SMT Process Qualification: What You Need to Know Beyond AOI & Co.

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AOI, X-ray, functional testing – all typical inline testing and inspection equipment. They allow nearly complete monitoring of the production process – based on pre-programmed decision thresholds. One thing is still done manually, however: the qualification and improvement of the production process.
This article presents an approach to comprehensive process qualification given the improvement potential in today's inspection environment.

	Detectability		
Method	Good	Satisfactory	Poor
ICT In-Circuit Test	Interruption Solder bridge Defective component Component value	Too little solder Missing component Fissured joint	Bent lead Positioning precision Entrapped air Cold solder joint
AOI Automated Optical Inspection	Bent lead Placement accuracy Solder bridge Missing component	Interruption Component value	Hidden solder joint Too little solder Entrapped air Cold solder joint
X-RAYS Laminography	Hidden solder joint Too little solder Entrapped air Interruption Solder bridge Missing component	Polarity	Defective component Component value Flux residue Fissured joint Cold solder joint

Table 1 Source: An Integrated Test And Inspection Strategy, David M. Mendez, SOLECTRON, Texas, IPC Proceedings of APEX, March 2000

The idea is simple: if we consider the production process, we see that modern production systems are generally capable of manufacturing quality constant within a certain tolerance range, by means of correctly adjusted process parameters.
Qualifying a production system proves more difficult, however. Qualification depends on the ability to detect souces of faults, to register the totality of all possible faults, and to assess the effects of these faults.

Insufficient qualification of the process can be the consequence of the inadequate detection of the possible causes of faults. The process then lies in the borderline area. Merely those faults occurring during the setup phase of the inline equipment can be generally be taken into account for the process. Faults that are not or cannot be detected are potentially dangerous for the process, however. The consequence can be early failure of the affected subassembly – no rare occurrence, as unfortunately seen in the past. The affected company may suffer financial loss if the failure is covered by the warranty, or at least the company's image may be tarnished. In such cases process engineers were of the opinion that reliability data such as the PPM indicated a relatively high quality process – an erroneous conclusion, as it turned out.

The Goal: Comprehensive Process Qualification

Process qualification largely employs manual inspection mechanisms – generally the microscope. The reliability of process qualification then crucially depends on the
- available inspection equipment

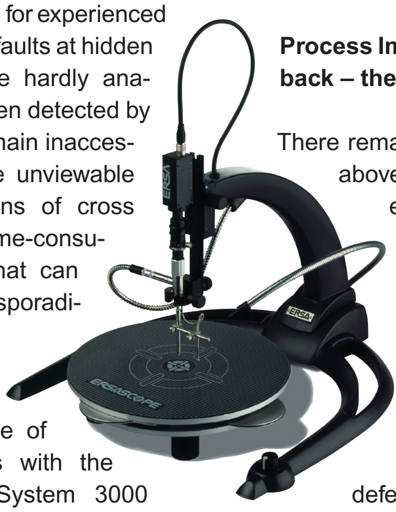
and the
- inspector's experience.

Both variables affect the reliability of process qualification and hence the quality of the process and the products.
As the producer of soldering and inspection systems, ERSA GmbH has been deeply concerned about these issues and has sought for solutions.

Available Testing and Inspection Equipment for Detecting Sources of Faults

Sources of faults cannot be detected without knowledge of the process itself. Take the soldering process, for example:
The current inline testing and inspection procedures are not capable of presenting a complete picture of all possible faults occurring in the soldering process, as Table 1 shows. For example, cold solder joints, fissured connections and flux residues remain largely undetected. According to analyses by Stig Oresjo of Agilent Technologies, inadequate solder joints make up nearly a fifth of all soldering faults (Year 1999 Defect Level and Fault Spectrum Study).

The good/poor decision thresholds defined for the inline inspection equipment in the setup phase are in turn based on incomplete information about faults. While the classical microscope is generally used as a support for inspecting fault phenomena more precisely, this inspection technology must keep pace with the rapid trend towards miniaturisation: greater and greater magnification is needed. The resulting new perspectives and types of faults become a challenge even for experienced inspectors. And faults at hidden solder joints are hardly analysable even when detected by X-rays. They remain inaccessible and hence unviewable except by means of cross sectioning – a time-consuming method that can be applied only sporadically.



