The Implementation of Autonomous Maintenance
(Part 1 in a series of the Total Productive Manufacturing Experience)

James Day, David Troy, Darryl Heller

ANADIGICS Inc, 141 Mt. Bethel Road, Warren, NJ 07059. Phone: 908-668-5000

jday@anadigics.com dtroy@anadigics.com dheller@anadigics.com

ABSTRACT

To improve overall cost management by increasing equipment efficiency and cycle time, ANADIGICS has begun implementation of a manufacturing methodology known as Total Productive Manufacturing (TPM). Improvements in equipment efficiency are obtained by systematically identifying and reducing all forms of loss on a piece of equipment. TPM identifies sixteen types of losses, which fall under the categories of equipment, people, material and safety. The measurement used to characterize the losses and thus measure the improvement is Overall Equipment Efficiency (OEE). OEE integrates all aspects of tool maintenance and operation, including equipment downtime, operator efficiency, and output quality.

Successful implementation of TPM methodology takes several years to complete and consists of eight areas of focus called pillars. This paper describes implementation of the first pillar, Autonomous Maintenance (AM), which provides the basic foundation for all future pillars. Implementation of AM teaches operators to maintain their own equipment on an ongoing basis. Initially, a team of operators and technicians follows a systematic approach to restore the tool to basic condition and characterize recurring problems. As AM is implemented, improvements in tool availability and performance are realized. Additionally, empowerment of the operators leads to improvement in the manufacturing culture through increased employee morale and job satisfaction.

INTRODUCTION

In order to improve manufacturing efficiency, the Operations group within ANADIGICS, Warren, NJ facility decided to implement an improvement strategy known as Total Productive Manufacturing. In the compound semiconductor industry and the semiconductor industry in general, equipment costs are one of the largest components in the overall cost model. Maximizing usage of the equipment offers a significant competitive advantage through capital avoidance.

Previously within ANADIGICS, numerous initiatives for manufacturing improvement had been implemented with varying degrees of success, but until the implementation of TPM, none had embraced everyone in the Manufacturing organization. None had attempted to change the overall culture in the organization. Cultural change of the manufacturing organization is necessary in order to ensure that the improvements made become embedded. Multiple methods of TPM implementation exist; the method adopted by ANADIGICS was the Japanese Institute of Plant Maintenance [1]. JIPM was one of the original institutions set up to spread the learnings of TPM. One of the difficulties in implementing TPM as a methodology is that it takes a considerable number of years. There is no "quick" way of implementing TPM. This flies in the face of traditional management improvement strategies, but is fundamental to embedding change into the way that the organization goes about its business.

Total Productive Manufacturing, as it is known today, was initially developed by post-war Japanese industry driven by the need to improve quality and reliability. Through the teachings of Dr. Deming, Japanese industry developed Total Quality Management (TQM) to improve productivity through statistical analysis. TPM developed as a spin-off that focused more on equipment efficiency. Initially embraced by Western industry during the late eighties, however, it soon fell out of favor as management teams, brought up on improvement through short-term gains, failed to commit to the long-term nurturing required by TPM. More recently though, as lean manufacturing has been embraced by Western industry, there has been a move back towards TPM as management teams begin to understand the benefits of lean manufacturing are not fully realized without the support of TPM.

GOALS

ANADIGICS goal for Autonomous Maintenance is to have 100% of its Operations personnel successfully complete Step 3 of the AM process.

INFRASTRUCTURE

Initially the infrastructure put in place consisted of two people working full time in the Office of TPM. The TPM manager was responsible for developing the initial plan and timeline. The role of the second person initially was to support the TPM Manager in an administrative role. This

second role has developed considerably since implementation to cover more logistics and strategic issues.

Once the Office of TPM was in place, the next step was to create a Central Council. The Vice President of Operations heads this group of individuals and other Central Council members consist of those members of his staff running the Manufacturing and Quality organizations. In addition, the Pillar owners are part of the Central Council. The role of the Central Council is to provide the strategic vision for TPM implementation, as well as establishing goals and boundaries. Once the Central Council and Office of TPM were in place, a vision was created which pictorially represents the goal of ANADIGICS TPM implementation that is "A World Class Manufacturing Machine Powered by TPM".

The next piece of the infrastructure put in place was the Autonomous Maintenance Pillar. The AM Pillar owner heads this up and the role of the pillar is to define the AM process for the teams to follow. This is done through the creation and maintenance of the AM workbook that all teams follow as they go through the AM process.

The final piece of the infrastructure required is the Area Council. This is headed up by a Central Council member and consists of those managers who have individuals involved in AM Teams. The role of the Area Council is to resolve issues that may arise between the business needs and the needs of TPM.

Although this infrastructure may look complicated and unnecessary, it is very important to the success of TPM to have it in place. It is also important to have the roles and responsibilities of the various councils and pillars well defined. From our own experience, at one point the Central Council became focused on tactical issues rather than strategic, resulting not only in a loss of focus and vision, but also by interfering with the function of the Area Council. From a resource perspective, only one person works on TPM full time, all others involved in TPM are part-time.

