DVD-20/21C
Reflow Soldering

Below is a copy of the narration for DVD-20/21C. The contents for this script were developed by a review group of industry experts and were based on the best available knowledge at the time of development. The narration may be helpful for translation and technical reference.

Part 1

Section 1

Welcome to part one of the reflow soldering video training series. In this tape, and in tape number 2, we will explain what reflow soldering is, what it does, and how it's done. We will also discuss what you, as an operator, need to know to eliminate the problems that lead to defective reflow soldered connections.

Reflow is the process of applying heat to a group of components that are positioned on solid solder, or solder in a paste form, on a printed board. The heat causes the solder to melt or flow, and since the solder may have been melted before, the term reflow describes the action taking place.

There are several processes used in the reflow soldering of electronic assemblies. There is vapor phase or condensation heating, infrared or radiation heating, air or nitrogen convection heating, both forced and natural. And also there is a combination of I/R and convection heating. This video, and tape two, will explain the various processes and the details that must be controlled in order to get a good solder joint.

To start, we will look at the nature of the reflowed solder connections. For our examples, we will use surface mounted electronic components on a double sided printed wiring board. There are two reasons for soldering the component to the surface of the printed wiring board. One is to **create a physical or mechanical connection** that will be sturdy and reliable. The second reason is to **provide an electrical path** between the electronic component and the printed board conductors. If both of these criteria are met, there will be an acceptable soldered joint. The process that takes place to provide this properly soldered connection is called **wetting**.

There are several steps that take place in a reflow soldering system to achieve wetting. When the assembly enters the oven, the components are positioned in their proper location on top of a mixture of flux and solder called **solder paste**. How this mixture is applied and how the components are placed will be discussed in some detail in the next video of this series.

Oxides are formed simply by contact of the metals with oxygen in the air. Oxides are a combination of oxygen and the surface metal of the leads, terminations, lands and solder. During the preheat stage, many fluxes become more active as their temperature increases. As the **flux** touches the surface metal of the lead and the land, its purpose is to remove the oxides that have formed on those metals.

When these metals (the solder also is a metal) are heated to the proper temperature, wetting can take place. The solder is pulled, or wicks, onto the surface metal of the lead or termination, and land on the printed board. At this point, the solder combines with the surface metal of the lead or termination and the land to form what is called the **intermetallic compound**. This thin layer of intermetallic is a combination of the surface metal of the lead or land, and the tin portion of the solder.

This is an example of wetting which indicates that there is a solder bond. Notice the **concave surface** of the solder fillet that **tapers to a thin edge**. These are signs of a properly wetted and therefore acceptable soldered connection.

Section 2

Next we will provide an overview of a simple convection reflow soldering system:

The first stage in the machine is the **preheat area**. ln this section the assembly's temperature is slowly raised. There are three things that are expected to happen in the preheat section:

- First, some fluxes are activated by heat.
- Second, the chemicals that hold the constituents of the flux evaporate. These volatiles must be driven off.
- And third, the parts to be soldered and the solder itself must be closer to the soldering temperature.

The second stage inside the machine is the **soldering area**. In this part of the process, reflow soldering takes place. The parts to be soldered and the solder reach soldering temperature. The amount of time that the parts remain at this temperature is important. Too short a time will mean that the solder will not flow properly. Too long a time will create an improper joint or may damage the parts being soldered.

The final stage is the **cool down area**. In this area the assembly cools gradually and the soldered joints are allowed to solidify.

The heating that takes place in a reflow soldering oven is controllable, more so in some systems than others. We need a way to measure the temperature and heat transfer in all the stages so that any necessary adjustments can be made. This measurement is called a **thermal profile**. Each oven has a generic profile, each assembly has a unique and specific profile. If an assembly is heated too quickly or at too high a temperature, there could be damage to the printed board or some of the electronic components. If an assembly is not heated enough, proper soldering will not take place. The temperature profile is shown as a graph of temperature versus the time that the assembly takes to pass through each stage.

