DVD-SMT-D
SMT Solder Joint Workmanship Standards

Below is a copy of the narration for the DVD-SMT-D video presentation. 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.

Copyright ©IPC – Association Connecting Electronics Industries. All Rights Reserved.

This DVD training program explains the important *workmanship standards* for evaluating surface mount solder joints. The contents are organized into four sections: an introduction – which is common to both Class 2 and 3 training; *dimensional criteria* – specific to Class 2 and Class 3 products; and *visual defect criteria* – common to both Class 2 and 3.

The focus on this training program is on solder joint evaluation using tin-lead solder. While the criteria covered is the same for lead free, there are important visual considerations between the two types. For a comparison and explanation of these differences, please see the training programs on Lead Free Surface Mount Assembly and Lead Free Surface Mount Rework.

This introduction will explain surface mount termination styles, industry specifications for solder joint acceptance standards, classes of products and solder joint terminology. Surface mount components are designed to be placed directly onto *lands* that serve as *connection points* on the surface of a printed circuit board. In this video, we'll be focusing on the three most popular surface mount termination styles – chip, J-lead and gull wing components. Let's briefly review each of these styles.

Chip components are typically ceramic-bodied packages with metal connections at either end – called *terminations*. These component types include resistors, capacitors and inductors. The J-Lead is a metal lead that bends down and underneath a component in the shape of the letter J. Examples of J-leaded components are Plastic Leaded Chip Carriers, or PLCCs; and Small Outline J-Leads, or SOL-Js. The *gull wing* component has a metal lead that bends down and away – similar in appearance to a seagull's wing. Examples of gull wing components are Quad Flat Packs, or QFPs; and Small Outline Integrated Circuits, or SOICs.

Two of the most widely used standards for determining solder joint acceptance are the IPC J-STD-001 – Requirements for Soldered Electrical and Electronic Assemblies – which establishes the minimum acceptability requirements. The IPC-A-610 – Acceptability of Electronic Assemblies – *illustrates* these requirements for many types of solder connections and assembly hardware. IPC has also developed a *Surface Mount Solder Joint Evaluation Training and*

Reference Guide to provide convenient reference data for solder technicians and inspectors. In addition, the same information is contained in a *digital* version called EWS-610. This program can be accessed over your company's computer network. Both of these training and reference products conform to the latest revision of the IPC-A-610. This DVD explains the solder joint acceptance requirements contained in IPC-DRM-SMT -- so it may be helpful to follow along in your DRM-SMT if you have a copy available. Any requirements not covered by the training and reference guide may also be found in the IPC-A-610 itself.

Let's start by describing an *acceptable* solder joint. We'll be specifying *minimum* and *maximum* dimensions for all the various sizes and shapes of the solder fillet. Solder joints that fall *outside* of these limits will be considered a *defect*. We'll be discussing what that means in a moment. We'll also be showing the *target*, or *ideal condition* for each type of solder joint. Although it's desirable to have nothing but perfect solder joints for every lead or termination, we all know that there are a multitude of factors that can affect the soldering process. For example, environmental conditions of the soldering area, or contamination of the solder or component leads can result in a less than perfect solder joint.

A solder joint that *barely* meets the minimum acceptance requirements for a stereo would *certainly* not be desirable for a life support system. That's why surface mount solder joint quality requirements are divided into *three classes* – depending on the end use, the life expectancy and the operating environment of the electronic assembly.

Class 1 refers to *general electronic products* – which covers consumer electronics such as televisions, stereos and video games. *Class 2* includes computers, telephone systems and other commercial equipment that falls into the category of *dedicated service* electronic products. The *Class 3* category is for *high performance* electronic products – equipment with high reliability applications such as military, aerospace and life support systems.

Your company may build only *one* class of products – or products within *all three* classes. It's important that you know which criteria to apply. The repercussions of applying class 1 workmanship requirements to class 3 products are obvious. However, applying class three criteria to class 1 products make the class 1 products much more expensive to manufacture. If you have any questions about the type of assemblies you're working with and evaluating, feel free to ask your supervisor or trainer.

Now, let's return to the subject of solder joints that fall *outside* the minimum and maximum dimensions. It's important to understand that you are not expected to *measure* every single dimension for every solder joint on the board. But *what should you do* when you see a solder joint that doesn't meet the minimum size requirements? Do you leave this defect alone or touch it up? In some cases, especially in class three products, the entire assembly could be rejected for one solder joint that doesn't meet the requirements of the specification. In cases like this, you may *have* to rework the solder joint.

