ELEC 6740: Electronics Manufacturing Chapter 14: Quality Control, Inspection, Repair & Testing

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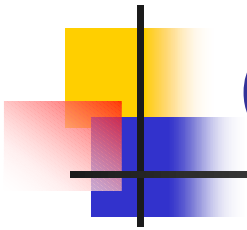
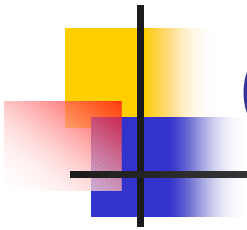


Outline

- Statistical Process Control
- Defects
- Quality Requirements
- Inspection
- Repair
- Test

Statistical Process Control: Goals

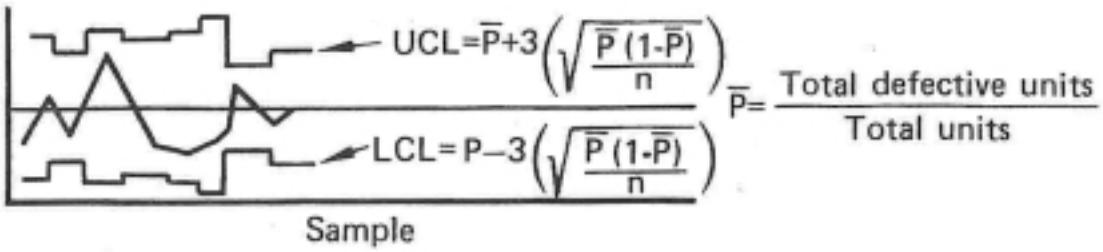


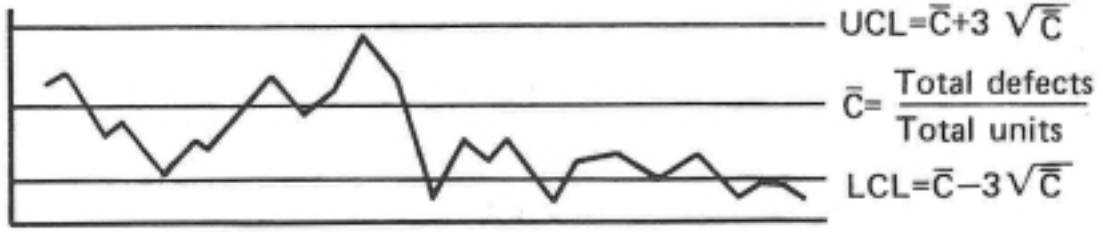
- Reduce defects by one or two orders of magnitude
- Shorten manufacturing times by a factor of 10
- Cut inventories by a factor of 2
- Cut floor space by a factor of 2
- Cut labor required on a specific job by a factor of 2

Statistical Process Control

- Process analysis to understand the system
- Inductive reasoning to measure the system
- Leadership to change the system

Statistical Process Control Charts





$$T=\frac{(\bar{X}_2-\bar{X}_1)-0}{\sqrt{S_1^2/n_1+S_2^2/n_2}}$$

Figure 14.1 Examples of common SQC analysis tools: P charts (top) showing fraction defective plot (n = sample size) and C charts (bottom) showing defects per unit plot.

Statistical Process Control

P Chart (Out of Control) Wave Soldering

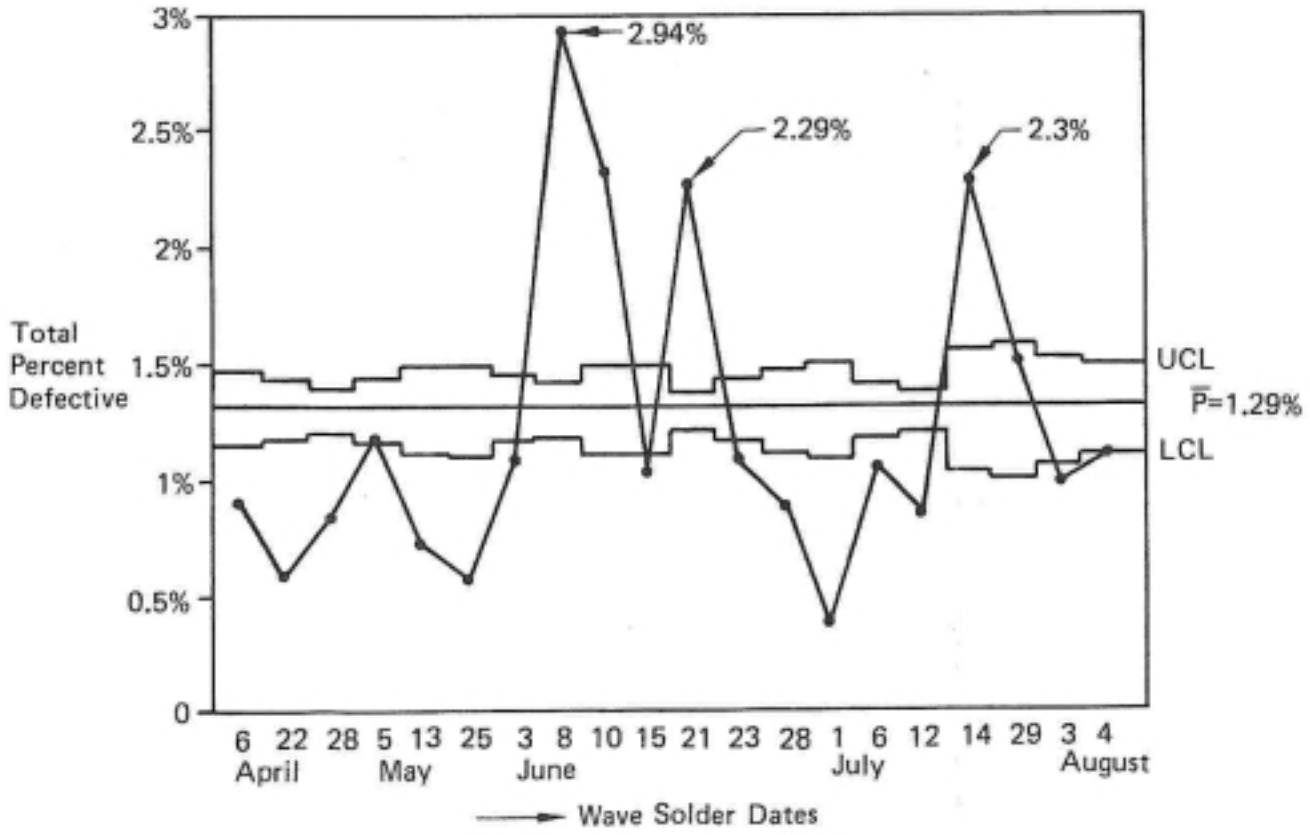


Figure 14.2 Control charts for Program A: April to August, 1983 [5].

Long Leads

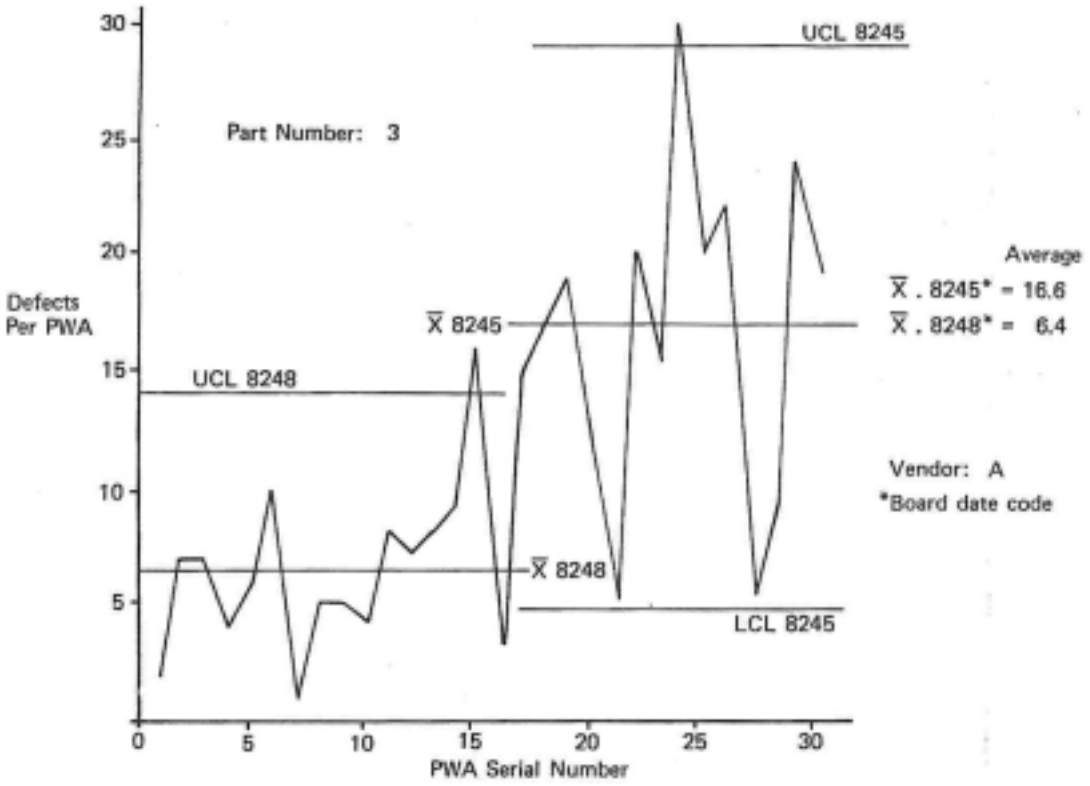


Figure 14.4 Defect versus board serial number for PWAs with 0.3 inch lead extension [5].

Short Leads

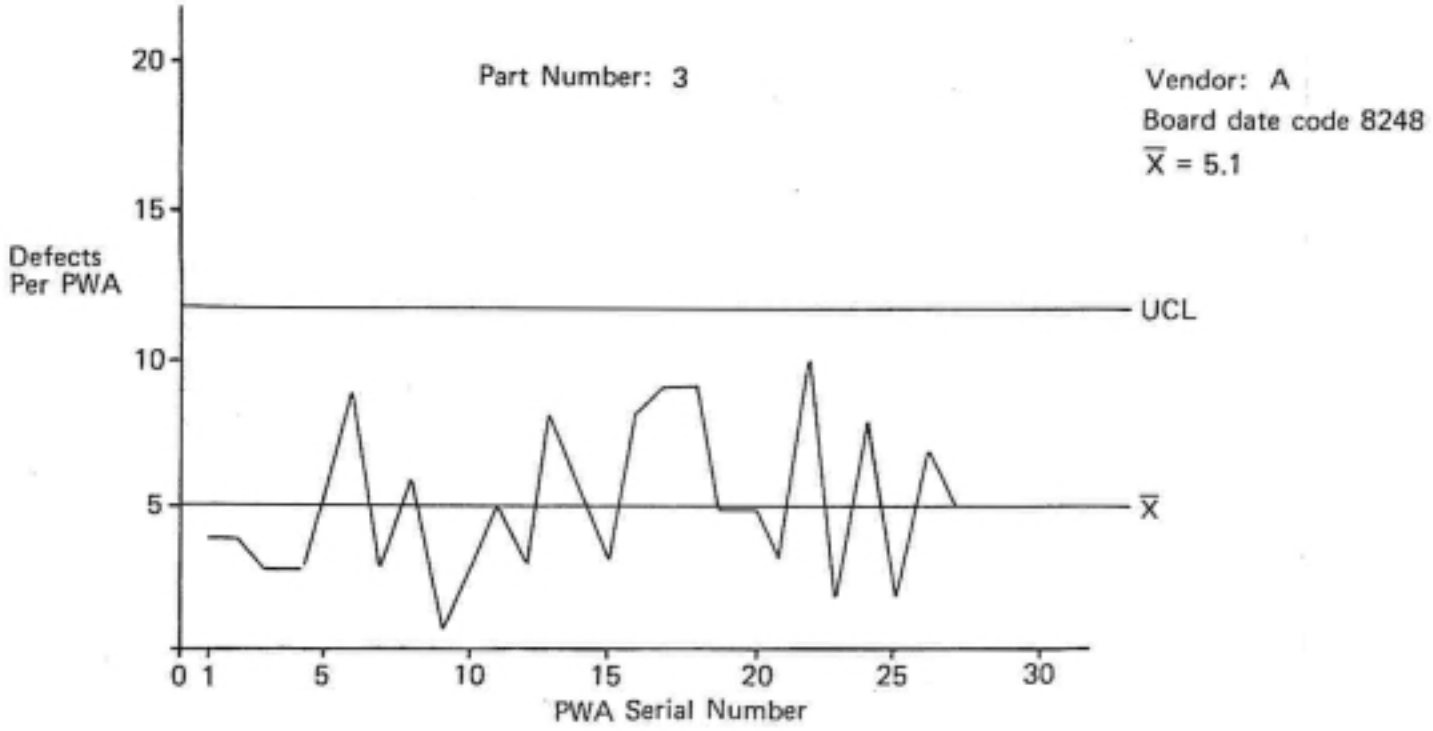


Figure 14.5 Defect versus serial number for PWAs with 0.1 inch lead extension [5].

