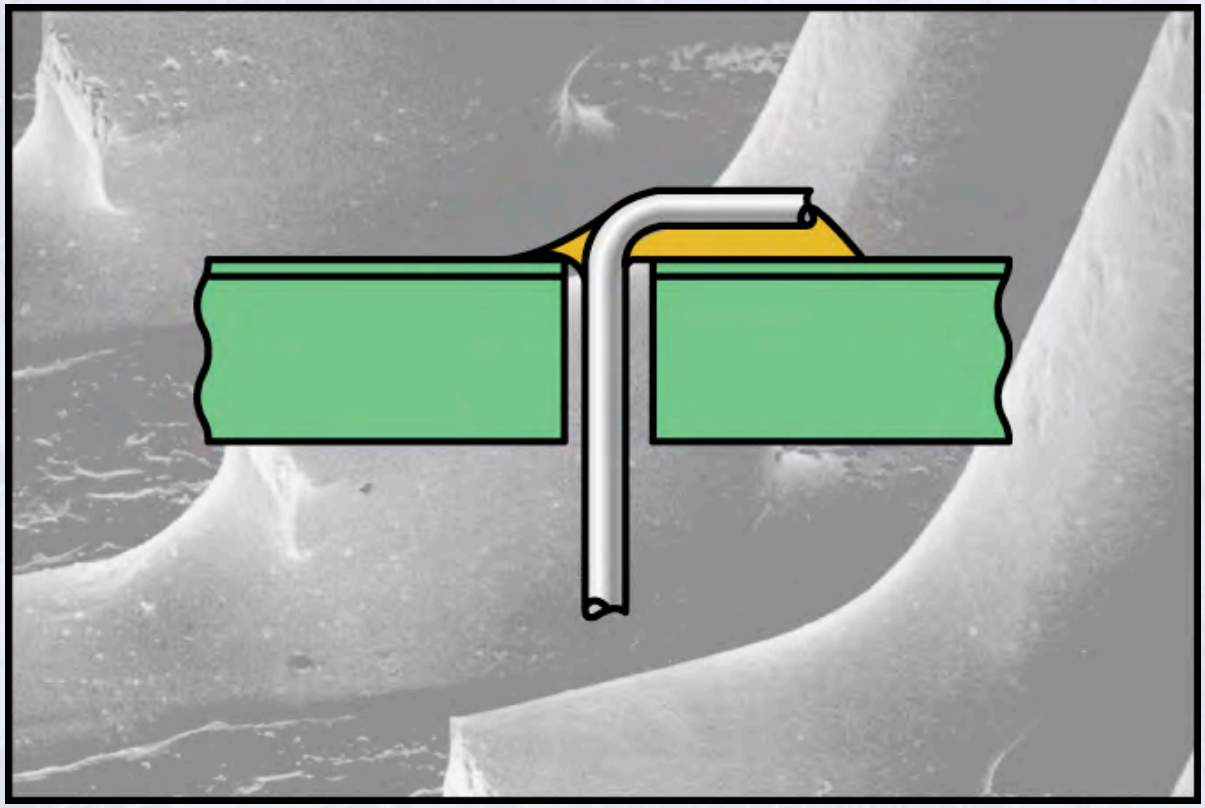
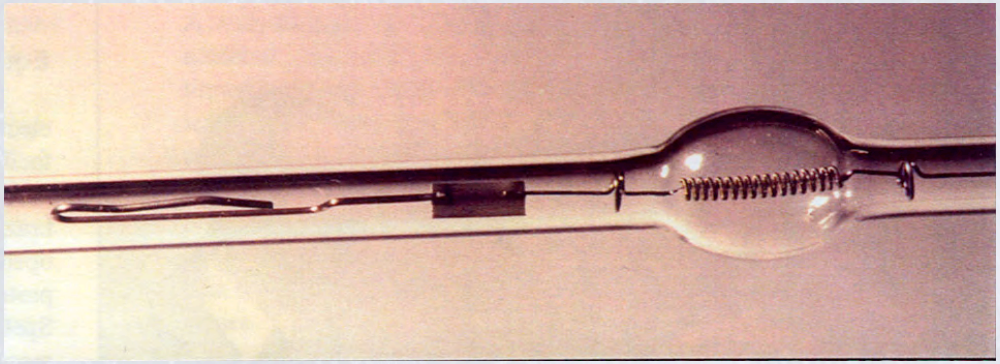
Chapter 32

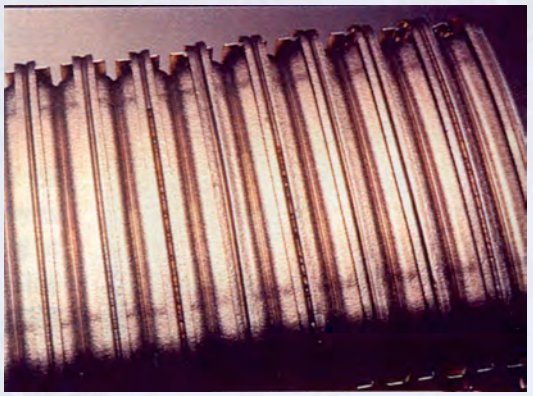
Brazing, Soldering, Adhesive-Bonding, and Mechanical-Fastening Processes



Brazed and Soldered Parts



(a)



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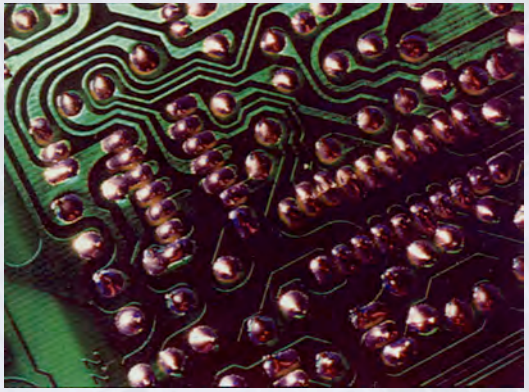

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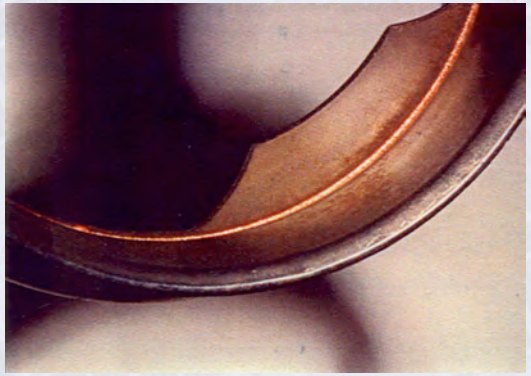


(d)

(e)

Figure 32.1 Examples of brazed and soldered parts. (a) Resistance brazed light bulb filament; (b) brazed radiator heat exchangers; (c) soldered circuit board; (d) brazed ring housing; (e) brazed heat exchanger. *Source*: Courtesy of Edison Welding Institute.

Furnace Brazing

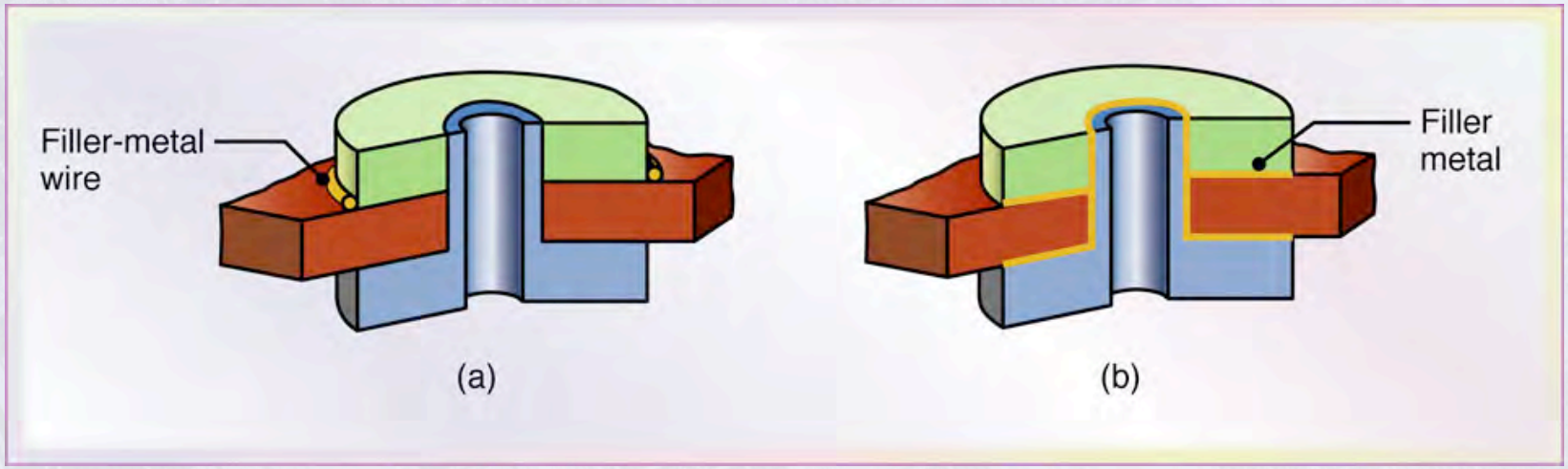


Figure 32.2 An example of furnace brazing: (a) before and (b) after brazing. The filler metal is a shaped wire and moves into the interfaces by capillary action with the application of heat.

