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Copper Removal from Plated thru Hole Barrels During Lead Free Minipot Rework

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LF Minipot Rework - Problem Definition

- Copper removal is induced by LF wave soldering and LF minipot rework of THM connector holes
- The amount of removal is greater on thick laminate PC boards (.093” used for DOEs).
- This problem is recognized in the industry and organizations such as iNEMI, IPC, etc.
- Causes of copper removal are:
  - Reaction of tin with copper forming Cu-Sn
  - Inter metallic’s that flake off PCB due to agitation/solder velocity from the Solder Fountain.

LF Minipot Rework Objectives

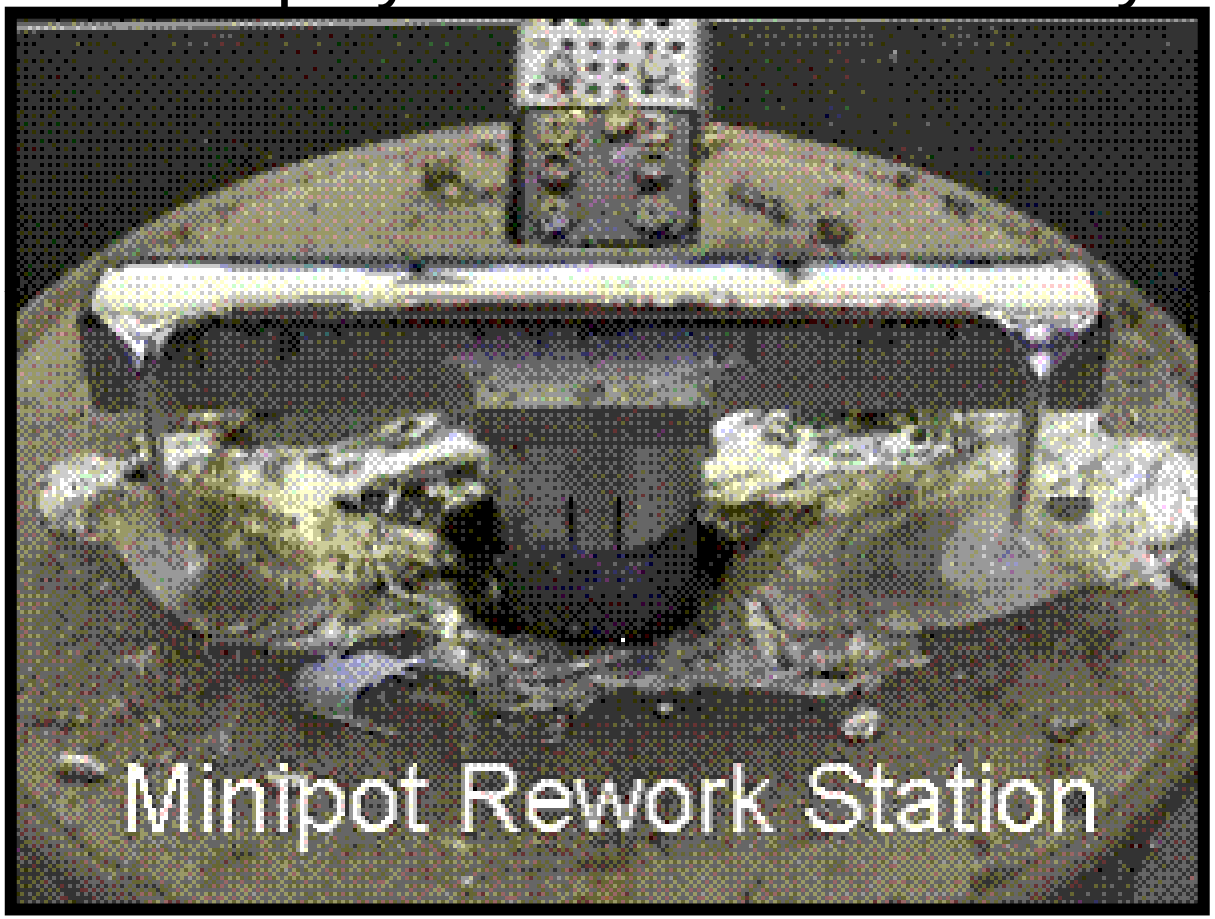
- Develop a good understanding of copper removal during the mini-pot rework process.
- Determine the minimum thickness of copper around the barrel knee required to meet Intel reliability criteria.

LF Minipot Rework Process Development - Scope

The study was done on thick PCB Laminate test board with the following features:

No. of Layers	**12**	**Through Holes**	**Direct Connect to Planes, thermal relief**
Thickness	**0.093”**	**Through hole Components**	**FB-DIMMs, PCI-E, PCI-E8, PCI –E16**
Ground Planes	**Several**	**PTH Diameters**	**28, 30 and 40 mils**
Trace width/space	**4 mils / 5 mils**	**Process Equipment**	**Mini pot Solder Fountain**
Barrel Copper Thickness	**1.67+/- 0.16mils**	**Solder**	**SAC 305**
Surface finish	**Immersion Silver**	**SMT Components**	**None**

