DVD-45C
Lead-Free Hand Soldering

Below is a copy of the narration for DVD-45C. 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.

The Switch to Lead-Free

VOICE 1: I'm concerned that our natural environment is being affected by our reliance on harmful materials.

VOICE 2: Here we go again – another bleeding heart.

VOICE 1: I just read an article about how disposing of our old electronic products….

VOICE 2: You scared of a little lead? Gimme a break!

VOICE 1: Duh – then why do we have lead-free gas?

Did you know the electronics assembly industry is beginning the move from tin/lead solder to lead-free solder alloys? Let's look at why. In the 1970s lead had become commonly recognized as a potential health hazard – and was eliminated from gasoline and paint. As part of the continuing effort to reduce environmental pollution from industrial and manufacturing wastes, there is now momentum for using lead-free solder in the electronics industry.

In fact, Europe has a legal mandate to change to lead-free soldering processes by July 1, 2006. Japan is also committed to this timetable. Given this global market commitment to lead-free electronics, the United States is preparing to do the same.

The question isn't *whether* the switch will be made to lead-free solder, but *when*. Everyone agrees that it's just a matter of time when lead will be *banned* in electronic products. The switch to lead-free solder will keep lead out of our landfills – and from being burned in our incinerators – which is much better for our environment and much better for our health.

Lead is a poison that can severely affect our central nervous system. Ingestion is the most likely route of entry while performing electronics assembly.

Using proper precaution, we've learned how to minimize the potential hazards of tin-lead solder. We already know that lead can be ingested by touching food, cigarettes, chewing tobacco or make up after handling tin-lead solder, solder paste or soldered boards without hand protection.

And we also know that the hazard can be avoided by washing our hands with soap and water before touching any item that will come into contact with our mouths. What this means is that we can protect ourselves in the workplace.

But the situation involving lead is not so clear when we discard our old electronic products. Our landfills contain tons and tons of electronic components and circuit boards that were manufactured and assembled using tin-lead solder. There is concern that the lead in the landfills will somehow end up in the water table.

Now that you know why many companies are switching to lead-free soldering processes, let's take a look at the different types of lead-free solder alloys. There are many types of lead-free solders available today. In fact, the tin-silver alloy has been used for many years in higher melting point applications. The melting point for this alloy is about forty degrees C higher than tin-lead – which becomes liquid at 183 degrees. This means there's more potential for heat damage to the circuit board and components.

The most common lead-free alloy for hand soldering applications is tin-silver-copper. This alloy typically contains 3% silver and .5% copper. Tin-silver-copper has a slightly lower melting point of 217 degrees C. A variation of this alloy is also used for reflow soldering.

Another lead-free alloy is tin-copper – a less expensive compound used for wave soldering applications. The melting point of tin-copper is somewhat higher at 227 degrees C.

Your company will have already selected the specific lead-free soldering alloy it will be using for hand soldering applications. It's important to become familiar with its characteristics. Lead-free solder alloys tend to have a stronger surface tension – meaning they are more difficult to spread along the surface of the connection than their tin-lead counterparts. As stated previously, the melting temperatures are up to 40 degrees C higher. For example, a soldering iron temperature for a lead-free process may be 400 degrees C versus 360 degrees C for tin-lead.

Although studies have indicated that lead-free solder joints can be as reliable as tin-lead, there are definitely challenges to implementing the process. Here are some things to be aware of –

Components and circuit boards need to be able to withstand the higher soldering temperatures. Solder defects may increase due to poor wetting, and may create more rework. Fluxes will need to clean surfaces more aggressively and will need to function properly at higher temperatures. That's because there's more possibility of oxidation, and potentially longer soldering times because of the higher melting temperature.

The more active fluxes, in turn, may require a more thorough cleaning process to remove the more aggressive (and possibly still active) residues. Finally, the solder joints may have a different appearance depending on the lead-free alloy used, and the visual inspection criteria may be slightly different.

Soldering With Lead-Free Alloys

In section one you learned about the characteristics of lead-free solder. In this section we'll be discussing the following hand soldering topics: soldering iron tips; temperature and heat transfer; oxidation and tinning the iron tip; flux; the soldering operation; and cleaning.

Let's review what we know about soldering iron tips. As you know, the amount of heat that is transferred to the parts being soldered depends not only on the temperature of the tip, but also on how much of the tip touches the parts to be soldered.

When selecting a tip, always select a tip that has the greatest contact area without overhanging the joint area. A conical, or pointed tip is used to transfer heat into a small area. A chisel, or screwdriver tip has a much greater contact area than a conical tip and will therefore transfer more heat. This is especially important with lead-free solder alloys because of the higher melting temperatures. It's important to realize that these solder connections should be completed in the shortest possible time to prevent excess heat from spreading to nearby areas of the board so there won't be thermal damage.

