SPECIFICATION GUIDELINES

FOR

HOT AIR SOLDER LEVELING

REV 5A

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Issue Date: 06/04/97

1.0 PURPOSE

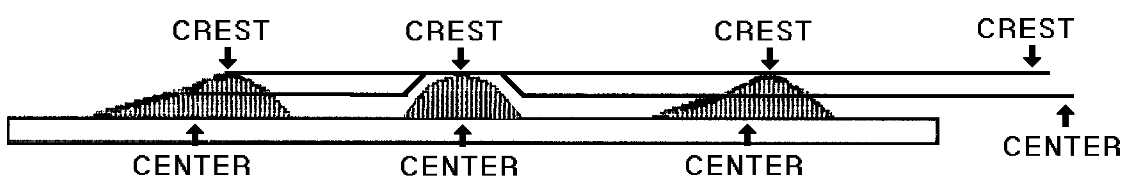
To define solder leveling capabilities and meaningful solder thickness measurement techniques. This document will establish achievable solder thickness requirements that can be used for specifying and standardizing solder thickness on printed wiring boards (PWBs). This document is intended to provide a common set of terms, definitions and measurement techniques for PWB manufacturing and "End User" or OEM customer. All information, requirements, and techniques given in this document are based on the results of extensive testing and production being processed through the component assembly process unless otherwise indicated.

2.0 GENERAL

Hot air leveling applies a coating of eutectic solder (Sn63) on copper surfaces of the printed wiring board. Solder protects the PWB from contamination and provides a uniform solderable surface with extended shelf life ready for component assembly. Other coatings may be more uniform (flatter); however, that does not guarantee solderability. Eutectic solder, as applied with HASL, is the most universally preferred coating. It provides the longest shelf life, preferred solderability, and shortest solder wetting times at assembly.

3.0 DEFINITIONS

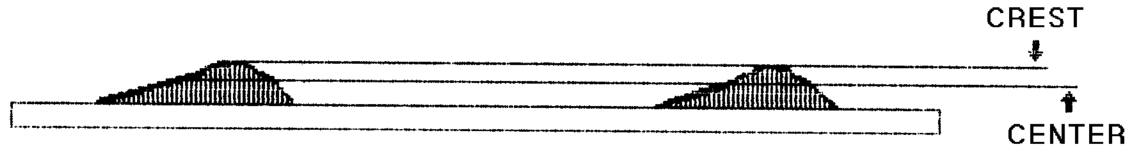
3.1 <u>CENTER:</u> Middle of a feature (PAD). Some geometries will have crests at the center; some may not. (See definition of CREST).



3.2 <u>COPLANARITY:</u> Levelness from PAD to PAD over entire board, or within certain feature size groups. This data is particularly helpful in determining thickness variations by feature, used in determining solder paste dispensing volumes for component placement.

- Measure crests of all features being evaluated as one data group.
- Measure the centers of all features being evaluated as a second data group.

- DO NOT mix data groups.
- The two data groups represent two (2) planes, centers and crests (reference diagrams below).



3.3 CREST: Highest point for a given feature (PAD). Since the process is geometrically dependent, smaller features on a given panel will tend to have a crest at the center of the feature. Larger features will tend to have the crest off-center as shown in Paragraph 3.1 (CENTER). This is due to normal surface tension and wet-back characteristics of the copper and solder.

3.4 DATA: The collection of X-Ray Florescence (XRF) measurements.

3.5 DATA GROUP: Data collected to show thickness range within a single feature size or different feature sizes at given measurement locations. A minimum of 24 points per group is recommended for statistically meaningful data. When doing CPK* or CP* evaluations, a minimum of 50 points per group is recommended.