Mini Pot Solder Fountain employed in the current study



LF Minipot Rework Process - Parameters used in our study

No	Parameters	Values
1	Solder Pot Temperature	545°F (285°C)
2	Solder Alloy Composition	SAC305
3	Flux	Kester 186 -18
4	Dwell Time	14-40 seconds
5	Distance between the nozzle and the board	1-3 mils
6	Preheat Temperature	140°F (60°C)
7	Preheat Time	5-8 minutes
8	Minimum tape clearance	0.08 inch
9	Connector preheat	104°F (40°C)

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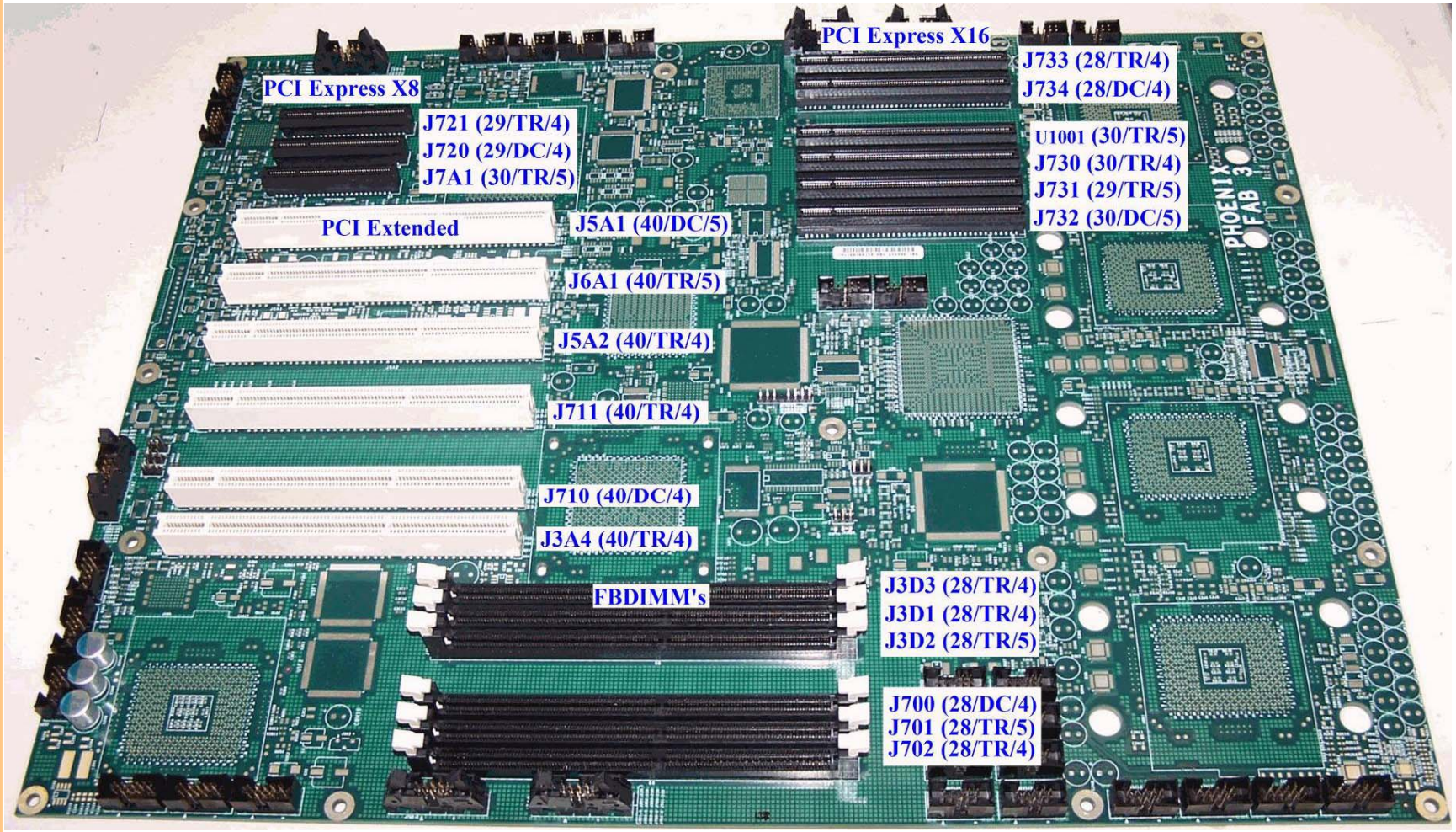
LF Mini-pot Rework Locations



