**Objectives**

* Define soldering.
* Define solder.
* List the advantages of soldering.
* List the disadvantages of soldering.
* Define flux.
* List the common types of flux.
* Compare and contrast manual soldering with machine soldering.
* Provide general background on soldering in the electronics industry.
* Explain what happens during the soldering process.
* List the tools and accessories used in soldering.
* Discuss basic soldering preparation and safety procedures.

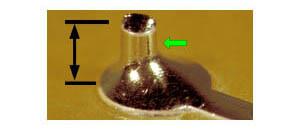
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| **What is Soldering?**   |  | | --- | | The most common method used to join delicate electrical parts is **soldering**. Soldering is a process in which metal filler is heated to liquid form and used to join two other pieces of metal together. The liquid filler then cools and solidifies to form the **joint**.  Soldering offers many traits that make it particularly suitable for delicate work in jewelry making or electronics and also distinguish it from other joining methods. Figure 1 shows a jeweler soldering a ring with a small soldering torch, while Figures 2 and 3 show examples of small components soldered to circuit boards to make electronic chips.   Like **welding** and **brazing**, soldering joins parts by melting metals. However, soldering uses much lower temperatures, and it does not melt the base metals. This makes soldering well suited for more fragile work.  Soldering also shares some traits with **adhesive bonding**, which can be used to join delicate parts as well. However, soldering uses metallic filler, which provides an **electrically conductive** joint. This makes soldering perfectly suited for electrical and electronic assembly.  In this class, you will get an overview of the basic tools and components used for soldering. You will also briefly explore the importance of soldering to the electronics industry, and learn basic procedures for soldering preparation, safety, and cleanup. | |

**What is Solder?**

**Solder** is an **alloy** that becomes liquid when heated at relatively low temperatures, and then solidifies when it cools. Because it has a low **eutectic point**, less than 840°F (449°C), solder is relatively easy to work with in its liquid state. In this liquid state, solder is spread across the surface of two metals to form a bond. This is known as **wetting**. When a drop of liquid comes in contact with a surface, it will spread out over a greater area, making that surface wet, as shown in Figure 1. In its solid form, solder often comes pre-mixed in the form of paste or as a thin wire wrapped around a spool, as shown in Figure 2. A cleaning agent called **flux** is usually mixed in with the solder.  
  
Typically, solder consists of **lead** and **tin**. In fact, a basic solder is referred to by its lead-to-tin ratio. For example, 60/40 solder contains 60% lead, 40% tin. Lead is added to solder to prevent **whiskers**, which can occur in tin-based solders. Whiskers are a serious hazard in electronics, as they can cause **short circuits** and **arcing** in electrical equipment. Figure 3 is a highly magnified photo of tin whiskers.   
  
Occasionally, other types of metal such as **silver** or **bismuth** are combined with lead to form solder. However, lead poses health and environmental risks. Because of these concerns, there is a growing trend toward using lead-free solder. Ultimately, most metals are poor solders when used alone. For this reason, manufacturers blend various metals into a solder to produce the best blend of properties.

