OPERATIONAL EXCELLENCE IN ACTION: A DATA DRIVEN APPROACH TO WORLD CLASS OEE

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ABSTRACT

Achieving world-class Overall Equipment Effectiveness (OEE) is a critical milestone for manufacturing organizations committed to operational excellence. This paper outlines how Allegro Microsystems' Wafer Probe operations significantly improved OEE from 74% Q4FY24 to 86% by Q4FY25, reaching a level recognized as world-class through the implementation of a structured data driven approach for success.

Key elements include effective maintenance strategies, improvement on probe card design and robust quality control systems. By leveraging data analytics and fostering a culture of proactive problem-solving, the team was able to garner significantly enhance equipment availability, performance, and product quality.

The data driven approach outlines practical steps and best practices, supported by case studies and empirical evidence. Implementing these strategies not only boosts productivity and cost avoidance but also ensures sustainable competitive advantage in the global manufacturing landscape.

1. 0 INTRODUCTION

Overall Equipment Effectiveness (OEE) is a critical metric in manufacturing that evaluates how effectively equipment is utilized. It combines three key performance indicators: availability, performance, and quality.

Availability measures the proportion of scheduled time that the equipment is operational. Performance assesses the speed at which the equipment operates compared to its maximum potential. Quality evaluates the percentage of products that meet quality standards without requiring re-work.

By analyzing these components, OEE provides a comprehensive view of equipment efficiency, helping manufacturers identify areas for improvement, reduce downtime, and enhance productivity. Achieving high OEE scores is essential for optimizing production processes and maintaining competitive advantage in the manufacturing industry.

Wafer Probe operations began with an OEE baseline of 74%. Guided by a clear management directive to prioritize OEE improvement, the team set a strategic goal of reaching 85%—a benchmark widely recognized in the industry as world-class performance (see Fig. 1).

Source: https://www.leanproduction.com/oee/

Fig. 1: OEE category as per industry standard.

To achieve world-class OEE, the team developed a series of activities using a data driven approach that evolved into best practices.

1.1 The Data Driven Approach

The following are the data driven approach to achieve world class OEE:

- Develop Sustaining Maintenance Repair Tracking System (SMART): Implement the SMART system to reduce repair time by leveraging AI-driven insights from historical maintenance data.
- Technical Clustering by Area: Assign technicians to specific areas to enhance focus and accountability. This approach fosters familiarity with machines and setups, leading to quicker repairs and setups.

- Best of the Best (BOB) and Worst of the Worst (WOW): Analyze equipment performance by identifying top and bottom performers. Use high-performing machines as benchmarks to drive improvements across the fleet.

- Retest Rate Reduction (3R): Minimize retests and rework caused by electrical or mechanical issues by identifying root causes and applying systematic problem-solving methods.

- OEE-Focused Employee Engagement and Recognition: Cultivate a culture of OEE excellence through awareness campaigns and recognition programs that celebrate employee contributions.

- Probe Card Contact Optimization: Decrease hardware downtime from persistent contact issues by enhancing probe card contact designs and implementing timely corrective actions.

- Process Simplification: Streamline operations by identifying and eliminating redundant or unnecessary steps in procedures or work instructions, either through replacement or complete removal.

- Yield Enhancement Initiatives: Target high-potential devices to boost yield through collaborative improvements in fabrication, design, and test programs.

2. 0 REVIEW OF RELATED WORK

"Refer to 1.0 Introduction".

3.0 METHODOLOGY

Historical analysis to deep dive issues affecting OEE were used. Several conditions were also performed to validate the effectiveness of the defined best practices.

3.1 Sustaining Maintenance Repair Tracking System (SMART)

The SMART system represents the team's initial move toward achieving full AI capability—our long-term vision. Designed as an intelligent assistant tool, SMART empowers users to resolve equipment issues with just a few clicks. By leveraging a vast repository of historical repair data, the system enables users to quickly search, filter, and analyze past cases. With its intuitive interface, SMART identifies the most effective corrective actions for any given repair scenario, streamlining troubleshooting and minimizing downtime (see Fig. 2).

