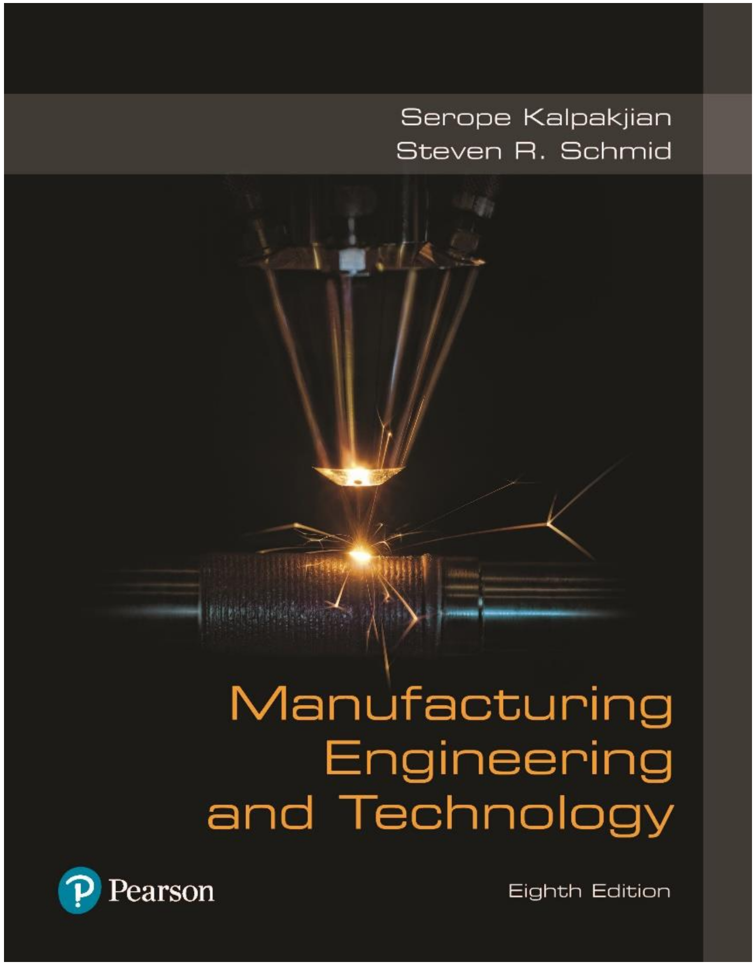
Manufacturing Engineering and Technology

Eighth Edition



Chapter 30-32

Pearson

Figure VI.1

Various parts in a typical automobile that are assembled by the processes described in Part VI.

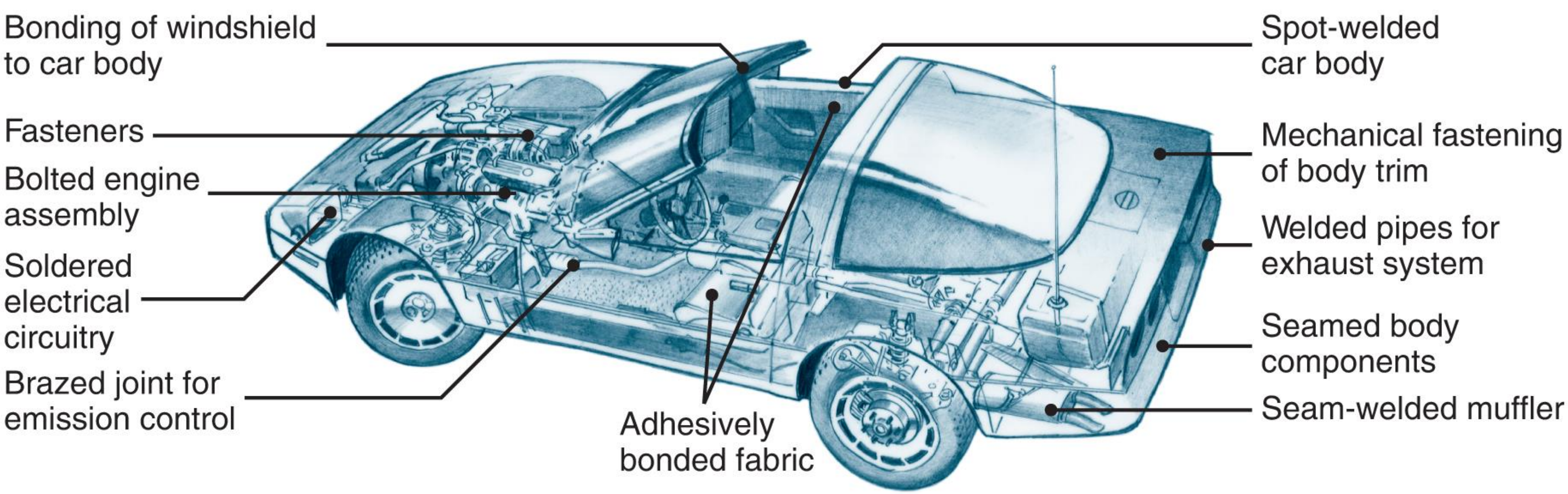
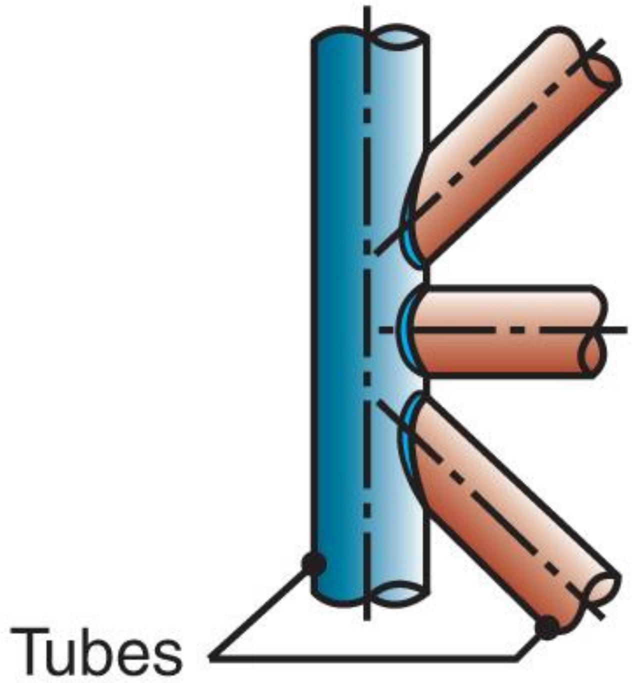


Figure VI.2 (1 of 3)

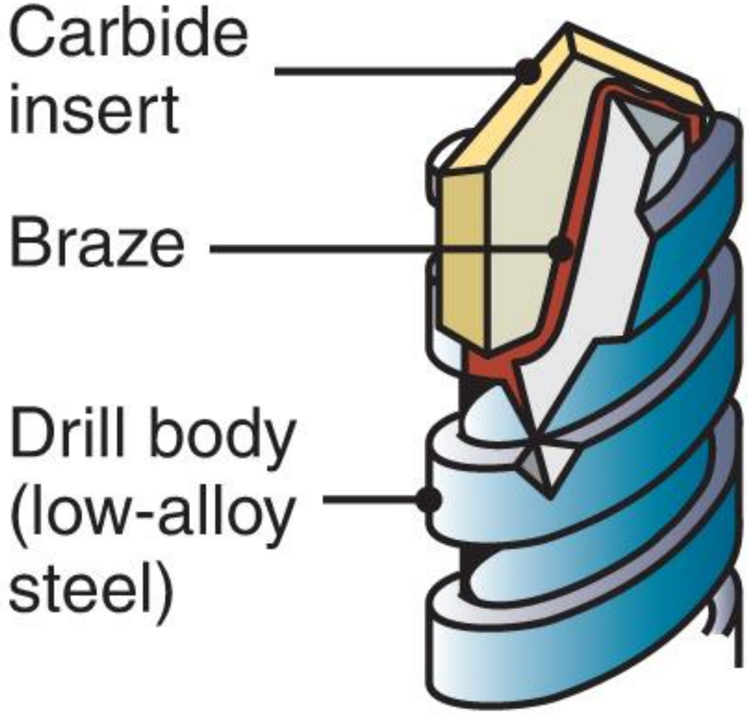
Examples of parts utilizing joining processes. (a) Atubular part fabricated by joining individual components. This product cannot be manufactured in one piece by any of the methods described in the previous chapters if it consists of thin-walled, large-diameter, tubular-shaped long arms.



(a)

Figure VI.2 (2 of 3)

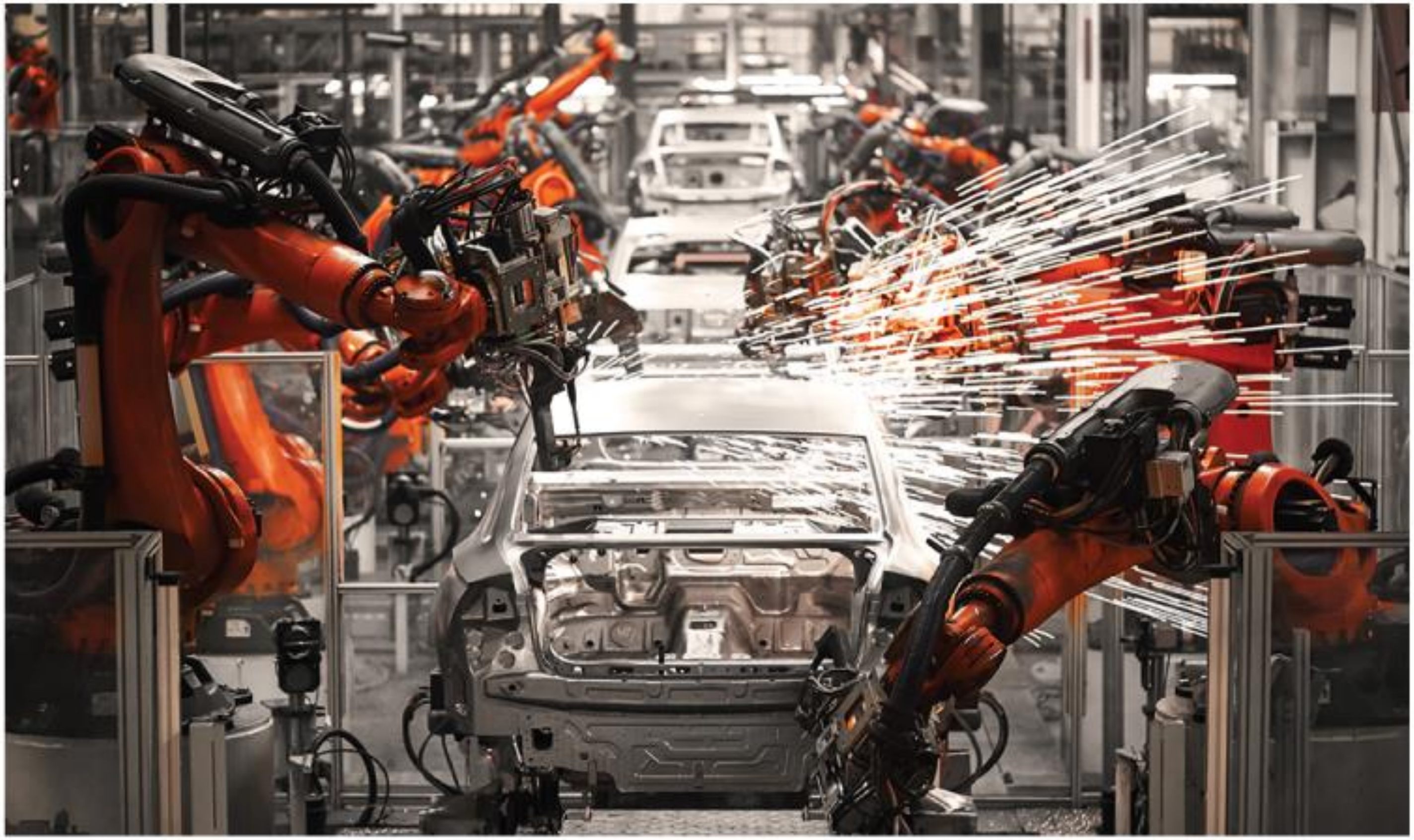
Examples of parts utilizing joining processes. (b) A drill bit with a carbide cutting insert brazed to a steel shank—an example of a part in which two materials need to be joined for performance reasons.



(b)

Figure VI.2 (3 of 3)

Examples of parts utilizing joining processes. (c) Spot welding of automobile bodies.



(c)

Source: (c) Shutterstock/Jensen.

Figure VI.3

Outline of topics described in Part VI.

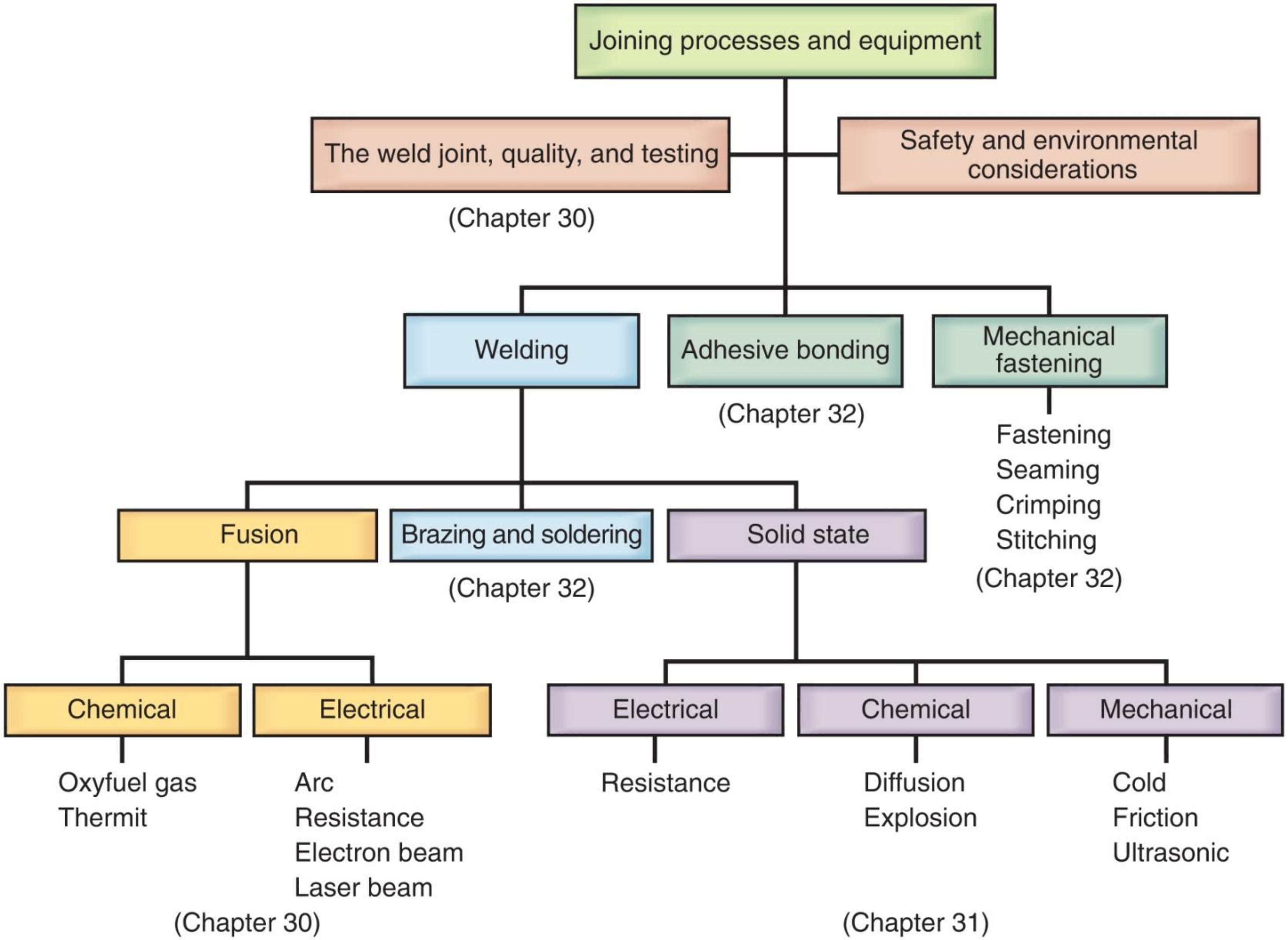


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Figure VI.3

Outline of topics described in Part VI.

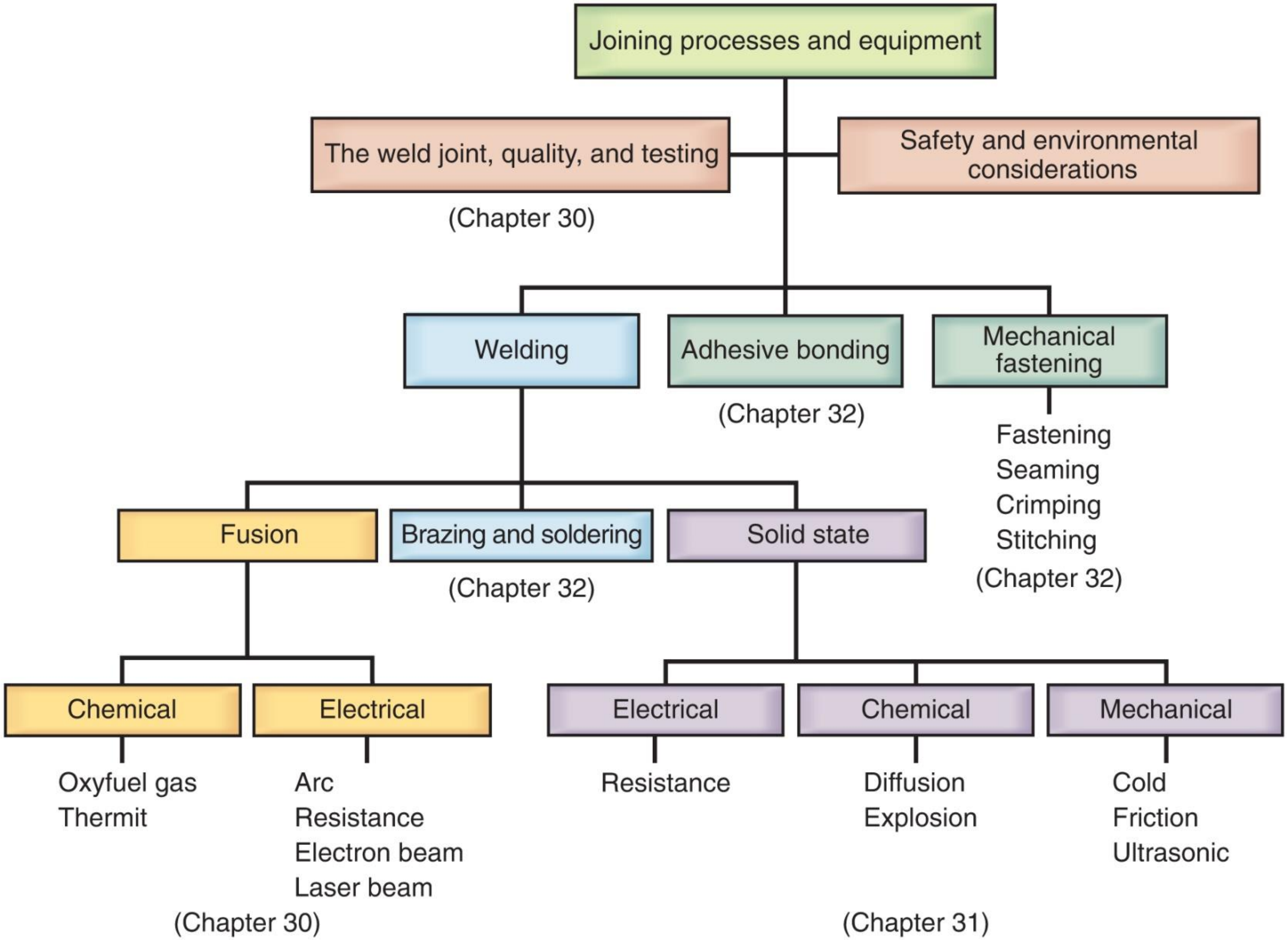
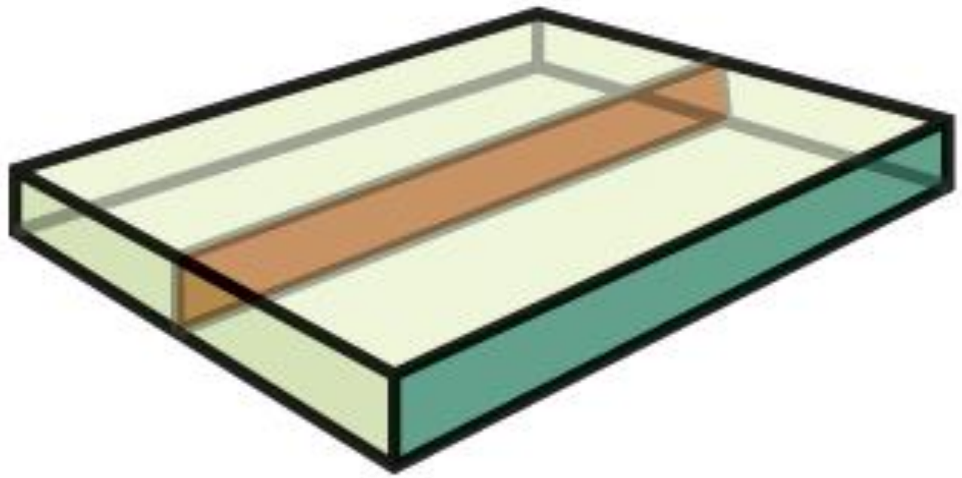


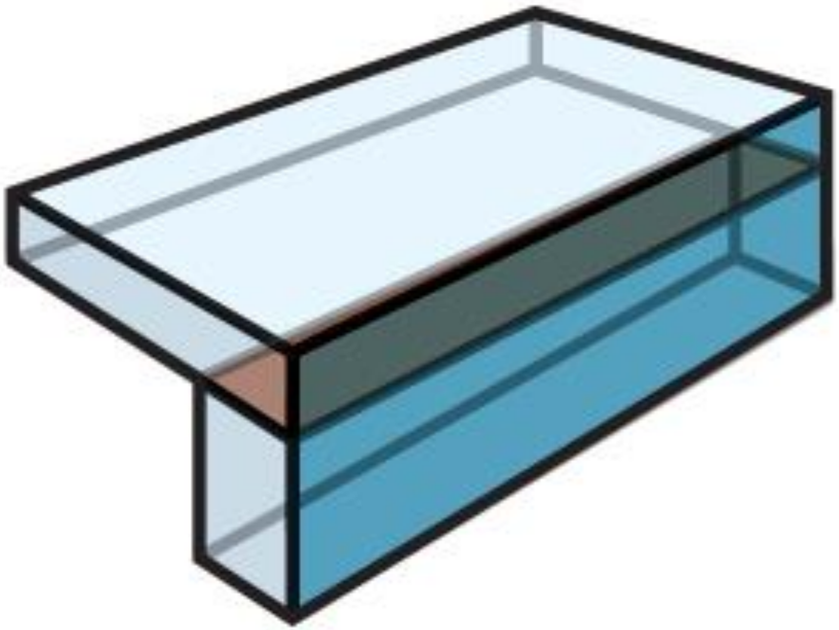
Figure VI.4 (1 of 5)

Examples of joints that can be made through the various joining processes described in Chapters 30 through 32.



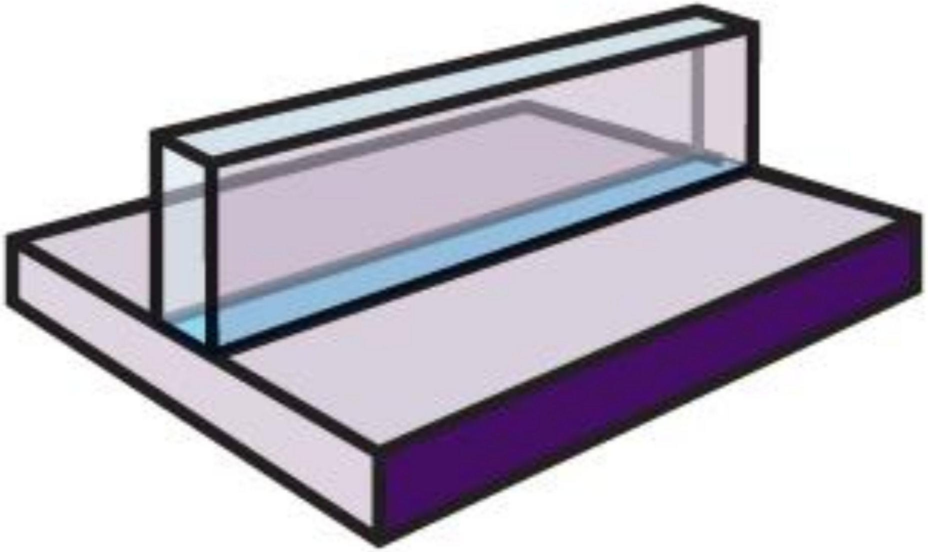
(a) Butt joint

Figure VI.4 (2 of 5)



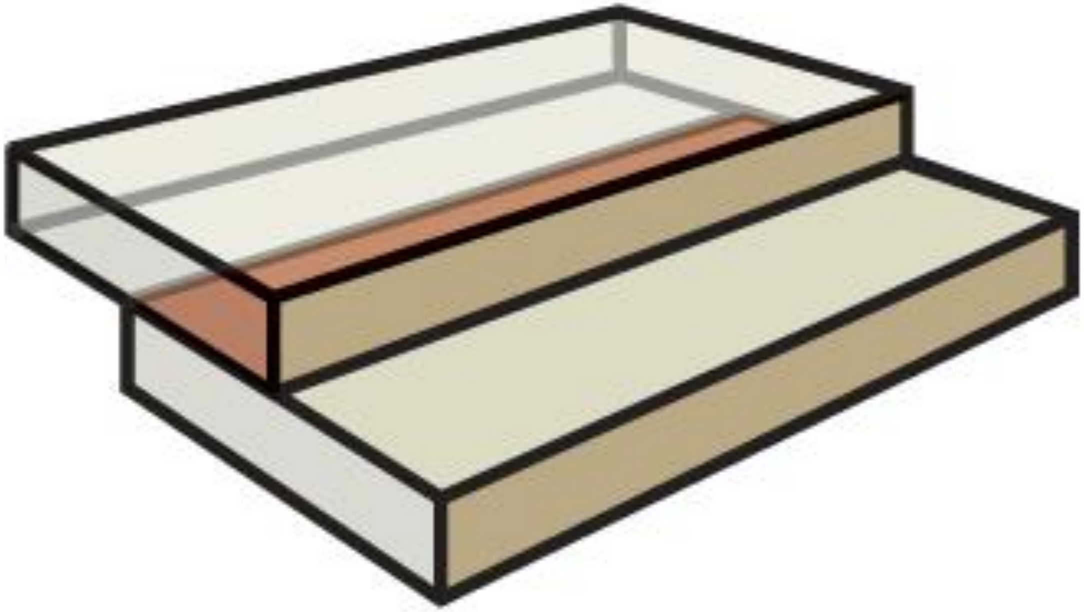
(b) Corner joint

Figure VI.4 (3 of 5)



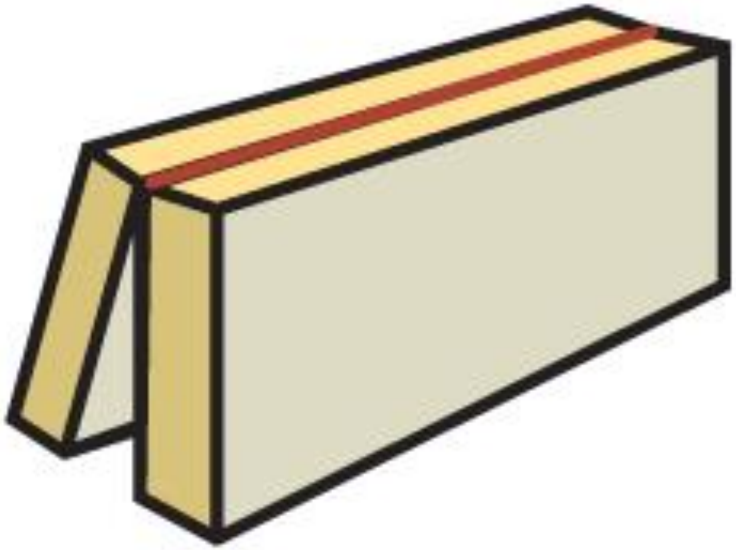
(c) T joint

Figure VI.4 (4 of 5)



(d) Lap joint

Figure VI.4 (5 of 5)



(e) Edge joint

Table VI.4

Comparison of Various Joining Methods.

Method	Strength	Design	Small parts	Large parts	Tolerances	Reliability	Ease of manufacture	Ease of inspection	Cost
	Characteristics								
Arc welding	1	2	3	1	3	1	2	2	2
Resistance welding	1	2	1	1	3	3	3	3	1
Brazing	1	1	1	1	3	1	3	2	3
Bolts and nuts	1	2	3	1	2	1	1	1	3
Rivets	1	2	3	1	1	1	3	1	2
Seaming and crimping	2	2	1	3	3	1	3	1	1
Adhesive bonding	3	1	1	2	3	2	3	3	2

Note: For cost, 1 is the lowest.

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Table 30.1

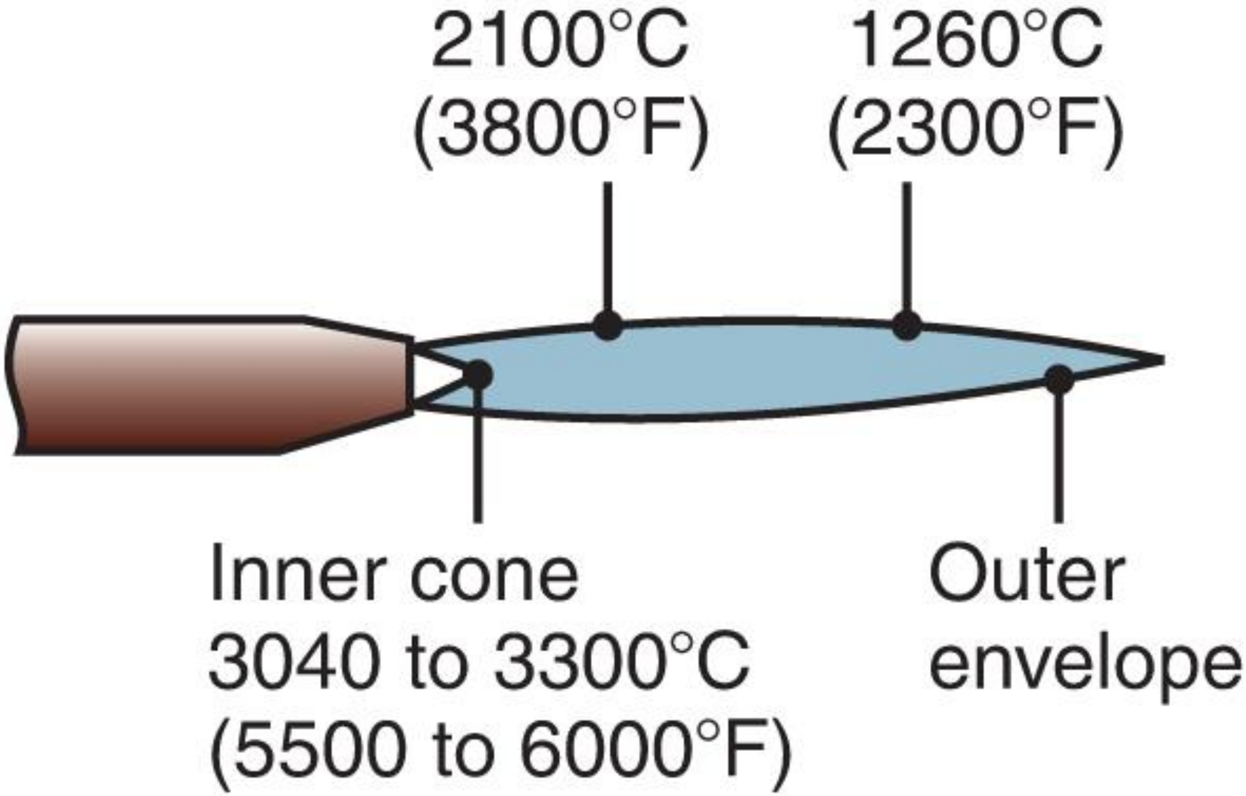
General Characteristics of Fusion-welding Processes.

Joining process	Operation	Advantage	Skill level required	Welding position	Current type	Distortion*	Typical cost of equipment ($)
Shielded metal arc	Manual	Portable and flexible	High	All	AC, DC	1 to 2	Low (1500+)
Submerged arc	Automatic	High deposition	Low to medium	Flat and horizontal	AC, DC	1 to	Medium (5000+)
Gas metal arc	Semiautomatic or automatic	Most metals	Low to high	All	DC	2 to 3	Medium (5000+)
Gas tungsten arc	Manual or automatic	Most metals	Low to high	All	AC, DC	2 to	Medium (2000+)
Flux-cored arc	Semiautomatic or automatic	High deposition	Low to high	All	DC	1 to 3	Medium (2000+)
Oxyfuel	Manual	Portable and flexible	High	All	–	2 to 4	Low (500+)
Electron beam, laser beam	Semiautomatic or automatic	Most metals	Medium to high	All	–	3 to 5	High (100,000–1 million)
Thermit	Manual	Steels	Low	Flat and horizontal	–	2 to 4	Low (500+)

* 1 = highest; 5 = lowest

Figure 30.1 (1 of 4)

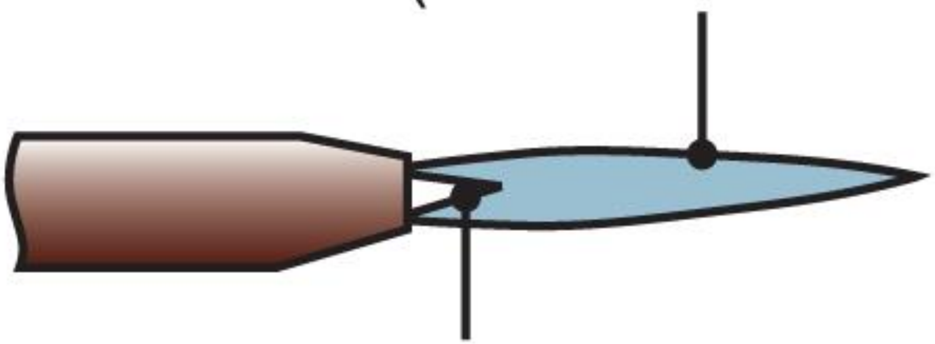
Three basic types of oxyacetylene flames used in oxyfuel–gas welding and cutting operations: (a) neutral flame.



(a) Neutral flame

Figure 30.1 (2 of 4)

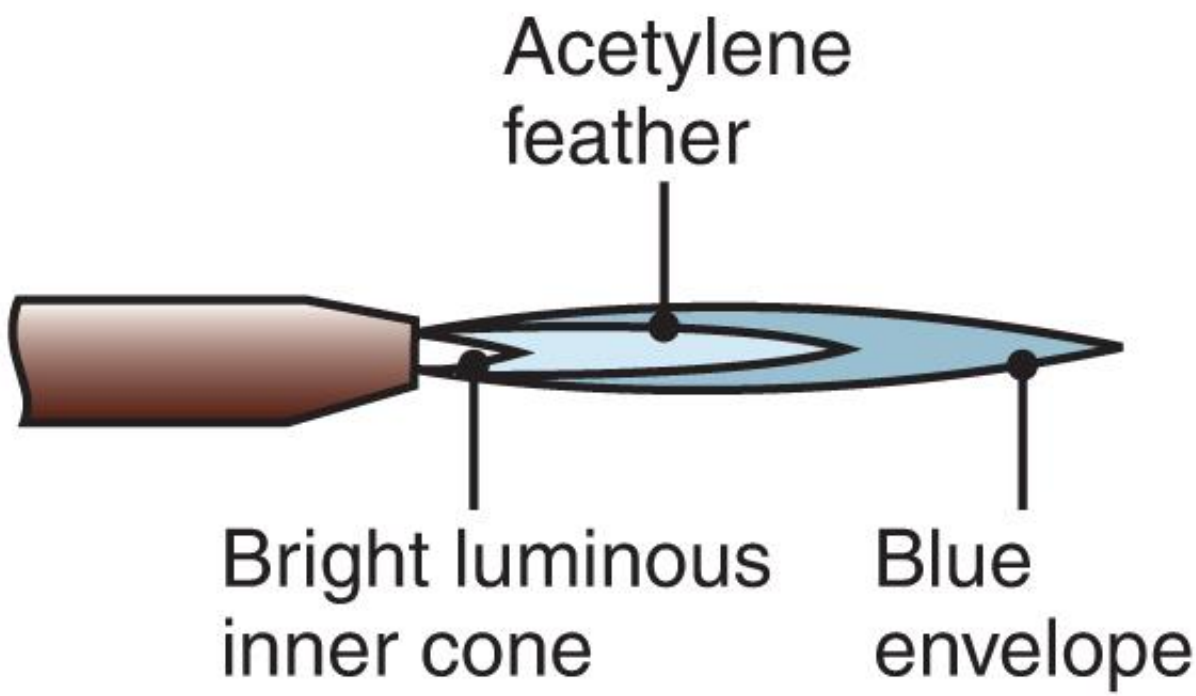
Three basic types of oxyacetylene flames used in oxyfuel–gas welding and cutting operations: (b) oxidizing flame.



(b) Oxidizing flame

Figure 30.1 (3 of 4)

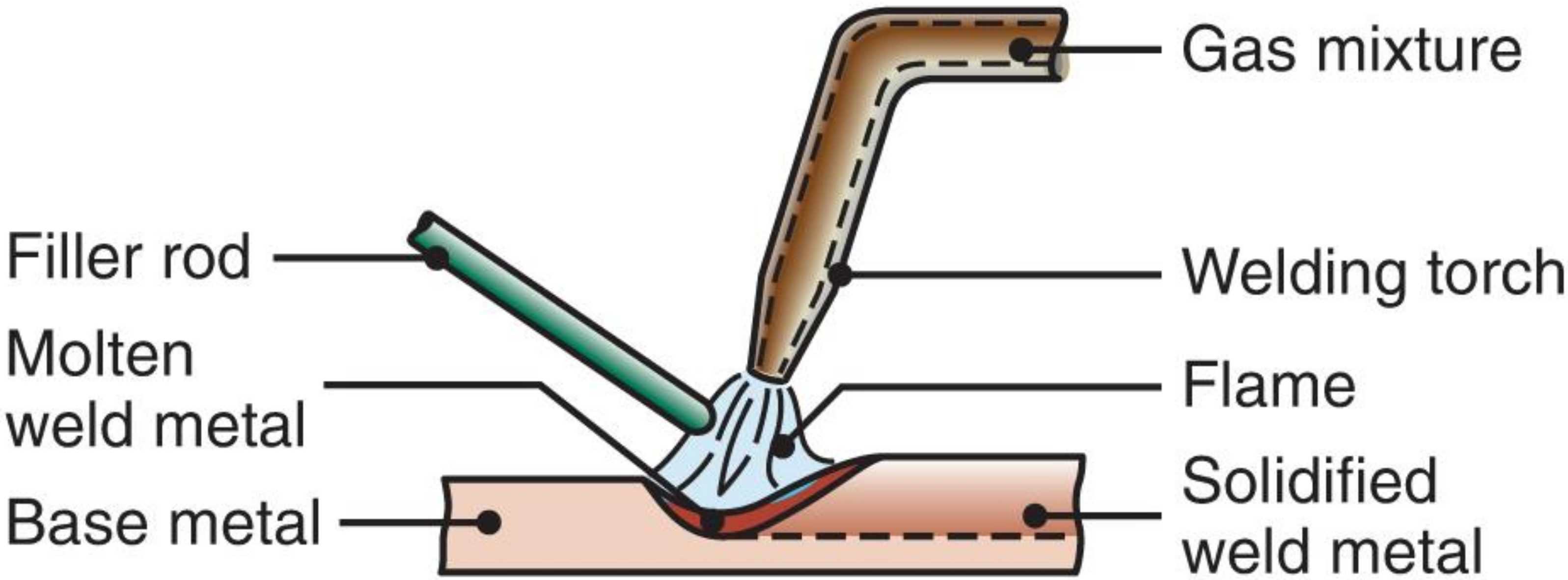
Three basic types of oxyacetylene flames used in oxyfuel–gas welding and cutting operations: (c) carburizing, or reducing, flame. The gas mixture in (a) is basically equal volumes of oxygen and acetylene.



(c) Carburizing (reducing) flame

Figure 30.1 (4 of 4)

Three basic types of oxyacetylene flames used in oxyfuel–gas welding and cutting operations: (d) The principle of the oxyfuel–gas welding process.



(d)

Figure 30.3 (1 of 2)

Schematic illustration of the pressure-gas welding process: (a) before.

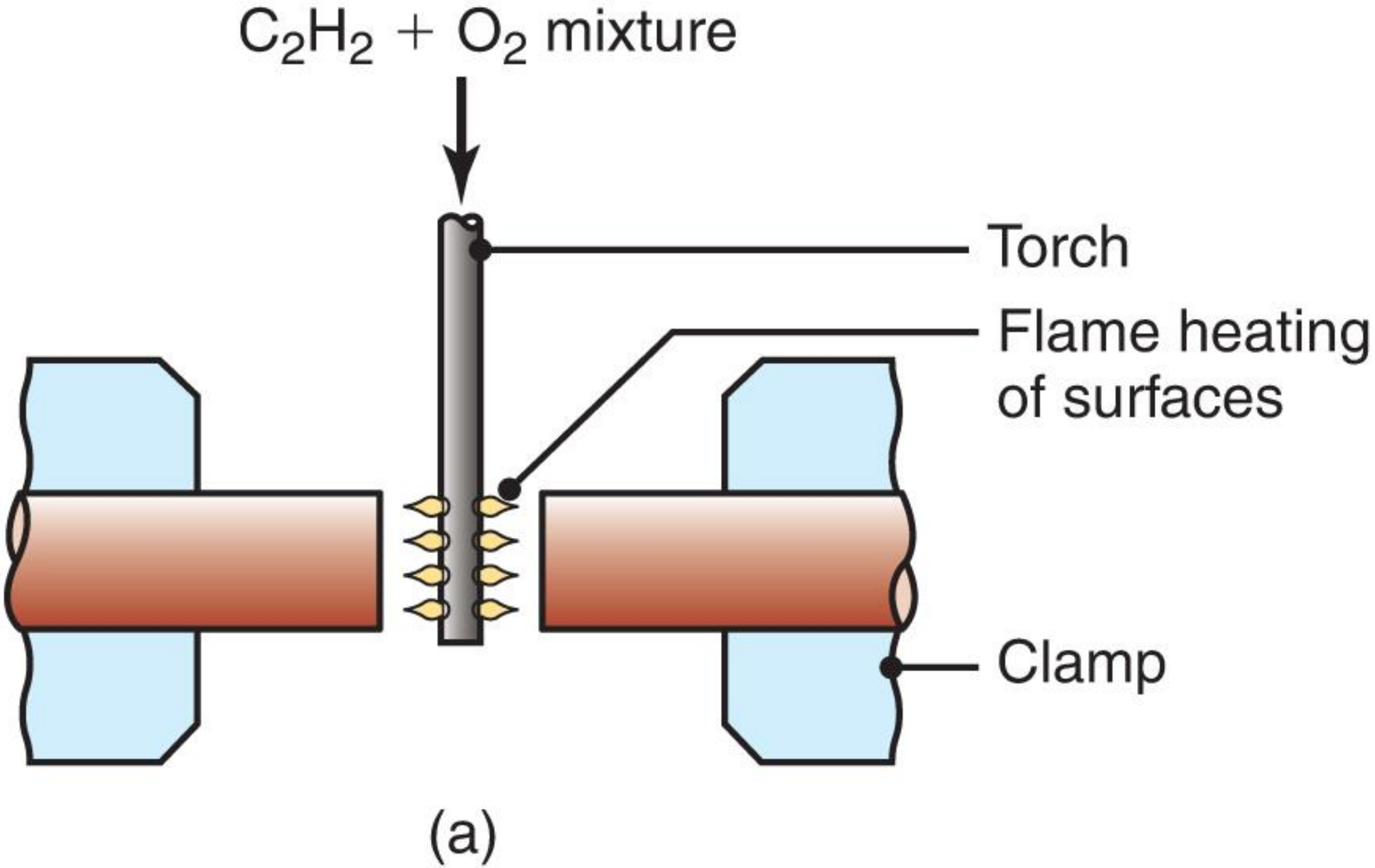
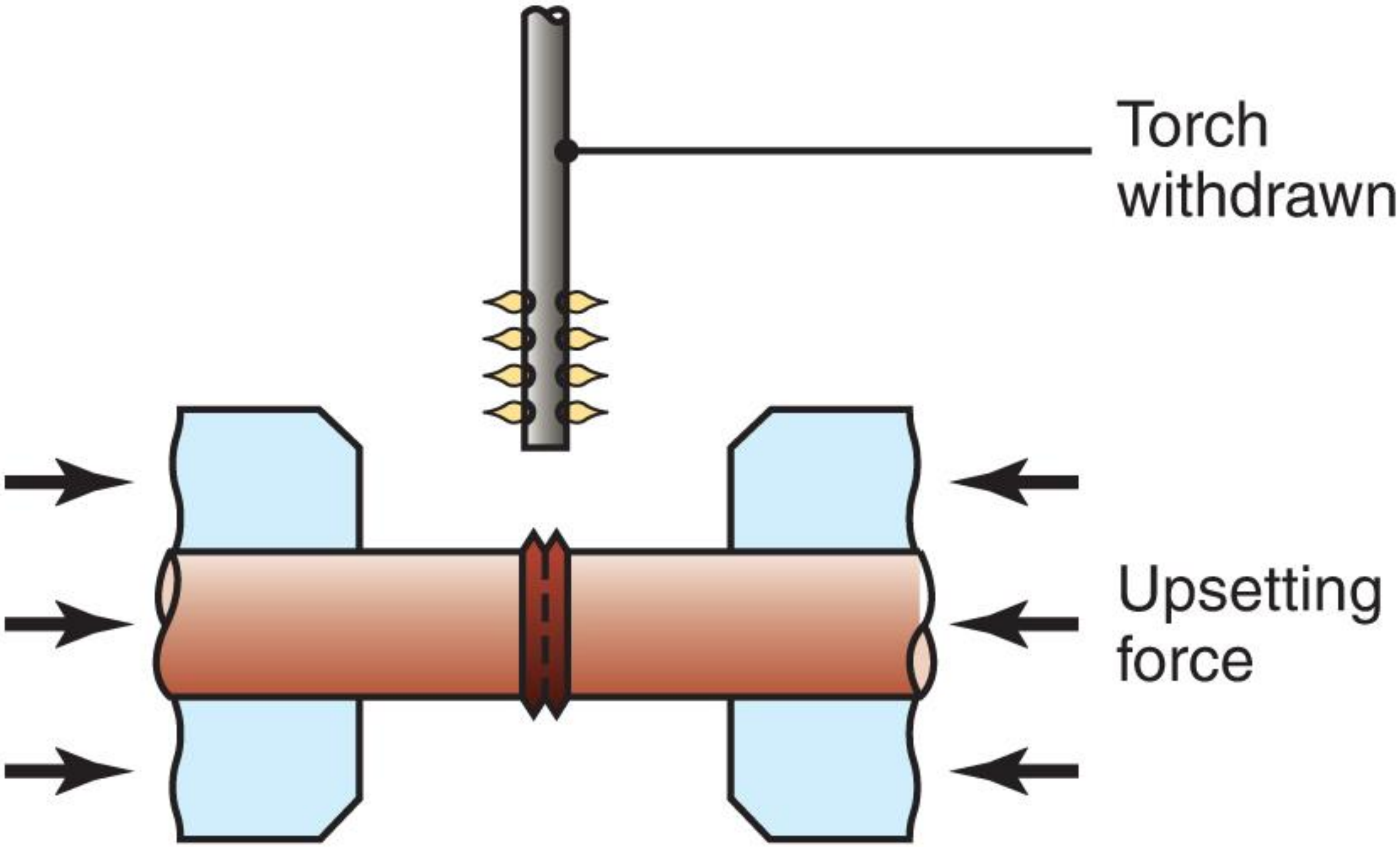


Figure 30.3 (2 of 2)

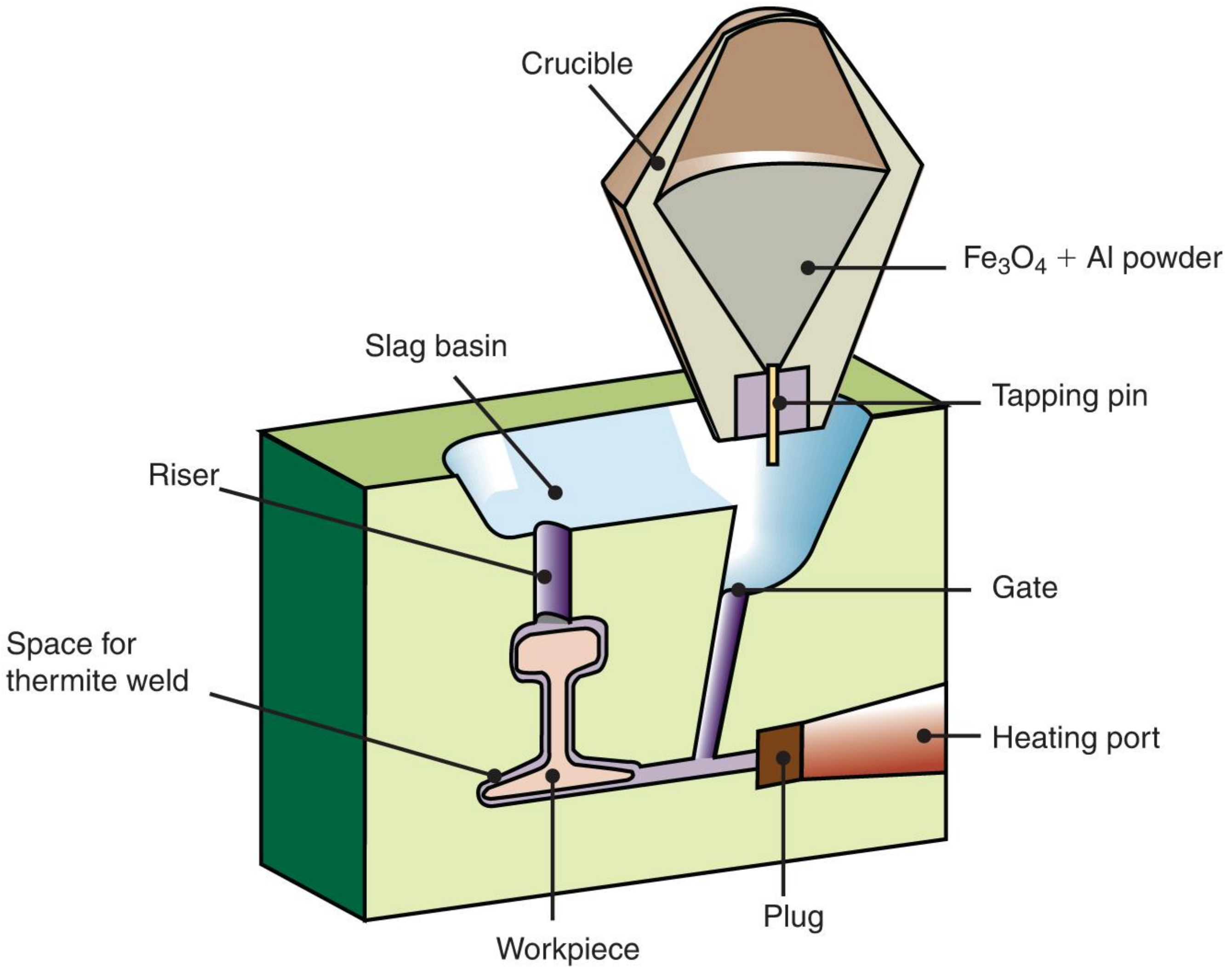
Schematic illustration of the pressure-gas welding process: (b) after. Note the formation of a flash at the joint; later the flash can be trimmed off.



