FabTime Cycle Time Management Newsletter

Volume 12, No. 5 October 2011

Information

Mission: To discuss issues relating to proactive wafer fab cycle time management

Publisher: FabTime Inc. FabTime sells cycle time management software for wafer fab managers. New features in the software this month include stacked WIP and Moves Trend and Pareto charts, with user ability to select the "stacked by" variable.

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Welcome

Welcome to Volume 12, Number 5 of the FabTime Cycle Time Management Newsletter! In this issue, we have community announcements about the upcoming Fab Owners Association meeting at Spansion, and a call for editors for the International Journal of Production Research. Our FabTime software tip of the month is about setting default filters for charts. This month's subscriber discussion forum includes several responses sparked by the main topic of the last issue, PM Scheduling. We also have a new question about capacity analysis for cascading tools.

Our main article this month is about using OEE to enhance fab performance. Recently, in response to a suggestion from one of our customer sites, FabTime changed the method by we calculate OEE (Overall Equipment Effectiveness) Loss Factors. Several of our customers were interested in the details of not only the equations used; but also the methodology of using OEE to improve operations. In this article we discuss the definition and calculation of OEE, introduce FabTime's current methodology for calculating OEE Loss Metrics, and review how to properly use the information provided by OEE to continuously improve an organization's manufacturing capacity. We hope that other subscribers will find this useful, and we welcome your feedback (particularly in the area of the loss factor calculations, as outlined below).

Thanks for reading – Jennifer

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Community News/Announcements

Fab Owners Association Meeting in Austin, TX

This quarter's Fab Owners Association meeting is also being held in Austin. The meeting will be held on November 10th at Spansion (for FOA device members and associate members only). The FOA is an international, nonprofit, trade association of semiconductor & MEMS fab owners and industry suppliers who meet regularly to discuss and act on common manufacturing issues, combining strengths and resources to become more globally competitive. More details can be found at http://www.waferfabs.org.

FabTime's Jennifer Robinson and Sean O'Brien will be attending the FOA meeting at Spansion, and look forward to seeing some of you there.

International Journal of Production Research seeks Editors

Taylor & Francis seek applicants for the positions of Editor-in-Chief and Editors of the International Journal of Production Research. The official term is for a minimum of five years, starting in January 2012. The closing date for application is November 18, 2011.

Please visit www.tandfonline.com/tprs for information about the Journal and Publisher. If you would like more information about the editorial positions, please email newsletter@FabTime.com, and we will forward you the full job description from Taylor & Francis.

FabTime welcomes the opportunity to publish community announcements. Send them to newsletter@FabTime.com.

FabTime User Tip of the Month

Set Default Filters for Commonly Used Charts

We are just about to release a new software patch with a host of useful features. Several of these will be the topics of the FabTime tips for the next few issues. Today, we'd like to take a step back and look at a fundamental ease of use function in FabTime. We recommend that all users take a couple of minutes to set up a default set of filters on the Charts page. Simply navigate to the Charts page, and enter your most commonly-used filters in the text boxes and drop-down lists to the left-hand side of the page. Then press the "Set Defaults" button at the bottom of the list. Now, whenever you bring up a new chart from the Chart list, FabTime will pre-populate it with that set of filters (as applicable; some filters are not included on all charts). Once you are on the individual chart page, you can always clear out any filters that aren't needed for that chart. But if you have any filters that you find yourself typing in over and over again, setting defaults is the way to go.

One related bonus tip. You can also use the filter set on the chart list page to do a one-time pre-population of a chart with a set of filters. Just enter a value (or values) in the filters on the chart list, and don't press "Set Defaults" at the bottom. Instead, enter the values you need, and then immediately press the "Go" button to generate the chart of interest. FabTime will build the chart, pre-loaded with your specified filters, but your previous default settings will be left unchanged. This feature is especially useful when bringing up tool-related charts, since these require a Tool or ToolGroup filter to be set before the chart will be displayed.

If you have any questions about this feature (or any other software-related issues), just use the Feedback form in the software.

Subscriber Discussion Forum

Capacity Analysis for Cascading Tools

Amrusha Varadarajan from TowerJazz sent us a new question, seeking input from our other subscribers. Amrusha wrote:

"We are working on capacity analysis for cascading tools, where by cascading I mean processing several lots that require the same recipe in sequence (back-to-back) so that higher throughputs can be achieved than otherwise. Especially on PECVD tools that deposit films, cascading can make a big difference because if you ran different recipes back to back, the tool would have to empty itself out of all wafers from a previous lot before it could run the new lot. This would result in loss of time. Here are my questions for your subscriber community:

1) Given that a tool's throughput changes based on the cascading level, do you include the cascading level in capacity modeling calculations and in OEE rate efficiency calculations?