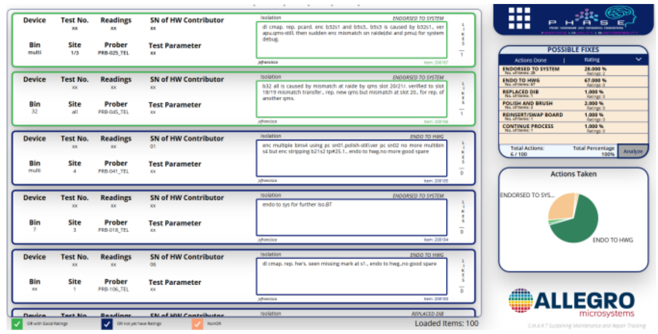

Fig 2: Sample SMART Graphic User Interface

3.2 Tech Clustering by Area

Clusters are established based on a thorough review of machine layout and positioning. Each cluster includes a designated number of machines, along with the corresponding personnel required to effectively manage and support that area (refer to Table 1).

Cluster	Machine Count	Manpower Needed Per shift	Needed Manpower On Actual Machine Running
Cluster 1	21	1.8	1.8
Cluster 2	45	3.3	4.2
Cluster 3	24	1.6	2.2

Table 1: Sample Cluster Table with actual number of equipment and manpower required

Following cluster definition, data analytics tools are utilized to identify the most suitable personnel based on their skillsets, expertise, and performance history. The number of personnel assigned to each cluster is determined by analyzing the complexity and quantity of machines within that area (see Table 2). These allocations are then consolidated and visualized using a manpower calculator table for effective planning and resource management (see Table 3).

TOP Technician Per Machine Model/DT						
DT Contributor	Machine Model 1		Machine Model 2		Machine Model 3	
	Occurrence	Ave Duration	Occurrence	Ave Duration	Occurrence	Ave Duration
Handler	Technician 1	Technician 2	Technician 3	Technician 4	Technician 5	Technician 6
	Technician 7	Technician 8	Technician 9	Technician 10	Technician 11	Technician 12
Hardware	Technician 1	Technician 2	Technician 3	Technician 4	Technician 5	Technician 6
	Technician 7	Technician 8	Technician 9	Technician 10	Technician 11	Technician 12
Tester	Technician 1	Technician 2	Technician 3	Technician 4	Technician 5	Technician 6
	Technician 7	Technician 8	Technician 9	Technician 10	Technician 11	Technician 12

Table 2: Sample Technician skill matrix based on machine model

Allocate Manpower Here				
1st Team Lead	2nd Team Lead	Cluster 1	Cluster 2	Cluster 3
TEAM A	Needed Manpower	1.8	4.2	2.2
	Allocated Manpower	2.0	4.0	2.0
A	Team 1	Technician 1	Technician 2	Technician 3
			Technician 4	
	Team 2	Technician 5	Technician 6	
			Technician 7	
	Team 3	Technician 8	Technician 9	Technician 10
			Technician 11	Technician 12

Table 3: Sample Calculator Table

To maintain effectiveness over time, performance metrics are reviewed regularly. These periodic evaluations help identify the need for any adjustments in manpower allocation, ensuring optimal resource distribution and sustained operational efficiency.

3.3 Best of Best (BOB) and Worst of Worst (WOW)

Another key data analytics initiative focuses on monitoring the performance of the entire machine fleet. This involves identifying both the top-performing and underperforming machines. A second-level analysis is then conducted to understand the root causes behind significant performance gaps. The ultimate goal is to achieve consistent performance across all machines, ensuring uniform efficiency and reliability (see Fig. 3).

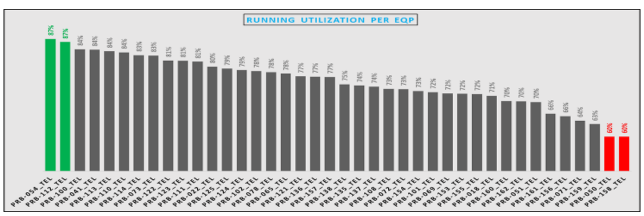

Fig. 3. Sample Top 2 BoB and Top 2 WoW Machines

3.4 Retest Rate Reduction (3R)

A structured approach was implemented through the development of a monitoring matrix that tracks top devices experiencing Retest and Rework issues (see Table 4). Once a device is identified as a candidate, the team conducts an in-depth analysis to uncover the root causes. Based on the findings, a targeted action plan is formulated. Where applicable, these corrective actions are extended to similar devices. The effectiveness of each action is continuously monitored to ensure measurable performance improvements (see Fig. 4).

