Soldering

- Soldering is similar to brazing and can be defined as a joining process in which a filler metal with melting point (liquidus) not exceeding 450 °C is melted and distributed by capillary action between the faying surfaces of the metal parts being joined.
- As in brazing, no melting of the base metals occurs, but the filler metal wets and combines with the base metal to form a metallurgical bond.
- Details of soldering are similar to those of brazing, and many of the heating methods are the same.
- Surfaces to be soldered must be precleaned so they are free of oxides, oils, and so on.
- An appropriate flux must be applied to the faying surfaces, and the surfaces are heated.
- Filler metal, called solder, is added to the joint, which distributes itself between the closely fitting parts.
- In some applications, the solder is precoated onto one or both of the surfaces—a process called tinning, irrespective of whether the solder contains any tin.
- Typical clearances in soldering range from 0.075 to 0.125 mm, except when the surfaces are tinned, in which case a clearance of about 0.025 mm is used.
- After solidification, the flux residue must be removed.
- **Soldering Applications:**

(1) As an industrial process, soldering is most closely associated with electronics assembly.
(2) It is also used for mechanical joints, but not for joints subjected to elevated stresses or temperatures.

- **Soldering Advantages:**

(1) low energy input relative to brazing and fusion welding,
(2) variety of heating methods available,
(3) good electrical and thermal conductivity in the joint,
(4) capability to make air-tight and liquid-tight seams for containers,
(5) easy to repair and rework.

- **Soldering Disadvantages:**

(1) low joint strength unless reinforced by mechanically means,
(2) possible weakening or melting of the joint in elevated temperature service.

Joint Designs in Soldering

- As in brazing, soldered joints are limited to lap and butt types, although butt joints should not be used in load-bearing applications.
- Some of the brazing adaptations of these joints also apply to soldering, and soldering technology has added a few more variations of its own to deal with the special part geometries that occur in electrical connections.
- In soldered mechanical joints of sheet-metal parts, the edges of the sheets are often bent over and interlocked before soldering, as shown in Figure (5-49), to increase joint strength.

