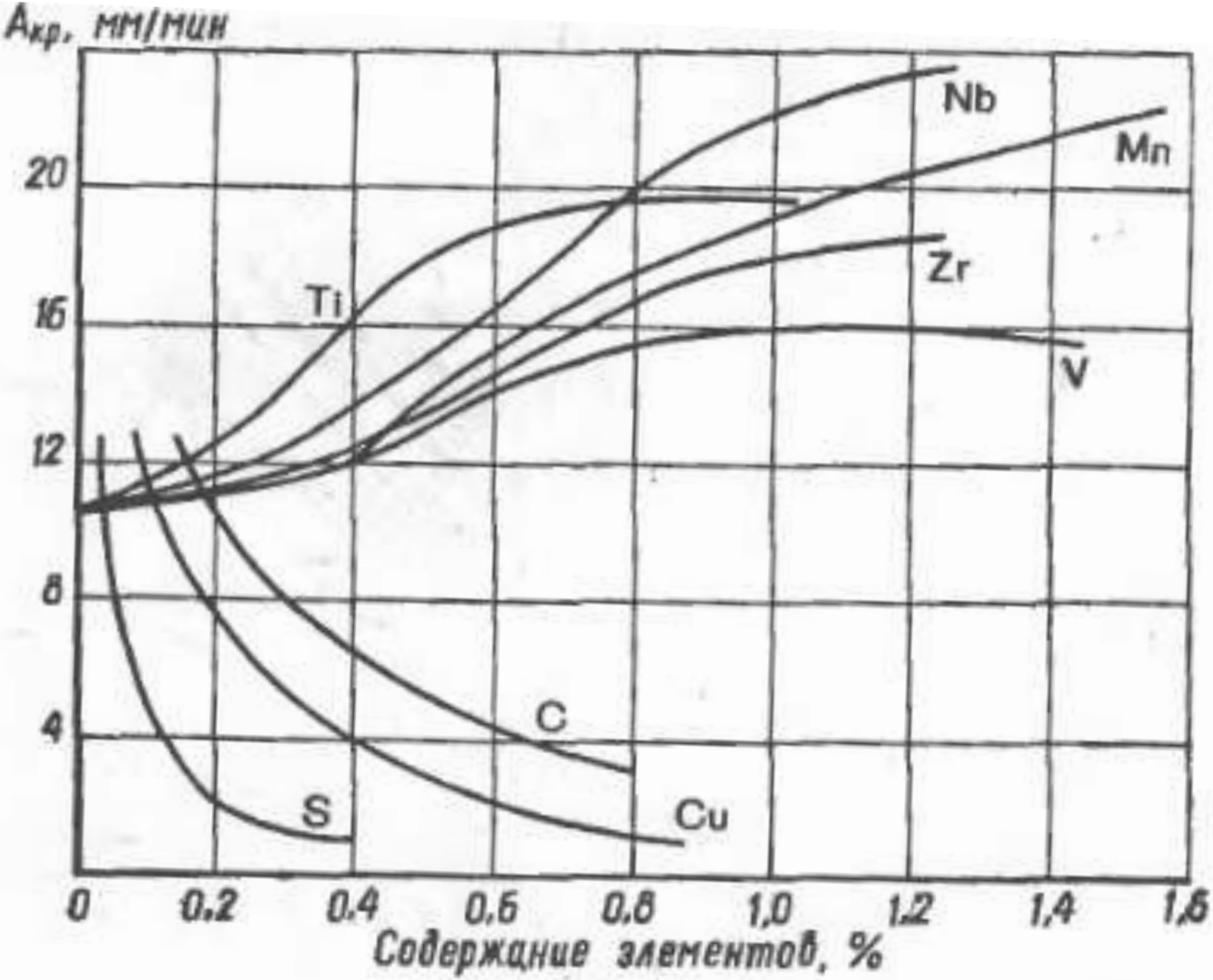


Рис. 180. Влияние некоторых элементов на технологическую прочность металла шва, выполненного на стали МСт3сп проволокой Св-08А ($I_{св} = 400 \div 420$ *а*; $U_д =$ $= 30 \div 32$ *в*; $v = 30$ *м/ч*; флюс системы $CaF_2 + Al_2O_3 +$