2) How do you determine the appropriate cascading level to use for a tool? Do you look at historical performance (which depends on WIP levels) or is there a methodology one could apply?"

FabTime Response: We have not looked at this question directly, and so open it up to the subscriber community.

Issue 12.04: PM Scheduling

And anonymous subscriber wrote in response to the last issue: "I worked for a while at a fab that would shut down completely on Wednesday day-shift for PM work. All maintenance was combined and performed on that shift. It may seem crazy but it maximized throughput. The techs not doing the PM work did jobs like wiping down tools, walls, and floors. A predictable 8 hours of down-time out of 168 hours per week is less than 5%. I don't know how successful this strategy was in practice. This was back in the days of 4M DRAM in the late 80's on 200-mm wafers. It probably couldn't be done now but the principle is sound."

FabTime Response: We can see that policy being nice in a management sense, with the downtime being utterly predictable (and they probably had a nice, clean fab). Thinking about it in terms of cycle time, you're adding 8 hours per week onto the cycle time of every lot during the shutdown. The question, then, is whether you get back those 8 hours per lot due to not having to do PMs at other times. We would imagine that the answer is yes in some cases. You can envision a lot waiting for 4 hours over here for a PM, and then waiting for 3 hours over here, etc. But we're guessing that you wouldn't recover the lost time in all cases. Especially for hot lots, and especially if you have sufficient redundancy in your toolset to not be taking down entire tool groups at one time. Which is probably why you don't see this type of shutdown in practice today (at least we haven't seen it). But it's an interesting idea.

V.A. Ames from ISMI also wrote in response to the PM Scheduling article in the last issue. He said: "After working to improve equipment productivity with many companies over the years, I found your article on PM Scheduling and Cycle Time interesting. There are several more things to consider regarding the grouping and shortening of PM time that helps cycle time. First, this practice is effective for any scheduled event, like changing consumables or performing regularly scheduled tool qualifications when possible. One of the goals that should be incorporated is to have no scheduled activity last longer than 8 hours. This allows the work to be started and completed on the same shift by the same technician. As many of your subscribers can attest, much time can be lost if the activity crosses over from one technician to another, especially on swing days. The last key thing to remember is that the PM, or any scheduled activity, is composed of work performed when the tool is down (internal) and much more work performed when the tool is running product (external). Things like gathering tools and parts, ensuring any test equipment that may be used is ready, inspecting removed parts, and putting things away are not done when the tool is down. While at Sematech and ISMI I have even had success breaking down annual PMs on ion implanters that took days to complete (a very painful experience) into no more than 8 hour PMs performed every other week on different parts of the equipment. The results were very successful with a dramatic positive impact to cycle time.

One last thing, I totally agree with your position on measuring mean time between downtime events for scheduled downtime. It serves no purpose unless your goal is as small a number as possible. Getting management to understand that strategy could be a challenge though. The most critical measurements for PMs are length of pm (efficiency and consistency), first pass qual (effectiveness), and number of failures (effectiveness)."

PM Effectiveness

Moving slightly beyond the question of PM scheduling, **Mike Hillis** from Spansion wrote to ask us about PM effectiveness. He said: "It is widely accepted that effective preventive maintenance will improve tool availability and downtime predictability. Most of us have elaborate PM procedures, scheduling systems, monitors and the like to help ensure we get the work done. One thing we have not done well is measure the effectiveness of the PM actions themselves. When a PM is done, does it recover as expected? Does it last until the next scheduled event? Was the PM completed in a timely manner? Basically we are talking about "first pass success" of the PM procedure.

We have found it to be a particularly dicey proposition defining what "first pass success" is and how to identify when it happens by pulling data from our MES systems. We have done it successfully on a small scale but found it to be extraordinarily labor intensive and prone to error. Not much help to a high volume operation.

The question is this: has anyone successfully identified a methodology for gauging first pass success for PMs? Even if it is at a rudimentary level, I'd like to hear how they approached the problem."

FabTime Response: Subscribers, does anyone have a methodology on gauging first pass success for PMs that you would be willing to share with Mike? We can include responses in the next issue, or put you in touch with Mike to discuss offline.