Key: **(29/TR/4)**

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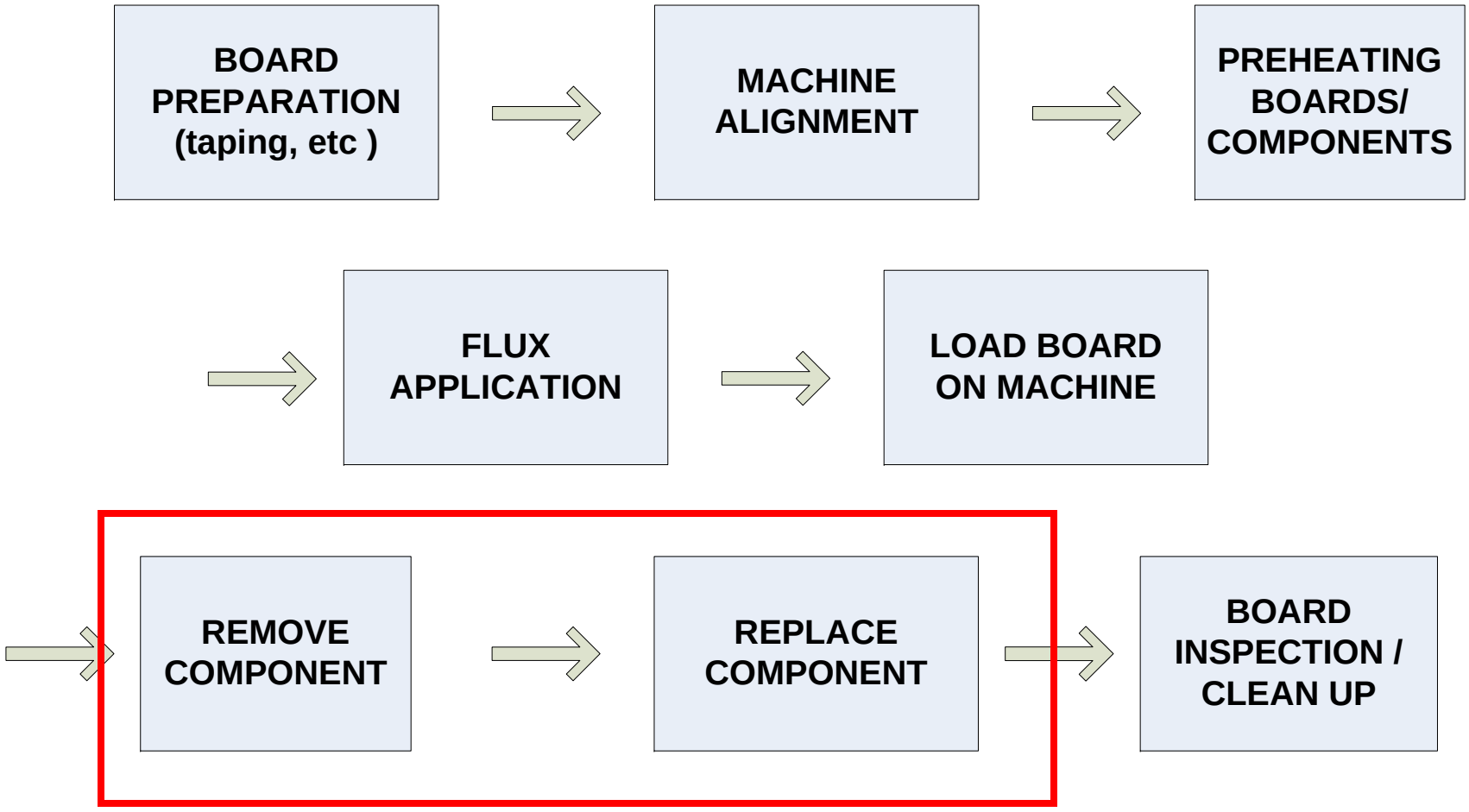
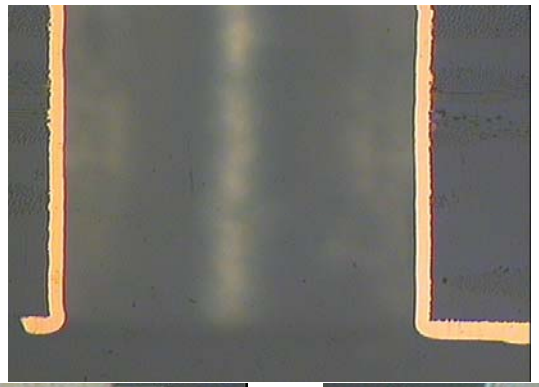
29=Finished Hole Size / DC=Direct Connect Pads TR=Thermal Relief Pads / 4=Trace Width