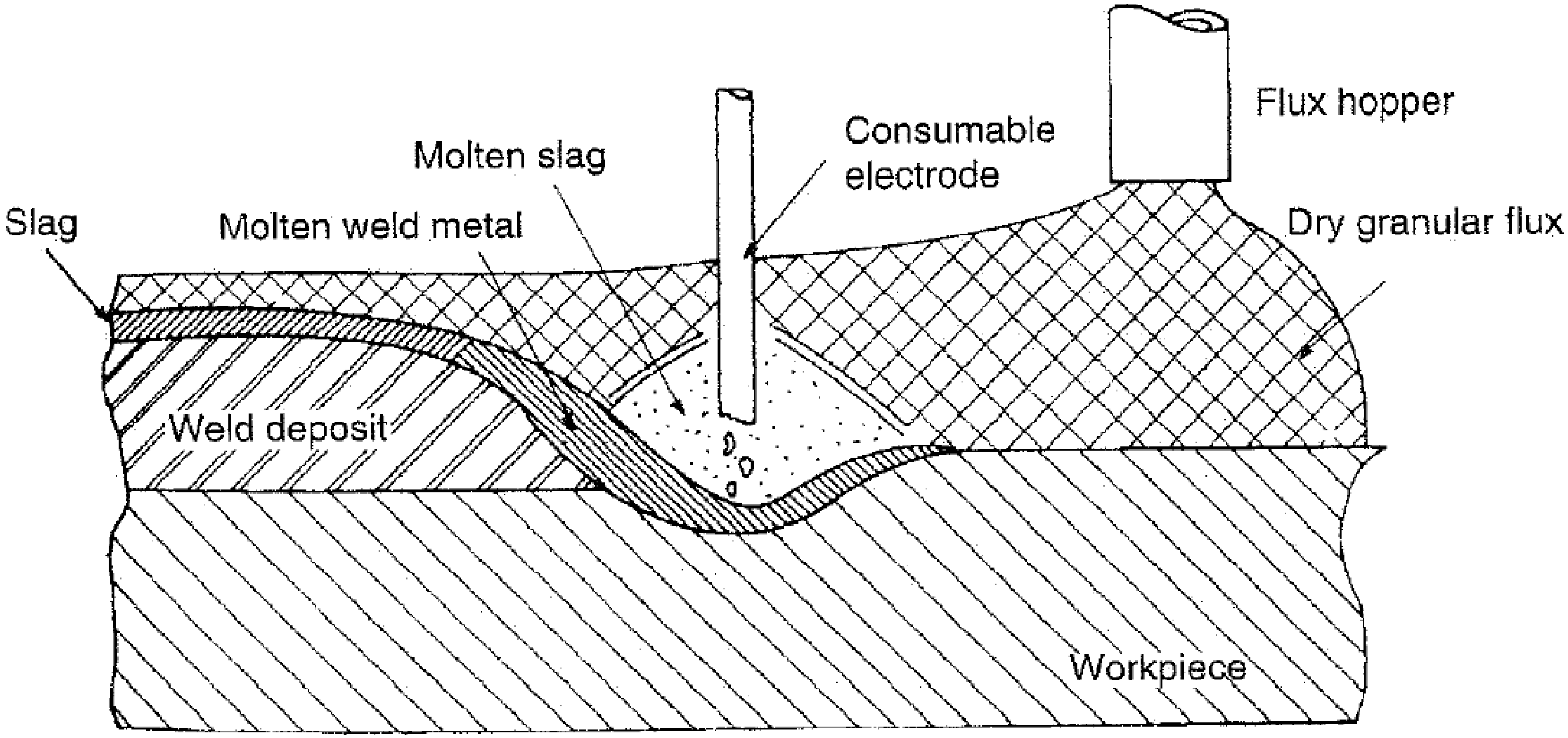


Fig. 9 Schematic illustration of the submerged arc welding process used for heavy deposition in plane (i.e., downhand) only. Source: Ref 2

