

Precision-guided Equipment Maintenance in a Modern Foundry – Case Study

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Keywords: Variability of Availability, Precise Equipment Maintenance, Total Productive Maintenance (TPM), Predictive Maintenance, MPM™

ABSTRACT

Maintenance teams in compound semiconductor fabs are challenged with maintaining high equipment uptime together with continuously decreasing maintenance costs and providing enough flexibility to fulfill complex production plans. These challenges become even more sophisticated in a foundry environment, where production mix changes frequently and there are more equipment dedications to a product/customer.

On this case study, the MAX Group explores the approach of a medium-size semi-automatic foundry to maintenance management, and it analyzes the gap to achieve the ultimate maintenance standard which claims the necessity of stepping away from traditional evaluation of Uptime towards a precision-oriented thinking and working methods.

INTRODUCTION

In modern semiconductor manufacturing, medium-sized 6"-8" foundries occupy an important niche which provides customers with flexible solutions. To achieve such flexibility these foundries must sustain a complex production mix consisting of small product runs and specifically dedicate different types of equipment to meet customer manufacturing requirements. This situation leads to a lower level of equipment redundancy compared to larger foundries and puts their maintenance teams to the ultimate test of delivering great performance.

MAX has developed a set of precision metrics (see Table 1) that allow sensitive monitoring of the maintenance team's performance and pin-pointing of sources affecting the variability of equipment performance. In addition, precise working methods and techniques allow the flexibility needed in foundries with continuously changing environments,

eliminate sources of performance variability, and create and sustain a culture of continuous improvement.

Table 1 – Examples of Precision Maintenance methods and metrics

Topic/Responsibility	Methods and Techniques	Metrics
Management	<ol style="list-style-type: none"> 1. Create and follow structured procedures for normal and crash working modes 2. Daily reviews of manufacturing plans, equipment status and HR status. Look ahead 24 hrs. and make necessary adjustments 3. Weekly HR forecast (skills and headcount) with a respect to maintenance plan. Utilization of CMMS for more precise PM scheduling 4. Creation Tech training and certification matrix and Area/Module targets 5. Projects 6. Periodical review of cost targets and performance 	<ol style="list-style-type: none"> 1. Periodical survey, score card 2. Shiftly attendance levels vs. targets 3. Number of scheduled PMs vs. actually performed, M-Ratio 4. Area/Module certification levels vs. targets 5. Maintenance cost vs. targets
Engineering	<ol style="list-style-type: none"> 1. Practicing Golden Tool approach for equipment Availability, Continuous standardization and improvement of working procedures and methods of troubleshooting, Active mechanism of corrective actions driven by the periodical OEE reviews 2. Continuous cost reduction 3. Precise spares stock management 	<ol style="list-style-type: none"> 1. CV of Availability 2. Monthly/Quarterly cost of maintenance per toolset 3. Stock inventory vs. target
Are/Module Tech Teams	<ol style="list-style-type: none"> 1. Sustain close cooperation with production management team 2. Learn and practice of Pit Crew methodology and techniques 3. Precise work place organization 4. Maintaining individual proficiency and excellency 	<ol style="list-style-type: none"> 1. Waiting tech 2. Green-to Green (PM speed), variability of PM duration 3. 5S or similar grades for work place organization 4. 1st time qual success (PM quality), first 48 hrs. failures (PM quality)

EVALUATING PRECISION OF MAINTENANCE

In order to quantify maintenance practices effectiveness MAX has developed a simple set of metrics as part of its overall package named MAX Precision Maintenance - MPM™. MAX analyzes toolset availability using two primary metrics:

1. **M-Ratio** = $\frac{\text{Sched.Maintenance Time}}{\text{Unsched.Maintanance Time}}$, expressed as X:1, for example M-Ratio of 4:1 indicates that the total maintenance time consists of 80% scheduled maintenance and 20% of unscheduled maintenance. MAX target for BIC average M-Ratio is 9:1.

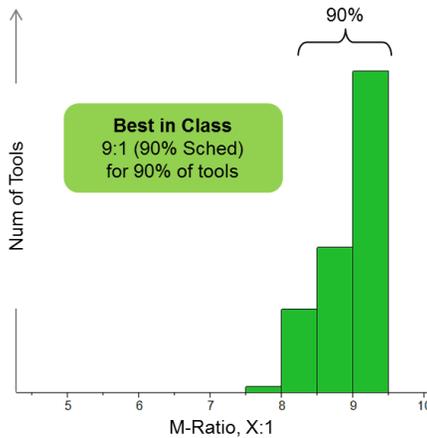


Figure 1: BIC foundry M-Ratio

A high M-Ratio shows the capability of predicting and planning maintenance events, which is the fundamental requirement for Precision of Operation.