FabTime welcomes the opportunity to publish subscriber discussion questions and responses. Simply send your contributions to Jennifer.Robinson@FabTime.com.

Using OEE to Enhance Factory Performance

Introduction

Recently, FabTime has changed the method by which it calculates OEE (Overall Equipment Effectiveness) Loss Metrics. Several of our customers were interested in the details of not only the equations used; but also the methodology of using OEE to improve operations. In this article we will discuss the definition and calculation of OEE, introduce FabTime's current methodology for calculating OEE Loss Metrics, and review how to properly use the information provided by OEE to continuously improve an organization's manufacturing capacity.

Background

OEE is a common measurement of equipment productivity in the semiconductor industry, and is technically approved by the Semiconductor Equipment and Materials International SEMI standard E79-0200 published in 2000. Semiconductor manufacturing is very capital intensive, so each company would like to utilize equipment as effectively as possible to maximize the value of each investment. It is estimated that up to 75% of the cost of new fabs is incurred directly from semiconductor processing equipment [Murphy et. al., 1996]. Due to the high value placed on tools, a metric was developed in 1988 by Nakajima based on methodologies known as TPM (Total Productive Maintenance) [S. Nakajima, 1988]. The goal of TPM is to maximize the value of equipment in a manufacturing environment. OEE is a subset of TPM and is built upon the lean concept of preserving value.

OEE = Availability Efficiency * Performance Efficiency * Quality Efficiency
Availability Efficiency = 100 - Unscheduled Downtime - Scheduled Downtime - Non-Scheduled time.
Performance Efficiency = Rate Efficiency * Operation Efficiency.
Quality Efficiency = (Total Moves - Scrap - Rework Moves) / Total Moves.
Rate Efficiency = (Theoretical Production Time for Actual Moves) / (Productive Time).
Operational Efficiency = Productive Time / (Productive Time + Standby Time + Engineering Time).

Table 1. OEE Definition

The OEE metric reflects how well a tool is performing. There are three major components to OEE: Availability Efficiency, Performance Efficiency, and Quality Efficiency. The computation of OEE can be seen above in Table 1.

The mathematical definitions above can also be defined verbally. According to the E79-200 spec, Availability Efficiency is "the fraction of total time that the equipment is in a condition to perform its intended function", Performance Efficiency is" the fraction of equipment uptime that the equipment is processing actual units at theoretically efficient rates", and Quality Efficiency is "the theoretical production time for effective units divided by the theoretical time for actual units".

Using the definitions above, one can say that OEE is the percent of total time which would have been required by the tool to produce the good units that were actually produced, had the tool been operating at maximum theoretical speeds. Thus, OEE represents the portion of available capacity required to produce the good units. OEE can be reduced to simply *TheoreticalProductionTime% * QualityEfficiency*.

TheoreticalProductionTime% is the percent of total time required (at maximum speed) to produce all units actually produced. *QualityEfficiency* is the ratio of good units to total units produced. Therefore the multiplication of *TheoreticalProductionTime% * QualityEfficiency* gives us the percent of total time required to produce only the good units at maximum theoretical speeds.

The theoretical goal for OEE measured equipment is to drive the metric to 100%. Achieving 100% OEE would mean that the tool is running at maximum possible capacity. Having 100% OEE has other implications, however, and will be discussed in a later section.

Defining Loss Metrics

As defined above, OEE is the multiplication of three ratios: Availability Efficiency, Performance Efficiency, and Quality Efficiency. Each major category of effectiveness has different categories of productivity losses that can be identified as domains for improvement. These three ratios, however, are difficult to graph in a meaningful way, or to use to understand the relative impact of the underlying root causes. Thus what we do is translate the OEE data into four loss factors:

1. **Availability Loss** (losses due to scheduled downtime, unscheduled downtime, and factory nonscheduled time)
2. **Rate Efficiency Loss** (losses due to the tool not operating at the optimal rate, including idling, work stoppages, etc.)
3. **Operational Efficiency** Loss (losses due to the tool not being used to run wafers – the tool may be idle, or could be being used by engineering)
4. **Assignable Quality Loss** (losses due to the tool being used to run scrapped or reworked wafers)

Although every type of loss that can affect operational performance was not included in the above list, all losses can be categorized under a) plant availability, b) plant/process performance, or c) process quality. By measuring these losses, an organization is able to quantify potential areas for capacity improvement of its equipment. The SEMI E79-0200 covers the relationship between SEMI Standard E10 Tool States and SEMI E79 productivity loss categories listed above. The SEMI Standard E79 specifically defines the E10 state relationship to Availability Efficiency and Operational Efficiency losses. However, this document does not explicitly define how to calculate productivity losses and improvement for Rate Efficiency losses and Assignable Quality losses.

