FabTime Cycle Time Management Newsletter

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Information

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

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Welcome

Welcome to Volume 3, Number 1 of the FabTime Cycle Time Newsletter. Here's hoping that 2002 will be a better year for the industry than 2001. In this month's issue, we have two FabTime announcements. We're very pleased to announce that Norbie Lavigne has accepted a position on FabTime's advisory board, joining Ken Beller and Marc O'Brien. We're also pleased to have donated a license for FabTime's cycle time management software to Arizona State University. We've included a conference announcement for the MASM Conference, organized by Arizona State, and one that we highly recommend. Frank Chance, President of FabTime, will be giving a talk on wafer fab cycle time management at ASU on January 23rd. If any of you in the Phoenix area would like to attend, simply RSVP to Frank (Frank.Chance@FabTime.com) by January 22nd, and he will be happy to send you the details.

This month we have four topics raised by newsletter subscribers: measuring shift performance to plan, including number of operators in performance measures, recommended model accuracy relative to actual values, and understanding the relationship between OEE and cycle time performance measures. This last issue is one that has been raised to us before, and we decided to expand it into this month's main topic. The issue is that striving for high OEE values, as defined in the original definition of OEE, tends to lead to high cycle times. There is, however, a modified version of OEE called Production Equipment Effectiveness (PEE) that takes this problem into account. In this issue, we will define PEE in detail, and show why fabs concerned with cycle time should strive for high PEE values, instead of high traditional OEE values.

Thanks for reading! -- Jennifer

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Community News/Announcements

FabTime Appoints Norbie Lavigne to Advisory Board

Menlo Park, CA. January 14, 2002 - FabTime Inc. today announced that Mr. Norbert (Norbie) Lavigne has accepted a position on FabTime's Advisory Board. Mr. Lavigne has over 25 years of semiconductor industry experience, both domestic and international. He was plant manager of IBM's Burlington fab from 1987 to 1991. During that time, he successfully introduced 8" wafer processing for the first time in the Semiconductor Industry. Following this position, Mr. Lavigne worked for two years as the Burlington World Trade Executive for IBM in Paris, France. He is currently retired from IBM (NYSE: IBM), and working as a consultant for the technology industry.

Said Mr. Lavigne, "I look forward to working with FabTime, and getting to talk about issues in the industry that I love. I decided to work with them because I feel that FabTime has a product that could make a difference for the industry."

"Norbie Lavigne brings valuable experience to FabTime," said Frank Chance, President of FabTime. "His background as plant manager for IBM represents the target customer for our software. His feedback will help us to sharpen our focus, to make the software more useful to fab managers who want to improve cycle time."

Other members of FabTime's advisory board include Mr. Marc O'Brien and Mr. Ken Beller. Mr. O'Brien is former CEO and founder of WebProject Incorporated, which was acquired by Novient. He is now a partner in Global Integrated Ventures. Mr. Beller has over 15 years in global high-tech management with such companies as Siliconix (NASDAQ: SILI), TEMIC, a DaimlerChrysler (NYSE: DCX) company, and Etec Systems, an Applied Materials (NASDAQ: AMAT) Company, and is currently President of Near Bridge, Inc.

International Conference on Modeling and Analysis of Semiconductor Manufacturing (MASM 2002) Conference

The MASM 2002 conference will be held April 10-12, 2002. The following description is from the MASM website, at http://www.eas.asu.edu/~masmlab/masm2002/index.html:

"This year's International Conference on Modeling and Analysis of Semiconductor Manufacturing (MASM) will be a forum for the exchange of ideas and best practices between researchers and practitioners from around the world involved in modeling and analysis. While we seek to know what's going on within the semiconductor industry, neither presenters nor attendees need be in the semiconductor industry to participate. We are interested in any methodologies, research, and/or applications from other industries, as well, that might also be utilized for the semiconductor industry."

"The electronics industry recently surpassed the automotive industry to become the largest basic industry in the world after agriculture. At the heart of this industry is the manufacture of semiconductor devices. The semiconductor market has maintained an average annual growth rate of 15% over the last 30 years despite periodic downturns, like the industry is now experiencing. However, costs continue to escalate; current wafer fabrication facility costs approach $3.5 billion. We invite you to present on topics related to modeling and analysis that might help address the escalating costs of this industry."

You can find a call for papers, as well as track, committee, and hotel information at the conference website. Abstracts are due January 31st, full papers on March 18th.