Joint Designs used in Brazing

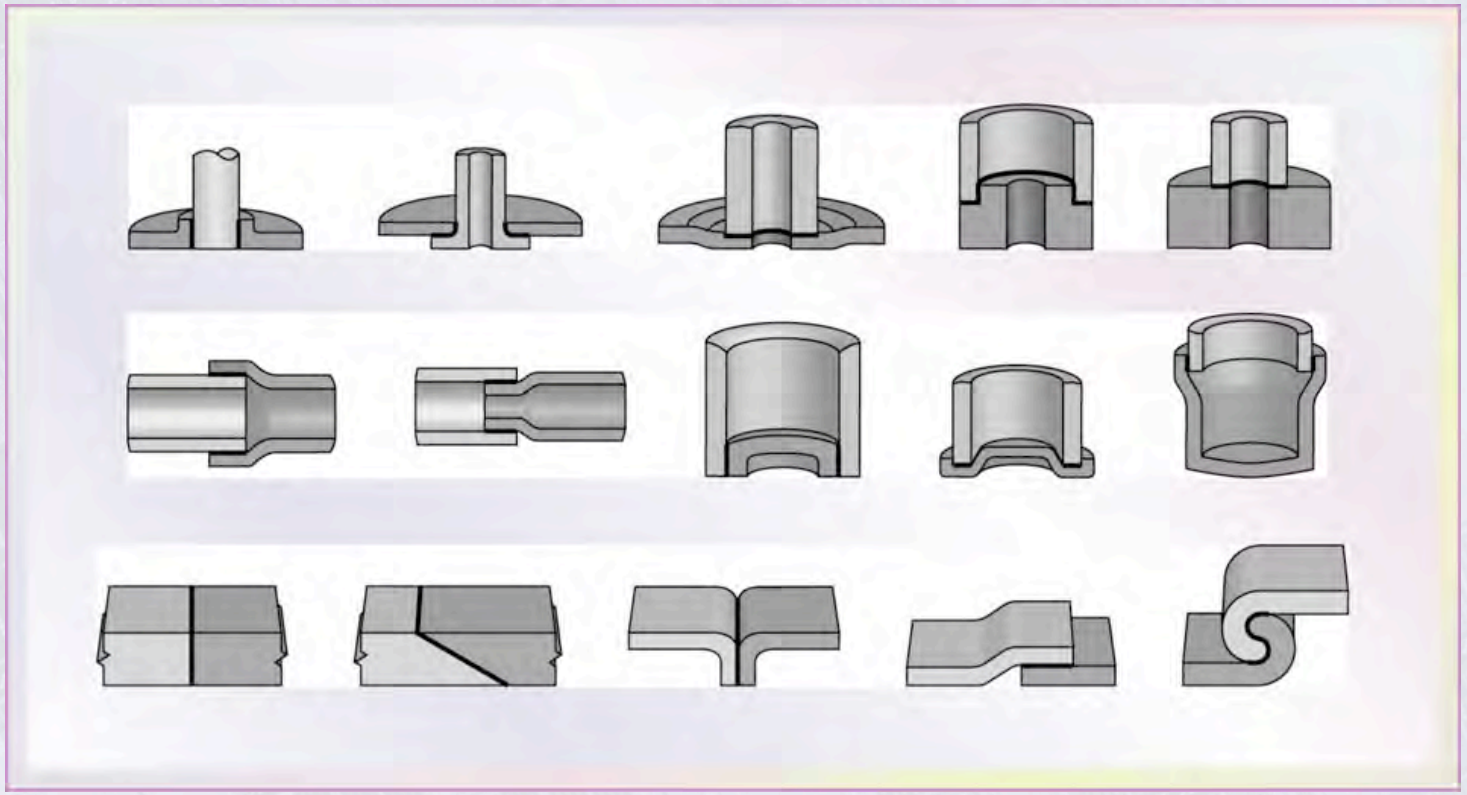


Figure 32.3 Joint designs commonly used in brazing operations. The clearance between the two parts being brazed in an important factor in joint strength. If the clearance is too small, the molten braze metal will not penetrate the interface fully. If it is too large, there will be insufficient capillary action for the molten metal to fill the interface.

Typical Filler Metals for Brazing Various Metals and Alloys

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	700-925
Ferrous and nonferrous (except aluminum and magnesium)	Silver and copper alloys, copper-phosphorus	620-1150
Iron-, nickel-, and cobalt-based alloys	Gold	900-1100
Stainless steels, nickel- and cobalt-based alloys	Nickel-silver	925-1200

Effect of Joint Clearance on Strength of Brazed Joints

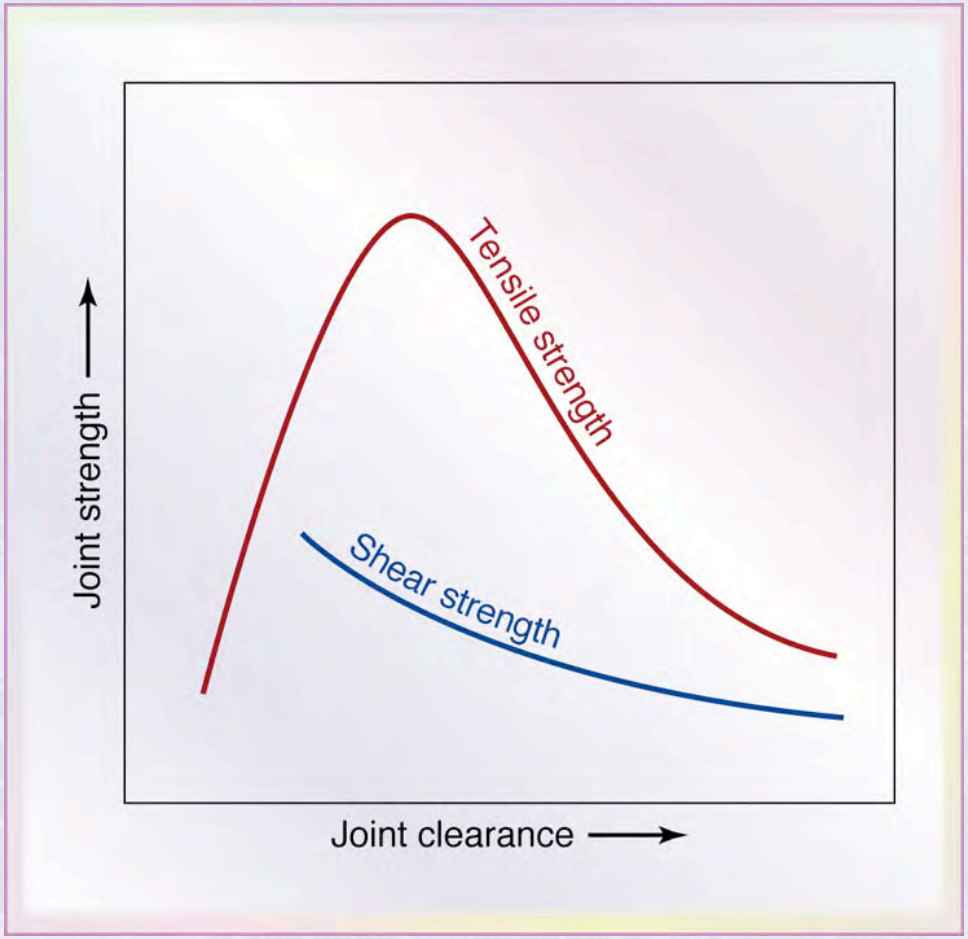


Figure 32.4 The effect of joint clearance on tensile and shear strength of brazed joints. Note that unlike tensile strength, shear strength continually decreases as the clearance increases.