The first step in the hand soldering process is tinning the tip of the soldering iron. We do this because oxidation can form on the iron tip. Oxidation acts as a barrier or an insulator – meaning it can slow down the transfer of heat. This characteristic is especially negative when using lead-free alloys. It's important that the tip be cleaned and tinned both before and after you solder. Lead-free solder is even more sensitive to a dirty tip than tin-lead solder.

Another variable is the flux contained inside the lead-free solder wire. Most lead-free alloys used in hand soldering have a core containing flux in plastic form. As you know, the main job of flux is to remove oxides or contamination from the metal surfaces to be soldered. This will allow the solder to bond properly.

Flux also assists in the transfer of heat from the tip of the iron to the metals being soldered. As we mentioned earlier, because of the higher soldering temperatures for lead-free alloys, the flux must be more robust so that it doesn't burn up and evaporate as a result of the higher temperatures encountered during the lead-free soldering operation.

Now, let's take a look at the soldering operation. For this example we'll use a tin-silver-copper alloy that has a melting temperature of 217 degrees C. We'll be using a temperature- controlled soldering iron with a chisel tip. The temperature will be set at 410 degrees C. The flux in the core of the solder is a high activity flux. And we'll be soldering a round component lead into a plated through hole. Normally this type of soldering operation would only take a few seconds to complete, but we'll be *stopping* the process in order to explain everything that happens as we go along.

We begin by *gently* placing the cleaned and tinned soldering iron tip against the lead and the land. This will transfer heat into both of these parts. Now the solder wire should quickly touch the tip of the iron – to melt *just enough* solder and flux to form a *heat bridge* between the metals. Then we'll move the solder wire over to the *opposite* side of the joint - still touching both the lead and the land. When there's enough solder melted into the connection, the solder wire is removed – followed by the soldering iron tip.

Now we'll *inspect* the joint to make sure it looks right. A *preferred* or *target* connection is where all of the metals are covered by solder and the *outline of the lead* remains visible within the solder connection. Notice that the tin-silver-copper alloy is *grainier* in appearance than the tin-lead solder joints you're used to seeing. This graininess is caused by the higher soldering temperatures and is generally considered a cosmetic issue.

After the solder joint is completed, the flux residue may need to be cleaned. The general idea is to remove the flux residue *right after* the hand soldering operation - by *brushing* the area with the appropriate cleaning solution.

Your company will select the right cleaning fluids… which will likely be *solvent* based – because of the stickiness of the flux we used. This cleaning operation should always be performed *immediately* after the hand soldering operation. If it's not done right away, the flux residue will harden and become even more difficult - if not impossible to remove.

An absorbent - lint free – and ESD safe tissue is often used to remove the solvent - so the residue doesn't just spread around the board. Even after this type of cleaning process, some of the flux may be trapped underneath the components – and may remain as an invisible film. If a *high level* of cleanliness is required, additional *machine cleaning* will be necessary.

Now, we'll take a look at another type of hand soldering operation using the tin-silver-copper alloy on a pierced terminal. The first step is to strip and tin the insulated wire prior to attachment to the terminal. There are many ways of stripping the insulated wire. Some methods are unacceptable because of possible damage to the insulation and the wire. One of the safest methods is the proper use of the thermal stripper that melts or softens the insulation. Use your fingers to twist the insulation slug off in the direction of the wire lay. Do not use the stripper to pull off the insulation slug as it can potentially damage the wire.

The stripped wire now needs to be tinned. This is done so that when the wire is bent it won't be damaged, and to improve solderability. You'll need to utilize the same lead free alloy that you'll be using for soldering. To tin the wire, you can move it across a solder coated iron tip, move a tinned tip over a stationary wire, or dip it in a solder pot. Your facility may require the use of an anti-wicking tool to secure the wire during the tinning operation. This will keep it from being damaged.

Pierced terminals have a hole in the middle. Wire can enter from either side, or from the top. The wire should be pushed through the hole, then wrapped and positioned to contact both the flat sides of the terminal.

Again, we'll be setting the soldering iron temperature to 410 degrees C for the tin-silver-copper alloy. Also, don't forget to clean and tin the soldering iron tip.

Now, let's watch the proper soldering operation for this particular terminal. There are four basic steps. First, the iron is placed at the point of greatest thermal mass -- in contact with the terminal and the wire. Next, a solder heat bridge is made to increase the thermal linkage between the tip and the work. Additional solder is then applied on the opposite side of the point of contact to form the necessary solder fillet. The solder wire is removed when a sufficient amount of solder has been added to the joint. Finally, the iron is withdrawn at the same angle it was introduced to the joint.

Now let's look at what we should expect to see in an acceptable solder joint. The minimum solder quantity is dependent on your company's workmanship specification. The maximum acceptable solder joint has a fillet that is no longer concave, but is beginning to bulge.

At this point, let's examine the difference in appearance between the solder joint with the lead-free alloy and the shinier tin-lead solder joint. Notice that the tin-silver-copper alloy is grainier and has a slightly different color.