Since the calculation of E79 Productivity Losses and Improvement Domains are not explicitly defined, there are variations of OEE loss metrics in use across the industry. In the past, FabTime was calculating loss metrics by taking the total OEE loss (100-OEE) and multiplying by the ratio of the given metric percentage loss (100 – metric) divided by the summation of all the efficiency losses (*100 – Availability Efficiency + 100 – Rate Efficiency*… etc.), for example:

Loss(Avail): Portion of OEE loss due to availability efficiency:

*= (100-OEE) * (100 - Availability Efficiency) / (100 - Availability Efficiency + 100 - Rate Efficiency + 100 - Operational Efficiency + 100 - Quality Efficiency).*

FabTime used this formula in order to maintain a common reference point in which to compare all of the efficiency metrics (and make all of the numbers add up to 100%). However, it was pointed out by one of our customer sites that the denominator mixed different reference points, e.g. Availability Efficiency relates to the total time, whereas Operational Efficiency relates to available time. This was causing some cases in which the loss metric could be less than the actual loss event. This is the reason that FabTime moved from its prior method of calculating OEE loss metrics to methods that we believe are more common in the semiconductor industry.

The calculations FabTime now uses follow industry norms for OEE Loss categories and can be found below in Table 2. As one can see, Availability Loss and Operational Loss follow in line with the SEMI E79 standard. Rate Loss and Quality Loss now are directly proportional to the loss category they are defining.

To confirm the validity of the loss definitions shown above, we want OEE plus the sum of the losses to equal 100%. Thus, we require:

Loss Factor	Equation	Explanation
Availability Loss	ScheduledDowntime% + UnscheduledDowntime% + Non-ScheduledTime%	% of total time tool is not available to produce wafers
Rate Loss	(1 - Rate Efficiency%) * Productive%.	% of total time lost due to actual average tool speed being less than theoretical units per hour
Operational Loss	Standby% + Engineering%	% of total time tool is available, but not producing production wafers
Quality Loss	(1-QualityEfficiency%) * Productive% * RateEfficiency%	% of total time lost due to poor first pass quality

Table 2. OEE Loss Factor Definitions

OEE + Availability Loss + Rate Loss + Operational Loss + Quality Loss = 1

Using our simplified OEE definition from the Background section, we have:

*OEE = TheoreticalProductionTime% * QualityEfficiency*

Filling in the loss factor definitions (and using color to indicate different terms), *OEE + AvailabilityLoss + RateLoss + OperationalLoss + QualityLoss* becomes:

*TheoreticalProductionTime% * QualityEfficiency + (ScheduledDowntime% + UnscheduledDowntime% + Non-ScheduledTime%) + ((1 - Rate Efficiency%) * Productive%) + (Standby% + Engineering%) + ((1-QualityEfficiency%) * Productive% * RateEfficiency%)*

Combining Availability Loss and Operational Loss, we get *1-Productive%*, so the sum becomes:

*TheoreticalProductionTime% * QualityEfficiency + (1-Productive%) + ((1 - Rate Efficiency%) * Productive%) + ((1-QualityEfficiency%) * Productive% * RateEfficiency%).*

Multiplying through the last few terms, we get:

*TheoreticalProductionTime% * QualityEfficiency + 1-Productive% + Productive% - Rate Efficiency% * Productive% + Productive% * RateEfficiency - QualityEfficiency% * Productive% * RateEfficiency%.*

Cancelling terms we get:

*TheoreticalProductionTime% * QualityEfficiency + 1 - QualityEfficiency% * Productive% * RateEfficiency%.*

Expanding RateEfficiency, we have:

*TheoreticalProductionTime% * QualityEfficiency + 1 - QualityEfficiency% * Productive% * TheoreticalProductionTime% / Productive%.*

Cancelling terms we get:

*TheoreticalProductionTime% * QualityEfficiency + 1 - QualityEfficiency% * TheoreticalProductionTime%.*

And cancelling terms one last time, we simply get 1. So we have confirmed that *OEE + AvailabilityLoss + RateLoss + OperationalLoss + QualityLoss = 1*. This confirms that FabTime's new method of calculating loss metrics meets the criteria for mathematical validity.

