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Auditing Contract Manufacturing Processes

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Introduction

DfR has investigated multiple situations where an OEM is experiencing quality issues. In some cases, the problem occurs at their Contract Manufacturer (CM). In these situations, DfR, with our extensive background in manufacturing, is requested to perform an audit of the CMs/OEMs (Original Equipment Manufacturer) manufacturing facility to identify where the defect is being generated. This white paper identifies the activities that are typically explored in such an audit, why each particular operation is important, and what some of the commonly occurring defects are at each specific operation.

Process

These sections of the white paper identify the steps in a typical SMT manufacturing flow and why they are audited.

Procedures

Specific operational procedures must be available at all steps of the manufacturing process. Standard Operating Procedures (SOP) must also available to review. Weekly maintenance logs identifying what procedures are performed on all systems to ensure the highest performance must also be available.

Operator training data and all ISO-9000 procedures should also be available for review.

Handling of Received Parts and Circuit Boards

At this stage, the audit verifies the way that bare printed circuit boards are received from the supplier. Depending on the surface finish, boards may be received in sealed or even moisture barrier bags with desiccant to protect them from oxidation and moisture.

Component handling also addresses the Moisture Sensitivity Level (MSL) of the components to ensure proper storage and handling on the manufacturing floor. MSL parts must be baked according to the requirements when exposed longer than allowable times. If parts are received in sealed packages, then baking does not need to be performed unless parts are left open for longer than the specified time.

In addition to controls on the the manufacturing line, ESD measures must be implemented at these incoming operations. To help control ESD, the facility should be maintained at a 35-40% humidity level. If paper is used at work stations, it should be placed in ESD bags so it can't generate any static. All operators should wear two heel straps and one wrist strap when seated at a workstation. Ideally, all operators wear ESD smocks over their clothing as well. Heel strap testers can be used to ensure that the heel straps are functional before going onto the manufacturing floor. If possible, the floor in the entire manufacturing area should be a special conductive floor to further minimize ESD.

Solder paste storage must also be audited. This includes evaluating the refrigeration method, the storage temperature, the length of time paste is out of the refrigerator before it can be used, expiration date, and the method for refrigeration after use.

Screen Printing

Screen printing accurately and consistently provides the correct volume of solder paste onto each pad and is a critical operation. See Figure 1. The audit process inspects the method for dispensing paste onto the stencil, how paste is replenished, how long is it left on the stencil and how is it disposed of.

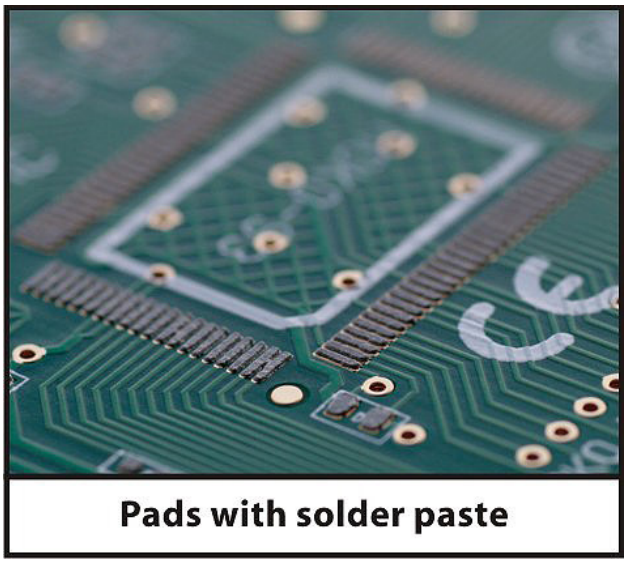

Figure 1- Typical Solder Paste Print

In addition, the method for inspecting the print is critical. In some cases, this can be accomplished using the screen printer technology; but frequently, it is a separate piece of equipment, such as a Cyberscope.

If a misprint occurs, the board must be cleaned manually using wipes, run through a wash and the apertures are simultaneously cleaned in the stencil to ensure the next print. Auditing this operation is vital.

DfR also audits the characteristics of the stencil apertures to identify if sufficient solder paste is being placed on the pads to ensure optimum solder joints without causing bridging. A typical stencil is shown in Figure 2.