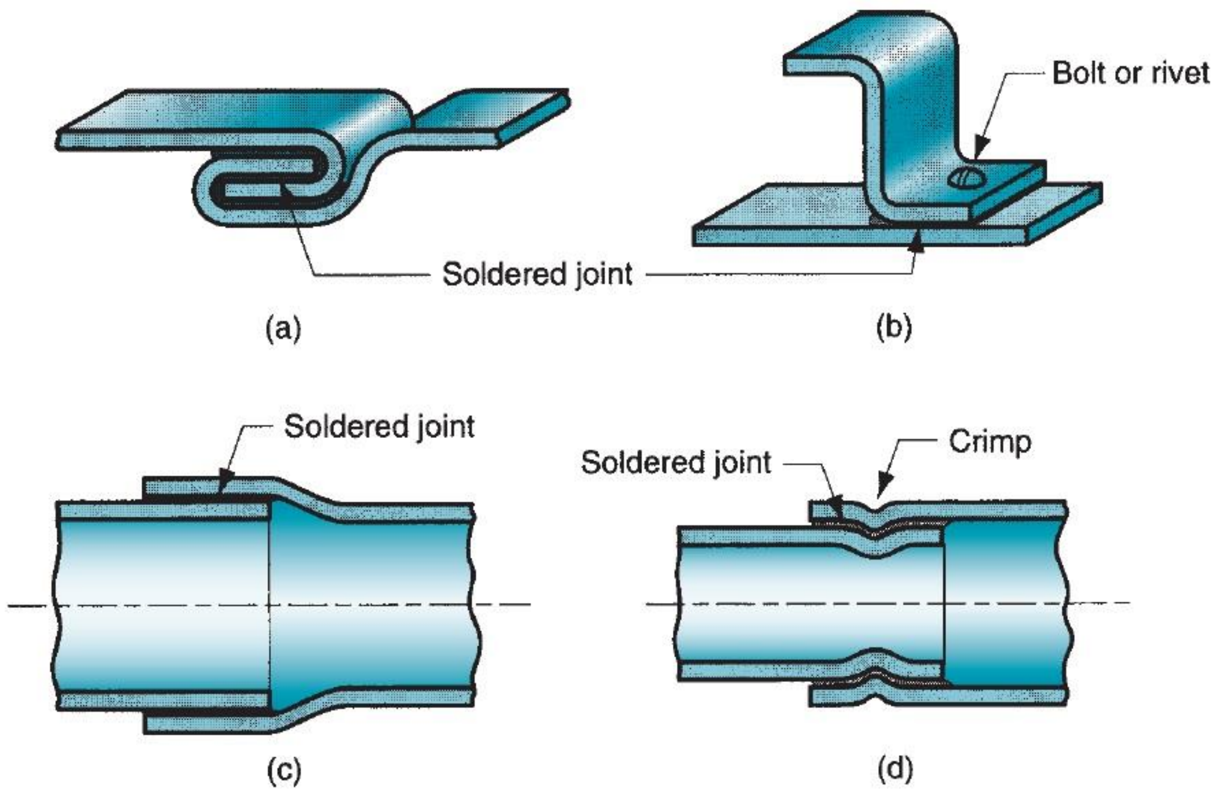

Figure (5-49) Mechanical interlocking in soldered joints for increased strength: (a) flat lock seam; (b) bolted or riveted joint; (c) copper pipe fittings—lap cylindrical joint; and (d) crimping (forming) of cylindrical lap joint.

- For electronics applications, the principal function of the soldered joint is to provide an electrically conductive path between two parts being joined.
- Other design considerations in these types of soldered joints include heat generation (from the electrical resistance of the joint) and vibration.
- Mechanical strength in a soldered electrical connection is often achieved by deforming one or both of the metal parts to accomplish a mechanical joint between them, or by making the surface area larger to provide maximum support by the solder.
- Several possibilities are sketched in Figure (5-50).

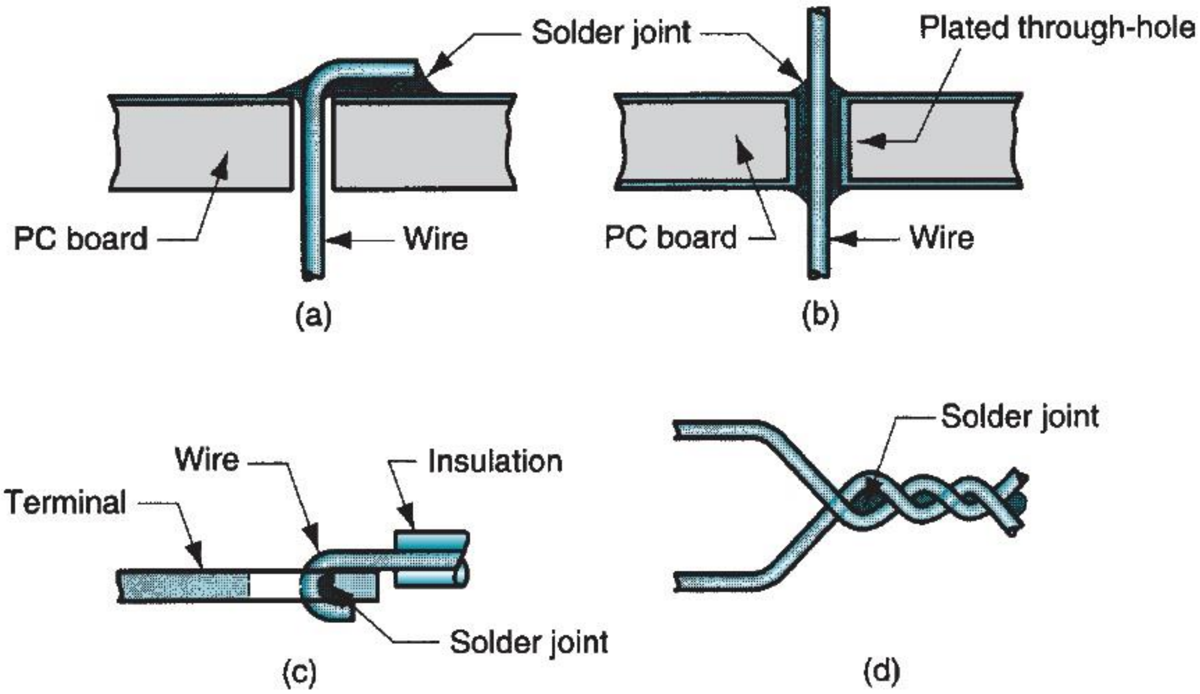

Figure (5-50) Techniques for securing the joint by mechanical means prior to soldering in electrical connections: (a) crimped lead wire on printed circuit board (PCB); (b) plated through hole on PCB to maximize solder contact surface; (c)hooked wire on flat terminal; and (d) twisted wires.

Solders and Fluxes

Solders:

- Most solders are alloys of tin and lead, since both metals have low melting points see Figure (5-51).