TOP Devices - Monitoring Matrix (Running Retest/Rework Hours)																		
Device	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	Ave Last 3 Months	Result	W/ Improvement Plans?	Remarks
Device 1	196	111	77	119	70	89	157	109	71	12	74	46	64	24	13	34	▲	Yes	Improved
Device 2	140	45	10	0	3	10	4	5					0	14	5	6	▲	Yes	Improved
Device 3	99	62	77	67	19	47	81	83	64				0	8	14	7	▲	Yes	Improved
Device 4	93	34	28	140	96	126	5	0	12	1			0	0	0	0	▲	Yes	Improved
Device 5	81	15	9	0	34	9	18	0					0	0	0	0	▲	Yes	Improved
Device 8	52	72	96	103	0	60	12	0	3				0	27	0	9	▲	Yes	Improved
Device 9	52	35	43	36	22	8	0	30					2	0	0	1	▲	Yes	Improved
Device 10	46	18	16	113	55	16	81	33		34	19		0	7	0	2	▲	Yes	Improved

Table 4: Retest/Rework Monitoring Matrix

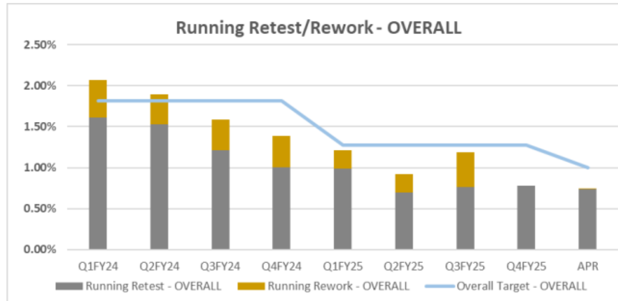

Fig 4: Retest/Rework Improvement

3.5 OEE Employee Engagement and Recognition

Another key element of achieving world class OEE is cultivating awareness and a shared understanding of performance goals. This involves building a culture where every task is executed with the highest level of excellence. Technician performance data is regularly tracked, with top performers recognized and rewarded (see Image 1). For those identified as needing improvement, coaching sessions and skill assessments are conducted to support their development. Recognition and personalized coaching not only enhance individual performance but also uplift team morale by reinforcing that every team member is valued.

Image 1: Technician Recognition

3.6 Probe Card Contact Improvements

KAIZEN approach was employed to identify and address contact issues caused by light or missing probe marks. The team conducted a thorough investigation and developed a comprehensive resolution strategy.

As part of the analysis, the needle design was revisited and revalidated against the wafer bond pad structure. Historical downtime data revealed that the existing 3-mil needle exhibited insufficient penetration, leading to poor contact and resulting in light or missing probe marks. This prompted a re-evaluation of the needle's gram force compatibility with the bond pad thickness.
It was confirmed that under a maximum overdrive setup of 100 µm, the needle exerted only 7 grams of force—insufficient to effectively penetrate the wafer bond pad (see Fig. 5). This insight guided the team toward optimizing the needle design and force specifications to ensure reliable contact performance.

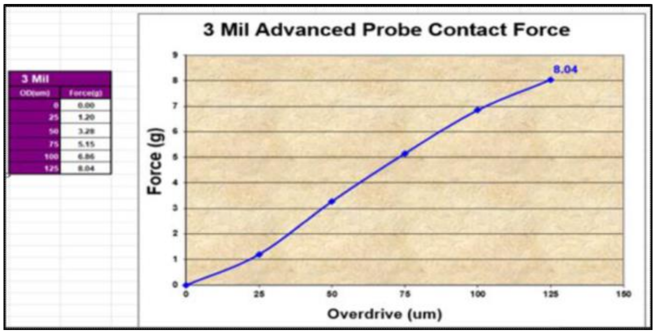

Fig 5: 3mils needle gram force vs. overdrive showing 7 grams force for a maximum 100 um overdrive.