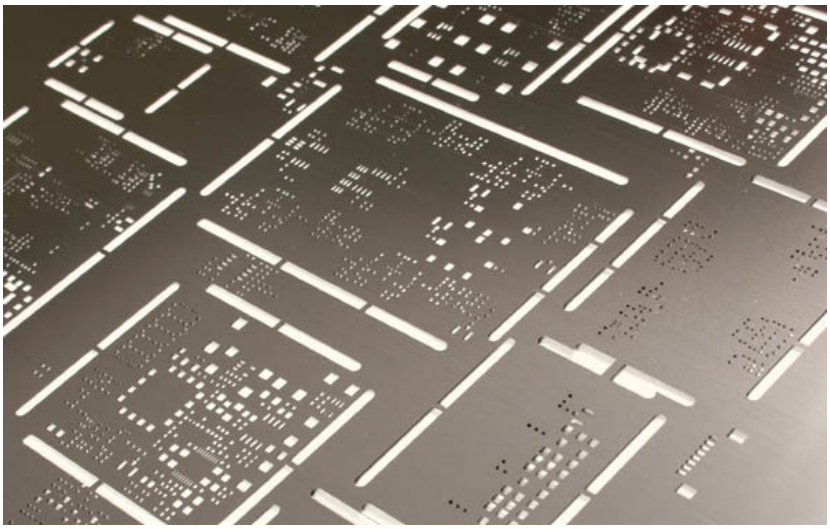

Figure 2– Typical Stencil Showing Apertures

Pick and Place

Pick and Place robotics can take many forms, from table top units to multiple in-line systems. The audit must address the procedures for feeder loading and verification and then first article inspection to ensure that all placements are as programmed. Placement accuracy for the product requirements must also be verified.

For area array parts, the vision system operation must be verified to ensure that all balls on BGAs are present prior to placement. Figure 3 illustrates this concept.

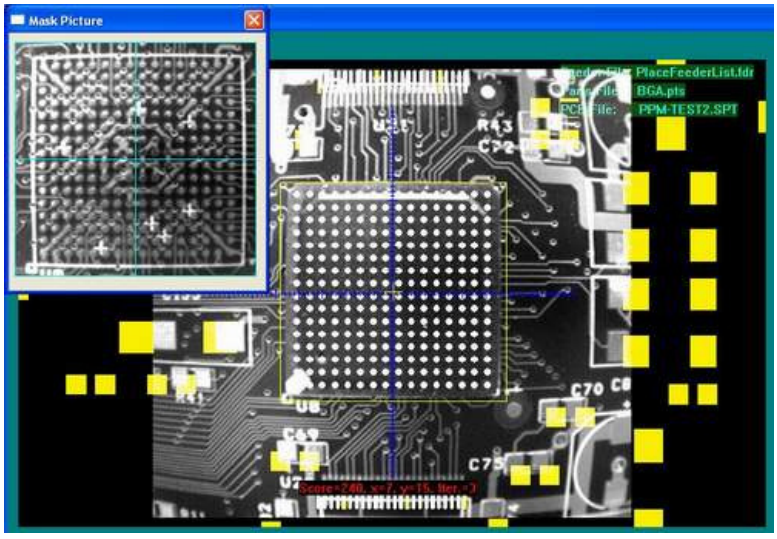

Figure 3– BGA pads on Board and LookUp View of Bottom of BGA Package

DfR also looks at the methods used for line balancing as that can impact the overall process flow and exposure of the solder paste.

First Article Inspection/Visual Inspection

The audit examines how the first article visual inspection is performed, (e.g. microscope, standard visual with no magnification, 3X ring light, Automated Optical Inspection (AOI) etc. as each approach has its limitations. Also, who performs the inspection – is it a line operator, QA inspector, line lead, or variations of all three.

Solder Reflow

This operation is also critical. The audit addresses the number of zones in the reflow oven as this plays heavily into whether the system can successfully process Pb-free assembly. In looking for potential problems, the reflow profile is audited to ensure compliance with the solder paste formulation. The profile should have pre-heat zones, ramp and soak zones, reflow zones, and a cool down zone for optimum operation. DfR also audits the degrees C per second change in the ramp up and down rates to reduce the possibility of flux burn off prior to entering the reflow zones and thermal shock on exiting the oven. **Figure 4** shows a typical Pb-free profile that must be properly mapped to the number of zones in a reflow oven to be effective.