LF Minipot Rework Process Flow

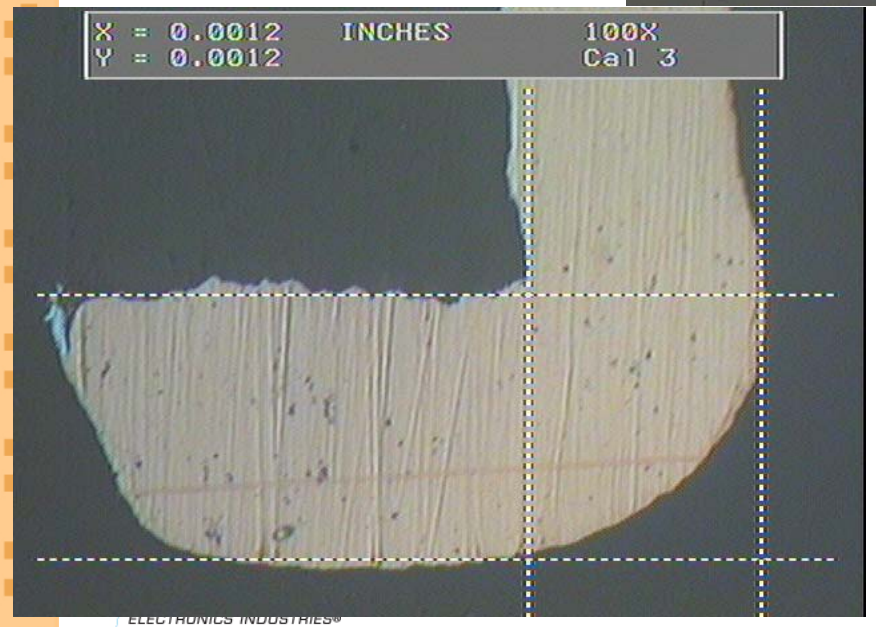


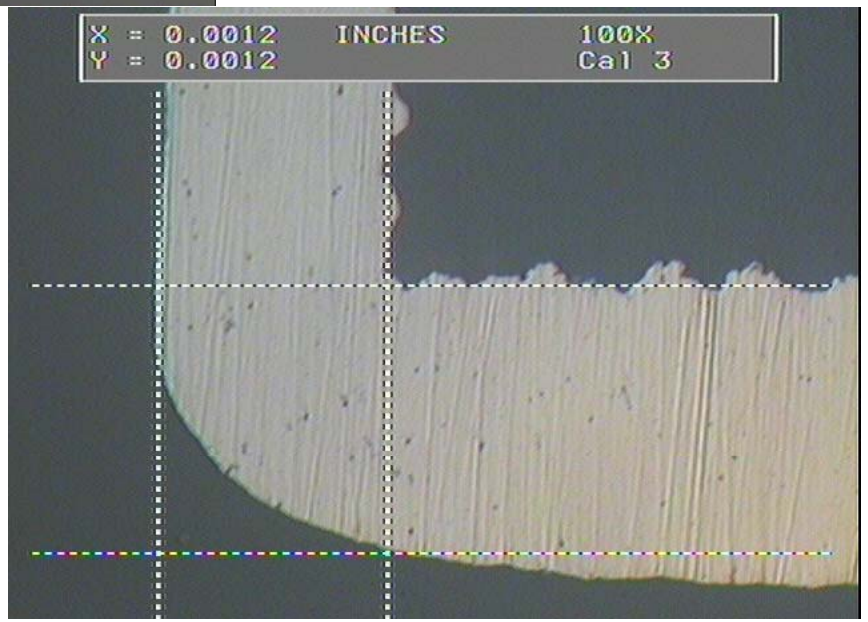
Critical activity zone

PTH Barrel at FBDIMM in the Incoming Bareboard

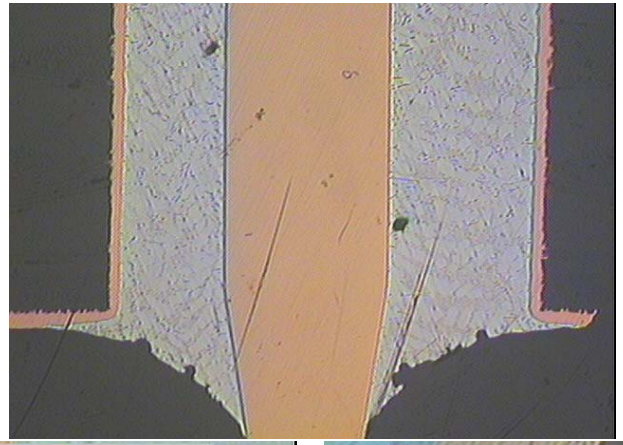


Average copper thickness on incoming PCB: 1.2 mils

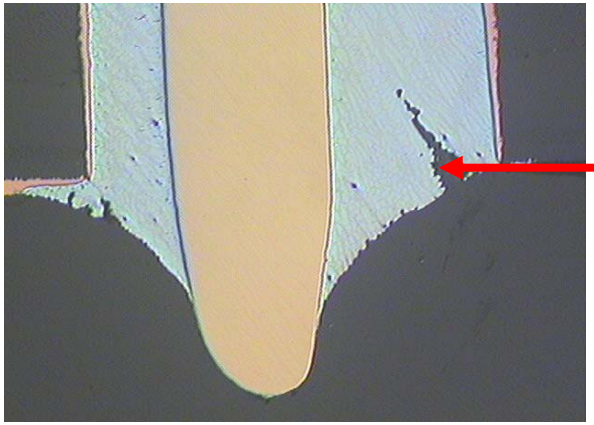




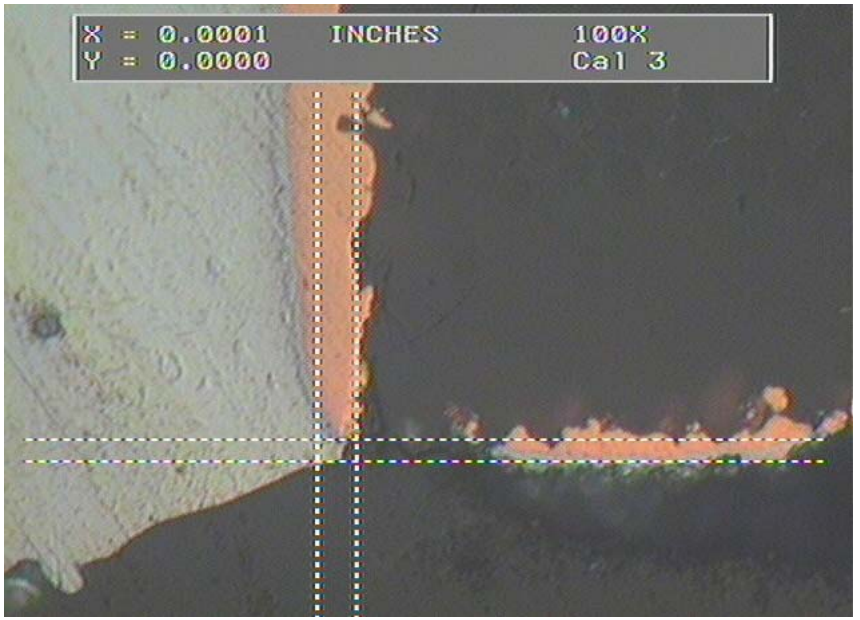
PTH Barrel after Wave Soldering



PTH Barrel after Mini-pot Rework



Shrink Void



Reliability Test Suite

- 85°C and 85% relative humidity (85/85)
- Shock and Vibration
- Temperature Cycling