IMPLEMENTATION

Implementation of Autonomous Maintenance began at the end of 2000. At that time, ANADIGICS sent nine managers from all areas within Operations to attend a week long training course in Atlanta. The Atlanta training covered the theoretical training and was followed up by an additional week of practical training viewing TPM sites in Japan. The highlight of the training was the trip to Japan, which not only showed everyone best practices in TPM award winning factories, but also gave everyone an exposure to a culture that not only minimizes waste and loss but is founded on precision, consistency and reliability. At the conclusion of the training, ANADIGICS had nine JIPM certified instructors in place.

Following the training, a plan was developed to begin implementation of AM. The plan began with two management "Pilot" teams implementing AM on two tools. One team was from the Wafer Fabrication area, and one from the Final Test area, with members taken from the certified instructors and other managers within Operations. Team size for all teams is usually greater than eight people and less than twelve. The goal for the "pilot" teams was not only to complete the AM process on the two dedicated tools, but to develop the AM process for other teams to follow and to help develop leaders to lead subsequent teams. The teams began in January of 2001 meeting for five hours per week, and by the end of August 2001 both teams had reached their goal of completing the first three steps of Autonomous Maintenance. The additional goal of creating a document or AM workbook followed within the next five months. The need to develop such a document arose from the difficulty in translating the original JIPM Manual [1] into a process that could be used in semiconductor manufacturing. The resulting document created by ANADIGICS was our attempt to develop an easily understood, step-by-step manual complete with Tips, Hints, Pictures and Examples of teams work. The balance was to create a document that was easy to understand while losing none of the "purity" of the original JIPM Manual. At that point, two new teams began the process over again on a new piece of equipment. The team membership this time included operators to allow the process to become truly autonomous. Following the second group of teams, another two were begun. During this phase a JIPM consultancy visit was arranged and the message from the consultant was clear- not 100% of tools, but 100% of every individual within Operations.

A plan was put in place that would effectively implement the 100% Operations goal. While initially attempting to plan a "big bang" of seventeen teams all starting at the same time, a sense of realism set in leading us to plan for a phased start over three quarters. The goal therefore would be to have 100% of all Operations people involved in TPM within nine months. In addition, the phased start allows the existing infrastructure to better support the teams. The meeting time was also reduced to two-and-a-half hours per week, meaning the process would now take sixteen months to complete instead of eight. A steep production ramp has put a temporary hold on teams beginning in some areas, while other teams are starting as planned. All existing teams have continued to meet.

PROCESS

The AM Process we are implementing consists of four steps. Step zero, one, two and three. The process can be summarized with the following Mantra:

Step zero	Preparation
Step one	Clean to Inspect, Inspect to Detect
Step two	Detect to Correct
Step three	Correct to perfect

Step Zero. This is where the teams learn how the tool operates, learn the safety aspects of tool, create a risk assessment for working on the tool, become certified on the safety aspects and operation of the tool and decide which loss related metrics they will track. Safety is a major focus for this step and the reason for this is simple. The process we are learning is an Autonomous Maintenance process. By the end of the process, operators will be capable of maintaining the tool at a level that maintains a basic level of condition. This means they will be working in areas of the tool that are not only new to them but may expose them to certain safety hazards. Understanding and minimizing those hazards in the form of a risk assessment is essential. As the team completes their risk assessment, the relevant equipment engineer must sanction the assessment. An audit at the end of step zero is designed to prevent progress to the next step unless everyone on the team is safety certified and the risk assessment has been approved. The team will also demonstrate how to safely power up and power down the tool.

Step One. At this stage the team will divide the tool into different sub-assemblies and begin cleaning. The key part of this is not to clean for the sake of cleaning, but clean to INSPECT. As the team begins to clean they will identify defects. These defects need to be documented with details of what has been found and the exact location. Colored dots will be added to a large poster of the tool to help understand groupings of defects. The defects are also divided into two very different categories, Yellow and Red. A Yellow defect is a defect that can be corrected by the team members, while a Red defect is a defect that can only be corrected by someone outside the team. This cleaning process can take some weeks and may result in anything from two to five hundred defects being identified. Before moving on to Step Two, the team will have to pass the Step One audit. The Office of TPM conducts the Step One audit and the audit itself describes in great detail what is required to pass the audit. For Step One the audit will not only look at the defects found and corrected but also the condition of the tool. The tool should begin to look better than it did when the process began. When a team passes their Step One audit, a celebration lunch or dinner at a local Japanese restaurant recognizes their achievement.