Substrate Related Defects

1. Uniformity & thickness of solder on pads
2. Solderability
3. Trace width and spaces
4. Finished via hole sizes
5. Selective gold plating, if used
6. Type & quality of the solder mask
7. Warpage (<0.5%)
8. Twist

Component Related Defects

1. Nickel underplating of passive
2. Solderability
3. Component markings
4. Coplanarity

$$thermal\ shock\ parameter = \frac{K\sigma}{\alpha E}$$

Component Related Defects

1. Cracking of ceramic capacitors
   - Heating ramp rate

$$thermal\ shock\ parameter = \frac{K\sigma}{\alpha E}$$

K = thermal conductivity of material
σ= tensile strength
α= coefficient of thermal expansion (CTE)
E = effective modulus of elasticity

Adhesive Related Defects

- Stringing characteristics
- Viscosity
- Dispensing characteristics
- Volume
- Voiding
  - Flux entrapment and corrosion

Defects Related to Solder Paste

1. Solder balls
2. Paste viscosity and slump
3. Clogging

Process Related Defects

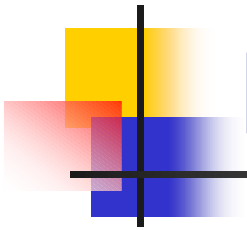
1. Solder opens
2. Solder bridges
3. Solder wicking
4. Tombstoning
5. Misalignment
6. Part movement
7. Solder balls

Design Related Defects

1. Poor land design
2. Incorrect component orientation
3. Inadequate component spacing

Solder Joint Quality Requirements

- Procurement as agreed upon between customer & vendor
- Master drawing or master assembly drawing reflecting the customer's detailed requirements
- J-STD-001 and/or IPC-A-610 when specified
- Other documents as specified by customer



Requirements

- Class I: Consumer (radio, TV, games)
- Class II: Commercial (computer, business)
- Class III: High reliability, critical mission

Requirements

Table 14.1 Solder joint requirements for rectangular chip components [11, 12]

DIMENSION	REQUIREMENT
Side overhang (dimension A)	• Target condition: No side overhang • Acceptable condition: 1/2P or 1/2W or 1.5 mm, whichever is less (1/4 for Class III)
End overhang (dimension B)	• No overhang permitted
End Joint Width (dimension C)	• Target condition: Same as P or W • Acceptable condition: 1/2P or 1/2W, whichever is less (3/4 for Class III)
Side joint width (dimension D)	• Target condition: Equal to termination length T • Acceptable condition: Not required as long as some termination is on pad (dim J)
Maximum fillet height (dimension E)	• Not specified as long as solder does not get on component body
Minimum fillet height (dimension F)	• 1/4H (termination height) or 0.5 mm, whichever is less (roughly 15 to 30 mil high)
Minimum solder thickness (dimension G)	• Wetted joint (for Class III 0.2mm or less if good cleaning can be demonstrated)
Minimum end overlap (dimension J)	• Dimension J applies only to rectangular and cylindrical components. There is no specific requirement as long as the component is long enough to bridge the gap between the leads (reasonable)

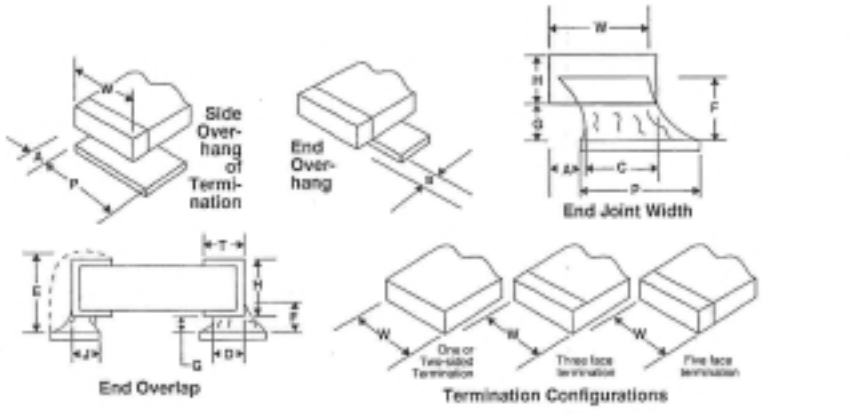
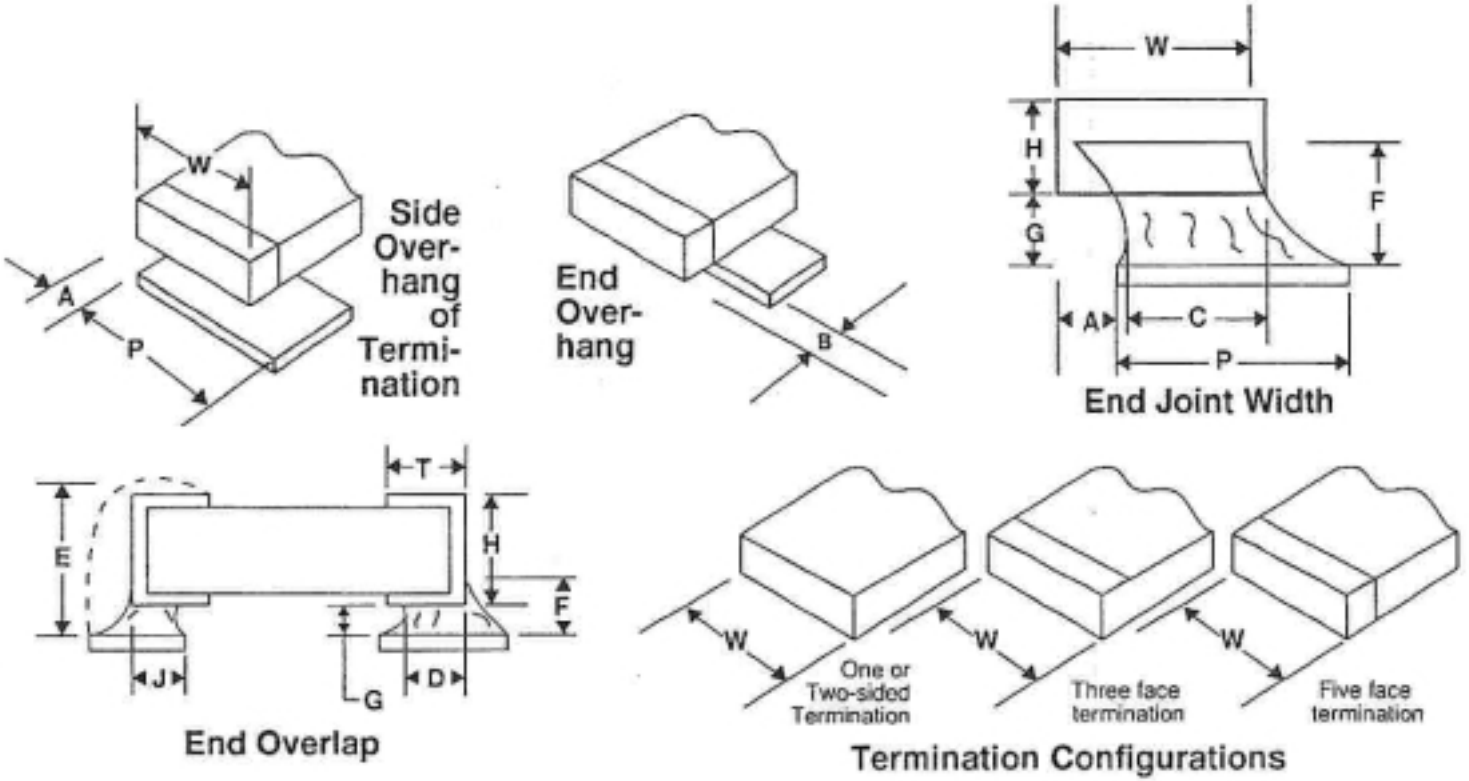


Figure 14.6 Joint illustrations for rectangular chip components [11].

Requirements



W = Width of Termination Area • T = Length of Termination • H = Height of Termination • P = Width of Land

Figure 14.6 Joint illustrations for rectangular chip components [11].

Requirements

Table 14.2 Solder joint requirements for cylindrical (MELF) components [11, 12]

DIMENSION	REQUIREMENTS
Side overhang (dimension A)	• Target condition: No side overhang • Acceptable condition: 25% W (compare this to 50% for rectangular chip components. Reason: Bonding area decreases rapidly for cylindrical comp)
End overhang (dimension B)	• End overhang not allowed for any class
End joint width (dimension C)	• Target condition: Greater than or equal to W • Acceptable condition: 1/2W
Side joint width (dimension D)	• Target condition: Equal to termination length T • Acceptable condition: D=50%T or termination plating length (75% for class III)
Maximum fillet height (dimension E)	• Not specified as long as solder does not get on component body
Minimum fillet height (dimension F)	• Properly wetted fillet (G+ 1/4W for class III)
Minimum solder thickness (dimension G)	• Wetted joint
Minimum end overlap (dimension J)	• For dimension J, there is no specific requirement as long as the component is long enough to bridge the gap between the lands (same as in rectangular components)