ERSA supplements the range of inspection tools with the ERSASCOPE System 3000 (Fig. 1 in the top). The 90° optics of the system allows viewing of areas on the electronic subassembly that in the past were hardly accessible optically. The scope of performance includes both the consideration of hidden solder joints and the inspection of solder deposits through side views. The device can thus display faults not detectable by other procedures. Moreover, it is an indispensable aid for graphically representing suspected problems indicated by the other procedures. Fig. 2 shows a few ERSASCOPE images of faults detected by X-rays.

In combination with other systems, the ERSASCOPE thus forms a solid basis for uncovering fault types in the production process to the widest possible extent.

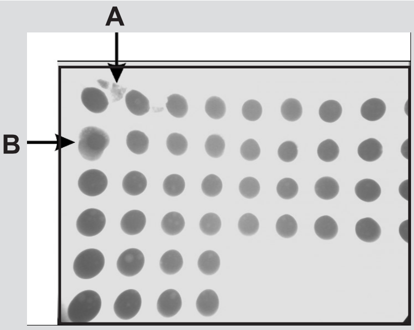
Process Improvement through Feedback – the Inspector‘s Experience

There remains the second issue noted above – the inspector‘s experience. Every wrong decision by the inspector means reduced profitability, either because the failure to detect faults leads to defective goods being prodced, or because there is a high rejection rate for subassemblies with non-critical defects. Repairs are costly, as is the manufacturer‘s reputation. The inspector thus bears a burden that should be alleviated. The subjective dimension of the decision-making process must be brought under control, if that process is to be objectively assessed.

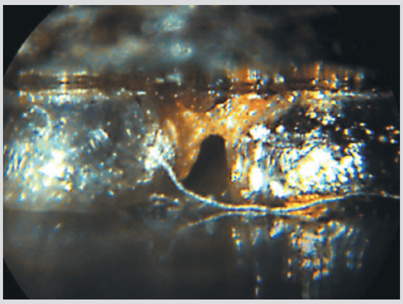
Inspection has basically just one goal: process improvement. Inspection assures that the current status quo of the process is coupled to the tasksetting of process improvement and hence quality improvement for the process in the future. And since this step is supposed to be comprehensible and reconstructible for future decision processes, complete documentation of the inspection results is equally necessary.

The process improvement comprises altogether the steps of fault detection, decision (good/poor), analysis, process modification, documentation and chekking. Deming already graphically represented this concept in the middle of the last century (Fig. 3). R.J. Klein Wassink & M.M.F. Verguld analogously state the requirements in their work on „Manufacturing Techniques for Surface Mounted Assemblies“ as follows: no inspection without documentation, no documentation without analysis, no analysis without action. But what does the practical approach look like for the SMT process?

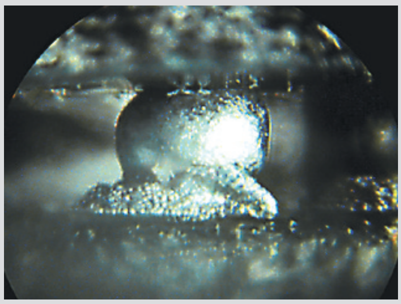
Taking the soldering process as an example, we encounter an immense range of distinctive soldering faults. Their structure, form, colour, etc. vary enormously. In particular with the solder balls of the BGAs and flip chips, the hidden solder joints, a criteria tree cannot be set up without undue expenditure that would allow automation of analysis.
The approach by ERSA GmbH with the quality assurance software for process qualification, ImageDoc 1.2, opts for decision-making supported by the following software structure:



X-ray image of PBGA 225: A and B show mistakes but are unclear of source



***A.** ERSASCOPE reveals flux residue bridge with conductive particles*



***B.** ERSASCOPE shows incomplete solder melt of paste.*

Fig. 2: X-ray image and explanatory ERSASCOPE views

The inspector retrieves good/poor examples, or reference images, stored in the system for the element under inspection (Fig. 4).

Comparing his inspection results with the reference images, he can easily reach an objective decision guided by the software.On the basis of this decision, the software displays to the operator the fault type at issue. The operator receives not only a definition of the fault, but also information on the effects of this type of fault as well as scientifically prepared background information (analytical step). The operator thereby increases his range of experience (training effect).