FabTime Donates Cycle Time Management Software to Arizona State

Menlo Park, CA. December 19, 2001. FabTime Inc. today announced that it had donated a license for its FabTime cycle time management software to Arizona State University. The software will be used by the Modeling and Analysis for Semiconductor Manufacturing (MASM) Lab within the Department of Industrial Engineering.

Professor John Fowler, co-director of the MASM Lab said, "Among other things, we intend to use FabTime to support our research in wafer fab scheduling. We may be able to use the software to identify trigger points for rescheduling, based on fab conditions."

"We are looking forward to working with Arizona State," said Jennifer Robinson, Chief Operating Officer of FabTime. "FabTime analyzes work-in-process levels and tool state information in real time. Using this information to trigger rescheduling seems like an exciting new application of FabTime's technology."

Corporate customers for FabTime's cycle time management software include Advanced Micro Devices (NYSE: AMD) and Headway Technologies, a division of TDK (NYSE: TDK). A form for requesting more information about the software, including university licensing options, is available at www.fabtime.com/software.htm.

About the Modeling and Analysis for Semiconductor Manufacturing Lab

The Modeling and Analysis of Semiconductor Manufacturing Laboratory at Arizona State University is housed in the Industrial and Management Systems Engineering department. Professors John Fowler and George Runger are co-directors of this lab. The lab is focused on how modeling and analysis tools and techniques can be used to improve semiconductor manufacturing. The lab has had research projects with NSF, SRC, SEMATECH, Intel (NASDAQ: INTC), Motorola (NYSE: MOT), Infineon Technologies AG (NYSE: IFX), STMicroelectronics (NYSE: STM), Tefen, Amkor (NASDAQ: AMKR), Abpac, and TSI. The website for the lab is at www.eas.asu.edu/~masmlab/home.htm.

FabTime Talk at ASU: Cycle Time Management in Wafer Fabs

Frank Chance will be speaking about wafer fab cycle time management at Arizona State University on January 23rd. The talk is open to the public. RSVP to Frank.Chance@FabTime.com by January 22nd for details. The abstract follows.

Mathematical theory tells us that cycle time is a function of utilization and variability. So far so good -- we know that cycle time increases with utilization, and that variability is evil. But it's a large leap from this theoretical foundation to the practicalities of cycle time management in a wafer fab. There is pressure from all sides to take actions that can worsen cycle times. Higher capital costs drive the demand for higher utilizations. Shorter life cycles mean frequent new-product introductions and the corresponding variability of engineering time and hot lots. Smaller feature sizes bring stricter qualification requirements and lead to single-path tools. Fab managers and supervisors must juggle these competing demands, and still meet moves, shipment, and cycle time goals. In this talk we will focus on several of these high-profile issues. We will discuss the theory and how it guides our general understanding, and we will describe how managers have been translating theory into action on the fab floor.

Subscriber Discussion Forum

Measuring Shift Performance

A subscriber wrote: "We are looking into the way we measure the shift performance - currently we use move outs and if a shift made record high moves they get a pat on the back - regardless of whether or not they did the right thing. Do you know of other shift performance parameters being used that give better understanding of how the shift performed to plan / other?

Since people's actions are in alignment to the way they are measured, we have come to believe that measuring wafers out of an operation encourages slack (if I load now and then they unload - they get the credit...) and so are trying to estimate in advance whether counting wafers loaded to production in the operation will be better. Also we think that conformance to the goal needs to be measured, as not all operations are created equal (some are faster) but all must get done in order to get Fab outs. Other parameters being considered are quality, holds, test wafers, PM execution and so on. You can see there is a lot to measure - but we don't want to come out with a huge package but rather with a comprehensive measurement or package of up to 3 measurements so that it is easy to see at a glance if the performance of a shift was good or bad. Speed is also important here - the answer must be ready immediately and we should be able to track its progress over time (at least in some dimensions) there for parameters that need extensive calculations are out. The tricky part here is that we really can't afford to blow it - if we decide to move to some other parameter and it turns out just as good (or bad...) or worse we can't come back to the manufacturing people and say "OK, that's not what we wanted, now let's try something else" - we'll need a chill out period of a few years before we try again in the case we don't succeed. It is important to remember that this is a difficult change that you need to communicate to all people as you implement it. One other thought that we had is connected to the Goldratt thinking process idea (from the book "It's Not Luck") that points out that there might be one root cause underlying all the issues you see. Have you heard of any work done in that venue in a Fab environment?"

