Benchmarking of Factory Level ESD Control

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50 Words Abstract - A standard compliance of the factory level ESD control varies between organizations. We have audited twelve different factories during the 24-month benchmarking period. These audits were focused on the ESD control programs and the process control. The summary of results and examples of the best practices are presented in this paper.

I. Introduction

The requirements for establishing, implementing and maintaining an ESD Control Program are provided in ANSI/ESD S20.20 [1] and IEC 61340-5-1 [2] standards. Despite the normative requirements, there are many ways to establish ESD control in practice. Some organizations are focusing on the image meanwhile the others are considering more technical issues.

Certification bodies, distributors and consultants may have different aspects to highlight standard requirements. Therefore, original equipment manufacturers and contract manufacturers do not necessarily have the awareness of how an optimal ESD control should be established in practice. Without clearly expressed customer requirements, standards may also be ignored.

This study was launched to clarify the standard conformities in different organizations. On-site assessments focused on the control program and the processes control. Twelve organizations from Europe and Asia participated in the project.

Results of the study were primarily utilized for optimizing ESD control [3]. Product and process related information is confidential, but a summary of the results and conclusions is presented in this paper. General information can also be used to estimate process capability and readiness to handle ESD sensitive devices (ESDS). The information is required, if components will be more sensitive to ESD in future [4]. Outcome of the project may help organizations to improve their ESD control programs.

II. Benchmarking project

On-site audits of twelve factories were carried out each in a 2 to 4 day assessment period depending on the processes. At first the focus was on the standard compliance. The next step was a process assessment where the focus was on the critical path of ESDS instead of insignificant surroundings. Each audit included several process assessments e.g. in a surface mount assembly (SMA), final assembly, testing, and rework area.

A. Standard compliance

Assessment criteria were IEC 61340-5-1:2007 and ANSI/ESD S20.20-2007 standards. Requirements based on the standards were formulated to questions into an Excel based assessment tool. The questions were presented to each organization during the on-site audit. Assessments of standard compliance were mainly based on the answers, whereas some of the answers were audited in detail.

Nonconformities were categorized as a minor, major and critical instead of commonly used two-step classification in quality audits. ESD control may affect the costs related to the loss of yield, rework, quality issues and an image. In addition, inadequate material selections or improper control procedures may have impact to costs [3]. All the nonconformities were therefore evaluated with the same qualitative criteria:

MINOR	may not increase costs
MAJOR	may increase costs
CRITICAL	probably increases costs

In addition, answers were rated with the following criteria based on the estimation of actions needed for achieving both an optimal ESD control and 100 % standard compliance:

3 Actions are not needed
2 Actions may not be needed
1 Actions may be considered
0 Actions are recommended

The results were expressed as a percentage of the maximum possible score (three times the number of questions). The total number of questions was 63. The results of each organization under assessment were then compared with the minimum, maximum and average values of all factories under benchmarking. Consistence of assessment was ensured in each process step. All assessments were carried out by the same lead auditor.

1. General requirements

Statistics of ESD control program, ESD coordinator and tailoring completeness are presented in Figure 1. Squares in charts represent minimum and maximum values and a circle represent an arithmetic mean.

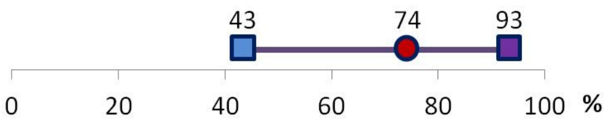

Figure 1: Completeness of general requirements

2. Administrative requirements

Statistics of ESD control program plan completeness is presented in Figure 2. Completeness of the training plan and compliance verification plan are shown in Figures 3 and 4.

