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IPC-TM-650 TEST METHODS MANUAL

1 Scope This test method details the dye and pull procedure (formerly known as dye and pry) utilizing dye penetrant analysis of surface-mount technology (SMT) components to confirm assembly process parameters and solder joint quality/integrity.

This Test Method is for observation only, to determine the existence of dye indications.

2 Applicable Documents

IPC-7095 Design and Assembly Process Implementation for Ball Grid Arrays (BGAs)

3 Test Specimens The specimen is a SMT part soldered to a board. Typically, this method is used on ball grid arrays (BGAs) to evaluate their solder joint quality/integrity; however, it also can be used on other SMT parts, such as bottom termination components (BTCs) and connectors.

4 Apparatus or Material

4.1 Recommended dye: Red Steel Dykem® or equivalent

4.1.1 Oil-based dyes are not recommended for this procedure.

4.2 Vacuum pump and chamber (typically a mechanical pump and bell jar)

4.2.1 Recommend metallurgical epoxy vacuum chamber with vacuum gauge

4.3 Stereo microscope with digital camera

4.4 Baking oven capable of 100 °C

4.5 Cutting tool to section-out desired components from the board without exerting excessive stress on the solder joints

4.5.1 Diamond sectioning saw recommended

4.6 JB Weld or equivalent structural adhesive strong enough to bond the tee nut to the part package surface and withstand the pull force

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Originating Task Group Bottom Termination Components (5-22k)	

4.7 Tool to separate the component from the board

4.8 Compressed or canned air

4.9 Appropriate solvent (or solvent agreed upon between the lab and the customer) for removal of flux residues remaining on the board

4.10 General/assorted lab equipment (e.g., tongs, glass beaker, cut-down plastic beaker, funnel, etc.)

4.11 Recommended safety equipment (e.g., fume hood, gloves, eye protection, etc.)

4.12 Tee nuts appropriate to the size of the part

4.13 Sand paper (320 grit)

5 Procedure

5.1 Identify components to be dye and pull evaluated (consult test plan).

5.2 Perform an initial visual examination of the selected SMT part.

5.2.1 The initial visual examination is used to detect signs of mechanical damage/stress. If flux is present, examine for fractured/broken-up or disturbed flux around the SMT solder joints (see Figure 1 and Figure 2).

5.2.2 If the SMT part required the use of corner-applied adhesive and the adhesive is visible, examine and document it per customer requirements to determine if dye and pull testing is applicable. See IPC-7095 for additional guidance on the proper use of corner-applied adhesive.

5.3 If the part has a heatsink, package metal heat spreader or any other assembly that is attached, proceed as follows to avoid inducing any mechanical stress into the solder joint.

5.3.1 Remove the heatsink. If there is any concern with the proper method to remove an attached heatsink, it is highly recommended that it be left in place until after the dye-drying step (5.11).

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5.3.2 If there is a metal heat spreader on the BGA, it must be left in place until after the dye-drying step (5.11).

5.4 Section out the desired component area leaving about 19 mm to 38 mm [0.75 in to 1.5 in] of board around the part. If the board is small enough to fit the pull fixture, leave the board intact.

5.4.1 A diamond sectioning saw is recommended to perform this step. Other sectioning equipment (e.g., diamond saw, milling tool, water jet, etc.) can be used if it does not induce stress on the sample area.

5.5 A detailed visual examination under stereomicroscope is required at this stage. If needed, clean the sectioned part with only water and compressed air. It is important to not use solvent for this step.

5.5.1 A thorough visual examination can detect signs of mechanical damage/stress, which are indicated by fractured/broken-up flux around the SMT solder joint (see Figure 1 and Figure 2).

5.5.2 If the SMT part utilizes corner-applied adhesive which was not easily visible before, examine it now. Document the glue coverage per IPC-7095 or as determined between the lab and the customer.

5.5.3 Document the findings in lab notes and with photos.

5.6 Clean any flux residue from around the SMT solder joints using the appropriate flux remover.

Note: Isopropyl alcohol is not acceptable due to its inability to dissolve flux.

5.6.1 The sectioned part/board area should be submerged in liquid flux remover for at least one hour. The goal is to fully remove the flux residue. The exact amount of time the part/board is submerged depends on the sample conditions.

5.6.1.1 Approximately two to three times during soak, gently swirl the beaker containing the sectioned part for at least 20 seconds. This will aid the flux solvent in removing the flux ring residue.

5.6.2 Reworked samples may require additional time in the liquid flux remover.

5.6.3 Examine the sample under a microscope to determine if additional time is needed to remove the flux ring.

5.6.4 After using the liquid flux remover, use a spray can flux remover to thoroughly flush all four sides of the component.

5.6.4.1 Removing all flux residues and other particles/oils enables the dye to penetrate the fractures.

5.6.4.2 Failure to completely remove the flux from around the solder joint will prevent dye penetration and give false indications of a good solder joint.