**Advantages of Soldering**

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| |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | | The general purpose of soldering is to provide a strong joint, create an electrical conduit, or create an airtight and watertight seal. As a metal joining technology, soldering has some unique advantages:   * There are a wide variety of solders and heating methods available. * Soldering requires low energy compared to other metal joining methods. * Soldered joints are easy to repair. * Solder is inexpensive to purchase. * Hand soldering allows the operator a high degree of control. * Solder provides excellent electrical and thermal **conductivity**.   **Disadvantages of Soldering**  Combined, these advantages make soldering perfectly suitable for certain key applications. Within the field of electronics, soldering is the joining method of choice because of its high degree of electrical conductivity. Soldering is also used in making jewelry and stained glass windows, as shown in Figure 1.  Despite its unique advantages, soldering is not suitable for all types of joining. In general, the disadvantages of soldering include the following:   * Soldering requires a great deal of preparation and cleanup. * The low melting point of solder makes it unstable in high temperature situations. * Poorly soldered joints fatigue easily and lose their joining properties, as shown in Figure 1. * Some formulations of solder contain **toxic** substances, such as **lead** or **antimony**. Figure 2 lists some of the dangers of lead poisoning. * Hand soldering requires an element of practice and skill. * Solder bonds with very few metals.   Because of these limitations, soldering is not used for joints that will experience a lot of stress. More heavy-duty processes, such as mechanical fastening or welding, are used when a joint must be very strong. Soldering can be used only for joining metal parts. It cannot be used for combining a wide range of different materials.   |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | **What is Flux?**   |  |  |  |  |  | | --- | --- | --- | --- | --- | | In order to form a strong, conductive bond, metal surfaces must be absolutely free of rust or tarnish caused by any **oxidation** that occurs before soldering takes place. Figure 1 shows how oxidation occurs. To clean the joint, assemblers use **flux**. Flux can be applied separately with a **flux pen** like the one in Figure 2, but it is usually already mixed in with the solder itself.   There are many types of flux to match different uses. The correct choice of flux depends on:   * Soldering methods. * Type of materials to be soldered. * Quality standards required for the finished product.   Flux strength is measured in terms of **activity**. The more active the flux, the more effectively it cleans. At the higher soldering temperatures, **activators** in flux break down to create **ammonia** or **hydrochloric acid**, which ultimately cleans the metal surface. However, the fluxing process often creates a **residue**. Depending on the type of flux, this residue may or may not need to be removed. Figure 3 shows an example of flux residue.  **Types of Flux**   |  |  |  |  | | --- | --- | --- | --- | | |  |  |  | | --- | --- | --- | | Fluxes fall into two categories: rosin-based and water soluble. **Rosin-based** fluxes are made from purified pine tree sap and have three levels of activity:   * R – Rosin only * RMA – Rosin mildly activated * RA – Rosin activated   Rosin-only fluxes are the least active and leave almost no residue. However, this type should be used only on surfaces that are very clean. RMA fluxes are more active and leave some residue, while RA fluxes are the most active and therefore leave the most residue. RA fluxes provide the best cleaning action but also the greatest chance that the residue must be removed.  **Water-soluble** fluxes are derived not from water but from synthetic resins and organic acids. The water solubility refers to the ease with which flux residue can be removed with water.  Water soluble fluxes can be **organic** or **inorganic**. Organic water-soluble fluxes are more active than rosin-based fluxes, while inorganic water-soluble fluxes are the most active and corrosive. Figure 1 shows an example of corrosion, while Figure 2 illustrates the different categories of flux. Regardless of the specific type, flux is a critical component of soldering.  **Manual Soldering Vv. Automated Soldering**   |  |  | | --- | --- | | |  | | --- | | There are numerous ways to solder parts together. However, all soldering processes involve some sort of **heat transfer**. Heat transfer occurs through the action of conduction, convection, radiation, or a combination of the three, as illustrated in Figure 1. **Conduction** is the process by which adjacent atoms vibrate against each other, and it occurs most easily in metal. **Convection** is the physical movement of hot particles to cooler areas, and it usually occurs in liquid. **Radiation** employs the natural heat emitted by energy particles called **photons**, and it is transmitted by electromagnetic wave.  Soldering can be done by hand or machine, or sometimes a combination of both. You can see a large wave soldering machine in Figure 2. The method of soldering is determined by:   * The types of materials being processed. * The type of solder and flux being used. * The desired quality of the end product. * The production volume, most importantly.   **Hand soldering** is the oldest and most common method. It is performed manually by an individual with a **soldering iron**. The handheld iron transfers heat primarily through conduction. Because hand soldering requires practice and skill, it is typically used for repairs or for highly sensitive work that does not require high-speed production.  On an industrial scale, soldering jobs are done primarily by programmed machines through a variety of heat transfer methods such as molten metal, focused light, hot gas, hot vapor, radiant energy, or soldering irons. Figure 3 illustrates heat transfer through focused light  http://www.toolingu.com/multi_media/images/660_16.jpg. | | | | | | |  |  |  | | --- | --- | |  |  |   **Electronics Fabrication**  The vast majority of industrial soldering is done in the fields of **electrical assembly** and **electronics fabrication**. These areas include the manufacturing of circuit board assemblies, light switches, light bulbs, fuses, or any other type of electrical item.  The primary soldering method used in electronics is **reflow soldering**. In this process, solder is printed on circuit boards in the form of a paste. These printed circuit boards, or **PCBs**, are run through an oven on a conveyor belt, and the granules of solder melt to form a joint, as shown in Figure 1.  **Wave soldering** is the second most frequently used type of automated soldering. PCBs are loaded onto a conveyor, which passes over a vat of molten solder. As the conveyor belt moves, a wave is created with a pump. The bottom of the board hits the crest of the wave, and the solder sticks through **capillary action**, as shown in Figure 2.  The third most common type of machine soldering is by **robot**. The robot solders joints individually with great efficiency and accuracy and has the ability to use a variety of heating tools, such as a soldering iron, torch, laser, or focused high energy light.  A fourth method is **vapor-phase soldering**. In this process, PCBs are put in a chamber with a volatile liquid chemical at the bottom. The chemical is heated to its boiling point to form steam, and the steam heats the solder paste at the bottom of the board, as shown in Figure 3.  **The Soldering Process**  Although there are numerous ways to solder, most electrical assemblers must know first how to hand solder. Suppose you want to solder an electronic circuit. How would you go about it? First, you must prepare the surface to be soldered by cleaning it with flux.  The next step is **tinning**, as shown in Figure 1. Apply a small amount of solder to the tip of the soldering iron. This helps to conduct heat. Next comes preheating. Lay the soldering iron tip against the joint for 1-2 seconds. Now you may begin soldering. Apply solder by touching it to the joint, as shown in Figure 2. Avoid touching solder to the tip of the soldering iron. Heat will cause the solder to melt and flow freely.  When you have finished, allow the joint to cool for a few seconds. Remove any flux residue, and then inspect your work. A good joint will appear smooth, bright, and shiny, while a **cold joint** will be dull and grainy and may result in a non-working circuit. Figure 3 shows a good soldered joint. If you have a cold joint, you must fix it by removing the solder with a **desoldering** tool, then resolder the joint.  http://www.toolingu.com/multi_media/images/660_35.jpg  http://www.toolingu.com/multi_media/images/660_34.jpg |