Requirements

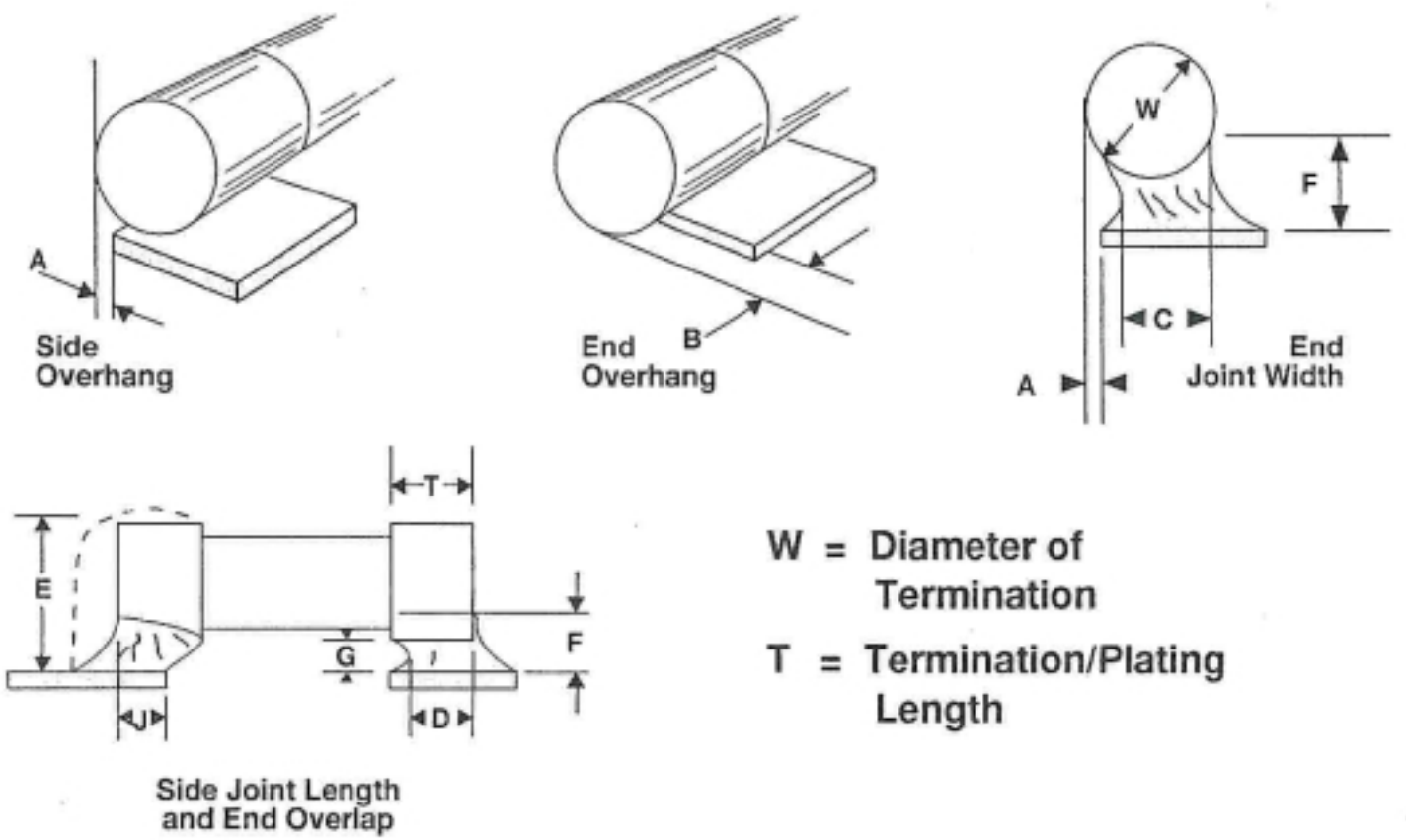


Figure 14.7 Joint illustrations for cylindrical (MELF) components [11].

Requirements

Table 14.3 Solder joint requirements for gull wing components [11, 12]

DIMENSION	REQUIREMENTS
Side overhang (Dimension A)	• Target condition: No side overhang • Acceptable condition: 1/2W or 0.5 mm, whichever is less (1/4W for Class III)
Toe overhang (dimension B)	• Acceptable for any class if minimum design conductor spacing is not violated
End joint width (dimension C)	• Target condition: C=W (lead width) • Acceptable condition: C=1/2W or 0.5 mm, whichever is less (3/4W for Class III)
Side joint length (dimension D, top of toe fillet to top of heel fillet)	• Target condition: Equal to lead width: W plus evidence of heel fillet • Acceptable condition: Equal to W
Minimum fillet height (dimension F)	• G (at toe) + 1/2 T (G+T for Class III)
Minimum solder thickness (Dimension G)	• Properly wetted fillet (no dimension)

Requirements

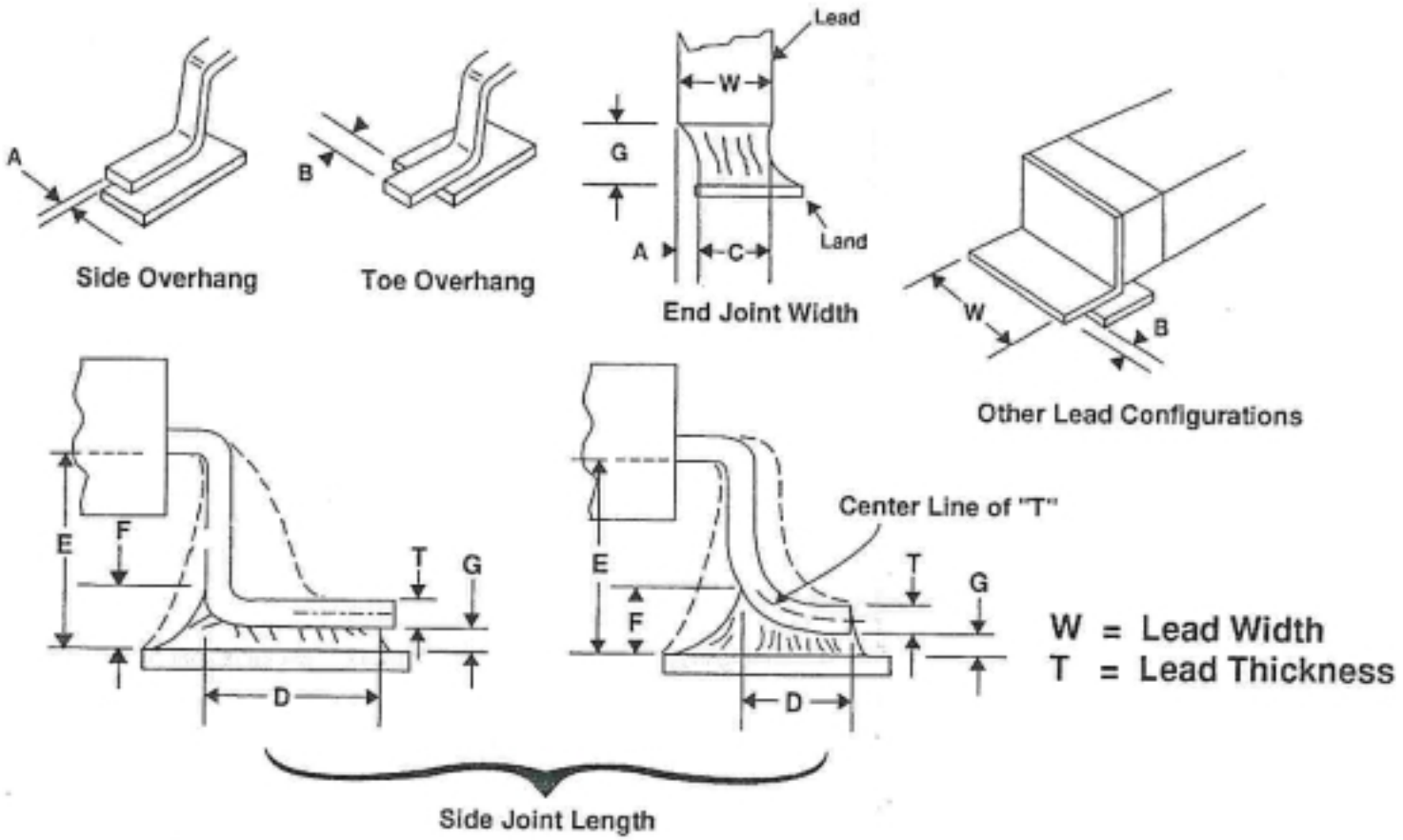


Figure 14.8 Joint illustrations for gull wing components [11].

Requirements

Table 14.4 Solder joint requirements for J-lead components [11, 12]

DIMENSION	REQUIREMENTS
Side overhang (dimension A)	• Target condition: No side overhang • Acceptable condition: 1/2W (1/4W for Class III). W is the lead width
Toe overhang (dimension B)	• Not specified for any class • Toe sticks up, is underneath the package and looks like the heel fillet
End joint width (dimension C)	• Target condition: C=W • Acceptable condition: C=1/2W (3/4W for Class III). C is measured at thinnest point
Side joint length (dimension D, measured at the top of toe and heel fillet)	• Target condition: > 150% lead width • Acceptable condition: Equal to 1.5 W
Maximum fillet height (dimension E)	• Solder fillet not touch package body
Minimum fillet height (dimension F)	• 1/2 T (G+T for Class III)
Minimum solder thickness (dimension G)	• Properly wetted fillet

Requirements

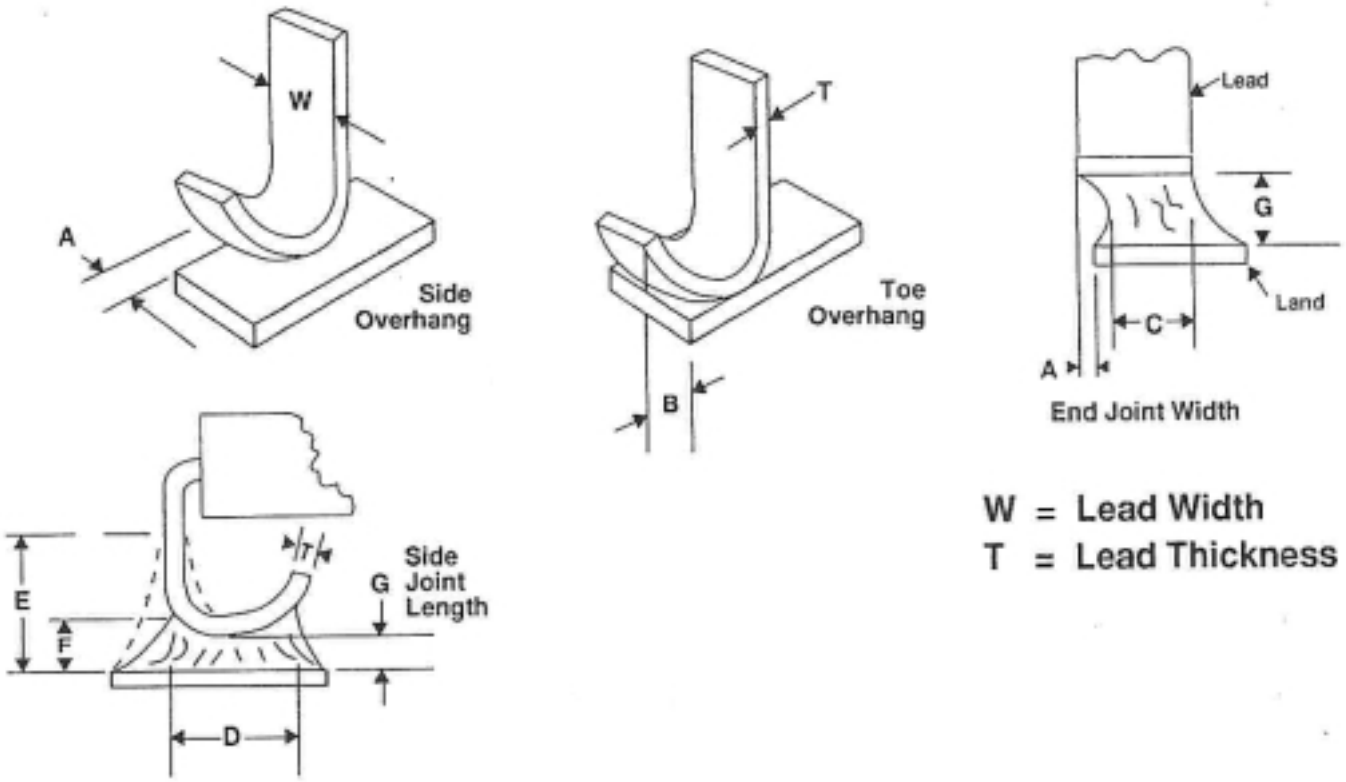
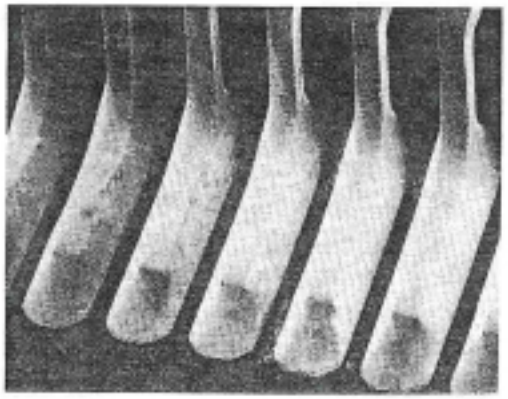


Figure 14.9 Joint illustrations for J-lead components [11].