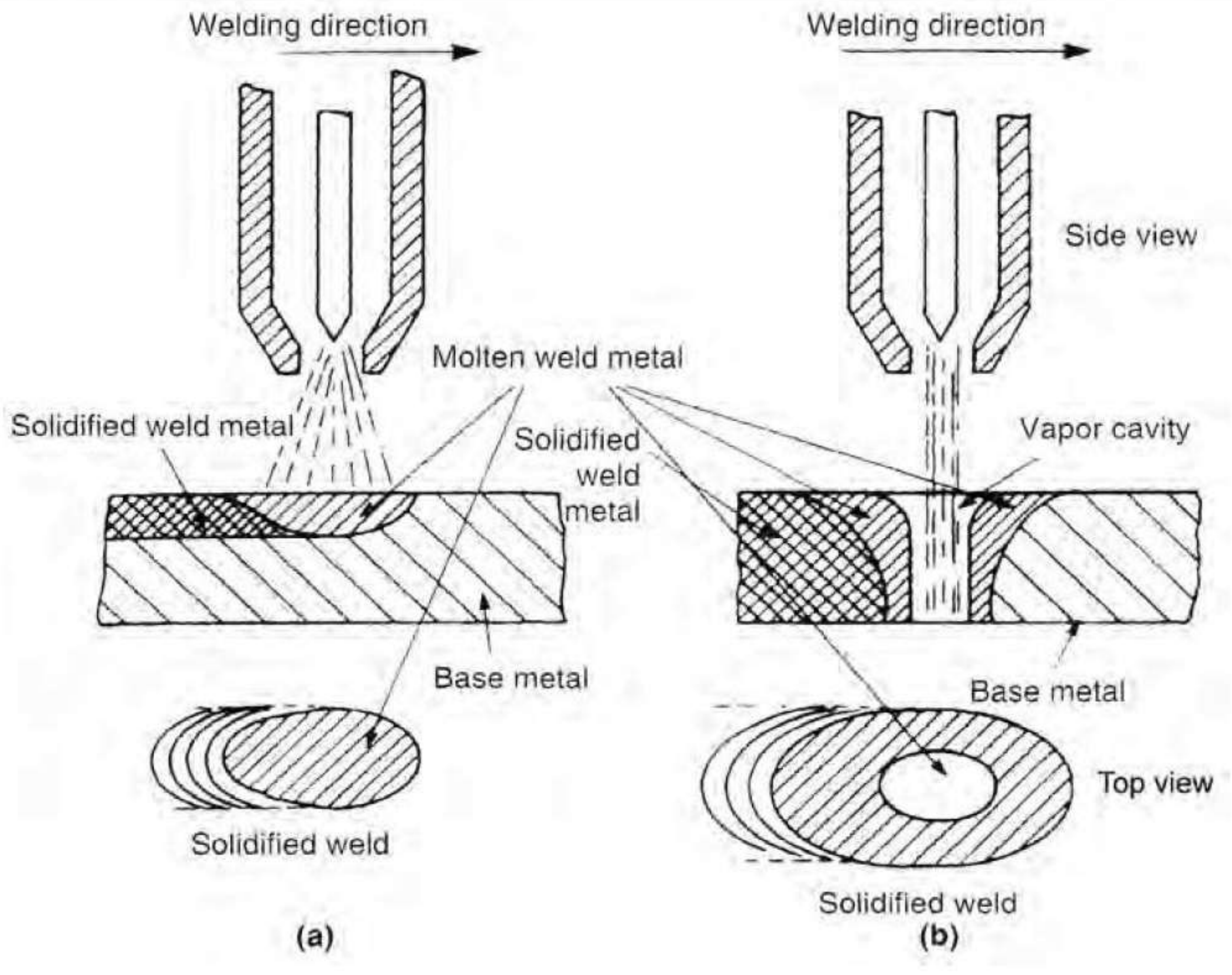


Fig. 16 Schematic illustrations of the (a) electron beam welding and (b) laser beam welding processes. The former is virtually always operated in a hard vacuum, while the latter can operate in air, in an inert gas atmosphere, or in vacuum. Source: Ref 2

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