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Critical Factors in ESD Program Management

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Developing a successful ESD management program is key to minimizing ESD damage to sensitive devices.

Electrostatic discharge (ESD) events can have serious detrimental effects on the manufacture and performance of microelectronic devices, the systems that contain them, and the manufacturing facilities used to produce them.[1] Submicron device technologies, high system operating speeds, and factory automation are making ESD control programs a significant element in the quality and reliability of ESD-sensitive devices.

Developing, implementing, and managing a successful ESD program requires a total system approach that extends from product design to customer acceptance.[2,3] The program must be well managed and woven into every aspect of the manufacturing process in order to produce lasting success. In fact, a well-managed program can be far more effective than one well stocked with expensive supplies. The 12 critical factors described in this article form the basis of successful ESD program management (see the sidebar "Critical Factors" on page 30).

The first four factors described in this article give the project its much-needed organization and authority during the start-up and implementation phase, as well as afterward during the long-term continual-improvement phase. These factors consist of a written implementation plan, management commitment, a long-term process owner, and an active ESD leadership team.

The next five factors described are the process owners' essential tools: realistic requirements, a training program, an auditing program, a test lab, and an extensive communication effort. The three remaining factors—systemic planning, human factors engineering, and continuous improvement—focus on management principles designed to help the program run more efficiently.

The ESD process owner must be aware of the 12 critical factors and fully understand their significance. The factors need to be managed by the process owner just as actively as the controls protect sensitive devices and assemblies. Sound management of these factors produces a cost-effective program and sustained success.

This article is an introduction to the 12 critical factors. By highlighting them here and out of context, they can be kept in mind as a mental checklist. Some factors in this article are only briefly introduced; however, all are very important. A complete discussion of each factor can be found in the book, *ESD Program Management*.[4]

Factor One: An Effective Implementation Plan

The success of an ESD program depends on how well it is implemented. The best of programs can fail in the absence of a sound implementation plan. Therefore, it is important to develop an effective implementation plan, in writing. Take into account manufacturing environments such as self-directed work teams, and begin by developing a thorough understanding of the concepts. Be sure that the outline of the implementation plan reflects the intent of all 12 critical factors. The details of the plan should then be put into an action plan to document individual responsibilities, deadlines, and progress.

The finished plan organizes the massive undertaking of implementing a new or examining an ongoing program into a series of smaller projects. The plan also provides the first approximation of the work schedule. Be sure to include suppliers, distributors, subcontractors, and original equipment manufacturers when developing the plan because they are extensions of the program and must comply with its particulars. In fact, these companies should be chosen based on verifiable compliance with proper ESD procedures and approved packaging materials.

The plan is built around the other 11 factors. As one studies the information in this article, talks with members of the ESD leadership team, and surveys the manufacturing plant, plan details should be inserted under the appropriate category such as management commitment, a test lab, purchasing, automation, and so on. With each entry, the

process owner should include notes on who should work on each task and when.

By organizing the implementation effort in this way, the process owner can see the larger picture and is less apt to get mired in details. Priorities can be set more effectively, tasks can be delegated to appropriate coworkers, and timing can be regulated based on how well employees are progressing with the programs.

Factor Two: Management Commitment

ESD control transcends the entire company, its suppliers, and subcontractors. Therefore, it is important to have support from all levels of management, especially from the top levels. This enables a coordinated effort to be established swiftly and efficiently to implement the details of the plan. Otherwise, insurmountable roadblocks can develop along the way and the program will fail.

Consequently, management commitment must be actively sought and then periodically reaffirmed for the program to succeed in the long run. A large plant might have 200 or 300 managers working in different capacities in the organizational hierarchy. A small plant, however, might have only two or three managers. In either case, managers at all levels who have authority over employees and who have commitment to the ESD solution are a major part of ensuring the program's success. Without a clear and strong commitment early on from top management, there can be no long-term effort at solving the problem. Even if a few middle- or lower-level managers are resistant at first, they will be more inclined to support the effort if top management believes strongly in the program.

Once the commitment has been established, the plan should be announced to all employees in the form of a signed statement describing the company's program to prevent ESD damage to devices, and the nature of the ESD solution. Management should reissue this statement every year. Evidence of management commitment should include a budget to implement items such as training, purchasing, auditing, and so on. Included in this budget must be the money for a long-term process owner.

Factor Three: A Long-Term Process Owner

Successfully implementing an ESD program requires stability, including leadership by a well-qualified professional over a long period of time. A full-time effort is critical in the early stages. Later on, a part-time effort may be sufficient in smaller companies. However, in large companies, the task cannot be done effectively on a part-time basis. Studying the technology, selecting and purchasing the needed equipment, preparing the procedures handbook and manuals, building a training program, and putting the critical factors into place requires full attention.

The difficulty in implementing a program is compounded by the fact that very few engineers understand ESD technology, and even fewer understand ESD risks. The ESD process owner must serve as a consultant to all of the engineering disciplines in addition to overseeing the plan. Implementing an effective ESD management program requires a dedicated effort by the process owner for a minimum of two years to reap the financial benefits.