(b)

Figure 30.4

Schematic illustration of thermite welding.



Thermit Welding

https://youtu.be/gXp3aRKO4Yc

Figure 30.5 (1 of 2)

(a) The gas tungsten-arc welding process, formerly known as TIG (for tungsten–inert gas) welding.

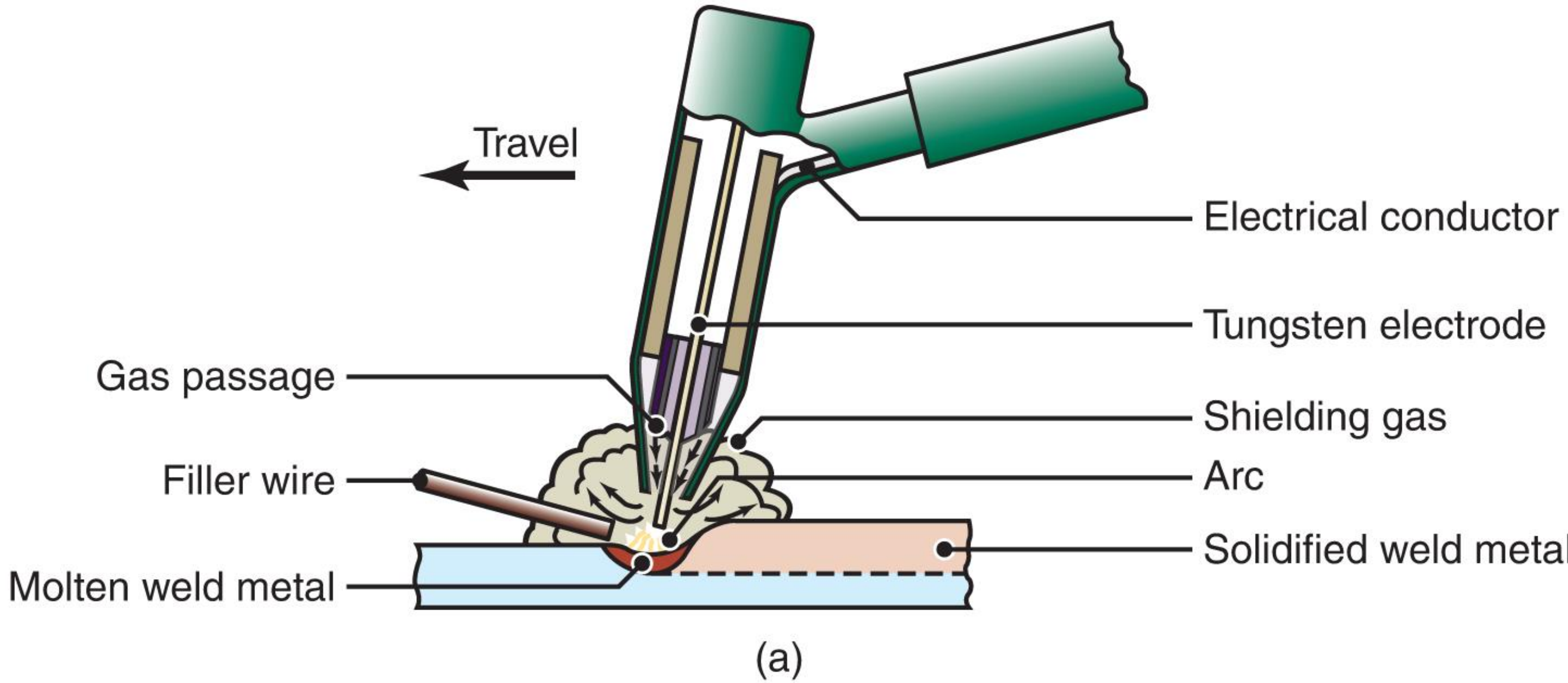
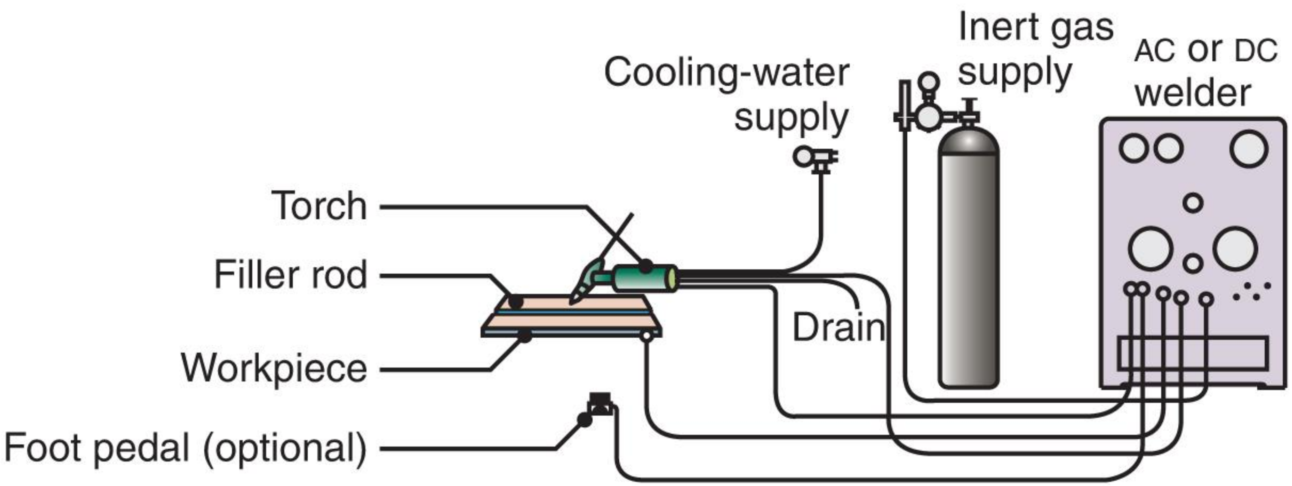


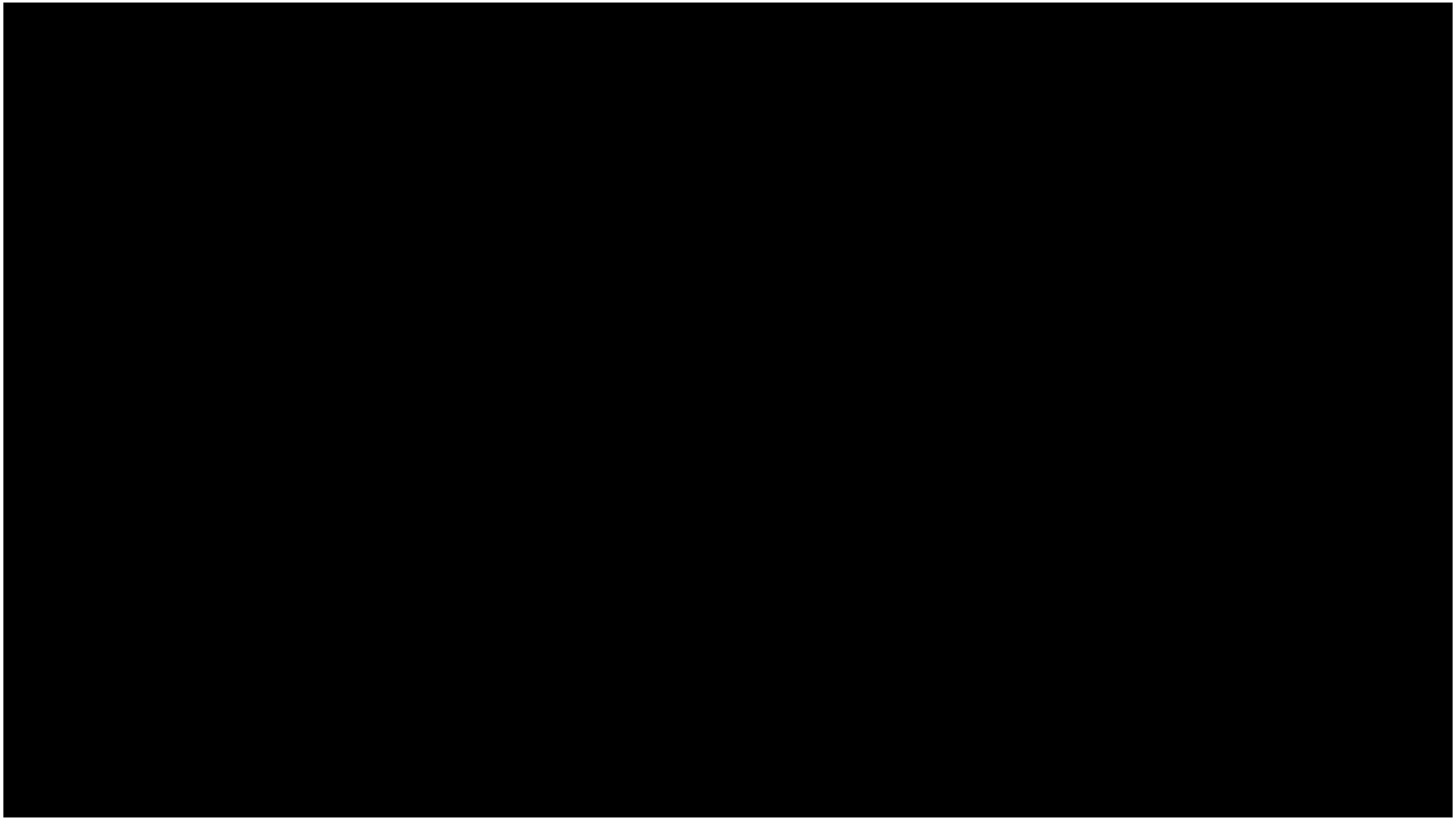
Figure 30.5 (2 of 2)

(b) Equipment for gas tungsten-arc welding operations.



(b)

GTAW



https://youtu.be/GLTxG31Kw8M

Table 30.2

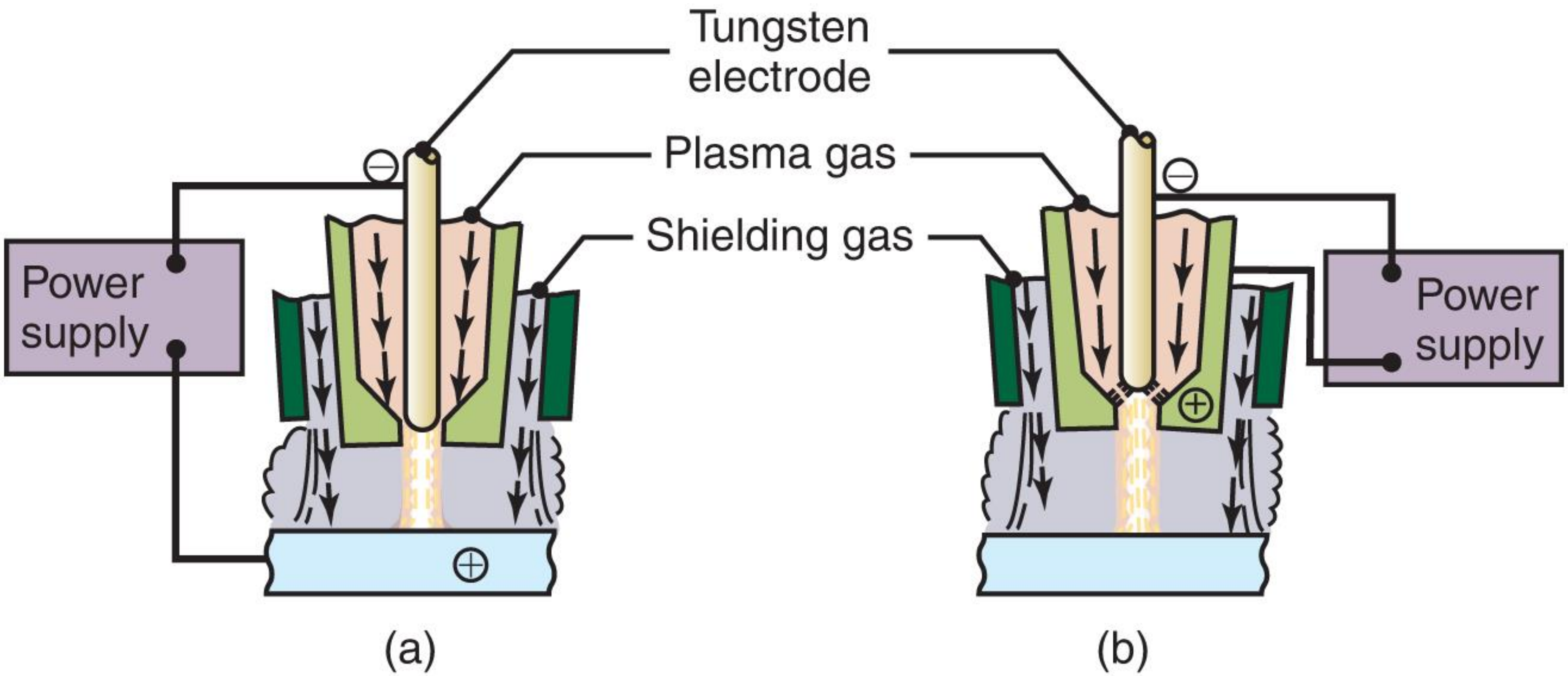
Approximate Specific Energies Required to Melt a Unit Volume of Commonly Welded Metals.

Material	Specific energy, u	
	J/mm^3	BTU/$^in3$
Aluminum and its alloys	2.9	41
Cast irons	7.8	112
Copper	6.1	87
Bronze (90Cu–10Sn)	4.2	59
Magnesium	2.9	42
Nickel	9.8	142
Steels	9.1–10.3	128–146
Stainless steels	9.3–9.6	133–137
Titanium	14.3	204

Note: 1BTU = 1055 J = 778 ft-lb.

Figure 30.7

Two types of plasma-arc welding processes: (a) transferred and (b) nontransferred. Deep and narrow welds can be made by these processes at high welding speeds.

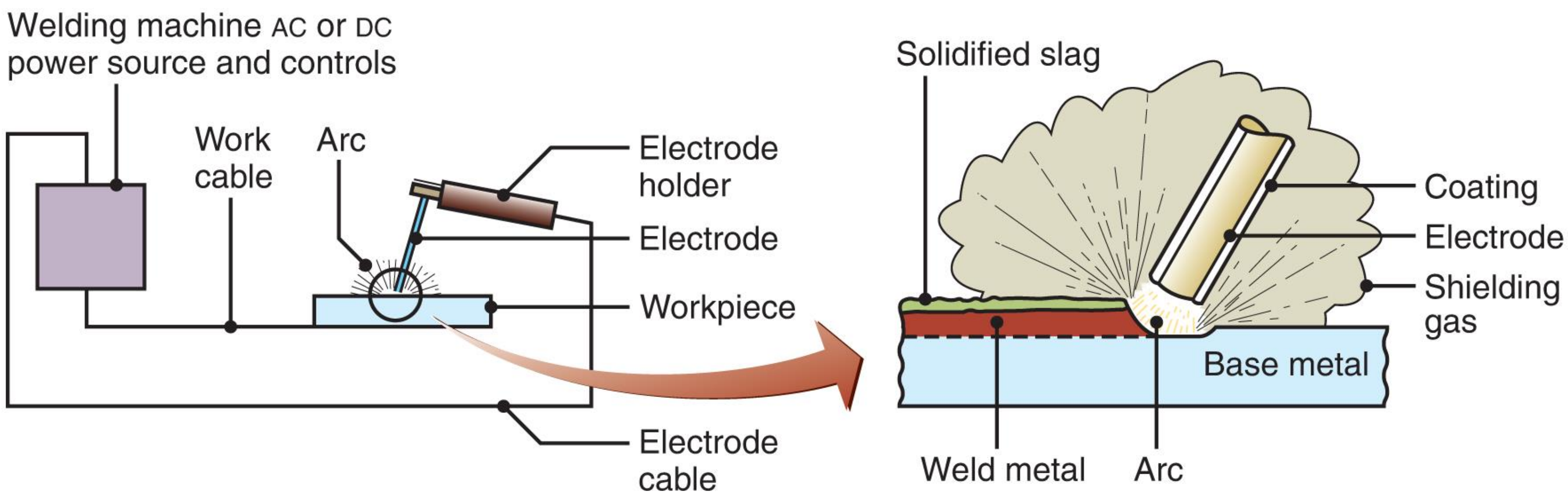


Plasma Welding

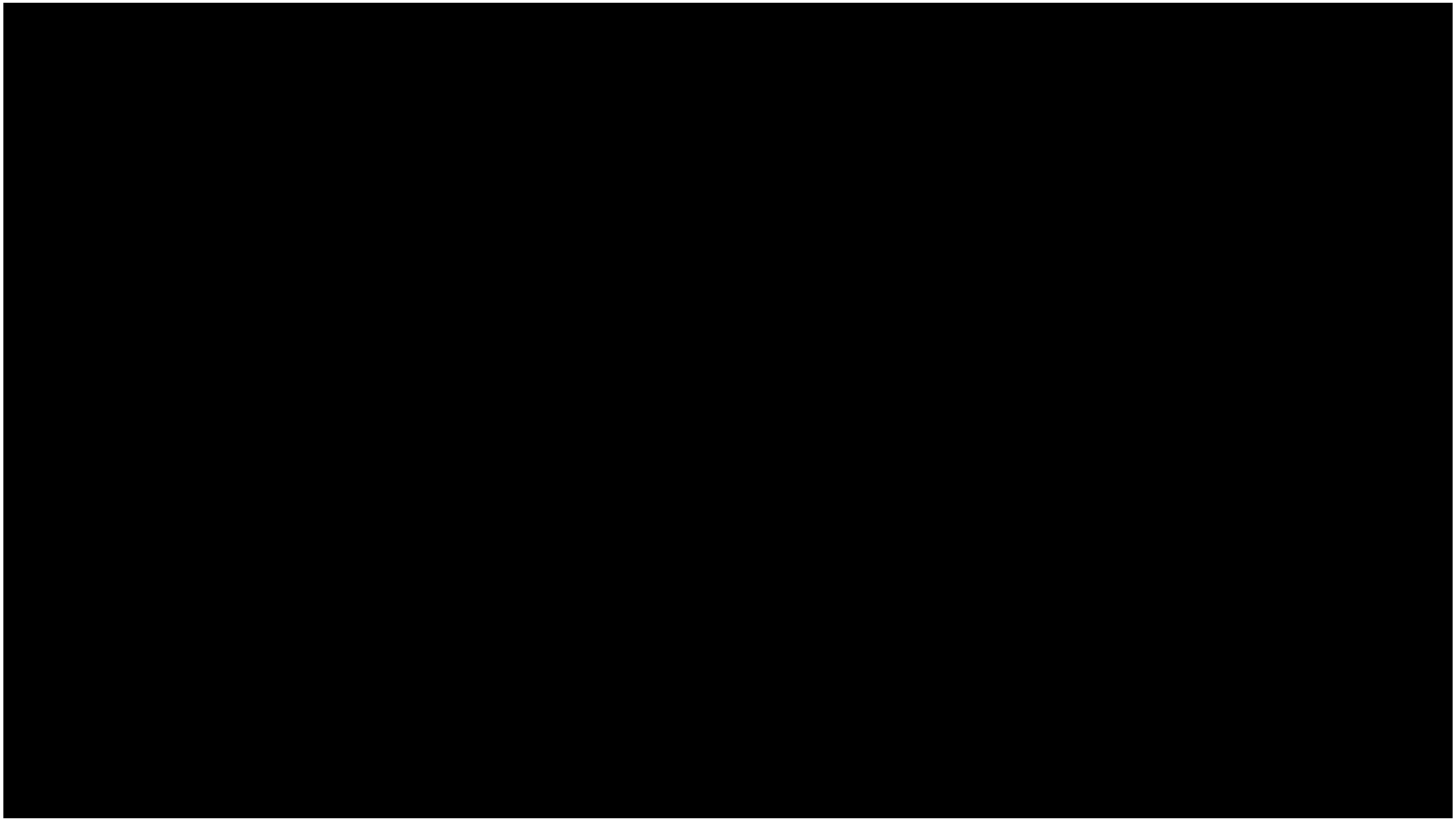
https://youtu.be/588EJInHLsc

Figure 30.8

Schematic illustration of the shielded metal-arc welding process. About 50% of all large-scale industrial-welding operations use this process.



SMAW



https://youtu.be/TeBX6cKKHWY

Figure 30.9

A deep weld showing the buildup sequence of eight individual weld beads.

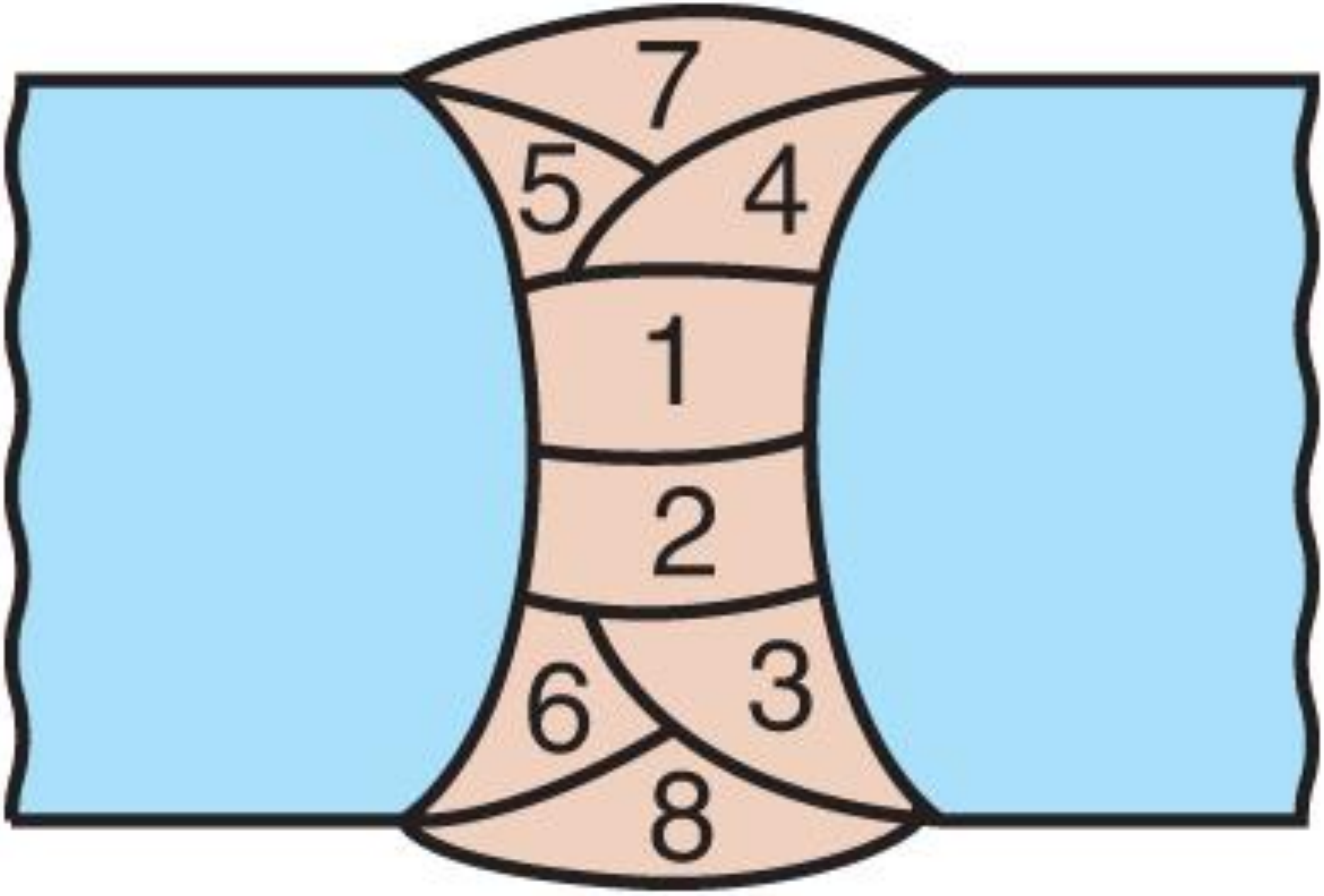
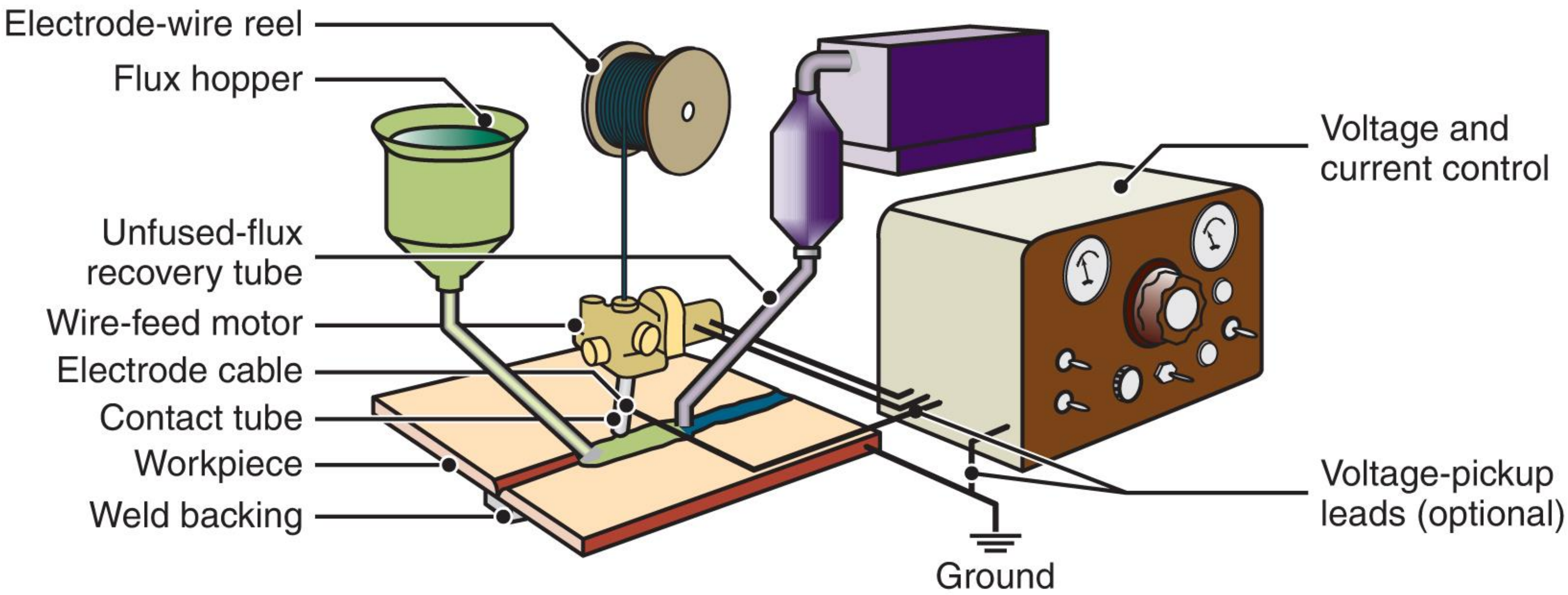
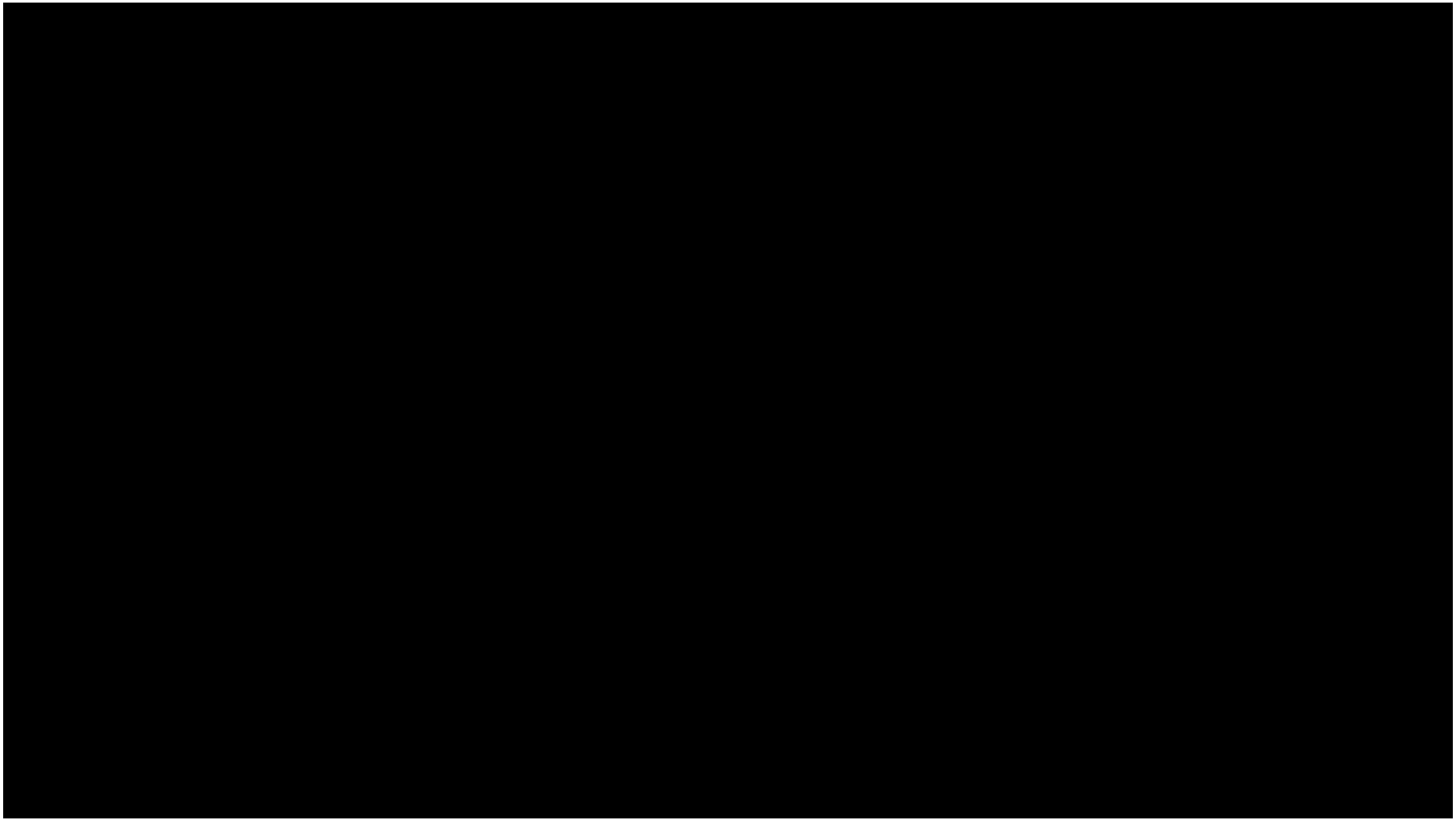


Figure 30.10

Schematic illustration of the submerged-arc welding process and equipment. The unfused flux is recovered and reused.



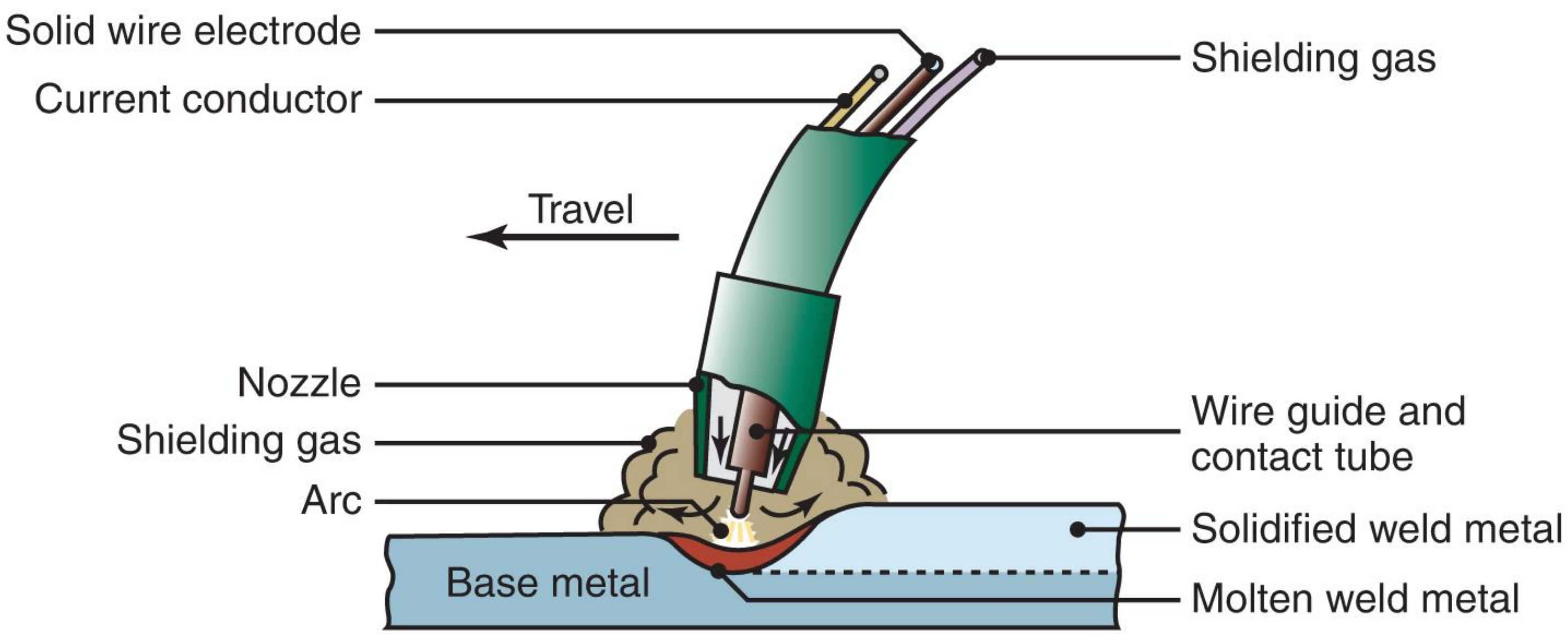
Submerged Arc Welding



https://youtu.be/Zc3Fu1AVCjc

Figure 30.11 (1 of 2)

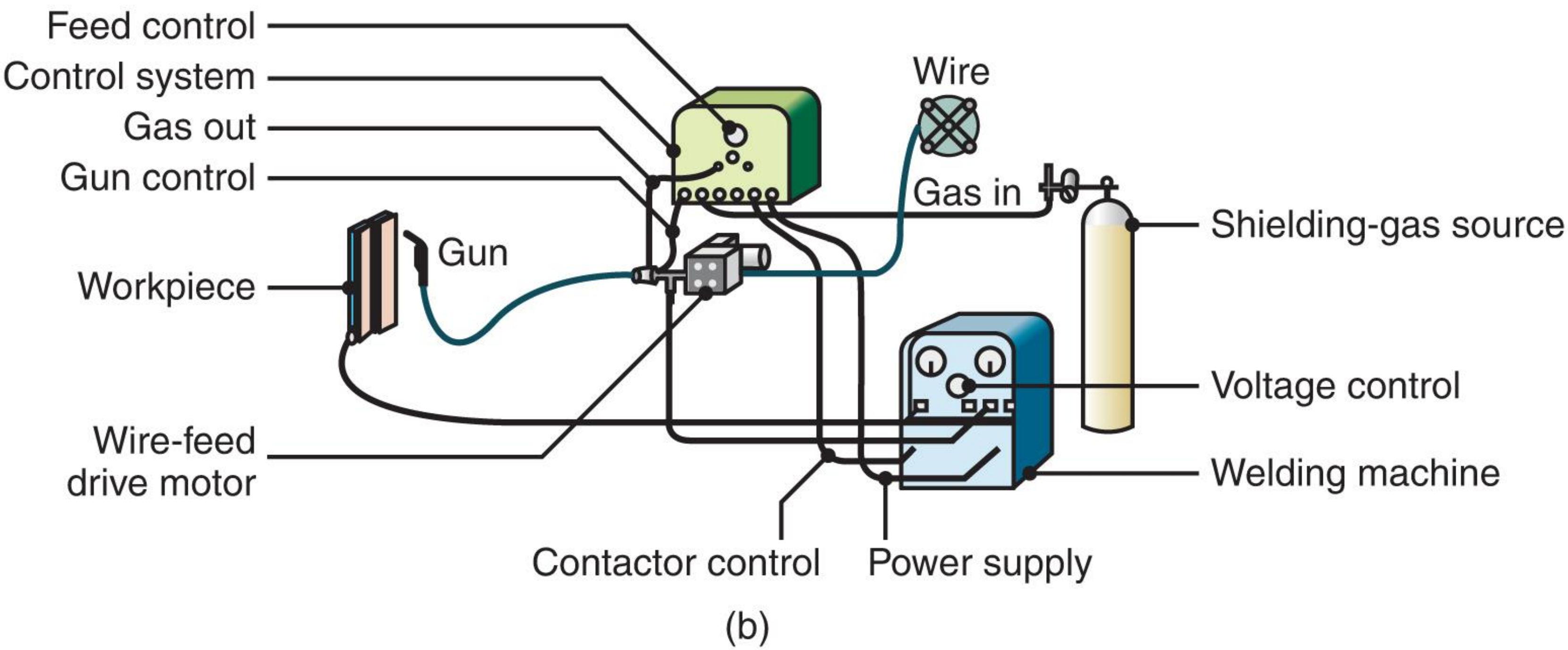
(a) Schematic illustration of the gas metal-arc welding process, formerly known as MIG (for metal inert-gas) welding.



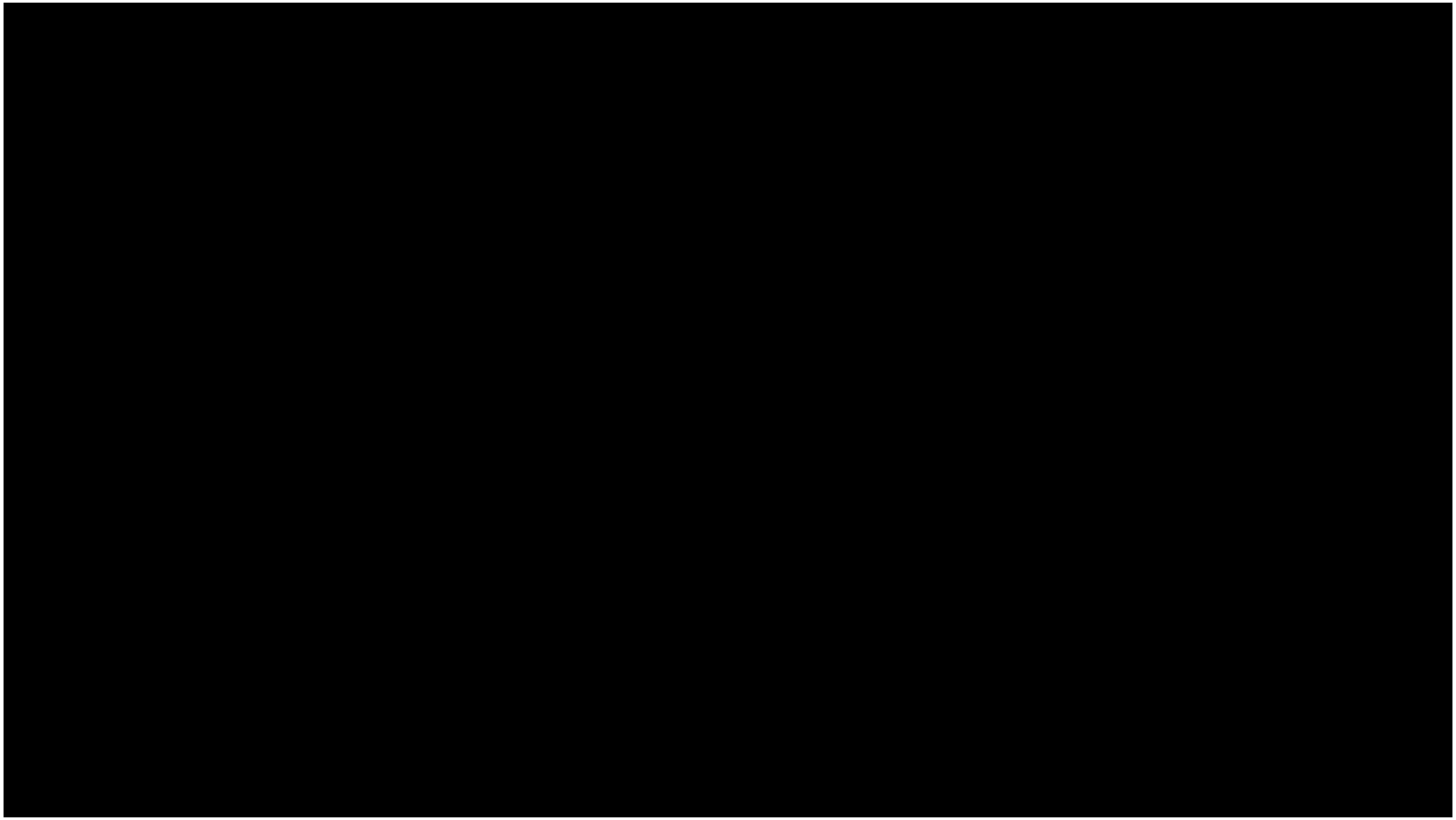
(a)

Figure 30.11 (2 of 2)

(b) Basic equipment used in gas metal-arc welding operations.



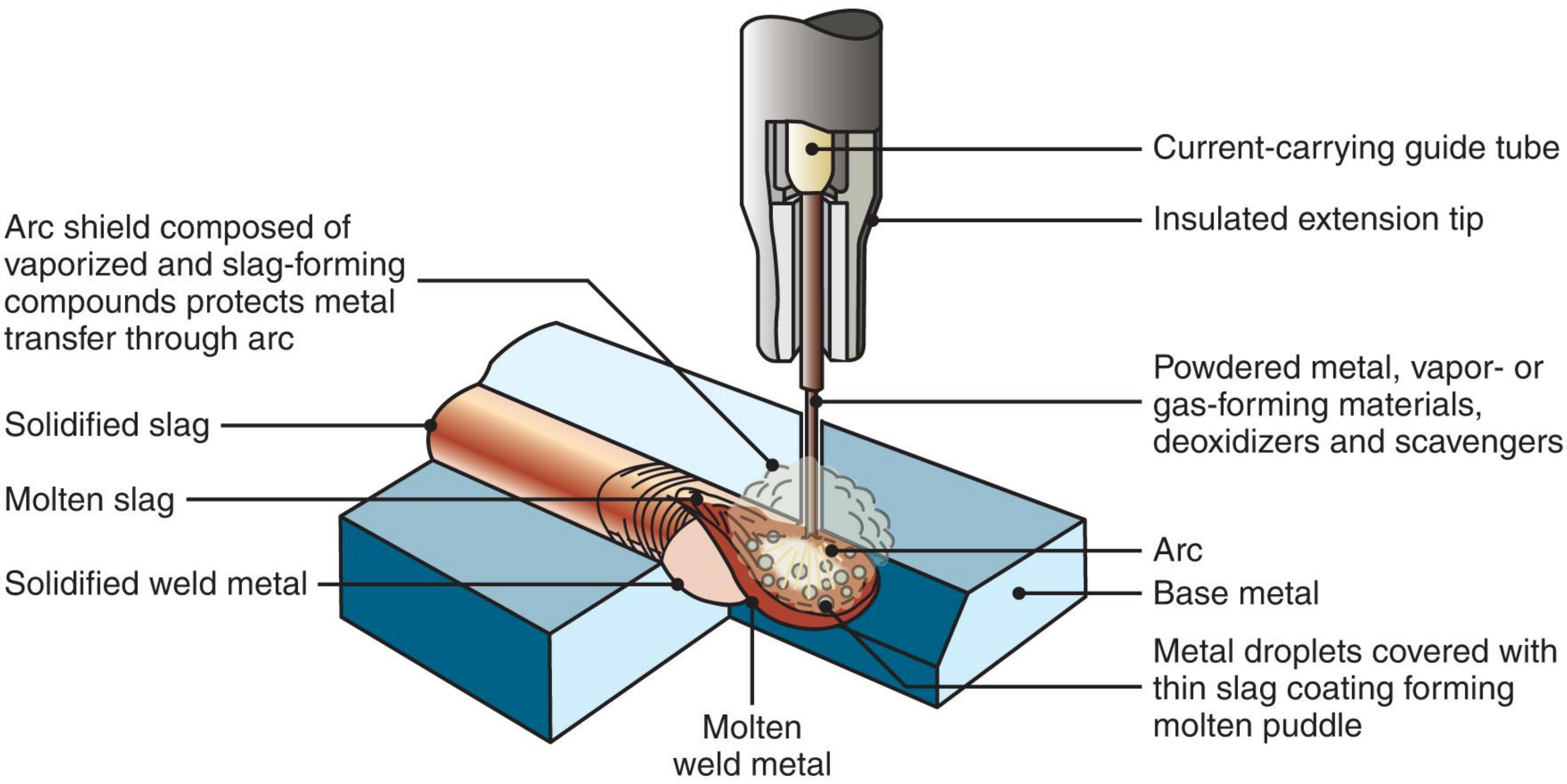
Gas Metal Arc Welding



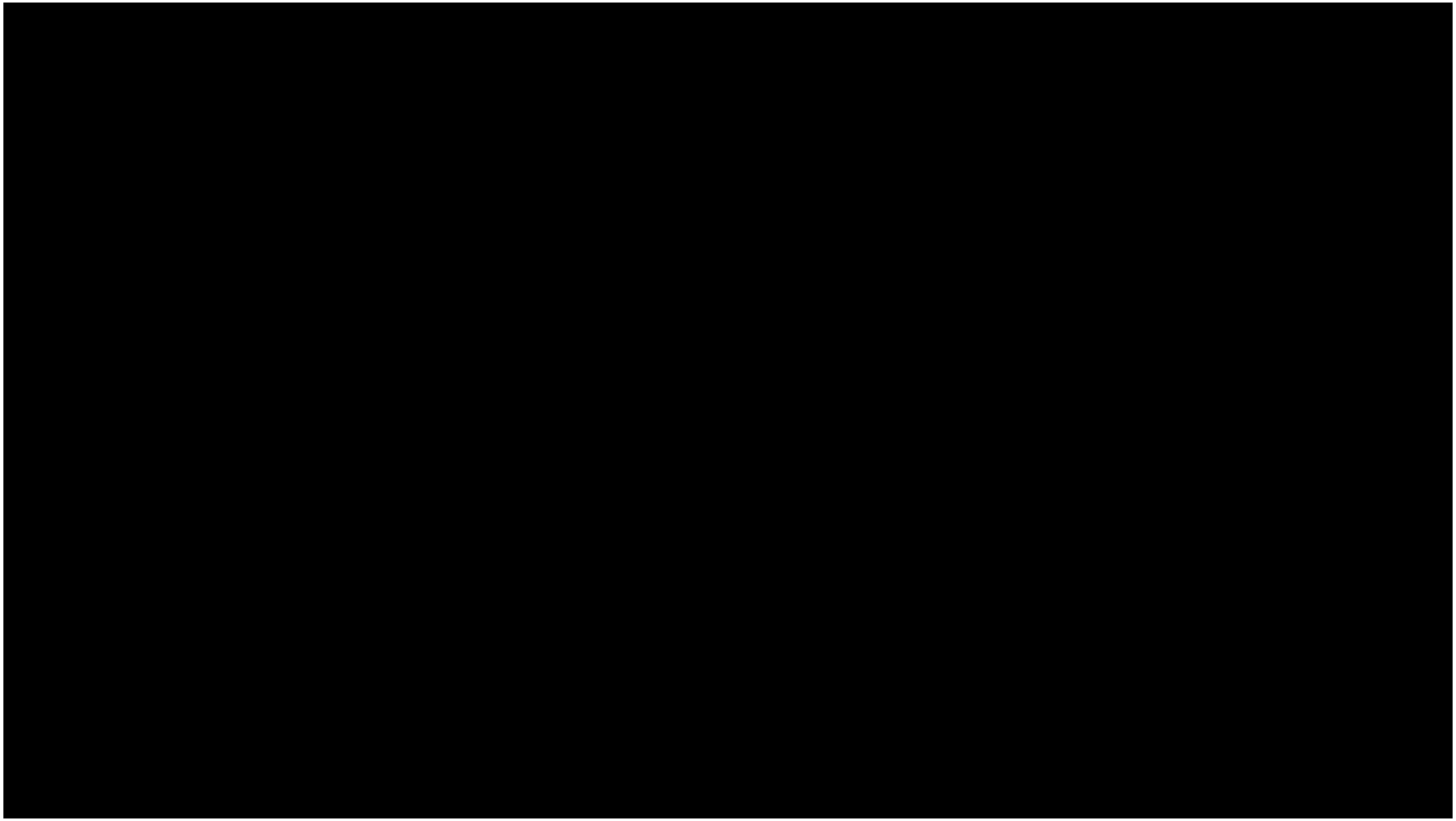
https://www.youtube.com/watch?v=eI0UE2lahV8

Figure 30.12

Schematic illustration of the flux-cored arc-welding process. This operation is similar to gas metal-arc welding, shown in Fig. 30.11.