Induction-Brazing

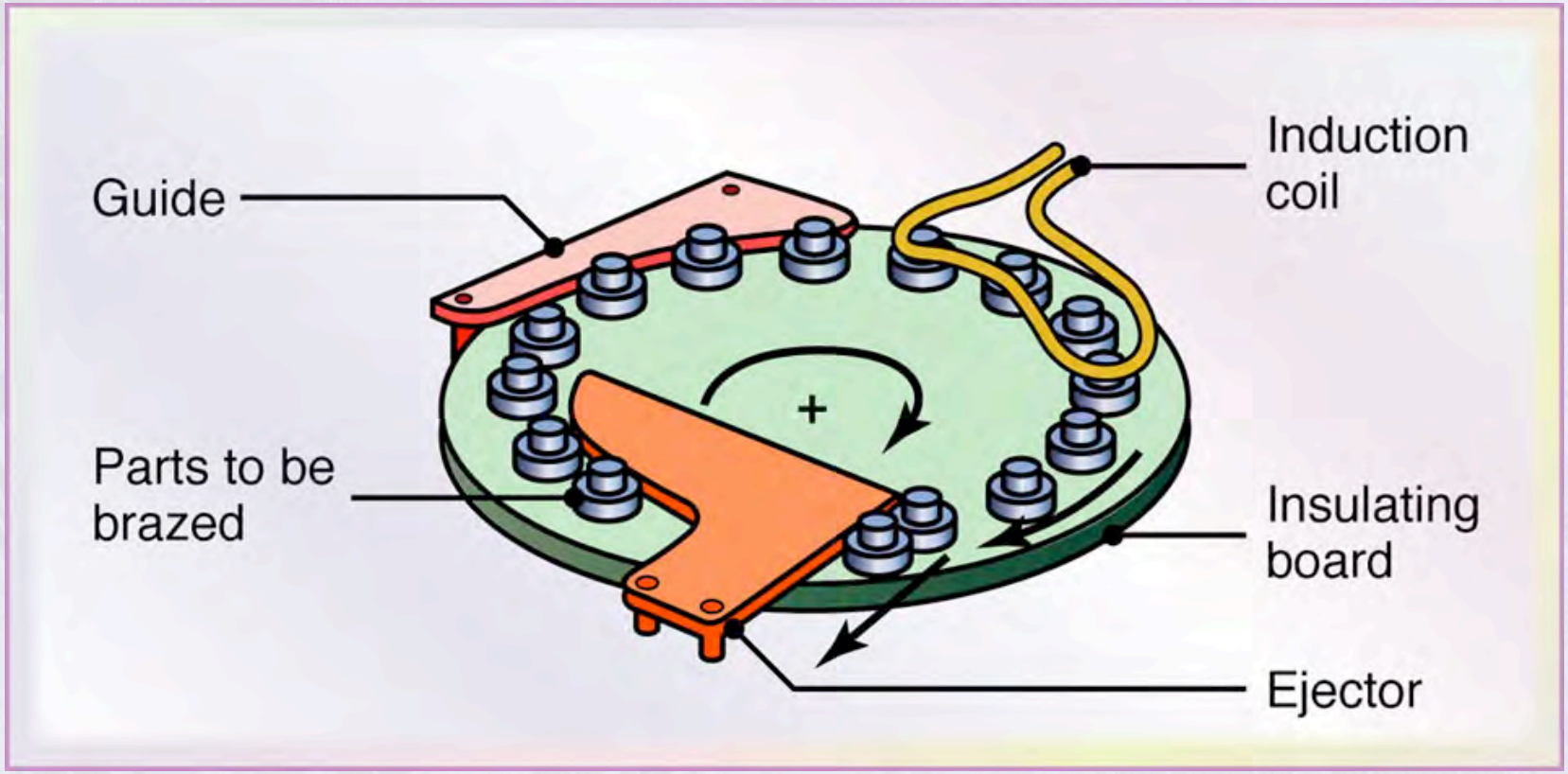


Figure 32.5 Schematic illustration of a continuous induction-brazing setup for increased productivity.

Good and Poor Brazing Design

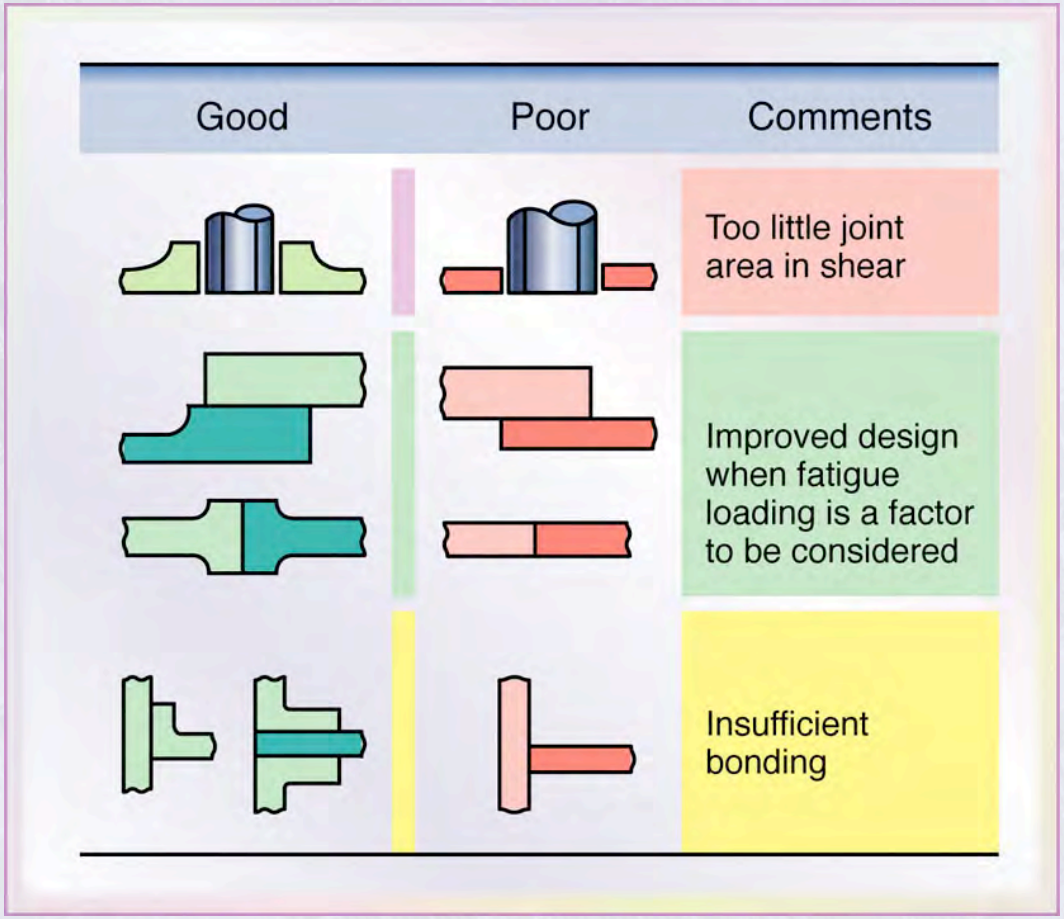


Figure 32.6 Examples of good and poor design for brazing. *Source*: American Welding Society.