For class 1 or 2 products the decision may not be so simple. If there is only one solder joint that is *slightly* less than the required minimum size, it's important to check with your supervisor or a quality assurance person to determine whether the assembly can be passed, or whether it needs to be reworked. This communication will also insure that the source of the problem is corrected.

On the other hand, when a class one or two assembly has a solder joint that is *way below* the acceptable limits – so much that the joint is clearly too small to hold up during the mechanical

stresses of day-to-day operation – you would need to make a decision to rework the solder joint. Again, the decision to rework a specific connection is different for every assembly – and every company. The dimensional requirements in the J-STD-001 provide you with information you need to help you make these important decisions. Your company's, or customer's requirements may be slightly more or less stringent than the J-Standard, and, of course, those workmanship standards will be the final criteria. But it is helpful to know what the industry standards are, to gain some perspective on the relative importance of each type of deviation. Your job is to know what the current requirements should be for every assembly you build.

Our last topic in this introductory section deals with *terminology*. Regardless of the soldering specification you use, there are standard terms used to describe the *attributes* of a solder joint. Perhaps the most important term in the entire soldering vocabulary is the concept of *wetting*. *Wetting* is defined as the formation of a relatively uniform, smooth, unbroken film of solder, metallurgically bonded to the basis metal.

Various degrees of wetting are characterized by the *angle of contact* between the solder and the basis metal. A smaller *contact angle*, between the two surfaces is a general indication of better wetting and a stronger bond. A *larger* contact angle indicates a decreased ability of the solder to wet and flow over the surface.

On any type of solder joint, the *target* contact angle is less than 90 degrees. A contact angle that *exceeds* 90 degrees usually indicates poor wetting, or excessive solder. If a solder joint has a *convex* appearance as a result of excessive solder, however, it can be difficult to tell whether the surface is properly or poorly wetted. Convex fillets caused by excess solder extending over the land can sometimes be an acceptable condition.

One attribute of a properly wetted joint is the presence of a smooth and uniform layer of solder, both on the surfaces of the lead (or termination), and on the surface of the land. The solder should also *feather out smoothly* onto the *fillet*, or *outline* of the solder joint, and be slightly *concave*, or curved *inward*.

One of the more easily detected conditions is *nonwetting*. *Nonwetting* is where the solder simply does not bond to the surface of either the land, the lead, or the termination. *Complete* nonwetting is an unacceptable condition for *any* class of solder joint.

*Dewetting***,** by contrast, is characterized by irregularly shaped mounds of solder that are formed when the solder *pulls back*—almost as if it had changed its mind about wetting. Dewetting is harder to identify, and may appear as a *partially-wetted* condition, since the surfaces can be wetted at some locations, while the basis metal is covered with only a relatively thin film of solder in other places. Various degrees of dewetting or nonwetting may be acceptable, depending on the nature and class of the final product.

Dimensional Criteria – Class 2

Now that you've been introduced to the concept of acceptance requirements, product classes and soldering terminology, let's examine the *dimensional criteria* for Class 2 surface mount solder joints. We'll start by reviewing the target condition, or the *ideal* surface mount solder joint for rectangular chip components, J-lead components and gull wing components. Notice how the solder *feathers smoothly* 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 smooth and shiny. The outline of the lead is visible beneath the solder. The amount of solder here is just about perfect.

The following examples show the *limits* of component misalignment and solder joint size for chip, J-lead and gull wing components. Solder joints that *do not* meet any of these minimum conditions are considered *defects*. In these examples, the termination or lead will be identified as dimension “W”, and the land will be identified as dimension “P”.

The first parameter we’ll look at is *side overhang*, or dimension “A”. Chip components may overhang the side of the land a maximum of 50% of the width of the component termination, or 50% of the width of the land, whichever is less. For example, if the width of the component termination is less than the width of the land, then we’ll have to use “half the width of the termination” as our maximum guide. J-leads and gull wings can also overhang the *side* of the land a maximum of one half the width of the lead, or 0.5 mm, whichever is less, for gull wings.

The next parameter we’ll examine is *end overhang*, or dimension “B”. This dimension is called *toe overhang* for J-lead and gull wing components. For chip components, *any* part of the termination extending beyond the land is *unacceptable*. That’s because you want maximum connection with the land. This dimension is not specified for J-lead connections. As long as the solder joint meets all of the other dimensional criteria, this condition would be acceptable. Any extension of the *toe* of a gull wing lead must not violate the *minimum electrical clearance* between any adjacent component or exposed circuit trace.