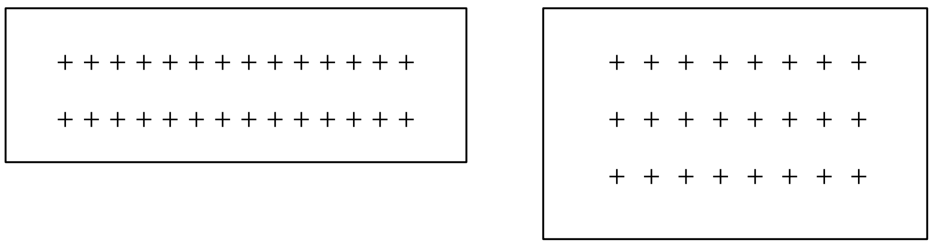
* Note: CP is the Process Capability Index.

CPK is the Process Capability Index which evaluated the systematic error.

3.6 DISTRIBUTION: Levelness within ONE PAD.

- To determine the range of solder thickness over a feature (PAD). A minimum of five (5) points should be measured over the feature. Measurement area typically excludes the edge of the pad. See Paragraph 7.0 for measurement techniques.
- The number of data points required will usually be determined by the end user; however, a minimum of 24 data points per pad is recommended.

+ = MEASUREMENT POINT



3.7 IMC: Intermetallic Compound.

- IMC formation is the key to soldering. It is a local alloying between the boundary of the solder liquidus and the surfaces of the basis metals to which it is in contact, which is the essence of soldering. Without intermetallic formation, there is no solder joint formation. Some processes, such as laser soldering, require only a very thin layer of IMC; however, IMC is required. High temperature and intimate contact of the liquid solder enhance the rate and area of IMC formation.
- Although IMC is required for the formation of the solder joint, the IMC layer itself is not a wettable surface. That is why there must be sufficient additional eutectic solder thickness to guarantee solderability at assembly.

  Examples:

  1. For a solder thickness of 100 microinches (2.5 microns) with 80 microinches (2.0 microns) of IMC, solderability or shelf life problems are likely.

2. For a solder thickness of 100 microinches (2.5 microns) with 6.0 to 12.0 microinches (0.152 to 0.3 microns) of IMC, solderability shall remain excellent during storage.

3.8 MEAN: Average thickness for a given number of thickness readings.

3.9 PROCESS WINDOW: The range between the lower control limit (LCL) and the upper control limit (UCL).

- Some processes require a ±3 sigma distribution on critical features:

MEAN ± [3 x Standard Deviation] = Capable Process Window (Range)

The capable process window, or ±3 sigma distribution must fall within the specification limits (LCL, UCL).

3.10 UNIFORMITY: Levelness from PAD to PAD within a single feature size or other specified data group.

- Measure one (1) geometry (feature size) only.

Examples:

1. Specification calls out an Upper Control Limit (UCL) and Lower Control Limit (LCL) on 25 mil (0.64 mm) pitch QFP sites with a specified CPK.

Measure only 25 mil (0.64 mm) pitch quad flat packs (QFPs).
DO NOT mix data groups.
25 mil (0.64 mm) pitch features = one data group
50 mil (1.28 mm) pitch features = one data group

2. Specification calls out 100 microinches (2.5 microns) LCL and 1000 microinches (25.0 microns) UCL (CPK is not specified).
Measure all features.

Data group in this case includes multiple feature sizes

- If only one (1) geometry (feature size) is measured, it should be the most critical feature (reference Paragraph 6.0).

3.11 Surface Mount Features

QFP = Quad Flat Pack, 4-sided, rectangular pad pattern.

PLCC = Plastic Leaded Chip Carrier, 2-sided rectangular pad pattern.

BGA = Ball Grid Array, circular dot pattern arrays in a square or rectangular grid.

Chip = Small to large, square or rectangular, normally in pairs.

3.12 WET-BACK: The distance solder flows back over a copper feature after exiting the air knife.

4.0 PROCESS VARIABLES

4.1 COPPER SURFACE: The copper surface must be clean and free of organic contaminants and oxidation that restrict solder distribution within a feature or prevent solder from adhering to the copper. Other metal surfaces to be soldered have the same requirements; however, they are not covered in this document.

4.2 FEATURE GEOMETRY: The geometry of a feature will affect the thickness results at a given leveling machine set-up. Large features tend to be thinner than small features on the same side of the panel. This is due to surface tensions of the copper and solder and the distance of the solder to wet-back on a given feature.