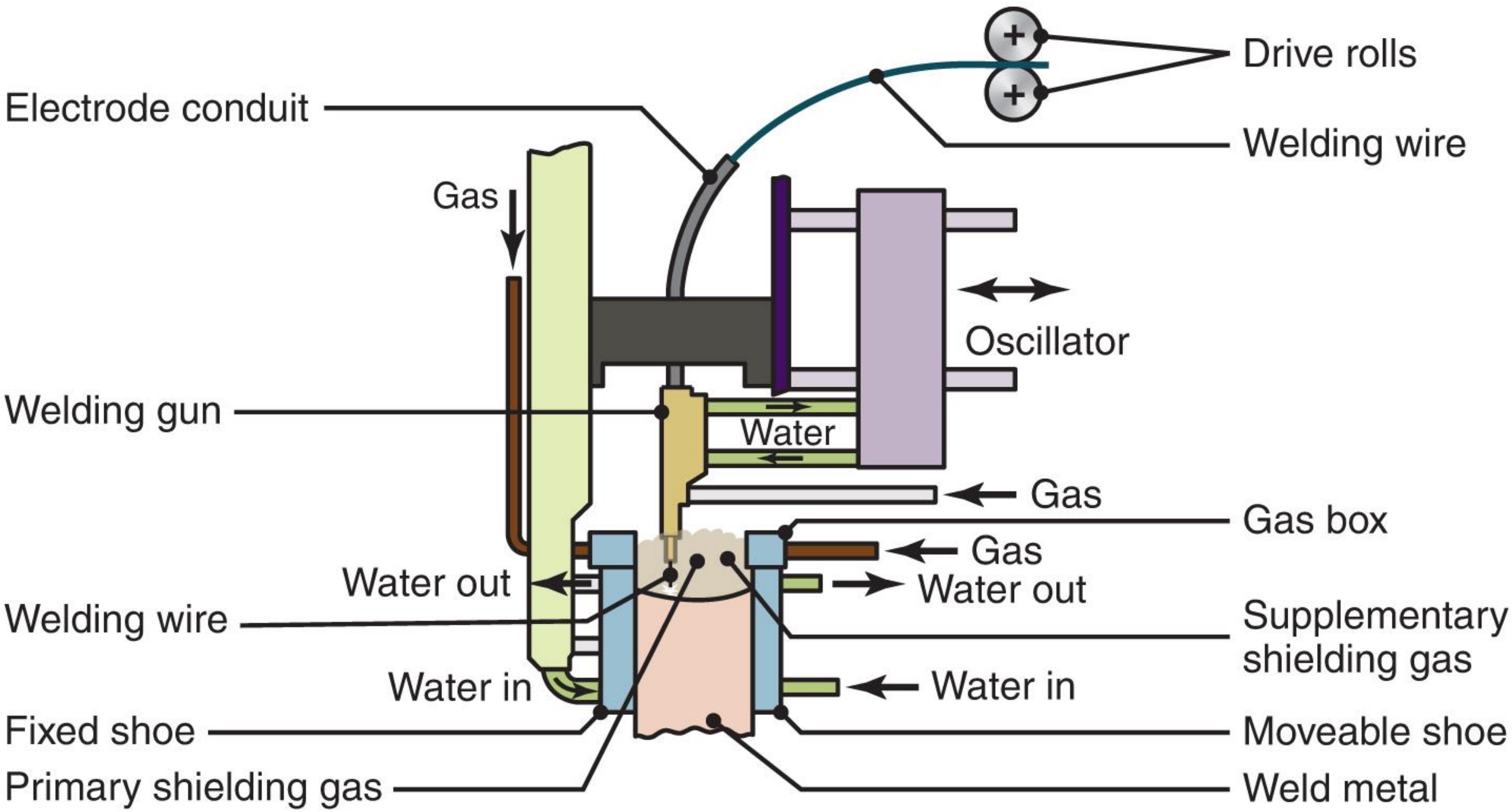
Flux Cored Arc Welding



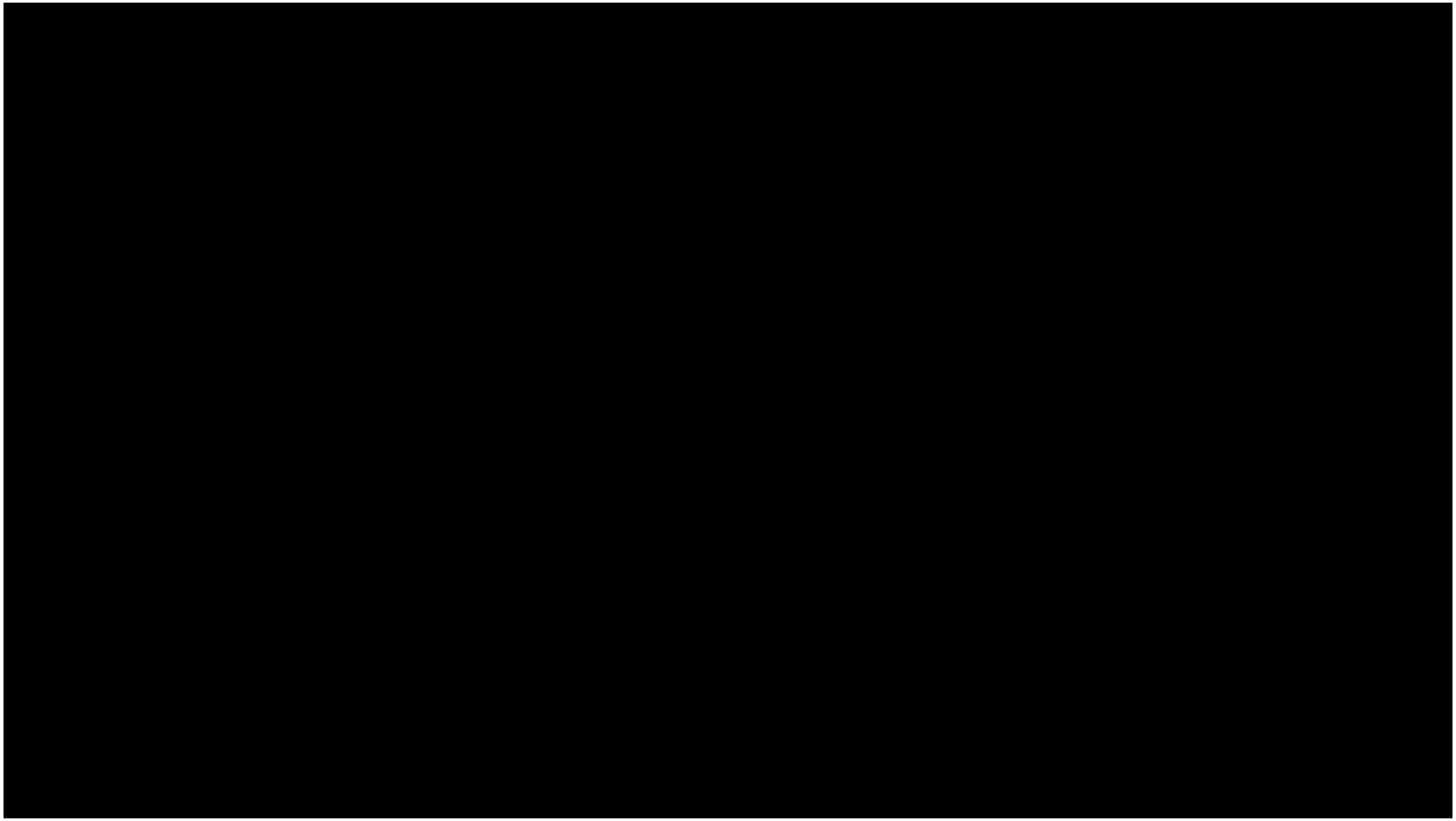
https://youtu.be/WUYQ87_o_6g

Figure 30.13

Schematic illustration of the electrogas-welding process.



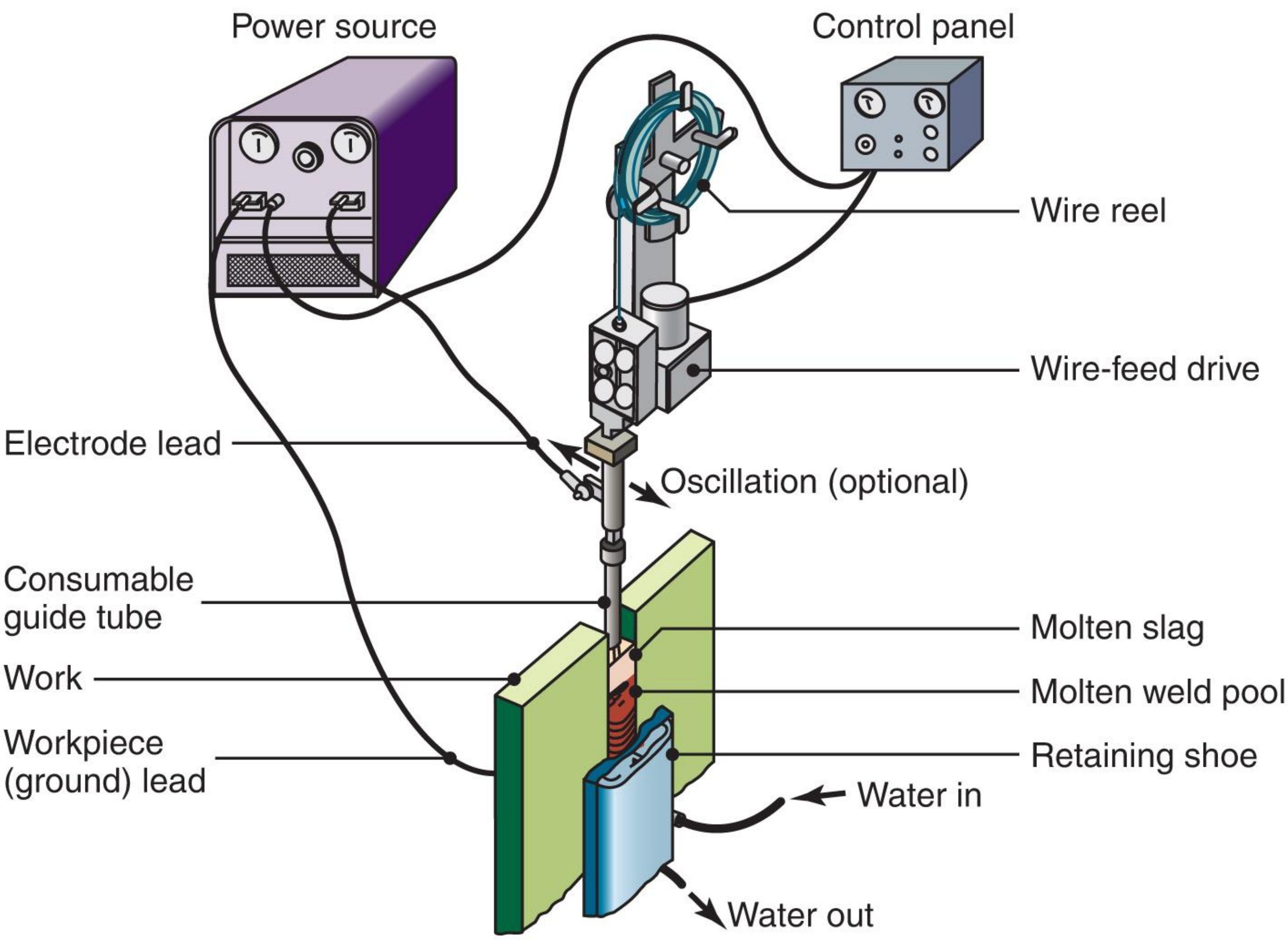
Electro-gas welding



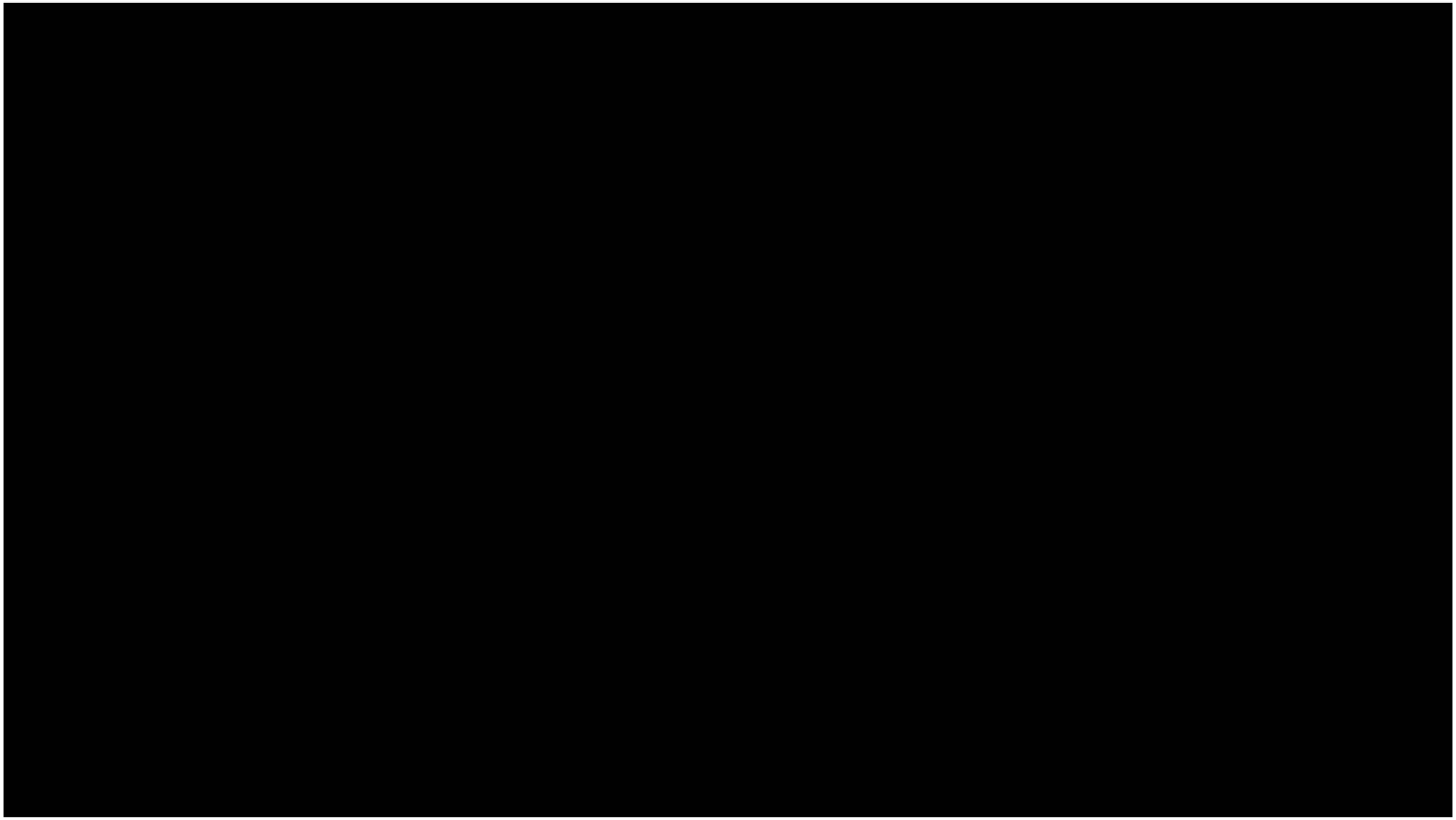
https://youtu.be/oLAGqvQyKPA

Figure 30.14

Equipment used for electroslag-welding operations.



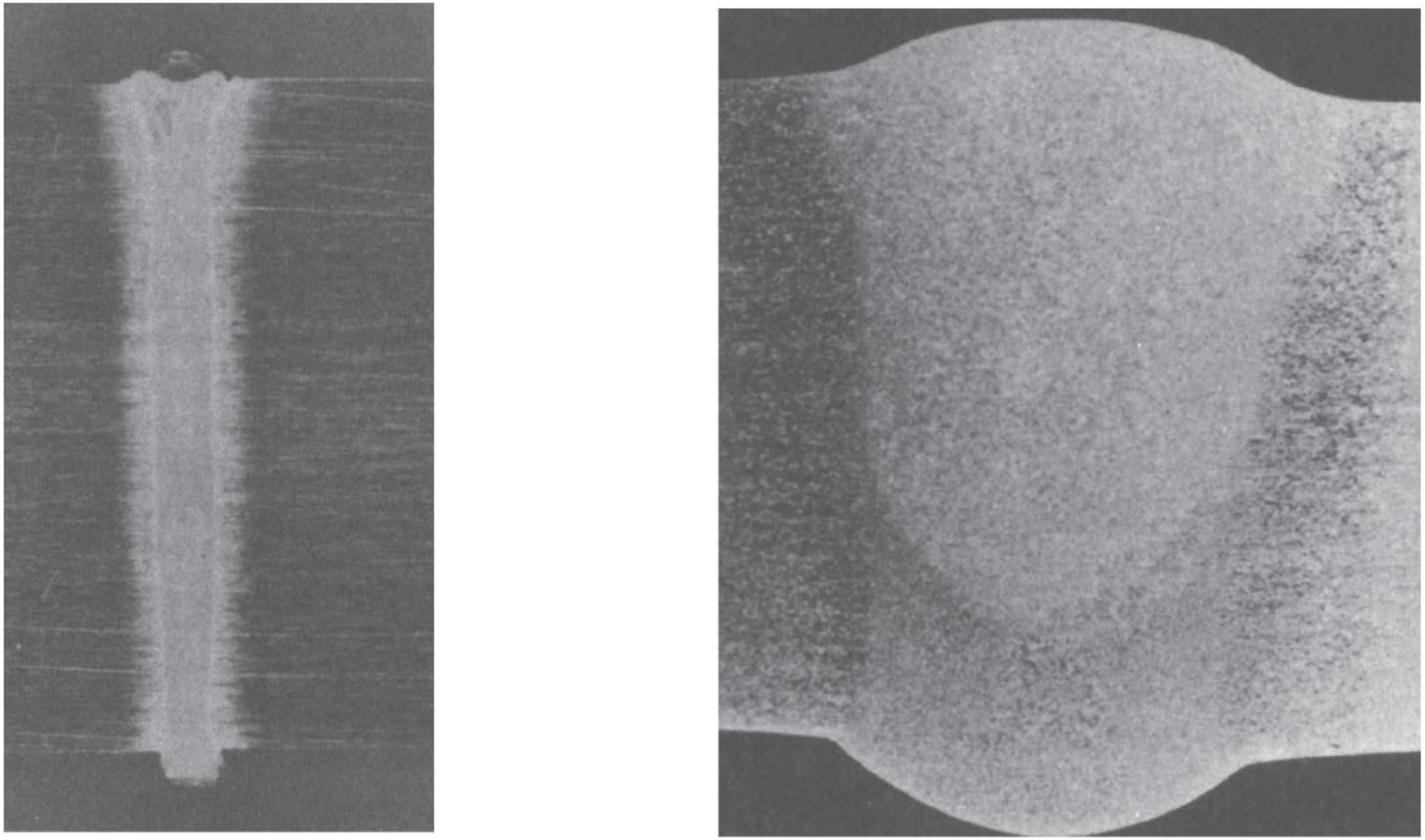
Electro-slag welding



https://youtu.be/IfkVKP7YSdk

Figure 30.15

Comparison of the sizes of weld beads: (a) laser-beam or electron-beam welding, (b) tungsten-arc welding



(a) (b)

Figure 30.16

Detail of razor cartridge, showing laser spot welds.

Source: Shutterstock/All About Space.

Figure 30.19

Characteristics of a typical fusion-weld zone in oxyfuel–gas and arc welding.

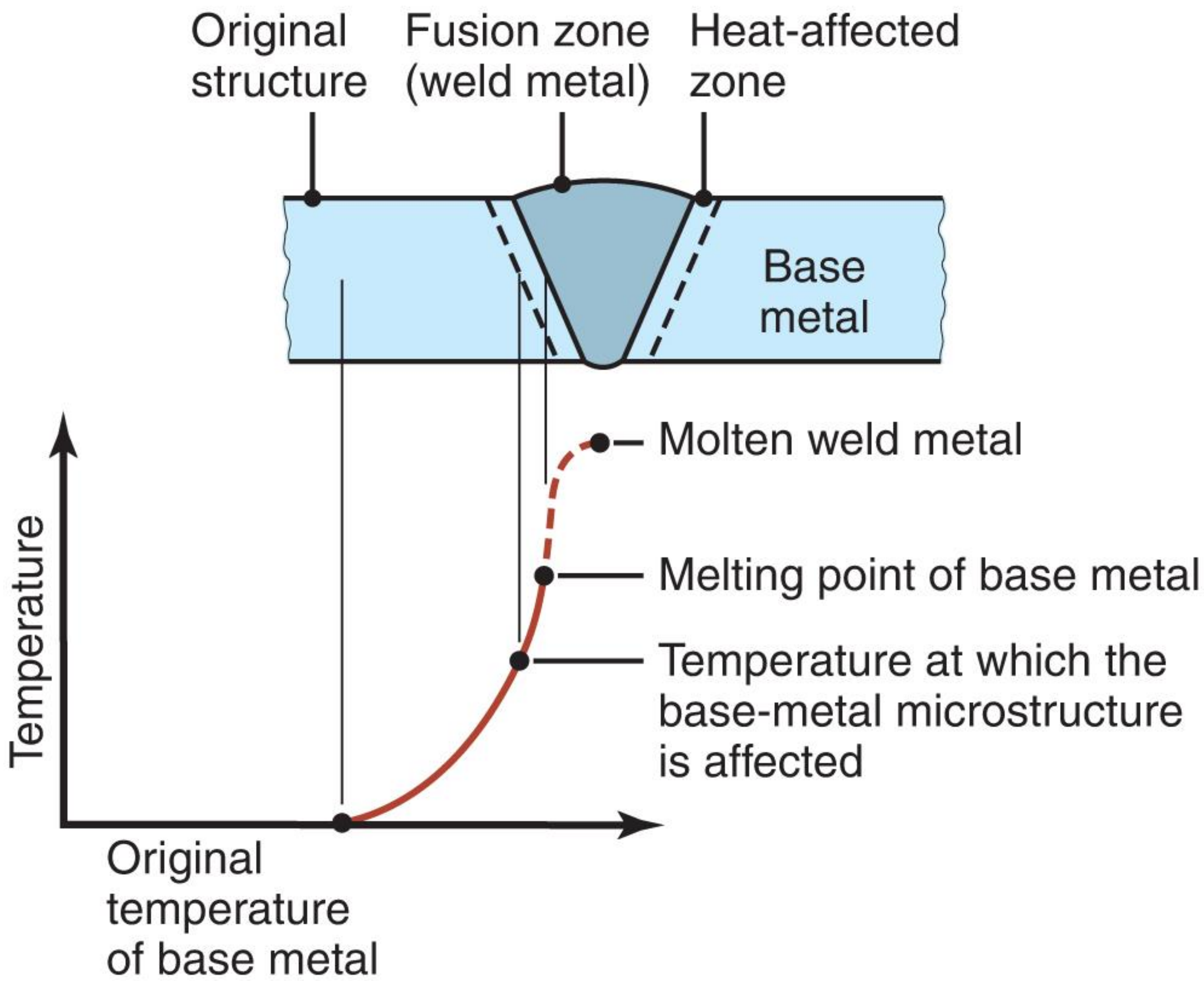


Figure 30.20

Grain structure in (a) a deep weld; (b) a shallow weld. Note that the grains in the solidified weld metal are perpendicular to their interface with the base metal; (c) Weld bead on a cold-rolled nickel strip produced by a laser beam; (d) Microhardness (HV) profile across a weld bead

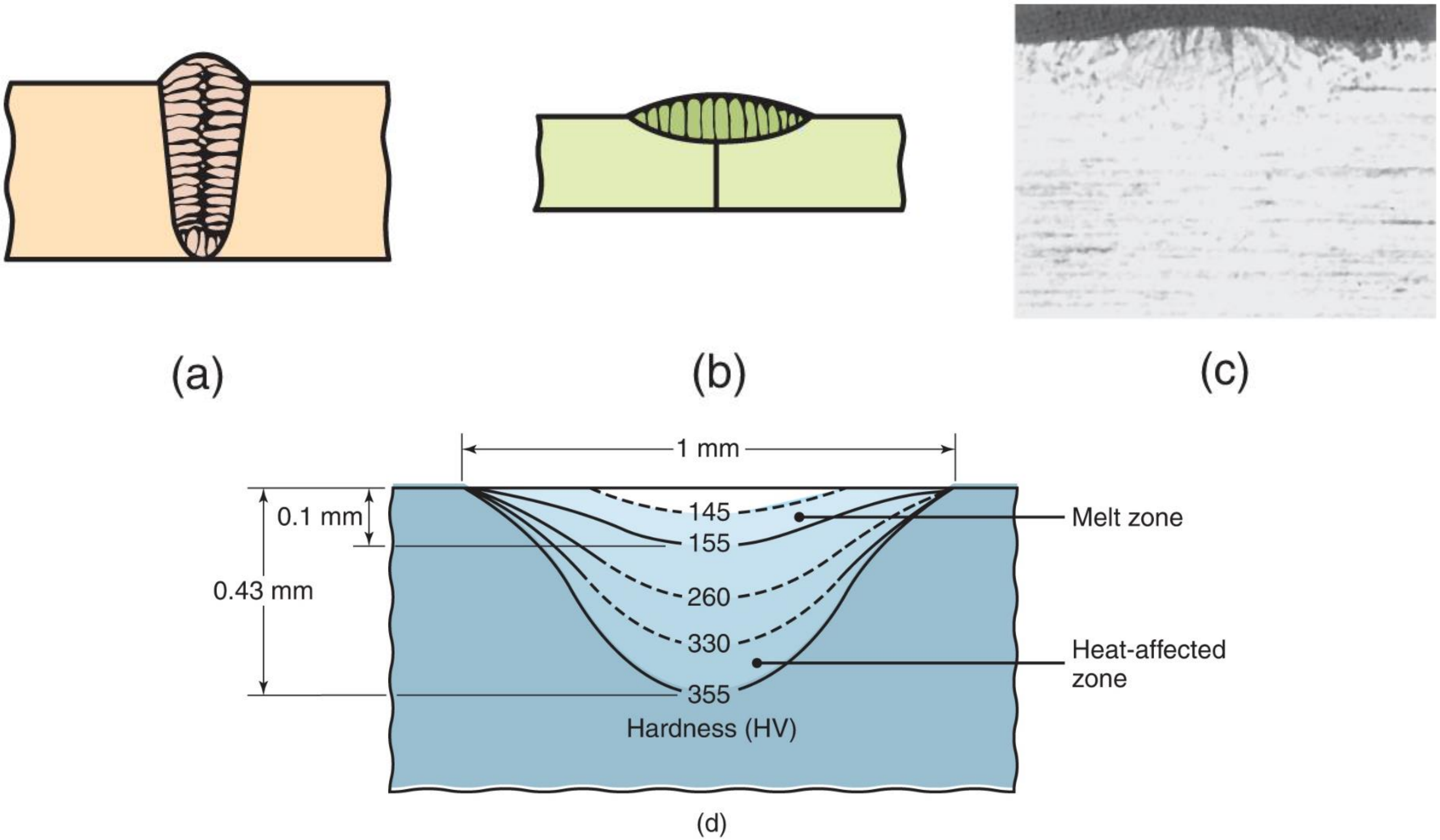


Figure 30.21 (1 of 3)

Examples of various discontinuities in fusion welds.

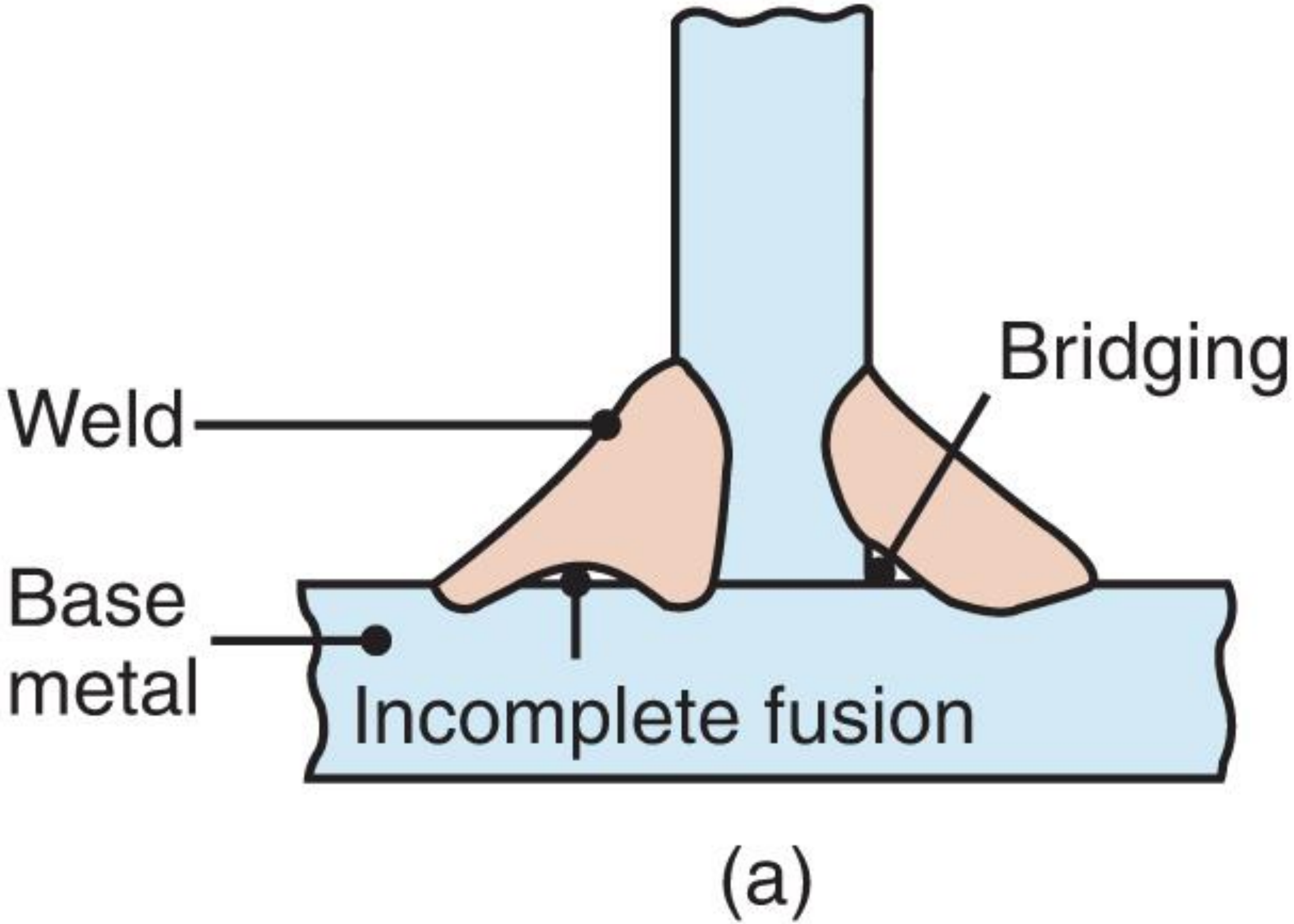
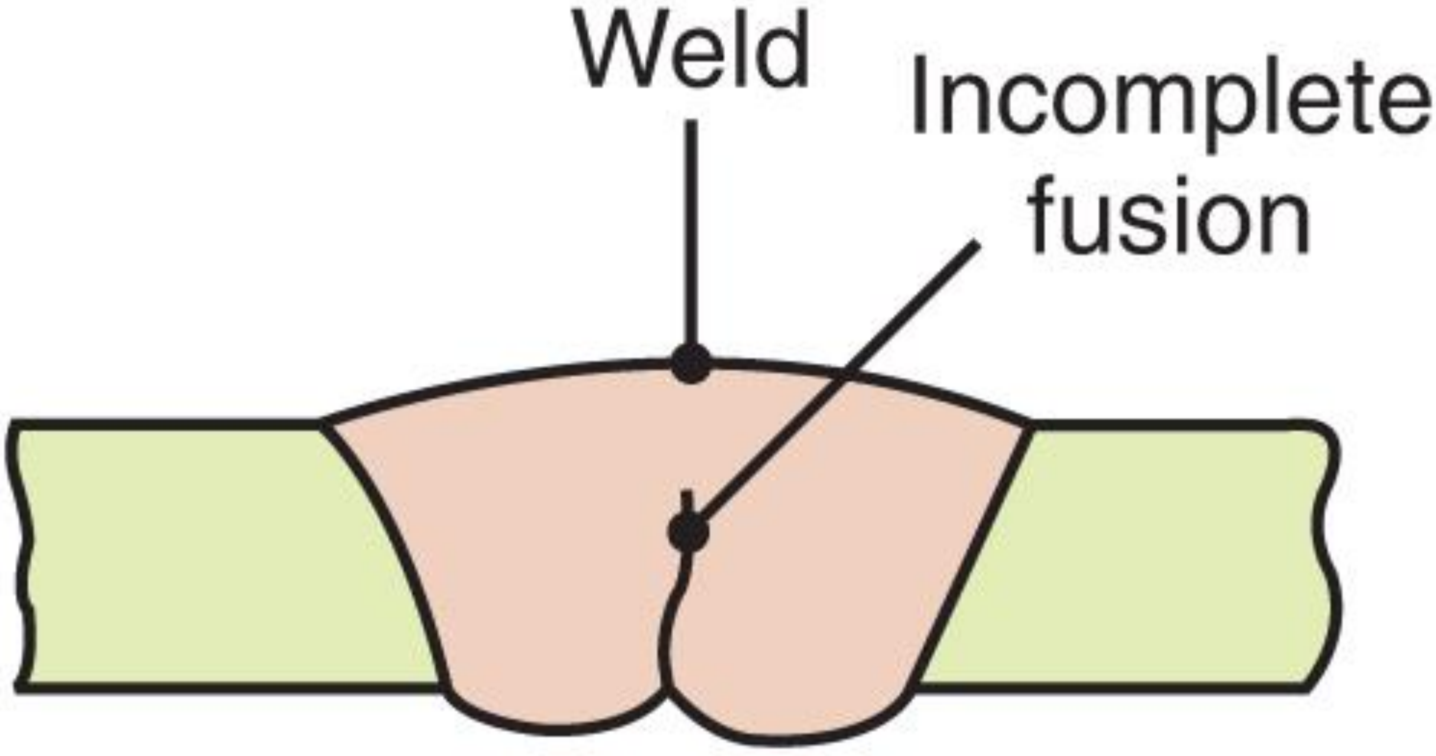
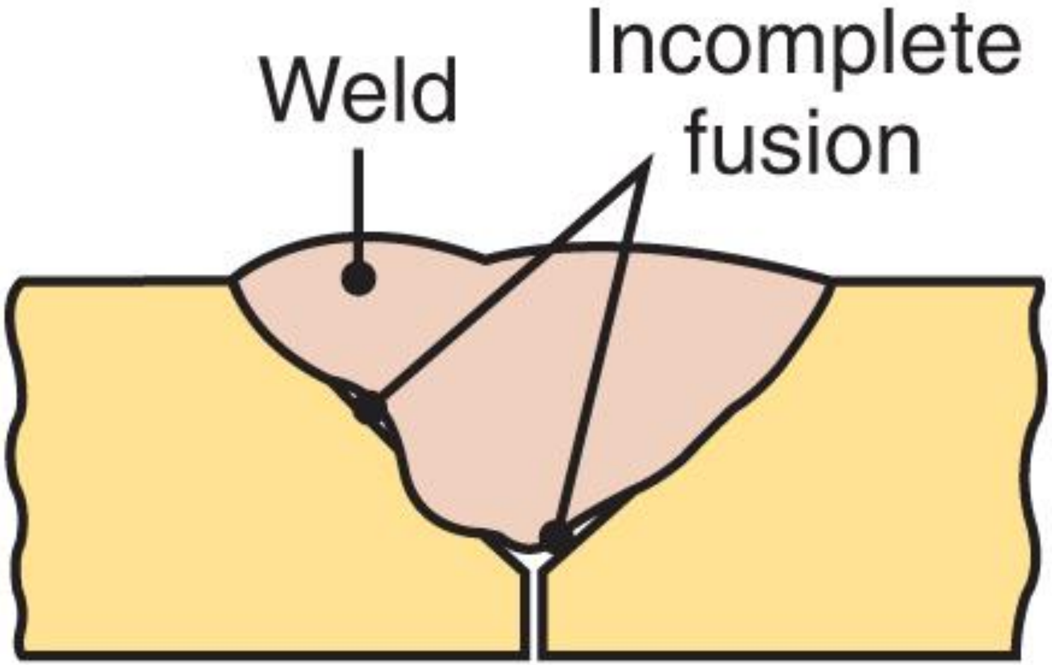


Figure 30.21 (2 of 3)



(b)

Figure 30.21 (3 of 3)



(c)

Figure 30.22 (1 of 3)

Examples of various defects in fusion welds.

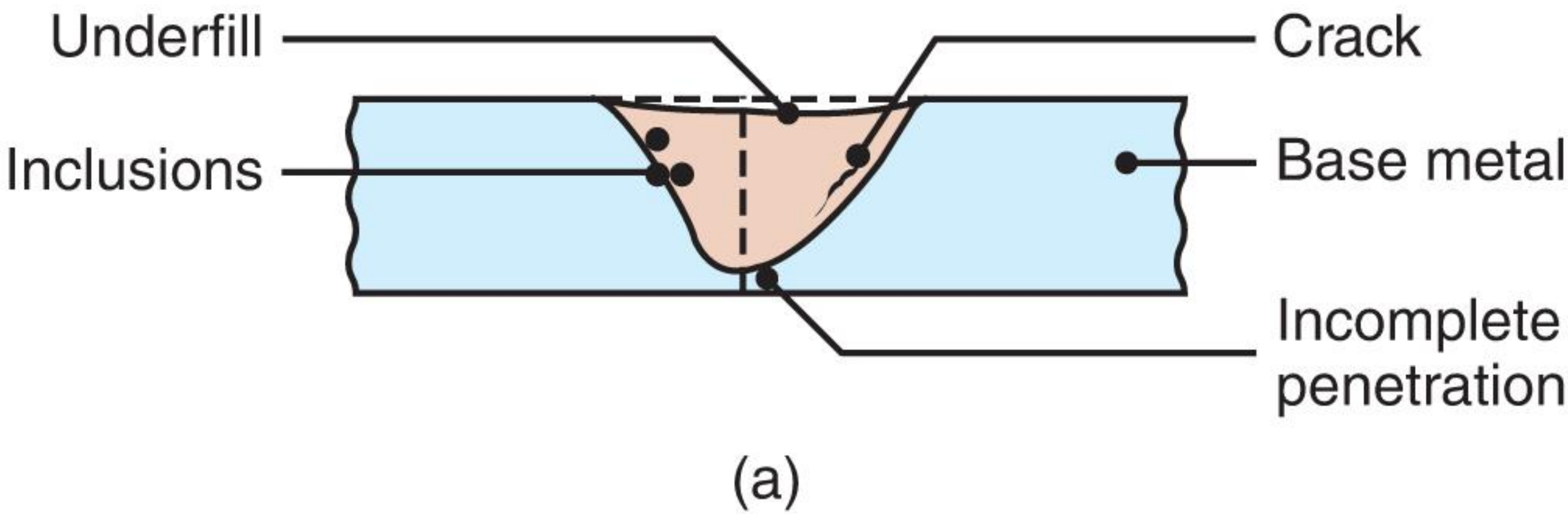
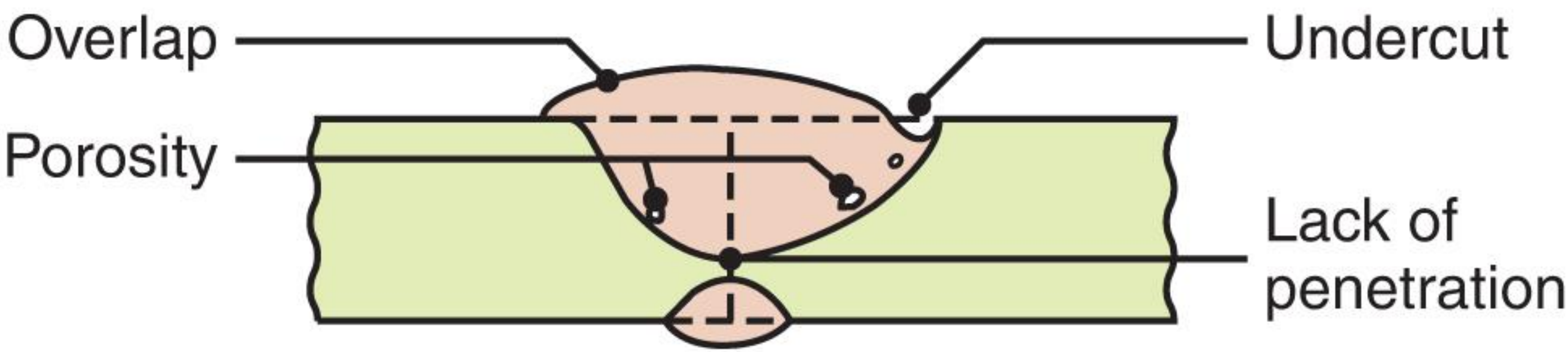


Figure 30.22 (2 of 3)



(b)

Figure 30.22 (3 of 3)

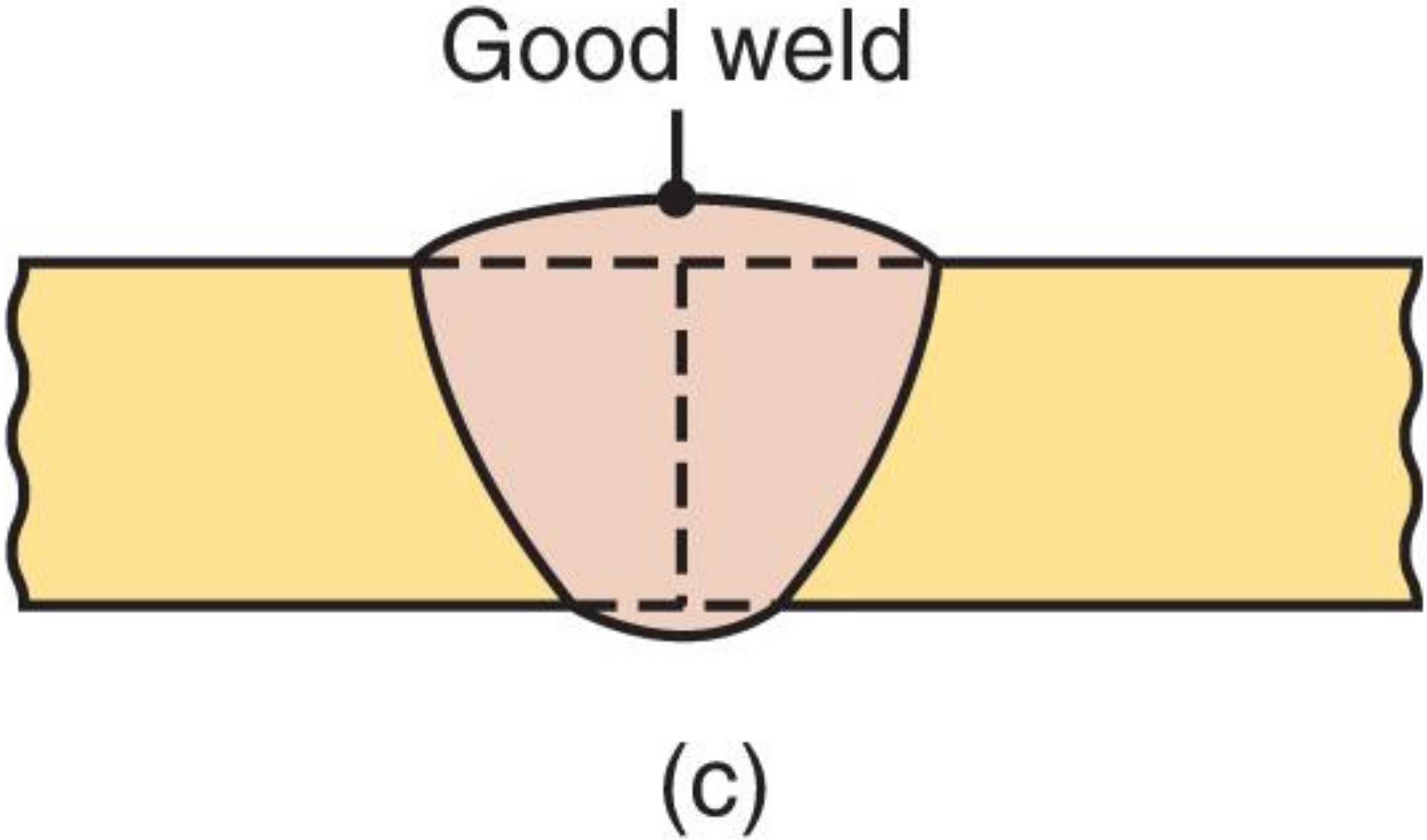
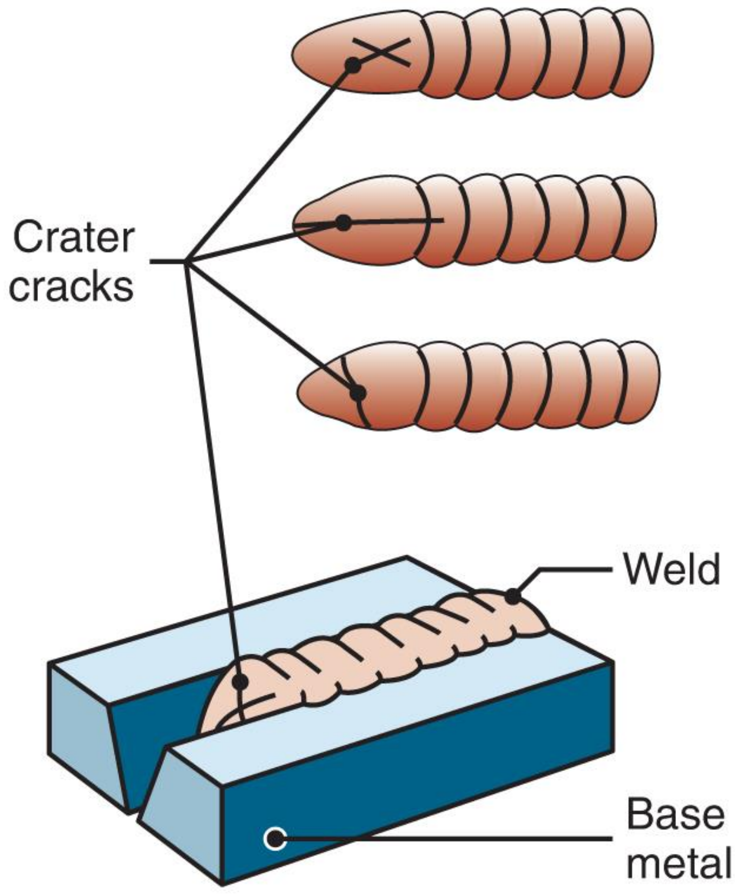


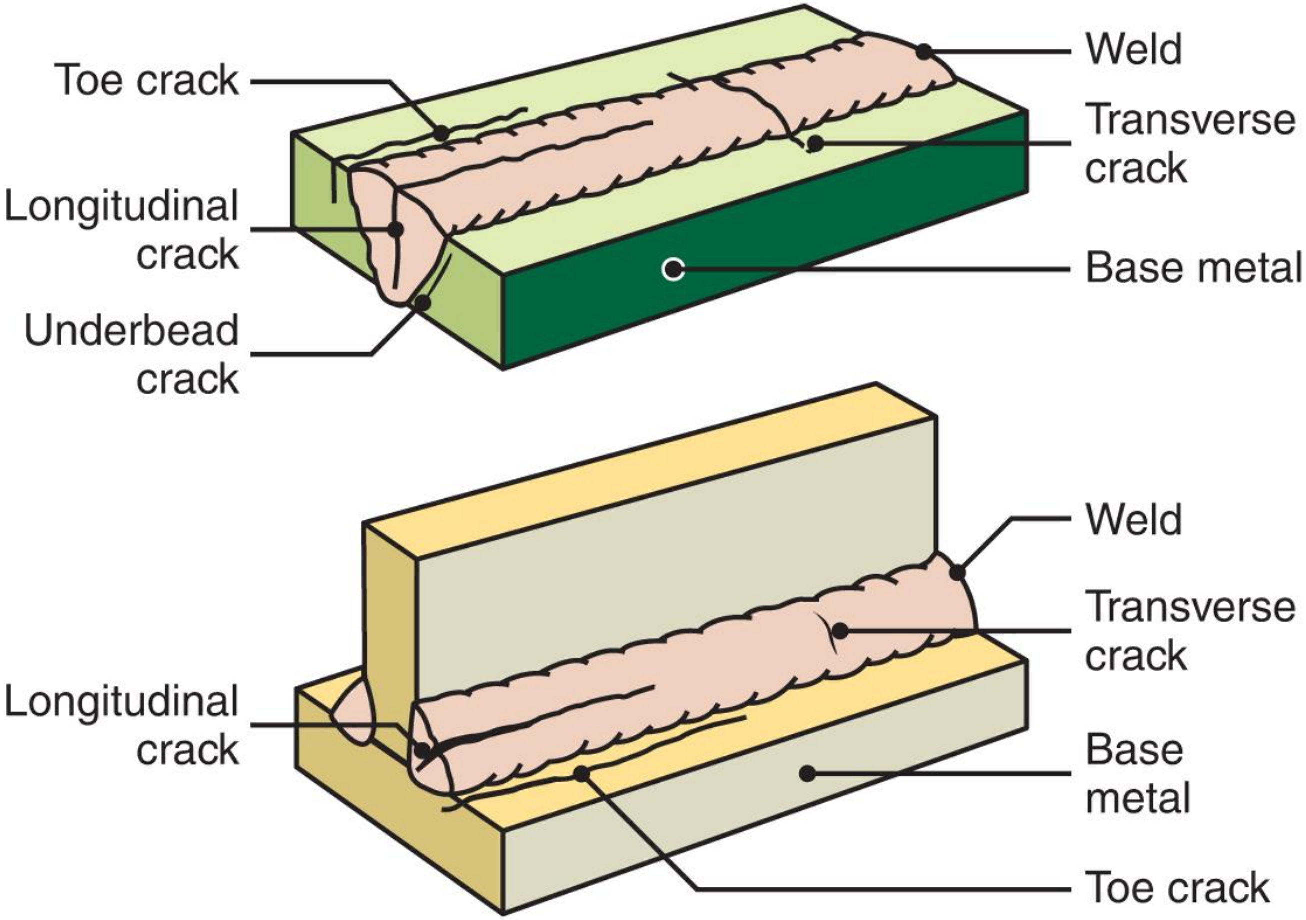
Figure 30.23 (1 of 2)

Types of cracks developed in welded joints. The cracks are caused by thermal stresses, similar to the development of hot tears in castings, as shown in Fig. 10.14.



(a)

Figure 30.23 (2 of 2)



(b)

Figure 30.24

Crack in a weld bead. The two welded components were not allowed to contract freely after the weld was completed.