LF Minipot Rework Solder Joint Reliability – Pass/Fail Criteria

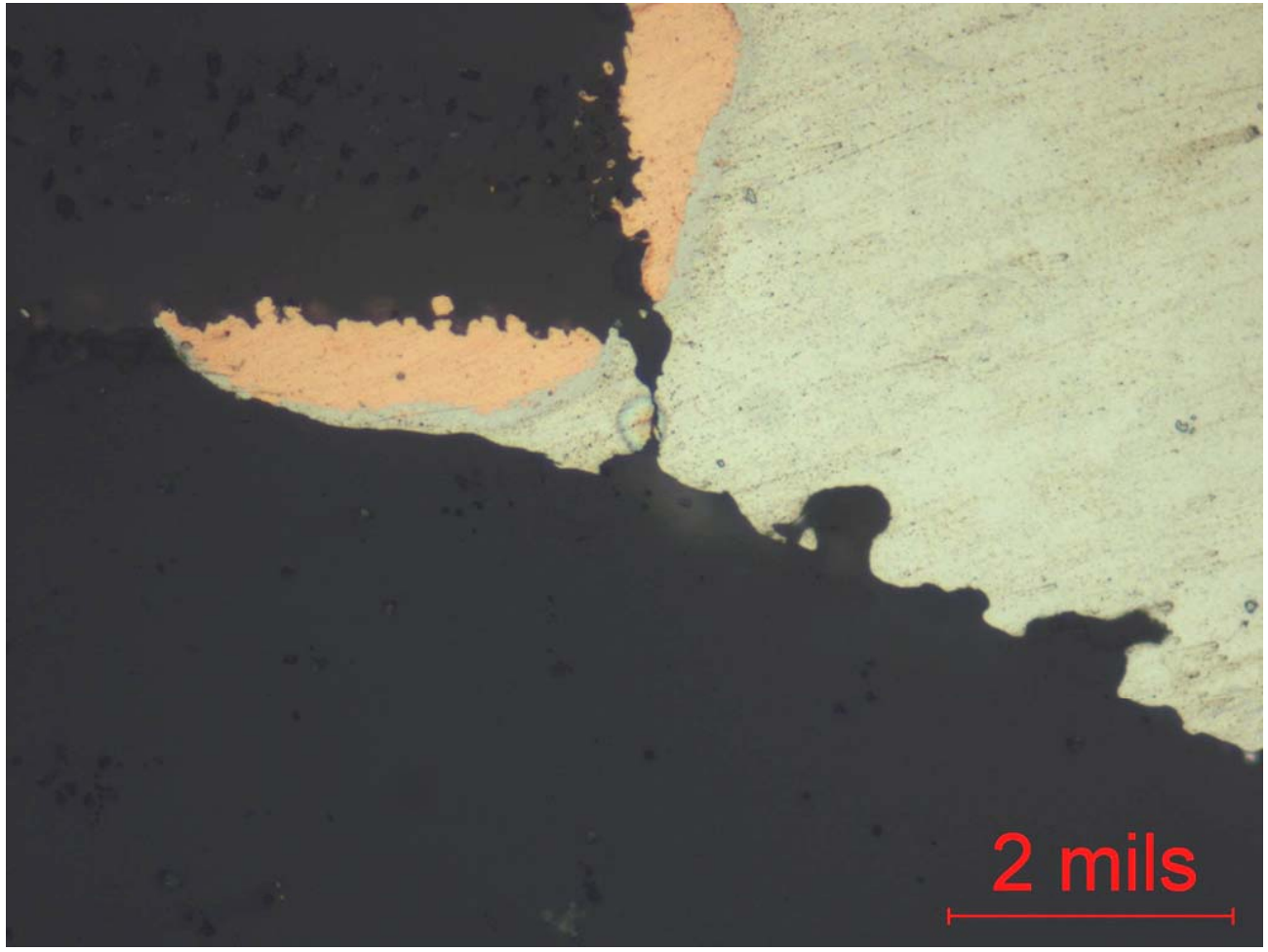
- **Open in e-test;**
- **Even e-test shows a pass, it is considered a failure if crack (open) size at the trace or the barrel is 100% in T/C or >50% in Shock and Vibration Tests.**

  - **To be more specific, the pass/fail criteria are:**
    - **Crack in Cu barrel wall and surrounding solders:**
      - **If crack is seen on the side of PTH with 0° trace, treat it as a failure;**
      - **If cracks are seen on both sides of PTH, treat it as a failure.**
    - **Crack in copper trace;**