To enhance probe contact reliability, the team recommended upgrading the needle size from 3.0 mils to 3.5 mils, based on the hypothesis that thicker needles generate higher gram force, resulting in better penetration into wafer bond pads. Testing validated this assumption: at a 100 µm overdrive, the 3.5 mil needle delivered 9 grams of force compared to just 7 grams from the 3.0 mil needle (see Fig. 6).

This strategic adjustment led to stabilized electrical testing, a significant reduction in downtime, and improved equipment utilization.

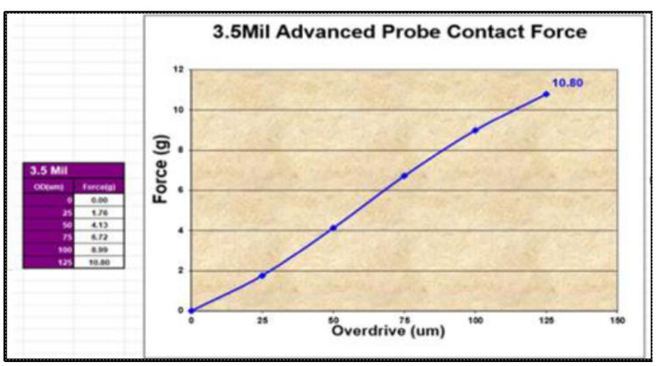

Fig. 6: 3.5mils needle gram force vs. overdrive showing 9 grams force for a maximum 100 um overdrive.

A statistical analysis using a t-test was conducted to determine whether the difference in First Pass Yield (FPY) performance between the 3.0 mil and 3.5 mil needles was statistically significant (see Fig. 7).

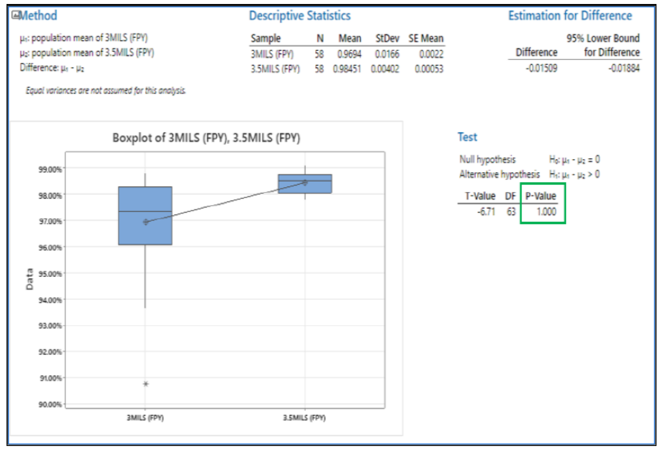

Fig. 7: The data shows that there is a significant improvement on First Pass Yield using 3.5mils vs 3mils.

To ensure a systematic implementation, this finding has been incorporated into the probe card matrix and is now considered during the probe card design phase.

3.7 Process Simplification

Another core item for improving OEE is process simplification using LEAN concept. The team conducted a thorough review of various operational procedures that contributed to extended downtime. One key area identified was the setup process, particularly how technicians hand over machines back to production.

The focus was on pinpointing redundant or non-value-adding steps that could be streamlined. Processes that do not impact the final output or quality were either eliminated or replaced with more efficient alternatives (see Fig. 8). This initiative ensures smoother workflows and reduced downtime without compromising results.

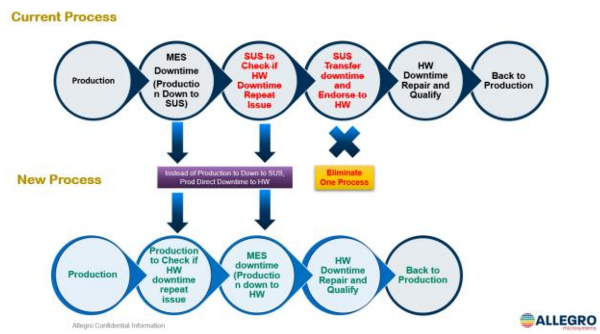

Fig 8: Sample Process Reduction removing Sustaining Intervention on HW Related Downtime Issues

3.8 Yield Enhancement

Yield enhancement involves improving the baseline yield of a specific device by identifying and addressing the primary sources of loss.