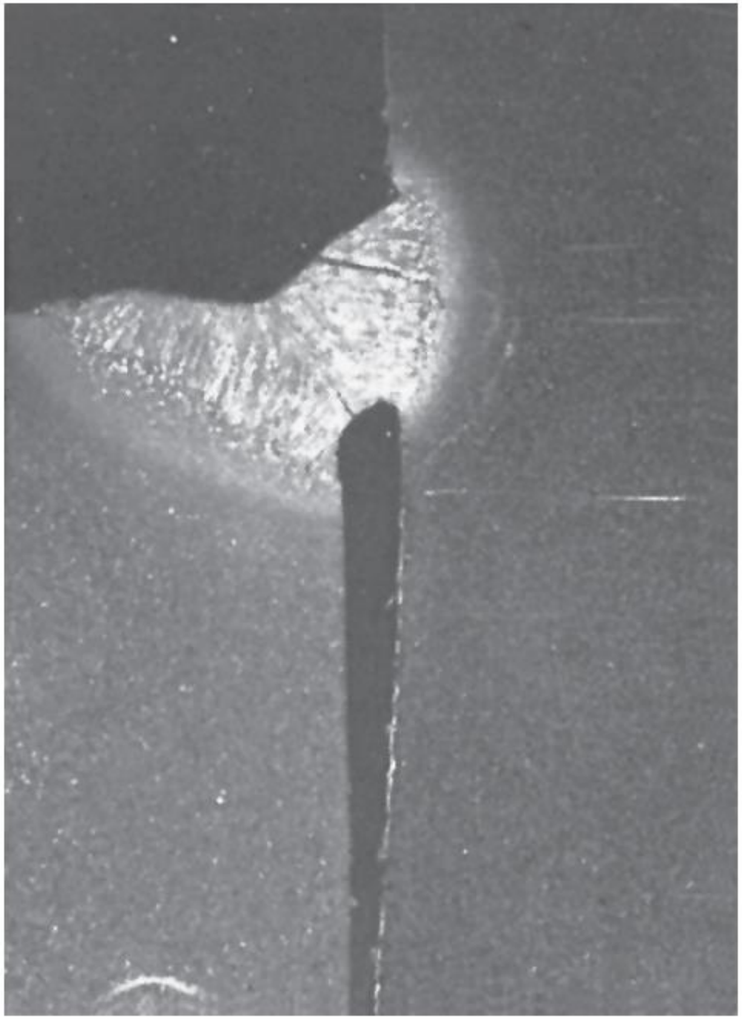
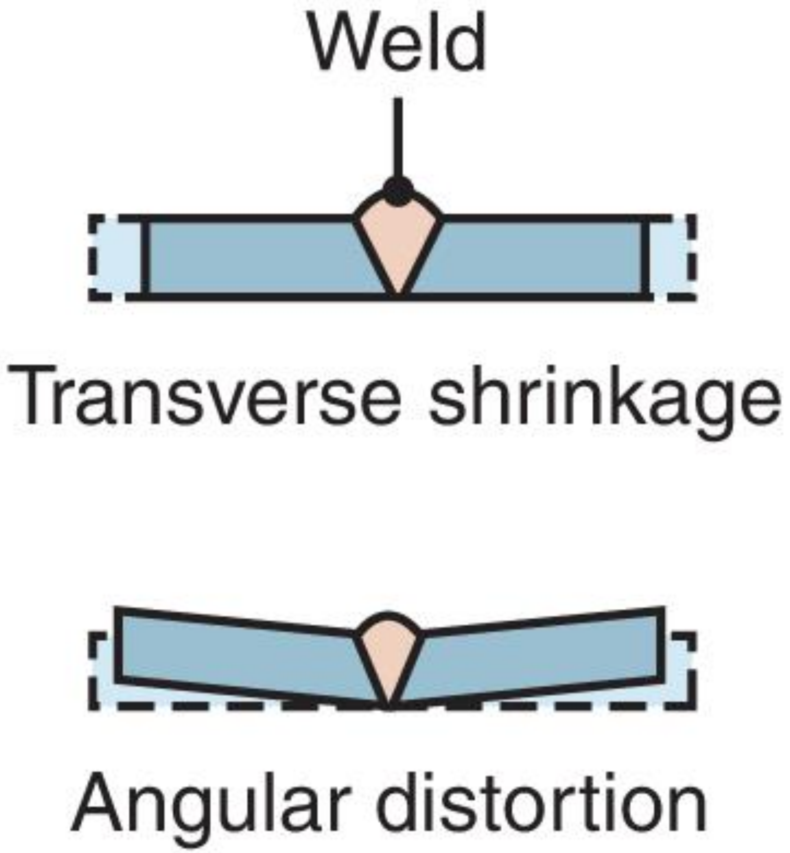


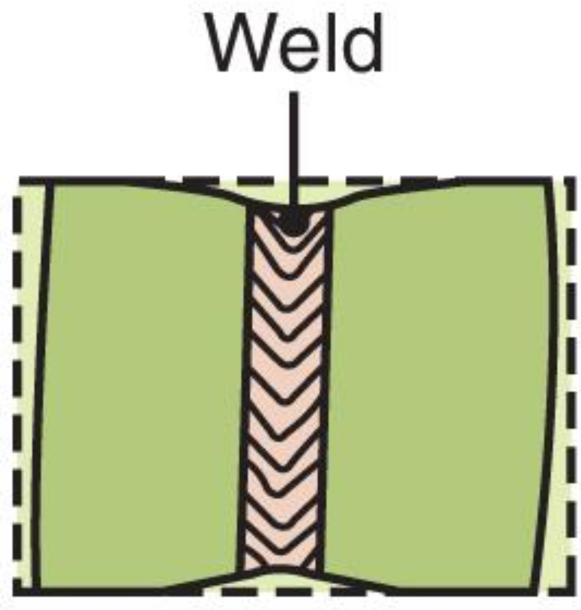
Figure 30.25 (1 of 4)

Distortion of parts after welding. Distortion is caused by differential thermal expansion and contraction of different regions of the welded assembly.



(a)

Figure 30.25 (2 of 4)

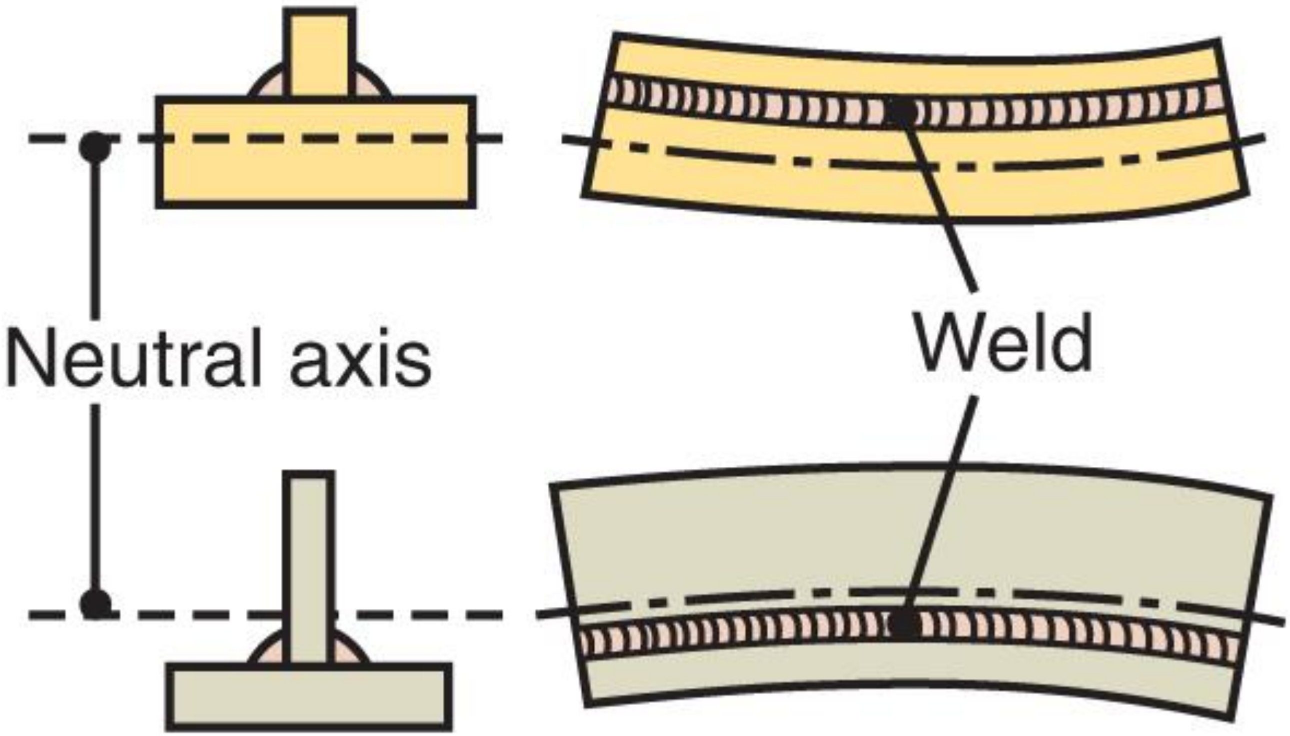


Longitudinal shrinkage
(b)

Figure 30.25 (3 of 4)

(c)

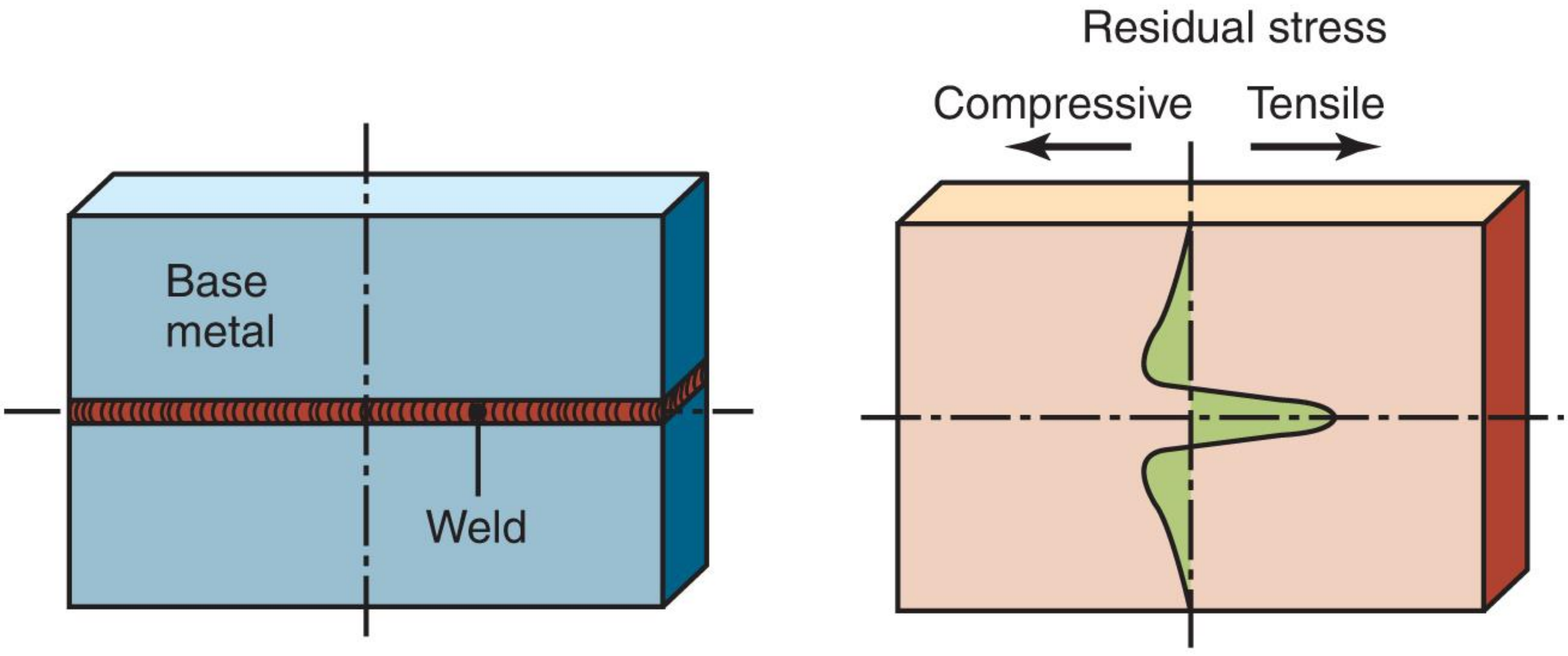
Figure 30.25 (4 of 4)



(d)

Figure 30.26

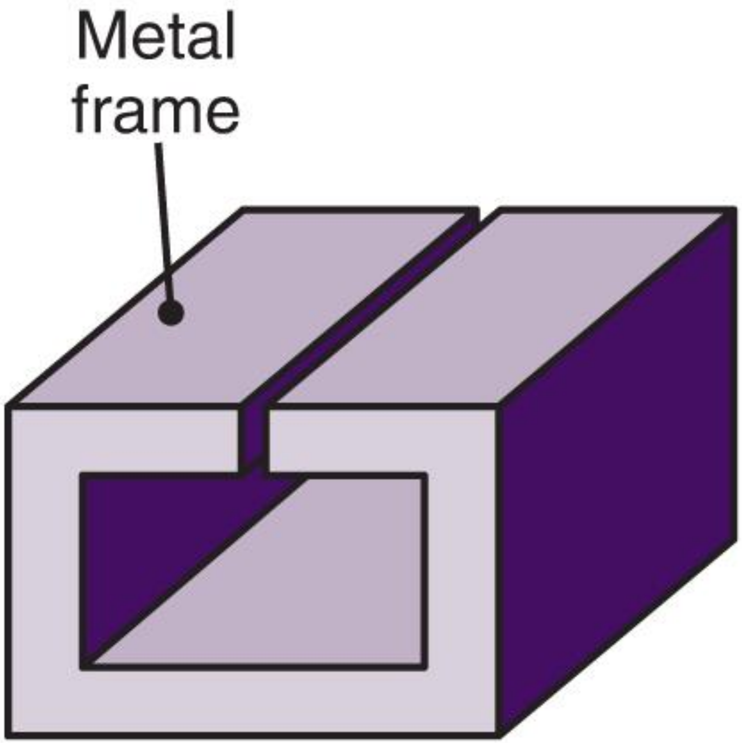
Residual stresses developed in (a) a straight-butt joint; note that the residual stresses shown in (b) must be balanced internally (see also Fig. 2.30.)



(a) (b)

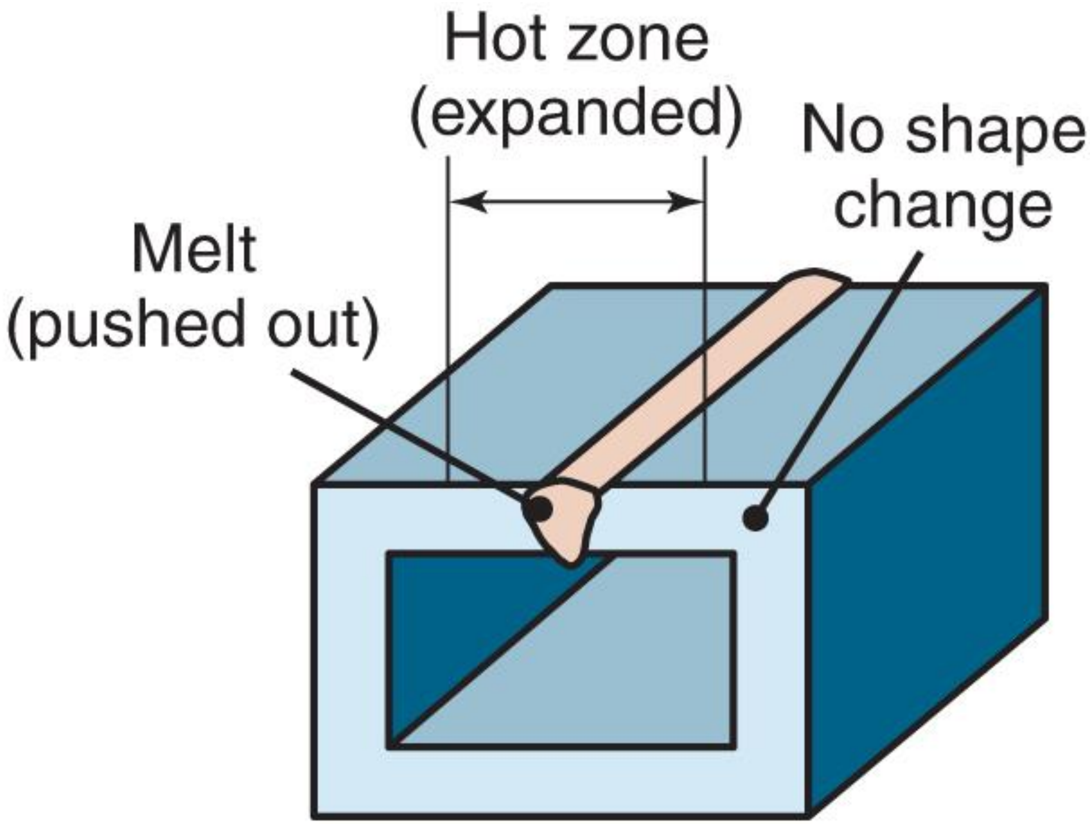
Figure 30.27 (1 of 3)

Distortion of a welded structure.



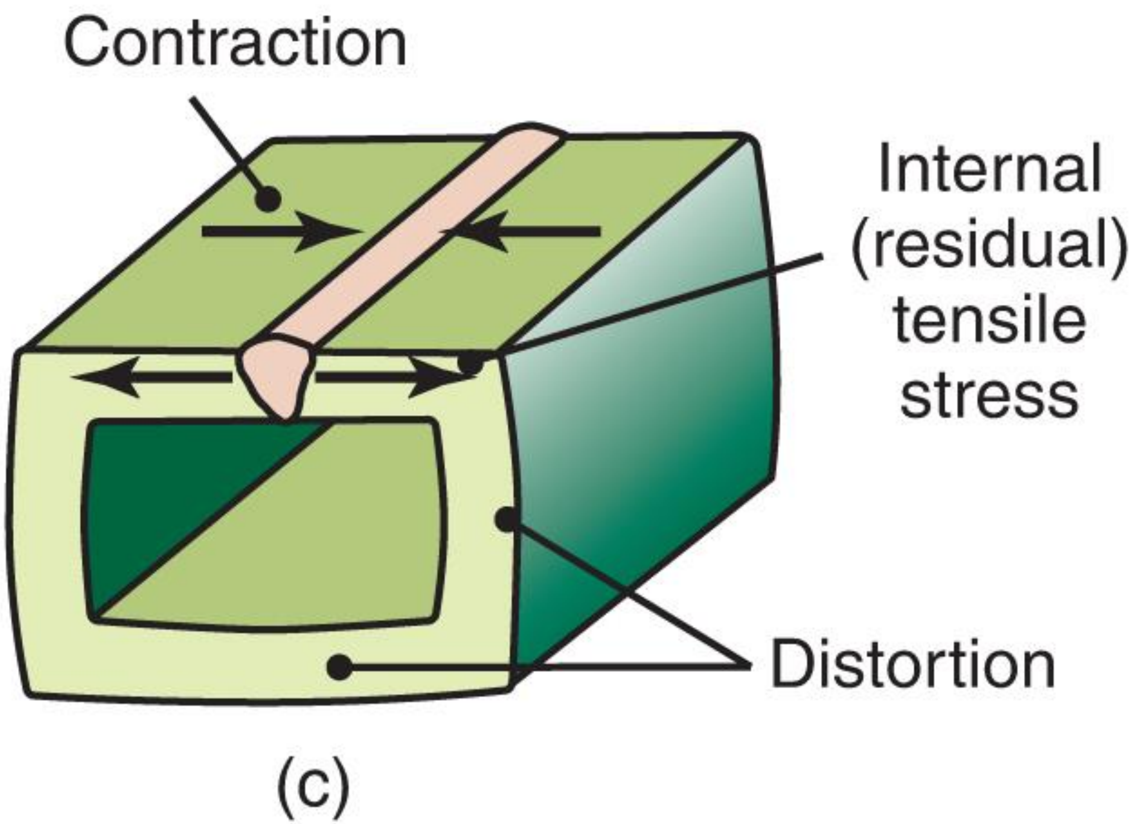
(a)

Figure 30.27 (2 of 3)



(b)

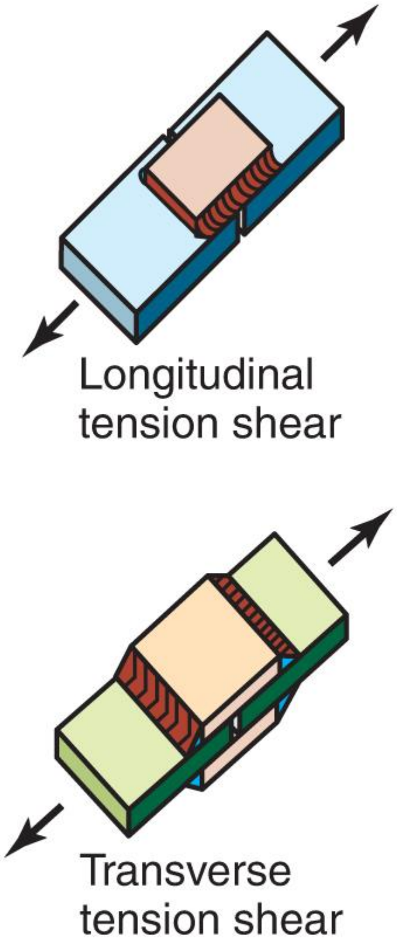
Figure 30.27 (3 of 3)



Source: After J.A. Schey.

Figure 30.28 (1 of 3)

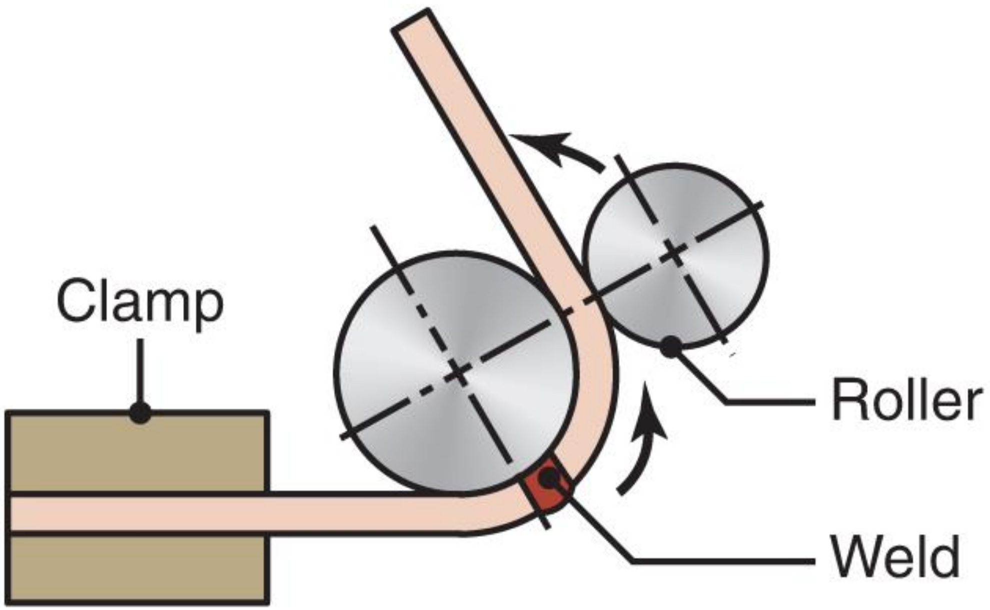
(a) Specimens for longitudinal tension-shear testing and for transfer tension-shear testing.



(a)

Figure 30.28 (2 of 3)

(b) Wraparound bend-test method.



(b)

Figure 30.28 (3 of 3)

(c) Three-point transverse bending of welded specimens.

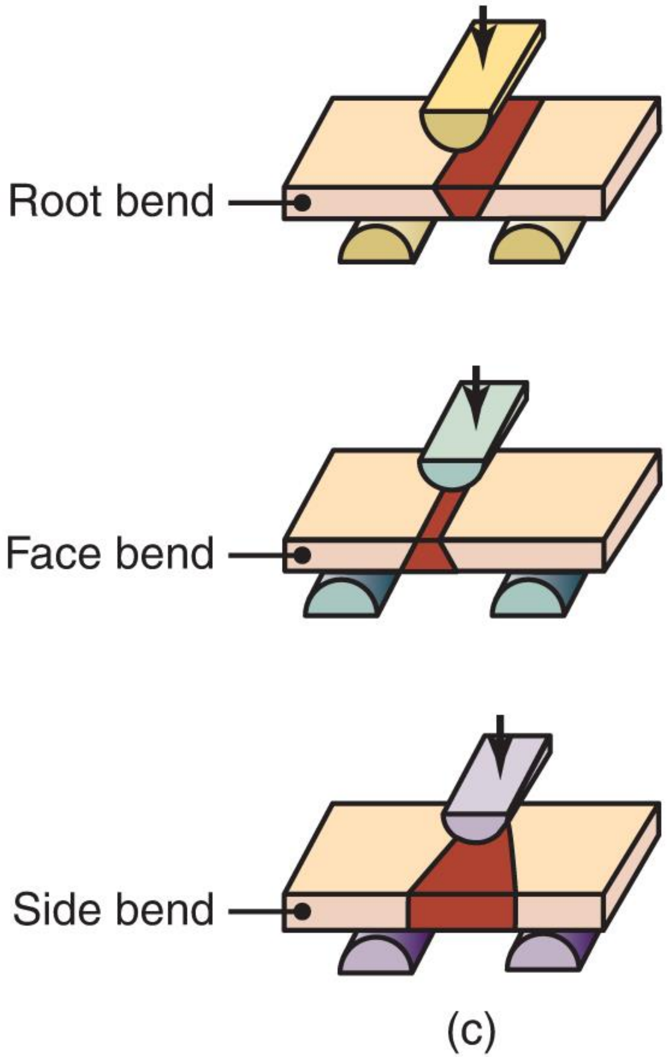


Figure 31.1

Schematic illustration of the roll-bonding, or cladding, process.

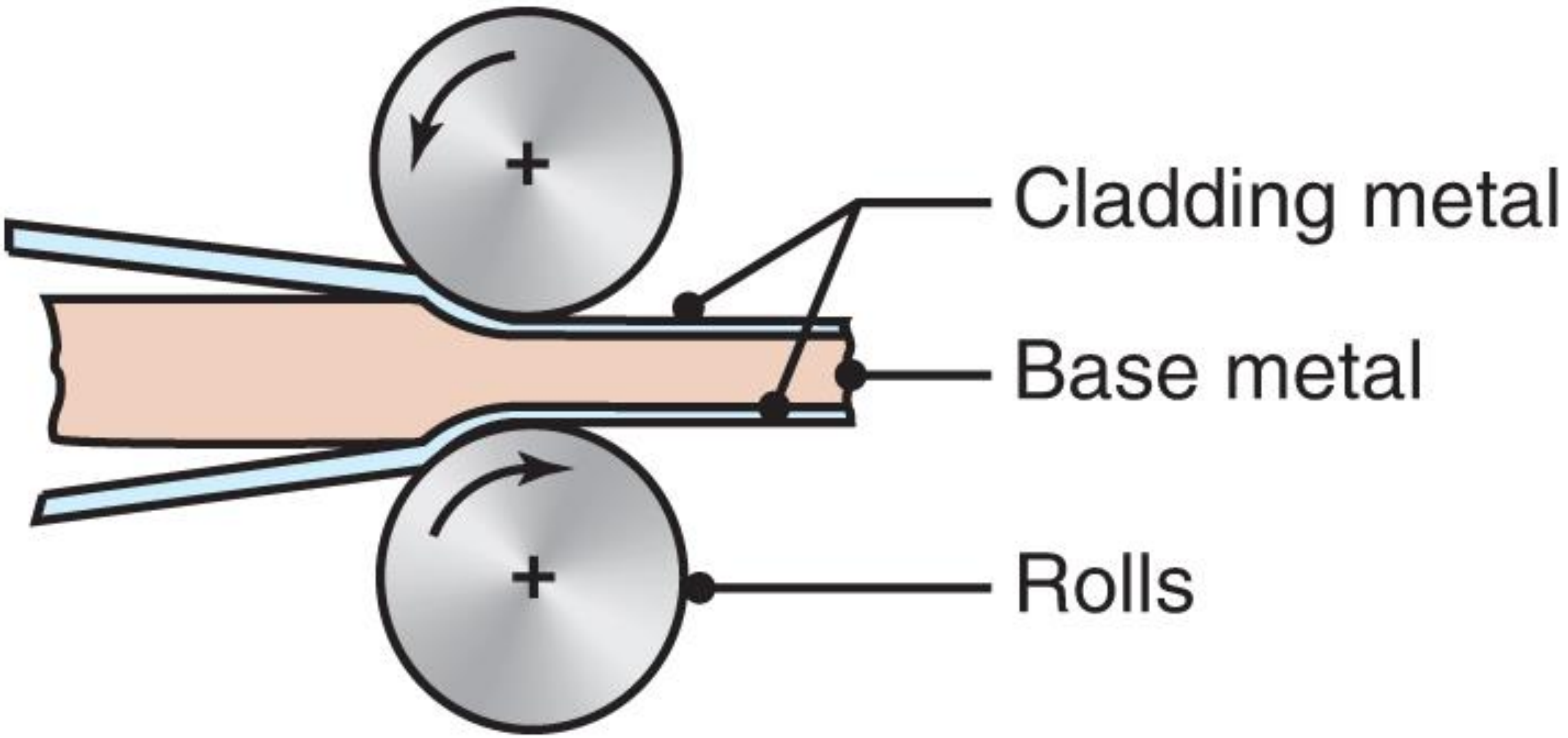
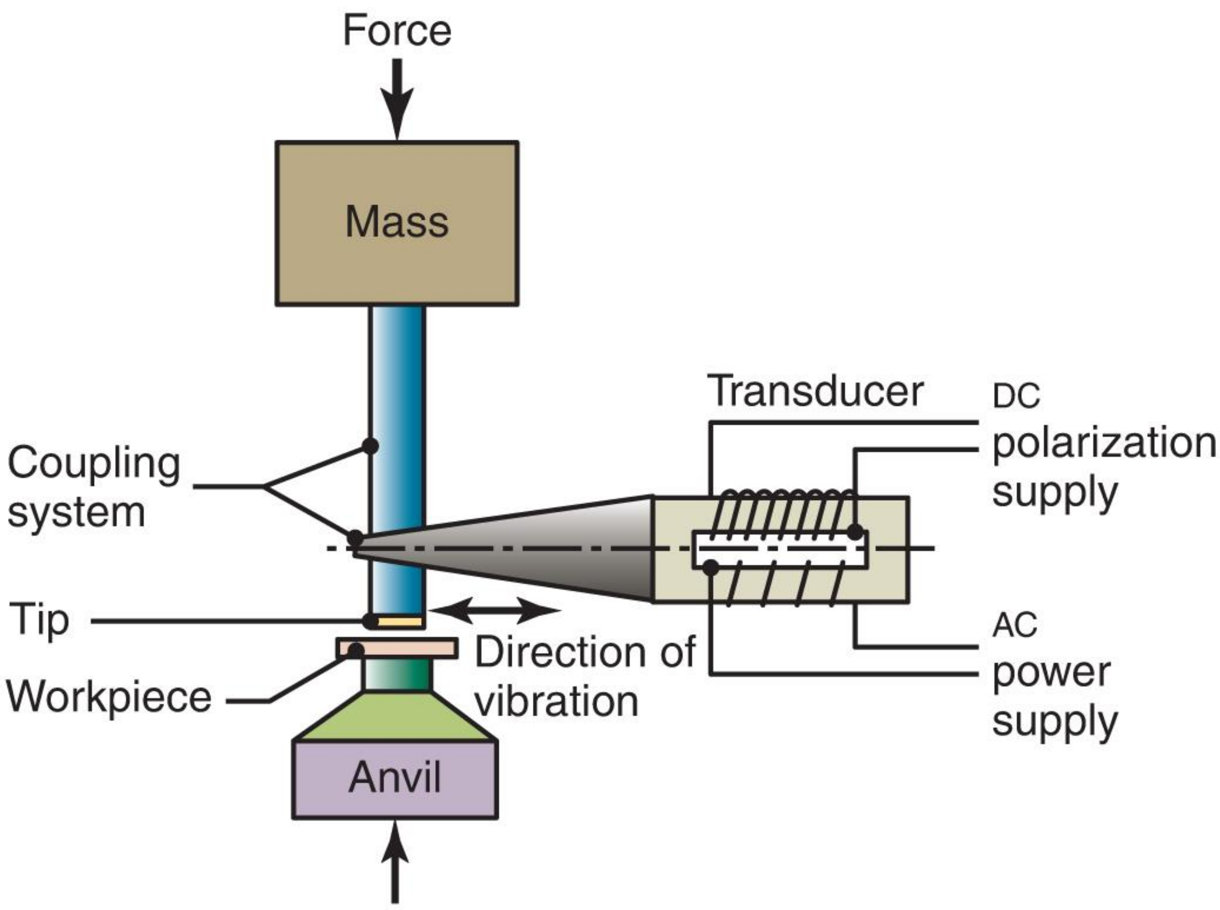


Figure 31.2 (1 of 2)

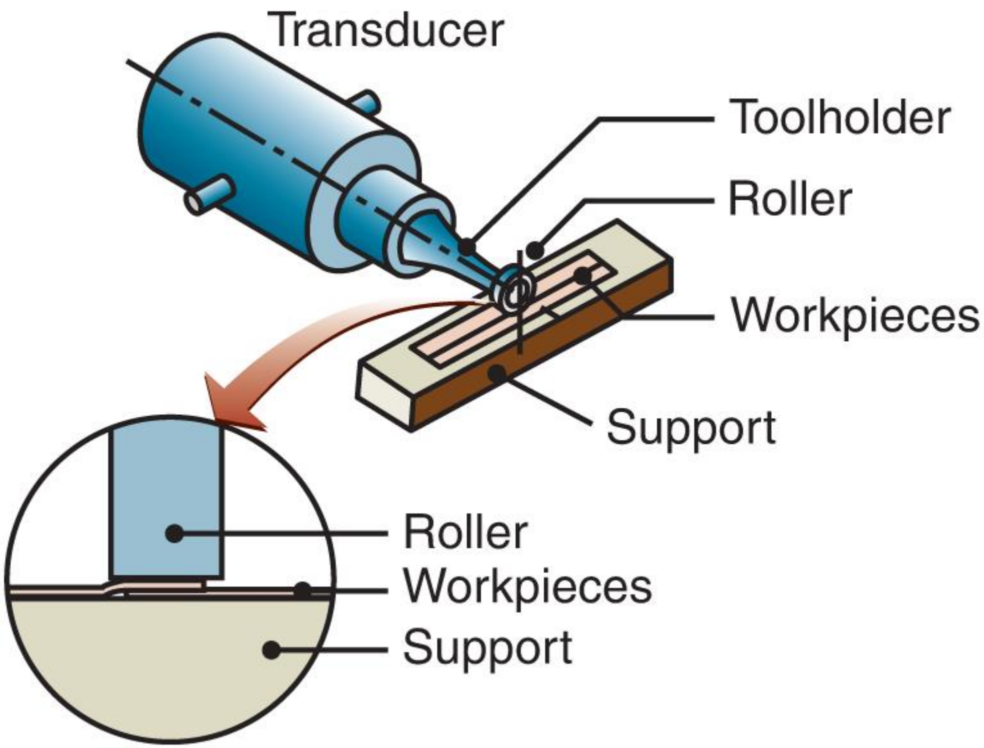
(a) Components of an ultrasonic-welding machine for making lap welds. The lateral vibrations of the tool tip cause plastic deformation and bonding at the interface of the workpieces.



(a)

Figure 31.2 (2 of 2)

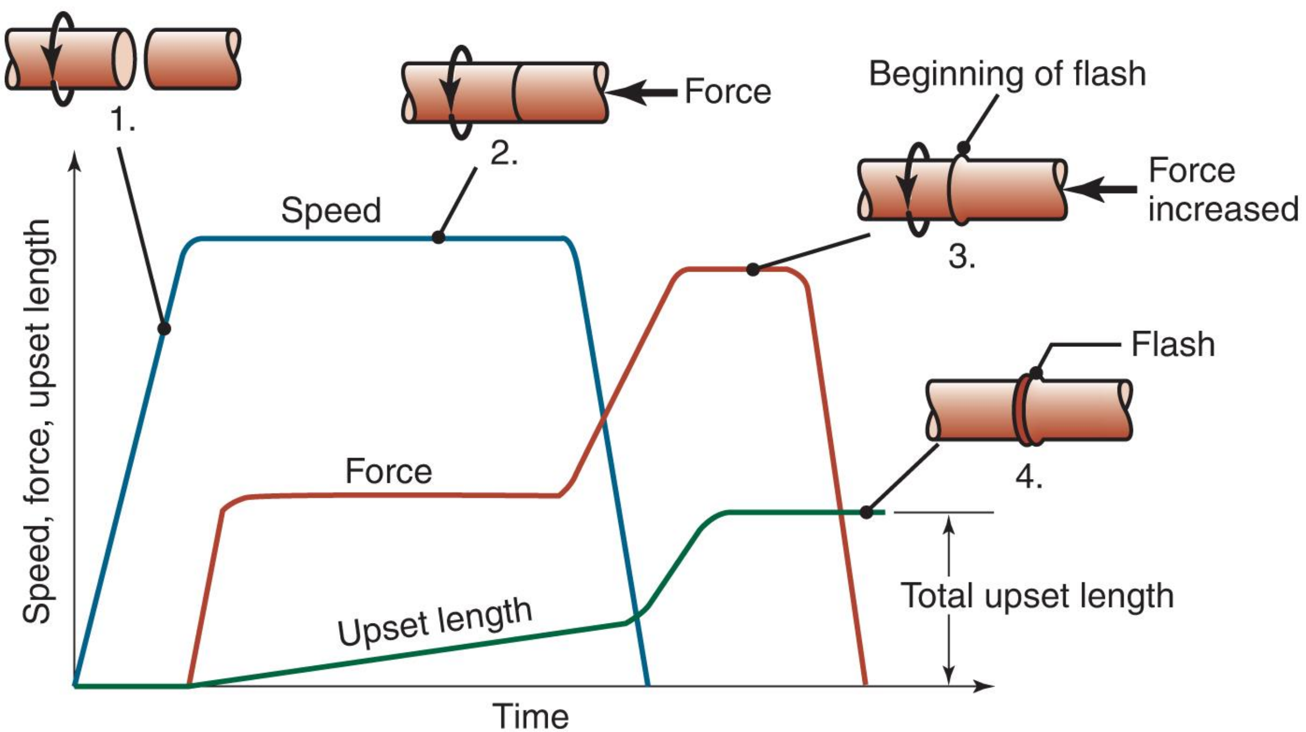
(b) Ultrasonic seam welding using a roller as the *sonotrode*.



(b)

Figure 31.3

Sequence of operations in the friction-welding process: (1) The part on the left is rotated at high speed. (2) The part on the right is brought into contact with the part on the left under an axial force. (3) The axial force is increased, and the part on the left stops rotating; flash begins to form. (4) After a specified upset length or distance is achieved, the weld is completed. The *upset length* is the distance the two pieces move inward during welding after their initial contact; thus, the total length after welding is less than the sum of the lengths of the two pieces. The flash subsequently can be removed by machining or grinding.

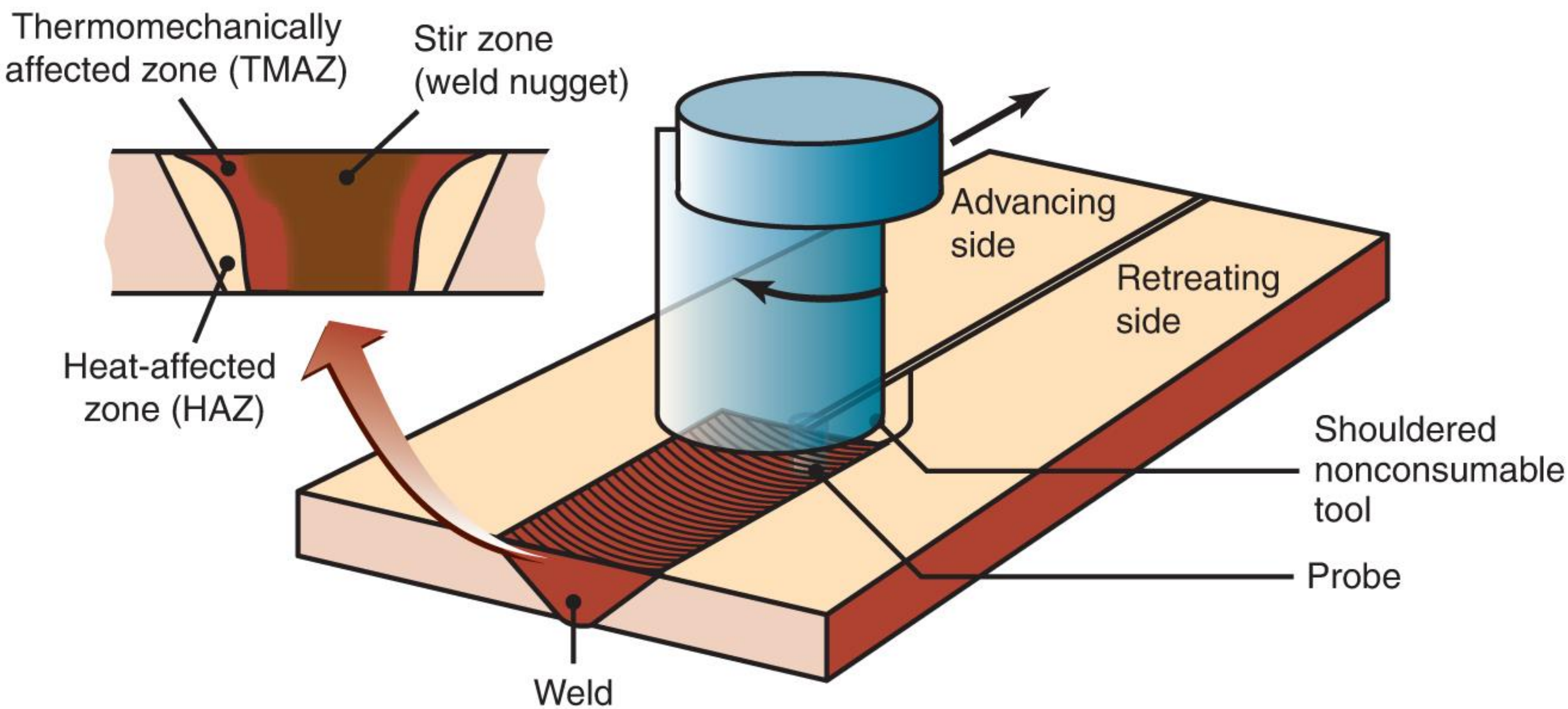


Friction Welding

https://youtu.be/-aEuAK8bsQg

Figure 31.5 (1 of 2)

The friction-stir-welding process. (a) Schematic illustration of friction-stir-welding. Aluminumalloy plates up to 75 mm (3 in.) thick have been welded by this process.



(a)

Figure 31.5 (2 of 2)

The friction-stir-welding process. (b) Multi-axis friction stir welding machine for large workpieces such as aircraft wing and fuselage structures. This machine can develop 67 kN (15,000 lb.) axial forces and welding speeds up to 1.8 m/s. It is powered by a 15 kW (20 hp) spindle motor.

(b)

Source: (b) Courtesy of Manufacturing Technology, Inc.

Figure 31.6 (1 of 2)

(a) Sequence of events in resistance spot welding of a lap joint.

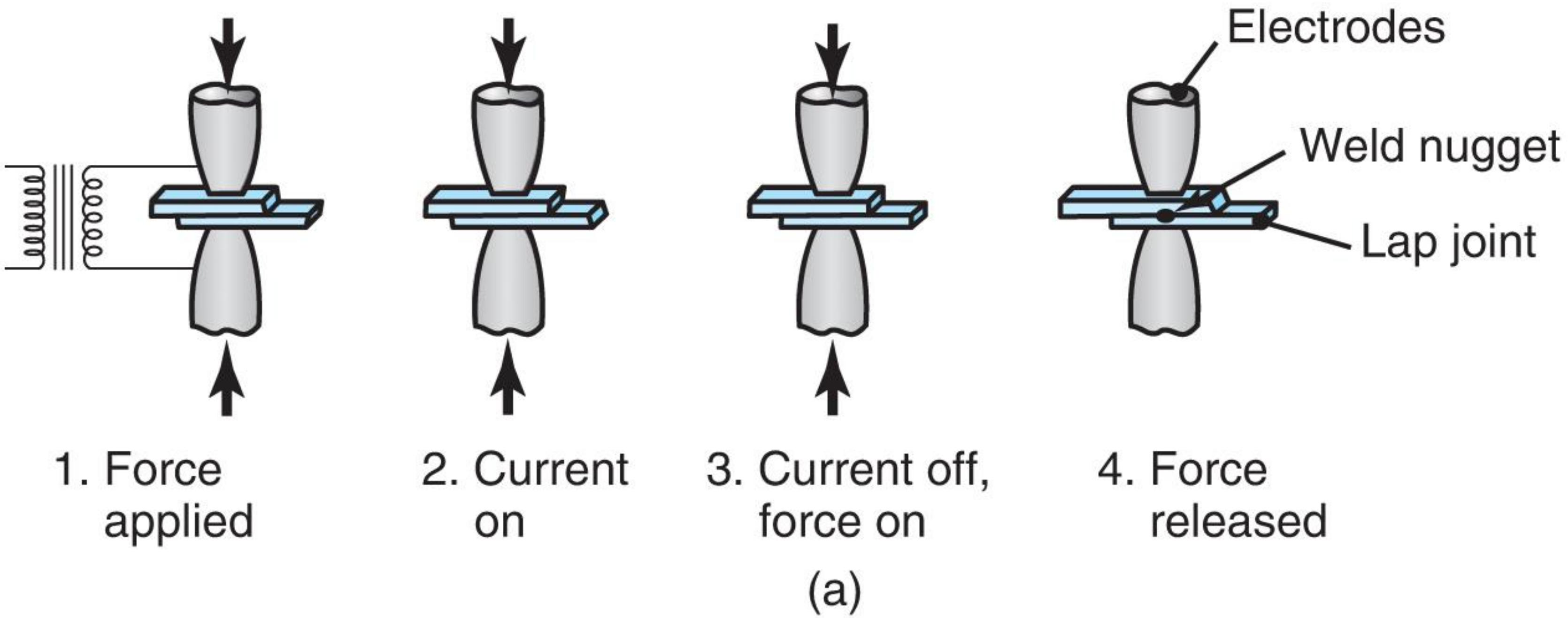
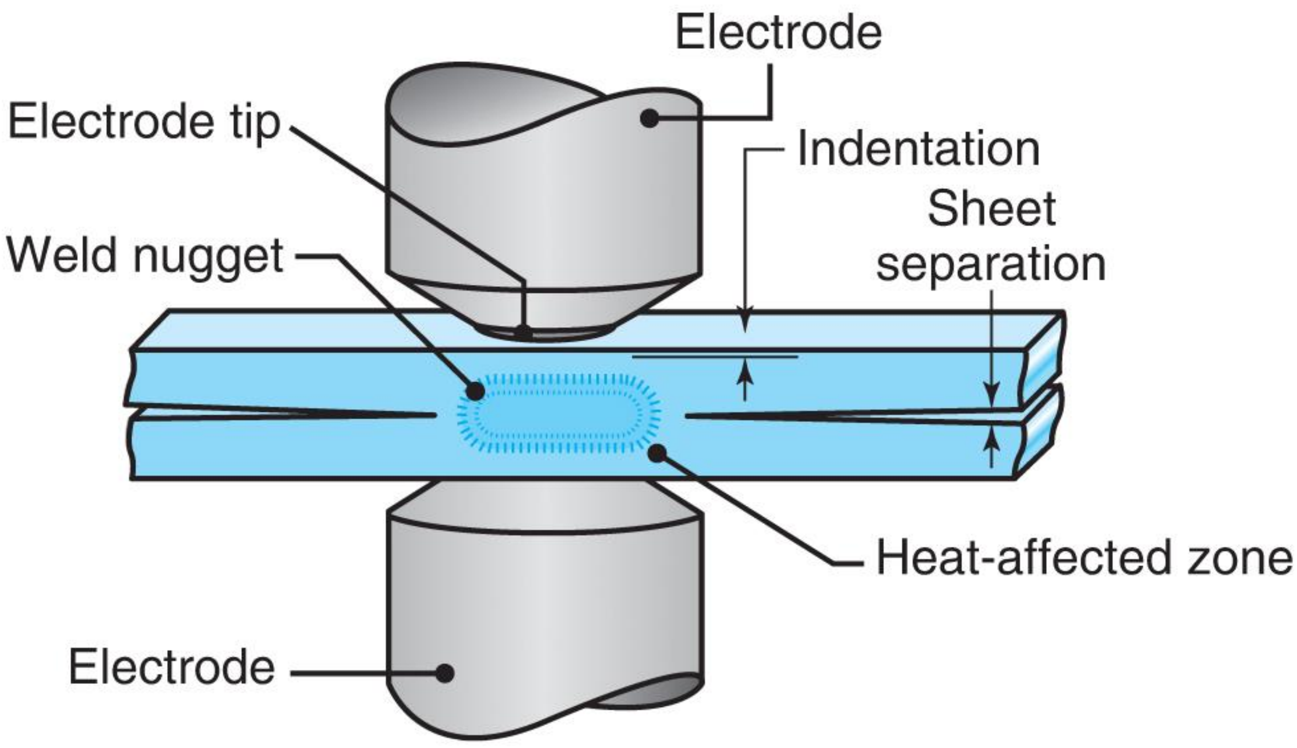


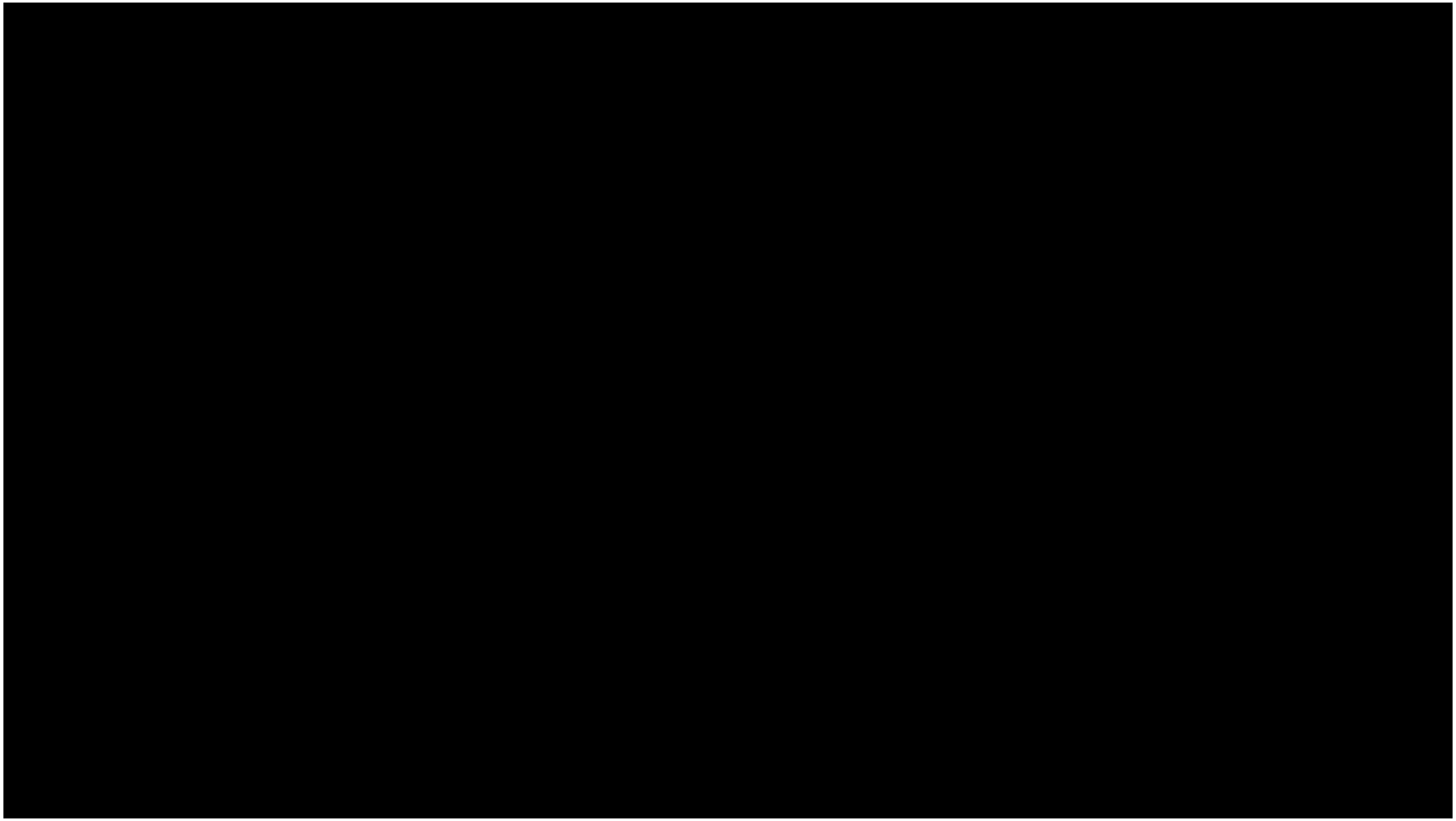
Figure 31.6 (2 of 2)

(b) Cross-section of a spot weld, showing the weld nugget and the indentation of the electrode on sheet surfaces. This is one of the most commonly used processes in sheet-metal fabrication and in automotive metal-body assembly.