Factor Four: An Active Leadership Team

An active ESD team unifies the effort and helps solve problems more efficiently. The leadership team is a critical factor because even a full-time process owner cannot implement or upgrade a program alone; the task is too great and affects too many disciplines.

A working team that shares information and enlists help from many experts and managers is an invaluable resource for the process owner. Such a team is a vital part of the communication process and results in an appropriate sharing of responsibility.

Factor Five: Realistic Requirements

The ESD control requirements must be realistic and formally documented because they are the foundation of the entire plan. All activities, procedures, and support documents are based on these requirements.

It is, therefore, important for the requirements to be both mindful of training needs and well documented in easy-to-understand language. Consistent compliance with proper procedures depends on a complete understanding of the requirements; therefore, thorough documentation is essential. Furthermore, the program requirements must be realistic to be enforceable.

Written as a handbook, the requirements can also serve as a text during training and as a common reference for all employees. The information in the handbook is then a comprehensive statement of the ESD control program. Training is based on it, the auditing checklist is written to ensure compliance with it, and the employee's work is structured from it.

Although the requirements are extensive and complete, they must also be realistic so that people can follow them easily. They must be written in such a way that human error is improbable. This is accomplished by explaining procedures clearly and by placing a high priority on human factors engineering (see Factor Eleven) whenever possible.

Support manuals should be written for activities such as process checking, auditing, and maintaining facilities. These documents should also be comprehensive and realistic.

Critical Factors

Factor One	An Effective Implementation Plan
Factor Two	Management Commitment
Factor Three	A Long-Term Process Owner
Factor Four	An Active Leadership Team
Factor Five	Realistic Requirements
Factor Six	Training for Measurable Goals
Factor Seven	Auditing Using Scientific Measures
Factor Eight	ESD Test Facilities
Factor Nine	A Communication Program
Factor Ten	Systemic Planning
Factor Eleven	Human Factors Engineering
Factor Twelve	Continuous Improvement

Factor Six: Training for Measurable Goals

Training is an obviously critical factor in successful ESD control and must be a primary consideration at all times.[5] A training program built on measurable goals derived from the auditing program allows the process owner to aggressively pursue the identification and resolution of training needs. The auditing results clearly identify when training is needed, who needs training, what needs to be taught, and whether the training was successful.

Factor Seven: Auditing Using Scientific Measures

Auditing is the binding force behind a sound program and is critical to a program's long-term success. Its mere presence spurs compliance and a strong management commitment that fosters continuous improvement. The four auditing techniques listed here enable the ESD process owner to manage the program on a scientific and cost-effective basis. The four techniques are

- ESD system audits.
- Internal auditing.
- Statistical process.
- Employee self-checks.

Published reports can motivate managers and engineers toward improving the program in their department. Reports provide the process owner with the tools necessary to effectively manage and maintain the program. They make it possible to easily identify problems and then solve them.

The selection of the auditor and process checker is critical. These people must be able to withstand peer pressure. They must report all deviations as initially detected. The objective is to protect sensitive products from ESD damage by supplying management with valid information that can be used for timely corrective action.

Statistical sampling techniques, auditing, and process checking are invaluable tools for measuring departmental compliance with the prescribed ESD control procedures. These procedures must be included in the handbook and manuals that employees are trained to follow. The statistical unit of measure for the program is the deviation from prescribed procedure.

For an audit, the procedures are transformed into a questionnaire to be used as a checklist. In addition to this checklist, the auditing program consists of an auditing inspector, a manual, a portable test cart, and software for filing and organizing data. The collected data are printed in graph form as either a trend chart or a Pareto analysis. The process owner uses these graphs to spot trends, identify and pinpoint problems, and report progress to management. Audit reports are an invaluable training tool. The net result of an auditing program is continual improvement.

Factor Eight: ESD Test Facilities

Having adequate testing capabilities is a critical tool for the process owner. Such capabilities allow the process owner to use electrical tests to scientifically evaluate many aspects of the program and its success. For instance, testing is an integral part of such activities as auditing, qualifying equipment and sensitive components for purchase, defining effective requirements and procedures, inspecting incoming control products, solving manufacturing problems, demonstrating during training, providing failure-mode analysis on devices and systems, and testing and qualifying devices or systems prior to shipment.

Although some testing can be very sophisticated, much of the testing recommended in this article is basic. This is in keeping with the program's philosophy of being realistic. For instance, by testing and qualifying ESD control equipment, greater standardization of the auditing test procedures can be achieved. In fact, the program can be set up such that all of the periodic prequalification tests done by manufacturing process checkers can be accomplished with a wrist-strap tester. This one idea lowers maintenance costs considerably, encourages compliance, makes the test easier to perform, and simplifies training.

The test facilities on hand depend on a company's budget, plant size, and testing goals. A variety of test equipment and three types of testing facilities should be established or made available as necessary. Equipment and facilities can include a field audit kit that fits in a suitcase, a general test lab that includes a portable test cart, and an analytic/failure-mode analysis (FMA) laboratory.