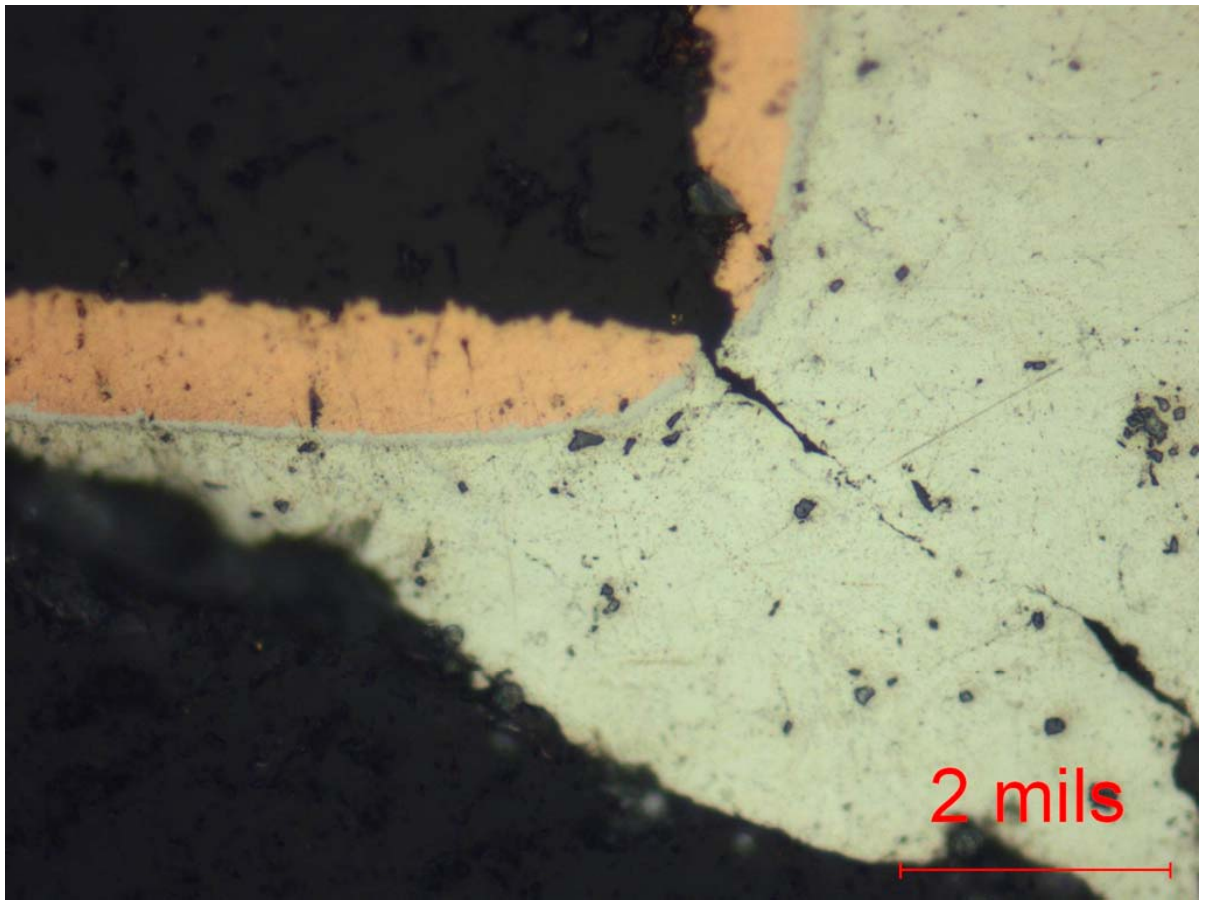
Reliability Test Results

- No failures after 85/85 and Shock/Vibration Tests.
- No failures seen after 1/3 EOL TCS tests.
- Some failures noted after 2/3 EOL, EOL and 2XEOL TCS tests.

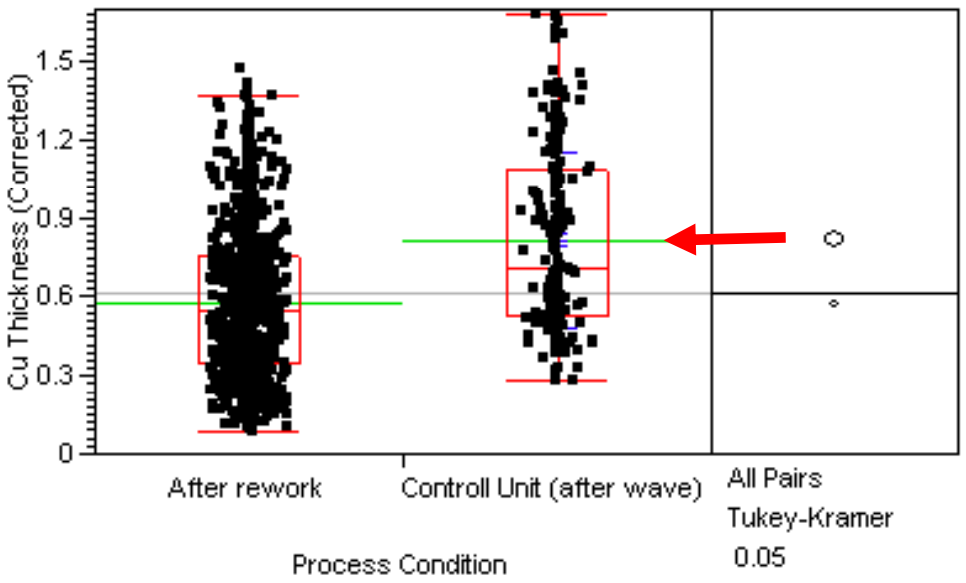
Example # 1: Cracks in Solder - After Temp Cycling