In an ideal profile, the rise in the assembly's temperature during the preheat stage will be slow and gradual. The temperature should also be essentially uniform for the whole assembly. In the soldering stage, the temperature of the assembly and the solder must reach the reflow temperature range. Each part to be connected, that is the lead or termination of the components and the land to which they are being attached, must reach soldering temperature at the same time. For instance if the lead gets to soldering temperature first, the solder wicks up that lead. By the time the land reaches the proper temperature, there is not enough solder left to form the connection.

The final stage of reflow soldering is the cool down, where the assembly slowly approaches room temperature. This is recorded as the end of the temperature profile. The cool down stage must also be controlled so that the temperature change is not too quick.

Section 3

There are many ways to check the heat transfer in a reflow soldering system. In some facilities, **waxes** that melt at specific temperatures or **stickers** that change color at a certain temperature are applied to the printed board's surface. These devices will indicate that a specific temperature has been exceeded, but will not tell the actual upper limit of the temperature of the board's surface.

Another device used to record the temperature profile is built into some machines. As the assembly on the conveyor travels through the reflow soldering machine, thermocouples take readings at predetermined locations in the oven. Information from the thermocouples inside the oven is passed to an on-board computer that will display the profile on a screen.

Another method that is used to determine the thermal profile is a device that actually travels with the assembly through the reflow soldering machine. This device is wired to **thermocouples** that are attached to various locations on the assembly. The readings are sent to a receiver via radio signals or are stored in the profiling device and unloaded to a computer after exiting the reflow soldering machine. The information from the device is used to form the graph of the temperature at the assembly versus the time of travel through the various areas of the machine.

Some systems employ a series of **inframometers** which are like small TV cameras. As each board passes, the meters read the board surface temperature and convey that information to the system computer. If preset temperature limits are exceeded, this machine notifies the operator.

Any of these methods can be used to simulate or give a picture of the assembly's temperature rise at given locations on the board or component surface as the assembly travels through the reflow soldering process.

A typical temperature profile might look like this:

These colored lines indicate the journey of three specific locations on the assembly through the preheat section of the reflow soldering machine. This particular profile shows a temperature gain of about 2 degrees Celsius per second during the preheating. In this stage of the operation, the assembly temperature will plateau at 80 to 120 degrees Celsius. After preheat, the assemblies pass into the reflow soldering area. In this section they will be heated to the proper soldering temperature.

For a solder alloy that melts at 230 degrees Celsius or greater, the upper heating temperature that the assembly must reach needs to be at least 20 degrees Celsius above that melting point. In some situations that upper limit may be even greater. If the melting point of the alloy is less than 230 degrees Celsius, the upper limit of the temperature profile during soldering needs to be at least 30 degrees Celsius above that temperature.

Exposure of the assembly to this upper temperature is only required for a few seconds. However the various parts of the joints to be soldered may reach soldering temperature at different times depending on location, component type and size. Some joints will be at soldering temperature for only about 10 seconds while others may be there for 40 or 50 seconds.

Then the assembly exits the soldering section of the machine and goes into cool down.

The information in this video is intended to give you an idea of what happens inside a reflow soldering machine. In Reflow Soldering - Part 2, we will discuss the mechanisms used to effect that heat transfer.

Part 2

Section 4

In the first video of this reflow soldering series, we studied the reasons for the heat transfer that takes place inside a reflow soldering system. We also learned what happens to the components and the printed wiring board when that heat transfer occurs properly. If you feel you don't understand that part of the reflow soldering process, ask your trainer or supervisor for help.

Before our discussion of the various reflow soldering equipment, we will review the techniques for applying the correct amount of solder to the printed board. This is done before the components are positioned.