2. Graphical representation of equipment availability fitted by its statistical *coefficient of variation* (CV).

CV of Availability = $\frac{\sigma}{\mu}$, where σ represents the standard deviation, and μ represents the mean Availability for the observed population.

In addition, during the evaluation of work practices MAX conducted series of interviews and observations, and it used specially developed score cards to benchmark personnel proficiency.

Precision KPI - CV of Availability:

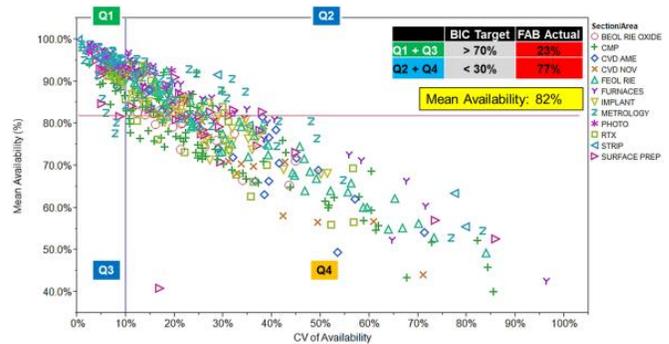


Figure 2 - Example of CV chart

As it is shown in figure 2, the actual mean availability (horizontal blue line) and the BIC CV of Availability vertical red line divide the chart area into the four quartiles (Q1-Q4). Each point represents the mean of the actual weekly Availability for a single tool, in this case 52 weeks per tool.

- The tools in upper left corner (Q1) are performing with highest precision levels, repeatedly (CV<10%) achieving high Availability values.
- For the tools in Q2, despite of their high mean availability, their Precision of Maintenance requires improvement which will yield lower performance variability and better predictability of lot delivery to the next operation in the manufacturing process. The higher performance variability on these tools is often the consequence of non-precise technician and equipment engineer work or poor maintenance management practices.
- From the management level standpoint, modern foundries sometimes prefer lower mean availability but higher precision – lower CV of availability (a tool plotted in Q3 over Q2) to assure steady supply of lots to the next operation.
- Tools plotted in Q4 perform with the lowest level of precision, showing lower Availability and higher CV values. These are the toolsets the Foundry will focus on first for any improvement program initiated by the maintenance team.

Case study – Photolithography

Photolithography tools are widely considered to be de facto FAB bottleneck due to their high utilization and complex maintenance; therefore, this area was a natural subject of interest during the study.

Step 1 – Data Analysis

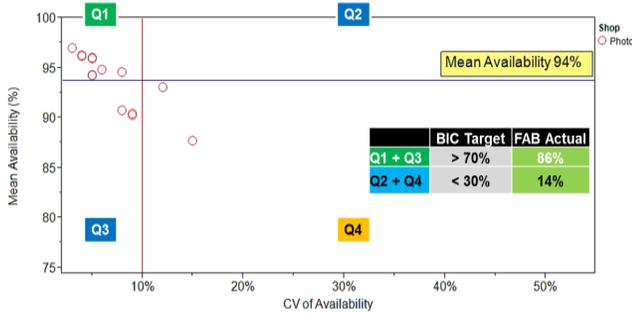


Figure 3 – Photo Cluster CV of Availability

It is clearly seen through the CV of Availability chart in Figure 3, that photo cluster performs at BIC level of precision maintenance achieving great mean Availability of 94% and low variability <10%. This fab demonstrated high levels of performance even without having a precision maintenance program in place. We will look at the factors that allowed it to achieve such high numbers, and how a precision maintenance program will enable them to sustain these levels.

Step 2 – Benchmarking working practices

1. Team Experience Level: the foundry, and especially the photolithography module, benefited from *highly experienced technician and engineering team*, with an average tech experience of over 12 years in one specific area. This level of proficiency allowed them to keep a very lean tech team (10 tools per tech per shift) and still achieve great equipment performance. There was no formal certification and proficiency system. New hires were trained by more experienced piers and progressed to more advanced tasks when their trainer considered them ready.
2. Mode of Operation – Technicians team: unlike in the vast majority of the foundries, the technicians’ team was *extremely empowered* to plan and execute almost all aspects of maintenance including PM planning and execution, all levels of equipment troubleshooting, development and implementation of working procedures, handling improvement projects and more. Another notable finding was a *very positive culture learning sharing and constructive competition* between technicians, leading to the *continuous improvement* of precision on individual and team skills. Figure 4 shows a pristine condition of a 14-year-old photolithography track observed during a scheduled PM. Such condition could only be achieved by the precise

repeated actions of the maintenance team. *Pit Crew techniques* were seamlessly implemented into PMs and troubleshooting, making the working routines fluent and brief. Optimal *workplace organization* methods and techniques of the teams were also developed and maintained contributing to the precision of execution of maintenance tasks.