5.7 Use low-pressure compressed air to blow off excess flux solvent.

5.7.1 If desired, perform a final rinse with isopropyl alcohol or acetone at this time.

5.8 Pour the dye into a small tray until the sectioned sample is completely immersed in the dye.

5.8.1 If dye is being reused, ensure it has sufficient viscosity. Viscosity is critical to the ability of the dye to penetrate into cracks within the parts being dyed. If there are any concerns with dye viscosity, discard the old dye and use fresh, new dye.

5.9 Place the tray containing the sectioned sample into a vacuum chamber.

5.9.1 Draw a 67.7 kPa [20 in Hg] vacuum for three to four minutes.

5.9.2 Partially vent and then reapply vacuum to the chamber to aid in dye penetration.

5.9.3 Leave the part submerged in dye for a minimum of 30 minutes with a constant vacuum of 67.7 kPa [20 in Hg].

5.9.3.1 Do not exceed 67.7 kPa [20 in Hg] of vacuum at any time, or the dye will start to boil off.

5.10 Vent the vacuum chamber slowly and remove the sample from the tray.

5.10.1 Allow the excess dye to drain off the sample.

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5.10.2 Use low-pressure compressed or canned air to gently flush any remaining dye from under the part until no further dye runs out.

5.10.3 Dry the sample in an oven, not to exceed 100 °C or as appropriate for the sample. If possible, allow the part to dry overnight at ambient conditions. Wet dye can smear during component separation, resulting in false conclusions.

5.11 Remove the sectioned part from the oven and allow it to cool.

5.12 Perform the pull operation to physically/mechanically remove the part from the board.

5.12.1 Abrade the surface to allow for an improved bonding of the structural adhesive.

Example: One way to perform this is to use a small piece of coarse-grit sandpaper to lightly sand and roughen the part top surface. This will remove the dried dye and will allow the top surface to bond with the anchored tee nut.

5.12.2 Bond the tee nut to the top of the part using structural adhesive. Allow the structural adhesive to cure.

5.12.3 Use a pull-test fixture with a uniform tensile force to separate the part from the board.

5.13 Examine the board and component for dye indications. If necessary, gently dust with canned air or dry, filtered and regulated compressed air to the separated part to clear away pull debris (flakes of dye, solder mask, etc.).

5.13.1 Any fractured interface that was present will be stained with dye. Usually, both sides are stained in a common (mirrored) pattern.

5.14 Take photos of dyed regions and plot results as agreed upon between the lab and the customer.

5.15 Test Report Include the following (or as agreed upon between the lab and the customer):

- Initial visual observations (see 5.2 and 5.5)
- Dyed interface separation location
- If required, dye indication amount/percentage (acceptability criteria to be determined between laboratory and customer)

Other items that can be included in the test report include:

- Mapping of all separation locations

6 Notes/Figures

The figures in this section are included for informational purposes only. They do not depict a correct or incorrect method for conducting this test method.

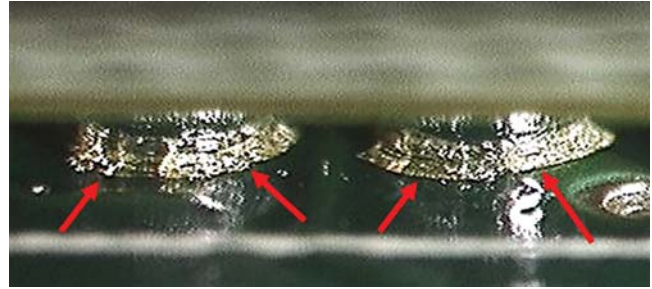


Figure 1 Ball Grid Array (BGA) With Disturbed Flux, Indicating Possible Solder or Laminate Fractures

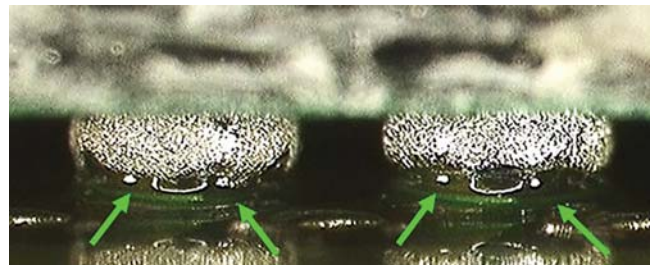


Figure 2 Ball Grid Array (BGA) Without Disturbed Flux

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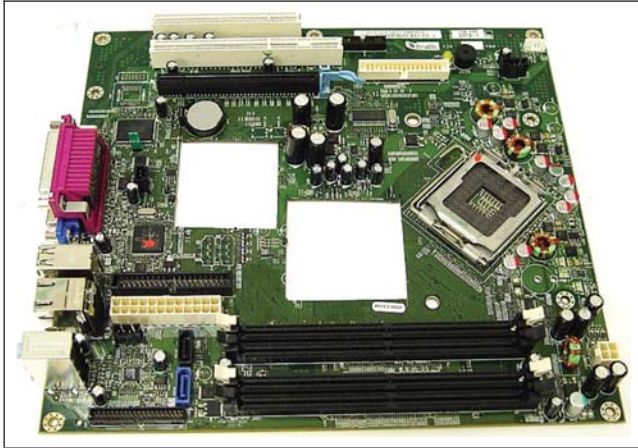