As an approach to finding a solution, suggestions are made to the operator for improving the process, so that he can effect the feedback to the process (Fig. 5). Finally, the inspection findings are documented and entered in the database, where they remain available for later applications. The latter could be a verification of a decision, statistical analysis or recording of the inspection results in the reference image list.

This hardware-software concept can be applied to all processes possibly involving faults difficult to detect because of the wide variety of forms in which they occur.
The structure of the software allows a separate database to be set up geared to the problems typically encountered by the user. Users can create, manage and expand their own reference image groups. The broader the basis of the information sources, the more objective will this inspection tool become. The system continually grows, and can always be supplemented with new fault types related to new technology, for example.

The software supplied by ERSA already contains, for example, a problem database with typical faults of the soldering process.

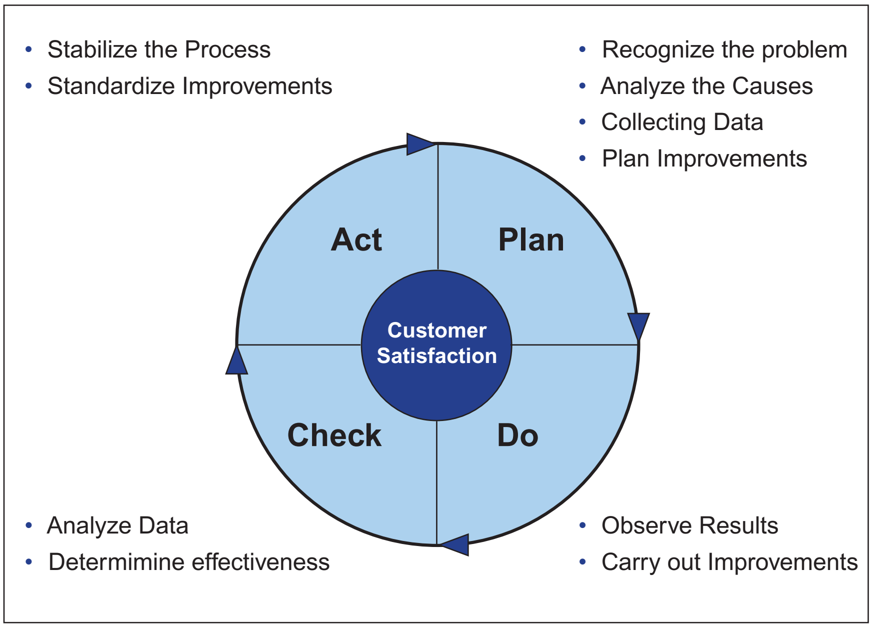


Fig. 3: PDCA cycle for process improvement acc. to W.E. Deming, 1950

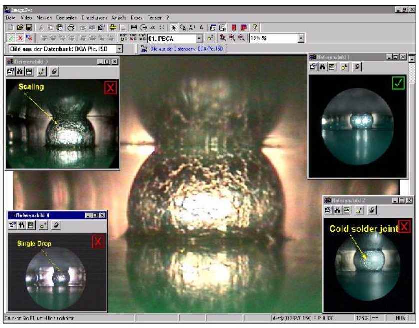


Fig. 4 ImageDoc 1.2 software:
Reference images for PBGA

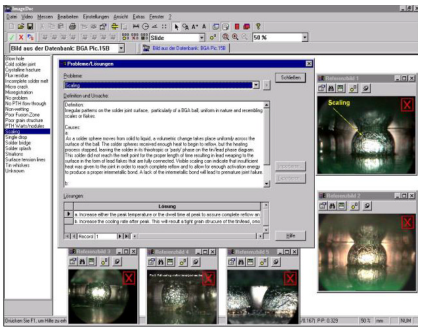


Fig. 5 ImageDoc 1.2 software:
Problem/solution description

Summary

The broad spectrum of applications allows ImageDoc 1.2 to be combined not only with the ERSASCOPE, but also with microscopes and X-ray equipment, for example. The consistent application of the structures contained in the software will always produce the desired results of a procedure appropriate to today's quality requirements on the inspection of production processes.
ERSA intends its products ERSASCOPE and ImageDoc 1.2 to provide the foundation for comprehensive process qualification, which together with the procedures of AOI, X-ray radiography and functional testing constitutes a combined testing and inspection strategy for state-of-the-art SMT processes.

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