FabTime Response:

One thing that some companies do is use more short-term move goals, that are actually adjusted to reflect the current situation (e.g. tool downtimes, etc.). Other companies use turns instead of moves. Turns are defined as Operation Moves/ Starting WIP, for a time period. If WIP is low, for example, then turns will still look ok, even if you have fewer moves (and you probably should reduce moves if the WIP is low at an operation, and go concentrate on some other operation).

We also know a company that uses something called Summed Operation Cycle Time. This is a little trickier to calculate, but you basically measure the average cycle time by operation for all operations completed during a given shift, and then sum across all operations for a process flow, to get a forward-looking estimate of what the total cycle time would be, if the factory behavior for the current shift were continued throughout the lifetime of a wafer. What makes the calculations a bit tricky is that during each shift, there are some operations that don't get done at all, so you have to make some sort of estimate of their performance.

Another thing that we're planning to add to our software, because we think it will be useful, is a chart that shows the delta to moves goals, and sorts in descending order by absolute delta from goal. So if the moves are much higher or much lower than goal for an operation, those operations (or areas, or tools) would come to the top of the list. Of course this chart would be more useful if the goals were adapted to reflect short-term behavior (factoring in downtimes, starting WIP, etc.), but that's a harder problem.

If you have a capacity model that generates required moves by operation, you could measure moves against that. Or a more detailed view would look at moves by operation against required. This would be a little more fine-grained and would identify operations where moves are required in order to meet throughput goals, but are not being met. (e.g. 200 moves on op1000 and none on op1010 isn't as good as 100 moves on op1000 and 100 on op1010 if that's the goal).

Performance Indices - The Human Dimension

Sihar Snir of Tower Semiconductor wrote: "First, I would like to say that I find your Site & Newsletter very interesting and practical. You're definitely making my life easier when trying to justify cycle time activities these days. There's one major issue we've been dealing with lately (naturally) and that's the quantity of operators needed for our current activity level. Currently, we're using "Moves per Operator" as the major performance measure but I've also seen other Fabs use "Photo Layers per Operator". In addition, defining what's commonly used as the "Number of Operators" is not trivial. Some Fabs use only actual Operators, some also include the Support Groups, Process Technicians, and others.

What I wanted to find out is what are the most widely used Performance Measures in the industry regarding Human Resource to Activity relations. I believe this issue is directly impacting Cycle Time (and I'll be glad if you could elaborate on that too) but I'm definitely not looking for another Staffing Model."

FabTime Response:

We don't have any firm data on this subject, and would like to pose the question to our subscribers.

Model Accuracy Relative to Actuals

Raymond Yang of Chartered Semiconductor asked: "I have one question. In your papers Getting To Good Answers; Effective Methods for Validating Complex Models (see www.fabtime.com/abs_SMOMS99.htm), on page 6 under the section of Lessons Learned, "in the end we came out with a model that very closely tracked the floor and in which the client had considerable faith." I was wondering what was the percentage the model described in the papers deviated from the floor. I am also asking guidance for a universal acceptable percentage the semi cond industry can accept. At times we come close to 95% accuracy in our materials capacity planning model."

FabTime Response:

I think that getting 95% accuracy between a model and actual shop floor performance is great! I don't remember the exact numbers referenced in our paper, but I think that anything greater than 80% accuracy is doing pretty well. The answer does depend on whether you're talking about static or dynamic performance measures. For measures like moves and tool utilization, it should be possible to build highly accurate models (>90%). The inputs that are used to calculate these types of metrics are very straightforward. Dynamic metrics like cycle time and WIP, however, depend on inputs that are harder to quantify, such as the amount of variability in the fab, the distribution of downtime parameters, etc. For this reason, a lower level of accuracy (such as 80%) between model data and actual fab data is usually acceptable. I don't know of any industry standard on this topic, however. I think that it depends on what you are doing with the model. If you use a model to predict when individual lots will exit, for the purpose of promising due dates to customers, then you need a very accurate model. If instead you are using a model to identify opportunities for performance improvement, you can get by with relative answers (e.g., which change is likely to yield a better result). In the latter case, it doesn't make sense to have an extremely detailed model, because so much work is involved in keeping the model up-to-date.

OEE vs. Operating Curves

Juan Manuel Torres of Seagate Technology asked: "Operating characteristic curves of Utilization vs. Cycle Time clearly show that high utilizations lead to long cycle times. Long cycle times lead to WIP build up and all of its associated problems.