Once again, the flux residue needs to be removed from the solder connection with an appropriate solvent.

The last consideration for hand soldering using lead-free alloys is when performing rework. Let's take a look at a typical component removal using a vacuum extractor. A general starting point is 355 degrees C – which is 40 degrees C higher than for tin-lead solder. This should be sufficient for most vacuum extraction operations involving lead-free solders.

We'll need to apply a small amount of flux onto the joints to be desoldered. There are a variety of different ways to apply flux. Remember that the purpose of this flux application is to speed up the heat transfer between the desoldering tip and the solder joint. Always make sure to follow your company's recommended procedures for flux application and cleaning.

Now, let's watch the removal operation using the vacuum extractor. The process is similar to through-hole rework using tin-lead solder. For more information on through-hole rework see IPC-DVD-41.

Lead-Free Solder Joint Evaluation

In this final section we'll be examining the attributes of a typical lead-free connection - for a through-hole component. We'll be comparing the lead-free joints with their tin-lead counterparts so you'll be aware of what to expect when evaluating the lead-free connections. We'll also be looking at some of the *variations* that may or may not be acceptable.

This is good example of a *preferred* or *target* through-hole tin-silver-copper solder joint. Notice how the solder *feathers* onto the land… and up onto the lead. The solder fillet is curved inward - or *concave.* The solder *covers* all of the land, and the lead. The *texture* is a little bit grainy. The outline of the lead is visible beneath the solder. The amount of solder here is just about perfect.

Here's one now - with a little bit less solder… You can see that there is still some graininess… and the coverage is even. The fillet is concave. This solder joint is perfectly acceptable - even though there is less solder in the connection.

Now here's another one – with *quite* a bit more solder. The important thing to notice is the *angle of contact* between the solder and the metal. Proper wetting is indicated by a solder contact angle of *less than 90 degrees* – which is a *square* or *right angle.* The *lower* the contact angle, the better the *wetting.*

As you can see, there is a *range* of acceptable solder joints. You *will* be expected to know an acceptable solder joint from a defective one – before you begin soldering with lead-free alloys.

Now let's look at some solder joints that are considerably *less* than *ideal*… This is a *cold* solder joint. Notice that the surface of the solder is even duller and grainier than a typical lead free joint. This is caused by insufficient heat.

This is a *disturbed joint.* You can see that the solder shows *stress lines*, similar to the foothills in a mountain range. *Movement* during the cooling process can cause this condition.

This is a *fractured joint.* The component lead may have been moved after the solder solidified. Clipping the lead too close to the solder can sometimes fracture the joint.

Here we have a *burned board.* This was caused by contact with a hot soldering iron. And these are some additional examples of thermal damage.

This is a *lifted land. Lifting* can be caused by pushing or pressing down with the hot iron. Failure to allow cooling between heat applications can also result in a lifted land. Lifting can also indicate that the iron was left on the board for too long, or that too high of a temperature was used.

This joint has *excessive solder.* The fillet is not concave, and there is solder flowing over the edge of the land. Too much solder was added to this joint and we can't be sure that proper wetting has occurred.

This condition is called *solder bridging.* A bridge is an *electrical path* that was not intended.

Here is a *solder projection,* also known as an *icicle,* or a *peak.* These are typically caused by excessive solder or insufficient flux, and by the iron being too cool or not being removed quickly enough.

These are *solder balls.* They can create electrical *shorts* - by lodging in between two circuits.

Here's an example of *non-wetting.*. The solder does not feather to a thin edge… and some of the base metal is partially exposed.

Another type of imperfection is the *blowhole.* These are usually caused by gas escaping through the solder as it solidifies. If there is any moisture or solvent inside the hole - or excess flux- this can create a *blowhole* as the gas expands and escapes.

Although some of these conditions are *always* unacceptable - many of these imperfections could be allowed - in various degrees - depending on what type of product they would be used in. For example, we'd all expect that *any* aircraft or medical electronics would be highly reliable… but we may be able to live with some minor *cosmetic imperfections* in a portable CD player - as long as the product works.

The IPC A-610 has three *classes* of requirements, based on the final use of the end product. Class 1 is for *consumer* products, Class 2 is for *business* and *computer* products, and Class 3 is for high reliability electronics - where failure is not an option. The *specification* and the *class* of requirements that your company uses to inspect solder joints will be clearly explained to you. Some companies build a wide range of products with different requirements. Other companies build only *one* class of product. Part of your job is to make sure to always apply the *right* criteria to each assembly.

The program has presented the essential information required to successfully use lead-free solder alloys in hand soldering operations. We discussed the reason for the switch to lead-free and the characteristics of the alloys. Then we presented the details of the soldering operation. And we concluded with how to evaluate a lead-free solder joint.

The more time you spend hand soldering with the lead-free alloys, the more confident you'll become about creating and evaluating reliable lead-free solder joints. And you'll be helping the environment too.