Example #2: Cracks in Solder – After Temp Cycling



Statistical Analysis

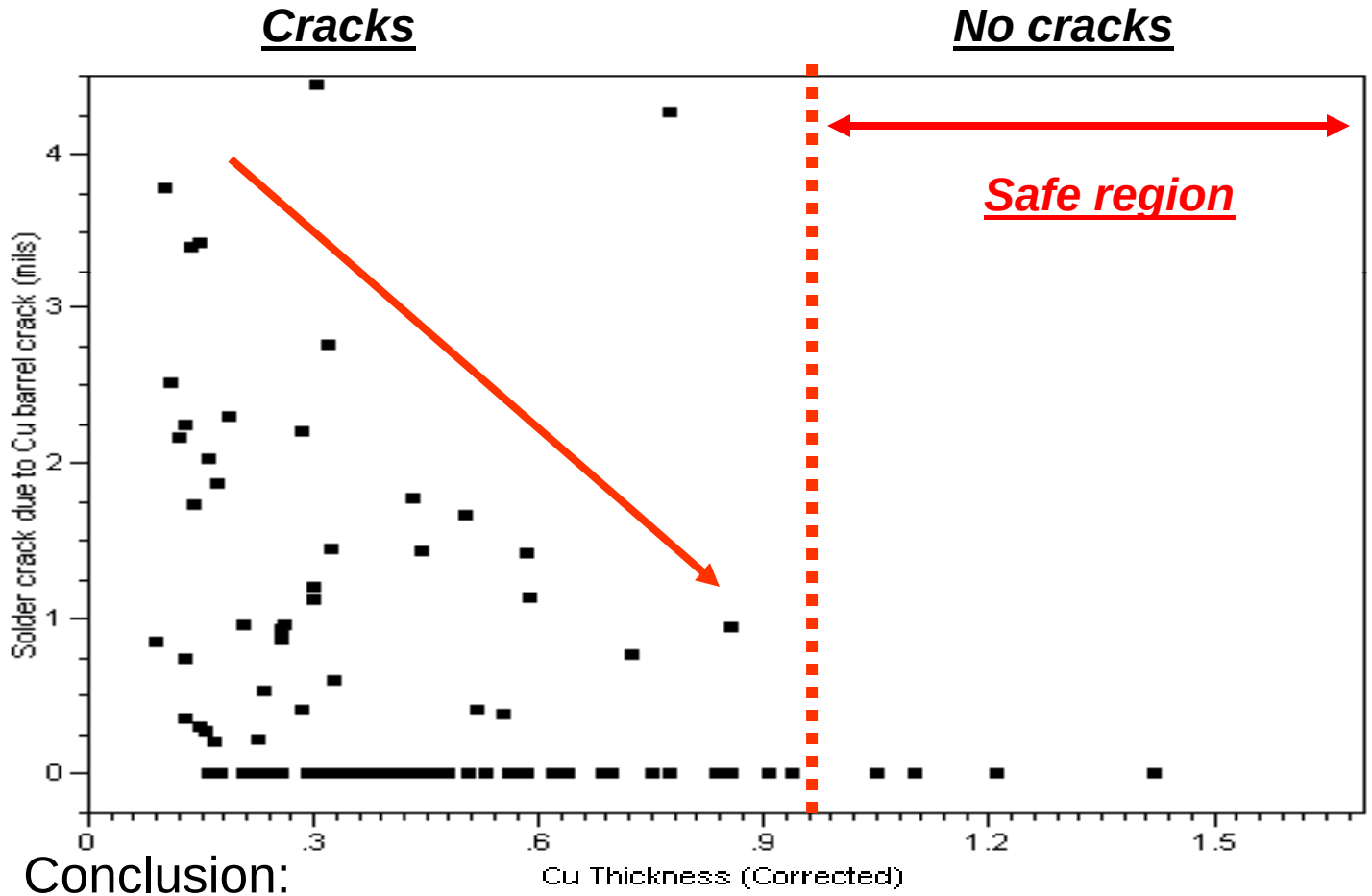


Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
After rework	1411	0.574169	0.270003	0.00719	0.56007	0.58827
Controll Unit (after wave)	240	0.816587	0.336292	0.02171	0.77382	0.85935

- **Conclusion:**
  LF Mini-pot Rework process consumes up ~0.25-0.3 mils of Cu due to Copper erosion.