This is not very intuitive though, and it makes it hard to explain to others when they are driven by metrics such as OEE. The higher the OEE value, the better, in their mind.

Does anybody know of a simple way of comparing and contrasting these two concepts to show that high utilizations are not only hard to achieve but that they adversely impact cycle time?"

FabTime Response:

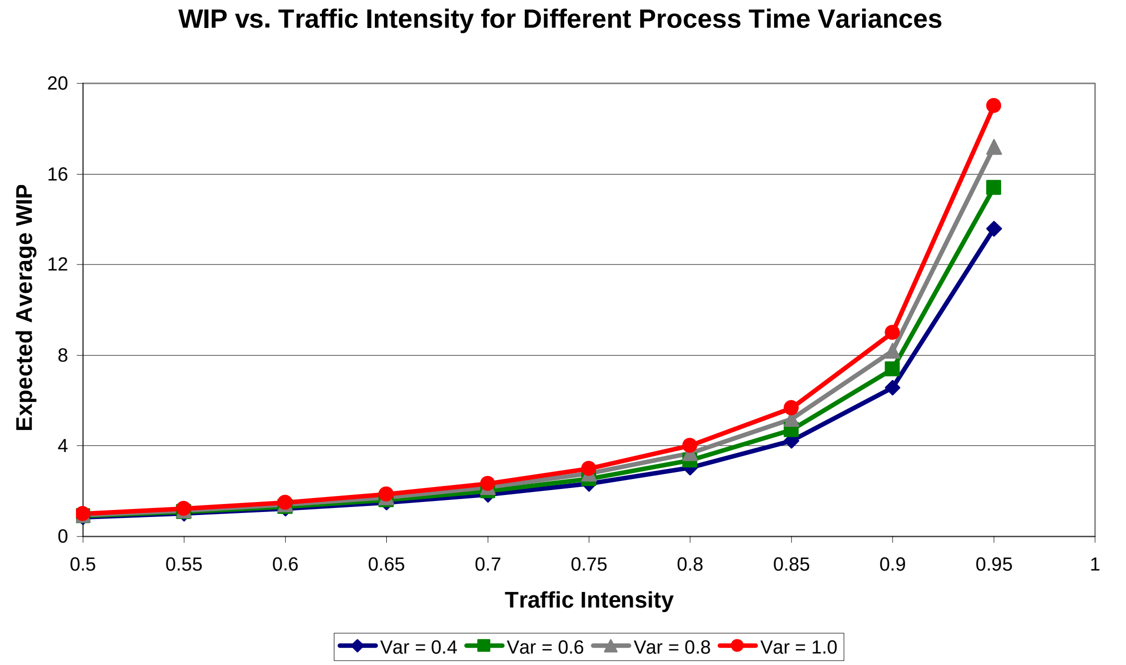
We think that this is such an important question that we've decided to make this FabTime's topic of the month. See the article below for details. If anyone has examples of studies that compare and contrast OEE and cycle time, we would be very interested in hearing about them.

OEE and Cycle Time

Cycle Time and Equipment Loading

In the presence of any variability at all, cycle time almost always increases as equipment loading increases (for an exception caused by batch size decision rules, see www.fabtime.com/ctbatch.htm). This is true for individual tools, and for entire wafer fabs. Way back in Issue 1.2 we discussed the P-K formula, a mathematical formula for the average WIP at a single tool as a function of equipment loading and variability. An example graph showing how WIP increases with equipment loading for different amounts of process time variability is shown at the top of the following page (and at www.FabTime.com/p-k.htm). In Issue 1.3 we described Little's Law, which states that for a given throughput rate, cycle time and WIP are proportional to one another. From Little's Law, we know that if WIP is high for a given throughput rate, then cycle time will also be high for that throughput rate. And thus cycle time for a fab generally increases with equipment loading, as WIP increases.