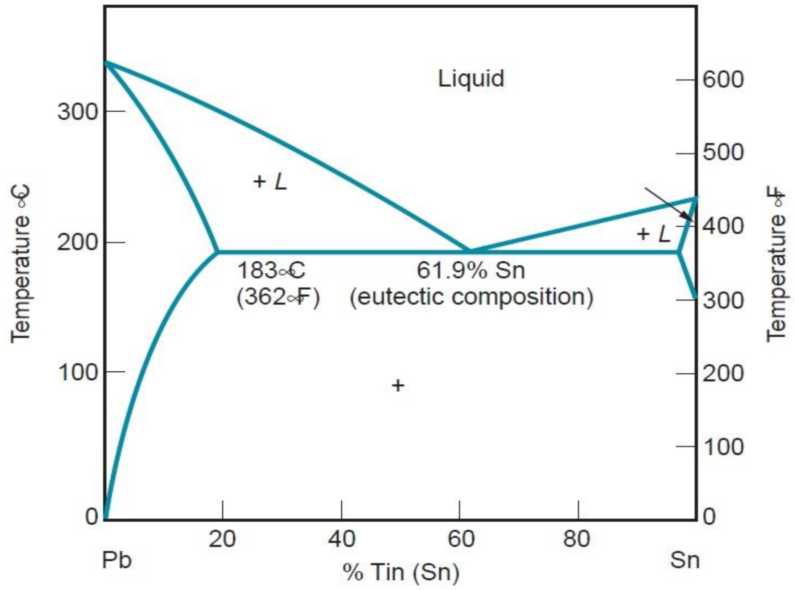

Figure (5-51) Phase diagram for the tin–lead alloy system.

- Their alloys possess a range of liquidus and solidus temperatures to achieve good control of the soldering process for a variety of applications.
- Lead is poisonous and its percentage is minimized in most solder compositions.
- Tin is chemically active at soldering temperatures and promotes the wetting action required for successful joining.
- In soldering copper, common in electrical connections, intermetallic compounds of copper and tin are formed that strengthen the bond.
- Silver and antimony are also sometimes used in soldering alloys.
- Lead-free solders are becoming increasingly important as legislation to eliminate lead from solders is enacted.
- Various solder alloy compositions, indicating their approximate soldering temperatures and principal applications are presented below:

Filler Metal	Approximate Composition	Approximate Melting Temperature °C	Principal Applications
Lead-Silver	96 Pb, 4 Ag	305	Elevated temperature joints
Tin-Antimony	95 Sn, 5 Sb	238	Plumbing and heating
Tin-Lead	63 Sn, 37 Pb	183	Electrical/electronics
	60 Sn, 40 Pb	188	Electrical/electronics
	50 Sn, 50 Pb	199	General purpose
	40 Sn, 60 Pb	207	Automobile radiators
Tin-Silver	96 Sn, 4 Ag	221	Food containers
Tin-zinc	91 Sn, 9 Zn	199	Aluminum joining
Tin-Silver-Copper	95.5 Sn, 3.9 Ag, 0.6 Cu	217	Electronics: surface mount technology

Soldering Fluxes:

- Soldering fluxes should do the following:

(1) be molten at soldering temperatures,
(2) remove oxide films and tarnish from the base part surfaces,
(3) prevent oxidation during heating,
(4) promote wetting of the faying surfaces,
(5) be readily displaced by the molten solder during the process, and
(6) leave a residue that is noncorrosive and nonconductive.

- Unfortunately, there is no single flux that serves all of these functions perfectly for all combinations of solder and base metals.

- The flux formulation must be selected for a given application.
- Soldering fluxes can be classified as **organic** or **inorganic**.
- **Organic fluxes** are made of either rosin (i.e., natural rosin such as gum wood, which is not water-soluble) or water soluble ingredients (e.g., alcohols, organic acids, and halogenated salts).
- The water soluble type facilitates cleanup after soldering.
- Organic fluxes are most commonly used for electrical and electronics connections.
- They tend to be chemically reactive at elevated soldering temperatures but relatively noncorrosive at room temperatures.
- **Inorganic fluxes** consist of inorganic acids (e.g., muriatic acid) and salts (e.g., combinations of zinc and ammonium chlorides) and are used to achieve rapid and active fluxing where oxide films are a problem.
- The salts become active when melted, but are less corrosive than the acids.
- When solder wire is purchased with an acid core it is in this category.
- Both organic and inorganic fluxes should be removed after soldering, but it is especially important in the case of inorganic acids to prevent continued corrosion of the metal surfaces.
- Flux removal is usually accomplished using water solutions except in the case of rosins, which require chemical solvents.
- Recent trends in industry favor water-soluble fluxes over rosins because chemical solvents used with rosins are harmful to the environment and to humans.