**Soldering Tools and Accessories**

The only essential tools you need for hand soldering are **solder** and a **soldering iron**. Soldering irons typically resemble a large pen. Inexpensive ones are powered by electricity. However, there are also portable soldering irons powered by gas or heavy-duty batteries, as shown in Figure 1. Many soldering irons come with interchangeable bits or tips of various sizes and shapes to accommodate different soldering jobs, as shown in Figure 2.  
  
There are additional soldering accessories that you may find helpful:

* A **soldering station** comes with a soldering iron, desoldering iron, heatproof stand, variable heat control, and a place for a cleaning pad, as Figure 3 shows.
* A **soldering iron stand** is an essential safety feature, providing you with a place to set your hot soldering iron while you complete other tasks.
* **Clamps** are often needed to hold small, delicate pieces or keep your hands free. They are especially useful when soldering electronic circuits.
* A magnifying glass can help you see small components, such as chip resistors.
* A **fume extractor** or an exhaust fan can be used to remove soldering fumes. The fumes from solder are toxic and must be evacuated from your work area.
* Flux remover may be necessary for removing flux residue. This is especially true for more active fluxes.
* Lastly, soldering iron tips must be periodically cleaned of solder. A cheap and effective way to do this is with a wet sponge.

**Basic Safety Precautions**

The process of soldering involves handling hot, acidic, and often toxic materials that can burn skin and produce harmful fumes. Therefore, you should take proper precautions when soldering:

1. Always wear protective gloves and safety glasses. Figure 1 shows the type of safety glasses worn for basic eye protection.
2. Solder on a fire-resistant surface only.
3. Never eat, drink, or smoke near the soldering area.
4. Always thoroughly wash your hands after soldering.
5. Work in a well-ventilated area, preferably one in which a fan draws fumes away from your face and exhausts them to the outside. Figure 2 shows a soldering station with a fume extractor.
6. Never leave a plugged-in soldering iron unattended.
7. Do not leave your soldering iron lying on a bench or worktable. Instead, use an iron stand.
8. Never use lead-based solder for any items that will come into contact with food.

If you use lead-based solder on a frequent basis, you should have a physician periodically check the level of lead in your blood.

**Summary**

Soldering is a process in which metal filler is heated to liquid form and used to join two other pieces of metal together for the purpose of creating a strong joint, seal, or electrical conduit. Soldering shares common characteristics with other metal-joining techniques, such as brazing, welding, and adhesive bonding, but has important differences as well.  
  
Soldering can be done individually by hand, or on an industrial scale using a programmed machine. In electronics assembly, where soldering is the preferred method of metal-joining, the primary methods of machine soldering are reflow soldering, wave soldering, robotic soldering, and vapor phase soldering.  
  
For hand soldering, the only tools necessary are a soldering iron and solder, which usually has flux cleaner already mixed in. You may want to invest in additional accessories such as a soldering station and fume extractor. You should also take appropriate safety measures by wearing gloves and protective goggles.