(b)

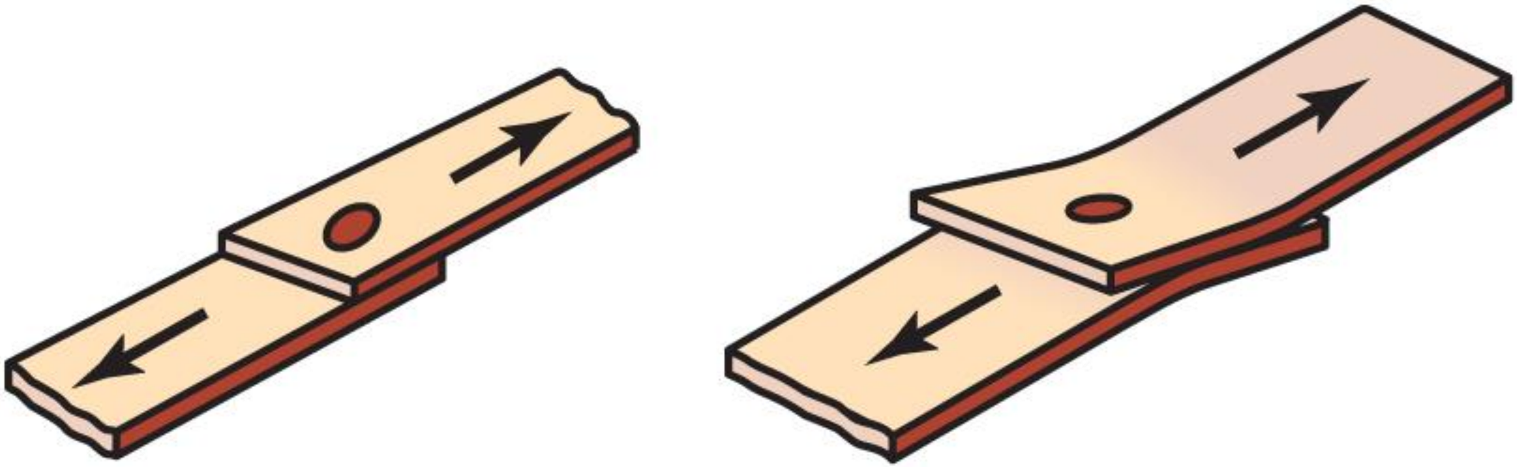
Resistance Spot Welding



https://youtu.be/66-RK0DPXfU

Figure 31.9 (1 of 4)

Test methods for spot welds: (a) tension-shear test.



(a)

Figure 31.9 (2 of 4)

Test methods for spot welds: (b) cross-tension test.

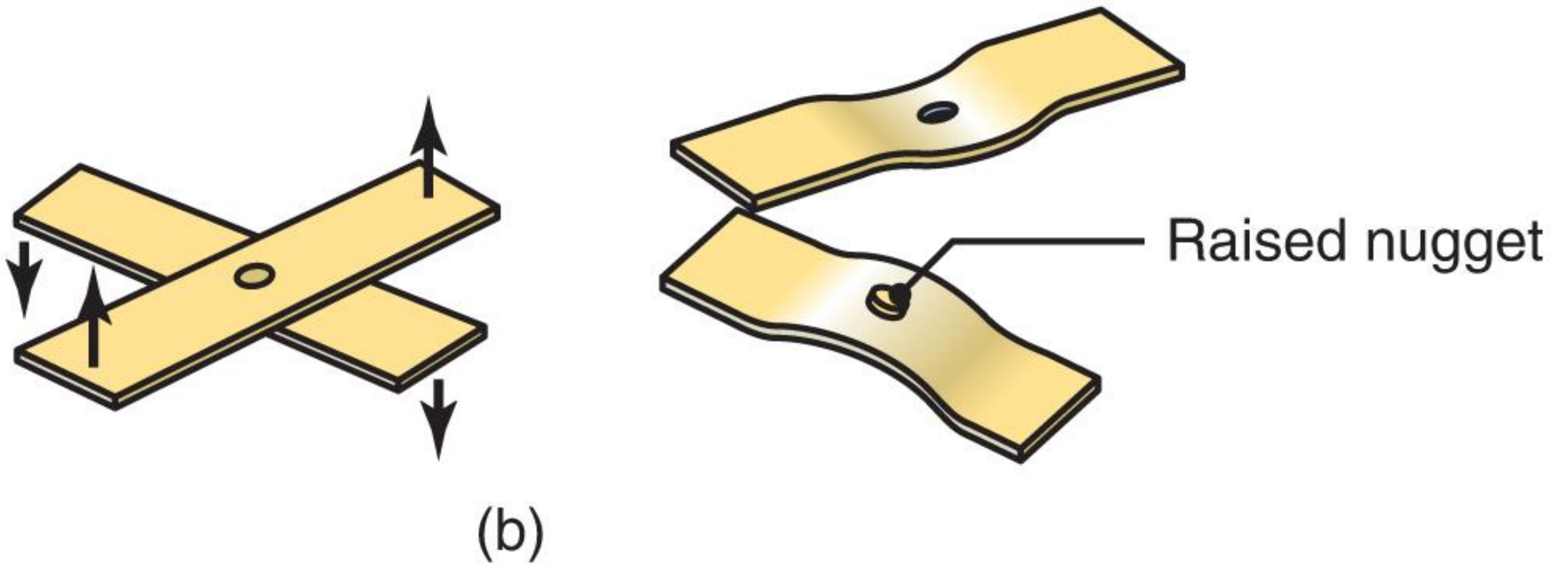


Figure 31.9 (3 of 4)

Test methods for spot welds: (c) twist test.

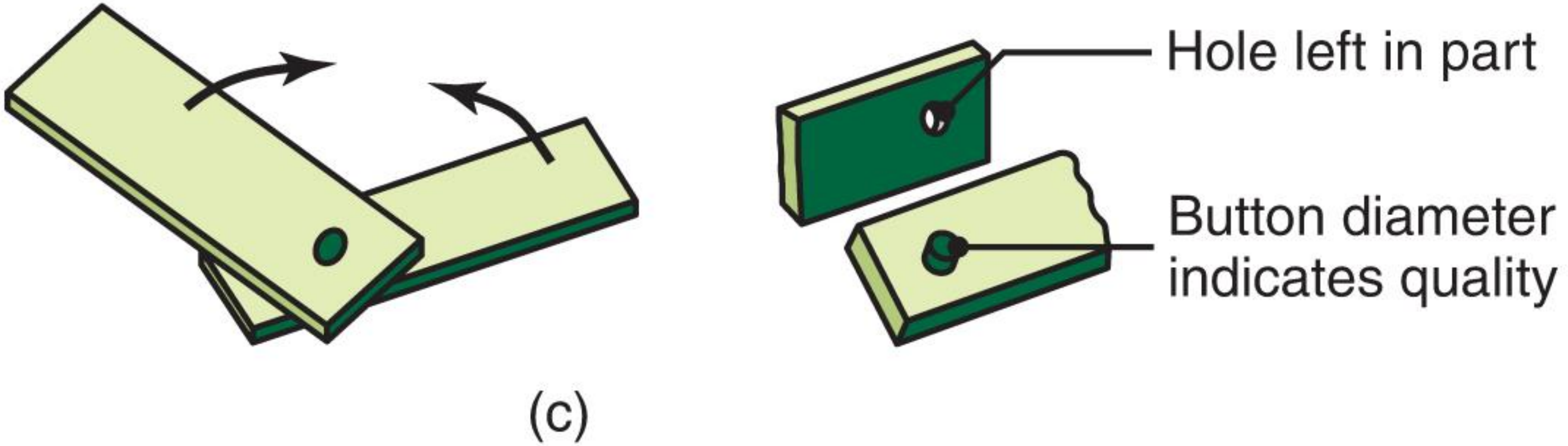
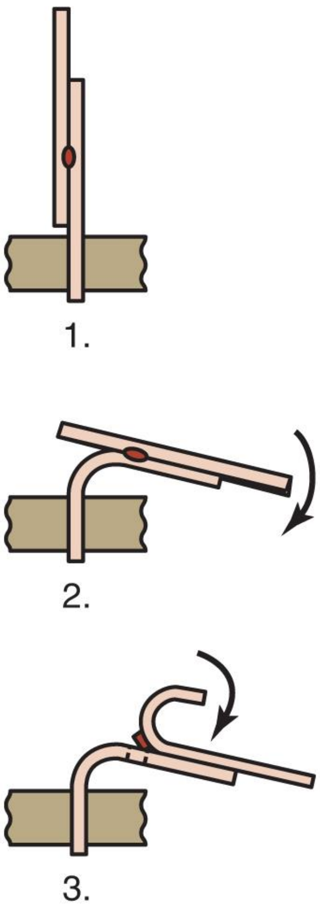


Figure 31.9 (4 of 4)

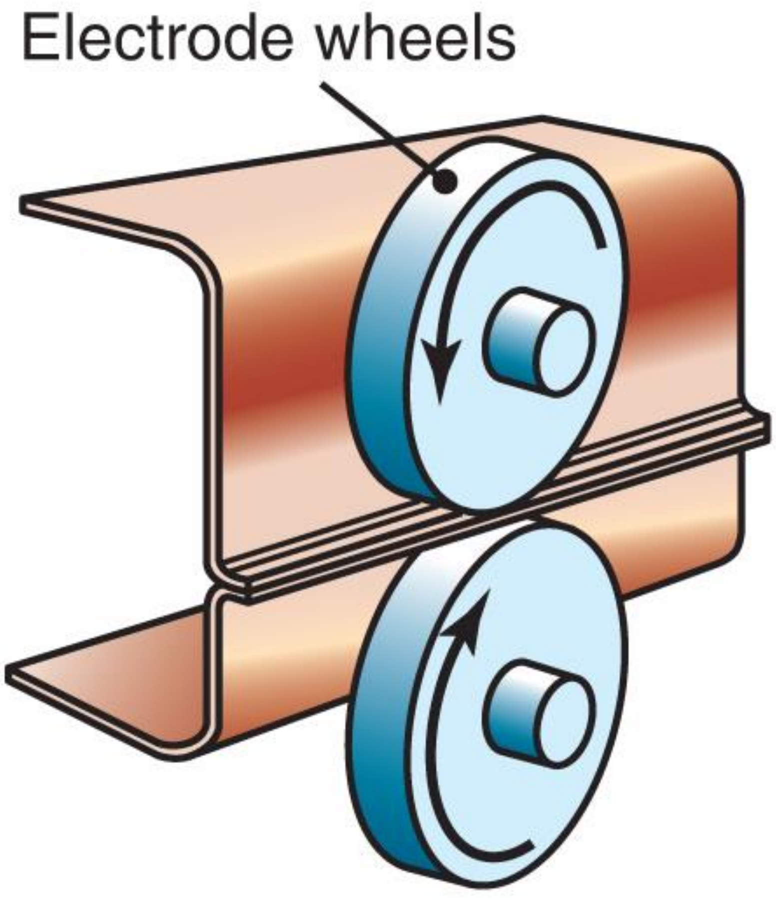
Test methods for spot welds: (d) peel test (see also Fig. 32.9).



(d)

Figure 31.10 (1 of 4)

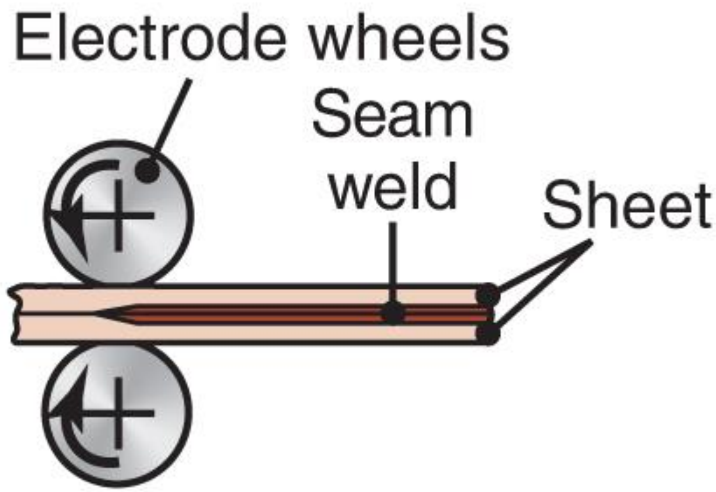
(a) Seam-welding process in which rotating rolls act as electrodes.



(a)

Figure 31.10 (2 of 4)

(b) Overlapping spots in a seam weld.



(b)

Figure 31.10 (3 of 4)

(c) Roll spot welds.

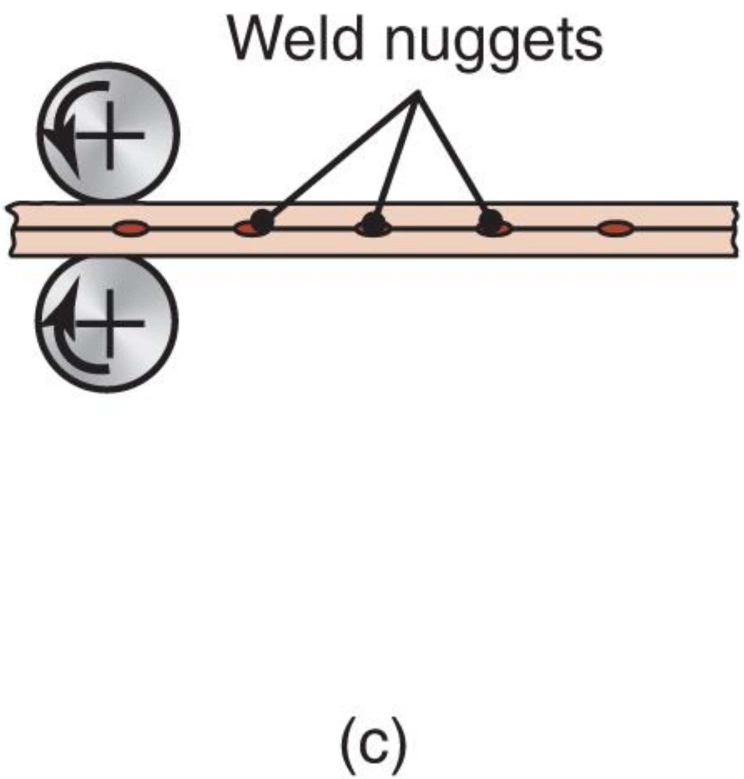


Figure 31.10 (4 of 4)

(d) Mash seam welding.

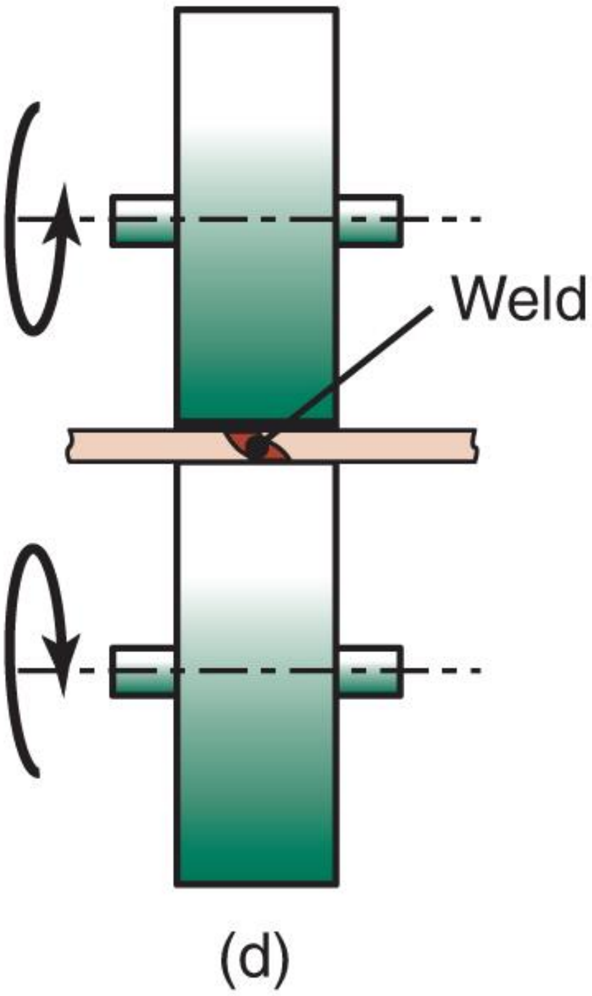
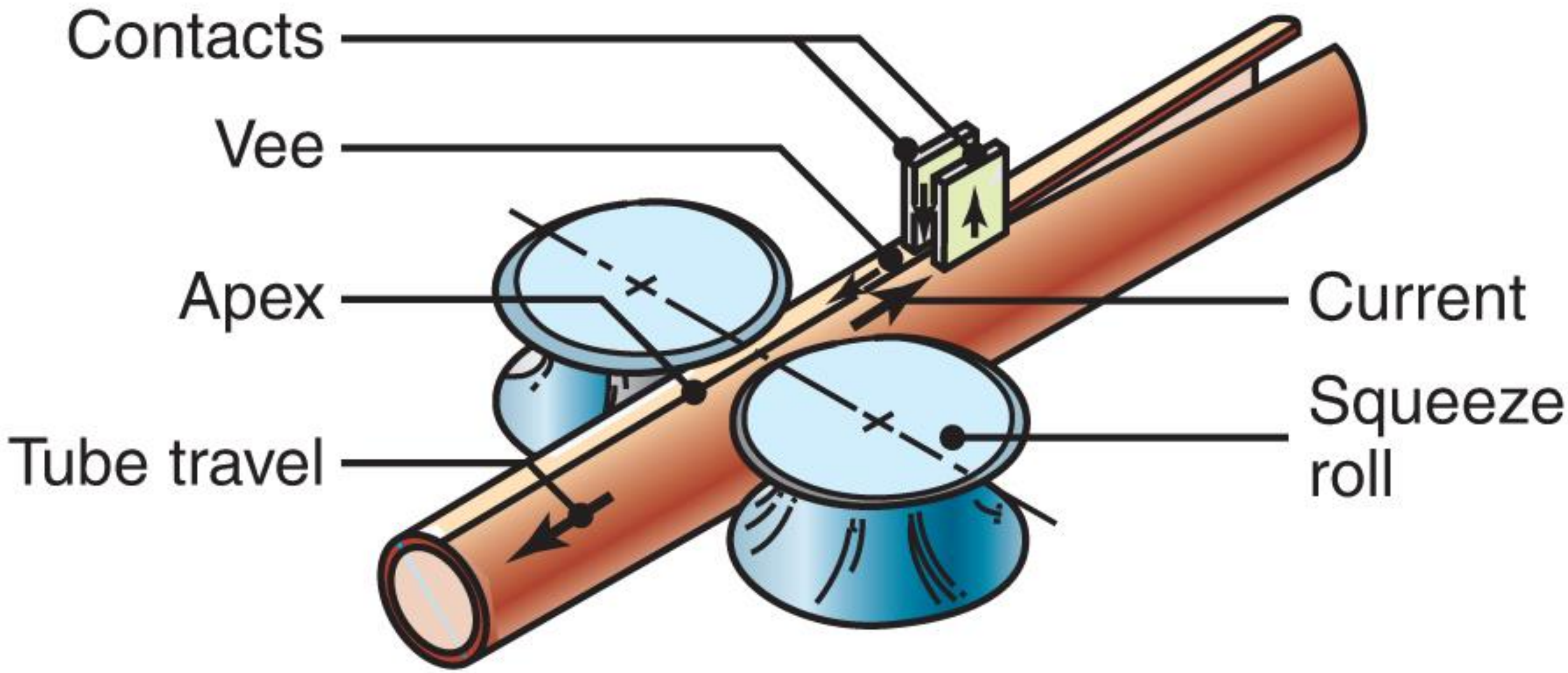


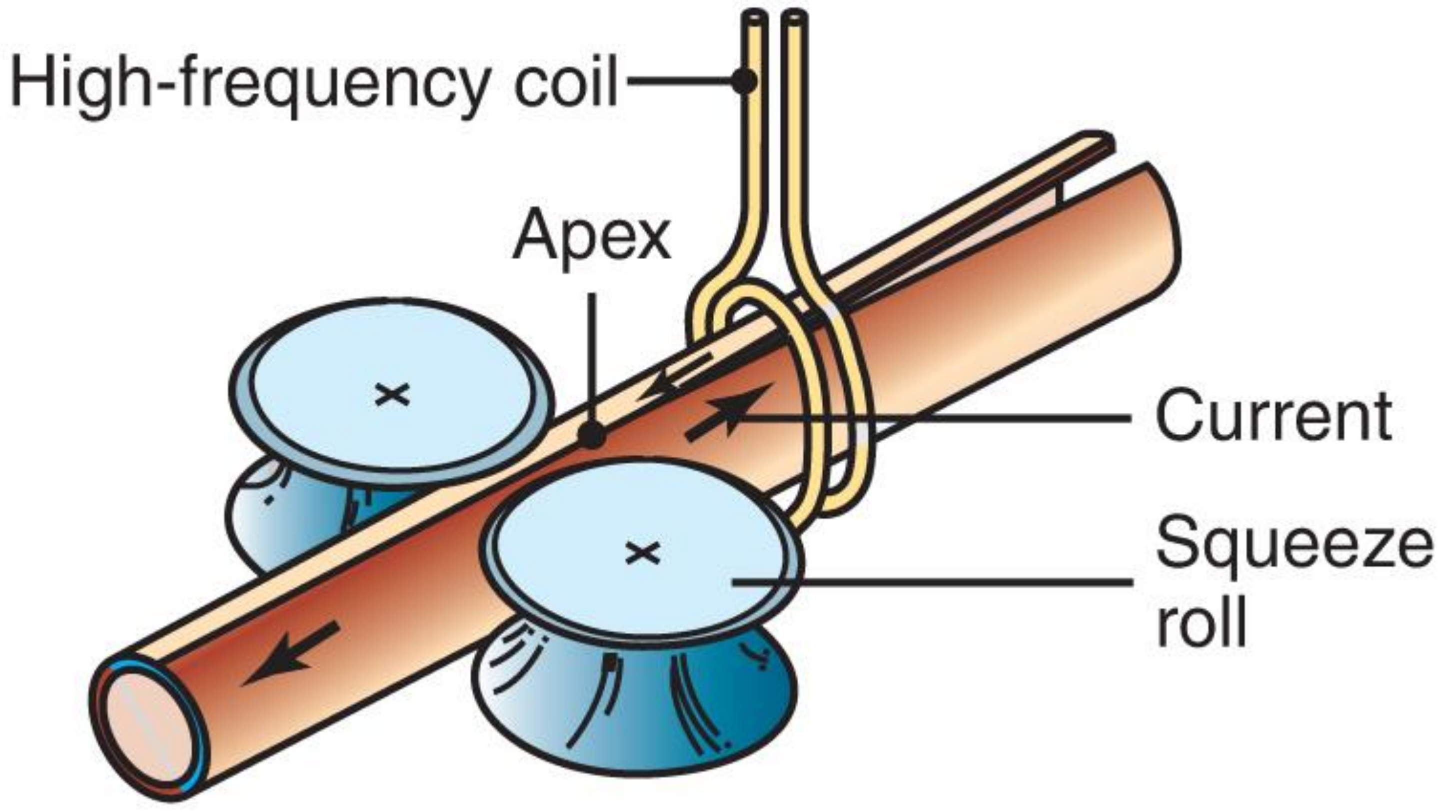
Figure 31.11 (1 of 2)

Two methods of high-frequency continuous butt welding of tubes.



(a)

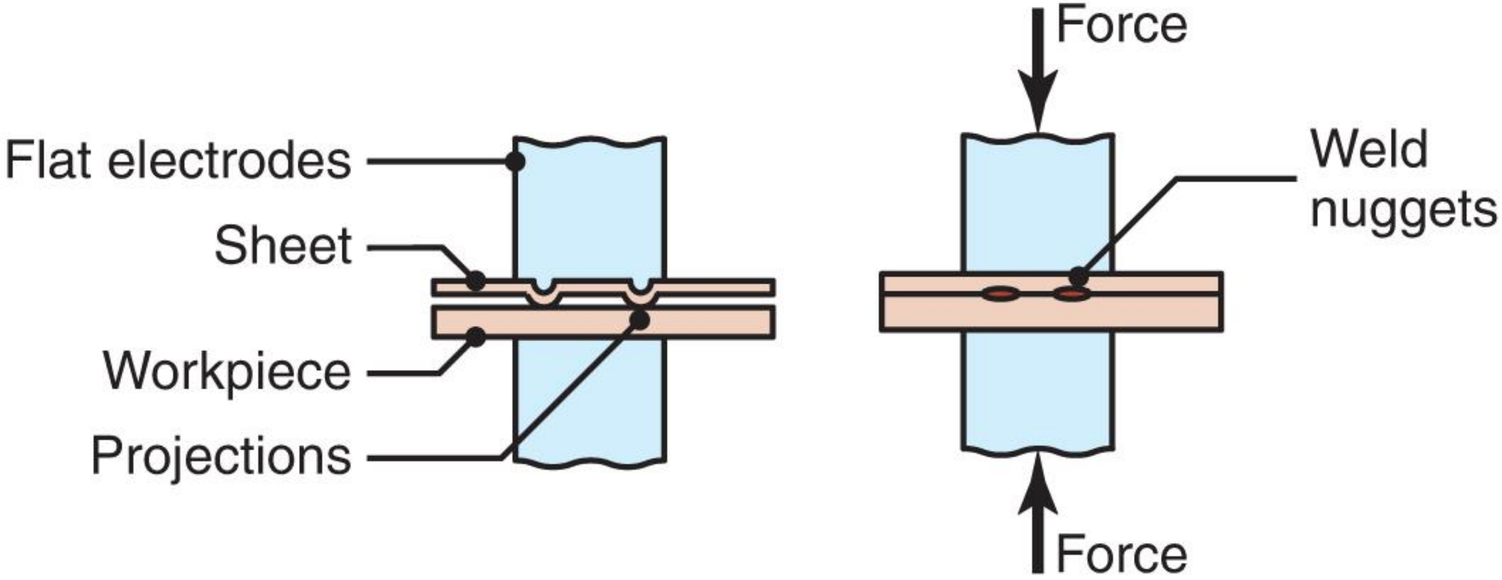
Figure 31.11 (2 of 2)



(b)

Figure 31.12 (1 of 5)

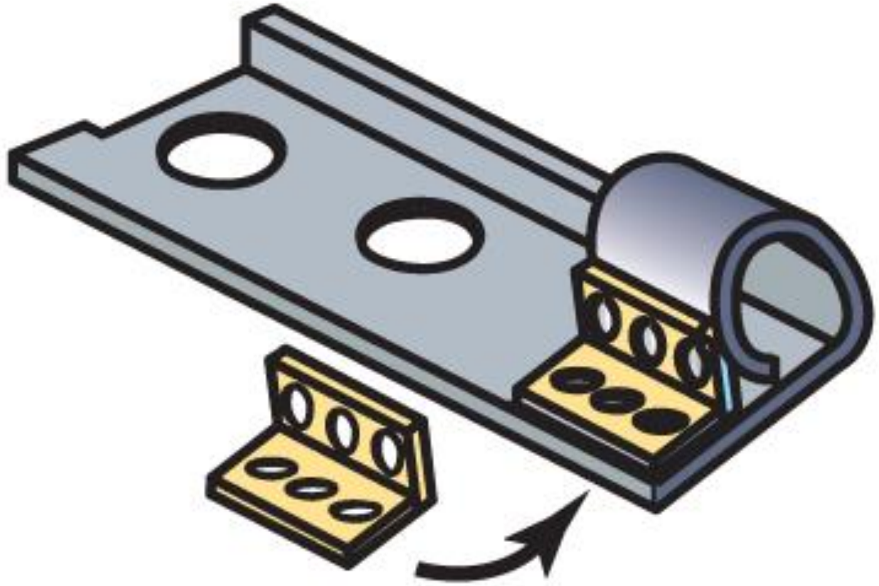
(a) Schematic illustration of resistance projection welding.



(a)

Figure 31.12 (2 of 5)

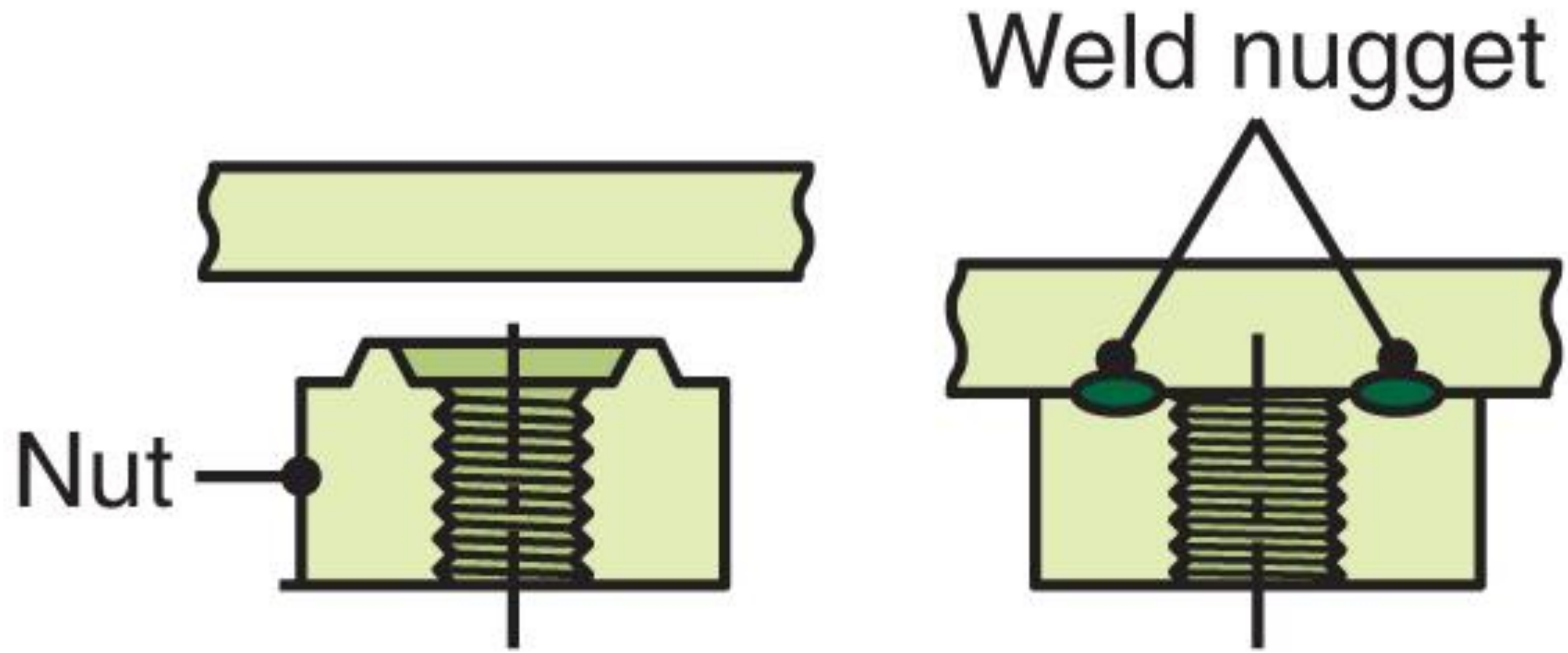
(b) A welded bracket.



(b)

Figure 31.12 (3 of 5)

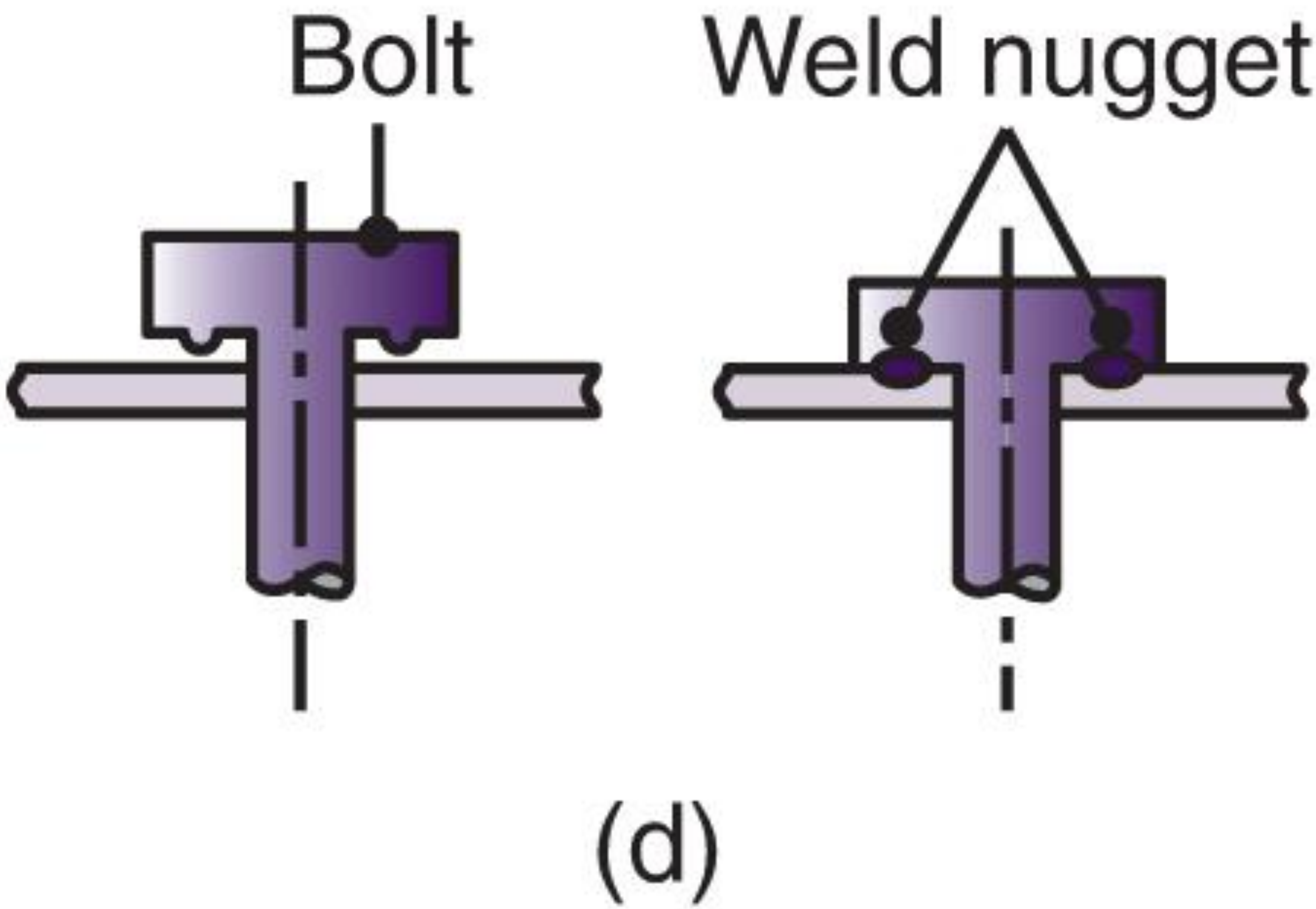
(c) Projection welding of nuts or threaded bosses and studs.



(c)

Figure 31.12 (4 of 5)

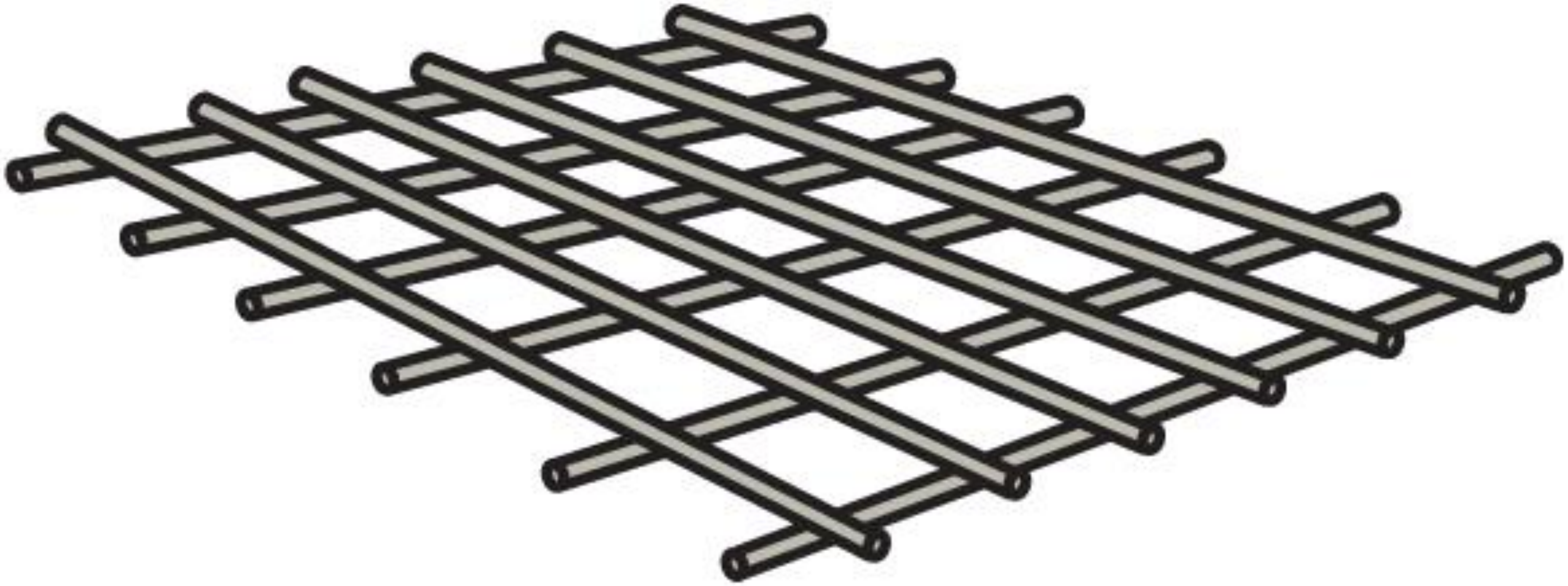
(d) Projection welding of nuts or threaded bosses and studs.



![Pearson logo]

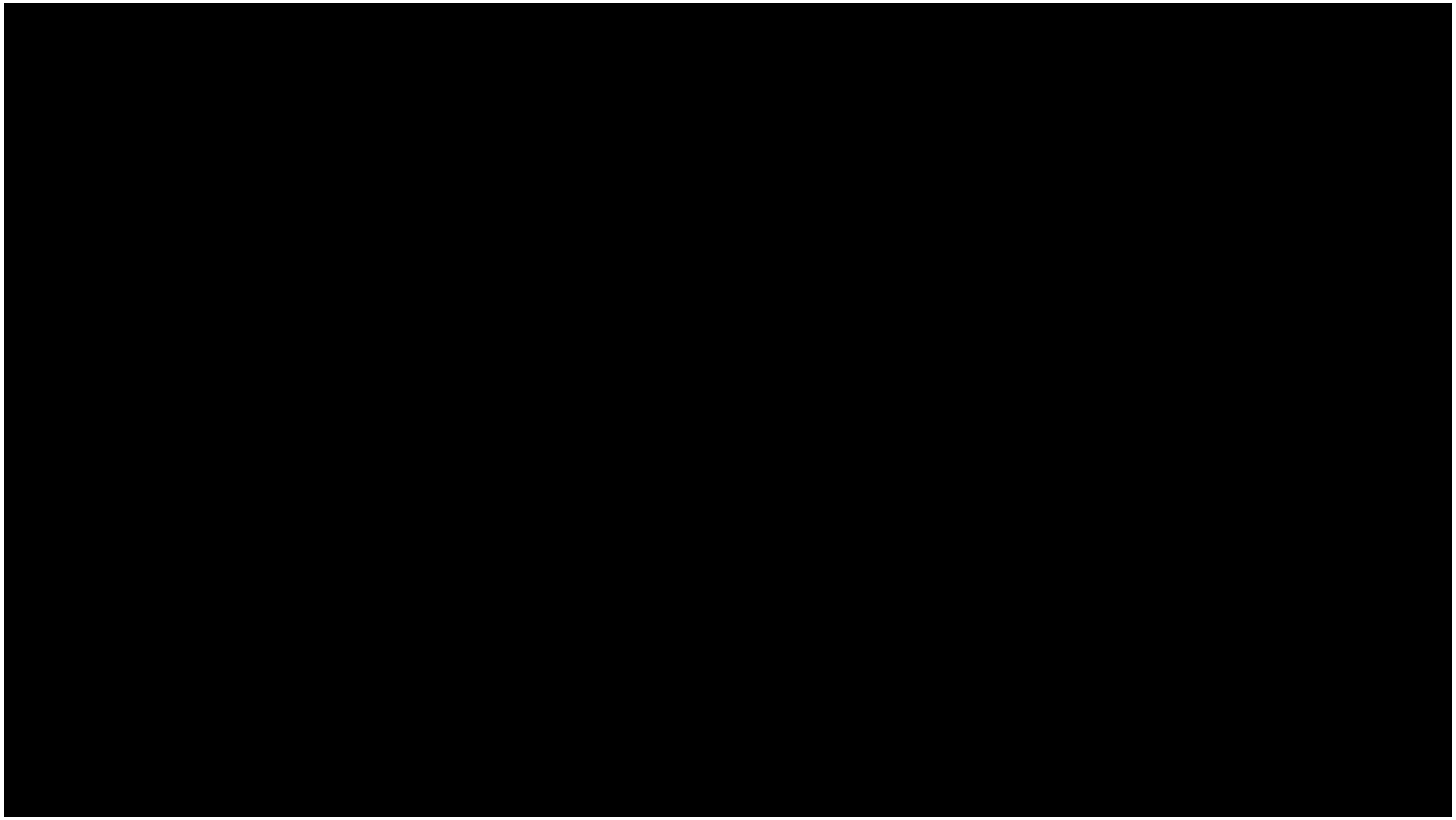
Figure 31.12 (5 of 5)

(e) Resistance-projection-welded grills.



(e)

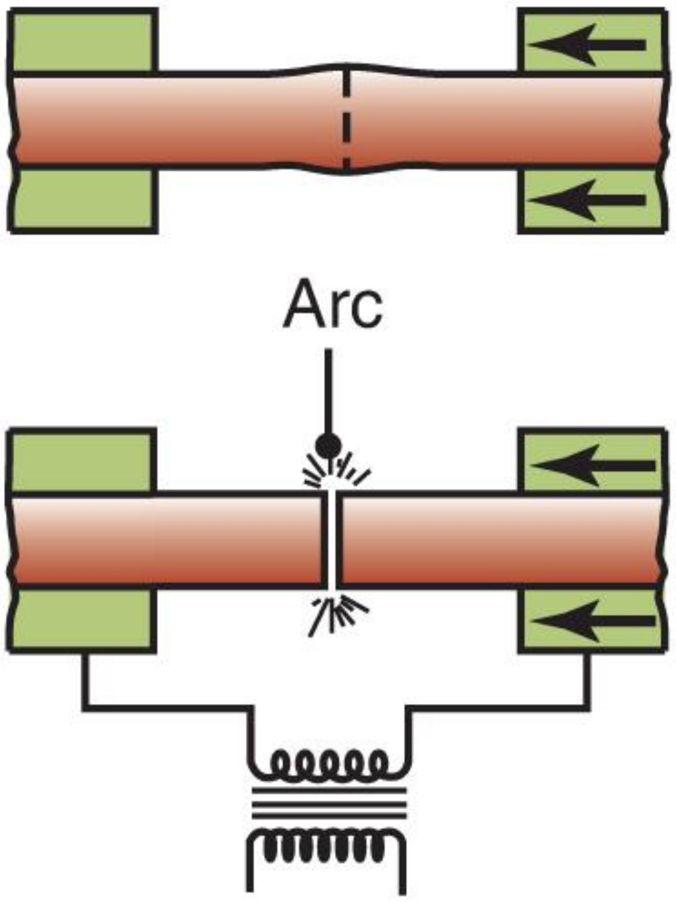
Resistance Projection Welding



https://youtu.be/KyLyrgWaL14

Figure 31.13 (1 of 5)

(a) Flash-welding process for end-to-end welding of solid rods or tubular parts.



(a)

Pearson

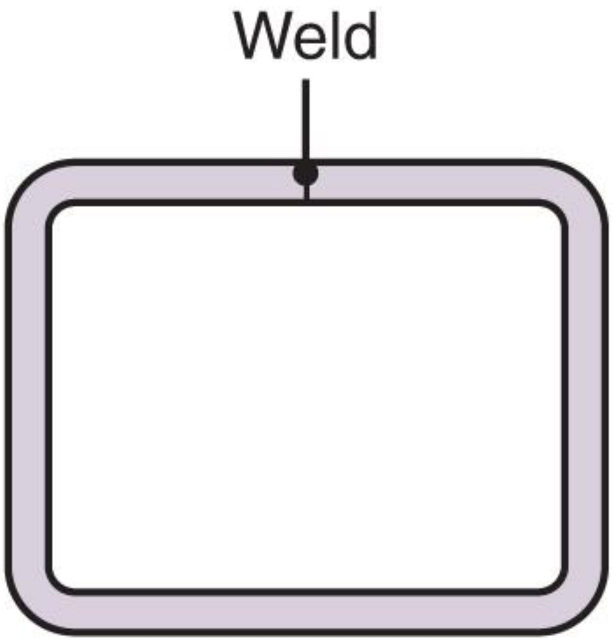
Figure 31.13 (2 of 5)

(b) Typical parts made by flash welding.

(b)

Figure 31.13 (3 of 5)

(c) Typical parts made by flash welding.



(c)

Figure 31.13 (4 of 5)

(d) Some design guidelines for flash welding.

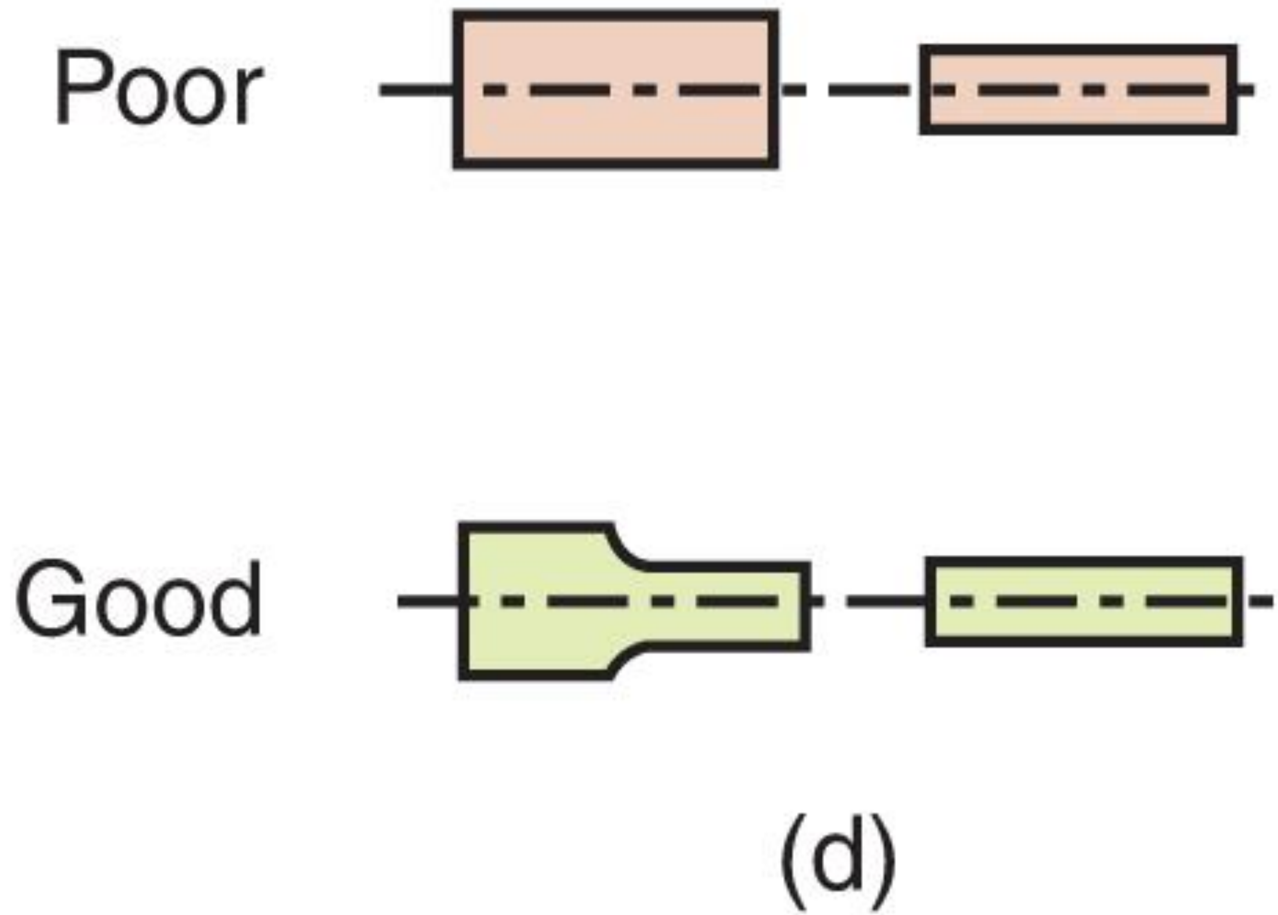
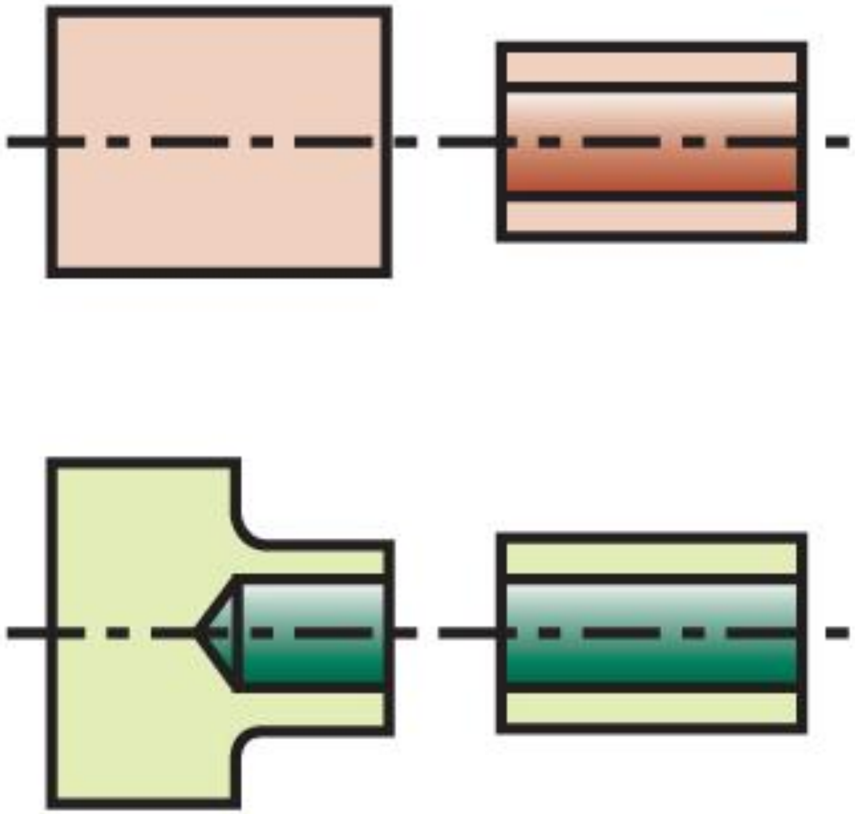


Figure 31.13 (5 of 5)

(e) Some design guidelines for flash welding.