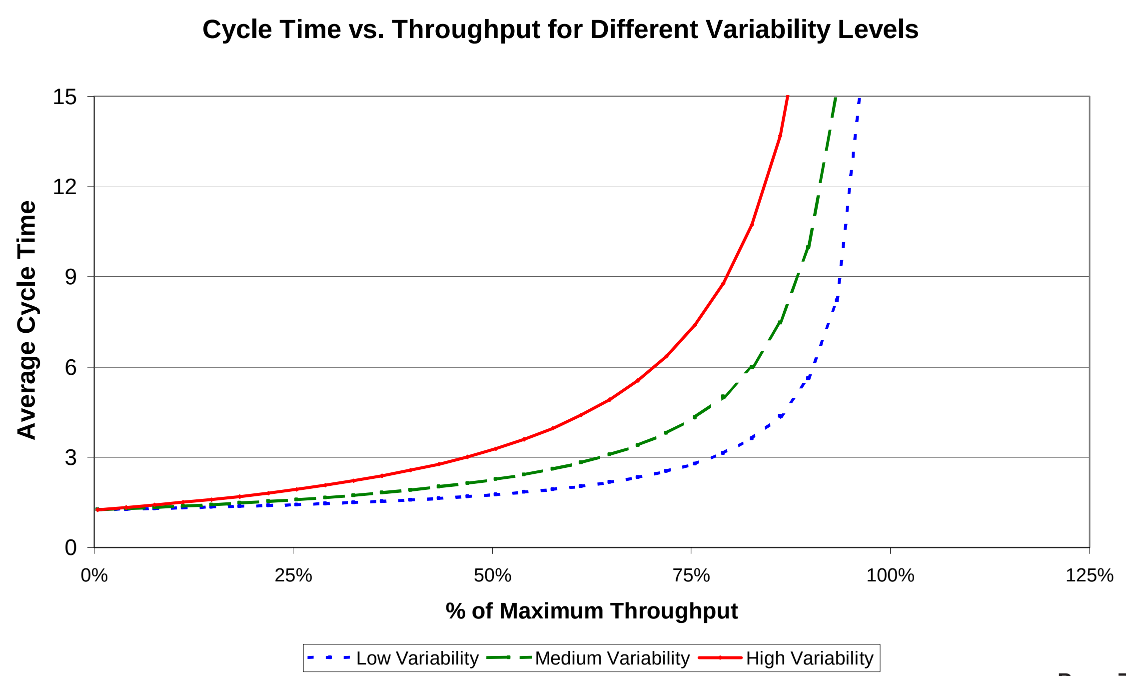
An example showing cycle time vs. percent of maximum throughput for different amounts of variability is shown at the bottom of the following page (and at www.FabTime.com/ctcapac.htm). Here maximum throughput is the throughput rate that would result in the fab bottleneck having no idle time, or being loaded to 100%. This is sometimes called the "hockey stick effect" because the graph of cycle time vs. percent of maximum throughput resembles a hockey stick. Cycle



time increases linearly at relatively low throughput rates (where equipment is not heavily loaded), but then increases much more rapidly at higher throughput rates. Graphs like this, showing cycle time vs. percentage of maximum throughput (or bottleneck utilization, or factory loading - all similar), are called Operating Curves or Characteristic Curves. They are commonly used to evaluate trade-offs in fab performance. For example, a change in lot release patterns might reduce variability, and lower the entire curve.

Equipment Loading, Cycle Time, and Overall Equipment Efficiency (OEE)

In the standard definition of OEE (SEMI Standard E79) for a tool, OEE = Availability Efficiency x Performance Efficiency x Quality Efficiency. Here Availability Efficiency is equipment uptime expressed as a percentage of total time. Quality



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Efficiency is theoretical production time for good units divided by theoretical production time for all units. Improving Availability Efficiency and Quality Efficiency will tend to improve cycle time, by reducing variability.

Performance Efficiency is a factor consisting of Rate Efficiency (the fraction of production time that equipment is processing actual units at theoretically efficient rates) and Operational Efficiency (time spent processing actual units vs. time available for processing). That is:

Performance Efficiency = Rate Efficiency x Operational Efficiency

where
Rate Efficiency = Theoretical Production Time for Actual Units / Actual Production Time

and

Operational Efficiency = Production Time / Equipment Uptime.

In the above, Production Time is time that the tool is busy processing. Equipment Uptime is the time that the tool is in a condition to be processing, the sum of Production, Engineering, and Standby states (with reference to the SEMI E10 states). One way to increase OEE is to increase Operational Efficiency, by driving Production Time to equal Equipment Uptime. Or, alternatively, by driving Engineering time and Standby time to zero.

The problem with driving Standby time to zero is that, as we discussed above, tools with no idle time (with the possible exception of batch tools) tend to have high cycle times. For the bottleneck toolgroup in the fab, this may make sense. However, many performance improvement programs strive to increase the OEE of all tools in the fab. And while increasing Availability Efficiency, Quality Efficiency, and Rate Efficiency may all help to reduce cycle time, increasing Operational Efficiency will tend to increase cycle time. For a fab trying to reduce cycle times, striving to increase the OEE of all tools, then, is counter-effective.