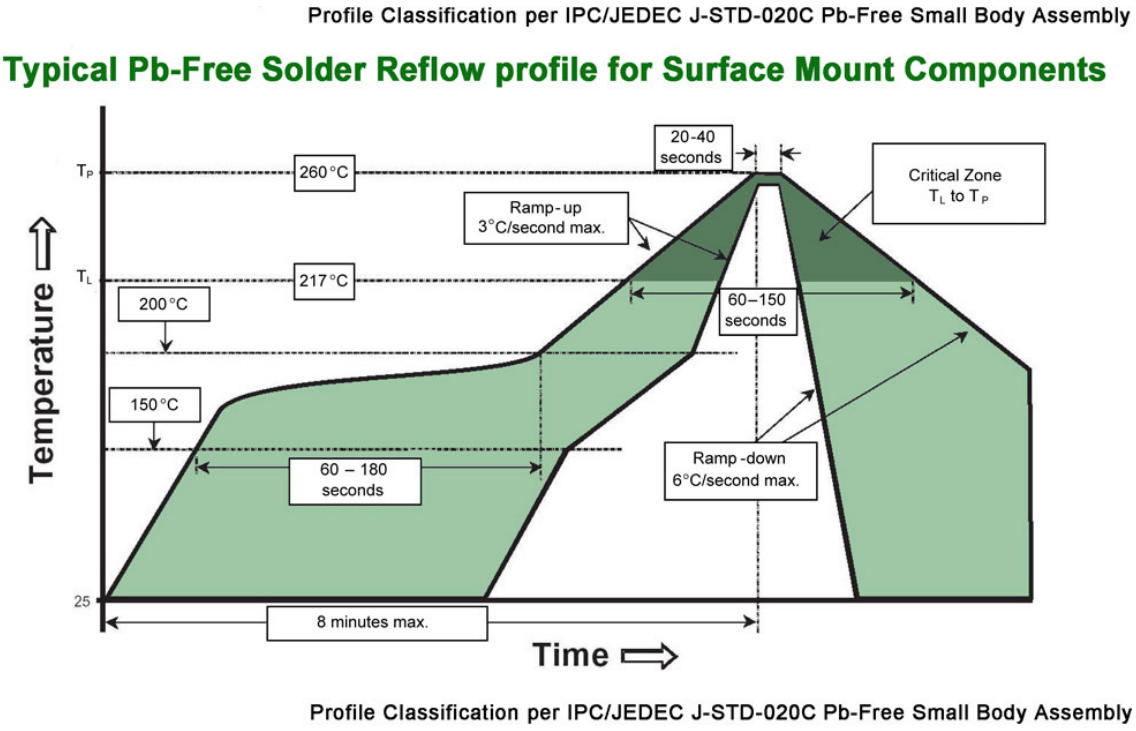

Figure 4– Typical JEDEC Reflow Profile.

DfR also audits how the various profiles are stored and specifically identified. Improper identification can result in the selection of the wrong profile for a specific circuit board.

Cleaning Systems

DfR audits the temperature of the cleaning system, with a preference for 140-150F for optimum cleaning. We also audit the way that deionized (DI) water is brought to the system and recycled, (e.g. reverse osmosis system). We observe the resistivity of the system to see if the CM is controlling the cleanliness of the wash system properly. If cleaning agents are used, the concentrations and process controls for them are verified. Nozzles or jets are evaluated for impingement angles and pressures. PCB spacing and speeds are reviewed for conveyorized systems. Finally, any material handling equipment used in the process, such as baskets or fixtures, are evaluated.

X-Ray Inspection

Most CMs have a 2D X-Ray system. DfR audits the extent that this tool is used to identify manufacturing defects. For example, the CM must recognize the limitations of x-rays systems. They are capable of identifying shorts under components and gross defects such as missing balls under BGAs, yet are not capable of identifying horizontal cracks in the solder joints. Figure 5 is an example of what can be observed with a 2D X-Ray.

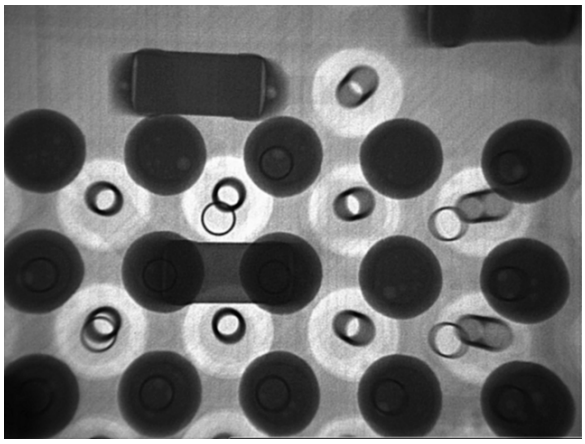

Figure 5– Typical 2D X-Ray

Automated Optical Inspection (AOI)

Most CMs perform Automated Optical Inspection (AOI) next. These systems can be programmed to verify polarities and orientations on components and also to verify the markings on most components. They are not capable of performing a good evaluation of the quality of all of the solder joints on the board. So, this operation should be followed by a 100% visual inspection of the solder joints. The audit determines the extent of this operation and whether it is being utilized properly.

Through-Hole Component Insertion

Typically, through-hole components are hand inserted and soldered although some facilities do have automated placement equipment. Through hole parts are soldered using different solder and flux formulations from the reflow process. The audit must verify that these materials are

compatible with the overall process, particularly an aqueous wash. It is also necessary to audit the solder tip selection and solder iron temperature if hand soldering is performed..

DfR recommends the following general hand soldering tips:

- Use a soldering iron with great thermal recovery - the lower the soldering temperature and the larger the tip, the less heat loss
- Use a high power soldering iron
- Use the largest tip commensurate with the size of the joint being soldered
- Typical tip temperatures for Pb-free solder are ~700F with 2-5 sec contact time. Higher temperatures can damage boards and components.