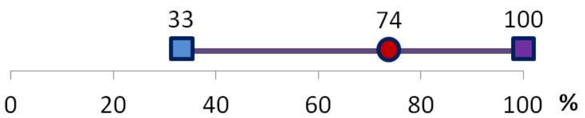

Figure 2: Completeness of control program plan

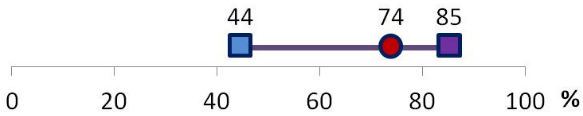

Figure 3: Completeness of training plan

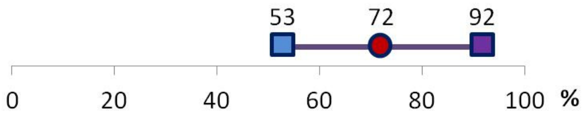

Figure 4: Completeness of compliance verification plan

3. Technical requirements

Completeness of groundings, personnel groundings, electrostatic protected areas, packaging and marking are shown in Figures 5, 6, 7, 8 and 9.

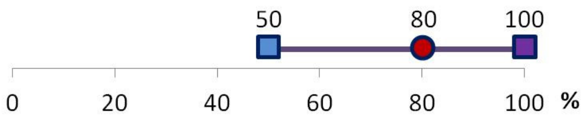

Figure 5: Completeness of groundings

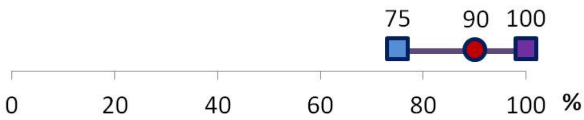

Figure 6: Completeness of personnel groundings

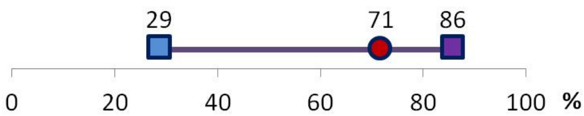

Figure 7: Completeness of ESD protected areas

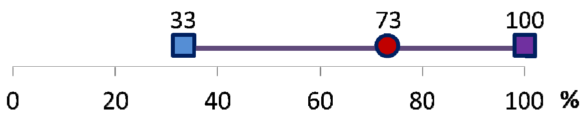

Figure 8: Completeness of packaging

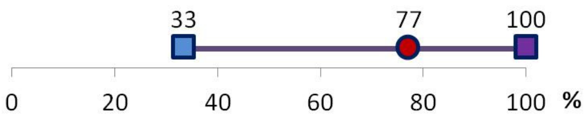

Figure 9: Completeness of markings

4. Summary of non-compliances

Statistics of non-compliances are shown in Figures 10, 11 and 12. Five critical non-compliances were reported.

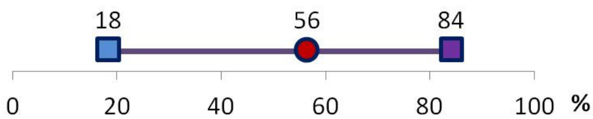

Figure 10: Pass

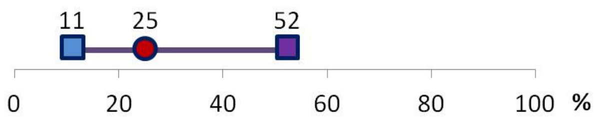

Figure 11: Minor

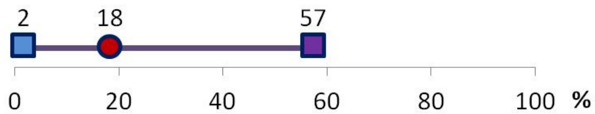

Figure 12: Major

Averages of the completeness of implementation varied between 49 % and 90 %. Overall score of twelve factories was 73 %. In general, improvements are needed for the training plan, compliance verification plan and electrostatic protected areas.

B. Process assessment

ANSI/ESD S20.20 [1] and IEC 61340-5-1 [2] standards do not necessarily provide detailed requirements for process control in all applications. In this benchmarking, a standard requirement is applied when possible. ANSI/ESD SP10.1-2007 [5] is also taken into account. In addition other known methods were used to assess process capability [6, 7, 8].