These calculations were accepted by all active FabTime sites in August, 2011.We share them here in the interest of obtaining a more broad industry validation of the calculations, and in the hope that our subscribers will find our work with our customers in this area useful.

Focusing Resources on Improving OEE

OEE is an excellent metric with which an organization can measure and potentially improve total available capacity for a tool. Usually the best method of improving capacity is to find the largest loss, perform root cause analysis to determine the cause of that loss, and then execute performance enhancements. The largest loss metric may not be the most valuable to improve, however, so it is up to the organization to determine its improvement strategy.

Although it is commendable for any organization using OEE to improve capacity, it is important to understand the importance of an efficient process vs. an effective value stream. It is recommended that OEE improvement should be directed at the bottlenecks of the process. The theoretical goal for bottleneck equipment in a fully loaded factory is to drive the equipment's OEE to 100%. Achieving 100% OEE on the bottleneck equipment would mean that the factory is operating at its maximum possible capacity.

In practice, 100% OEE is typically not possible on the bottleneck equipment due to unscheduled and scheduled downtime. For example, if scheduled downtime is 10%, then the maximum possible OEE is 90%. And achieving 90% OEE when there is 10% scheduled downtime is only feasible if there is very little variability in the factory, and there is a system in place to maintain a buffer in front of bottleneck equipment. Such a system must throttle down starts when this buffer gets too large. Otherwise, any variability in the system will lead to exploding queues and cycle time at bottleneck equipment. If the bottleneck equipment is not near the front of the factory, maintaining such a throttling system (e.g. a "drum-buffer-rope" system as popularized by Goldratt) is difficult in wafer fabs where the process flow is long and there are many pieces of bottleneck or near-bottleneck equipment spread throughout the process.

In general, OEE is not a useful metric for non-bottleneck equipment, as the goal of non-bottleneck equipment is to feed bottlenecks so that bottlenecks never starve for lack of WIP. If non-bottleneck equipment is loaded so that it achieves 100% OEE, by definition this means that there is too much work for bottleneck equipment, and this situation will result in exploding queues and cycle time at bottleneck equipment. Therefore, there is no financial sense in running a non-bottleneck tool above the capacity of slower tools.

It is also important to be careful when attempting to compare OEE across equipment or plants. Does a higher OEE always indicate better performance? It is not necessarily true depending on the situation, e.g. the influence of product mix produced on each machine. OEE is a tool to identify areas for improvement for individual machines; always keep in mind the value stream of the operation before striving for that "world class" moniker.

Conclusions

OEE is an excellent tool for measuring complete machine performance. By making losses visible to an organization, steps can be taken to improve overall effectiveness of the tool. However, this only makes sense if it will lead to improved value. Always remember to focus the attention of OEE improvement projects on constraint or bottleneck tools.

Closing Questions for FabTime Subscribers

Does your organization have any differences in the method by which it calculates OEE Loss Metrics? Does your organization use other metrics to characterize machine capacity utilization, e.g. TEEP (Total Effective Equipment Performance) or OFE (Overall Factory Effectiveness)?

Acknowledgements

FabTime would like to extend its appreciation to **John Matthews** at Anadigics for originally proposing the changes to the method in which FabTime calculates OEE Loss metrics. We appreciate any and all feedback; thanks to customers like John, FabTime is continuously improving.

Further Reading

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Subscriber List

Total number of subscribers: 2706, from 471 companies and universities.

Top 20 subscribing companies:

- Maxim Integrated Products, Inc. (154)
- Intel Corporation (146)
- Micron Technology, Inc. (105)
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- Nanyang Technological University (7)
- Virginia Tech (7)

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- MicroProbe
- Nanium S.A.
- OSRAM Opto Semiconductors
- Robins Air Force Base
- Silex Microsystems
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- Unisem
- Univ. of Applied Science Deggendorf

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- Centrotherm (1)
- CyOptics (5)
- DeHart Consulting, Inc. (1)
- Delphi Delco Electronics Systems (1)
- Dublin City University (3)
- Eastman Kodak Company (14)
- EDS (1)
- Heptagon Micro Optics Pte Ltd (1)
- Hutchinson Technology (1)
- Inotera Memories (1)
- L-3 Communications (2)
- Lantiq (1)
- Medtronic (7)
- Norwich Pharmaceuticals (1)
- SAE Magnetics (2)
- Samsung (16)
- Tata BP Solar (1)
- TriQuint Semiconductor (14)

Note: Inclusion in the subscriber profile for this newsletter indicates an interest, on the part of individual subscribers, in cycle time management. It does not imply any endorsement of FabTime or its products by any individual or his or her company.