Figure 3 Sample Areas Cut Away From the Board

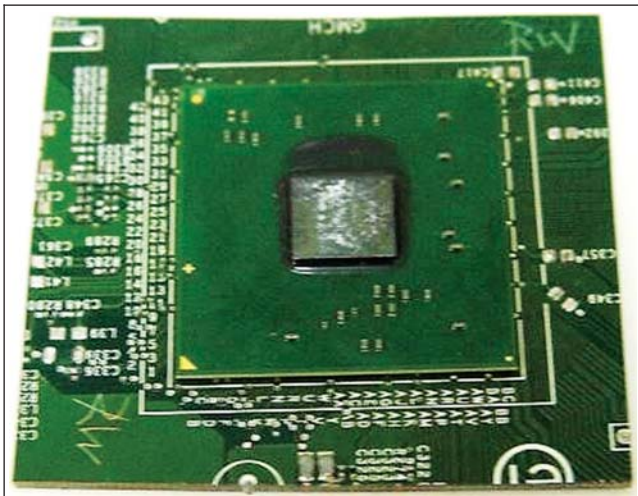


Figure 4 Sample Area Cut Out From the Board Shown in Figure 3

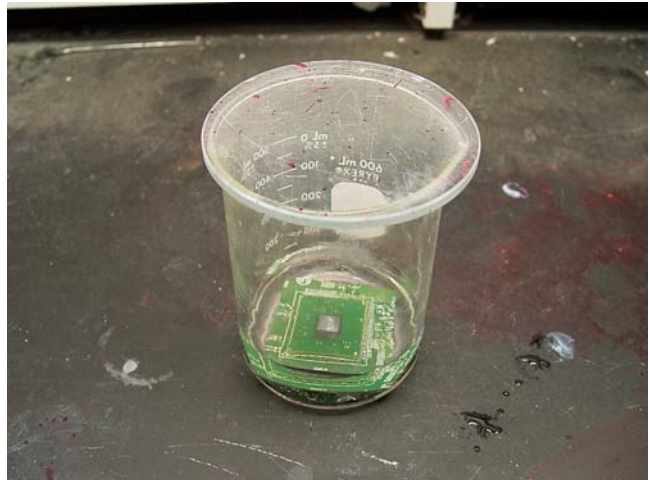


Figure 5 Sample Being Submerged and Cleaned in Liquid Flux-Removing Solvent



Figure 6 Sample Being Cleaned With Spray Flux Remover After Liquid Cleaning

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Figure 7 Dye Vacuum Station – Sample Completely Submerged in Dye