Soldering Methods

- Many of the methods used in soldering are the same as those used in brazing, except that less heat and lower temperatures are required for soldering.
- **These methods include** torch soldering, furnace soldering, induction soldering, resistance soldering, dip soldering, and infrared soldering.
- There are other soldering methods, not used in brazing, that should be described here.
- **These methods are** hand soldering, wave soldering, and reflow soldering.

(a) Hand Soldering

- Hand soldering is performed manually using a hot soldering iron.
- A bit, made of copper, is the working end of a soldering iron.
- **Its functions are**:
  (1) to deliver heat to the parts being soldered,
  (2) to melt the solder,

(3) to convey molten solder to the joint, and
(4) to withdraw excess solder.

- Most modern soldering irons are heated by electrical resistance.
- Some are designed as fast-heating soldering guns, which are popular in electronics assembly for intermittent (on/off) operation actuated by a trigger.
- They are capable of making a solder joint in about a second.

(b) Wave Soldering

- Wave soldering is a mechanized technique that allows multiple lead wires to be soldered to a printed circuit board (PCB) as it passes over a wave of molten solder.
- The typical setup is one in which a PCB, on which electronic components have been placed with their lead wires extending through the holes in the board, is loaded onto a conveyor for transport through the wave-soldering equipment.
- The conveyor supports the PCB on its sides, so that its underside is exposed to the processing steps, which consist of the following:

(1) flux is applied using any of several methods, including foaming, spraying, or brushing;
(2) preheating (using light bulbs, heating coils, and infrared devices) to evaporate solvents, activate the flux, and raise the temperature of the assembly; and
(3) wave soldering, in which the liquid solder is pumped from a molten bath through a slit onto the bottom of the board to make the soldering connections between the lead wires and the metal circuit on the board. This third step is illustrated in Figure (5-52).

- The board is often inclined slightly, as depicted in the sketch, and a special tinning oil is mixed with the molten solder to lower its surface tension.
- Both of these measures help to inhibit buildup of excess solder and formation of ‘‘icicles’’ on the bottom of the board.
- Wave soldering is widely applied in electronics to produce printed circuit board assemblies.

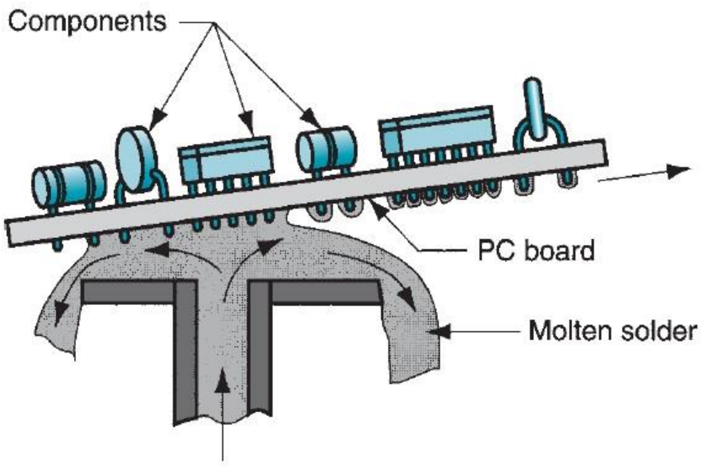

Figure (5-52) Wave soldering, in which molten solder is delivered up through a narrow slot onto the underside of a printed circuit board to connect the component lead wires.

(c) Reflow Soldering

- This process is also widely used in electronics to assemble surface mount components to printed circuit boards.
- In the process, a solder paste consisting of solder powders in a flux binder is applied to spots on the board where electrical contacts are to be made between surface mount components and the copper circuit.
- The components are then placed on the paste spots, and the board is heated to melt the solder, forming mechanical and electrical bonds between the component leads and the copper on the circuit board.
- Heating methods for reflow soldering include vapor phase reflow and infrared reflow.
- In vapor phase reflow soldering, an inert fluorinated hydrocarbon liquid is vaporized by heating in an oven; it subsequently condenses on the board surface where it transfers its heat of vaporization to melt the solder paste and form solder joints on the printed circuit boards.
- In infrared reflow soldering, heat from an infrared lamp is used to melt the solder paste and form joints between component leads and circuit areas on the board.
- Additional heating methods to reflow the solder paste include use of hot plates, hot air, and lasers.