Solder Types and Applications

TABLE 32.2

Types of Solders and their 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

Wave-Soldering (WS)

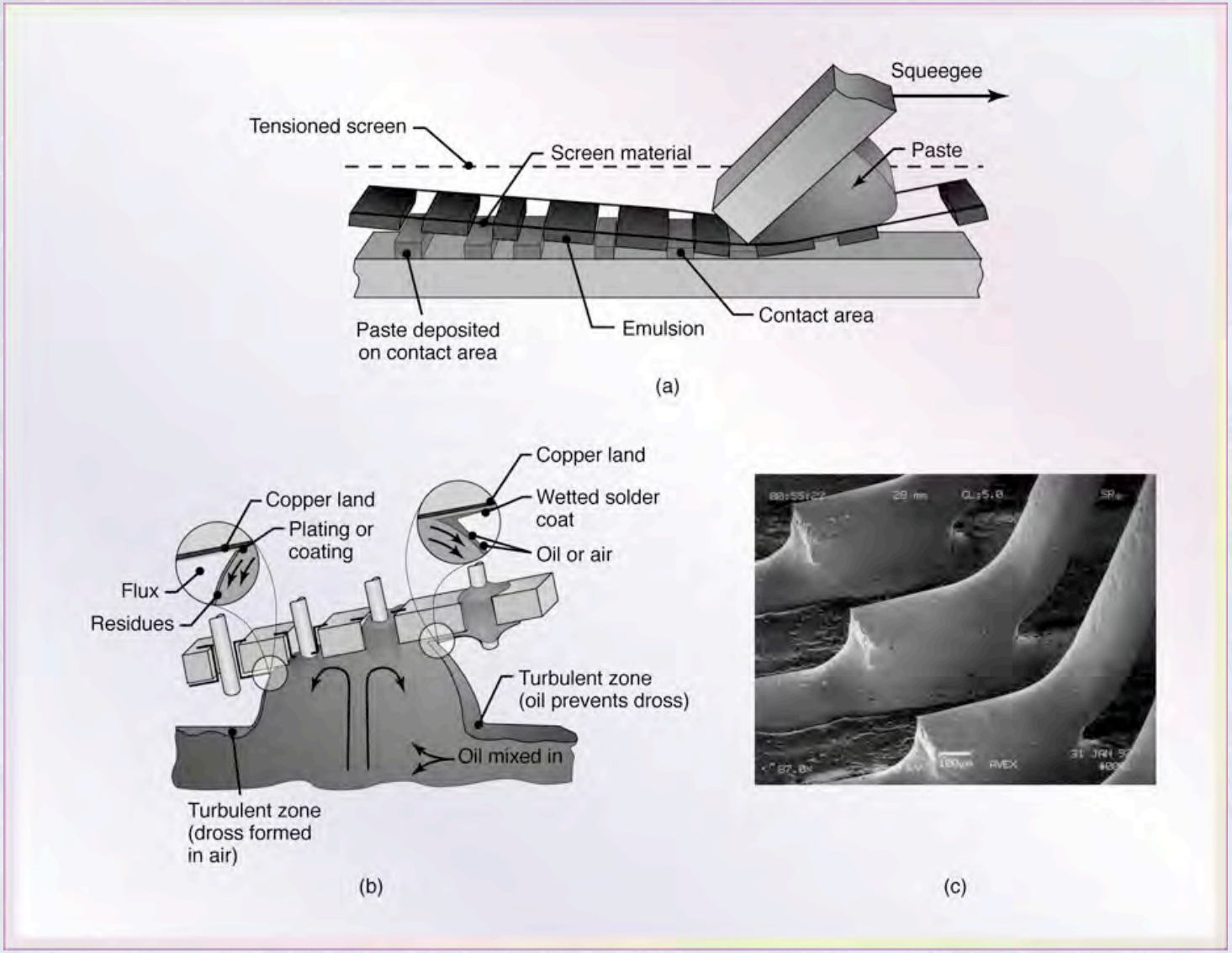


Figure 32.7 (a) Screening solder paste onto a printed circuit board in reflow soldering. (b) Schematic illustration of the wave-soldering process. (c) SEM image of a wave-soldered joint on surface0mount device. *Source*: (a) After V. Solberg.

Soldering Joint Designs

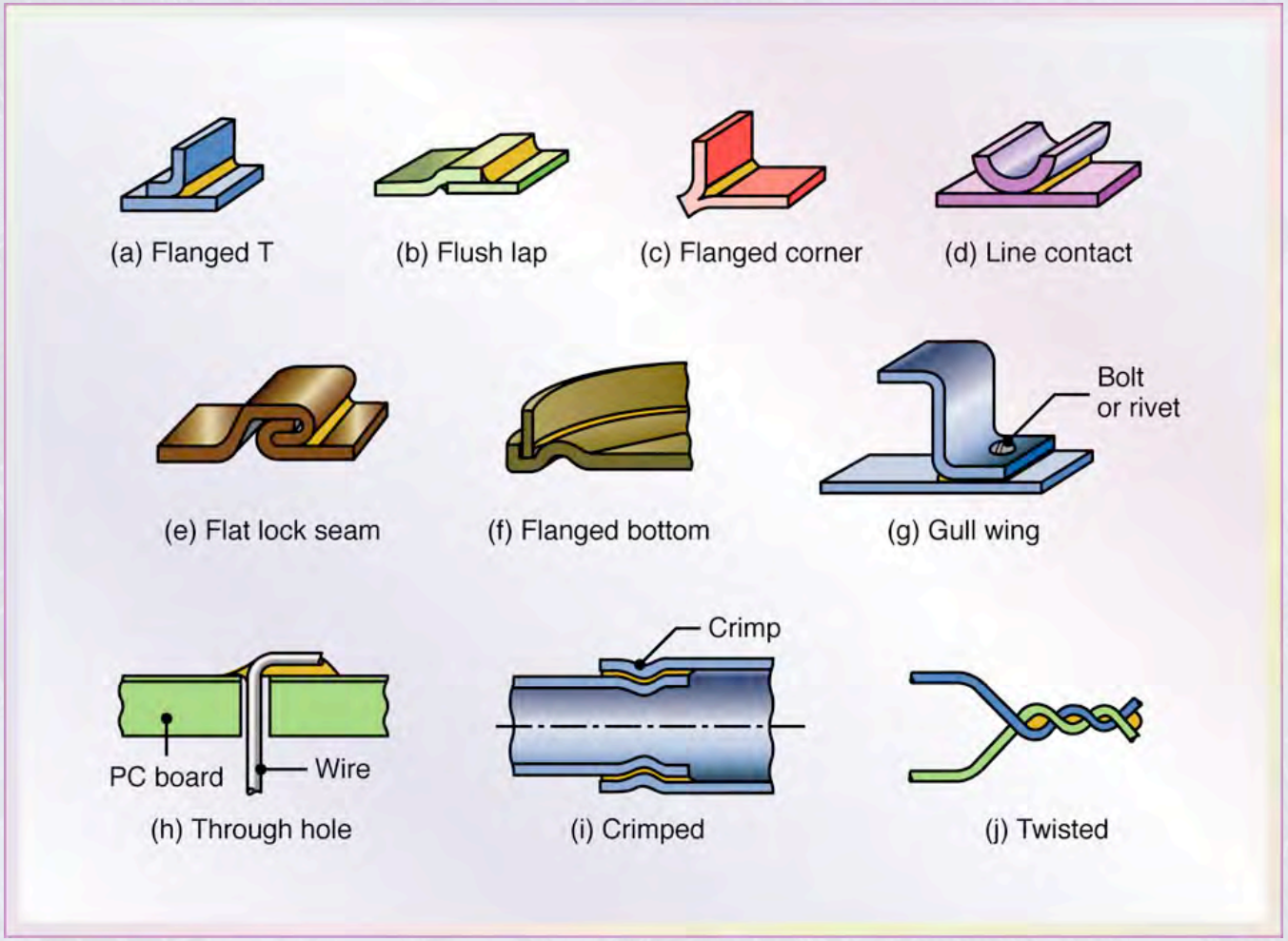


Figure 32.8 Joint designs commonly used for soldering.

Typical Properties and Characteristics of Chemically Reactive Structural Adhesives

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)	15.4 (2.2)	15.4 (2.2)	25.9 (3.7)	18.9 (2.7)	17.5 (2.5)
Peel strength, N/m (lbf/in.)	6525 (3)	14,000 (80)	5250 (30)	625 (3)	1750 (10)
Max. service temperature, °C, (°F)	120 (250)	80 (175)	120 (250)	80 (175)	150 (300)

TABLE 32.4

General Characteristics of Adhesives

Type	Comments	Applications
Acrylic	Thermoplastic; quick setting; tough bond at room temperature; two component; 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; and 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 component; 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	"Crazy glue™"
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; and 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; rubber-like	Gaskets and sealants
Formaldehyde Urea Melamine Phenol Resorcinol	Thermoset; strong with wood bonds; urea is inexpensive, available as powder or liquid and requires a catalyst; melamine is more expensive, cures with heat and the bond is waterproof; resorcinol forms 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.