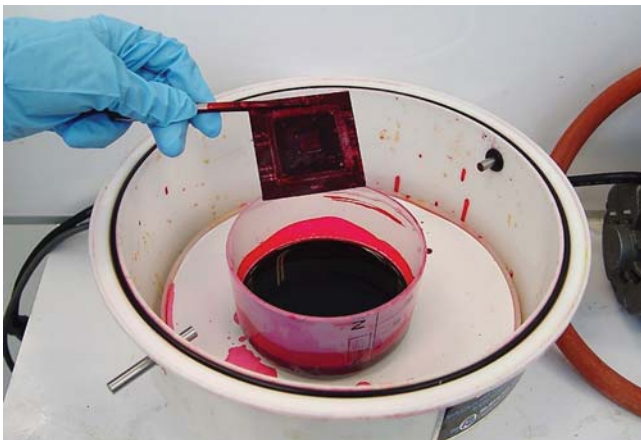


Figure 8 Sample Being Removed From Dye

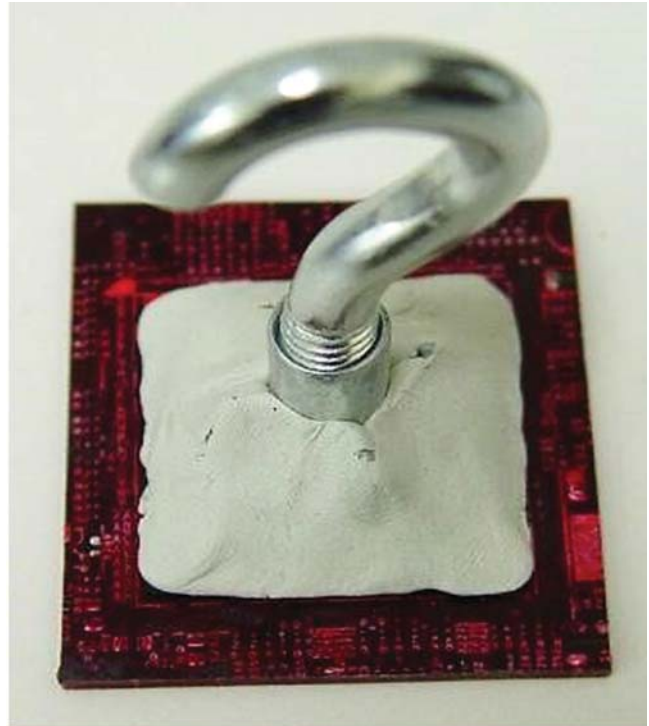


Figure 9 Sample Prepped With Tee Nut, Pull Hook and Molding Compound (Top) and Examples of Tee Nuts (Bottom)

Note: Sample is ready for pulling.

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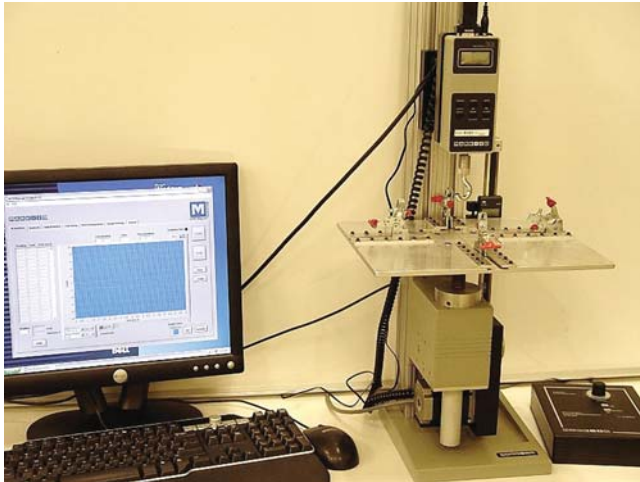


Figure 10 Example of Pull Method to Remove the BGA From the Board

Note: These photographs are for reference only and should not be construed as implying that a measurement is being made in accord with this method.

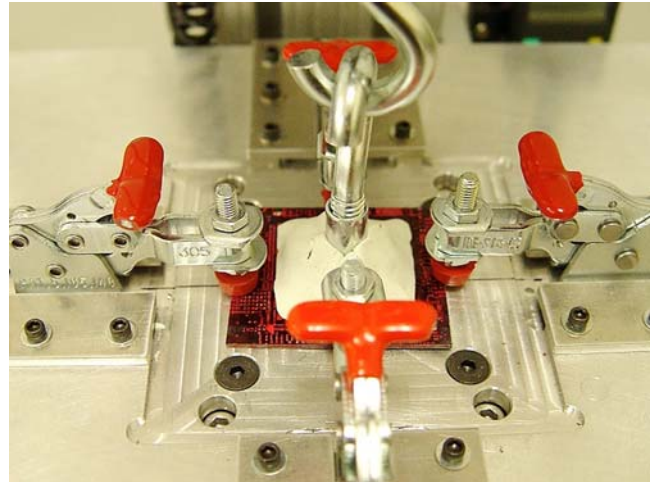


Figure 12 Typical Pull-Test Fixture With Stage Clamps

Note: These photographs are for reference only and should not be construed as implying that a measurement is being made in accord with this method.

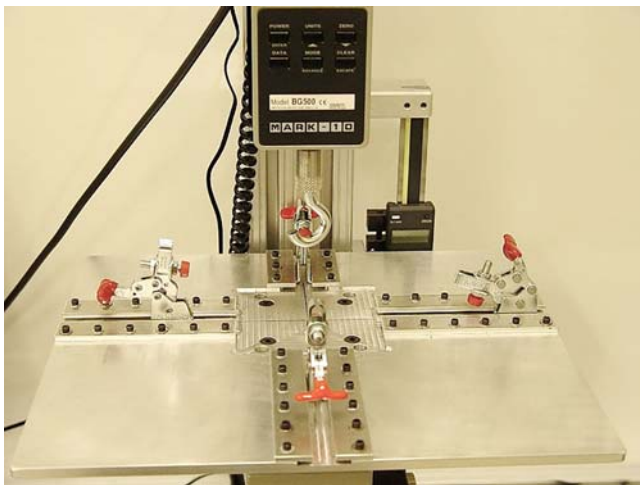


Figure 11 Example of a Pull Tester Stage and Clamps

Note: These photographs are for reference only and should not be construed as implying that a measurement is being made in accord with this method.