The lands to which the parts are to be attached will be covered with an application of **solder paste** which is a mixture of solder particles and flux. These compounds have various other ingredients, but they all have solder, flux and binders that determine the physical properties of that particular paste. Solid solder may also be used for reflowing. A solder addition during the printed board manufacturing process is sometimes used. These are known as **solder bumps**. In our examples however, we will use solder paste which is added just prior to component placement.

Most solders that are used in electrical soldering are an alloy of metals, most often **tin** and **lead**. In the paste form, the solder is a powder. In this extreme close-up, the solder looks like tiny balls of metal.

The **flux**, which you learned about in Reflow Solder **-** Part 1, is a chemical compound designed to remove oxides from the surface of the parts to be soldered. The type of flux is decided on the basis of what fluxing action is required and what type of post-soldering cleaning machine will be used. The **binder** that is used will determine the consistency and maintain the shape of the applied paste on the land to prevent slumping.

There are two basic ways of applying the paste that we will look at here. One printing pattern is made of metal, usually brass, and is called a **stencil**. Another method is called screen printing. It uses a plastic fiber or stainless steel mesh that has an image added to it to define the openings through which the paste is forced. The solder paste is wiped across the stencil or screen with a squeegee which pushes the paste through the openings, depositing it on the lands in only the right places.

The thickness of the stencil or screen, the type of solder paste, the kind of material the squeegee is made of, and the pressure that is applied by that squeegee, will determine the amount of paste that is deposited. The amount of paste deposited on the lands will be critical to the quality of the reflow soldered connection.

After the paste has been applied, the components are placed on the printed board. There are many machines that are available for the accurate placement of surface mount components on printed boards. We will not go into any detail here concerning these machines. It is important however that you understand that if a component is not properly placed or is moved out of place before it enters the soldering machine, the required connection may not be made.

Another situation that may exist in your facility is the need to solder components on both sides of a board in one pass through the machine. In some cases, the components that will travel through the reflow soldering machine on the underside of the board are glued in place. This glue, known as **adhesive**, can be applied by injection.

When all the required components are in place, the unsoldered assembly is ready to enter the reflow soldering machine.

Section 5

Now we will take a look at some of the ways of applying heat for reflow soldering.

The first method we will study is the **vapor phase** or **condensation reflow soldering** process. The heat comes from the vapor provided by a liquid that boils at a specific temperature. The liquid is heated in a tank. Some of it vaporizes into a gas and rises upward, in effect carrying the heat to the assembly above. As the vapor condenses on the assembly, it's heat is transferred to the assembly and the solder paste. With further heating, the solder in the paste melts and wetting can take place. No part of the assembly can be heated above the boiling temperature of the liquid.

With an upper temperature that cannot be exceeded, components that are sensitive to high temperatures are safe, and places that are hard to contact are easily reached by the heat of the condensing vapor. There are a variety of chemically inert, non-flammable liquids that are used to vary the boiling point. Although these liquids are quite expensive, they are recycled and reused. Most machines have **cooling coils** that cause the vapor that rises past the assembly to be condensed and returned to the heating pot. Another advantage of vapor phase reflow soldering is that the density of the vapor will keep oxygen out of the system. This will keep the metals from re-oxidizing during any point of the operation.

But vapor phase does have a disadvantage. Although the upper temperature that the assembly can reach is controllable, the amount of time it takes to reach that temperature is not. Some components can be damaged if their temperature goes up too quickly. This problem can be dealt with by having a **preheat area** before the vapor chamber.

Anyone that works around vapor phase reflow soldering machines should be aware of what chemicals are being used and refer to the Material Safety Data sheets for safe handling of those chemicals. The Material Safety Data sheet, or MSDS, should always be available in the work area where chemicals are being used. It is your responsibility to be aware of any safety precautions that are necessary.

The two types of systems used to vapor phase solder are the batch type and in-line systems.

In a **batch system**, the assemblies are lowered in a basket into the soldering section of the machine. After a predetermined amount of time, the basket is raised up and the soldered assemblies are removed. Batch equipment is used for small and prototype groups of assemblies.