Now, let’s look at *end joint width*, or dimension “C”. The width of a chip component solder joint at its narrowest point must be a least half the width of the component termination, or 50% of the width of the land, whichever is less. The width of a J-Lead or gull wing solder joint at its narrowest point also needs to be at least 50% of the lead width.

Side joint length, or dimension “D”, only relates to J-lead and gull wing components. The side joint length of the J-lead solder joint at its narrowest point should be a minimum of one and one half times the width of the lead. Let’s look at gull wing side joint length. If there is a long foot length – meaning that “L” is equal to or greater than three lead widths, the side joint length should be a minimum of three lead widths, or 75% of the foot length, whichever is longer. If there is a short foot length – meaning that “L” is less than three lead widths, the minimum side joint length is 100% of the foot length.

Our next parameter is *fillet height*, which is specified by dimensions “E” and “F”. These dimensions are called *heel fillet height* for J-lead and gull wing components. For chip components, the solder may overhang the land and extend onto the top of the termination, but should never touch the component body. For dimension “F”, the minimum fillet height is not specified. Only a *properly wetted fillet* must be evident.

For J-leads, the solder should never extend up high enough to touch the body of the component. The heel fillet, or dimension “F”, should extend a minimum of half the thickness of the component lead – also referred to as dimension “T”. For gull wings, the fillet height may extend to the top bend of the lead, or knee, but should *not* touch the component body or *end seal* as a maximum fillet height. As an exception to this rule, solder may touch the body of plastic SOIC or SOT components. For dimension “F”, the minimum heel fillet height should be at least as high as 50% of the component lead thickness at the toe.

Our final parameter is *end overlap*, or dimension “J”, which refers *only* to chip components. *Some amount* of overlap between the component termination and the land is required for minimum

acceptance. This means that *any* amount of overlap would be considered acceptable for a chip component solder joint.

Dimensional Criteria – Class 3

Now that you've been introduced to the concept of acceptance requirements, product classes and soldering terminology, let's examine the dimensional criteria for Class 3 surface mount solder joints. We'll start by reviewing the *target condition*, or the *ideal* surface mount solder joint for rectangular chip components, J-lead components and gull wing components. Notice how the solder *feathers smoothly* 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 smooth and shiny. The outline of the lead is visible beneath the solder. The amount of solder here is just about perfect.

The following examples show the *limits* of component misalignment and solder joint size for chip, J-lead and gull wing components. Solder joints that *do not* meet any of these minimum conditions should not be considered acceptable. In these examples, the termination or lead will be identified as dimension "W", and the land identified as dimension "P".

The first parameter we'll look at is *side overhang*, or dimension "A". Chip components may overhang the side of the land a maximum of one quarter of the width of the component termination, or 25% of the width of the land, whichever is less. For example, if the width of the component termination is less than the width of the land, then we'll have to use "one quarter the width of the termination" as our maximum guide. J-leads and gull wings can also overhang the *side* of the land a maximum of one quarter of the width of the lead, or 0.5 mm, whichever is less, for gull wings.

The next parameter we'll examine is *end overhang*, or dimension "B". This dimension is called *toe overhang* for J-lead and gull wing components. For chip components, *any* part of the termination extending beyond the land is *unacceptable*. That's because you want the maximum connection with the land. This dimension is not specified for J-lead connections. As long as the solder joint meets all of the other dimensional criteria, this condition would be acceptable. Any extension of the *tip* of a gull wing lead must not violate the *minimum electrical clearance* between any adjacent component lead or exposed circuit trace.

Now, let's look at *end joint width*, or dimension "C". The width of a chip component solder joint at its *narrowest* point must be a least three quarters of the width of the component termination, or 75% of the width of the land, whichever is less. The width of a J-Lead or gull wing solder joint at its narrowest point also needs to be at least 75% of the lead width.

Side joint length, or dimension "D", only relates to J-lead and gull wing components. The *side joint length* of the J-lead solder joint at its *narrowest* point should be a minimum of one and one half times the width of the lead. Let's look at gull wing side joint length. If there is a long foot length – meaning that "L" is equal to or greater than three lead widths, the side joint length should be a minimum of three lead widths, or 75% of the foot length, whichever is longer. If there is a short foot length – meaning that "L" is less than three lead widths, the minimum side joint length is 100% of the foot length.

Our next parameter is *fillet height*, which is specified by dimensions "E" and "F". These dimensions are called *heel fillet height* for J-lead and gull wing components. For chip components, the solder *may* overhang the land and extend onto the top of the termination, but should never touch the component body. For dimension "F", the minimum fillet height should

extend at least 25% of the height of the component termination, or 0.5 millimeters – whichever is less.