5.0 GROUPING DATA

The most meaningful thickness verification data is obtained when it is properly grouped, usually by geometry and measurement location.

5.1 Properly grouping data is a useful inspection tool when used to establish or verify process compliance with customer specifications. This should be evaluated at the time operators run the first piece after adjusting the leveling equipment.

5.2 Other methods of grouping data can be meaningful tools for gathering information. It is important that the purpose of these are clearly understood and used properly. This is a geometric-dependent process. Mixed data groups, when measured, will indicate a larger range which should not be confused with process capability.

6.0 MOST CRITICAL FEATURE [Surface Mount Device (SMD)]

The most critical feature, usually defined by the end user, represents the feature with the tightest solder thickness requirement. Typically the most critical feature is the finest pitch or smallest SMD feature on the panel and has a tight tolerance for solder thickness at assembly.

6.1 The most critical feature will be utilized for establishing the controls for solder thickness and uniformity as described in Paragraph 8.2.

6.2 Remaining features may be thinner or thicker depending on panel geometry, feature size, and orientation on panel.

6.3 Satisfactory assembly results are achieved with these thickness variations and thinner solder deposits on large chip sites

7.0 MEASUREMENT OF SOLDER THICKNESS

7.1 Measurements are typically taken using X-Ray Fluorescent equipment (XRF).

7.2 There are many XRF equipment manufacturers and each has its specific features that are unique. Discussed here are general requirements. Examples given in later paragraphs are based on the Seiko XRF Model STX 3000.

- Best results are typically achieved using a collimator diameter (or width) less than half the pad diameter (or width). If a collimator that is too large for a feature is used, then the measurement area can extend beyond the edge of the feature. PCB base material (FR-4) typically has bromine in it as a fire retardant. The bromine can affect the accuracy of the readings since it is very close to the spectrum of lead.
- Measurement point should be located .010" (0.25 mm) or greater from the edge of a soldered pad.
- Measurement time varies with the equipment manufacturer and calibration thickness range.
- The accuracy of measurement results is recommended to be verified against more conventional methods such as cross-sectioning.
- Measurements taken outside of the calibration range (curve) will not be accurate. Separate calibrations will be required for thickness readings outside the standard calibration range.

  Example:

  > For a calibration curve with a recommended measurement range of 70 to 900 microinches (1.8 to 23.0 microns).
  >
  > Measurements for a panel with a specification of 80 to 700 microinches (2.0 to 17.5 microns) would be accurate.

Measurements for a panel with a specification of 100 to 1500 microinches (2.5 to 37.5 microns) would require a different calibration curve if measurements fall outside the recommended range of 80 to 700 microinches (2.0 to 17.5 microns).

7.3 Panel orientation is important, especially for fine pitch QFP features. Many XRF units are capable of measuring small features in only one direction.

- When measuring small features [example: .020” (0.51 mm) pitch and finer], compare East/West measurements with North/South measurements. Rotate the panel 90° and repeat measurements. Monitor for differences in the result. If a large difference is detected, the measurements should be verified by cross section. Then adjust your measurement techniques based on the cross section results.

7.4 Choosing the correct collimator size is important, especially on small features (reference paragraph 7.2).

Alignment accuracy of machine and operator experience must be considered. The feature must be focused properly in the Z axis to assure accuracy.

Typical collimators used:

FEATURE SIZE		**COLLIMATOR**	
0.025” or greater	(0.64 mm)	0.008” circular	(0.20 mm)
0.015” - 0.025”	(0.38 mm - 0.64 mm)	0.004” circular	(0.10 mm)
0.005” - 0.015” x 0.036”	(0.13 mm - 0.38 mm x 0.91 mm)	0.001”x 0.016” rectangular	(0.02 mm x 0.41 mm)

7.5 Many XRF models calculate the suggested times for measurement accuracy. Typical times will range between 10 to 30 seconds. Inadequate measurement times will result in inaccurate readings.