Generic Solder Requirements

1. Minimum solder joint
2. Insufficient solder joint
3. Excess solder joint
4. Component misalignment
5. Solder bridges
6. Icicles
7. Tombstoning or drawbridging
8. Solder wicking
9. Adhesive contamination
10. Voids in the solder joint

Solder volume



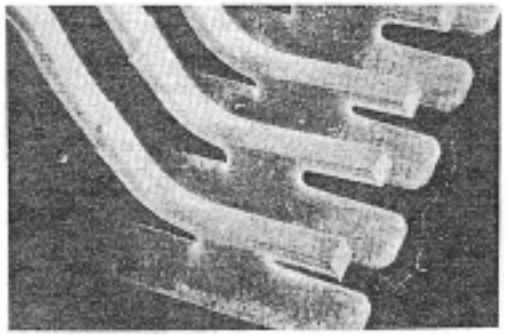


Figure 14.12 Photographs of preferred (top) and insufficient (bottom) solder joints in a fine pitch gull wing leaded device. (Photograph courtesy of Control Data Corporation.)

Adhesive

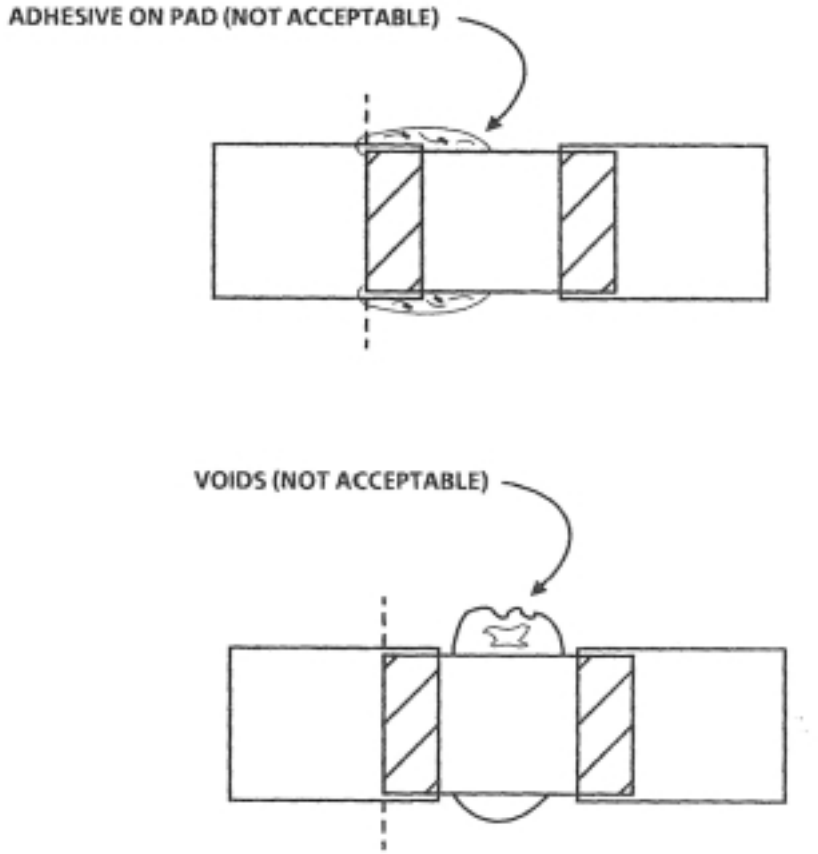
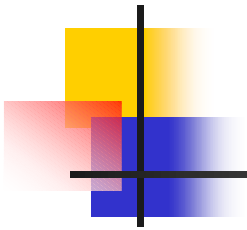


Figure 14.13 Adhesive contamination (not acceptable). Note adhesive on pad (top) and adhesive with voids (bottom).



Inspection

- Visual
  - Microscope with operators
- Automated Optical
  - CCD cameras comparing images to program file
- X-ray
  - X-ray image and calculate voids
- Laser
  - Heat solder joint with laser and measure temperature with IR detector

Visual

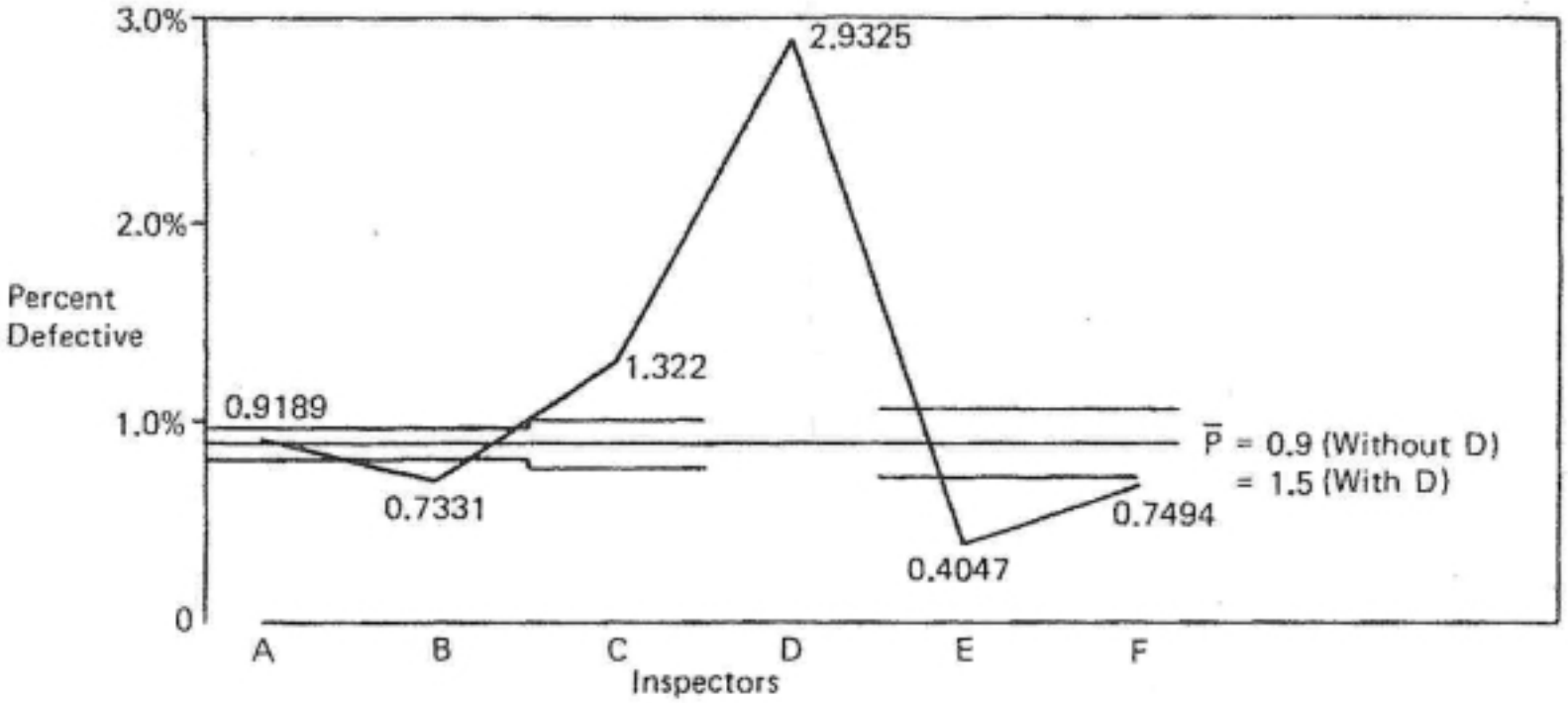


Figure 14.15 Defect rate versus inspectors for Program A, June to August, 1983 [5].

Cross Sections

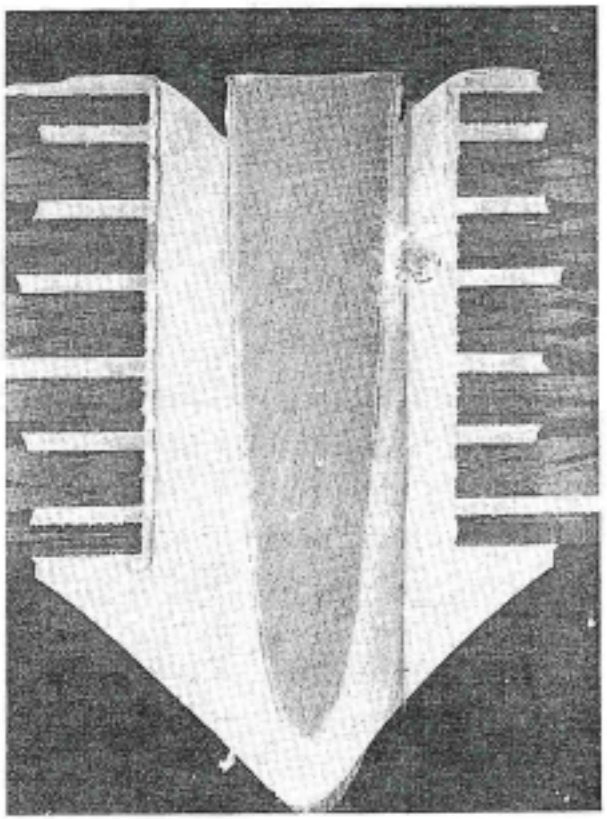


Figure 14.18 An example of unacceptable solder joint by x-ray and visual inspection but considered good by laser inspection.