General Characteristics of Adhesives

Peeling Test of Brittle and Tough Adhesives

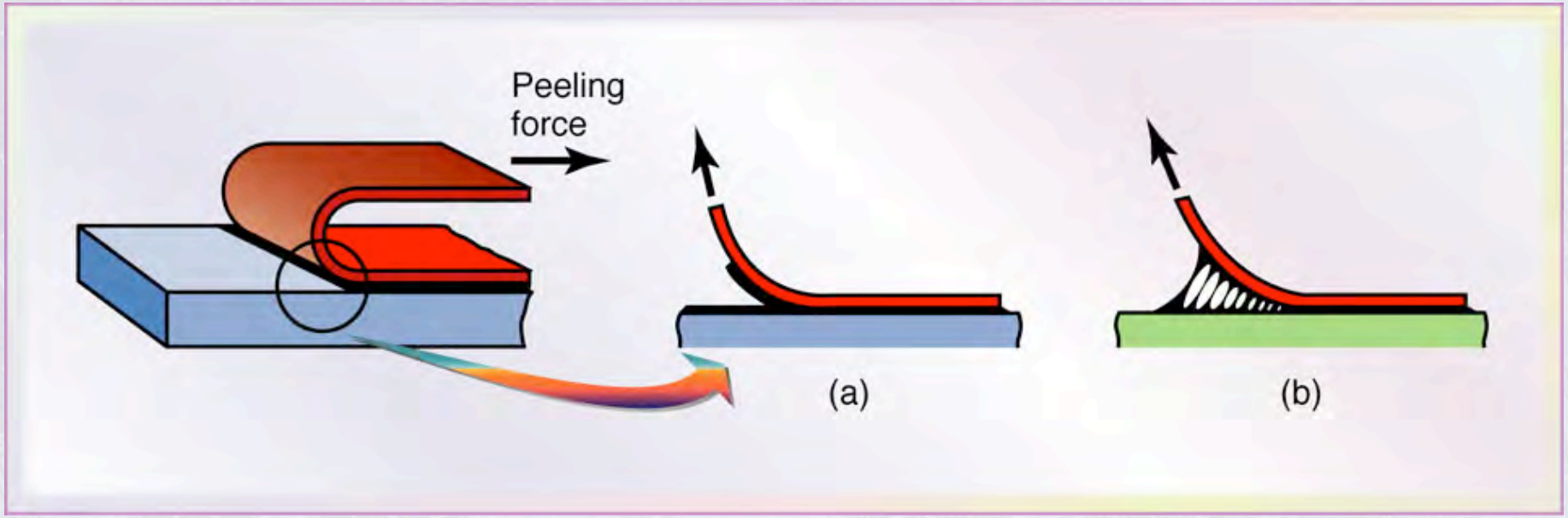


Figure 32.9 Characteristic behavior of (a) brittle and (b) tough adhesives in a peeling test. This test is similar to the peeling of adhesive tape from a solid surface.

Joint Designs in Adhesive Bonding

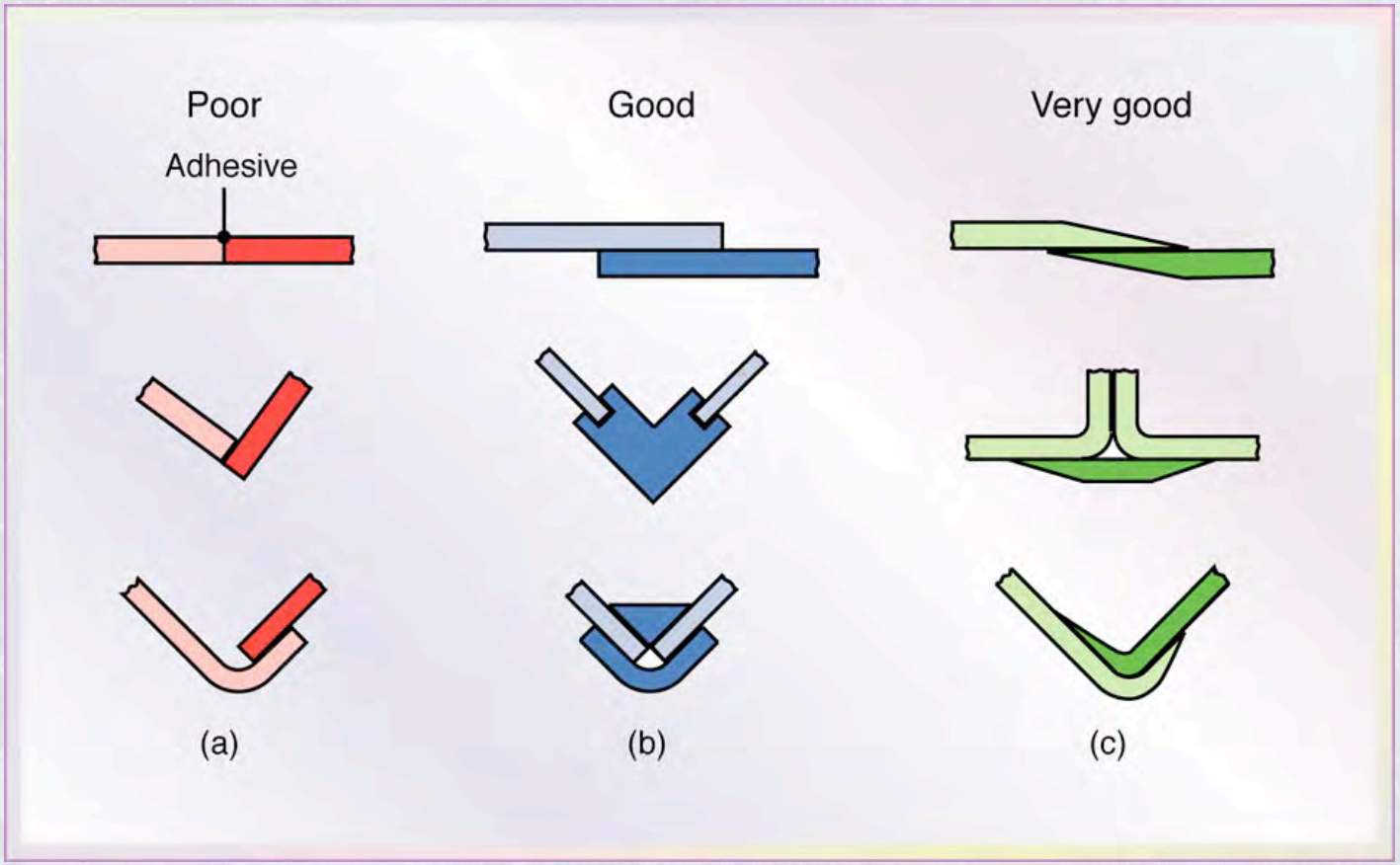
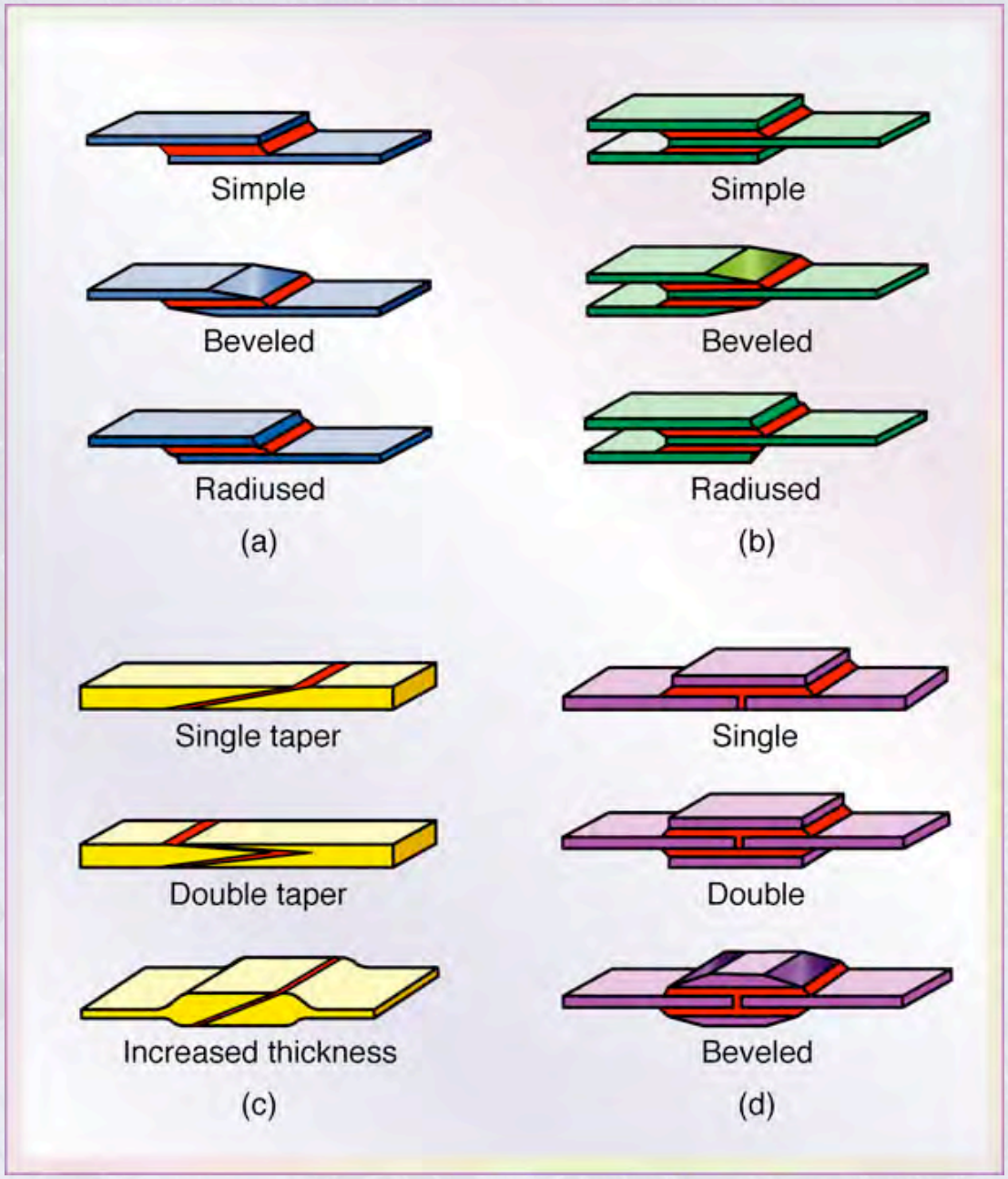