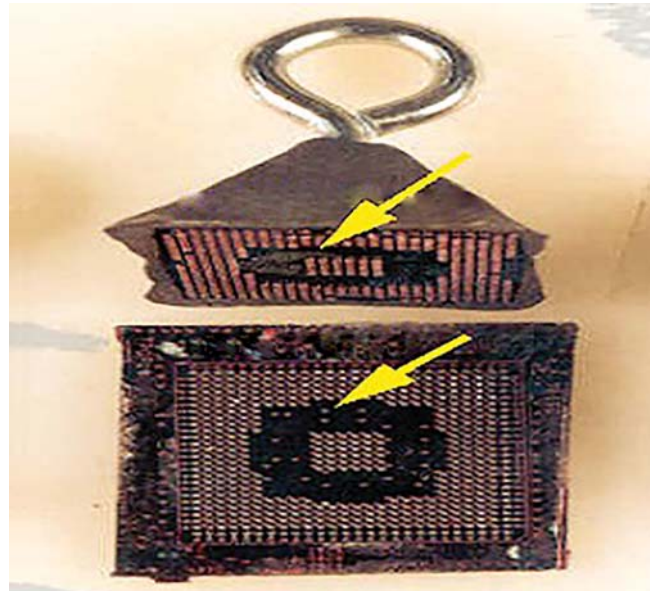


Figure 13 Example Showing Ball Grid Array (BGA)/ Part (Top) and Remaining Board (Bottom)

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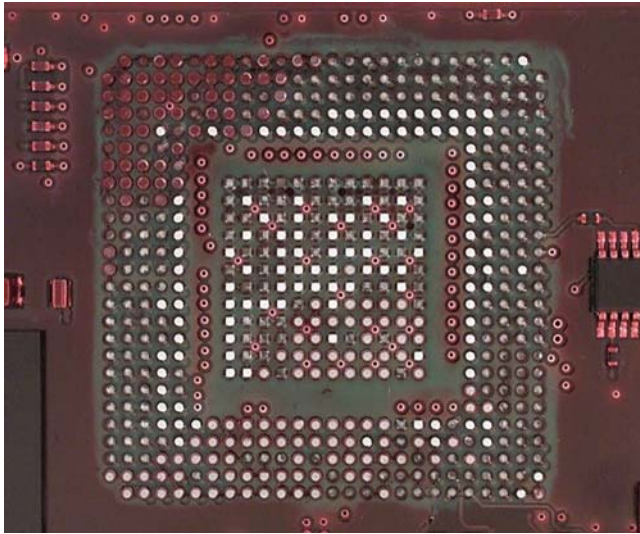


Figure 14 Mirrored Dye Indication Following Pull – Board Side

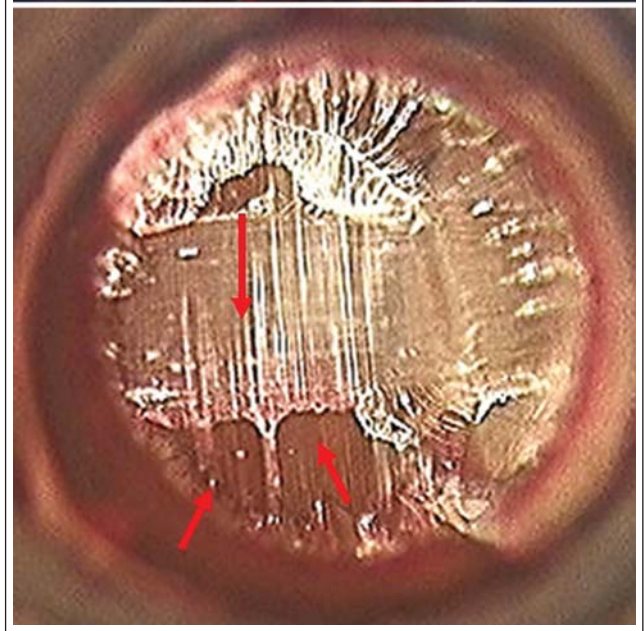
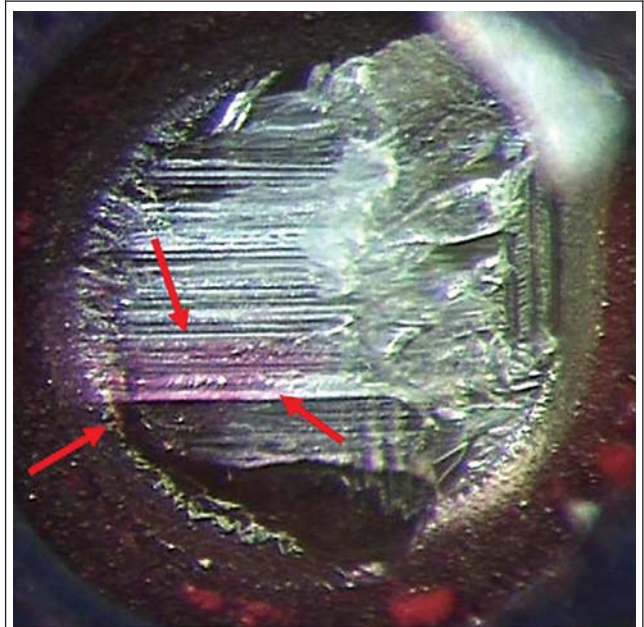


Figure 16 Examples of Board Showing Laminate Fractures (Pad Cratering)
 Note the faint (pink stain) red dye indication.