Cross Sections

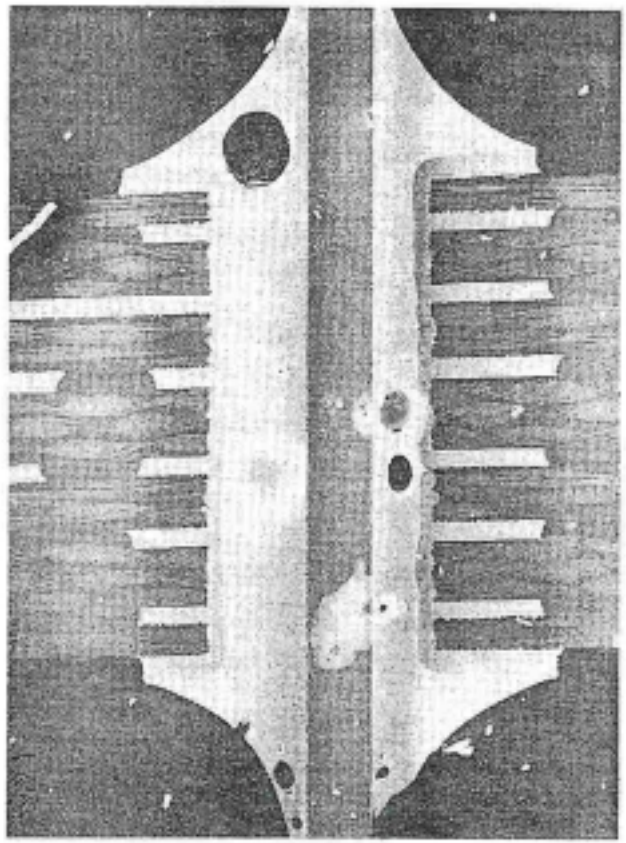
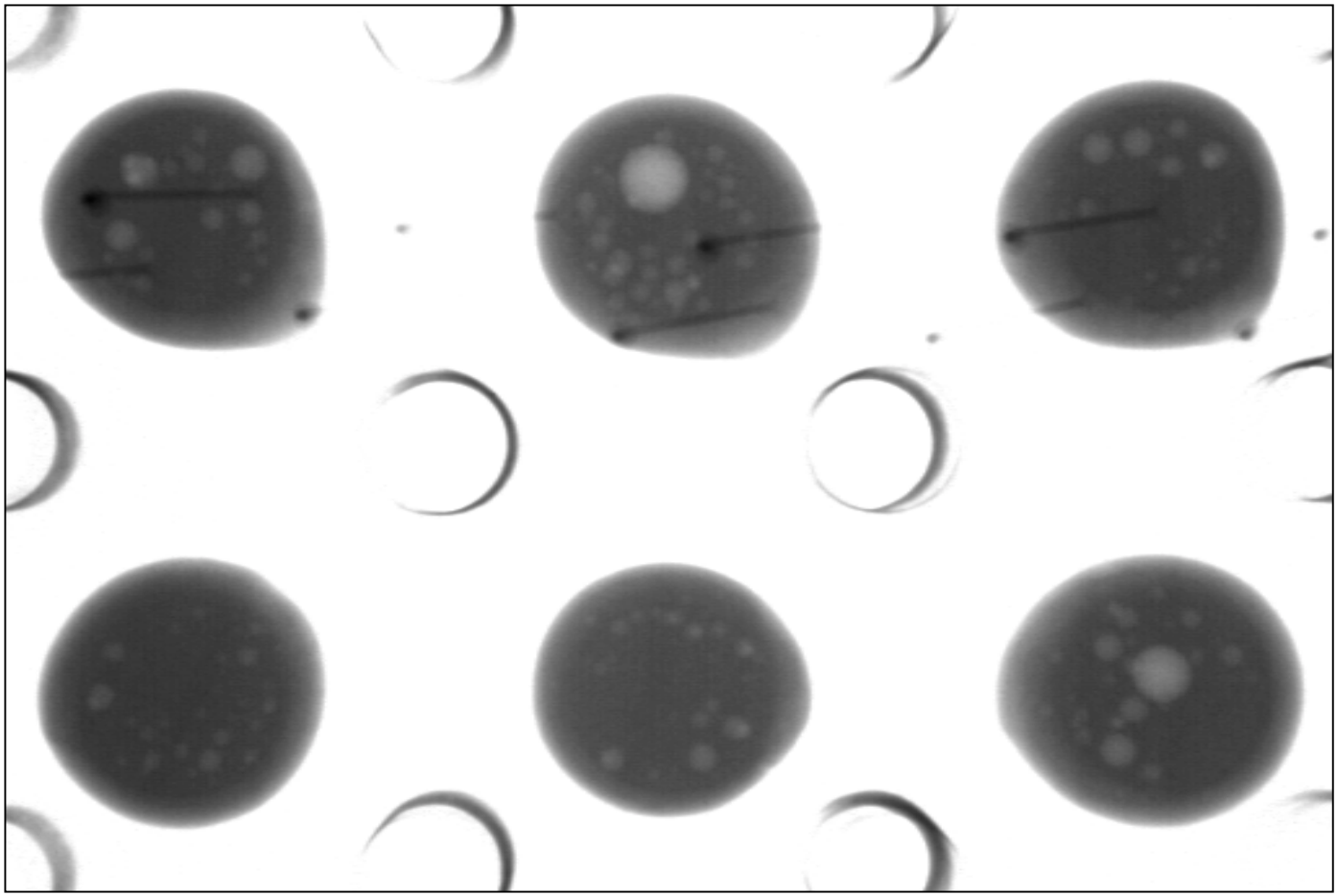
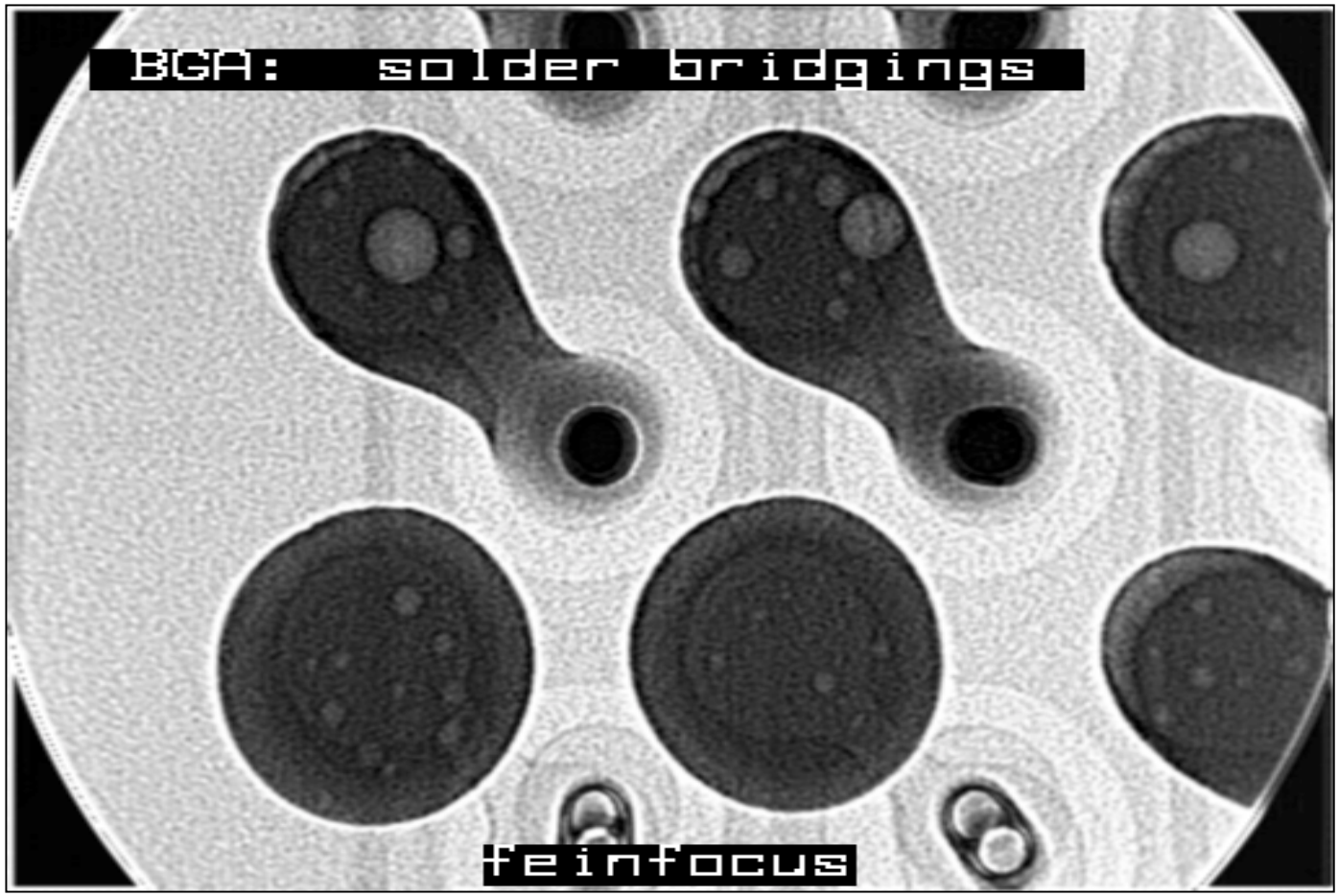


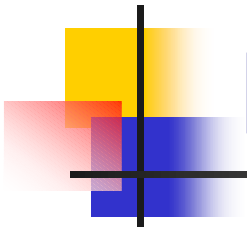
Figure 14.19 An example of a visually acceptable solder joint considered poor by laser and x-ray inspection.

X-ray



X-ray





Repair

- Manual
- Rework Stations

Manual Soldering Iron

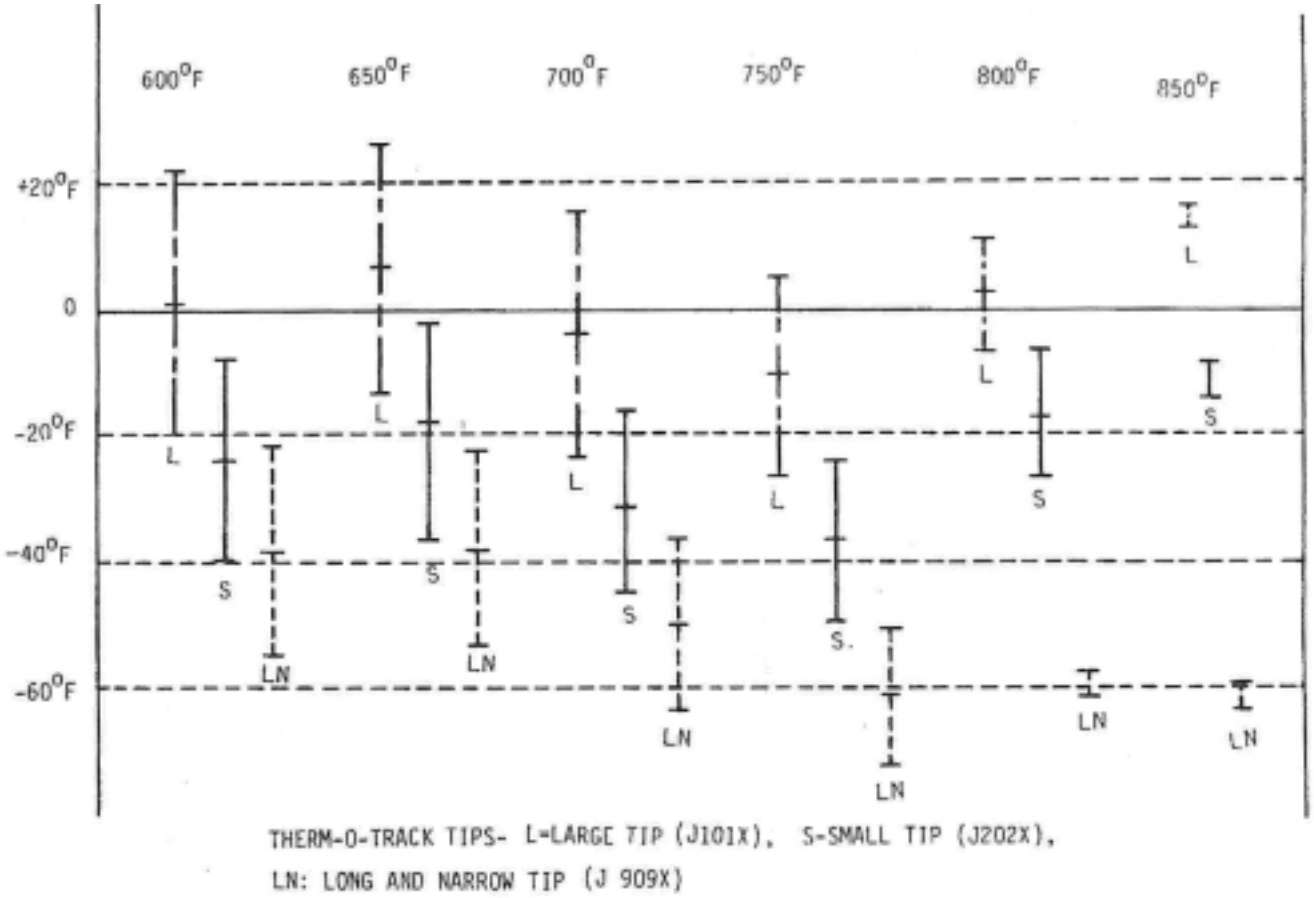


Figure 14.24 Variation in soldering iron tip temperatures for different sizes of tips at dial settings from 600–850°F [17].