Factor Nine: A Communication Program

Effective communication is a vital element in successful ESD control, and it is one of the most challenging critical factors. Process owners often underestimate the difficulty or fail to recognize the importance of establishing a communication program.

A sound communication program must be developed at the outset, and it must be actively managed at all times. Misunderstandings can affect the program. For instance, a quality auditor once asked why a certain requirement had changed three times in nine months.

In reality, the requirement had been published three years earlier and had never been changed; it was merely the auditor's understanding that had changed.

Factor Ten: Systemic Planning

The diverse elements of an ESD control program form a total system that will ultimately determine the success of the program. It is critically important to realize that each element is part of an integrated whole rather than a separate and distinct entity. A change in any part of the program has a ripple effect on other elements.Conversely, there are times when the program must be changed to effect desired improvement. Therefore, systemic planning becomes yet another aspect of the program that requires constant awareness and management on the part of the process owner.

First, by planning ahead for the ripple effect of a change, the process owner can anticipate its total consequence. This anticipation lessens confusion and prevents the creation of new problems while trying to solve an existing problem.

For example, consider the implication of a relatively minor change in wrist straps in which a company switches from using three different sizes to one adjustable wrist strap.

That single change should prompt the following questions:

- Will people need additional training in how to adjust the new strap?
- Must the section on wrist straps in the company handbook be rewritten?
- Does this change affect the inspector's manual or checklist?
- What is the most effective way to communicate this change?
- Can the new wrist strap be tested in the same manner as the ones being replaced?
- Must new test equipment be sought and purchased?
- If a new test is warranted, what written documents must be changed?
- Will one adjustable wrist strap really fit everybody?
- Will employees find the wrist straps comfortable and safe?
- Should there be backup wrist straps for very small or very large people?
- Can the new wrist strap be purchased without changing the company's long-term relationship with the current wrist strap vendor?

Second, the ripple effect in an integrated program often masks the root cause of a problem. Failing to identify the root cause in a program will mean facing the same problem again and again.

For example, in one company, auditing uncovered a problem with heel straps. Further study revealed that many employees were wearing the heel staps incorrectly. The obvious solution would have been additional user training. However, if it were not for the complicated nature of the heel strap, the repeated training would not have been necessary.

The root cause of the problem was really in the design of the heel strap and not in the company's training methods. After the heel strap was replaced with a simplified version, human error became improbable, and the problem was permanently solved.

Factor Eleven: Human Factors Engineering

The employees' ability to comply with the ESD control procedures is a major part of the ESD solution. Every aspect of the program that affects people must be engineered in such a way that all reasonable employee needs and desires are taken care of and that human error is improbable. For example, if the equipment is uncomfortable or inconvenient, employees are less likely to comply with the procedures. In fact, failure to consider employees' needs could cause a catastrophic breakdown in the program. Considering their needs through human factors engineering is also a critical factor, and one that must be examined throughout all aspects of the program.

Factor Twelve: Continuous Improvement

Continuous improvement of each of the previous 11 critical factors is an essential part of a sound ESD control program. Implemented effectively, the critical factors will produce a cost-effective program. However, it is the continuous improvement of those factors that sustains the success. Many companies, failing to recognize the importance of this, have undertaken control programs with enthusiasm only to allow them to deteriorate into a state of disrepair and total ineffectiveness. Consequently, the initial funds expended for the program have been wasted, and none of the quality improvements are realized. Often the deficiencies go undetected because there is no auditing program in effect.

In contrast, the ultimate goal of ESD control is to satisfy customers through better products, services, and costs. This is not a fixed goal like winning a road race. Continual improvement is an endless process of meeting one goal after another.

Fixed goals are an important first approximation when working toward continual improvement. For the first five years, the primary goal should be to achieve zero deviations from prescribed ESD control procedures. This measurable goal allows for the setting of priorities, putting the process owner in charge of tackling the most serious problem first, and the next serious problem second, and so on. It also provides a straightforward way to assess and report results.

But having zero deviations in the program does not mean the project is a success, or that it is complete. Rather, reporting zero deviations indicates that the project has accomplished a monumental achievement. There is always room for further improvement. Furthermore, failure to continuously improve the process translates into complacency and deterioration.

There are always better and more cost-effective techniques, new control products to evaluate, new solutions to consider, and better training techniques to incorporate. Add to this the trend toward devices of ever-increasing sensitivity to ESD damage, and staying abreast of the technology becomes vital.

References

1. *An ESD Management Focus,* (Rome, NY: EOS/ESD Association, 1989).
2. WJ Kirk, "Uniform ESD Protection in a Large Multi-Departmental Assembly Plant," in *Proceedings of the EOS/ESD Symposium,* (Orlando, FL: EOS/ESD Association, 1982).
3. DE Frank, "The Perfect 10—Can You Really Have One?" in *Proceedings of the EOS/ESD Symposium,* (Las Vegas: EOS/ESD Association, 1981).
4. T Dangelmayer, *ESD Program Management,* 2nd ed., (Boston: Kluwer Academic Publishers, 2001).
5. R Gagne, *Essentials of Learning for Instruction,* (Upper Saddle River, NJ: Prentice Hall, 1988).

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