Twelve factories participated in the process assessment part of the benchmarking project. The following questions were presented during the on-site audits:

1. Do you have product or process specific requirements?
2. Does your control program plan cover automated processes?
3. Do you have a charged device model (CDM), charged board event (CBE) and/or cable discharge event (CDE) considerations in compliance verification procedures?
4. Can you monitor mobile charges and potential energies of ESD sources if necessary?
5. Is a critical path of ESDS parts defined?
6. Are the requirements and test methods defined?

Some of the answers were audited in detail. All the answers were evaluated with the same qualitative criteria.

1. Technical requirements

The state of process control, based on the enquiry, is shown in Figure 13.

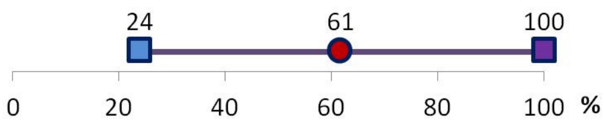

Figure 13: State of process control

Eight factories out of twelve did not have process monitoring in a critical path of ESDS parts.

2. Process measurements

Ten factories out of twelve participated in the process measurements. Process evaluation was the most difficult part from the benchmarking point of view. ESD risks depend on both products and processes. Therefore, the processes were assessed with the quantitative criteria based on the product specific requirements. Number of nonconformities was compared to the number of observations. If the standard limit or a product specific limit is exceeded, the observation was recorded as nonconformance.

Generally, manufacturing processes cannot be classified safe based on the measurements, if the product, process or environment is changing after the assessment. For example, a surface mount assembly (SMA) line can be safe for one product, but it may cause defects to another product. In addition, contact electrification is generally unpredictable in nature.

Measurements were focused on the critical path of ESD sensitive devices (ESDS). Electrostatic fields (E-fields), surface potentials and electrostatic charges were measured from the products in a running process. ESD-based electromagnetic interferences (EMI) were captured with a loop antenna and an oscilloscope. In addition, groundings of ESD control items were measured by random inspection.

The results of different products and processes are not comparable. Non-compliances based on the case specific requirements and quantitative measurements are shown in Figures 14, 15 and 16. Six critical non-compliances were reported.

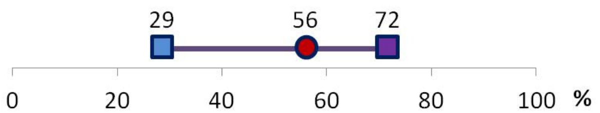

Figure 14: Pass

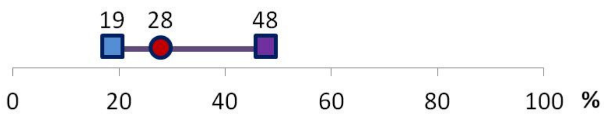

Figure 15: Minor

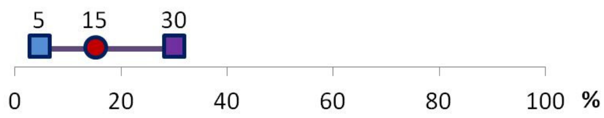

Figure 16: Major

III. Summary of observations

ESD control practices varied a lot. Some of the facilities had been audited and certified by third party before the assessment project. Certification obviously improves the image of the organization, but it didn't noticeably affect the real technical implementation of ESD control. For example, in some facilities information screens, certificate boards, access control systems, leaflets and area boundaries were impressive from the visitor point of view, but the real control actions did not reach the critical path where ESDS are handled.

Statistical uncertainty was too high for comparison between Europe and Asia regions. Suggestions for improvements were provided in both regions. Some of the most important subjects and best practices are discussed in the next chapters.