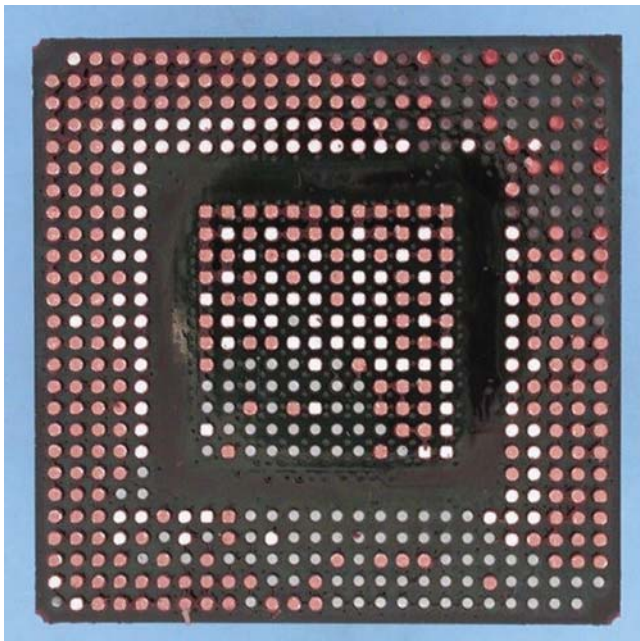


Figure 15 Mirrored Dye Indication Following Pull – Part Side

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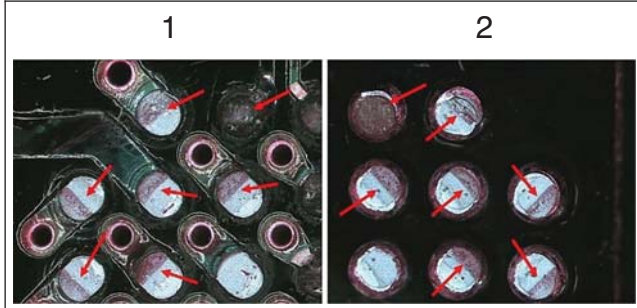


Figure 17 Example of Separation Surfaces After Component Removal

- 1. Board side
- 2. Part side

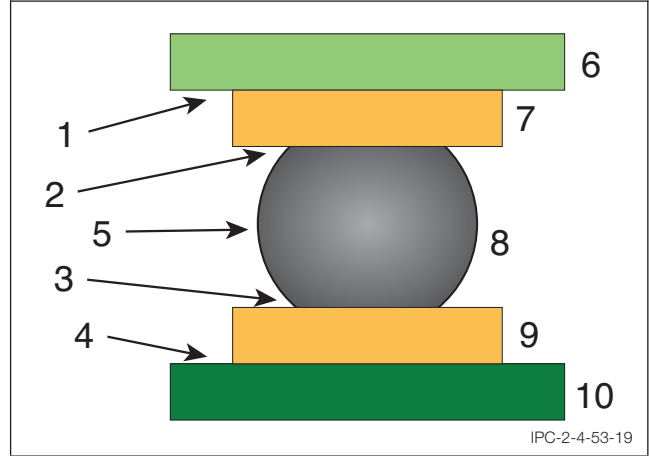


Figure 19 Example of Dye and Pull Location Type

- 1. Type 1X
- 2. Type 2X
- 3. Type 3X
- 4. Type 4X
- 5. Type 5X
- 6. BGA substrate
- 7. Copper pad on BGA
- 8. BGA solder sphere
- 9. Copper pad on board
- 10. Board laminate