(e)

Figure 31.14 (1 of 4)

The sequence of operations in stud welding commonly used for welding bars, threaded rods, and various fasteners onto metal plates.

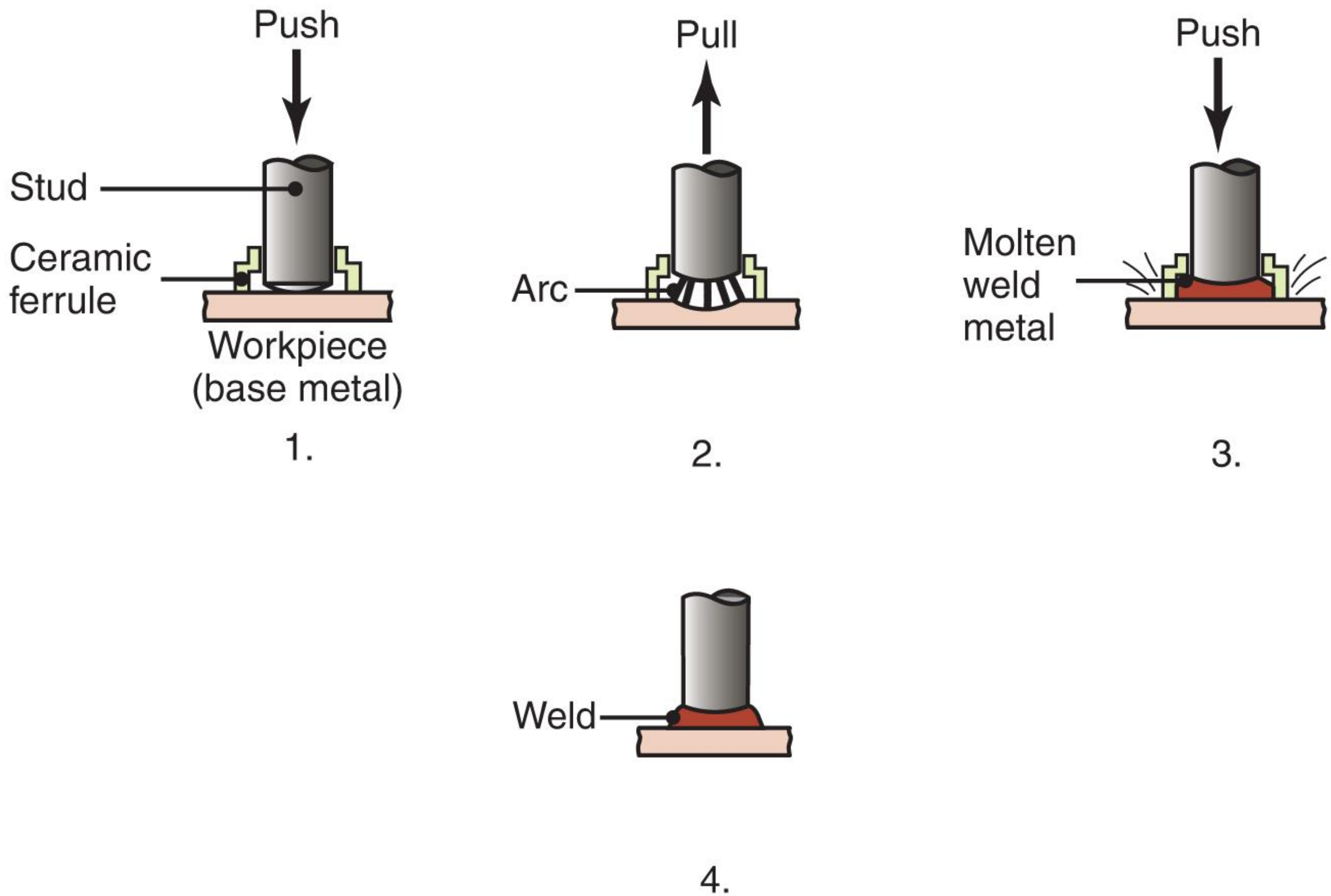


Figure 31.16 (1 of 4)

Schematic illustration of the explosion-welding process: (a) constant-interface clearance gap.

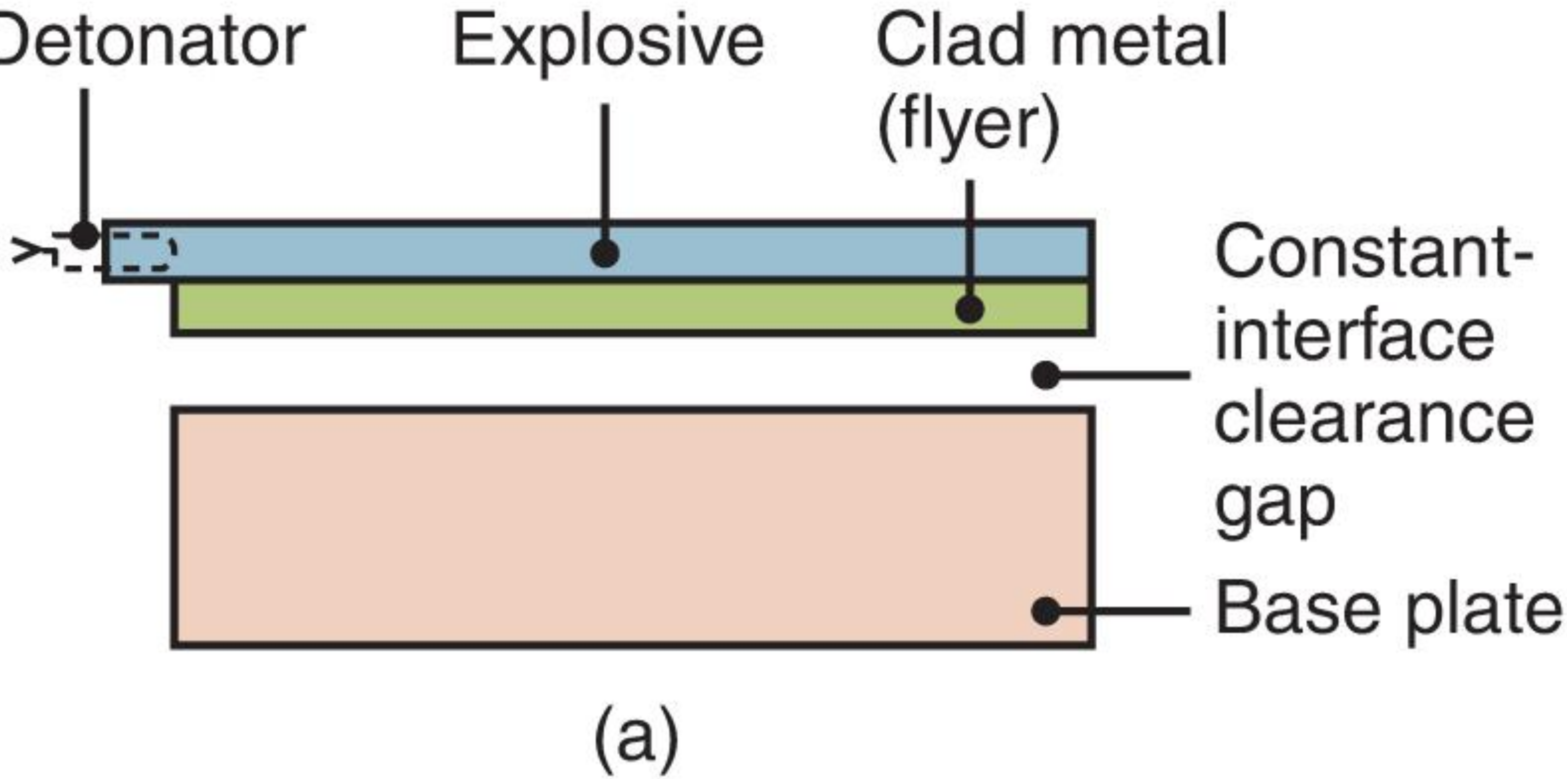


Figure 31.16 (2 of 4)

Schematic illustration of the explosion-welding process: (b) angular-interface clearance gap.

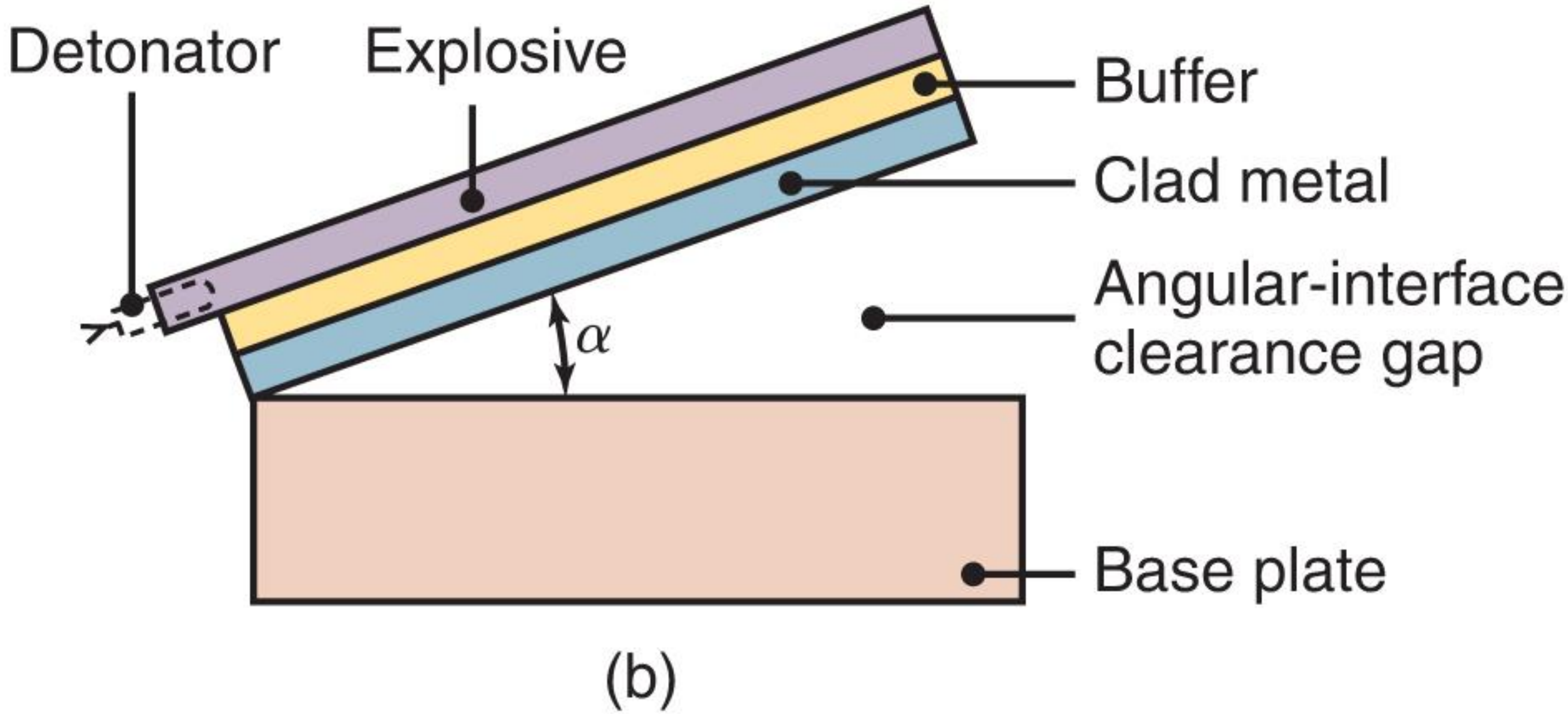
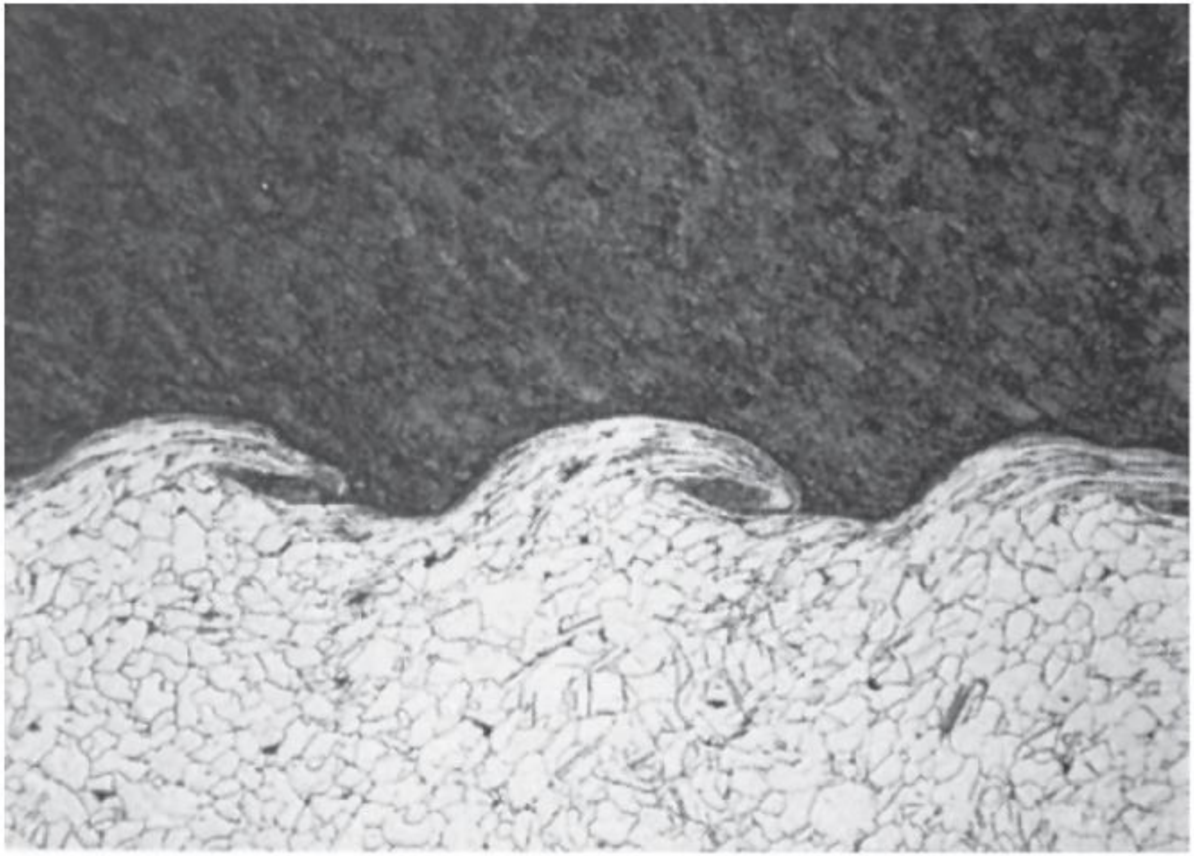


Figure 31.16 (3 of 4)

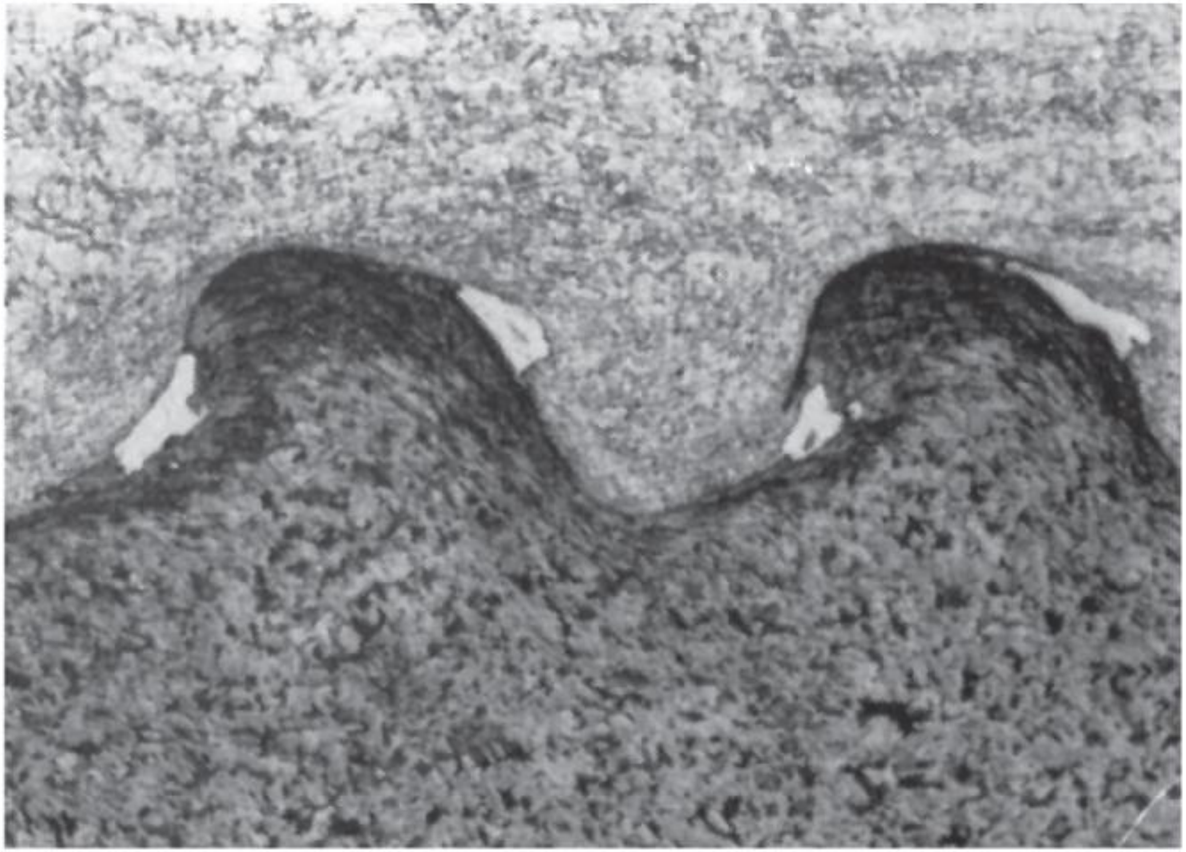
Schematic illustration of the explosion-welding process: (c) Cross-section of explosion-welded joint: titanium (top) and low-carbon steel (bottom).



(c)

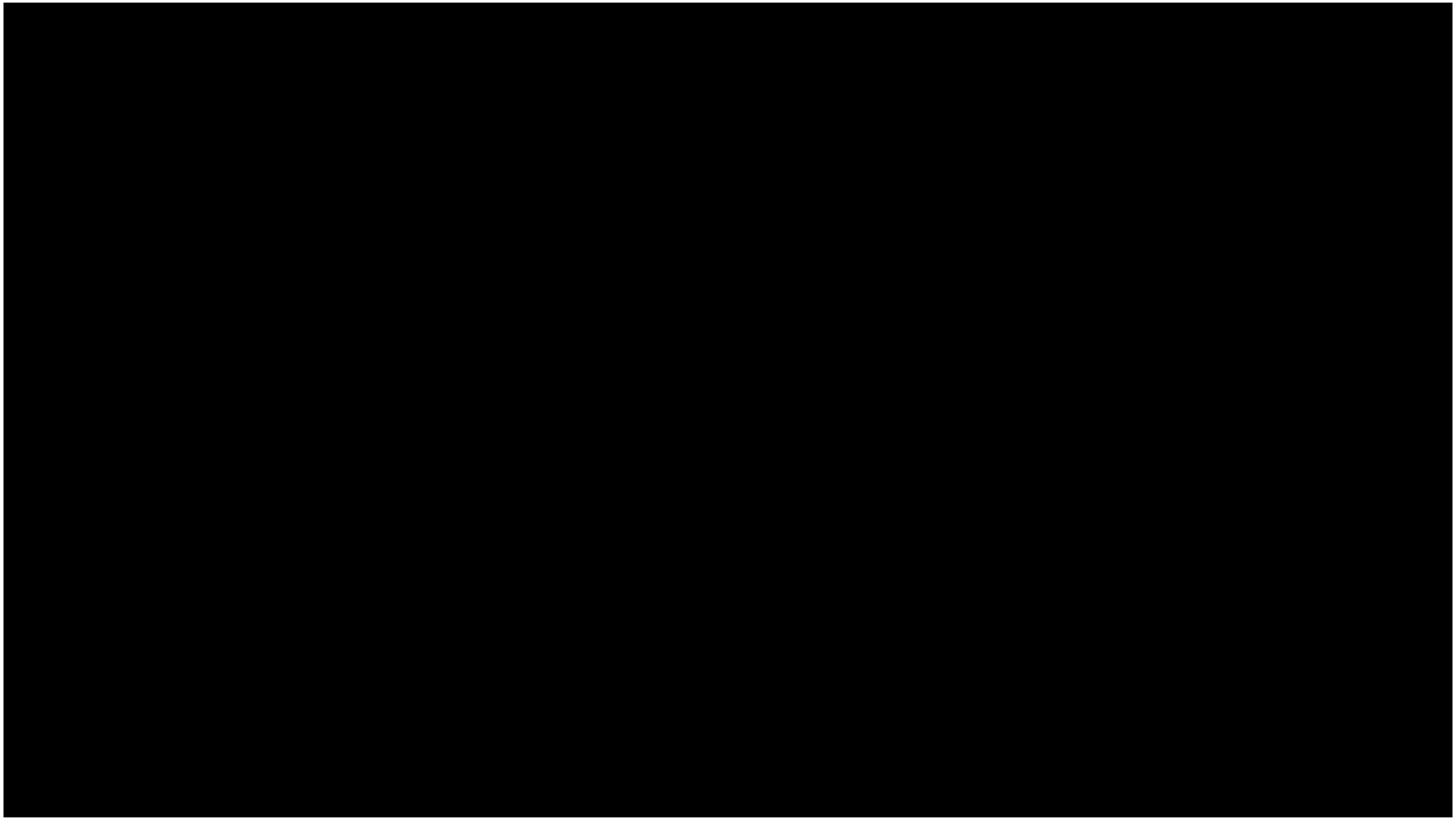
Figure 31.16 (4 of 4)

Schematic illustration of the explosion-welding process: (d) Iron–nickel alloy (top) and low-carbon steel (bottom).



(d)

Explosion Welding



https://youtu.be/u9_bqafUJfA

Figure 31.17

Aerospace diffusion bonding applications.

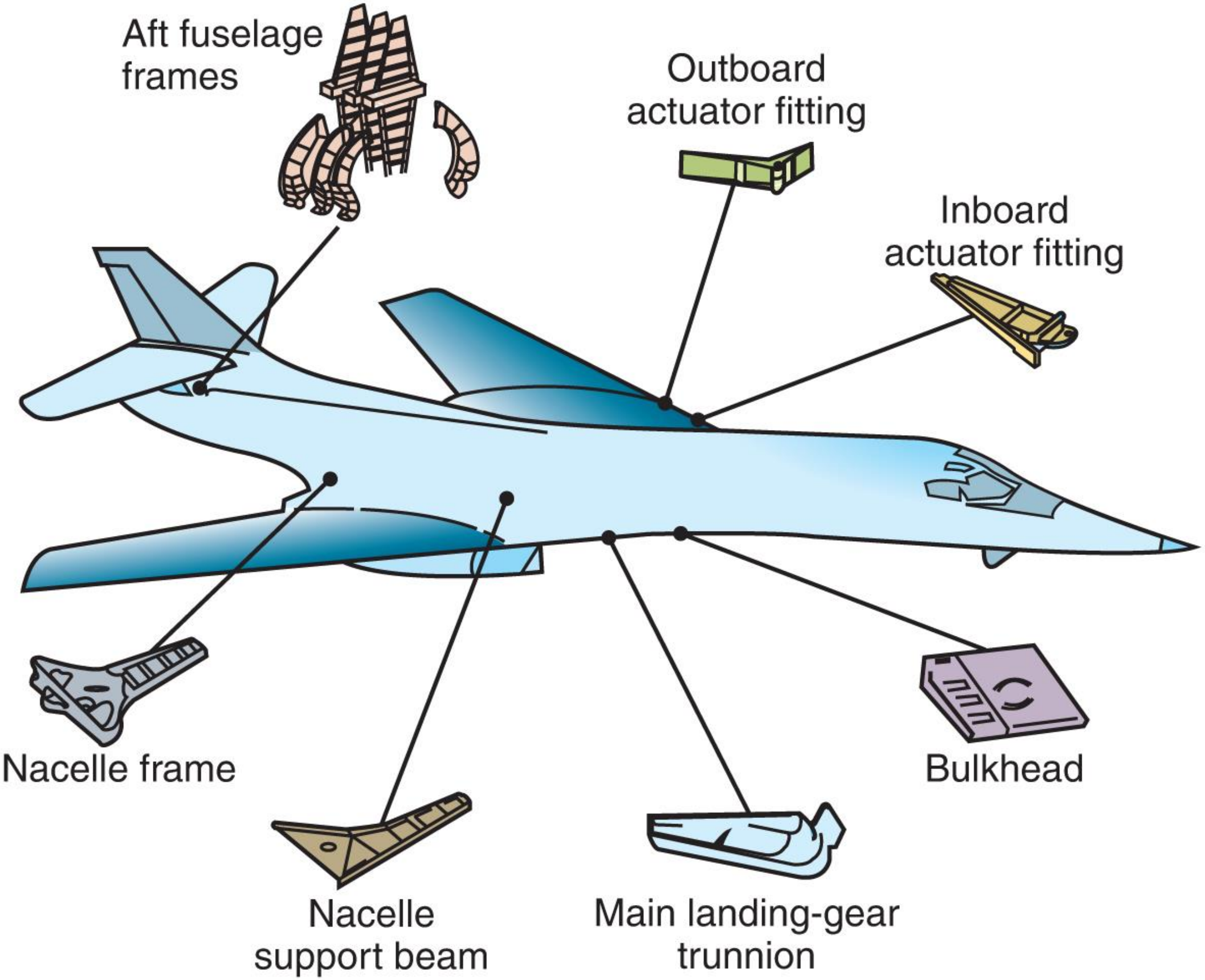
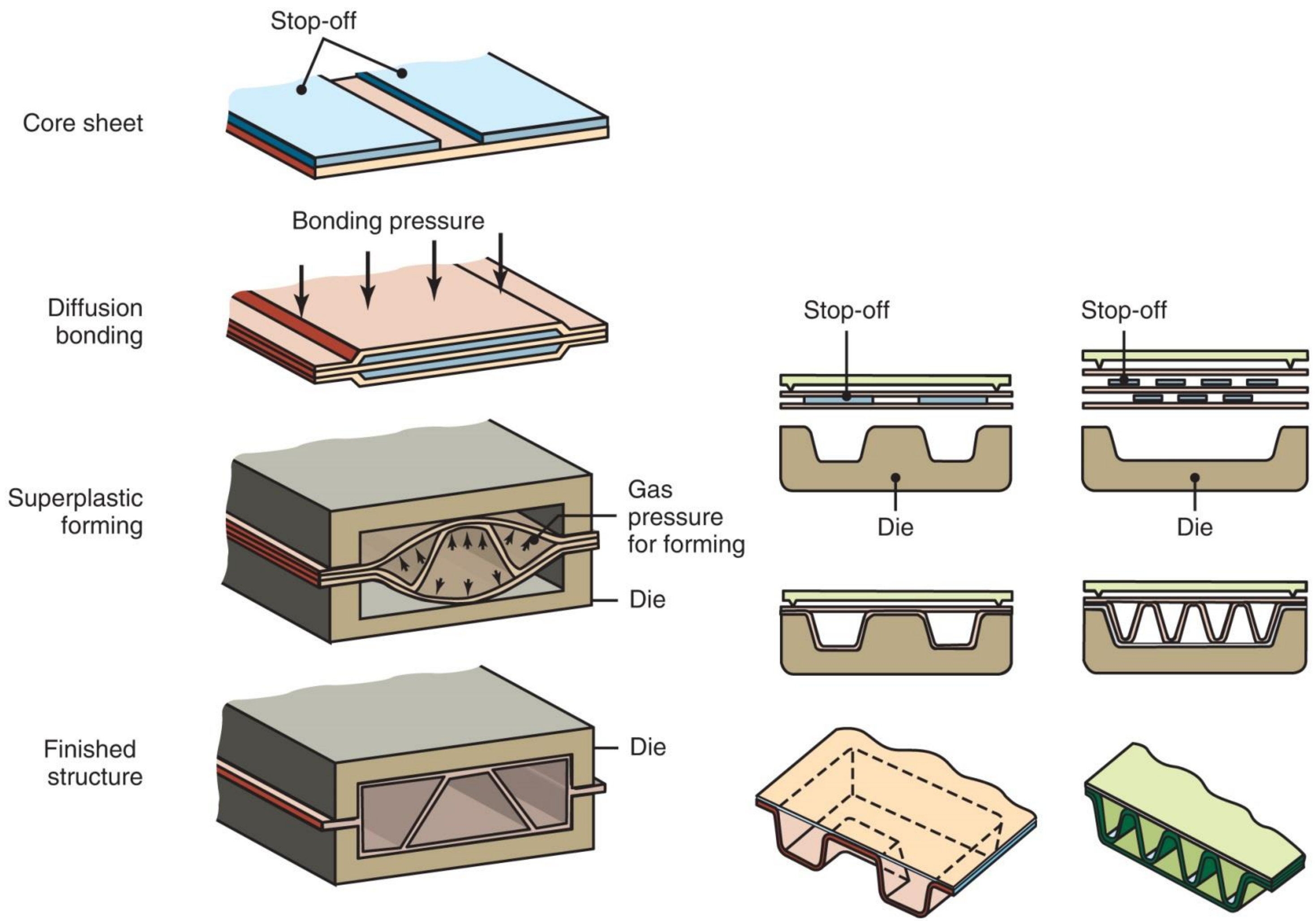
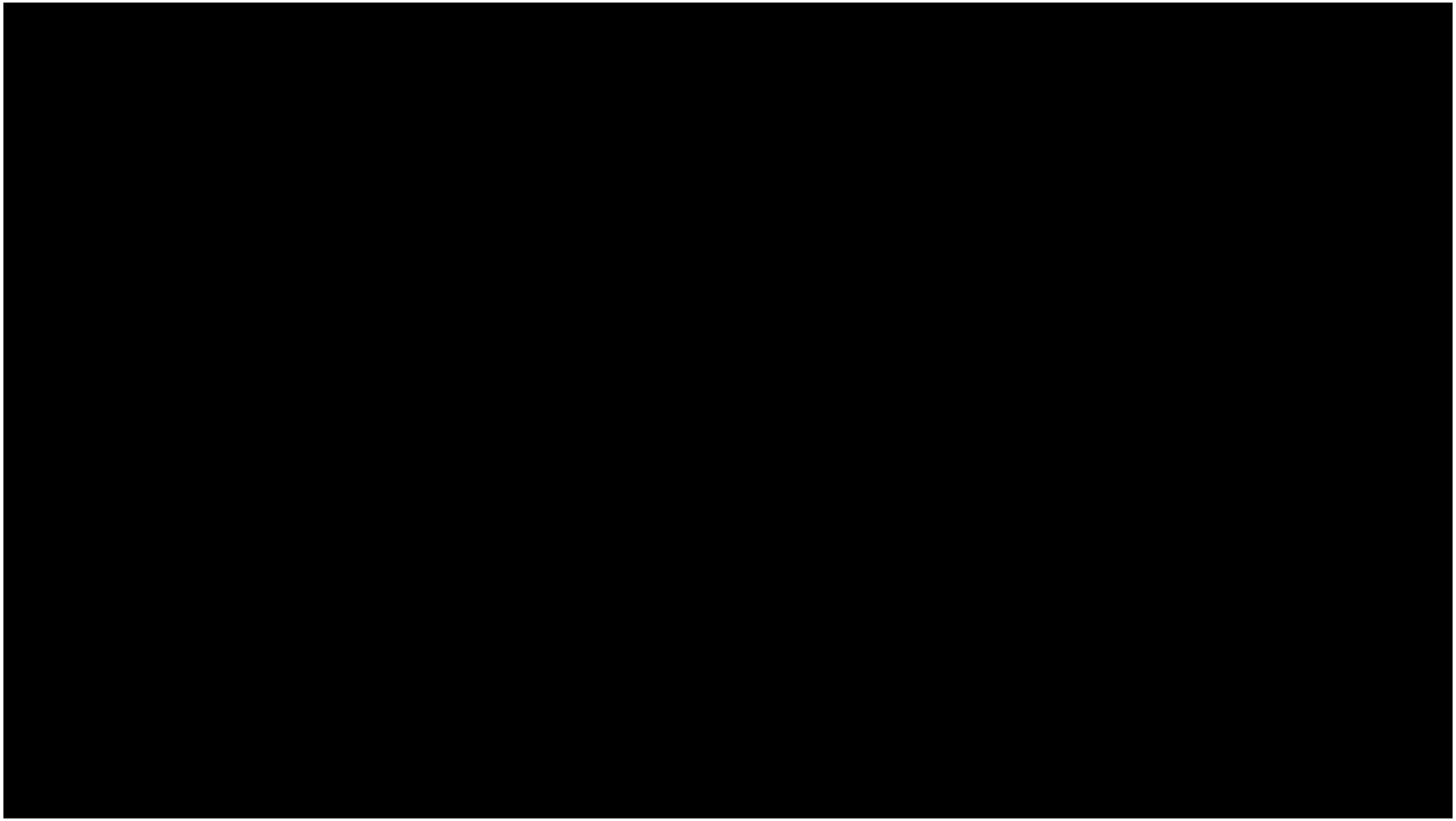


Figure 31.18

The sequence of operations in the fabrication of a structure by the diffusion bonding and superplastic forming of three originally flat sheets (see also Fig. 16.52).



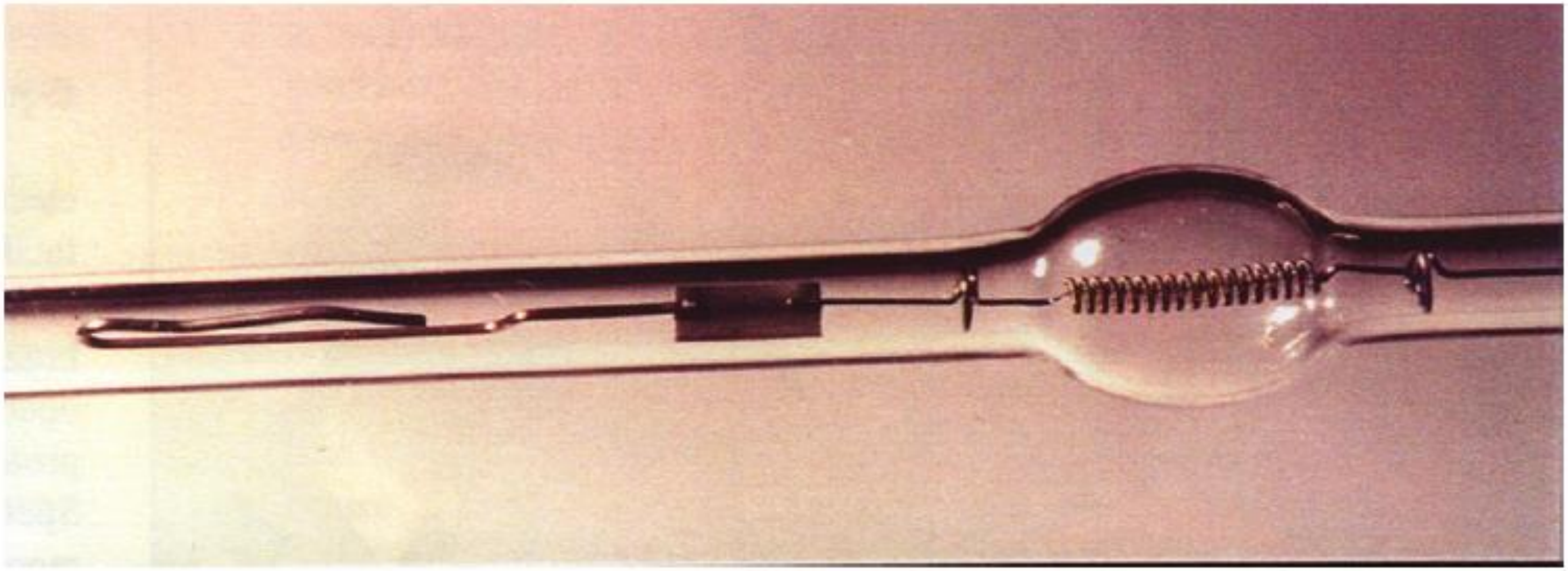
Diffusion Bonding



https://youtu.be/5EhMYMr834o

Figure 32.1 (1 of 3)

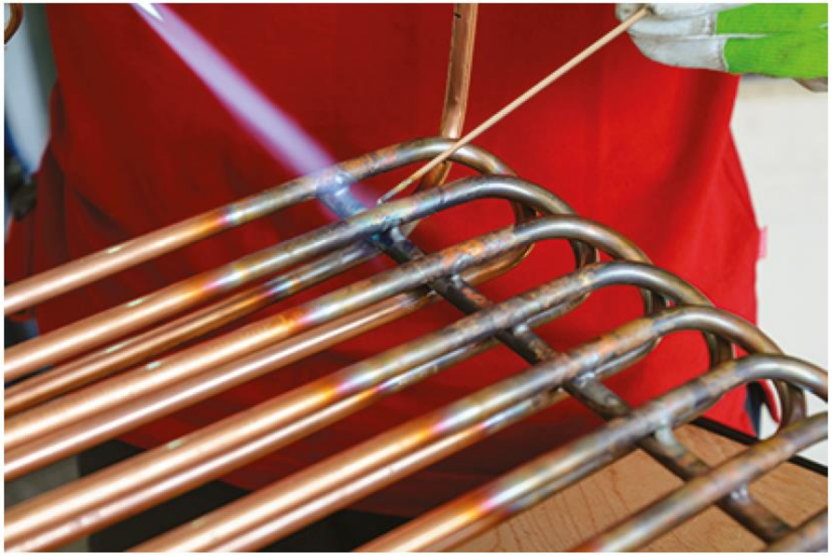
Examples of brazed and soldered joints. (a) Torch brazing of heat exchanger tubes; (b) a circuit board showing soldered components.



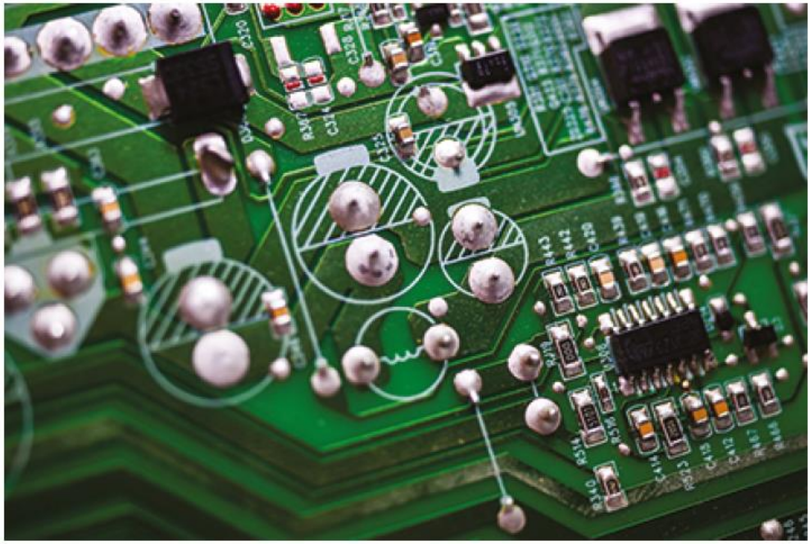
(a)

Source: Courtesy of (a) Shutterstock/Bildagentur Zoonar GmbH.

Figure 32.1 (2 of 3)



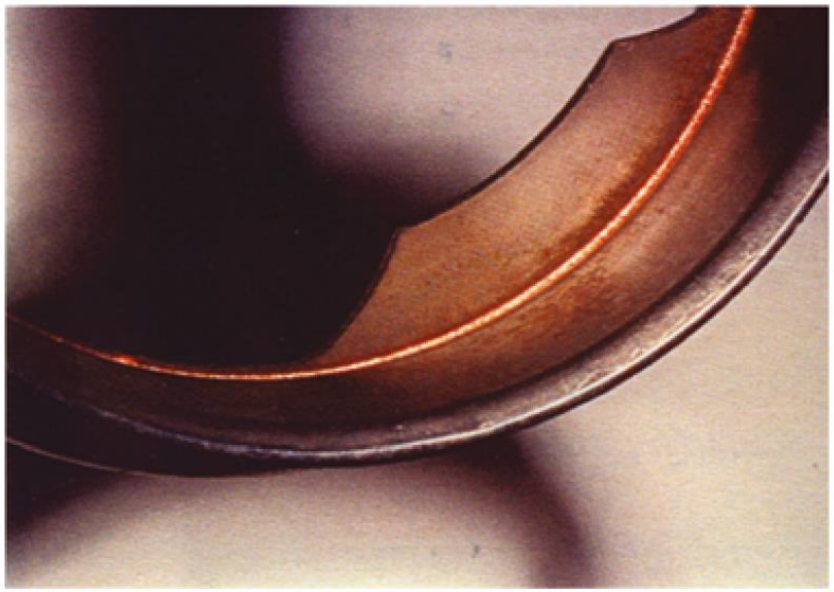
(b)



(c)

Source: Courtesy of (b) Shutterstock/Chaikom.

Figure 32.1 (3 of 3)

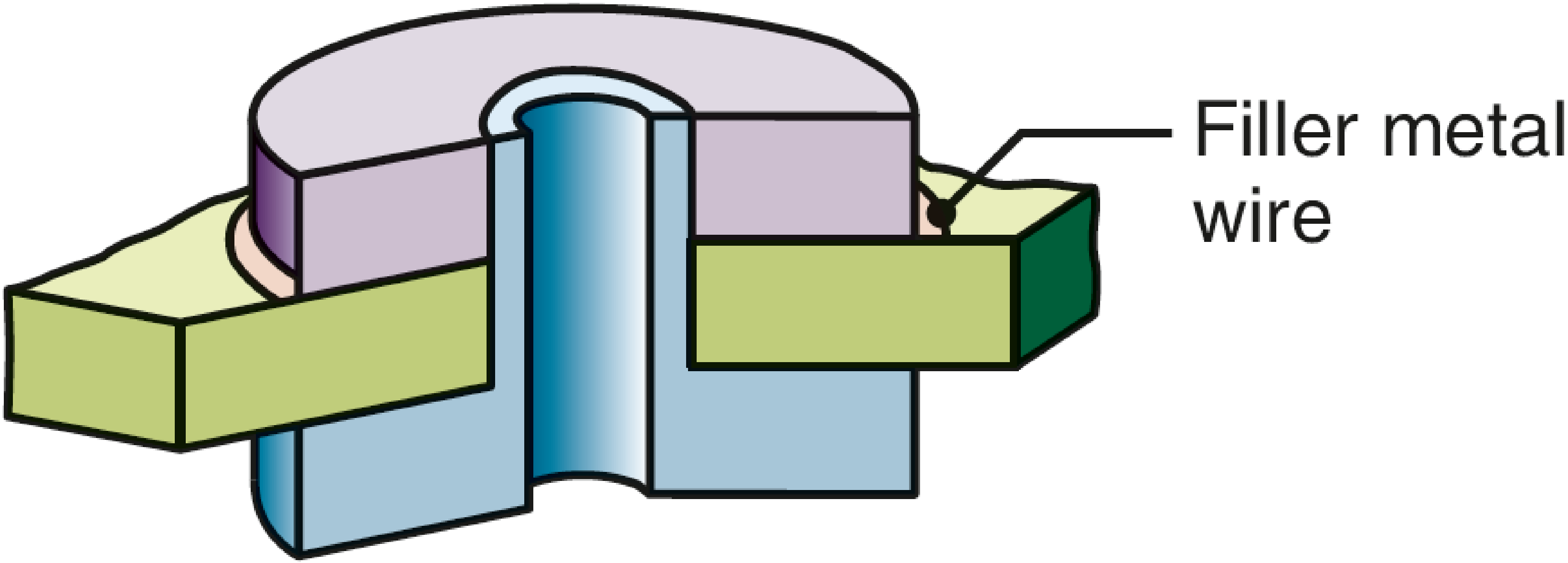


(d)

(e)

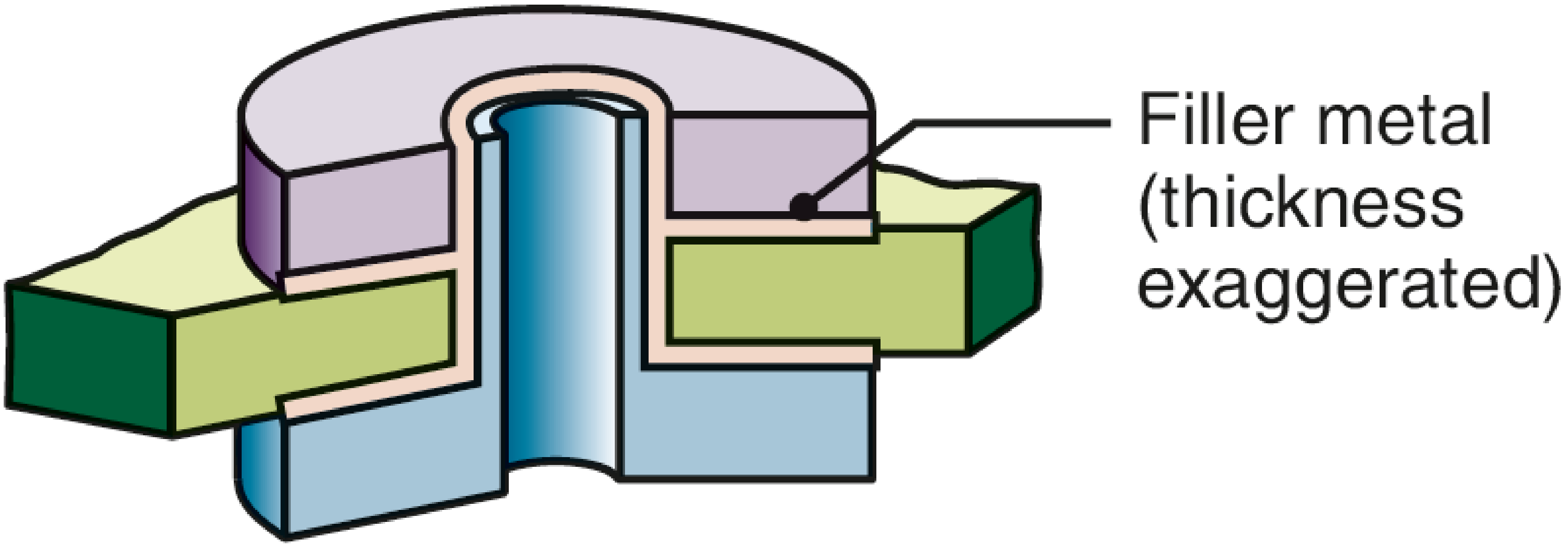
Figure 32.2 (1 of 2)

An example of furnace brazing (a) before and (b) after brazing. The filler metal is a shaped wire and the molten filler moves into the interfaces by capillary action, with the application of heat.



(a)

Figure 32.2 (2 of 2)



(b)

Figure 32.3 (1 of 8)

Joint designs commonly used in brazing operations. The clearance between the two parts being brazed is an important factor in joint strength. If the clearance is too small, the molten braze metal will not fully penetrate the interface; if it is too large, there will be insufficient capillary action for the metal to fill the interface.