As a rule, the smaller the collimator, the longer the measurement time. Factors used to determine measurement times include:

- thickness range
- calibration
- collimator size

8.0 THICKNESS CAPABILITY SPECIFICATION

Properly identifying the criteria for establishing appropriate data groups and measuring techniques will allow a capable process window to be defined.

8.1 Typical Specifications

- 80 to 800 microinches (2.0 to 20.0 microns) for QFP sites with a ±3 sigma capability on the finest pitch, down to 20 mil pitch (0.5 mm). This type specification is meaningful where component placement is critical within a feature size. Variations from pad to pad are limited within a component location.

  Example:

  Two adjacent tabs could measure 80 microinches (2.0 microns) and 800 microinches (20.0 microns). This will result in a standard deviation that is too high and will not meet the specification.

  A 3 sigma capability within this range provides a level of assurance against skewing of components at assembly.

- 100 to 1000 microinches (2.5 to 25.0 microns).

  This type of specification is meaningful where panel coplanarity is of most importance. It is most beneficial for panels with larger features or when combined with other requirements.

  Example:

  > Two adjacent pads could measure 100 and 1000 microinches (2.5 and 25.0 micron). There is no requirement in this specification for maximum variation; therefore, this would meet the specification.

Some specifications ensure feature uniformity with a requirement of a maximum variation between adjacent pads.

Example:

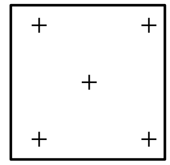
> Maximum variation between any two (2) adjacent pads shall be 100 microinches (2.5 micron).

Now the panel with adjacent pads measuring 100 microinches (2.5 microns) and 1000 microinches (25.0 microns) would not be acceptable.

This type of specification can also create confusion for large features. It is known that large features will be thinner than smaller features. Although the crest of a large feature should meet the 100 microinch (2.5 micron) requirement, there will likely be some measurement locations within a large feature that will measure below the specification LCL.

Example:

For a pad that is .100” x .100” (2.5 mm x 2.5 mm), if five (5) measurements are taken in a dice pattern,



one (1) or more measurements are likely to be under 100 microinches (2.5 micron).

Some specifications ensure solderability by requiring a certain number of readings over the minimum or measurement at a certain location on the pad to be within the specification.

Example:

Chip features over .060” x .060” (1.5 mm x 1.5 mm) may require three (3) of five (5) measurements within the specification when measured in the dice pattern.

8.2 Capability of the Unicote® Models 175, 350, and 375

- QFP capable Process Windows at Crest

On 20 mil pitch (0.5 mm) or greater, a range of 80 to 800 microinches (2.0 to 20.0 microns) with a ±3 sigma deviation and a mean between 250 and 500 microinches (6.25 and 12.5 microns) is typical.

On less than 20 mil pitch (0.5 mm), a range of 100 to 1000 microinches (2.5 to 25.0 microns) with a ±3 sigma deviation and a mean between 400 and 600 microinches (10.0 and 15.0 microns) is typical.

On less than 20 mil pitch (0.5 mm), a range of 200 to 1500 microinches (5.0 to 37.5 microns) with a ±3 sigma deviation and a mean between 500 and 800 microinches (12.5 and 20.0 microns) is achievable.

See comments at Paragraph 10.1 for ultra fine pitch QFP qualifications. Some pitch assembly practices require mean thickness only to guarantee solder volume.

- BGA capable process window

  On BGA sites, measured at the center, 80 to 800 microinches (2.0 to 20.0 microns) with a mean between 200 and 400 microinches (5.0 and 10.0 microns) is achievable.

- CHIP site capable process window

  When QFPs or BGAs are not the prominent or most critical feature on a panel, the chip site thickness can be dominate.

  On small chip sites .060” x .060” (1.5 mm x 1.5 mm) or less, a mean thickness at crests between 100 and 600 microinches (2.5 and 15.0 microns) is typical. A minimum of three (3) out of five (5) measurements should fall within the specification limits when measured in the dice pattern.

  Average minimum thickness at centers for HSL-350 without the Mark III upgrade is 30 microinches (0.75 microns). Average minimum thickness at centers for HSL-175, HSL-350 with Mark III, or WSL-375 is 70 to 100 microinches (1.75 to 2.5 microns).