Figure 32.10 Various joint designs in adhesive bonding. Note that the good designs require large contact areas between the members to be joined.



Desirable Configurations for Adhesively Bonded Joints

Figure 32.11 Desirable configurations for adhesively bonded joints: (a) single lap, (b) double lap, (c) scarf, and (d) strap.

Cobe Laboratories Blood Reservoir

Figure 32.13 The Cobe Laboratories blood reservoir. The lid is bonded to the bowl with an airtight adhesive joint and tongue-in-groove joint. *Source*: Courtesy of Cobe Laboratories.

Rivets

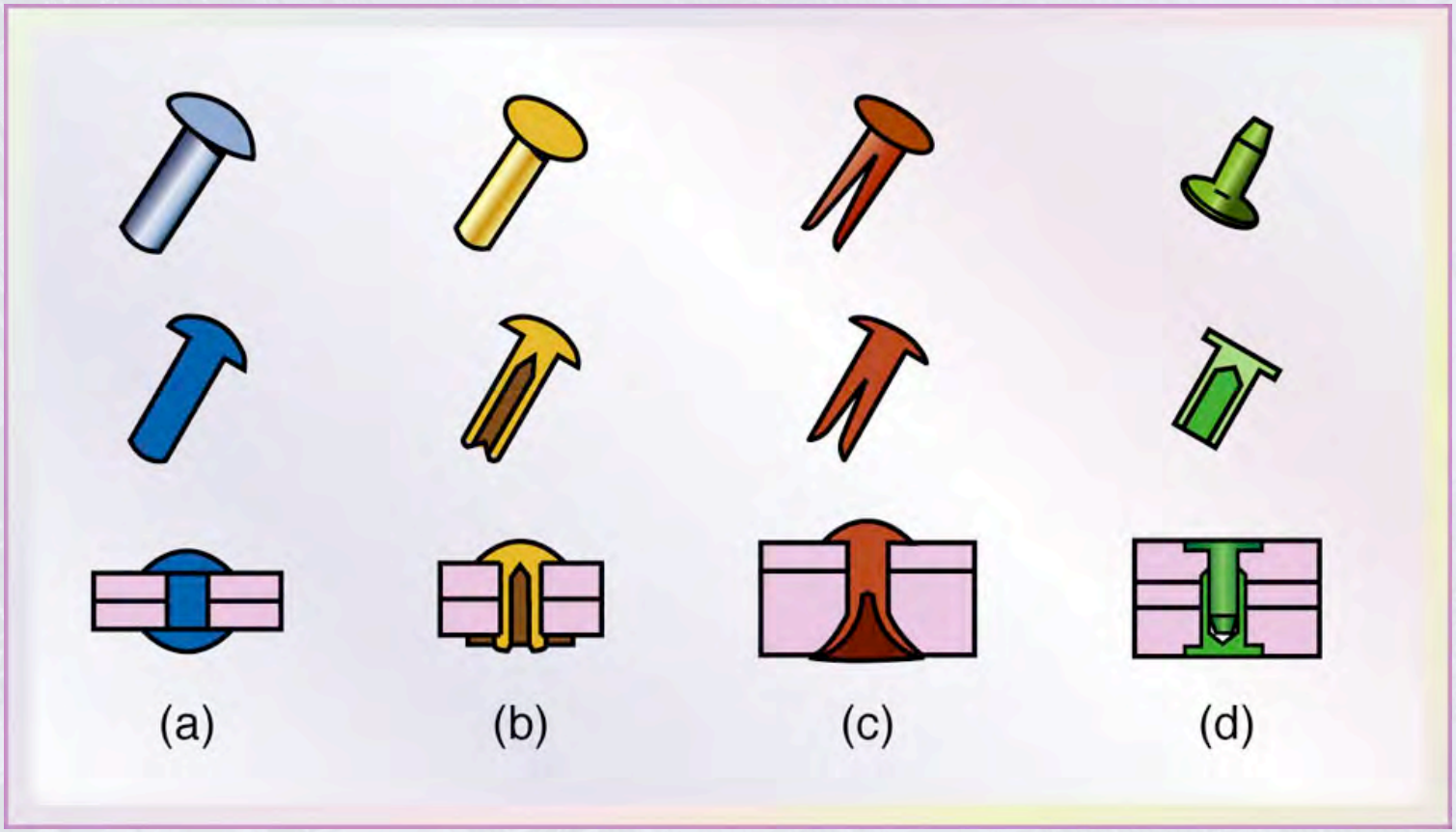


Figure 32.14 Examples of rivets: (a) solid, (b) tubular, (c) split or bifurcated, and (d) compression.