Damage due to temperature & pressure

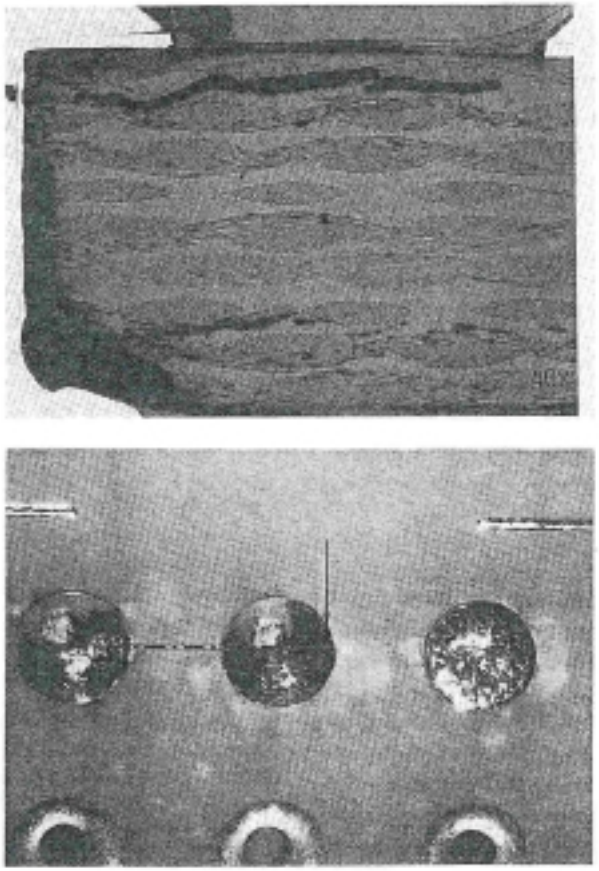
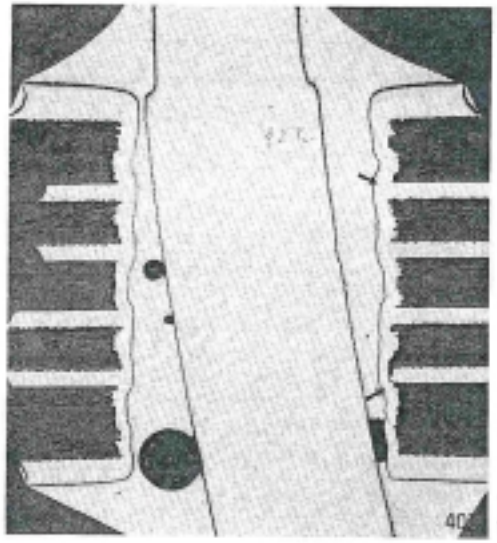
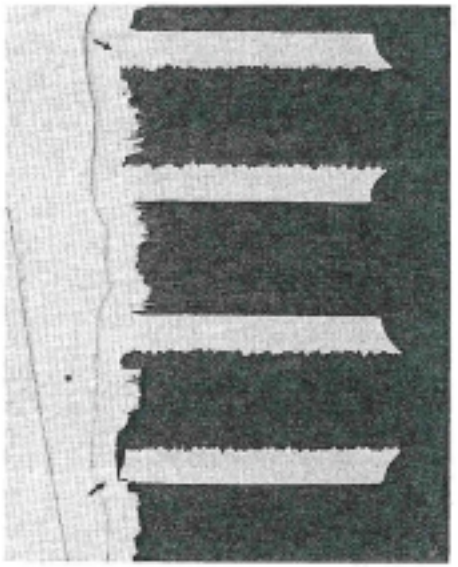


Figure 14.25 Thermal damage on board due to temperature and pressure of soldering iron. The bottom photograph shows the cross-sectional view of the top photograph. Note delamination in the bottom photograph. Due to absence of pressure, such damage is rare during rework of surface mount assemblies with hot air systems [17].

Damage during component removal



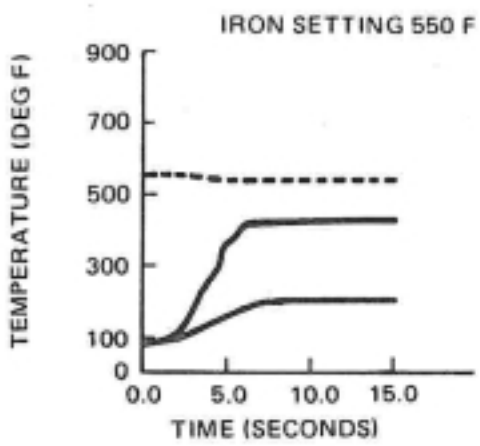
A
Internal Pad-Tubelet Separation

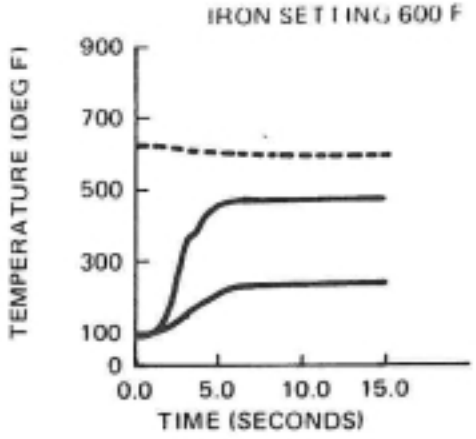


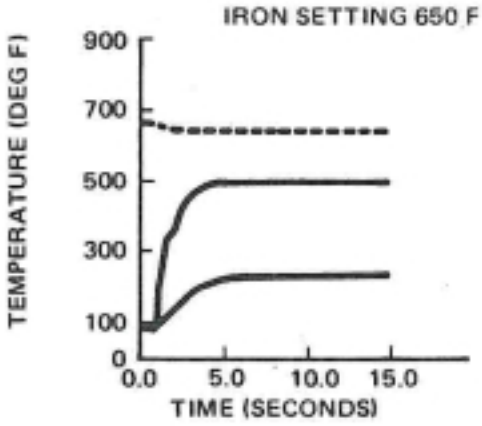
B
Magnified (100X) view of A

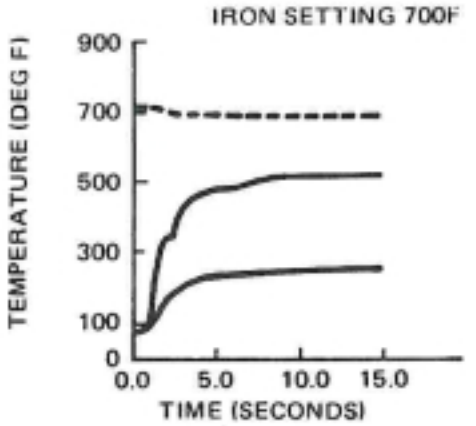
Figure 14.26 Internal pad-tubelet separation: at 40X magnification (top) and 100X magnification (bottom) [17].

Temperatures









IRON SETTING 750 F

IRON SETTING 800 F

Temperatures

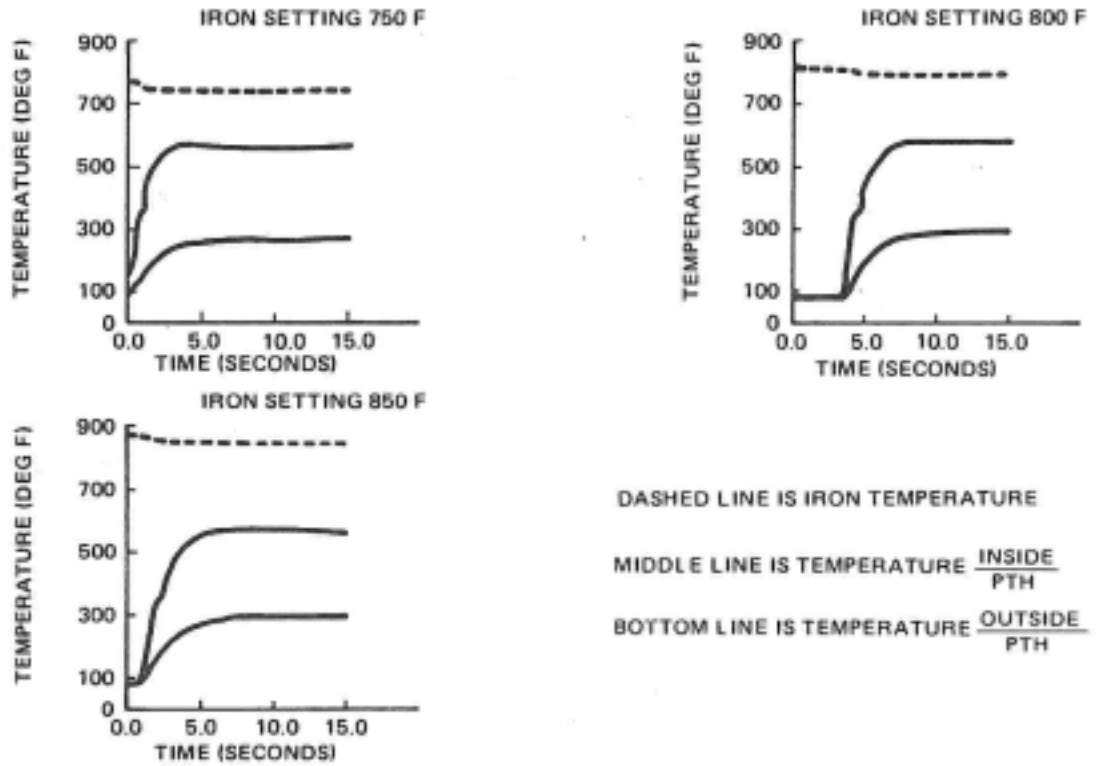
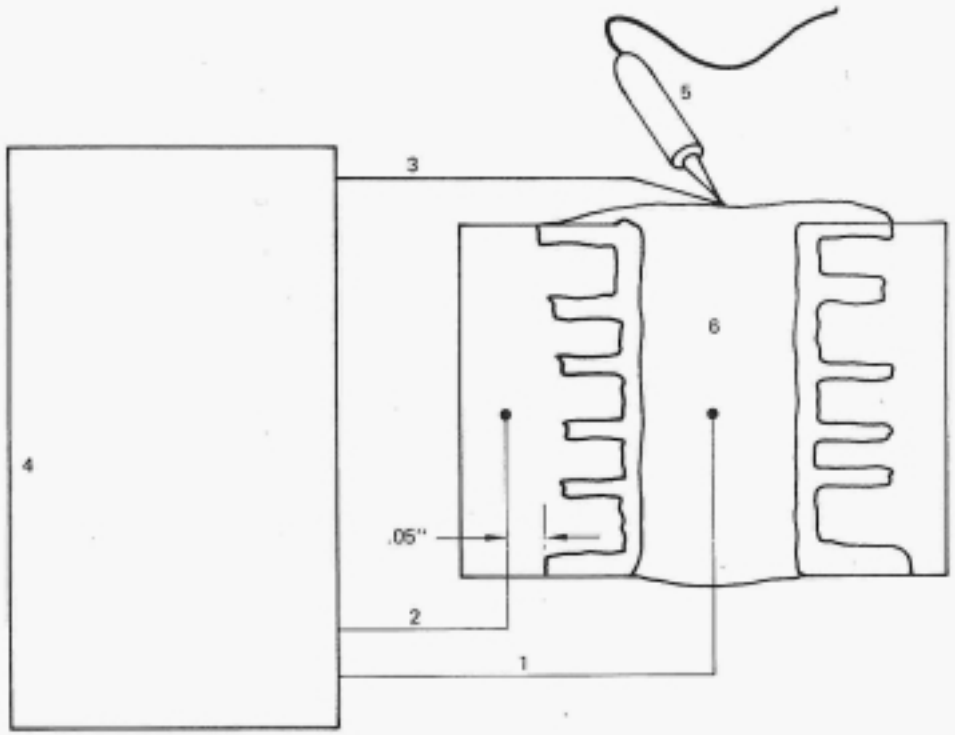


Figure 14.27 Relationship between soldering iron tip and plated through-hole temperature. Note that the solder joint melted within 1.5 seconds (inflection points in the middle curves) for all tip temperatures. See Figure 14.28 for locations of thermocouples [17].