Failures right after PM procedures and repeated failures were considered severe conditions; the team investigated their causes and shared the learning.

The technician teams also built and maintained a database of Best Known Methods (BKM) called TechNotes, improving precision by bringing *standardization* into equipment troubleshooting



Figure 4. 14 year old photo track in excellent condition.

3. Mode of Operation – Engineering: strong technician teams empowerment made it possible to bring the equipment engineer direct involvement in solving day-to-day issues to a minimum, putting the engineer in the sole position of supervision and continuous improvement. The evaluated foundry is among the fewest in the industry, where the equipment engineers actually supervise the technicians during shifts, being responsible for both professional and HR subjects. The Maintenance Engineering team also owns the process of new tool characterization and purchase, which is usually a R&D/NPI responsibility. This practice allows gaining early engineering and tech knowledge of

specific equipment issues, faster qualifications and in general a smoother process of new equipment integration, whilst the ownership is not transferred between the different organizations (Facilities, TI, Engineering) but stays in the hands of Maintenance Engineering from the moment the need for the new tool is raised by the IE department.

4. Mode of Operation – Management: Escalation MoO, roadmap of team development, KPIs/targets, and Continuous Improvement programs were still being planned, or at best, in early phases of implementation.

Step 3 – Sustainability

While this fab was able to achieve excellent availability results, it did it while the photo area was experiencing a low loading factor. Should the load increase, it is necessary to implement the metrics and methods described in Table 1 in order to sustain the current performance.

SUMMARY

This Photo cluster example shows how in order to gain the needed equipment performance, a small but very experienced and committed Tech and Eng. team developed and implemented the methods of Precision Maintenance in its daily operation. The teams were naturally forced into this direction because of a lean headcount where they simply couldn't handle the excess number of equipment issues but had to be able to predict those issues in advance and treat them in the quickest possible manner. Direct supervision of tech shifts by the engineering team created one integrated group, transforming technicians and engineers into members of the same pit crew. Management played an important role in this process by encouraging the Tech/Eng. team to take the responsibility and perform the needed changes.

However, there is a need to emphasize the fact that the main contributors to the teams' success were the high experience level and low fab loading, and in order to sustain and be able to improve this level of performance with the increased FAB loading and a number of new hired techs, it would be absolutely essential to implement precision-driven management and engineering infrastructures: Procedures, Systems, KPIs, Predictive Maintenance tools and etc.

About the MPM™ Methodology

Through our years of challenging our clients to achieve better and better Fab and equipment performance, MAX has been continuously searching for the way to achieve the right balance between the optimal equipment maintenances regimes and required equipment uptime. This research led to the formulation of the MAX approach to Precision in

Maintenance and the development of the MPM™ methodology.

MPM includes a wide variety of tools: KPI development, training procedures, organization structure, roles and responsibilities, maintenance practices, and support systems implementation. All these tools are customized to bring each fab to BIC from their current performance level.

CONCLUSION

Many Fabs still base their Maintenance on traditional evaluation of mean Uptime and Downtime metrics, without considering the variability of events. Engineering is mainly busy in the office, disconnected from the technician teams. Shift maintenance teams often communicate poorly, their working methods are not standardized and their success heavily depends on attendance of certain individuals. This is happening whilst the modern semiconductor space continuously challenges the device makers, especially mid-sized foundries with more aggressive targets on cost, quality and flexibility of product portfolio. MAX believes that in order to keep up with the challenge fabs, foundries in particular, have to achieve and sustain high levels of precision, especially in equipment Maintenance. MAX offers a Global Approach to Precision which is a next step of maintenance evolution.

ACKNOWLEDGEMENTS

The authors would like to thank all MAX and clients' personnel who contributed the observations and data analysis

ACRONYMS

BIC	Best In Class
CMMS	Computerized Maintenance Management System
EE	Equipment Engineering
KPI	Key Performance Indicator
M-Ratio	Maintenance Ratio
MoO	Mode of Operation
OEE	Overall Equipment Effectiveness (set of metrics)
PM	Preventative Maintenance
TI	Tool Install (organization)