In the **in-line system**, the assembly rides on a conveyor through the vapor chamber. With some in-line systems, the conveyor is inclined towards, and then away from the vapor chamber. This will help the condensed liquid to flow off the assembly to be recycled and reused.

Section 6

Now we'll have a study of radiation and convection heat transfer.

With **radiation**, rays of energy will heat any surface that absorbs them. The color and texture of the surface to be heated can affect how much heat is absorbed, depending on the wavelength of the I/R energy. And any area that is not in a straight unobstructed line from the energy emitting source will not receive direct heating.

Here is a simple example:

On a cold day, if you stand in the sun, you can feel quite warm. If you reach out your hand into a shaded area, it will feel much colder. It's not that the air in the shade is that much colder. You simply aren't getting the **radiant heat** from direct contact with sun rays.

With **convection** there must be direct contact with a heating medium, usually a gas or liquid. For instance, burning natural gas in an oven heats the air, and the hot air would then heat the food. There are two basic kinds of infrared reflow soldering. The first is call **near I/R radiation soldering**. In these systems, almost all the heat comes from a source that radiates infrared energy in the short wavelength range. Typically the source is a group of **I/R lamps**. About 5% of the heat in this type of system comes from **convection**, that is from the heated air in the oven.

One problem with this method is that the I/R energy is of a wavelength that is much more readily absorbed by some colors than by others. This means that some parts of the assembly will get hot faster than others, depending on their color. If the leads and lands don't reach soldering temperature at the same time, all the solder may wick to the hottest part. This would leave insufficient solder to bridge the gap necessary to make the connection.

The second infrared reflow soldering system is called **convection/lR** and uses the middle range of the infrared energy wavelength. About 60% of the heat transfer comes from convection through the hot air in the oven. The remaining 40% of the heat transfer comes from infrared radiation. In both of these I/R reflow soldering methods, the assembly travels through the machine on a **belt** or **conveyor**. The first area inside the machine transfers a low amount of heat to allow for a gradual temperature rise. In this **preheating area** of the system, the volatiles are driven off and the cleaning action starts. If these liquids do not evaporate slowly, and before soldering, they may be turned abruptly to gas at soldering temperatures and explode out through the solder. This will cause **blow holes** and **solder balls**. As the assembly travels on through the machine, the next heating zones are set at higher temperatures. These are the zones where reflow of the solder and wetting will take place. The amount of heat in the reflow area and the speed of the conveyor or belt will decide how much heat is transferred.

Section 7

Another type of reflow soldering machine transfers energy with 80% to 95% convection heating. In these **forced convection systems**, air or another gas such as nitrogen, is heated. It is then blown over and around the assemblies through many holes above and below the assembly conveyor. An advantage of the forced convection system is its ability to gradually and uniformly heat all of the assembly. Both the maximum temperature and the rate at which that temperature is reached can be controlled. This machine will also heat the parts to be soldered very evenly. Component leads, terminals and printed wiring board lands will reach soldering temperature at the same time.

One problem that has been observed is that sometimes the blowing hot air will dry out the surface of the solder paste and form a skin of resin. The paste may not be able to vent its volatiles completely by the time the soldering zone is reached. Again, this situation can create blow holes and solder balls.

Present developments indicate that the combination of radiation and convection heating will be the system of choice in the future. Radiation to add the correct amount of heat quickly. Convection to provide uniformity of heating to the surfaces.

An adaptation of all the I/R and convection systems is the **nitrogen blanket system** or equipment. This modification helps reduce the amount of oxide formation on the surface of the parts to be soldered. This is accomplished by substituting nitrogen for the oxygen normally present in the heating areas of the machine. If there is no oxygen to touch the metals, no oxides will form.

It's important that you have an overall understanding of the reflow soldering process. Ask questions. In the competitive environment that exists in our industry today, your company's ability to compete will depend on each employee doing the best quality job possible.