Measurement locations



1. THERMOCOUPLE INSIDE PTH.
2. THERMOCOUPLE OUTSIDE PTH.
3. THERMOCOUPLE WELDED TO IRON TIP.
4. TEMPERATURE RECORDER CONNECTED TO H.P. 9825A SYSTEM.
5. SOLDERING IRON.
6. SOLDER PLUG.

Figure 14.28 Schematic diagram of the thermocouple locations for recording of temperatures shown in Figure 14.27 [17].

Repair Requirements

- Limit number of times a part can be removed (2) to prevent internal damage
- Preheat the board to 94°C for 30 minutes is recommended during component removal
- The tip of the iron should not exceed 370°C

Repair Requirements

- Desoldering time should not exceed 3 seconds (heat source to land)
- Only low activity (rosin or no-clean) fluxes should be used
- Parts that are bonded to the substrate with adhesive should be removed with a tool that will cut through the adhesive bond or by holding the part rigid and twisting the part body

Hot air systems

- Blow hot air on the solder joint to provide heat input
- No pressure is applied to the board
  - Higher temperatures (air temperature to 400°C) and time can be used with hot air

Hot Air Systems

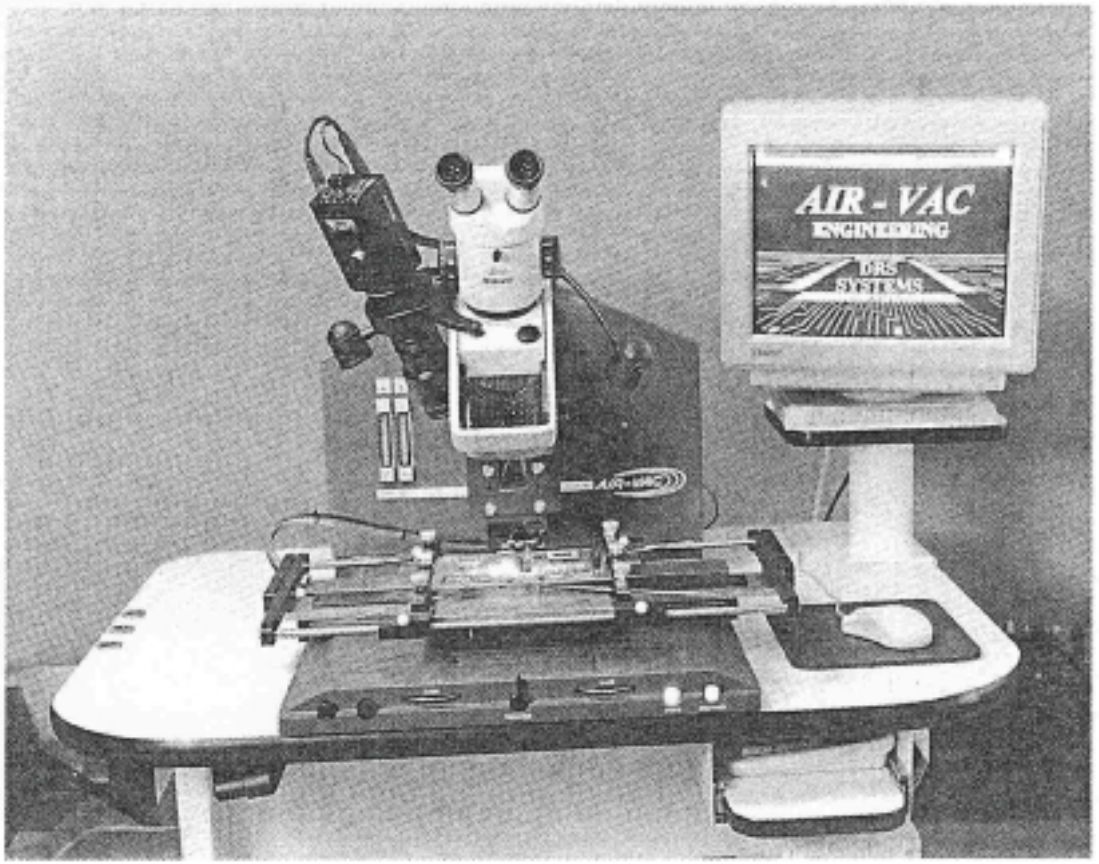


Figure 14.32 Hot air rework system for BGA devices. (Photograph courtesy of Air-Vac.)

Nozzle Design

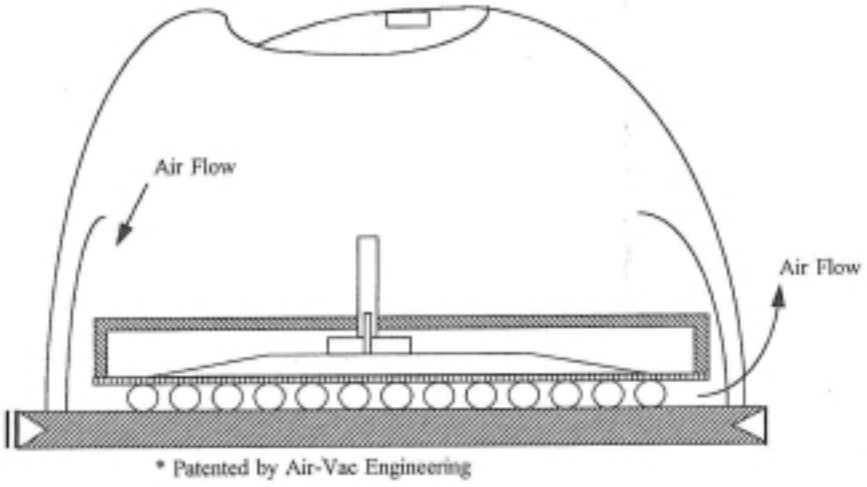


Figure 14.34 Schematic illustration of Air-Vac HFC nozzle.

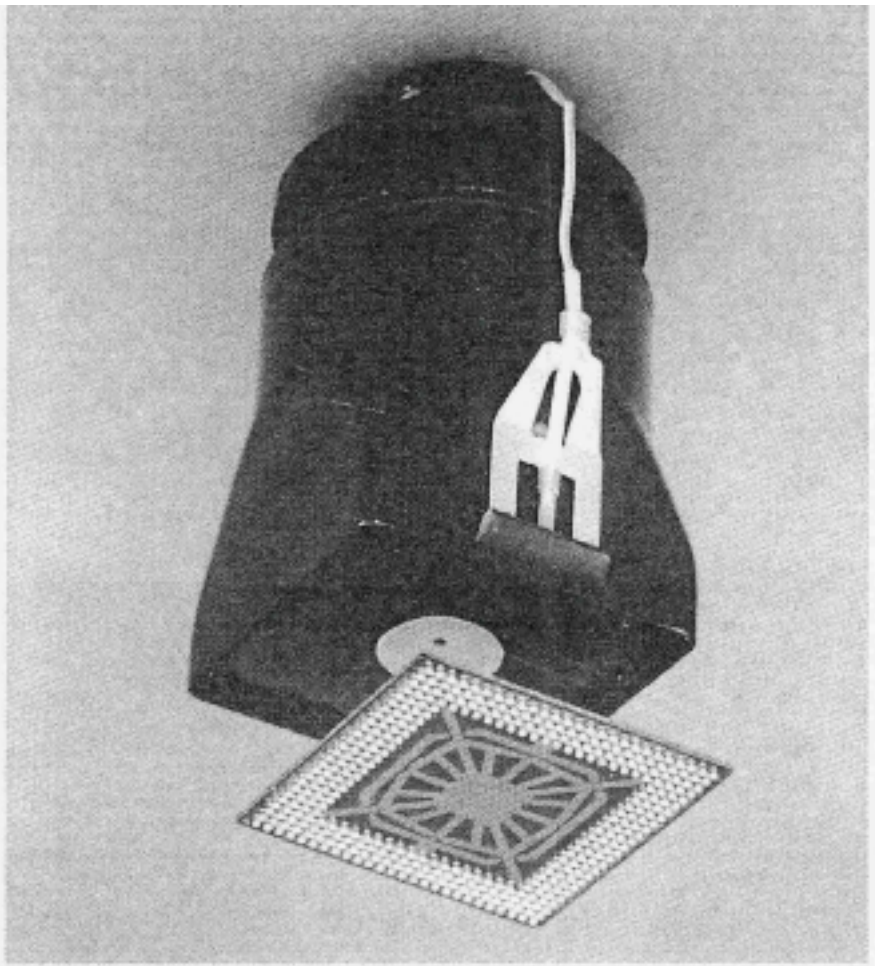


Figure 14.33 Photo of Air-Vac HFC nozzle with thermocouple. (Photograph courtesy of Air-Vac.)