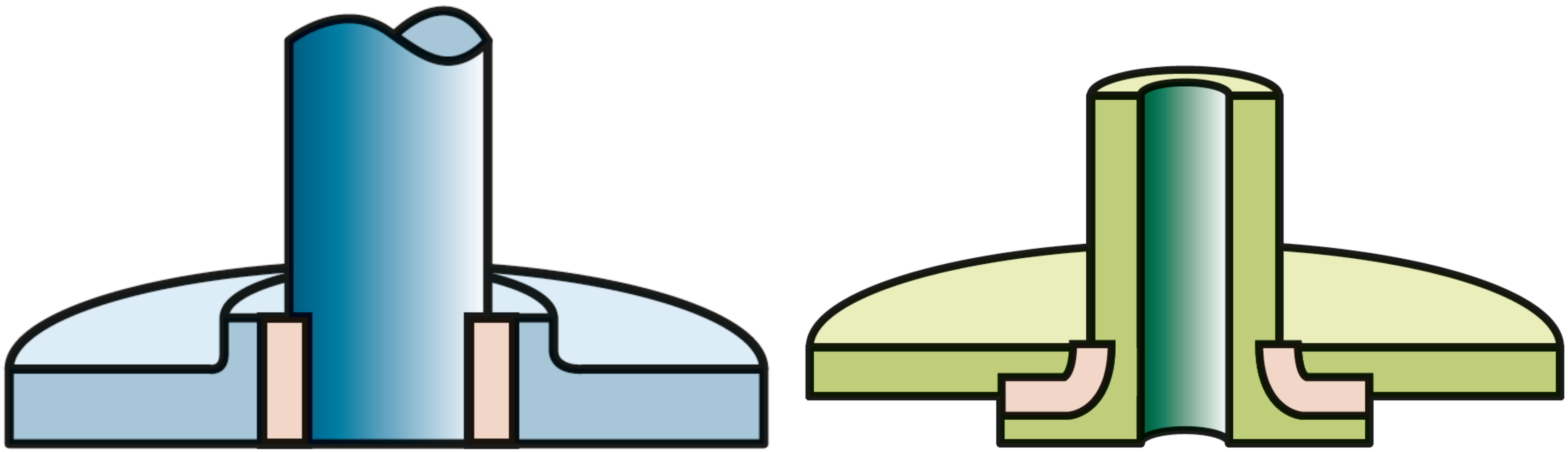


Figure 32.3 (2 of 8)

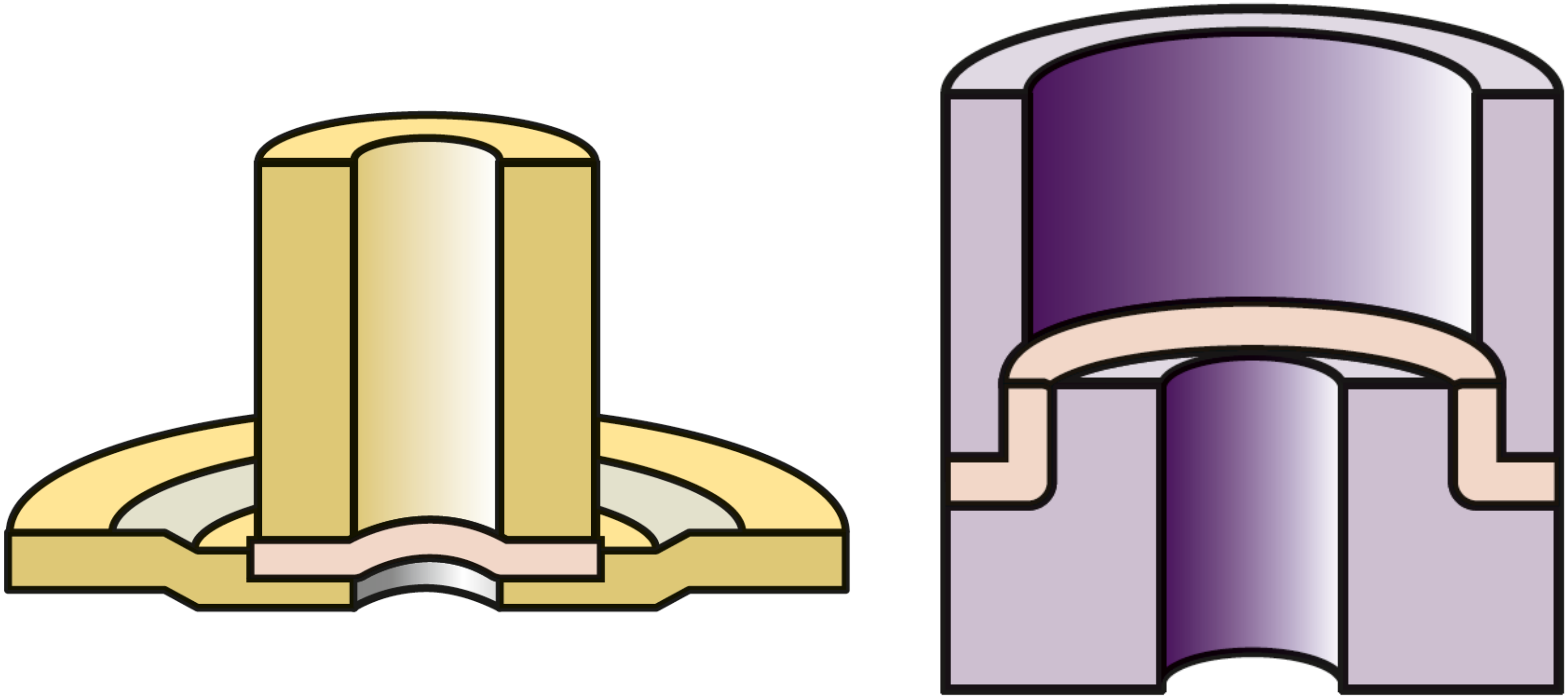


Figure 32.3 (3 of 8)

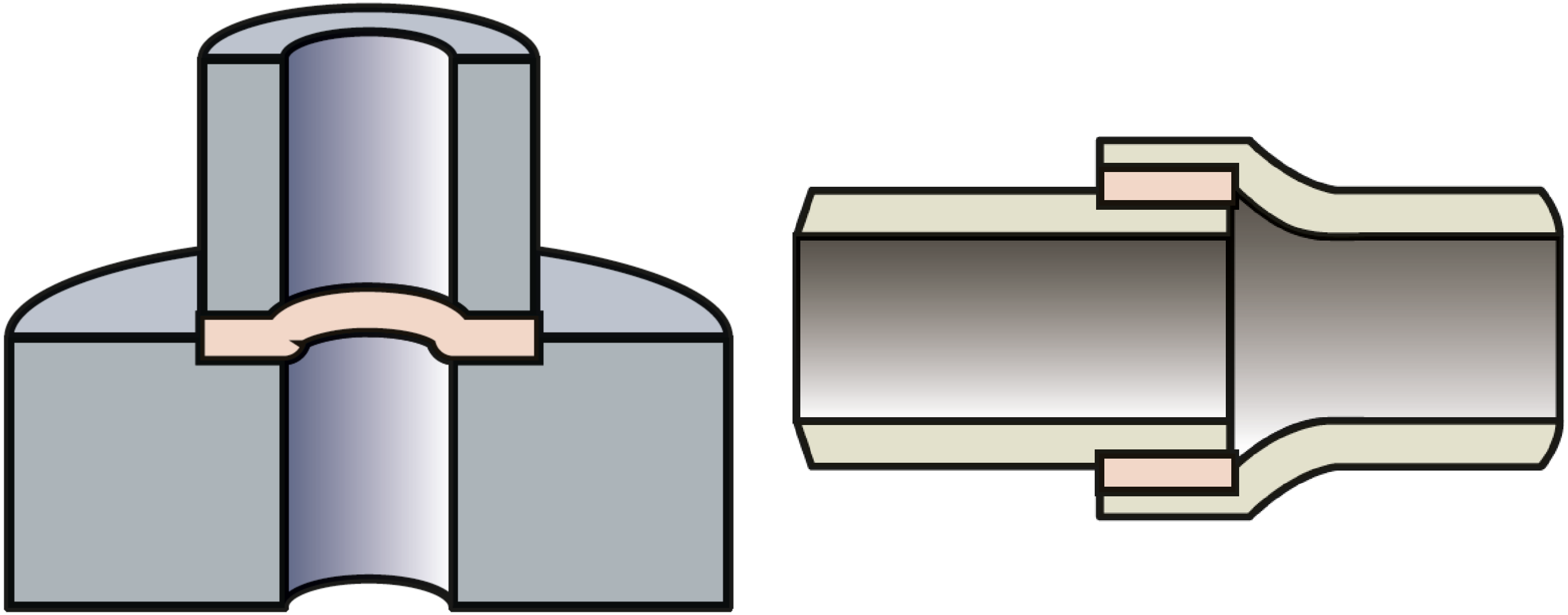


Figure 32.3 (4 of 8)

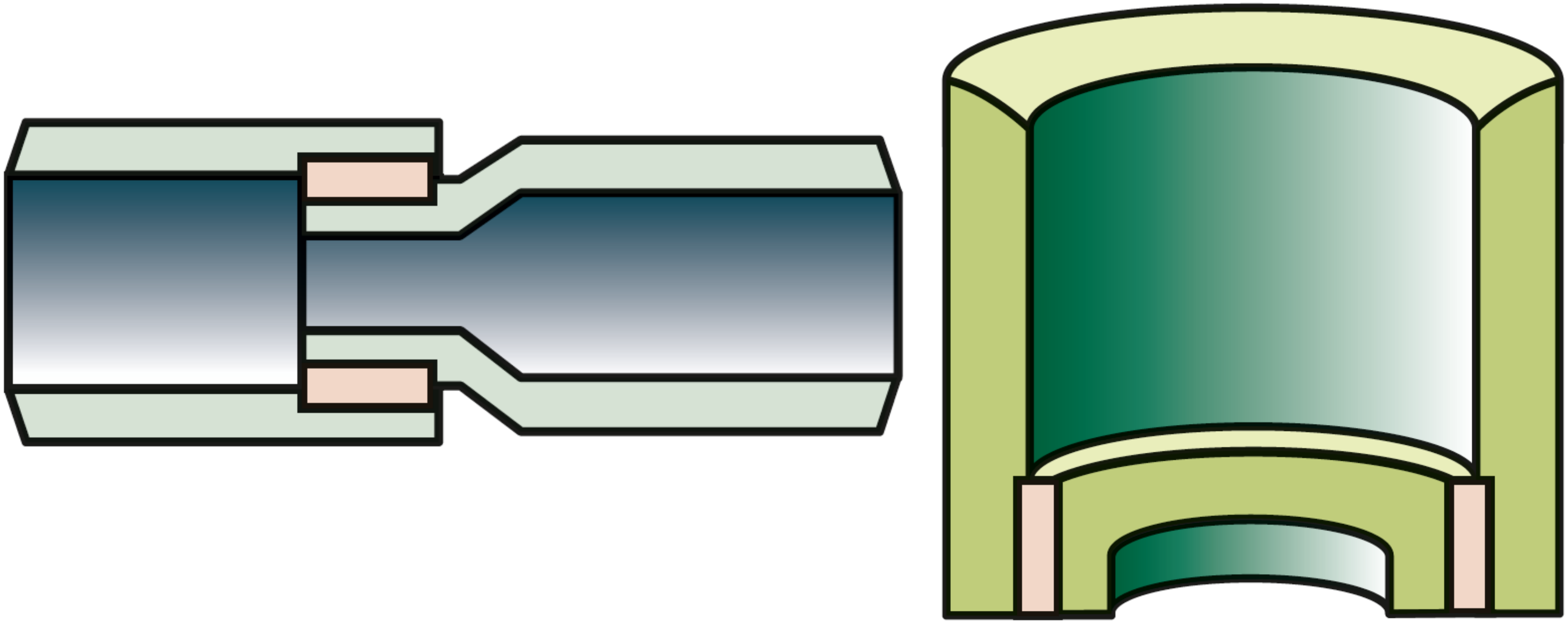


Figure 32.3 (5 of 8)

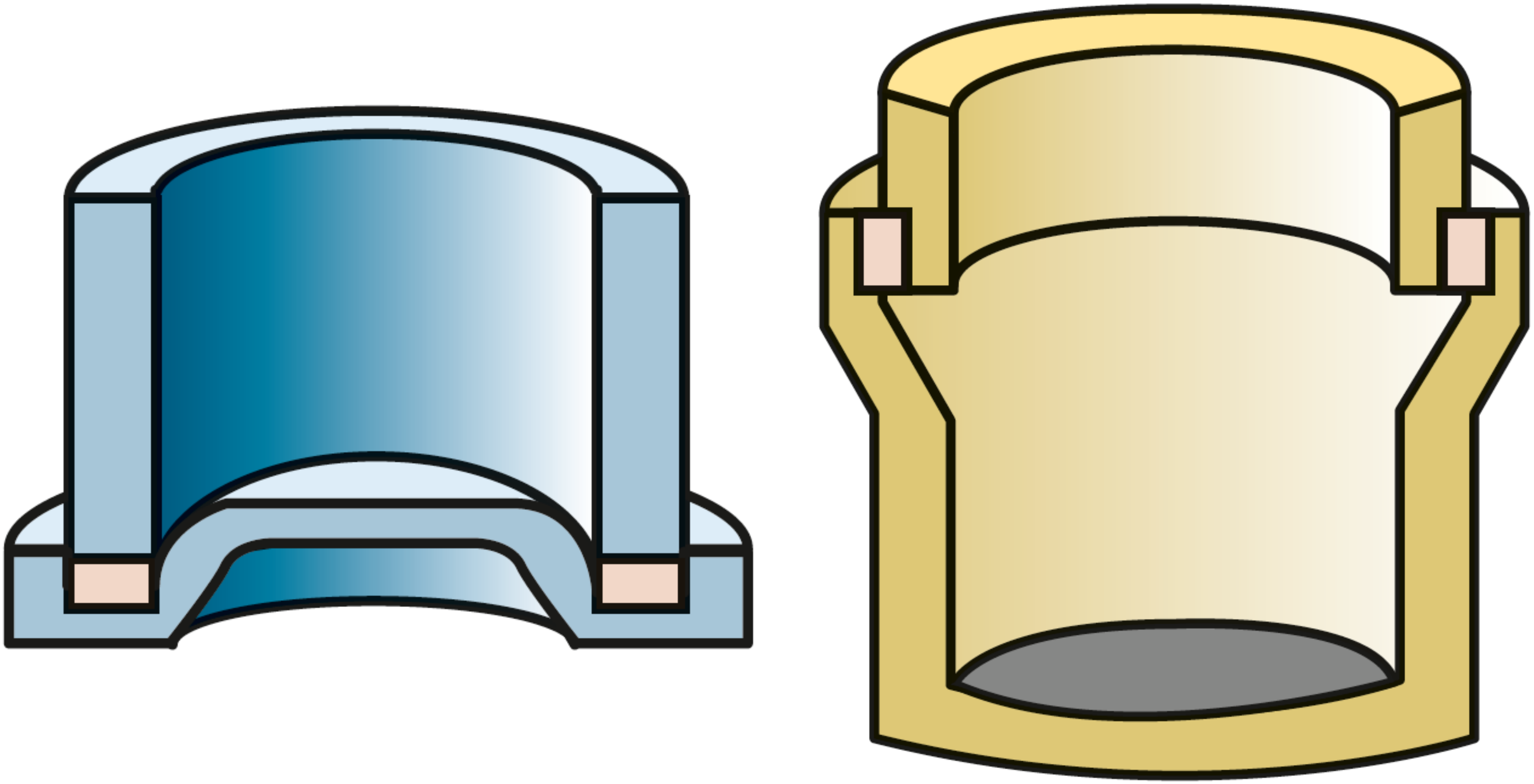


Figure 32.3 (6 of 8)

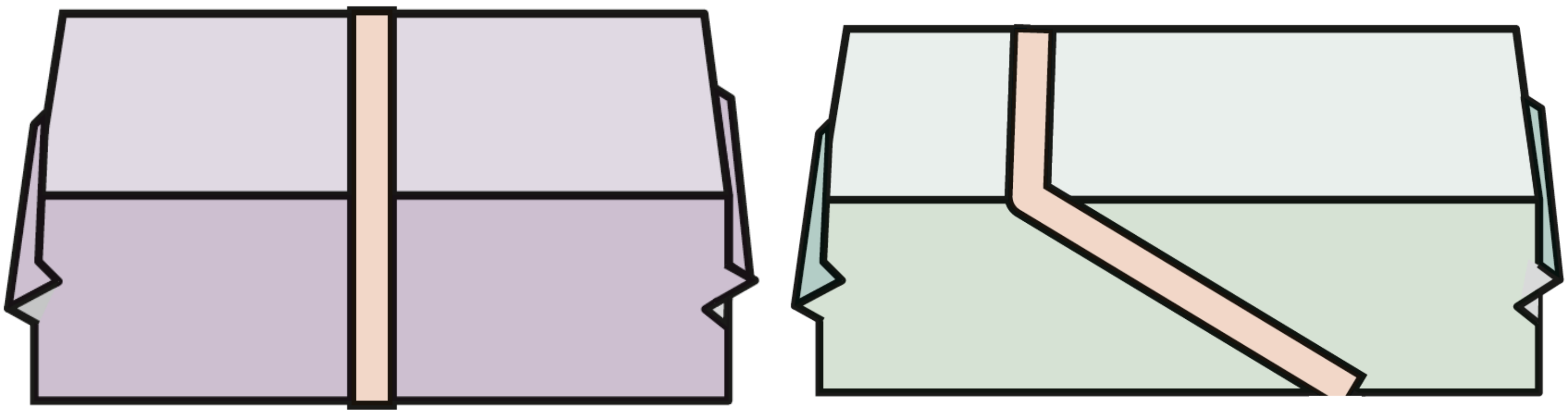


Figure 32.3 (7 of 8)

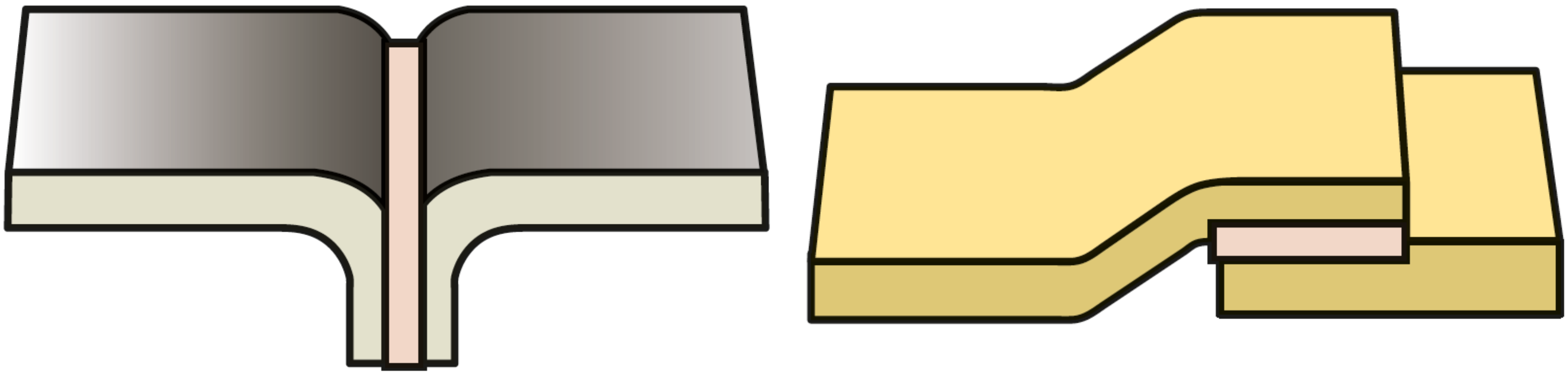


Figure 32.3 (8 of 8)

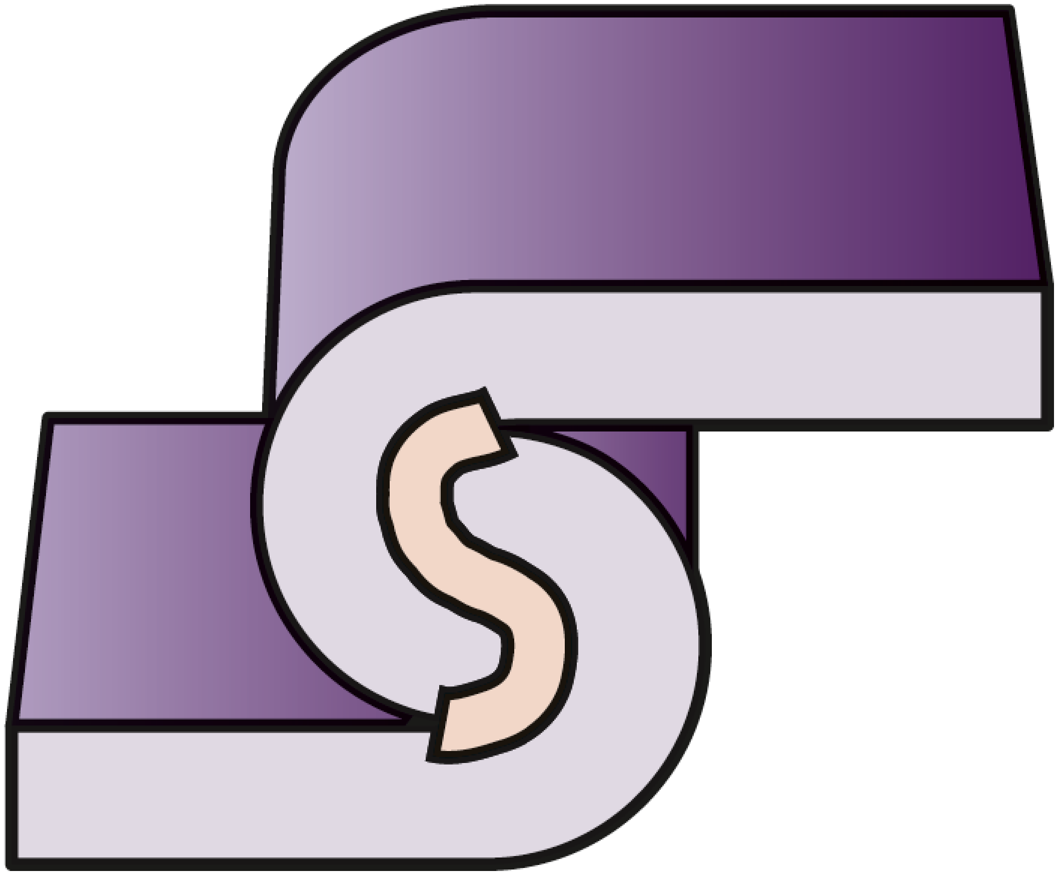


Table 32.1

Typical Filler Metals for Brazing Various Metals and Alloys.

Base metal	Filler metal	Brazing temperature (°C)
Aluminum and its alloys	Aluminum–silicon	570–620
Magnesium alloys	Magnesium–aluminum	580–625
Copper and its alloys	Copper–phosphorus and gold-copper-phosphorus	700–925
Ferrous and nonferrous (except aluminum and magnesium)	Silver and copper alloys, copper–phosphorus, copper-zinc	620–1150
Iron-, nickel-, and cobalt-based alloys	Gold-copper and gold-paladium	900–1100
Stainless steels, nickel- and cobalt-based alloys	Nickel–silver	925–1200

Figure 32.4

The effect of joint clearance on the tensile and shear strength of brazed joints. Note that, unlike tensile strength, the shear strength continually decreases as the clearance increases.

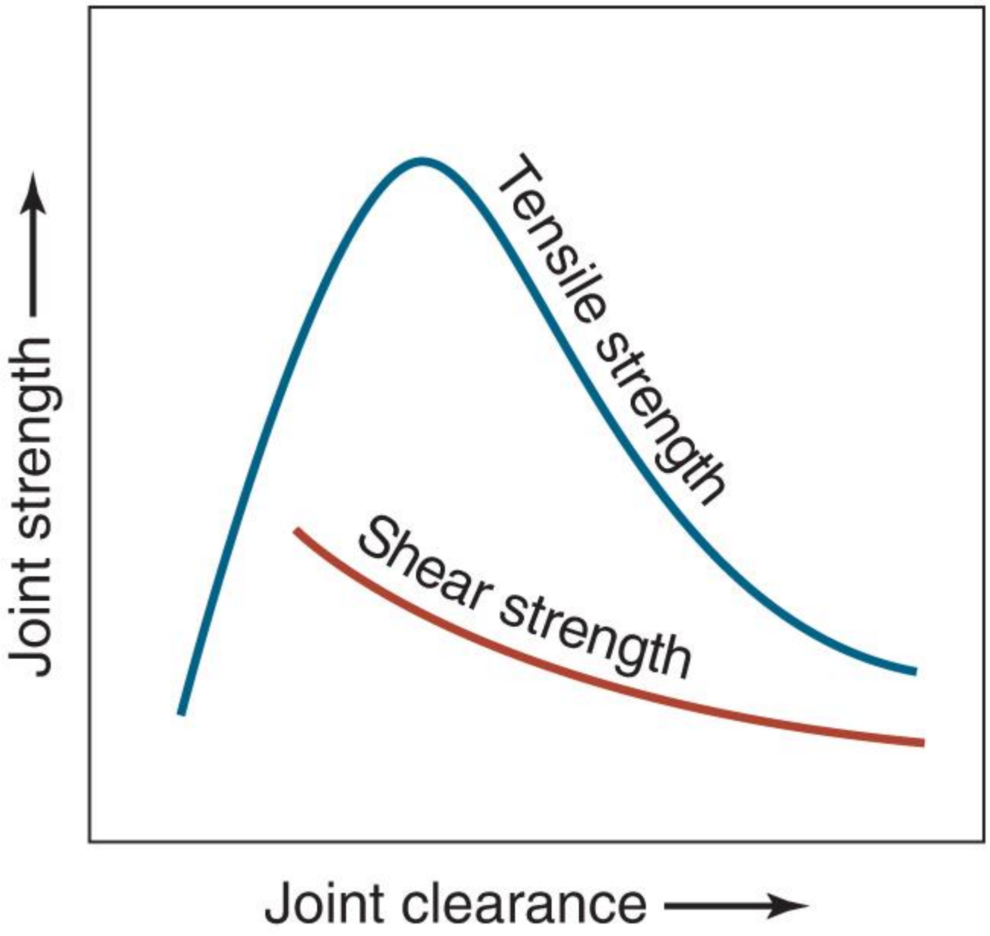


Figure 32.5

Schematic illustration of a continuous induction brazing setup for increased productivity.

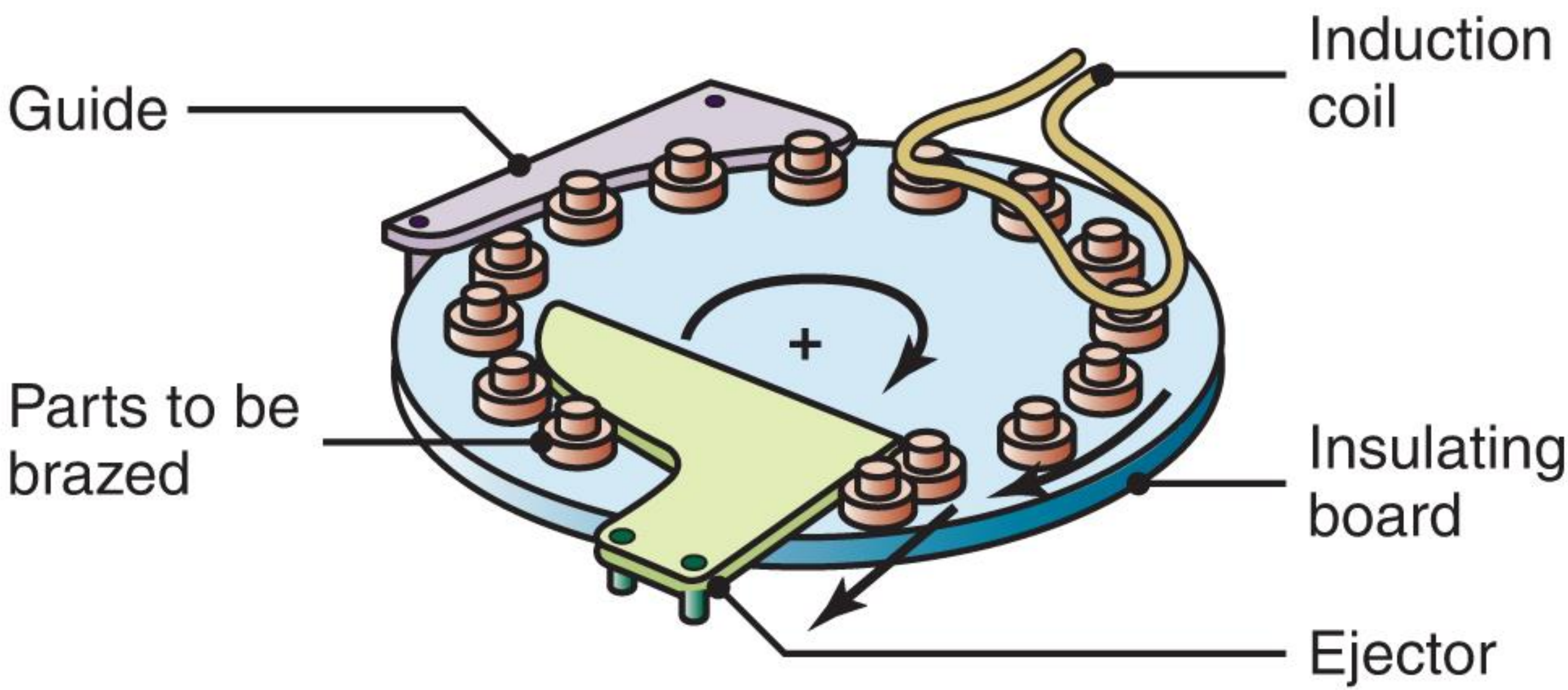
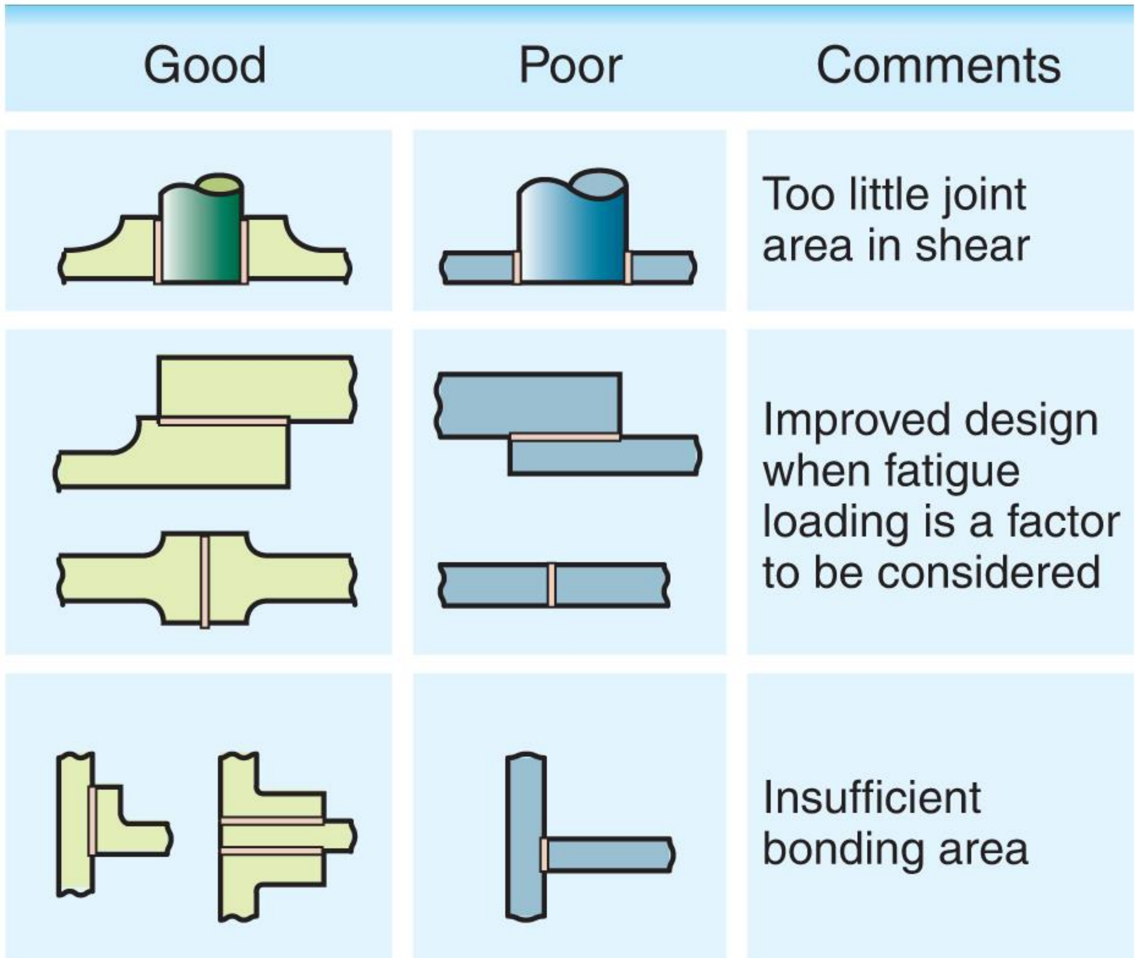


Figure 32.6

Examples of good and poor designs for brazing.



Source: American Welding Society.

Table 32.2

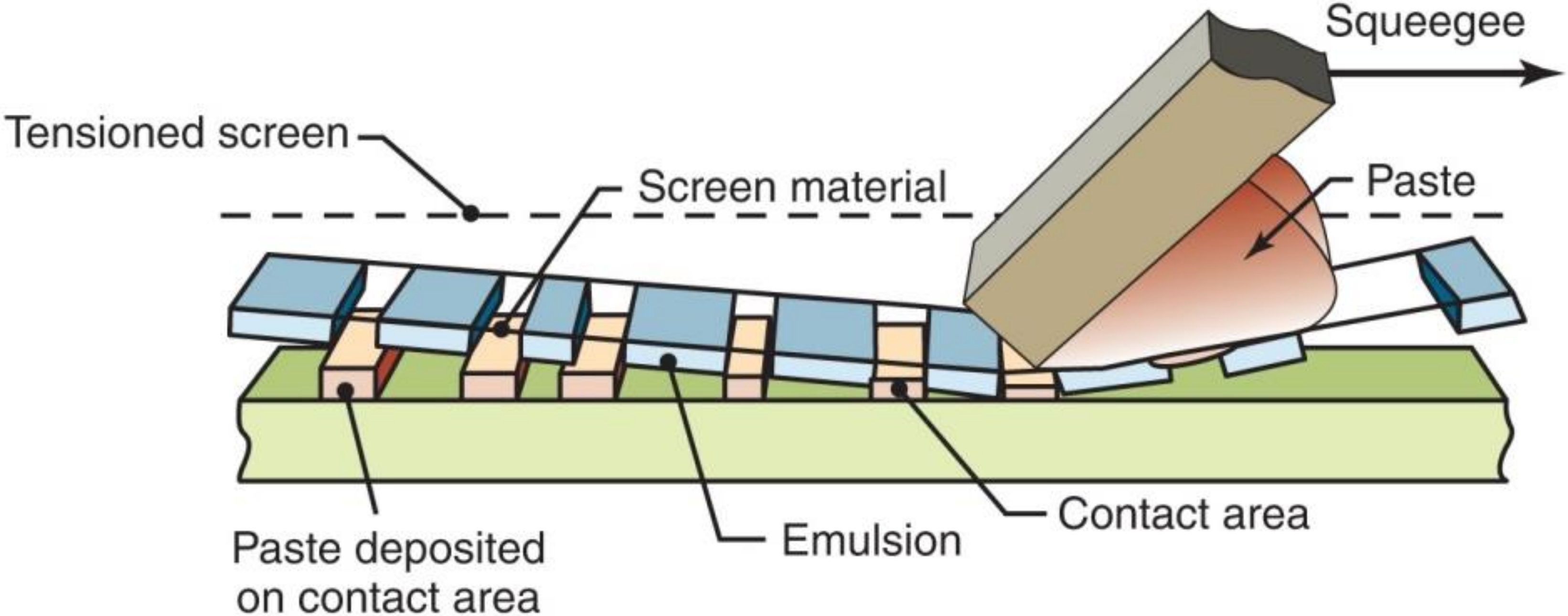
A Selection of Common Solders and Their Typical Applications.

Tin–lead	General purpose
Tin–zinc	Aluminum
Lead–silver	Strength at higher than room temperature
Cadmium–silver	Strength at high temperatures
Zinc–aluminum	Aluminum, corrosion resistance
Tin–silver	Electronics
Tin–bismuth	Electronics

Pearson

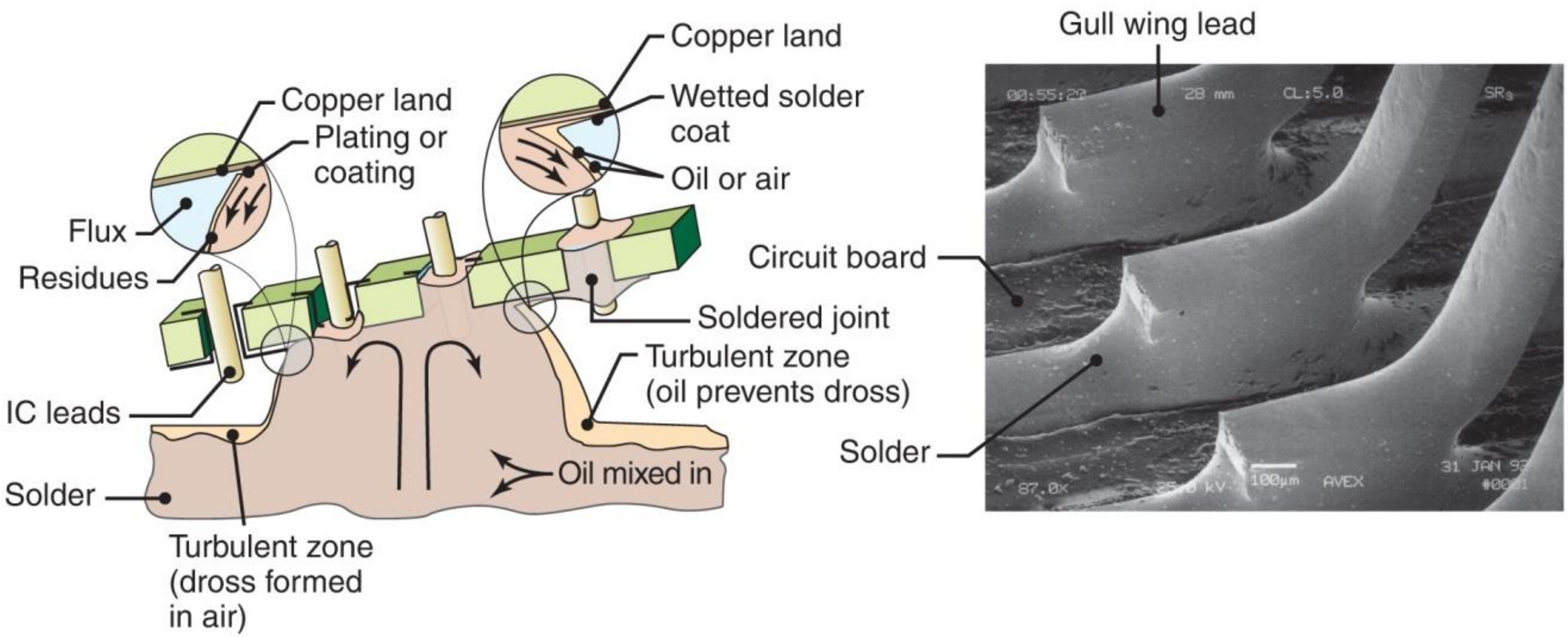
Figure 32.7 (1 of 2)

(a) Screening solder paste onto a printed circuit board in reflow soldering. (b) Schematic illustration of the wave-soldering process. (c) SEM image of a wave-soldered joint on surface-mount device.



(a)

Figure 32.7 (2 of 2)

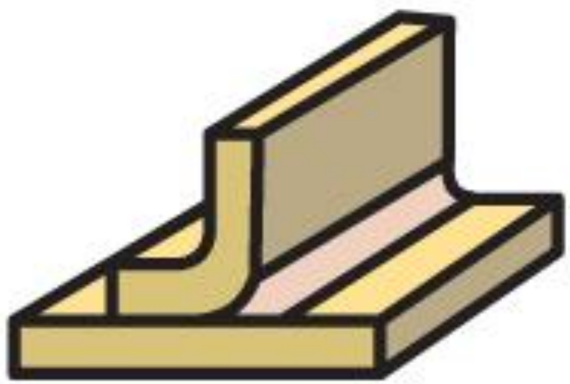


(b) (c)

Source: (a) After V. Solberg.

Figure 32.8 (1 of 5)

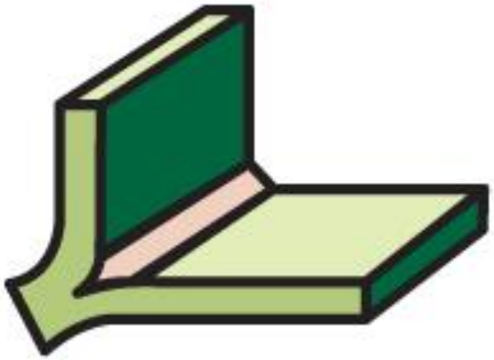
Joint designs commonly used for soldering.



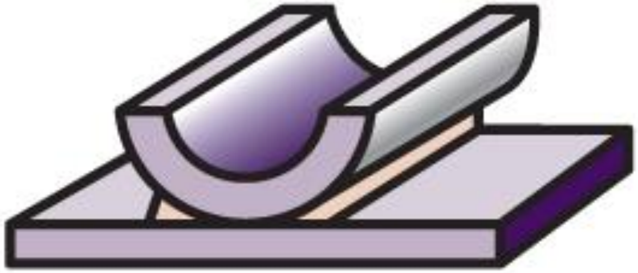
(a) Flanged T

(b) Flush lap

Figure 32.8 (2 of 5)



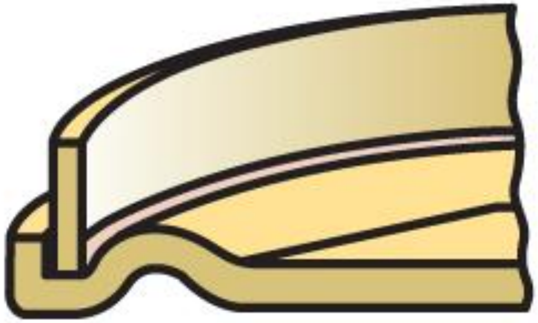
(c) Flanged corner



(d) Line contact

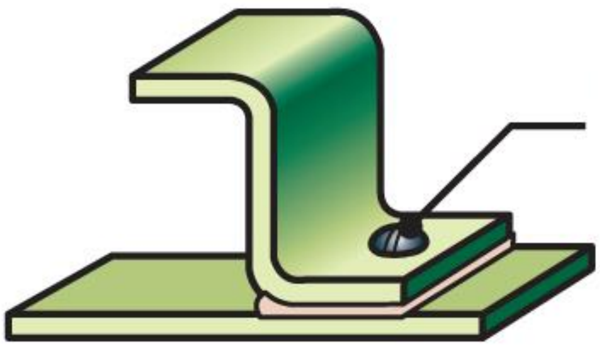
Figure 32.8 (3 of 5)

(e) Flat lock seam

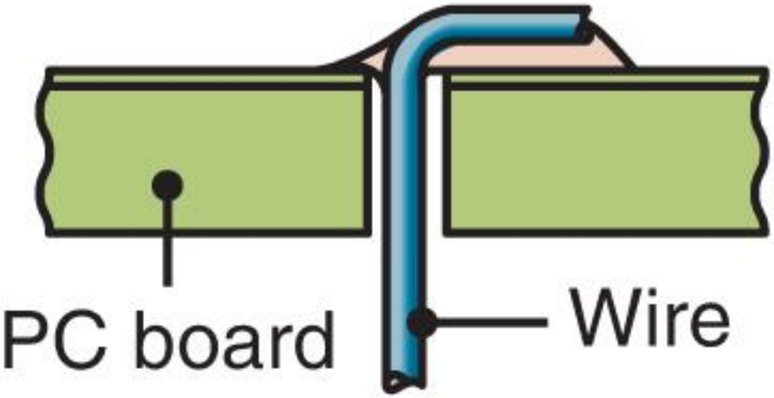


(f) Flanged bottom

Figure 32.8 (4 of 5)

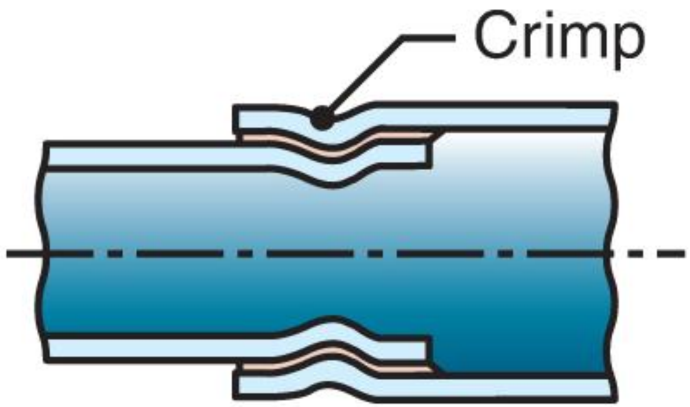


(g) Combination joint



(h) Through hole connection

Figure 32.8 (5 of 5)



(i) Crimped combination joint

(j) Twisted wire joint

Table 32.3

Typical Properties and Characteristics of Chemically Reactive Structural Adhesives.

	Epoxy	Polyurethane	Modified acrylic	Cyanoacrylate	Anaerobic
Impact resistance	Poor	Excellent	Good	Poor	Fair
Tension-shear strength, MPa (10^3 psi)	15–22 (2.2–3.2)	12–20 (1.7–2.9)	20–30 (2.9–4.3)	18.9 (2.7)	17.5 (2.5)
Peel strength*, N/m (lb/in.)	$<$ 523 (3)	14,000 (80)	5250 (30)	$<$ 525 (3)	1750 (10)
Substrates bonded	Most	Most smooth, nonporous	Most smooth, nonporous	Most nonporous metals or plastics	Metals, glass, thermosets
Service temperature range, °C (°F)	–55 to 120 (–70 to 250)	–40 to 90 (–250 to 175)	–70 to 120 (–100 to 250)	–55 to 80 (–70 to 175)	–55 to 150 (–70 to 300)
Heat cure or mixing required	Yes	Yes	No	No	No
Solvent resistance	Excellent	Good	Good	Good	Excellent
Moisture resistance	Good Excellent	Fair Fair	Good Good	Poor Poor	Good Good
Gap limitation, mm (in.)	None	None	0.5 (0.02)	0.25 (0.01)	0.60 (0.025)
Odor	Mild	Mild	Strong	Moderate	Mild
Toxicity	Moderate	Moderate	Moderate	Low	Low
Flammability	Low	Low	High	Low	Low

*Peel strength varies widely, depending on surface preparation and quality.

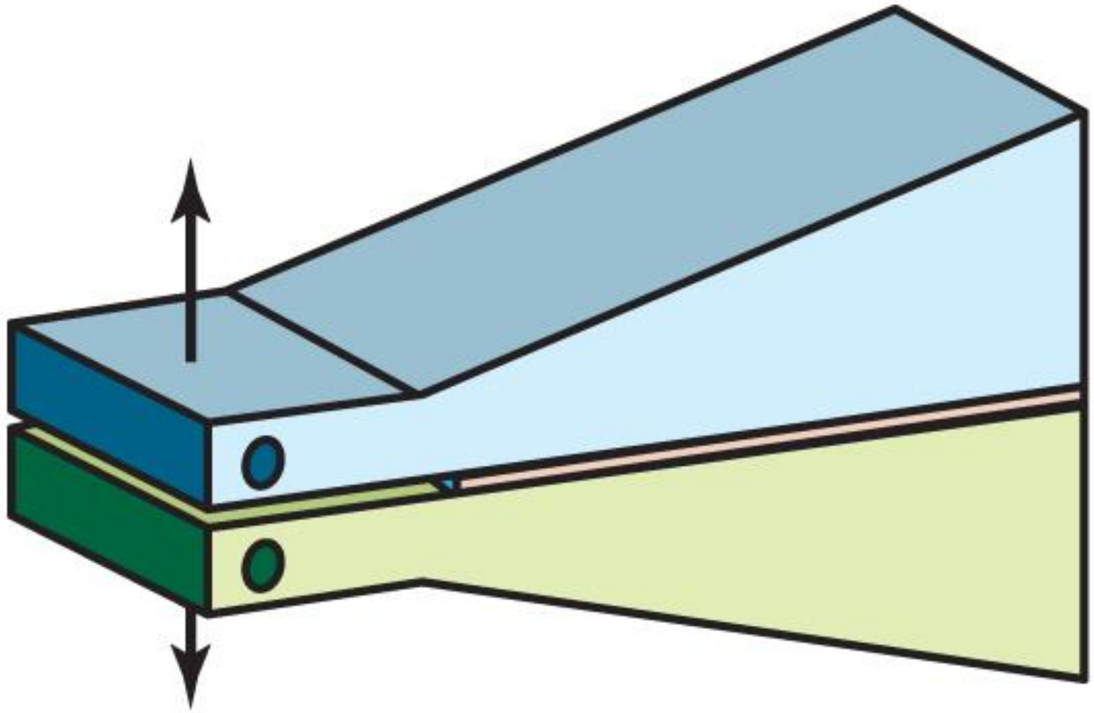
Table 32.4

General Characteristics of Adhesives.

Type	Comments	Applications
Acrylic	Thermoplastic; quick setting; tough bond at room temperature; two components; good solvent chemical and impact resistance; short work life; odorous; ventilation required	Fiberglass and steel sandwich bonds, tennis racquets, metal parts, and plastics
Anaerobic	Thermoset; easy to use; slow curing; bonds at room temperature; curing occurs in absence of air; will not cure where air contacts adherents; one component; not good on permeable surfaces	Close-fitting machine parts, such as shafts and pulleys, nuts and bolts, and bushings and pins
Epoxy	Thermoset; one or two components; tough bond; strongest of engineering adhesives; high tensile and low peel strengths; resists moisture and high temperature; difficult to use	Metal, ceramic, and rigid plastic parts
Cyanoacrylate	Thermoplastic; quick setting; tough bond at room temperature; easy to use; colorless	"Krazy Glue"; bonds most materials; especially useful for ceramics and plastics
Hot melt	Thermoplastic; quick setting; rigid or flexible bonds; easy to apply; brittle at low temperatures; based on ethylene vinyl acetate, polyolefins, polyamides, and polyesters	Bonds most materials; packaging, book binding, and metal can joints
Pressure sensitive	Thermoplastic variable strength bonds; primer anchors adhesive to roll tape backing material—a release agent on the back of web permits unwinding; made of polyacrylate esters and various natural and synthetic rubbers	Tapes, labels, and stickers
Phenolic	Thermoset; oven cured; strong bond; high tensile and low impact strength; brittle; easy to use; cures by solvent evaporation	Acoustical padding, brake lining and clutch pads, abrasive grain bonding, and honeycomb structures
Silicone	Thermoset; slow curing; flexible; bonds at room temperature; high impact and peel strength; rubberlike	Gaskets and sealants
Formaldehyde (Urea, Melamine, Phenol, Resorcinol)	Thermoset; strong with wood bonds; urea is inexpensive, is available as powder or liquid, and requires a catalyst; melamine is more expensive, cures with heat, and the bond is waterproof; resorcinol forms a waterproof bond at room temperature. Types can be combined	Wood joints, plywood, and bonding
Urethane	Thermoset; bonds at room temperature or oven cure; good gap-filling qualities	Fiberglass body parts, rubber, and fabric
Water-based (Animal, Vegetable, Rubbers)	Inexpensive, nontoxic, nonflammable	Wood, paper, fabric, leather, and dry seal envelopes

Figure 32.9 (1 of 3)

Common arrangements for evaluating adhesives: (a) tapered double cantilever beam.