Riveting Design Guidelines

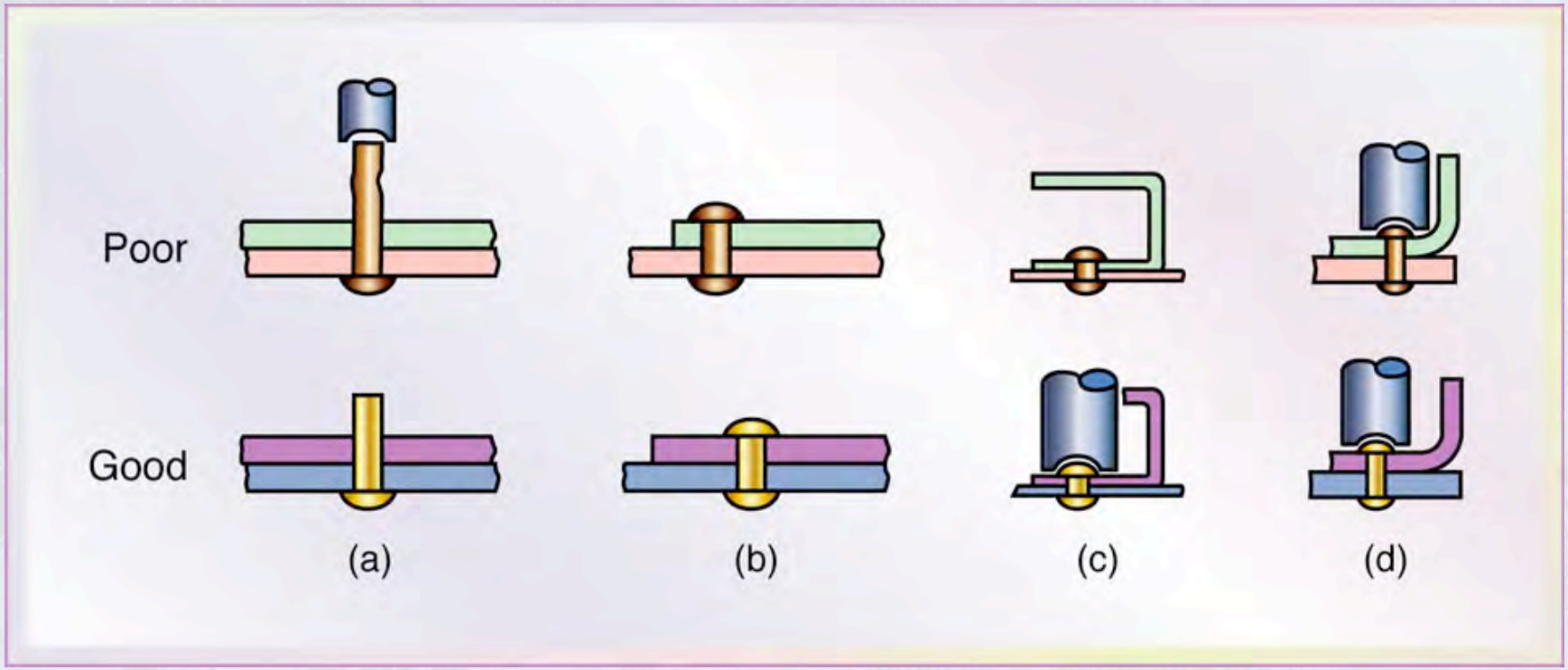


Figure 32.15 Design guidelines for riveting. (a) Exposed shank is too long; the result is buckling instead of upsetting. (b) Rivets should be placed sufficiently far from edges to avoid stress concentrations. (c) Joined sections should allow ample clearance for the riveting tools. (d) Section curvature should not interfere with the riveting process. *Source*: After J. G. Bralla.

Metal Stitching

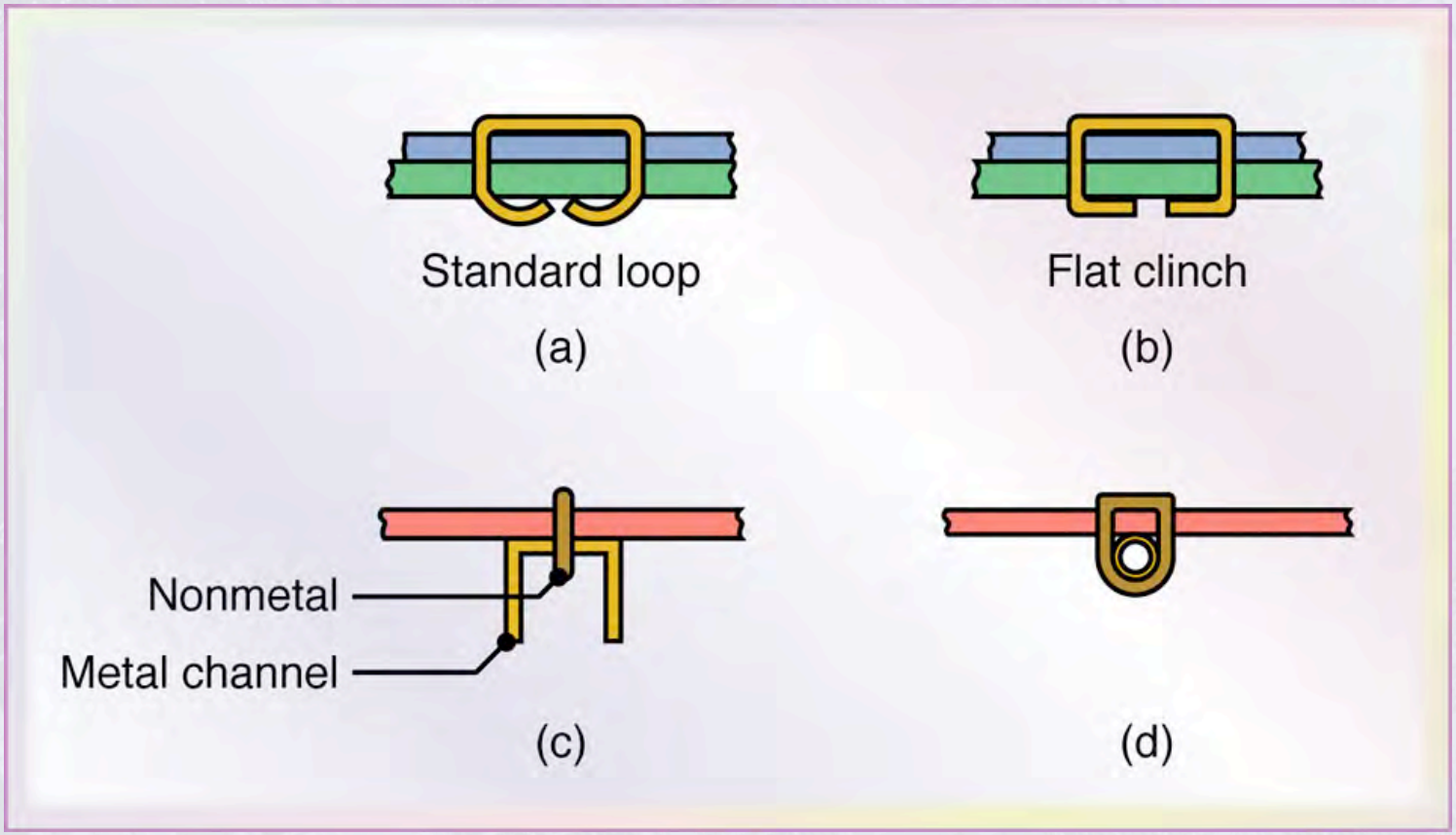


Figure 32.16 Typical examples of metal stitching.

Double-Lock Seam

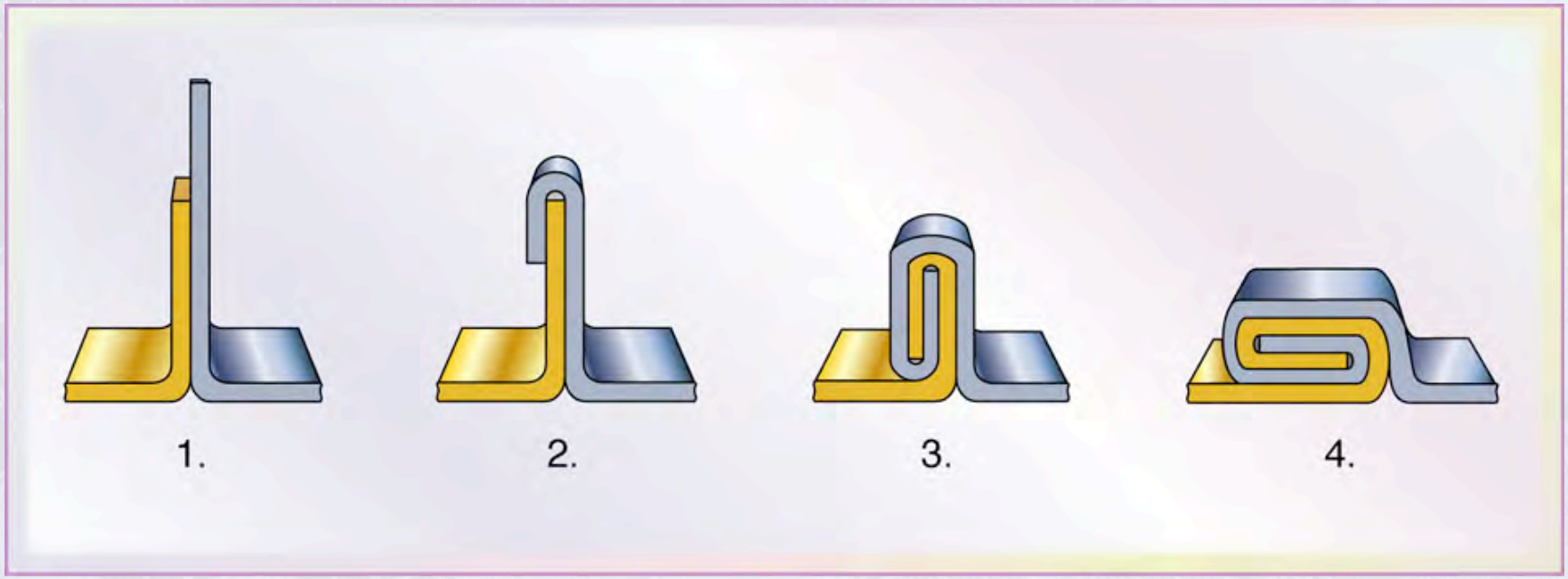


Figure 32.17 Stages in forming a double-lock seam.