The team prioritizes devices with the highest scrap cost losses and yield variance in dollar value for targeted yield improvement activities. Once these top-impact devices are identified, a detailed root cause analysis is conducted, followed by the development and implementation of corrective actions.

Key methods used to enhance yield include:

- Design Enhancement – Resolving design-related issues that contribute to defect sensitivity.
- Fab Process Optimization – Addressing fabrication process weaknesses that may lead to yield loss.
- Test Program Refinement – Fine-tuning test parameters to ensure consistent and accurate results.
- Other Supporting Initiatives – Including previously mentioned strategies that contribute to overall yield improvement.
- Through this structured approach, yield is increased, and scrap costs are reduced. Where applicable, successful actions and lessons learned are extended to other devices to drive broader, long-term improvements.

4.0 RESULTS AND DISCUSSION

OEE improved significantly from 74% in Q4 FY24 to 81% by Q2 FY25, resulting in $100K in overhead cost savings and $2.1M in CAPEX avoidance. This improvement was driven by the successful implementation of several key initiatives, including:

- Technical Clustering by Area
- Probe Card Contact Improvements
- Process Simplification
- OEE Employee Engagement and Recognition
- S.M.A.R.T System
- Usage Rate Alignment
- 3R Retest Rate Reduction
- Yield Enhancement
- Lookahead Planning for Hardware and Setup

Building on this momentum, OEE further increased to 86% by Q4 FY25, bringing the total overhead cost savings to $200K and CAPEX avoidance to $4M (see Fig. 9).

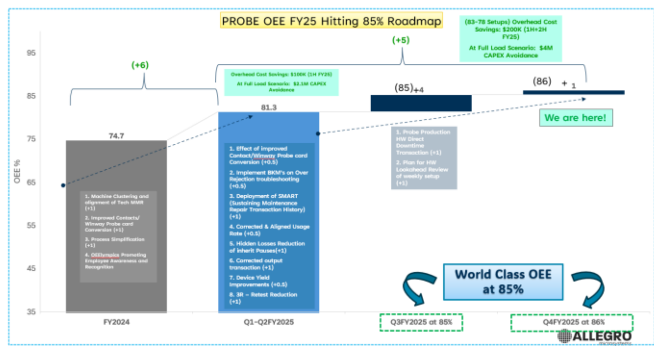

Fig. 9: Probe OEE Roadmap hitting the 85% World Class OEE

5.0 CONCLUSION

Achieving world-class OEE is not the result of isolated efforts but the outcome of a deliberate, structured, and sustained approach. By adopting the recommended data driven approach, organizations can create a strong foundation for operational excellence. Making OEE metrics transparent, standardizing processes, investing in targeted training, aligning initiatives with strategic goals, fostering a culture of accountability, and recognizing team achievements are all critical components of this journey. When consistently applied, these practices not only drive measurable improvements in equipment effectiveness but also cultivate a high-performance culture that supports long-term success and continuous improvement.

6.0 RECOMMENDATIONS

To achieve world-class OEE, the team recommends adopting a structured data driven approach designed to guide the organization toward sustained excellence. These initiatives should encompass the following key elements:

- Ensure OEE metrics—Availability, Performance, and Quality—are highly visible and easily accessible to both frontline operators and management.
- Implement and rigorously follow standardized operating procedures and efficient changeover practices to minimize process variability and equipment downtime.
- Provide targeted training for operators and maintenance personnel on best practices and continuous improvement tools to enhance technical capabilities and drive performance.
- Adapt Artificial Intelligence (AI) of data collection and analytics by leveraging the established S.M.A.R.T. system.
- Align OEE improvement initiatives with the organization's broader KPIs and long-term strategic goals to ensure cohesive progress.
- Foster a culture of accountability and ownership through the cluster concept, encouraging proactive problem-solving at all organizational levels.
- Establish a formal recognition program to celebrate team achievements in OEE, reinforcing a culture of excellence and continuous improvement.

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8.0 REFERENCES

1. https://www.augmentir.com > world-class manufacturing.

2. https://www.leanproduction.com/oee/

3. Robert C. Hansen **"Overall Equipment Effectiveness (Volume 1)" 2001**,

9.0 ABOUT THE AUTHORS

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