Secondary Operations

The audit should also address all secondary operations. This element of the audit could encompass operations such as press fit connector installation, mechanical assembly and conformal coating.

For press fit connector operations, the fixturing should be audited to ensure that the deflections being caused by the operation are minimal. Adequate board support and force control should be present.

Singulation is also audited to ensure that the process does not cause any undue deflection of the PCB during the process. Singulation can be accomplished using "mouse bites," a pizza cutter arrangement on V-grooves, simple breakaways or by being routed.

Mechanical assembly can encompass the addition of screws, brackets, heatsinks, spring loads or other types of mechanical support. Overstresses can be applied through excessive torque, through the loads placed by springs, and through the weight and placement of heatsinks. All need to be audited to ensure a robust mechanical product.

A conformal coating operation, whether spray, dip or brush should be audited to ensure full and proper coverage. This can be accomplished by inspecting under a UV light as the coatings fluoresce.

Rework

Any rework operations also need to be audited to ensure that the temperature profiles are not detrimental to the circuit board being reworked. Many CMs will use a higher temperature to perform this operation rather than mimicking the reflow profile. The higher temperatures can damage the circuit board if the Decomposition Temperature (Td) of the laminate is exceeded. As such, auditing the profile and contact time is essential.

Test Operations

Test can take on many forms(functional, flying probe, in-circuit). DfR audits these functions to ascertain the coverage in each test with respect to the circuit. We also look at the pogo pin configuration as we know that improperly placed pins can cause enough deflection in the PCB to damage solder joints. Figure 6, an image using DfR's Sherlock software, shows the distribution of

deflections as a function of the pressure applied by the ICT test pins. Knowing of this issue at the design stage is measurably better than determining there is a problem during an audit.

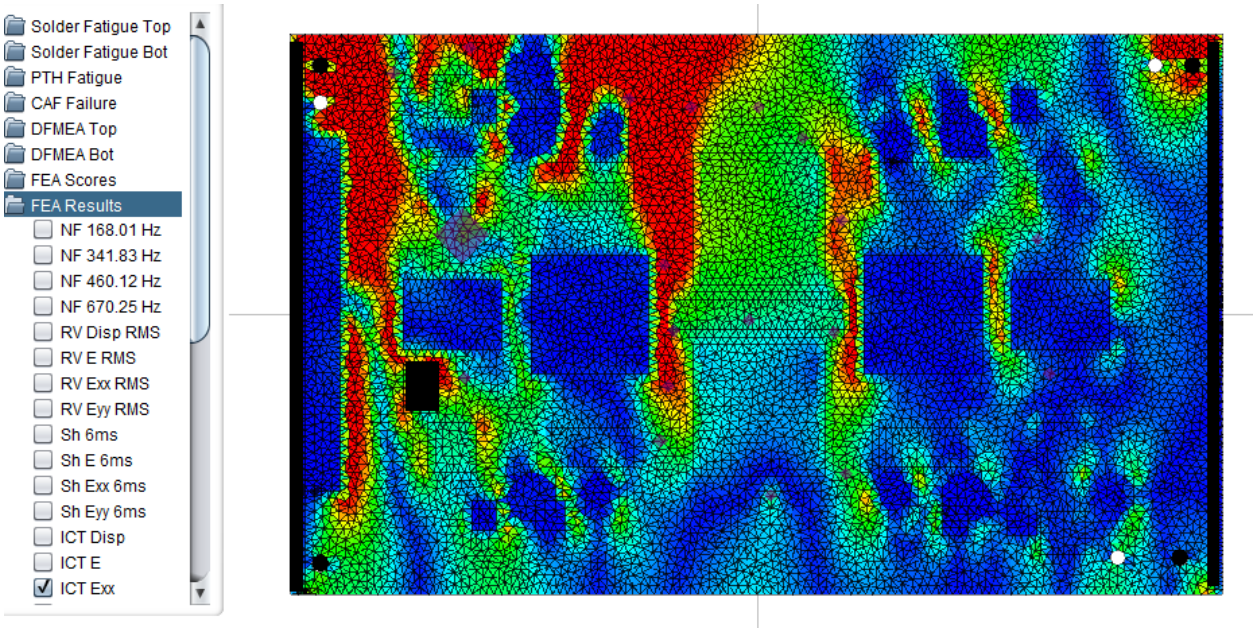

Figure 6– PCB Deflections from ICT Using DfR's Sherlock Software

Shipping

Proper shipping materials and methods are verified to ensure that failures are not induced after testing has been completed. Shipping documentation and labeling requirements are also reviewed.

Summary

This white paper has introduced a methodology for auditing a Contract Manufacturing facility, identifying what needs to be observed and audited, what the critical issues are, and how an audit can identify problems and move towards resolution.