Production Equipment Efficiency (PEE)

To combat this conflict, the people who developed OEE came up with an alternate, related measure called Production Equipment Efficiency, or PEE. PEE measures equipment productivity only during the time that products are at the tool, available for processing. SEMI E79 states that "PEE is based on theoretical production time for effective units and the proportion of operations time that excludes no product time and equipment unavailable no product time."

PEE = (Theoretical Production Time for Effective Units) / [(Operations Time) - (No Product Time) - (Equipment DownNo Product Time)]

or

PEE = OEE X Total Time / [(Operations Time) - (No Product Time) - (Equipment DownNo Product Time)]

Here (No Product Time) is Standby Time during which no product is available, while (Equipment DownNo Product Time) is time during which the equipment is experiencing either Unscheduled Downtime or Scheduled Downtime, and has no product waiting. Operations Time is Total Time - NonScheduled Time. Therefore, if you are already calculating OEE, and you also know how much time each tool spends with no product available (including the downtime spent with no product available), then you can easily convert from

OEE to PEE.

For example, suppose that we have a tool that spends, in a given week

- 0 hours nonscheduled
- 35 hours down (including scheduled and unscheduled downtime)
- 10 hours in engineering state
- 65 hours processing wafers (production time)
- 58 hours in standby state

for a total of 168 hours. Then we have,

Availability Efficiency = Equipment Uptime / Total Time = (Production + Engineering + Standby)/168 = (65+10+58)/168 = 0.79167.
Now suppose that the tool spends 5% of its productive time processing scrapped wafers, (Quality Efficiency = 0.95), and that all production is at 95% of peak efficiency (Rate Efficiency = .95). Then we just need to calculate Operational Efficiency to have all of the components of OEE.

Operational Efficiency = Production Time / Equipment Uptime = 65/(65+10+58) = 65/133 = 0.4887

and Performance Efficiency = Operational Efficiency X Rate Efficiency = .4887 X .95 = .4643

And OEE = Availability Efficiency X Quality Efficiency X Performance Efficiency = .79167 * .95 * .4643 = .3491.

Not a very impressive OEE. But now suppose that of the 35 hours of downtime on this tool, 20 were spent with no product waiting. And suppose that of the 58 hours in standby state, 50 were spent with no product waiting. Then we have:

PEE = OEE X Total Time / [(Operations Time) - (No Product Time) - (Equipment DownNo Product Time)]

= .3491 X 168 / [168 - 50 - 20] = .3491 X 168 / 98 = .3491 X 1.7143 = .599

A much more respectable value, and one that takes into account the fact that, although the tool is in standby state for 58 hours, most of that standby time is due to the presence of no WIP.

Side Note: PEE and Planned Downtime

As an extension to the above example, suppose that we eliminate the 10 hours of engineering time (replacing it with standby time), and suppose that there was no product present during any of the 35 hours of downtime or the 68 (58+10) hours of standby time. We would actually have the same OEE value for this case as for the previous case. But look what happens to the PEE value.

PEE = OEE X 168 / [168 - 35 - 68] = .3491 X 168 / 65 = .3491 X 2.5846 = 0.9025 = (.95*.95).

That is, the PEE value now reverts to the product of Quality Efficiency value and the Rate Efficiency value. If we have no time lost to engineering or nonscheduled time, and none of our downtime or engineering time ever causes product to wait, then Availability Efficiency reverts to 1 and Performance Efficiency reverts to Rate Efficiency, so that PEE is the product of Quality Efficiency and Rate Efficiency. So, when looking at PEE, if we could schedule a given tool such that all of the equipment downtime was planned, and occurred only when no product was available, there would be no real incentive to reduce the downtime percentage. Although this scheduling feat seems improbable, it's worth considering the viewpoint that downtime is only really a problem when it causes lots to wait.