For J-leads, the solder should never extend up high enough to touch the body of the component. For dimension "F", the minimum heel fillet height should be at *least* as high as the component lead thickness. For gull wings, the fillet height may extend up to the top bend of the lead, or knee, but should *not* touch the component body or *end seal* as a maximum fillet height. As an exception to this rule, solder may touch the body of plastic SOIC or SOT components. For dimension "F", the minimum heel fillet height should be at least as high as 100% of the component lead thickness at the toe.

Our final parameter is *end* overlap, or dimension "J", and refers *only* to chip components. *Some amount* of overlap between the component termination and the land is required for minimum acceptance. This means that *any* amount of overlap would be considered acceptable for a chip component solder joint.

Visual Defect Criteria

This final section describes the most common solder joint *defects* and *process indicators* for chip, J-lead and gull wing components used in class 2 and 3 products. Before we start, let's discuss *process indicators*. Sometimes a solder joint will meet the minimum acceptance criteria - although it may exhibit certain *cosmetic imperfections* that are *not detrimental* to the reliability of the solder joint. These types of conditions fall into a category called "Process Indicators". The idea here is that the *process* that created these cosmetic imperfections should be changed - rather than the cosmetic imperfection. This makes a lot of sense... because when you fix the process, the incidence of imperfections will be reduced or eliminated.

Now, let's examine the *defect criteria* for surface mount solder joints. This is what *insufficient solder* looks like for our three components. You can see that the solder fails to meet minimum fillet heights from our *dimensional criteria* – and there is no evidence of a properly wetted fillet.

When the solder extends *onto* the body of a surface mount component – this is considered *excessive solder*. Excessive solder is a defect for *either* class of component. As an exception to this rule, solder may touch the body of plastic SOIC or SOT components.

Now, let's look at *nonwetting*. Notice that the solder has not adhered to either the termination or the land. Nonwetting is a *defect* for all types of surface mount connections. *Dewetting* occurs when molten solder coats the surface, then pulls back, leaving only a thin film of solder covering the land in some areas, and irregular mounds of solder in others.

A *disturbed solder joint* is characterized by a gray, porous appearance with *stress lines* from movement of the solder while solidifying. This is what a *fractured or cracked* solder joint looks like on our three types of components. A cracked solder joint will not allow the electronic signal to flow. That's why this condition is a defect.

Tombstoning is a defect that's specific to chip components. Notice how one end of the component termination is completely lifted off the land. Tombstoning also interrupts the electronic signal and needs to be fixed. On the other hand, *coplanarity* is specific to J-leads and gull wings. This defect occurs when one lead - or a series of leads - is out of alignment and fails to make contact with the land. If there is no electrical contact, this condition will need to be repaired or reworked.

A *void* is an open area caused by air trapped within the solder joint. This is an allowable condition as long as solder joint dimensional requirements are met. Voids are an example of a process indicator. *Pinholes* and *blowholes* are also process indicators. Blowholes are larger than pinholes, and are created when heated gas escapes from inside the solder joint.

Solder webbing is a defect that occurs when a film or splash of solder covers any area of the assembly that should be free of solder. *Solder bridging* is a connection of solder across conductors that should *not* be electrically joined together. Bridging is always a defect – since it misdirects the electronic signal.

Incomplete reflow occurs when insufficient heat is applied to the assembly during the soldering operation. This means the solder paste may not have properly wetted the surfaces to be soldered -- and will not form an acceptable electrical and mechanical connection.

Any *balls of solder* that are not entrapped within a permanent coating, or attached to a metal contact, or violate minimum electrical clearance requirements are also considered defective.

Mounting adhesive that causes the formation of an incomplete solder fillet is considered a defect when it reduces the fillet to less than 50% of the width of the lead. Any adhesive material in the termination area is considered a process indicator for class 2 and a defect for class 3. Adhesive causing less than minimum end joint width is considered a defect for both classes.

Solder fines are small balls of solder paste that have splattered around the connection during the solder reflow process. This condition is considered a defect when the solder is not *encapsulated*, or attached to a metal surface – or the solder fines violate minimum electrical clearance.

Any significant cracks or stress fractures in the component *body* are also considered a defect – as well as any nick or *chip-out* that exposes the electrodes or resistive elements. Again, that's because the electronic signal will be interrupted.

This program has explained the workmanship standards for evaluating critical acceptance criteria for the most common surface mount solder joints. Solder joint evaluation is a very important job in electronics assembly. When the criteria are not properly understood, the results are unnecessary touch up and rework – *and* unreliable products. Your careful attention can make a big difference in the production of high quality electronic assemblies.