Step Two. During this step the clean to inspect will continue, but in a more formalized way. A Cleaning and Inspection map should be put in place that details what parts of the tool are cleaned or inspected at defined frequency. At this time, some defects will have determined to be recurring. During Step Two, these recurring defects need to be analyzed in order to determine the root cause. "Why-Why" Analysis and Fishbone diagram tools are used to determine root cause. Once root cause is established, a countermeasure needs to be implemented to prevent the recurrence. The effectiveness of the countermeasure is determined by the recurrence of the defect. The countermeasures are then added to the routine Cleaning and Inspection process. Progress to Step Three can only be achieved when the Step Two audit has successfully been completed. As with the Step One audit, the office of TPM conducts the Step Two audit. With this audit, the emphasis switches to how effectively the team has prevented the appearance of recurring defects. By this time, the tool should look pristine or back to original condition. This usually includes repainting the tool. Depending on the condition of the tool to begin with, the performance may also have increased through less downtime. On another level the team has begun to set a zero tolerance level for defects. Driven by the hard work expended on the tool, that zero tolerance level is passed on to non-team members who also operate the tool. This peer pressure is extremely powerful to maintain the tool in current, pristine condition.

Step Three. Although this step is the shortest to complete, it is in many ways the most crucial. During this step, the team makes some final adjustments again to the Clean to Inspection Map. They then have to take the Cleaning and Inspection process in place at this point and roll it out to everyone who works on the tool. A simple awareness and training session is insufficient. The reason for this is that it is crucial that whatever is put in place so far becomes embedded as the team disbands at the end of Step 3. This is the toughest part of all, and ANADIGICS implementation of Step Three has evolved considerably through both the pilot and subsequent teams. The evolution of this step is still not over. Gaps remain as ownership is "transferred" back to the original owner as the AM team disbands. Planned improvements to this step include routine audits conducted by the Office of TPM and the area manager.

Throughout all of the steps, the progress of the team is tracked on an Activity Board located close to the tool. The Activity Board will show all of the defect data, tracked metrics, Cleaning and Inspection Maps and "Before" and "After" photographs showing the condition of the tool before the process began, and also at the completion. Every Activity Board for every tool is laid out in exactly the same way. This is done not only to drive consistency, but also to allow teams to learn from each other.

LESSONS LEARNED

1. Put the Office of TPM in place before launching the program.
2. Put as much of the Infrastructure in place before initiating teams as possible. At minimum have the

Central Council in place and Autonomous Maintenance Pillar.

3. Ensure the Central Council focuses on the strategic issues. The Central Council became involved in tactical issues and it hindered the Area Council and AM pillar responsibilities. Strategic focus was lost during this time.
4. Use the "pilot" process, but do not shy away from full-blown implementation after the pilot process is complete.
5. Tailor the JIPM and external material [3][4] to fit the corporate culture and needs. At the same time ensure that the JIPM "purity" is not lost.
6. TPM must become a part of the regular way of doing business. When viewed simply as a "bolt-on" to existing activities it will ultimately not achieve the required results. This requires patience and is a slow, gradual process.
7. Involve upper management actively at the earliest opportunity. Anything less will fail.
8. Management must be seen to support TPM by attendance at several team meetings.
9. Be consistent and creative in recognition. Teams know that for passing a Step 1 audit they will be taken out to a Japanese restaurant for dinner. For passing a Step 3 audit they know they will another dinner at a restaurant of their choice.
10. Never overlook the importance of consistency. All activity boards are laid out in exactly the same way for all teams. All teams must keep a record of attendance and minutes- even management teams!
11. The audit process is crucial to successfully completing each step. It is also a useful tool for a manager to understand the stage a team in his or her area is at. Simply print a copy of the audit, and spend some time at the tool or at the activity board.

NEXT STEPS

1. Complete the goal of 100% Operations involvement in Autonomous Maintenance. Given the weekly hours a team spends on TPM, this is likely to be completed sixteen months after the last team starts.
2. Implement the second pillar, Planned Maintenance. Building on AM, PM is where the goal of zero failures becomes a reality. The process itself is a combination of the JIPM process [1] and a respected authority in the semiconductor industry [2]. The pilot PM team has begun already, but the process to eliminate equipment failures totally as well as improvement in overall efficiency will take eighteen months.
3. Implement the third pillar, Focused Improvement. Designed as the "SWAT" team of TPM implementation, the plan is for an FI team to be set up when a tool or process requires a short, sharp fix to be implemented. The process should not take any longer than six months on a given problem.

REFERENCES

[1] TPM Instructor Course manual, Japan Institute of Plant Maintenance, 1996.
[2] James A. Leflar, Practical TPM: the method for success at Agilent Technologies. Productivity Press, 2001
[3] Autonomous Maintenance for Operators, Productivity Press, 1997.
[4] TPM for Supervisors, Productivity Press, 1997.

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ACRONYMS

AM: Autonomous Maintenance.

FI: Focused Improvement.

JIPM: Japanese Institute of Plant Maintenance.

OEE: Overall Equipment Effectiveness.

PM: Planned Maintenance.

TPM: Total Productive Manufacturing, also referred to as Total Productive Maintenance.

TQM: Total Quality Management.