Conclusions

In a wafer fab, cycle time tends to increase with increasing equipment loading (with some exceptions for batch tools). In large part to combat high cycle times, fabs typically plan for some amount of idle time on most tool groups (see newsletter Issues 2.9 and 2.10 for details). OEE, in its traditional definition, is contradictory to such planned idle time, since all standby time (including planned idle time) drives down OEE values. This puts fab personnel in a tight spot when they are pushed to simultaneously increase OEE values and decrease cycle times. Production Equipment Efficiency (PEE) is a related metric that calculates equipment productivity only during the time that product is available at the tool. Improving PEE, therefore, is not in conflict with reducing cycle times. PEE only penalizes tools for standby time during which lots are waiting (e.g. time when WIP is present, but there is no operator to load the tool). For bottlenecks, there will likely be very little time during which no WIP is waiting. Therefore, for bottlenecks, PEE and OEE will yield similar values. For non-constraint tools, however, PEE values will usually be higher than OEE values. The important thing is that increasing PEE values will not conflict with reducing cycle times. For fabs trying to improve or maintain cycle times, using PEE instead of OEE may be more effective, at least for non-constraint tools.

Reference

SEMI E79-0200, Standard for Definition and Measurement of Equipment Productivity. Downloadable Standards are $50 each (Members and Non-members) unless you have a prepaid Web Download Package.

You can find E79 at www.semi.org. Click on the Standards Download link in the left-hand pane, then click on Equipment Automation Hardware. Go to the bottom of the screen and click Next Page (twice) to get to the third page in this category, and look for E79 (they are in numeric order). FabTime regrets that we are not able to distribute this standard ourselves, as it would violate SEMI's copyright restrictions.

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FabTime Recommendations

NewsScan Daily

NewsScan Daily is a daily (M-F) email containing brief summaries of important technology news of the day. It usually contains about six one-paragraph news stories, with links to full versions of each story at their original source (e.g. NY Times, San Jose Mercury News, Wall Street Journal). It's a great way to get a quick peek at some useful stories of the day, without having to browse through any ads or graphics. I find it especially useful when I'm traveling, and don't have time to read the paper. The best thing - NewsScan Daily is free. It is co-sponsored by Andersen and by RLG, and thus doesn't contain any annoying ads. I've been reading it for years now, using a unique email address, and have never become a spam target at that address. Therefore, I recommend it to you. Just go to www.newsscan.com to sign up.

WinZip 8.1

As the WinZip website says: "Zip files are 'archives' used for distributing and storing files. Zip files contain one or more files.

Usually the files 'archived' in a Zip are compressed to save space. Zip files make it easy to group files and make transporting and copying these files faster." WinZip's software is something of a standard for creating and extracting from Windows-based zip files. It has been on the market for years, and is very stable. WinZip Version 8.1 was recently released, and contains a number of features to enhance usability. My personal favorite a system tray icon that lets you open recently used archives with a single click. It costs $29 for a license to WinZip, which sounds like a lot for a little utility like this. However, once you pay for it once, and register, WinZip gives you essentially free upgrades for life. They send you an email whenever a new version is released, and make the upgrade process reasonably simple. So, if you don't have WinZip, you might want to consider purchasing it (www.winzip.com). And if you have a registered copy of an earlier version, Version 8.1 has some enhancements that you might find worth-while.

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Ohio State University (1)
Oklahoma State University (1)
ON Semiconductor (8)
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Pelita Harapan University (1)
Penn State University (1)
Peter Wolters CMP Systeme (1)
Philips (15)
Piezo Technology Inc. (1)
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Quanta Display Inc. (1)
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SAMES (1)
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SEMATECH (16)
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Shanghai Grace Semiconductor Mfg. (1)
SiGen Corporation (1)
Silicon Manufacturing Partners (4)
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SoundView Technology (3)
SSMC (1)
STMicroelectronics (22)
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Süss MicroTec AG (1)
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Synquest (2)
Takvorian Consulting (1)
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Texas Instruments (10)
Tokyo Electron Deutschland GmbH (1)
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TriQuint Semiconductor (3)
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TRW Systems (1)
TSMC (3)
UMC (5)
Unisem (1)
Unitopia Taiwan Corporation (2)
University of Arkansas (1)
University of California - Berkeley (4)
University of Mining and Metalurgy (1)
University Porto (1)
University of Texas at Austin (1)
University of Virginia (1)
University of Wuerzburg - Germany (1)
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Velocium (1)
Virginia Tech (3)
Vitesse Semiconductor (1)
Wacker Siltronic (4)
WaferTech (10)
Wright Williams & Kelly (9)
Xerox Brazil (1)
X-FAB Texas, Inc. (3)
Zarlink Semiconductor (6)
Zetek PLC (1)
Unlisted Companies (14)

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