Crimping

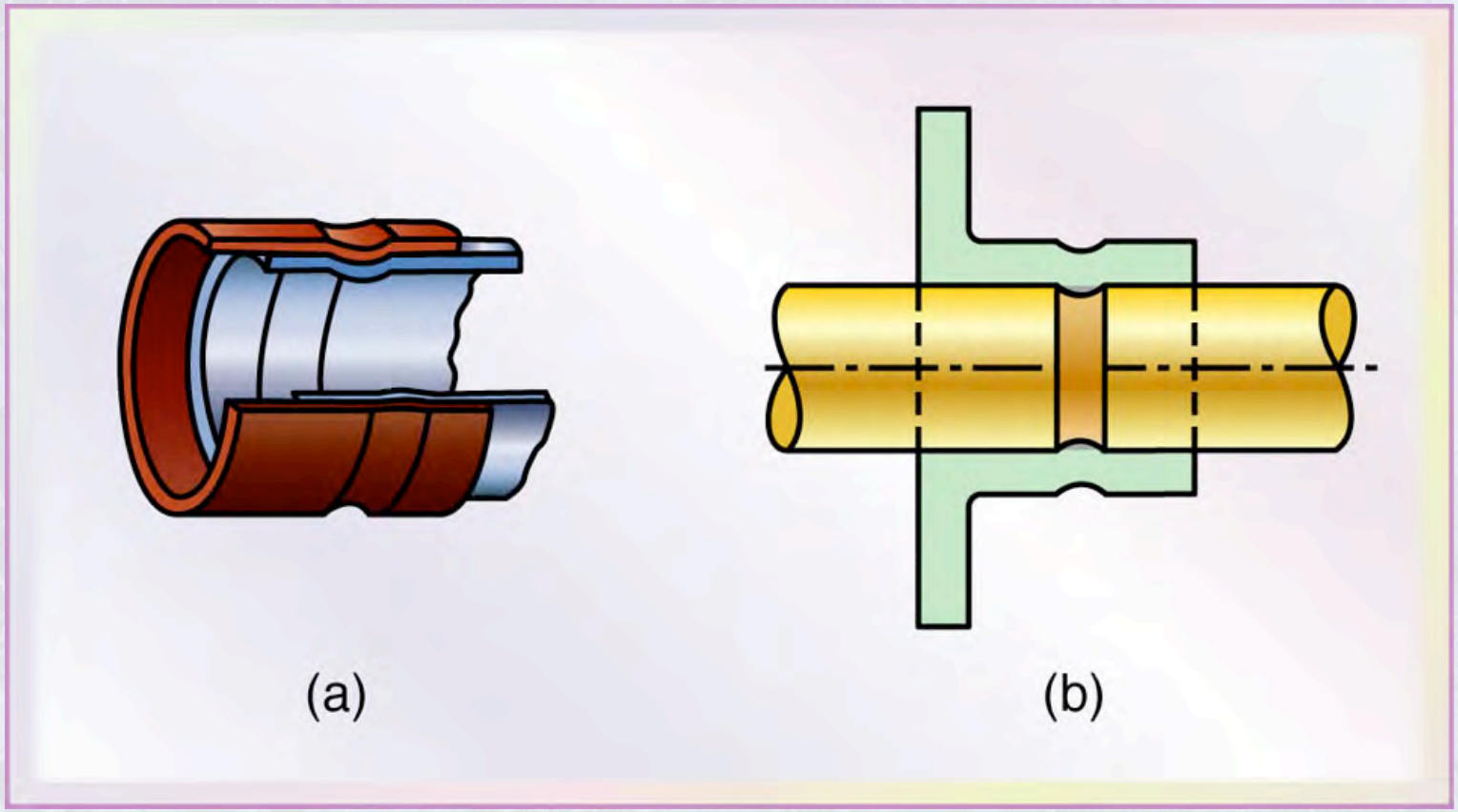


Figure 32.18 Two examples of mechanical joining by crimping.

Spring and Snap-In Fasteners

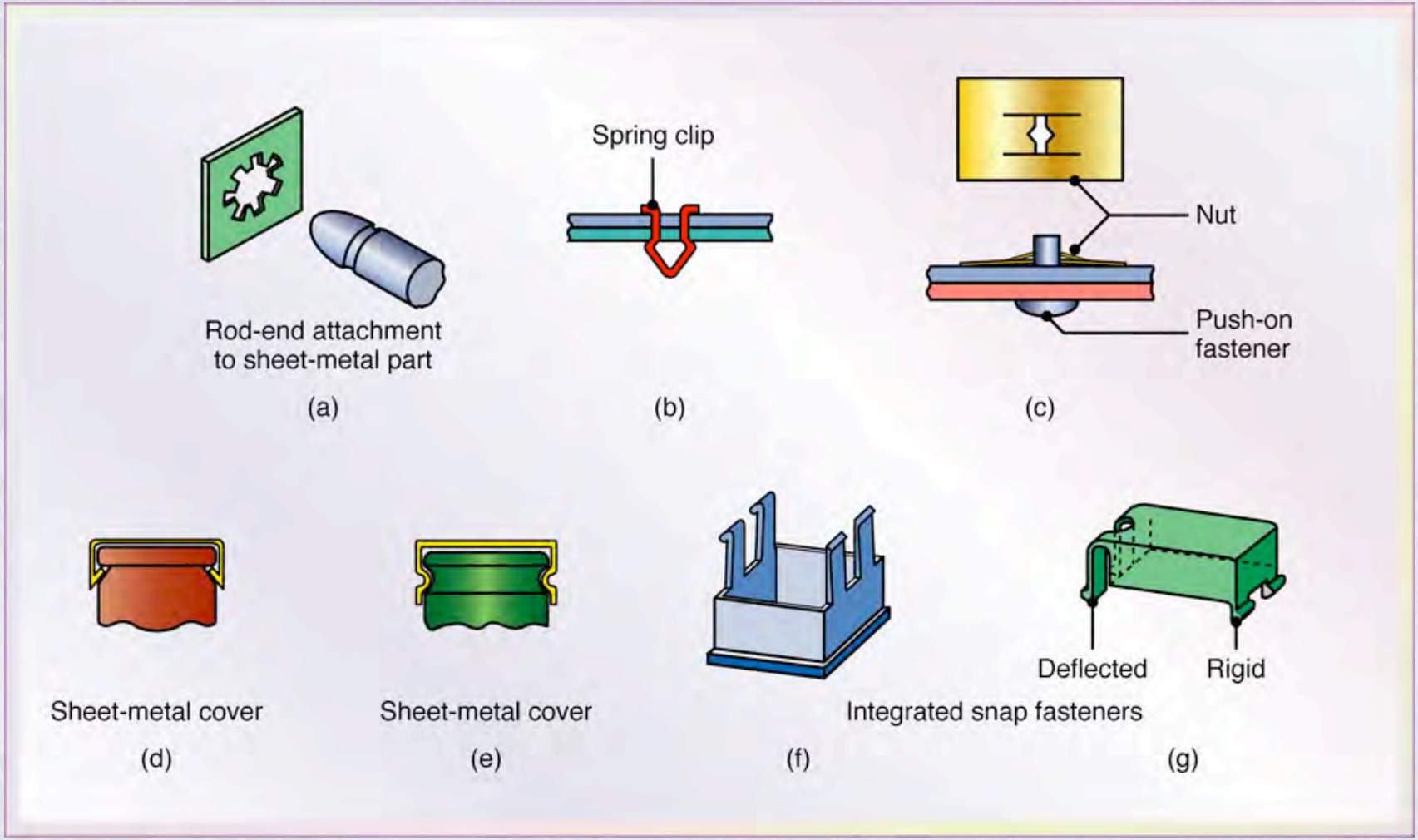


Figure 32.19 Examples of spring and snap-in fasteners used to facilitate assembly.