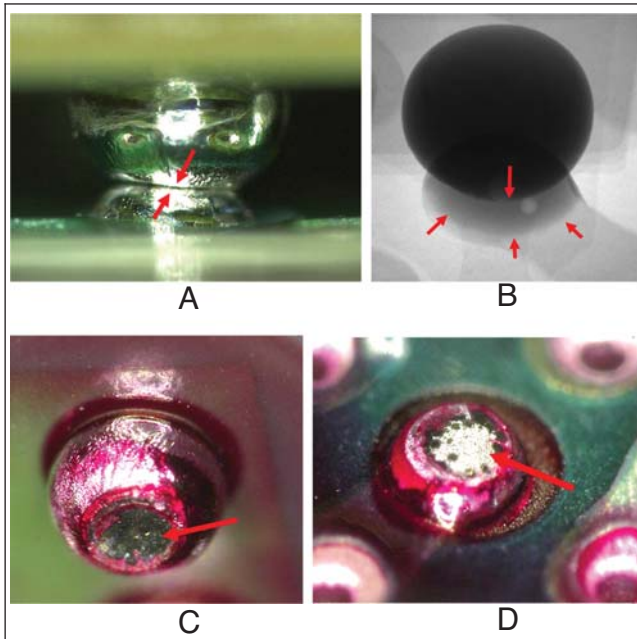
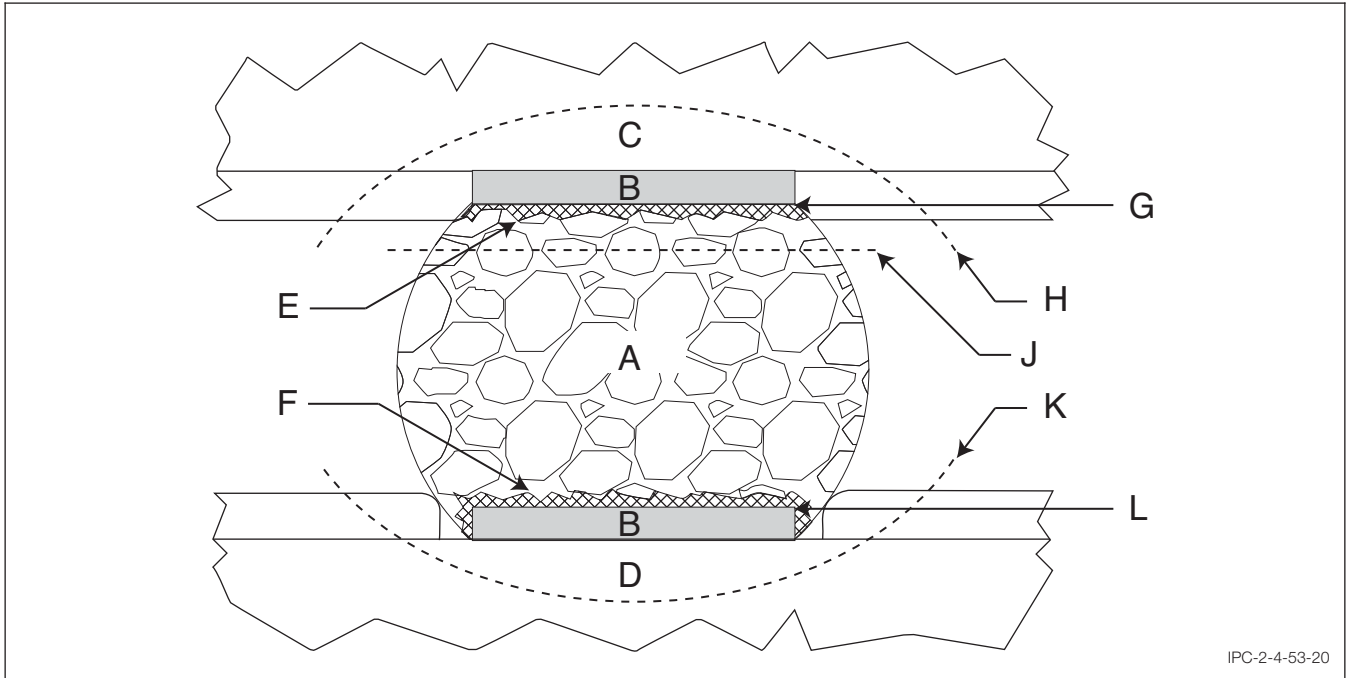


Figure 18 Examples of Head on Pillow (HoP) Failures

- A. Optical; IC carrier side on top and board side on bottom
- B. X-ray image
- C. Post dye and pull; IC carrier side
- D. Post dye and pull; board side

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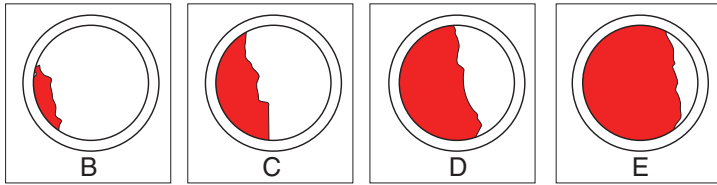


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Figure 20 Typical Dye and Pull Separation Locations

- A. Solder ball
- B. Metal pad
- C. Package substrate
- D. Board
- E. Fracture at package side intermetallic compound (IMC)/solder interface
- F. Fracture at board side IMC/solder interface
- G. Fracture at package metal/IMC interface
- H. Package pad lift/crater
- J. Fracture within bulk solder
- K. Board pad lift/crater
- L. Fracture at board metal/IMC interface