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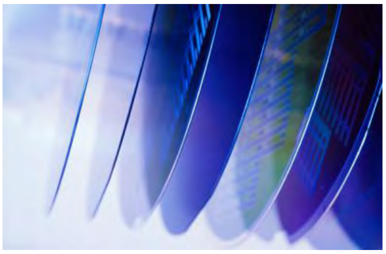
FabTime® Dispatching Module



Dispatch Configuration and Support

We offer our dispatching module for a single, fixed monthly fee (on top of your regular FabTime subscription). This includes:

- Dispatch rule configuration via user-friendly web-based interface for standard factors
- Training.
- Dispatch list feed to the MES (if applicable).
- Support and upgrades.

Custom dispatch rules and consulting from our dispatching expert available for additional fee

Dispatch Factors

- Batch code at the current tool.
- Lot priority.
- Downstream tool priority.
- Current tool FIFO.
- Current tool idle time.
- Downstream batch efficiency.
- Critical ratio.
- Earliest-due-date.
- Current step processing time.
- Remaining processing time.
- Current step qualified tool count
- WIP level or staging time at downstream tools.

Interested?

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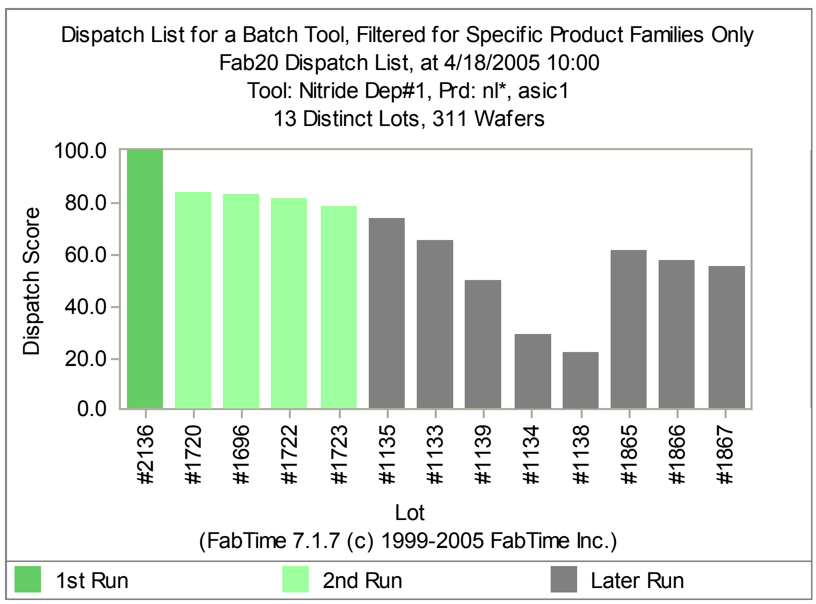
Do your operators make the best possible dispatching decisions?

- Do you struggle to balance lot priorities and due dates with tool utilization and moves goals?
- Do your critical bottleneck tools ever starve?
- Do you use standard dispatch rules, but feel that your fab's situation is more complex, requiring custom blended rules?
- Do you know how well your fab executes your dispatch strategy?

FabTime's dispatching module is an add-on to our **web-based digital dashboard software**. At any point, for any tool in your fab, FabTime will show you the list of all lots qualified to run on that tool. This list will be ordered by the dispatching logic that your site has selected for that tool. This logic can use standard dispatch rules such as Priority-FIFO and Critical Ratio. However, you can also create custom dispatching logic using any combination of dispatch factors (shown to the left).

You can display dispatch lists in FabTime, and/or export them back to your MES. FabTime also includes a dispatch reservation system to hold downstream tools when a lot is started on an upstream tool, as well as dispatch performance reporting.



FabTime Dispatching Module Benefits

- Ensure that wafers needed by management are in fact the wafers that are run, while requiring less manual intervention on the part of management.
- Improve delivery to schedule, and the display of performance to schedule.
- Document the dispatching logic used by the best operators and make this available to all shifts.