  On large chip sites greater than .060” x .060” (1.5 mm x 1.5 mm), a mean thickness at crests between 100 and 600 microinches (2.5 and 15.0 microns) is typical. The crest should always fall within the specification limits.

- Plated Through Hole (PTH) capable process window.

For PTHs on panels less than .125” (3.1 mm) thick and with hole aspect ratios less than 8 to 1, a .001” to .002” (0.025 mm to 0.051 mm) hole size reduction from copper diameter is typical, with a maximum hole size reduction from copper of .003” (0.07 mm).

Panels over .125” (3.1 mm) thick may need special process and capability evaluations for hole reduction depending on the thermal properties and hole aspect ratios of the panel.

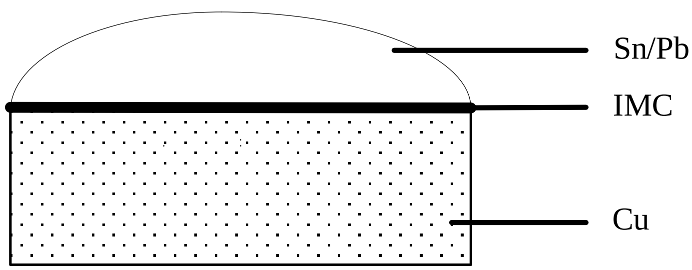
On the annular rings a mean thickness at crest between 100 and 600 microinches (2.5 and 15.0 microns) is typical. A minimum 300 microinches (7.5 micron) at crest is achievable on PTHs with lands (annular rings) of .002” (0.05 mm) minimum and .020” (0.5 mm) maximum.

Larger or smaller annular rings may be limited by other features on the panel. These annular rings will require special analysis.

9.0 INTERMETALLIC COMPOUNDS

Intermetallic compounds (IMC) thickness can be minimized depending on process parameters used. Typical tin/copper IMC thickness is 6.0 to 12.0 microinches (0.152 micron to 0.30 micron) average on a Unicote® horizontal leveler. Other hot air leveling processes can exceed 100 microinches (2.5 micron) of IMC. Organic coatings provide no IMC bond prior to assembly.

<u>IMC FORMATION FOR SOLDER (Sn63) OVER COPPER</u>



	Tin / Lead (Sn63)	
	Tin / Lead (+Pb)	
	Copper / Tin (Cu^3Sn)	
	Copper / Tin (Cu^6Sn^5)	
	Copper Cu	

10.0 ULTRA FINE PITCH FEATURES

Ultra fine pitch features are more critical to process and measure. To achieve the best uniformity, a consistent pad width is required. Thick solder deposits may result in “tear dropping” or high standard deviations if line width is substandard. Line widths under 6 mils (0.15 mm) may result in individual and mean solder thickness deposits of less than 400 microinches (10.0 microns). Typical thickness requirements on ultra fine pitch features is either 400 or 800 microinches (10.0 or 20.0 microns) minimum. At the location of a line width under 6 mils (0.15 mm), heavier solder deposits may result. The inconsistency can result in solder thickness measurements less than 400 microinches (10.0 microns). This is a problem for many ultra fine pitch applications.

Test results on the Model 175 indicate the following:

- Capability:

  For line widths of 6 mils (0.15 mm) with spacing of 4 mils (0.1 mm), 400 to 800 microinches (10.0 to 20.0 micron) average minimum thickness deposits are achievable.

- Cautions:
  - Uniform, 6 mil (0.15 mm) minimum line widths are required to achieve consistent results.
  - All 15 mil pitch (0.4 mm) and under must be run precisely at a 45° angle.
  - XRF alignment must be accurately calibrated. Proper collimator sizes must be utilized.
  - Accuracy verification by cross sections is recommended.
  - Machine set-up must comply with manufacturer instructions for consistent, optimum results.

These are general capabilities and can be tailored to meet your needs. Please contact Sherry Goodell at Teledyne Electronic Technologies, Halco (USA) for further information or assistance.

Rev 5A incorporates metric conversion corrections