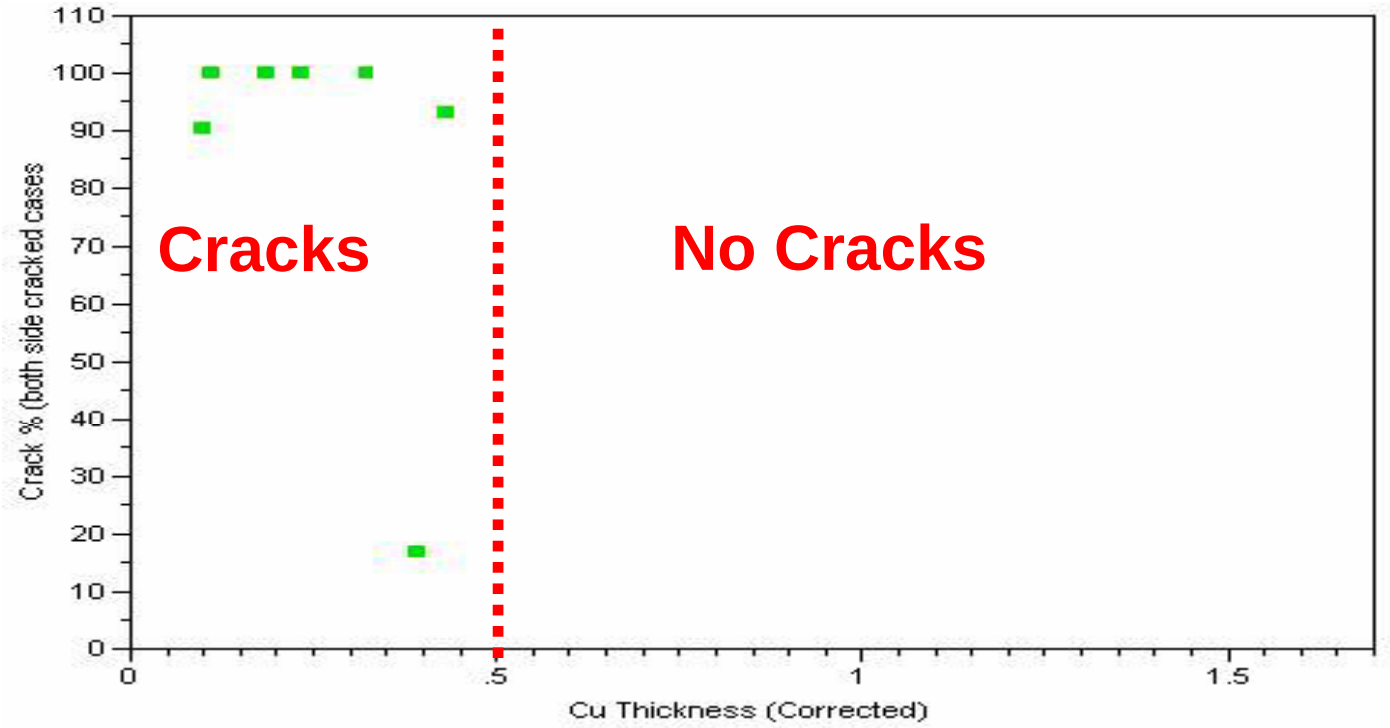
Solder Crack Length vs Copper Thickness after Temp Cycle. (Single side cracks)



Conclusion:

Minimum Copper thickness necessary to prevent solder cracks on one side of the PTH barrel knee is around 1.0 mil.

% Solder Cracks after Temp Cycle –
Crack on Both Sides of the barrel



Conclusion:

Minimum Copper Thickness where both the sides of a barrel knee is vulnerable to cracking is 0.5 mils.

Lead Free Minipot Rework Project Result Summary - 1

- Significant copper erosion is seen at the knee of the PTH Barrel and at the exposed parts of copper traces.
- Minimum of 0.5 mils thick copper (at the PTH barrel knee) is required to prevent cracks on both sides of PTH barrel
- Virtually all the E-test opens seen in test boards following temp. cycling were due to the cracking of copper traces on outer layer of board, which were less than 1 mil wide
- Total rework time varies from 14 to 40 seconds during cliff tests.
- No electrical failures were due to copper thinning or breaks at the knee of the PTH barrel.

Lead Free Minipot Rework Project Result Summary - 2

- Average copper barrel thickness observed after LF wave soldering process : 0.81± 0.34 mils,
- Average copper barrel thickness observed after LF mini pot rework process : 0.57± 0.27 mils.
- Mean copper eroded during minipot rework 0.24 mils.
- Minimum copper thickness at barrel knee after mini pot rework to ensure reliability : 0.5 mils.
- Desirable range of copper thickness in the barrel after wave solder required to allow for minipot rework: 0.80 mils.
- Mini pot technology removes more copper from center of connector compared to the ends.

Summary and Conclusions

- Minimum of 0.5mil thick Copper at the PTH barrel knee is required when a product goes into service to expect “reliable” performance over it’s lifetime.
- There is no evidence to suggest that copper thinning or breaks at the knee of the PTH barrel results in hard electrical failure in the product.
- As an aside, Copper breaks in bottom side traces will result in electrical failure of the product, and are possible if sufficient removal of copper takes place during the board processing.

Lead Free Minipot Rework Project – Suggestions for Process Improvements

- Change the board design such that the amount of exposed copper between the annular ring and the copper trace is minimized.
- Experiment with alternative alloys in minipot rework and determine the impact on the rate of copper erosion during “standard” rework time .
- Insure that the copper trace width is 4-5 mils.
- Use teardrop design for the copper trace originating from the annular ring of the barrel

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