Hot Air Sequence

1. Preheat the boards
2. Dispense flux
3. Heat the part to 210-220°C for 45-60 seconds and pick up the part by vacuum tip
4. Remove solder from the board and clean surface
   - Use vacuum

Hot Air Sequence

- Place new component
- Preheat board again
- Reflow
- Clean

Profile

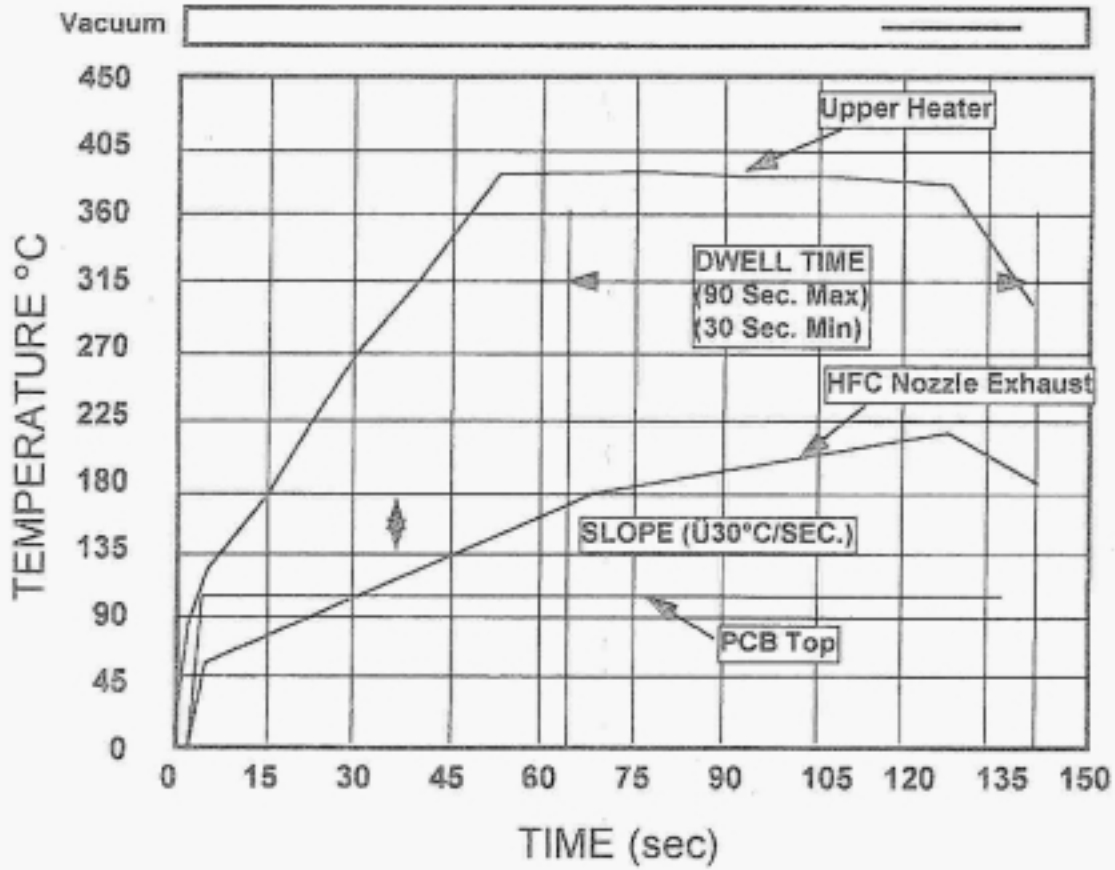


Figure 14.36 BGA rework profile using the Air-Vac equipment shown in Figure 14.32.

Profile

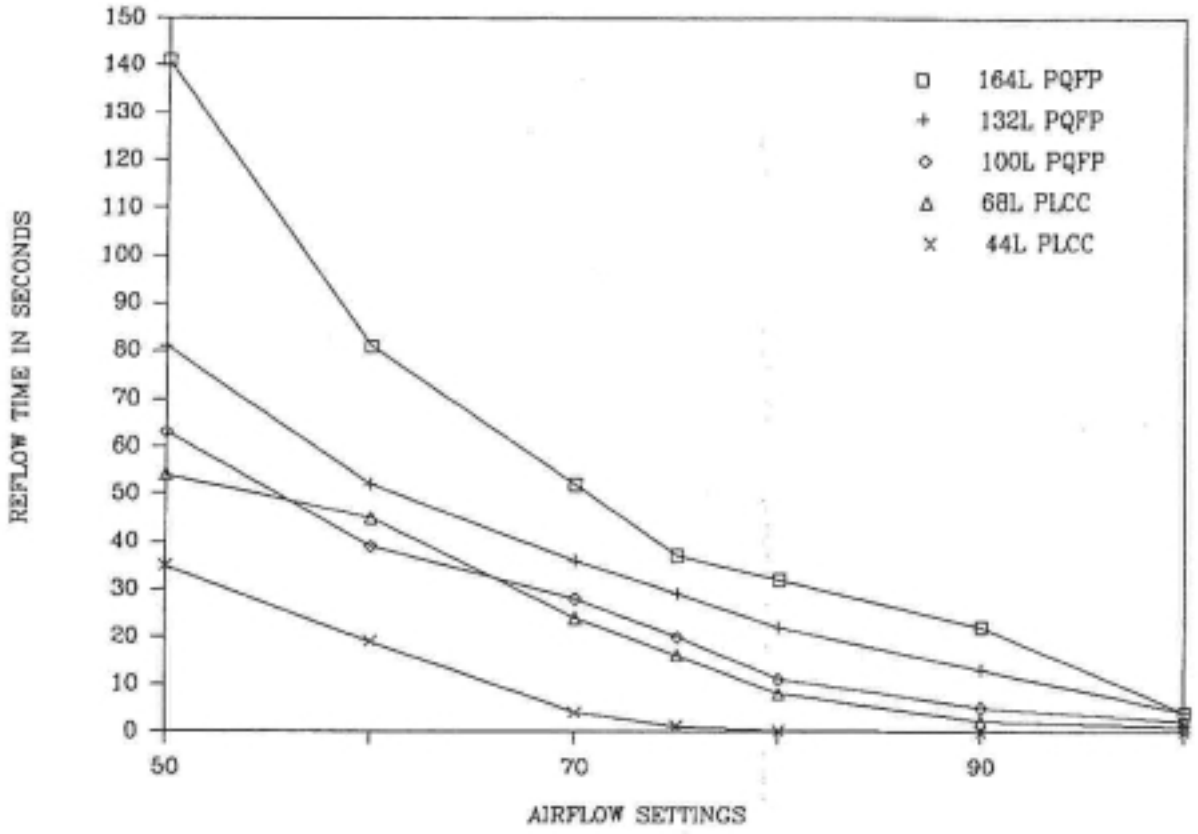


Figure 14.37 Rework profile for removing PLCCs and PQFPs using Air-Vac hot air equipment.

Testing – Probe Pads

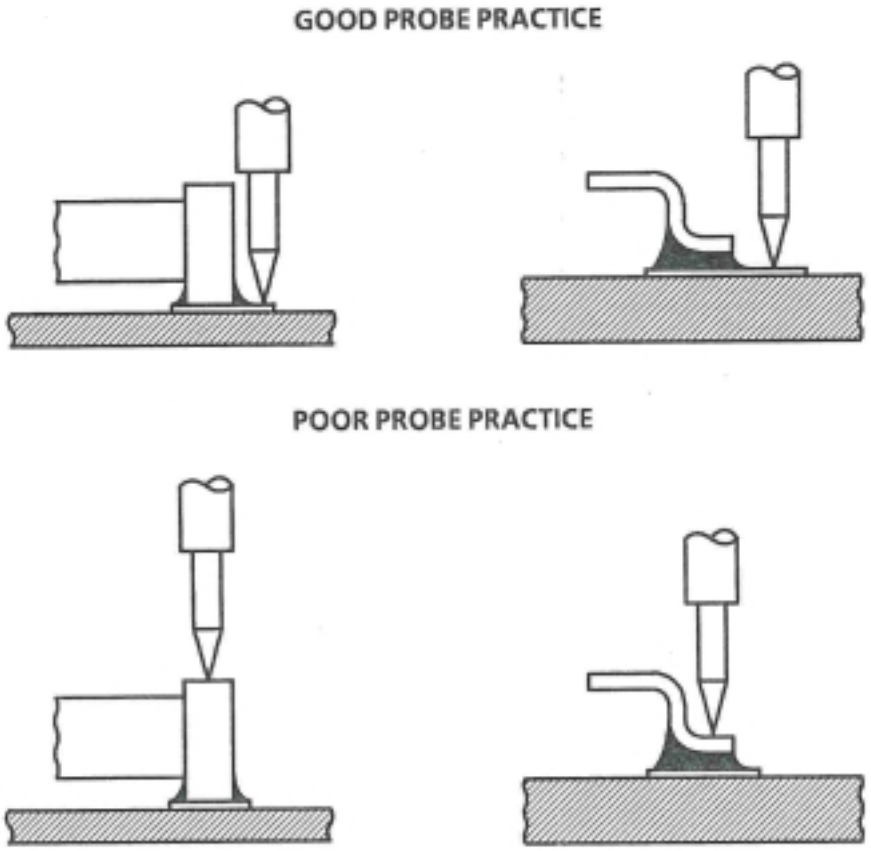
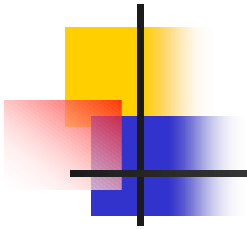


Figure 14.38 Good (top) and poor (bottom) practices for probing during test.

Automated Test Equipment (ATE)



- Single or double sided fixture
- 50 mil probes for SMT
- 100 mil probes for through hole
- Finer probes for Fine Pitch SMT

Probe

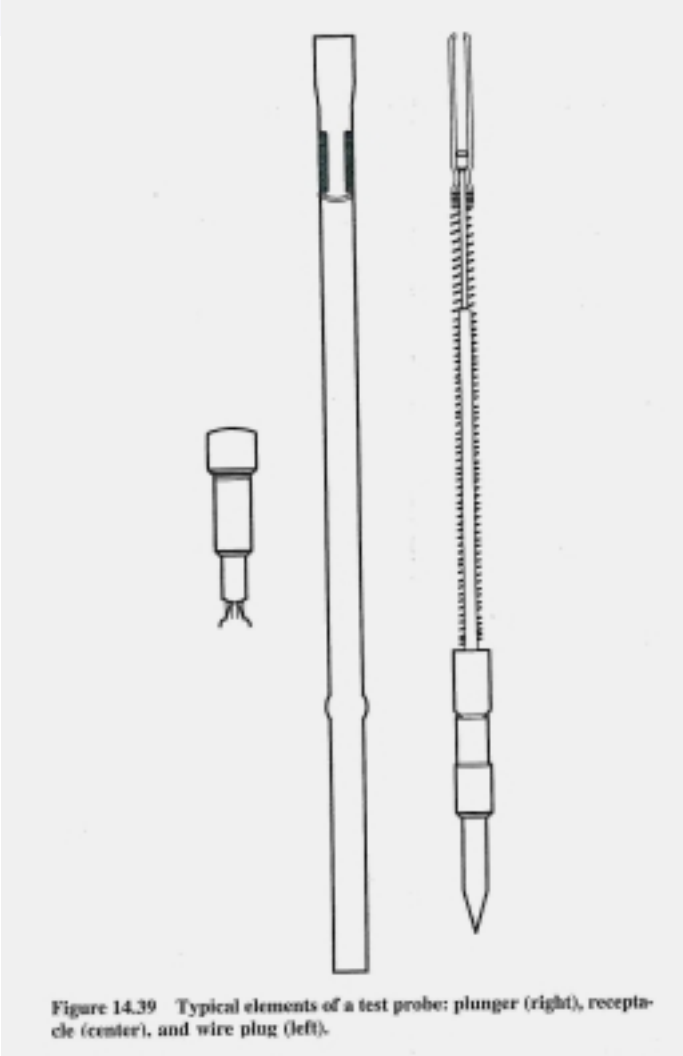


Figure 14.39 Typical elements of a test probe: plunger (right), receptacle (center), and wire plug (left).



RADIUS TIP -- The smooth radius tip will not scratch circuitry but requires clean surface.

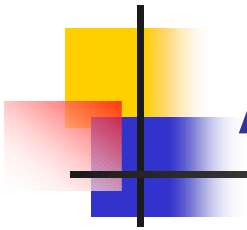
PYRAMID TIP -- Used for contacting plated through holes.

POINT TIP -- Sharp single point penetrates through surface contaminants for good electrical contact.

4 POINT TIP -- Sharp points penetrate surface contaminants for good electrical contact.

TRI-POINT TIP -- Sharp points penetrate surface contaminants for good electrical contact.

Figure 14.40 Various types of test probe tips for automated test equipment.



ATE Issues

- Fine pitch
- Flux residues
- Misalignment
- Test access
- Cost