A. ESD control program plan

Only few organizations had an existing "plan", but standard requirements were mainly defined in other documentation. Some organizations provided ESD control instructions for personnel, but administrative and technical requirements of standards had not been defined.

There are two main challenges for establishing ESD control program: The flexibility of standards and the management of change.

Control program managers and ESD coordinators should be able to make optimal definitions in the plan. For example, a copy paste strategy may result in expensive and ineffective actions. Misconceptions and worst practices may also be copied accidentally. Therefore, a control program plan should be based on the organization's own needs and requirements. Standards provide excellent flexibility to optimize investments for technical ESD control [3]. Sample programs should not be used. Instead, standard requirements should be followed step by step.

B. Ownership of ESD control

Generally, organizations do not have requirements for ESD coordinators or program managers. Optimal control requires ESD awareness, but an image oriented ESD control can be established without education.

Basic English skills should be required, because standards and other relevant documents have not always been translated into local language. The ESD coordinator or program manager should also be able to communicate in audits.

One of the best practices is to allocate all the responsibilities of ESD control to the quality and reliability organizations or to the management instead of maintenance.

Quality and reliability engineers having adequate awareness of ESD control are able to optimize ESD control from the products and process point of view. They are also able to prevent unnecessary investments related to product quality. Implementation work can be allocated to the maintenance or other similar organizations.

C. Training plan

A comprehensive training can be included in the plan for production personnel, but responsible persons who are making the decisions may not always be taken into account. A training plan should also be established for ESD coordinators, program managers, quality and reliability engineers, production engineers and personnel of procurement.

Generally, all the necessary information for production personnel can be shared in introductory briefing. An adequate refreshing training can be provided in minutes instead of hours. Oppositely, ESD coordinators and program managers should allocate several days for initial training. They must also keep themselves updated to ensure optimal decision making in technological development. An advanced level technical training shall be provided before establishing ESD control program or before other remarkable updates.

Management should also be aware that achieving professional skills in ESD control may take years. It is a common misconception that participants are ESD experts after two days training. In the optimal training plan, the content of the initial and refreshing training is carefully considered for different target groups. It is also challenging to keep competence on the adequate level if responsibilities are changed recurrently.

If the organization is small and there are no resources to establish an optimal control program, outsourcing possibilities may be considered.

D. Product qualification

Qualification practices of ESD control items were not clearly defined in compliance verification plans. Missing qualification may become expensive for organization. Remarkable cost savings can be achieved by establishing an adequate qualification [3].

In accordance with ANSI/ESD S20.20 [1] any of the following methods can be used: product specification review, independent laboratory evaluation or internal laboratory evaluation.

It is very important to recognize the differences between product specification review and laboratory evaluation. From the standard requirement point of view laboratory evaluation is not necessary. Therefore it is essential to assess supplier's qualification procedures or to demand the evidence of the standard testing before making a usage decision for ESD control item. This was recognized as the best practice of the study from the cost efficiency point of view. In many cases supplier cannot provide this evidence and other options have to be considered. If the decision has a remarkable impact to costs, laboratory evaluation is mandatory in optimal ESD control.

E. Compliance verification

Compliance verification plans had a tendency to underestimate process measurements and a tendency to overdo other verifications.

In a technically oriented ESD control, measurements and process monitoring are focused on the product parts and objects in a close proximity of ESDS instead of surroundings. Most of the verification measurements are then made in a critical path. ESD control items can be tested by random checks only.

In an image oriented ESD control, measurements are focusing on the control items and personnel groundings instead of the locations where ESD risks exist. There is a tendency to improve control by tightening the resistance limits and increasing the frequency of measurements. Without justification, these actions may cause overkill. According to the benchmarking, compliance verification plans were mainly an image oriented.