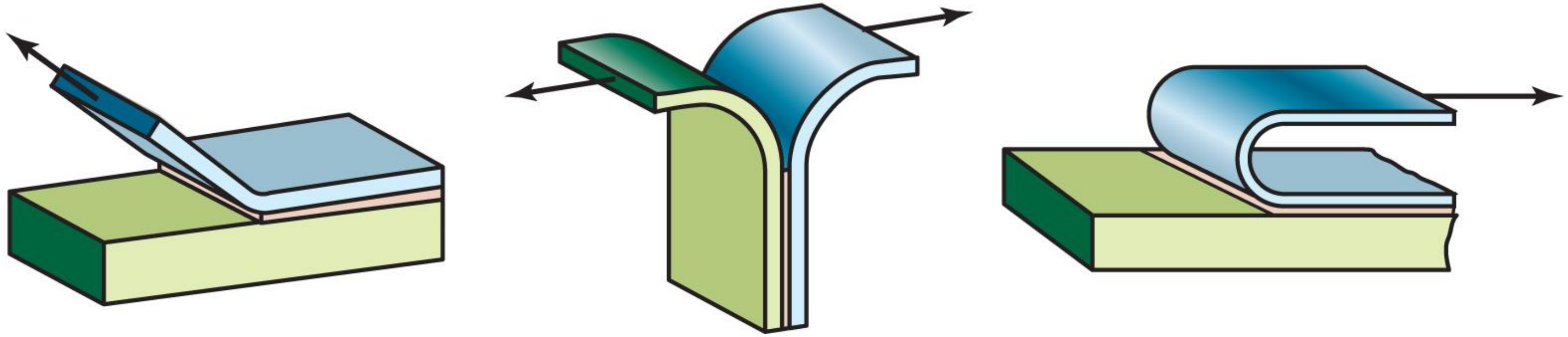


(a)

Pearson

Figure 32.9 (2 of 3)

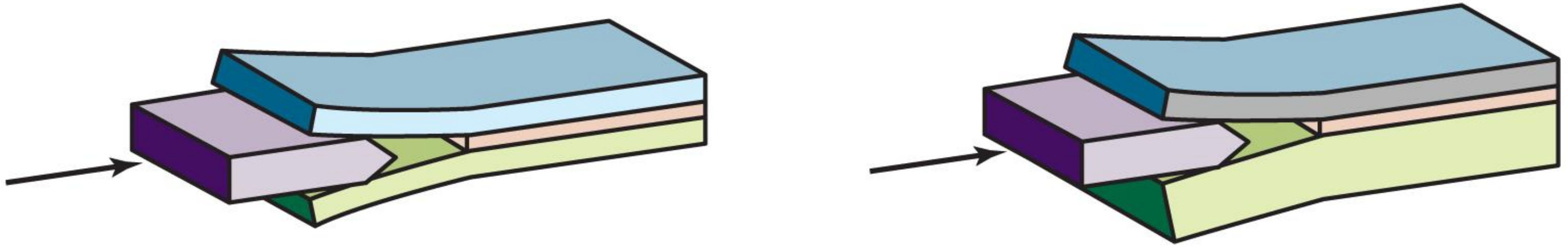
Common arrangements for evaluating adhesives: (b) peel tests.



(b)

Figure 32.9 (3 of 3)

Common arrangements for evaluating adhesives: (c) wedge tests.



(c)

Figure 32.10 (1 of 2)

Characteristic behavior of (a) brittle.

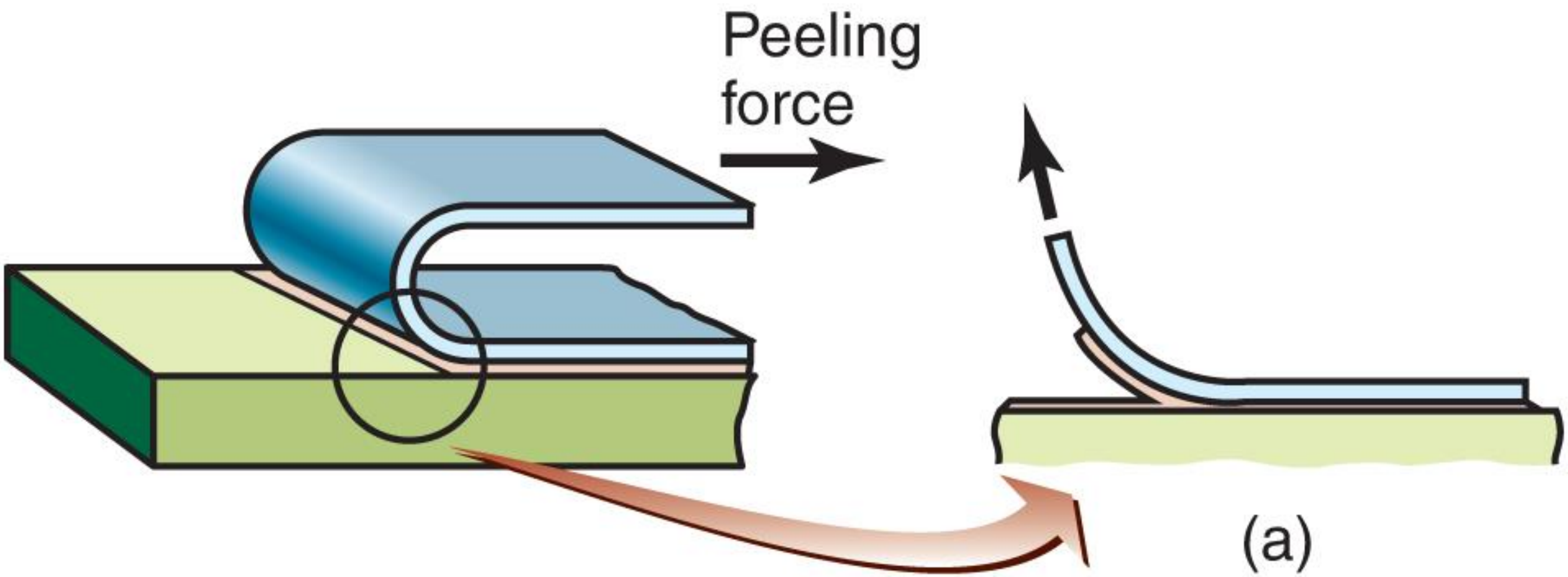


Figure 32.10 (2 of 2)

Characteristic behavior of (b) tough adhesives in a peeling test. This test is similar to the peeling of adhesive tape from a solid surface.

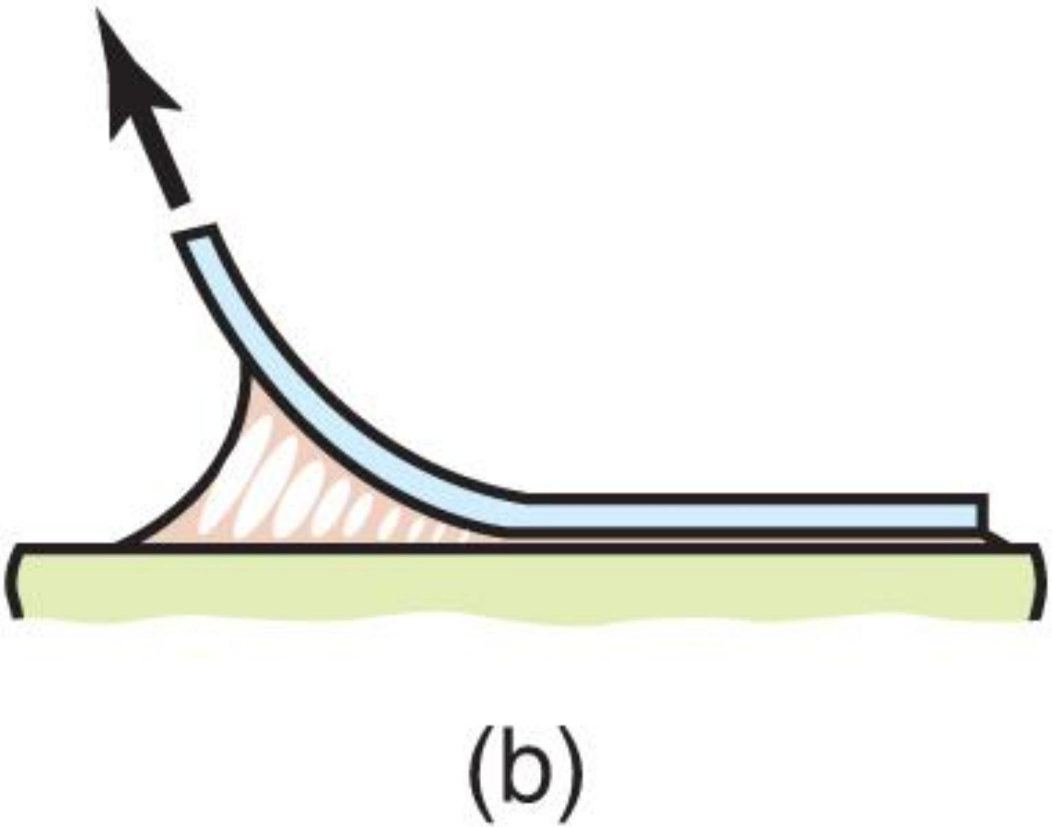


Figure 32.11

Various joint designs in adhesive bonding. Note especially that good designs require large contact areas between the members to be joined.

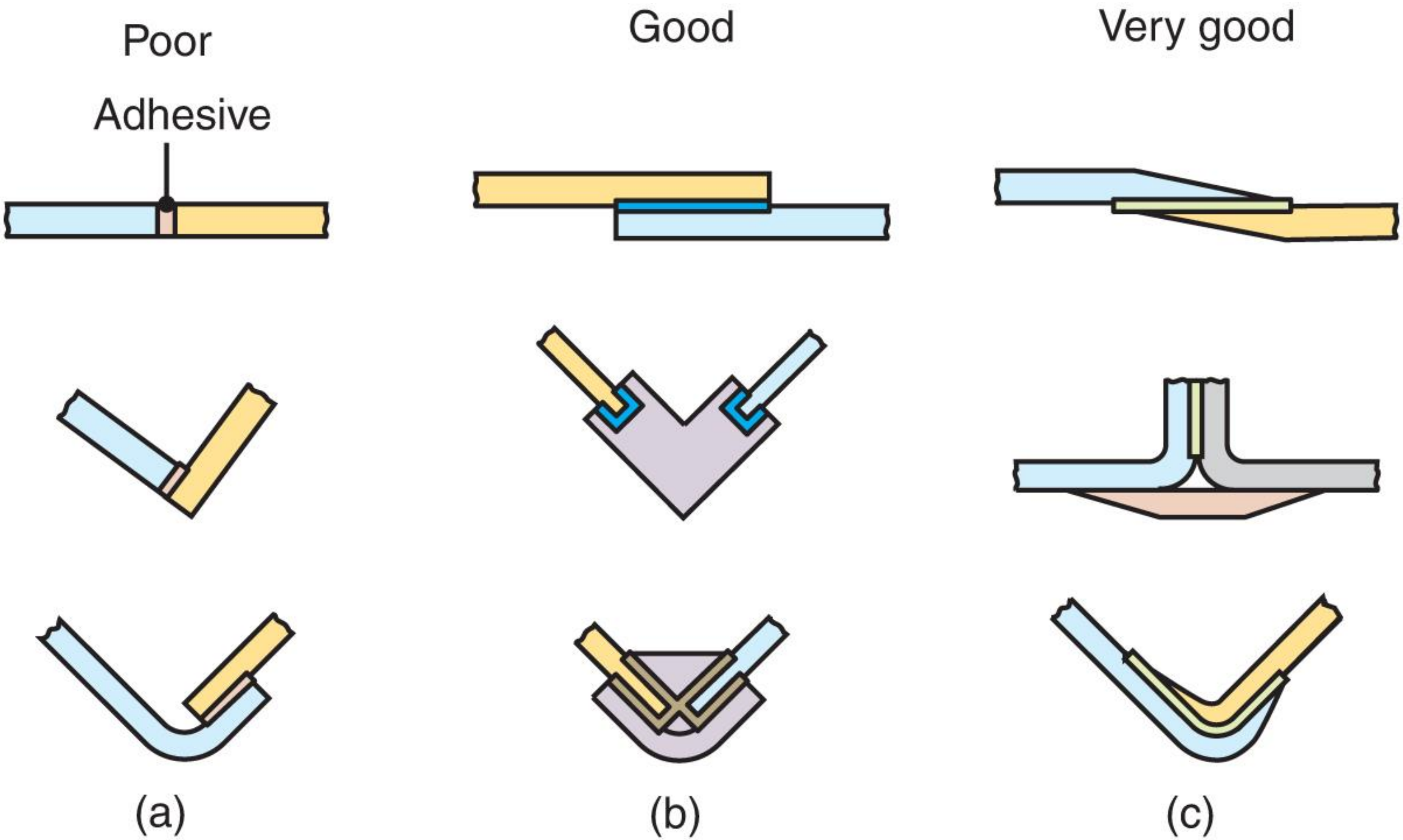
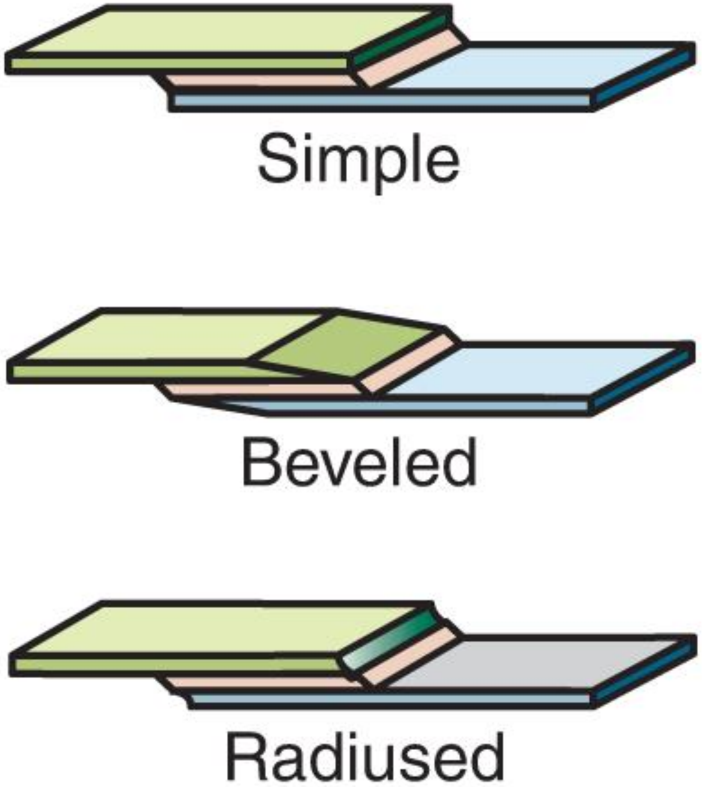


Figure 32.12 (1 of 4)

Desirable configurations for adhesively bonded joints: (a) single lap.



(a)

Figure 32.12 (2 of 4)

Desirable configurations for adhesively bonded joints: (b) double lap.

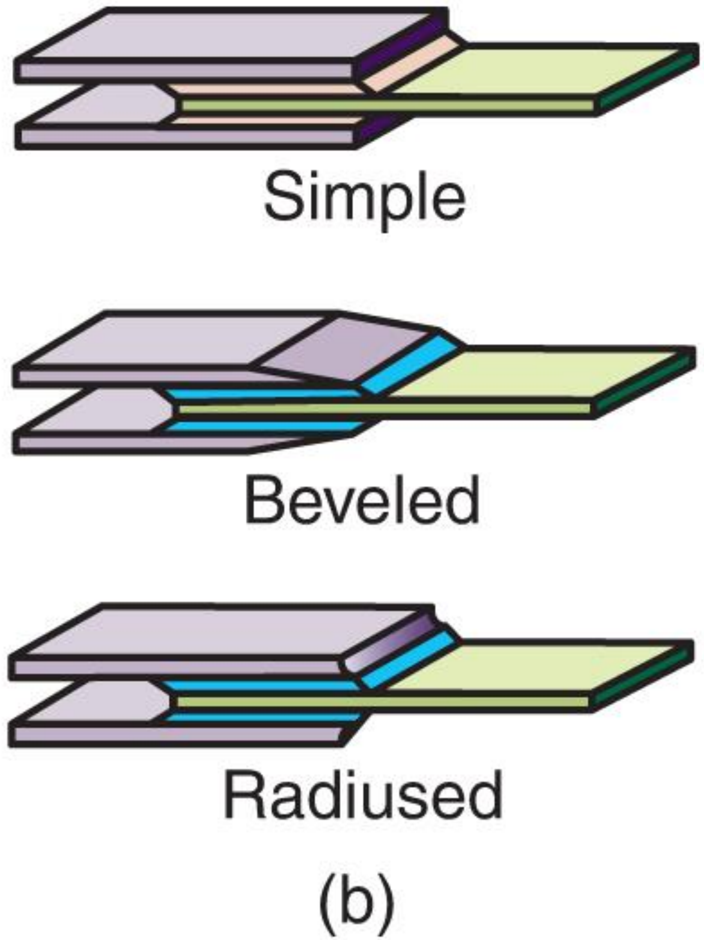


Figure 32.12 (3 of 4)

Desirable configurations for adhesively bonded joints: (c) scarf.

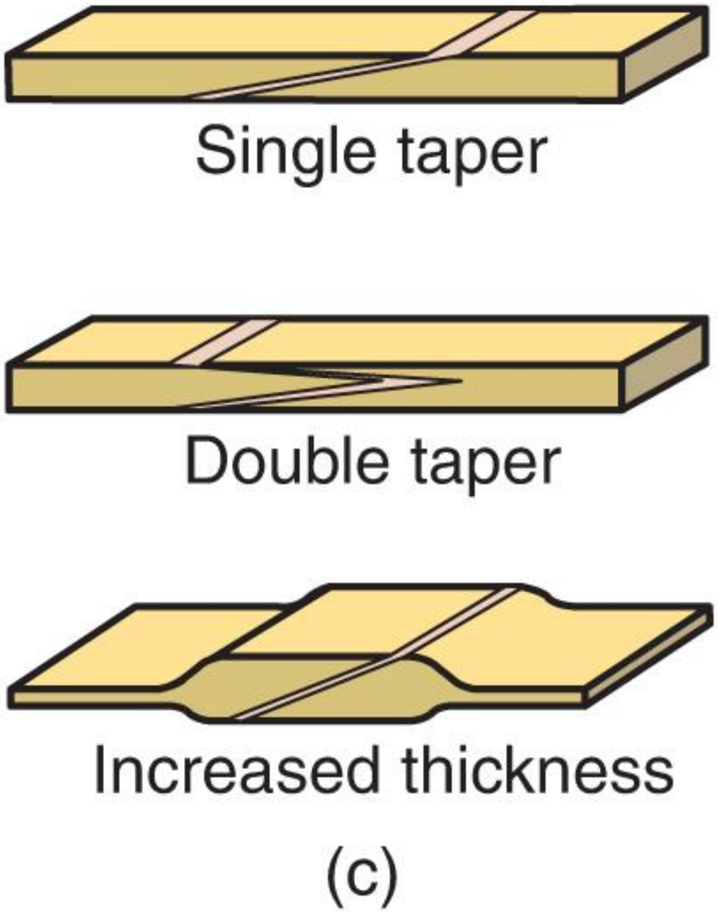
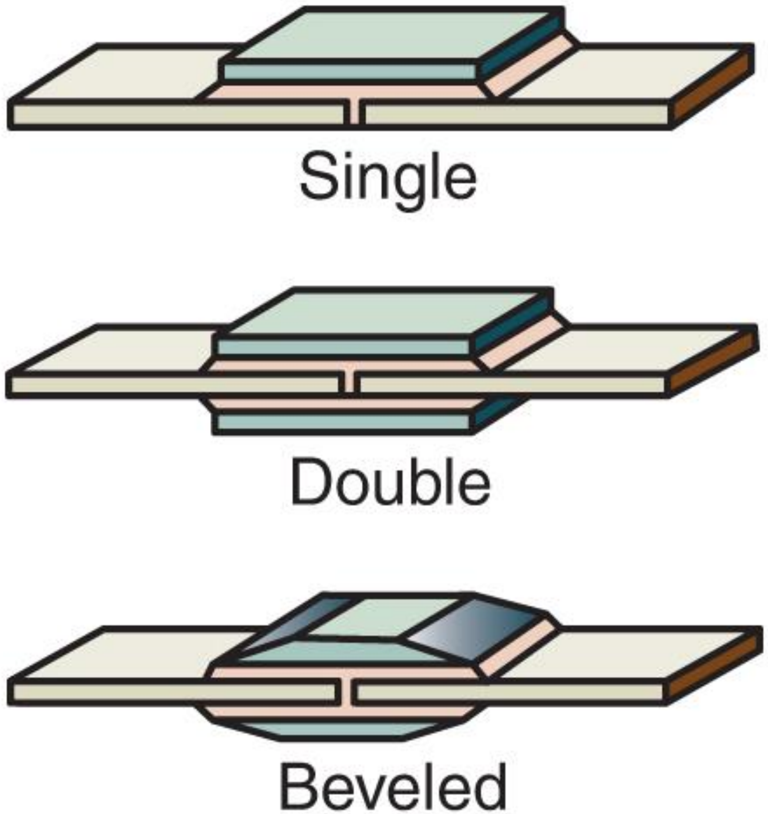


Figure 32.12 (4 of 4)

Desirable configurations for adhesively bonded joints: (d) strap.



(d)

Figure 32.13

Two examples of combination joints, for purposes of improved strength, air or liquid tightness, and resistance to crevice corrosion.

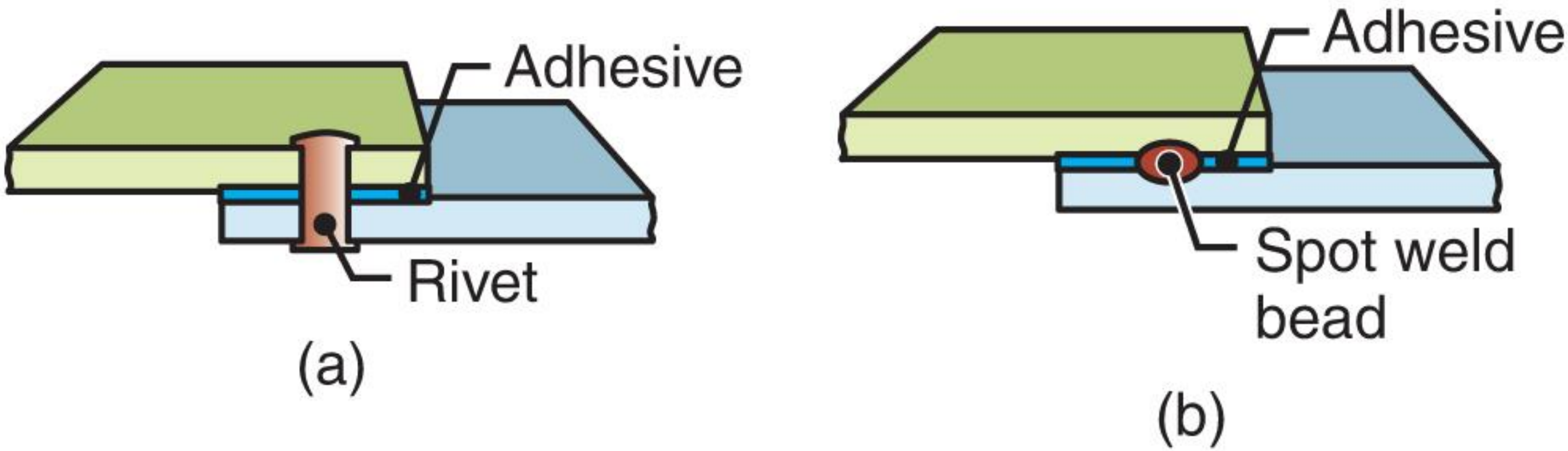
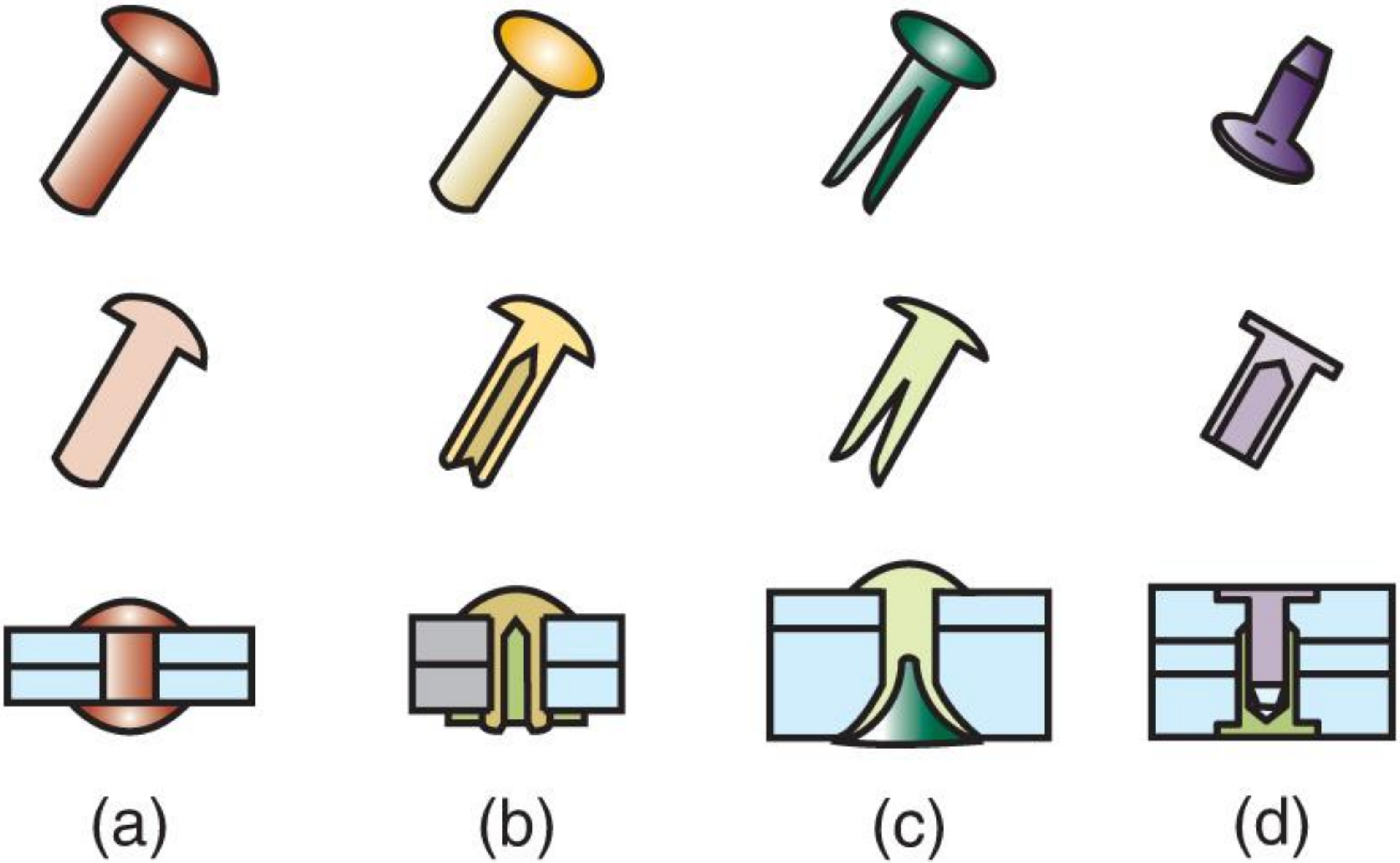


Figure 32.14

Examples of rivets: (a) solid, (b) tubular, (c) split or bifurcated, and (d) compression.



Pearson

Figure 32.15 (1 of 3)

Design guidelines for riveting. (a) Exposed shank is too long; the result is buckling instead of upsetting.

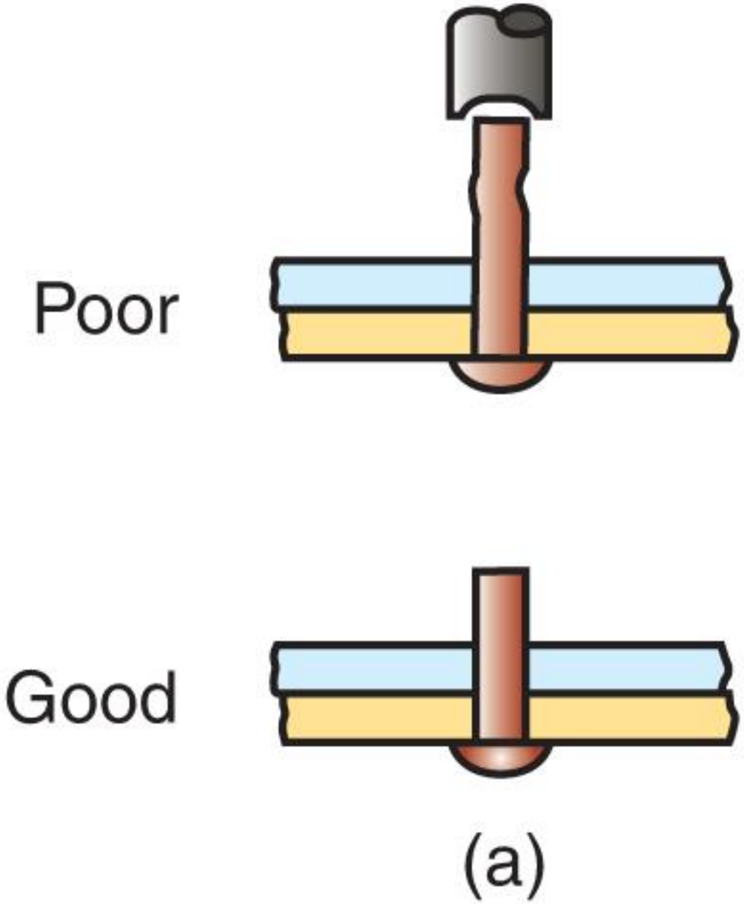
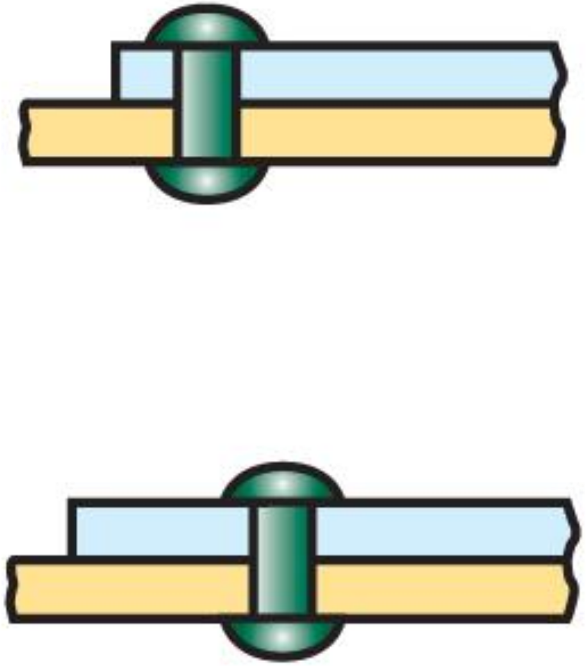


Figure 32.15 (2 of 3)

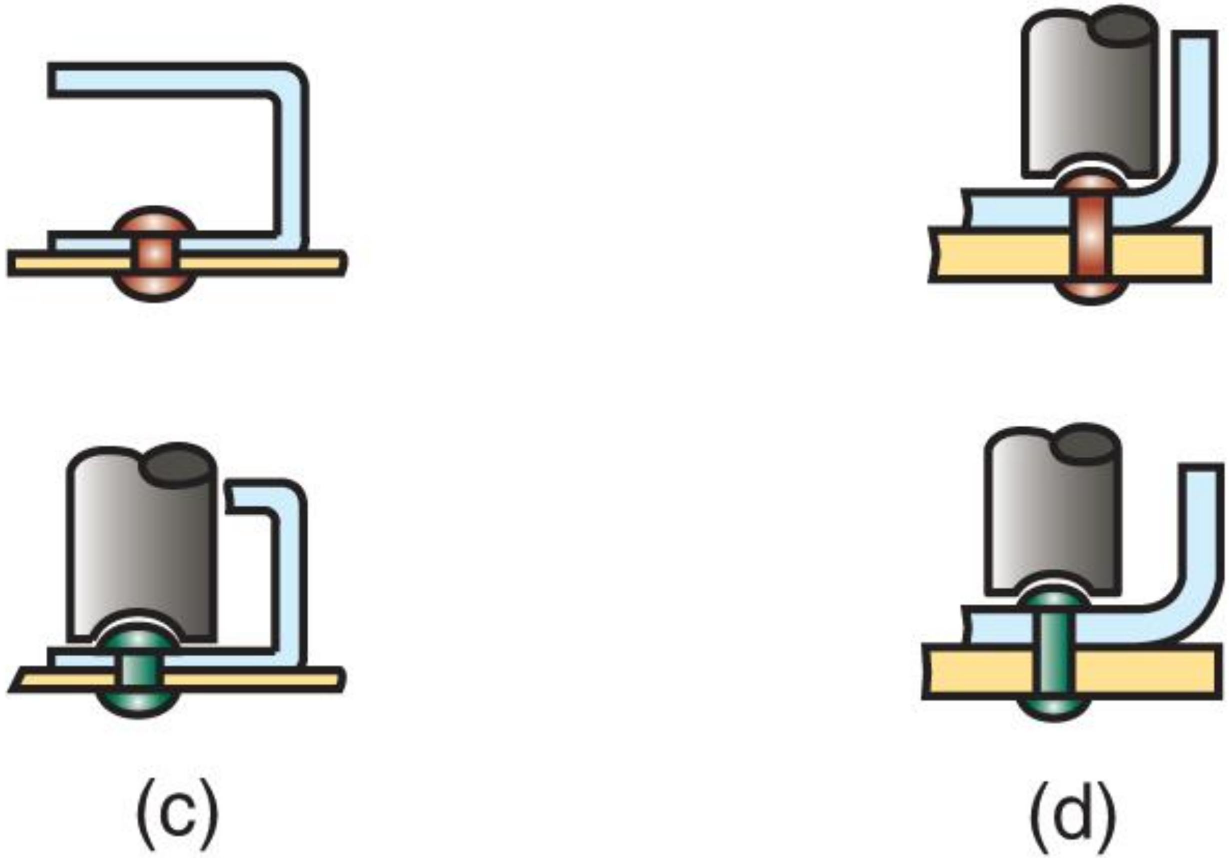
Design guidelines for riveting. (b) Rivets should be placed sufficiently far from edges of the parts to avoid stress concentrations.



(b)

Figure 32.15 (3 of 3)

Design guidelines for riveting. (c) Joined sections should allow ample clearance for the riveting tools. (d) Section curvature should not interfere with the riveting process.



Source: After J.G. Bralla.

Figure 32.16 (1 of 3)

Typical examples of metal stitching.

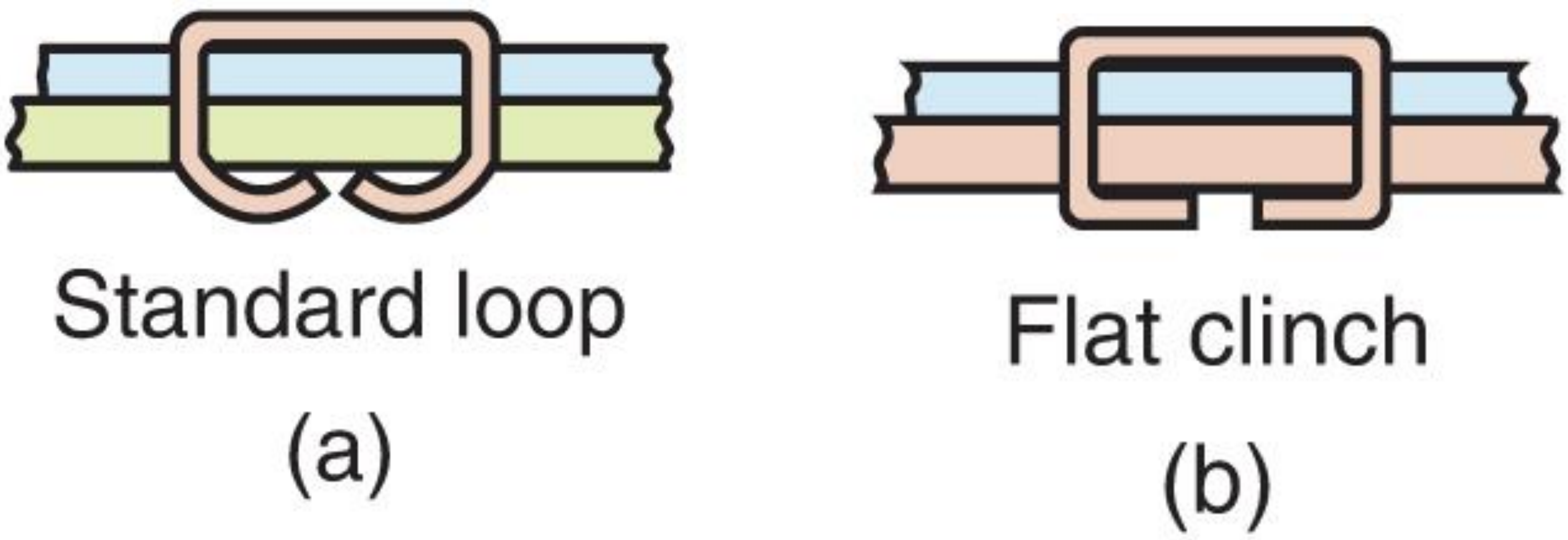


Figure 32.16 (2 of 3)

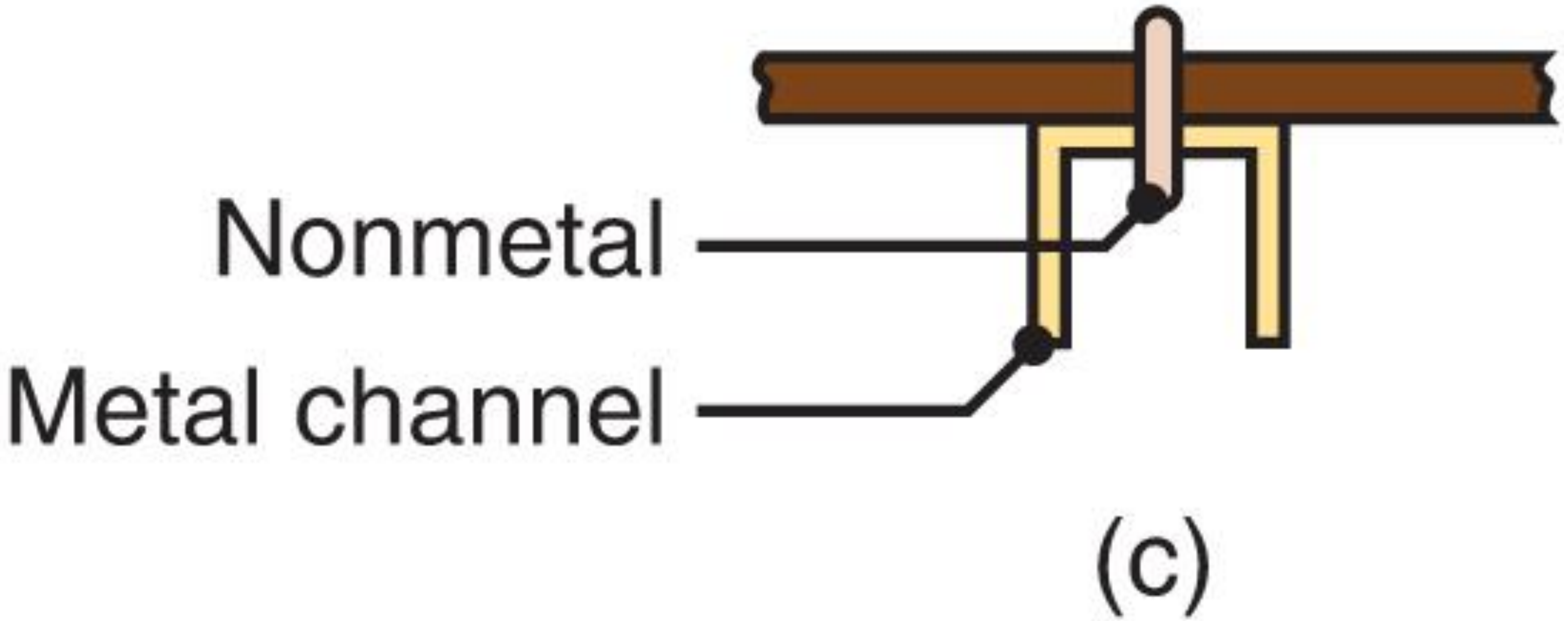


Figure 32.16 (3 of 3)

(d)

Figure 32.17 (1 of 2)

Stages in forming a double-lock seam.

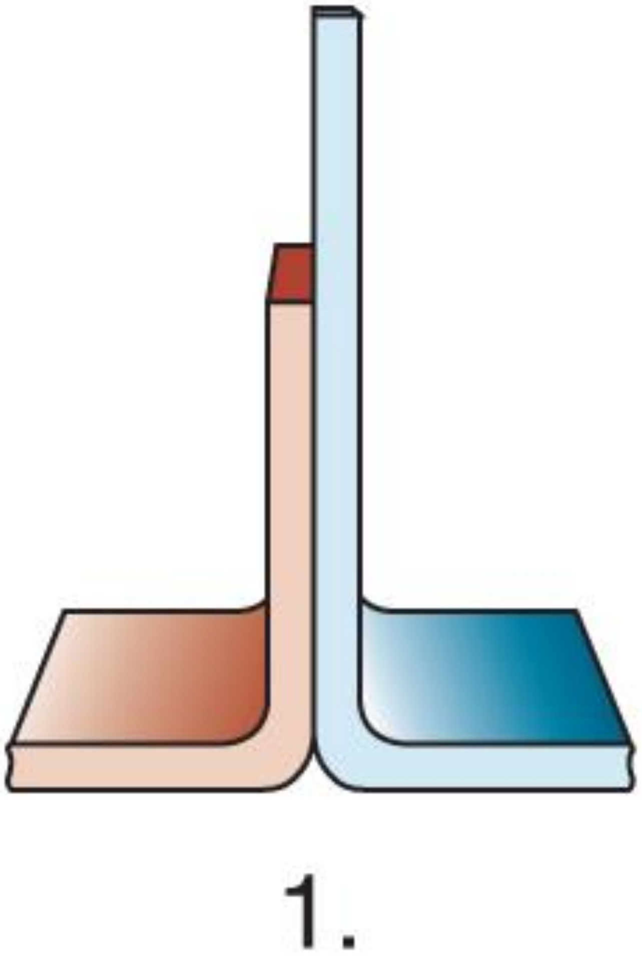


Figure 32.17 (2 of 2)

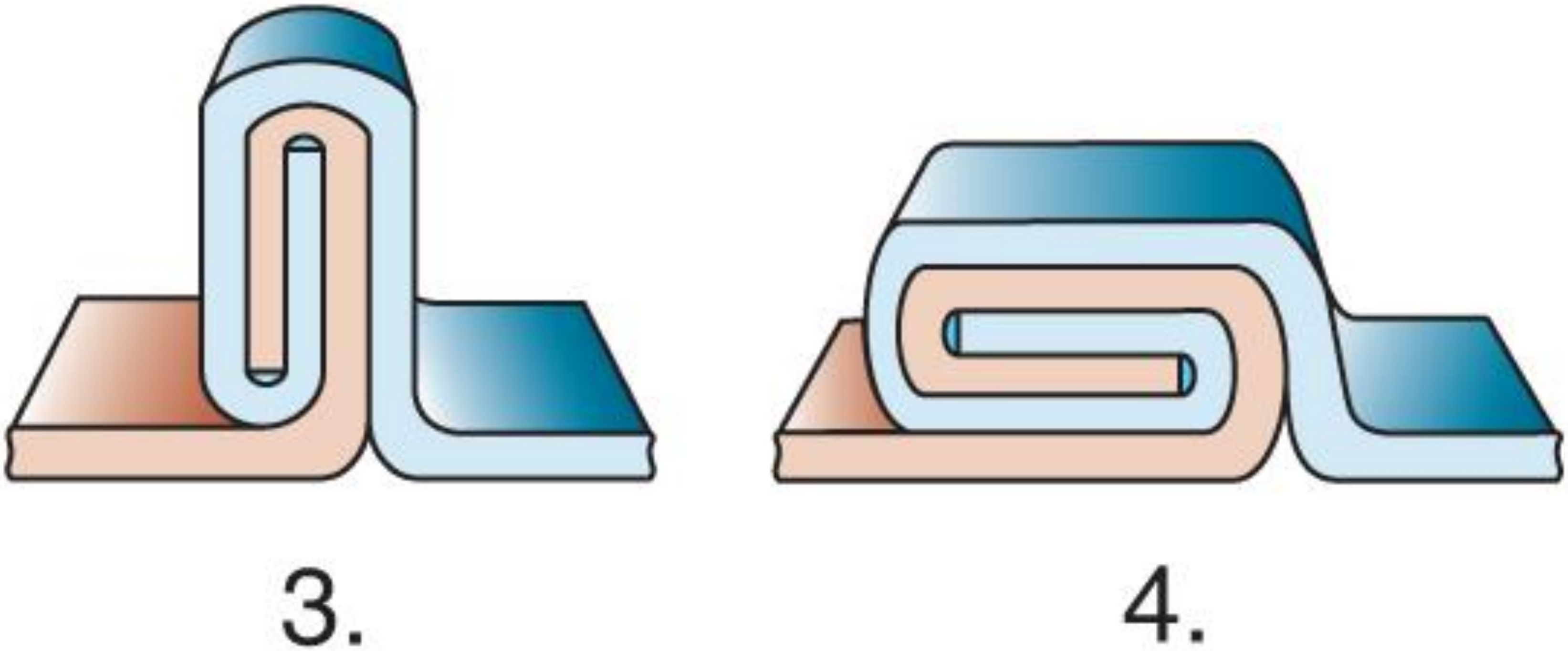
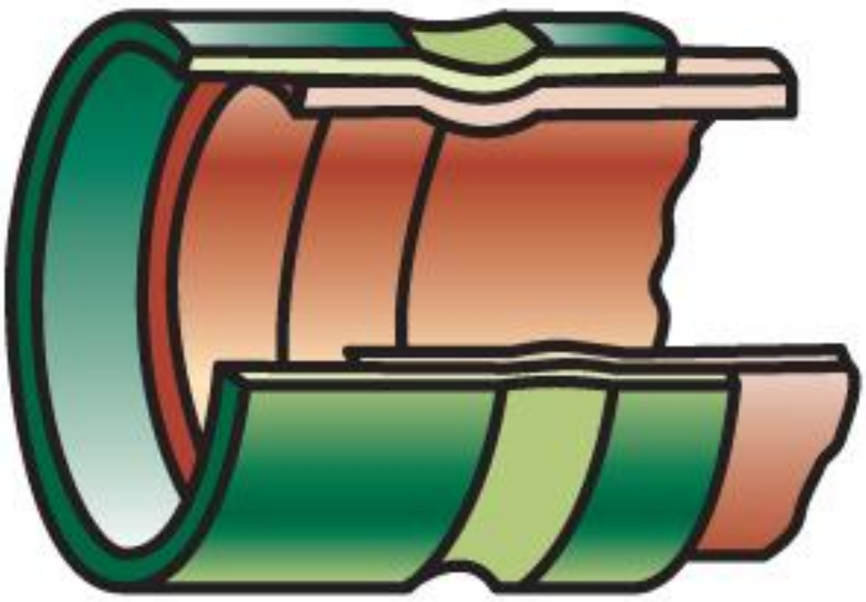


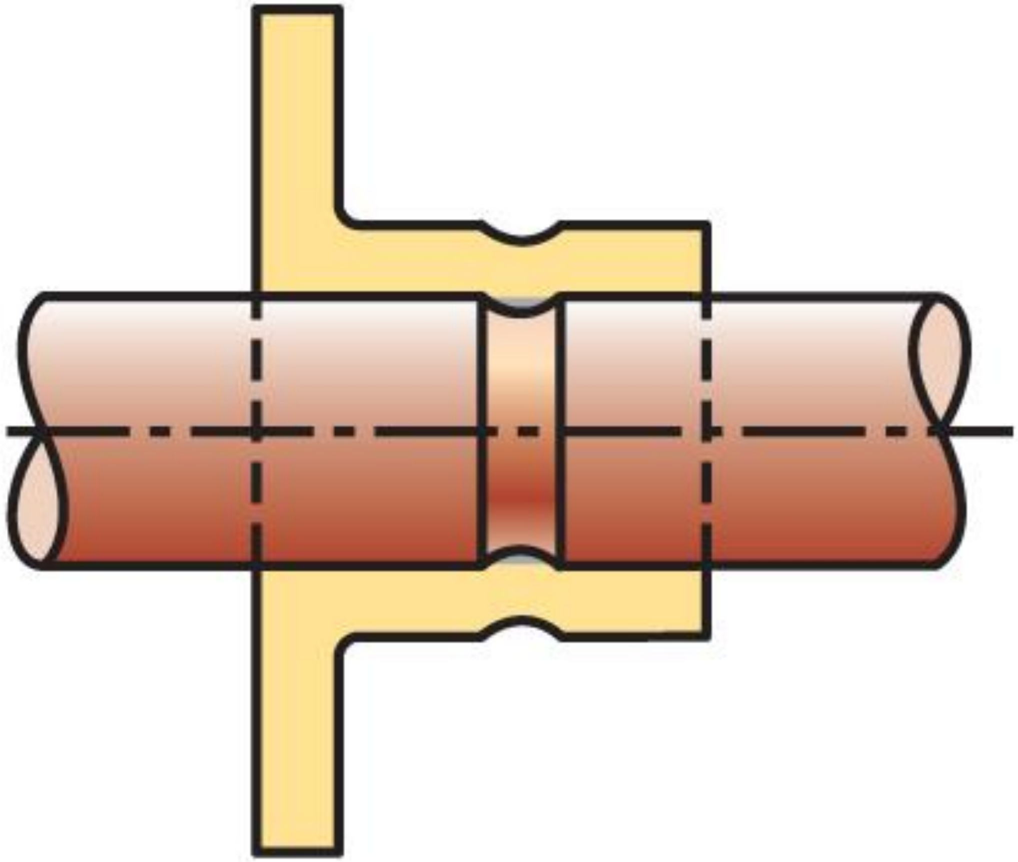
Figure 32.18 (1 of 2)

Two examples of mechanical joining by crimping.



(a)

Figure 32.18 (2 of 2)



(b)

Figure 32.19

Examples of spring and snap-in fasteners, used to facilitate assembly.