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- A = 0 %
- B = 1 to 25 %
- C = 26 to 50 %
- D = 51 to 75 %
- E = 76 to 100 %

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
A	X															2B	4B	3D	3E	X
B																		3B	2B	3D
C																			3B	2D
D																				2B
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Figure 21 Example of Dye and Pull Location Type Coverage Mapping

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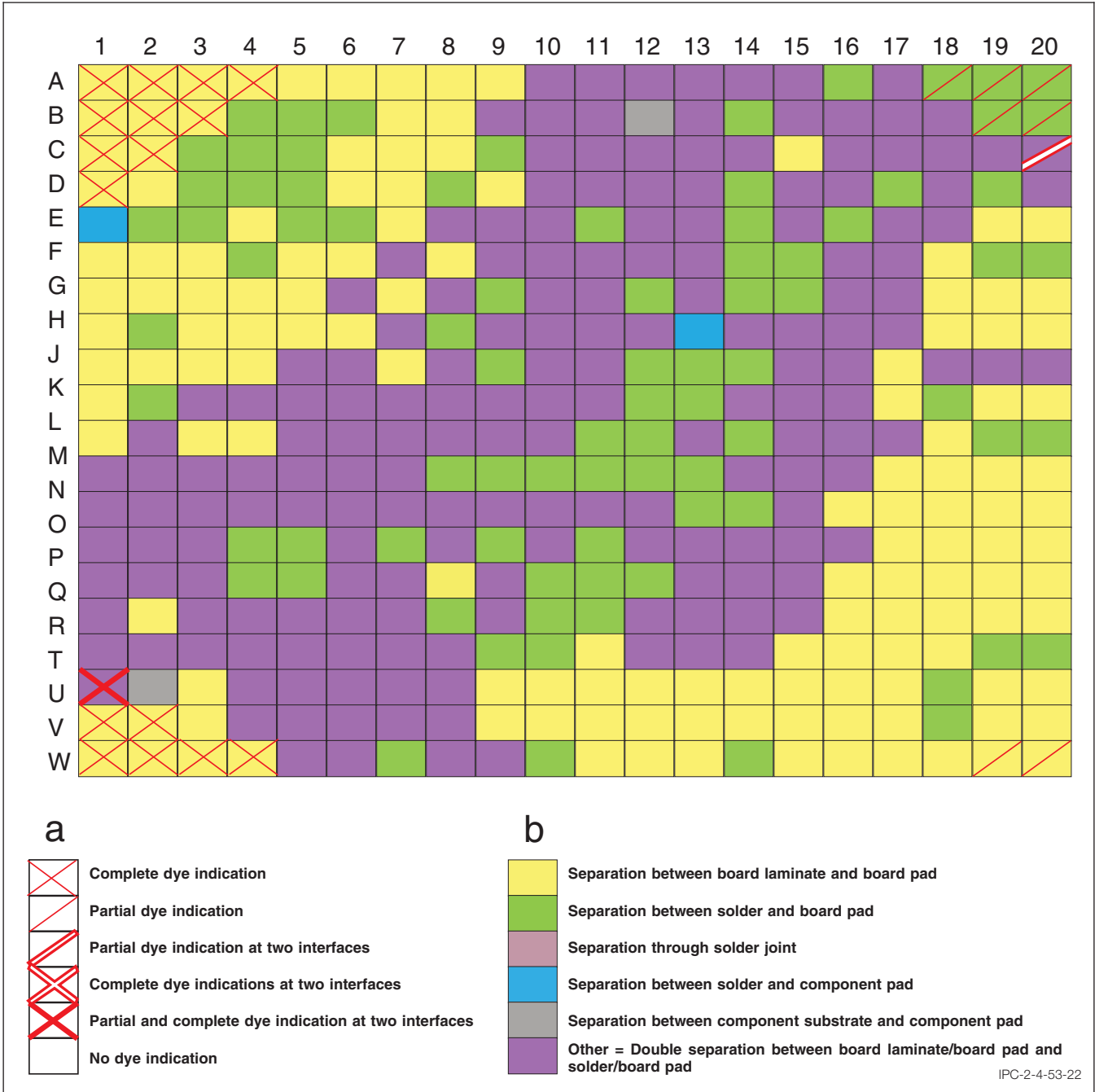


Figure 22 Second Example of Dye and Pull Location Type Coverage Mapping

- a. Dye indication type
- b. Separation mode

Note: The style of mapping in Figure 22 depicts every solder joint within the component by a color-coding system. Dye indications are then additionally indicated by a red slash or "X" at each joint location as needed. Mapping components in this manner allows for quick evaluation of the weakest interface of every solder joint and the location of any dye indications.