The other concern of compliance verification is insufficient awareness of the low level measurement techniques [9]. Instrumentation with a simple user interface creates illusion that the measurement is easy to make and it can be done without knowledge of physics and measurements. Simplified standards may enhance this illusion. Therefore, an adequate training is essential for electrostatics measurements. It is also necessary to know uncertainty factors for the prevention of errors on measurement. Uncertainty estimation cannot be done without adequate knowledge of measurement techniques. Erroneous measurements result in incorrect conclusions, thus increasing costs.

F. Process control

In a process assessment ESD source parameters are generally compared with the agreed maximum limits. In a risk assessment ESD source parameters are typically compared with the estimated withstand of the product in a certain assembly procedure.

Standard practices for the process assessment were not readily available at the time of the audits in the project. Due to the lack of this information, procedures had not been clearly defined in the control program plans. The assessment procedure used in the benchmarking project is shown in Figure 17.

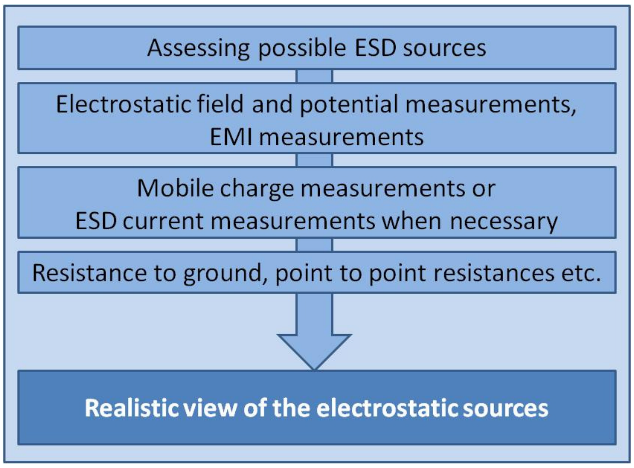

Figure 17: Process assessment

This procedure was also considered as one of the best practices. All the process phases and possible risk locations shall be clarified step by step together with process engineers. Measurements shall then be applied to the most obvious risk locations. Moving product and process parts are typical ESD sources.

There is a possibility to change electrostatic situation accidently before capturing the correct information. Electrostatic fields and potentials shall be measured before mobile charges. Instrument selection depends on the dimensions of an object [10] and the speed of the movement in a process. For example, an electrostatic voltmeter shall have an adequate response of the high speed measurements. In most cases charges cannot be measured from moving objects. Sometimes an estimation of the capacitive environment is the only way to assess ESD source parameters. Artificial friction and rubbing of insulating objects may result in a wrong conclusion.

An outcome of the assessment is a realistic view of electrostatic sources in a process. This information can be used in a risk assessment when necessary. A suspect of the ESD failure launches detailed monitoring of the yield. A manufacturing failure rate and a field failure rate shall be evaluated respectively.

In this project, the critical nonconformities were related to the influence of insulating product parts. Corrective actions were agreed after quality and reliability review: orders of work phases were changed, materials were replaced or charge mitigation techniques were applied.

IV. Conclusions

Organizations in the benchmarking project were committed to improve an image. Four factories out of twelve were also focused on the monitoring of a critical path instead of surroundings such as warning signs, gates, visitor information, leaflets and jackets.

It was clearly understood that the actions focused on the surroundings are ineffective from the ESD control point of view, especially if a process control is not established at all.

As a conclusion the image is more important aspect than the real ESD control at most factories. Exceptions were also recognized. There are products that cannot be produced without an adequate ESD control. Three factories out of twelve had a technically oriented ESD control program.

Organizations interested in continuous improvement were participated in the project. All the electronics factories are not necessarily as interested in ESD control as these participants.

V. Discussion

The purpose of the study was information sharing between the organizations participating in the benchmarking project. A lot of information is classified confidential, but the general outcome of the study may also be useful for estimating a readiness of control program and process capability from the ESD target levels point of view. It can also be used for helping work groups to take prevailing practices into account for further standardization work. More factories shall be audited for assessing differences between the regions.

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