FabTime Newsletter

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Information

Publisher: FabTime Inc. FabTime sells cycle time management software for wafer fab managers. FabTime's mission is to help the people who run fabs improve performance by 1) helping them to understand the factors that drive fab performance and giving them the data to identify current improvement opportunities; 2) letting them control that data by setting parameters for their own charts, so they don't have to go back to IT every time they want a different piece of information; and 3) including them in a community of people around the world who are all working to drive better fab operations.

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Keywords: Single-Path Tools; Tool Qualification; Holds; Operators

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Welcome

Welcome to Volume 23, Number 5 of the FabTime Cycle Time Management Newsletter. In this issue we have a call for papers for the upcoming Advanced Semiconductor Manufacturing Conference and a quick note about the upcoming Fab Owners Alliance meeting. Jennifer hopes to see some of you there! We also have, as usual, a few articles from Jennifer's LinkedIn. Our software tip of the month is about using our Ag-Grid charting engine to generate different types of charts on your own. Customers who have asked over the years for pie charts – this tip is for you.

In our subscriber discussion forum, we have a response to the previous issue's main article on holds. We also have two responses to our new cycle time improvement tip of the month feature, which we kicked off by talking about finding and eliminating process restrictions. We also have a new question about managing a fab with many one-of-a-kind tools. This question made us realize that although we often speak of why it's good NOT to have one-of-a-kind tools, some of our readers don't have that luxury. In our main article, we share recommendations for coping with one-of-a-kind tools. As always, we welcome your feedback.

Thanks for reading! – Jennifer, Frank, Lara, and the FabTime Team

Community News/Announcements

Call for Papers: 2023 Advanced Semiconductor Manufacturing Conference

The 2023 Advanced Semiconductor Manufacturing Conference (ASMC) will be held May 1-4, 2023, in Saratoga Springs, NY. ASMC is soliciting abstracts from professionals involved in all areas of semiconductor manufacturing. Submit a paper by October 21, 2022 for an opportunity to—

- Present your work at the ASMC 2023 conference.
- Publish your paper in a special ASMC section in IEEE Transactions on Semiconductor Manufacturing.
- Compete for the Entegris Best Paper Award and the GlobalFoundries Best Student Paper Award.

See topics and more details at the SEMI website.

Fab Owners Alliance Meeting

The Fab Owners Alliance (FOA) will be meeting in person on October 26-27 at the SkyWater facility in Kissimmee, Florida. The FOA, a SEMI technology community, is an international group of semiconductors & MEMS fab owners and industry suppliers who meet regularly to discuss and act on common manufacturing issues, combining strengths and resources to maintain and increase their global competitiveness. Jennifer will be representing FabTime at the meeting. Please do say hello if you are there.

A Few Highlights from Jennifer's LinkedIn

Jennifer continues to share articles about business management, the semiconductor industry, and productivity improvement on her LinkedIn feed. Recent links have included:

- An article from Windows Central (via the Semiconductor Engineering Week in Review) saying that NVIDIA CEO Jensen Huang told members of the media in a question and answer session at the GPU Technology Conference that Moore's Law is dead. What say you all? True? [LinkedIn Post.]
- A couple of articles from the Wall Street Journal (here and here) about how "The Queue" took over London prior to Queen Elizabeth's funeral. As someone who studied queueing theory in graduate school and uses queueing models in FabTime's cycle time management class, Jennifer enjoyed reading about the British respect for queues. [LinkedIn Post.]
- A WSJ article about the difference in the political response to US-based wafer fab spending after the CHIPS Act passed and the Wall Street response (not so favorable). [LinkedIn Post.] Here was the SIA's response to the CHIPS Act (very favorable).
- An AP article from the San Jose Mercury News about how "Armed with a new law that boosts U.S. support for computer chip manufacturing, Vice President Kamala Harris is seeking new investments and partnerships as she sits down with Japanese technology executives." A far cry from Jennifer and Frank's early days in the industry at SEMATECH (founded in part to regain competitiveness relative to Japan in the semiconductor industry). [LinkedIn Post.]
- An article from CNBC about Micron's plans to spend up to $100 billion over the next two decades building a wafer fab in upstate New York. Great news for the region, though we wonder where they'll find people to staff what Semiconductor Engineering's Week in Review says will be "9,000 company jobs and 40,000 construction and supply chain jobs." [LinkedIn Post.]

For more industry news, connect with Jennifer on LinkedIn.

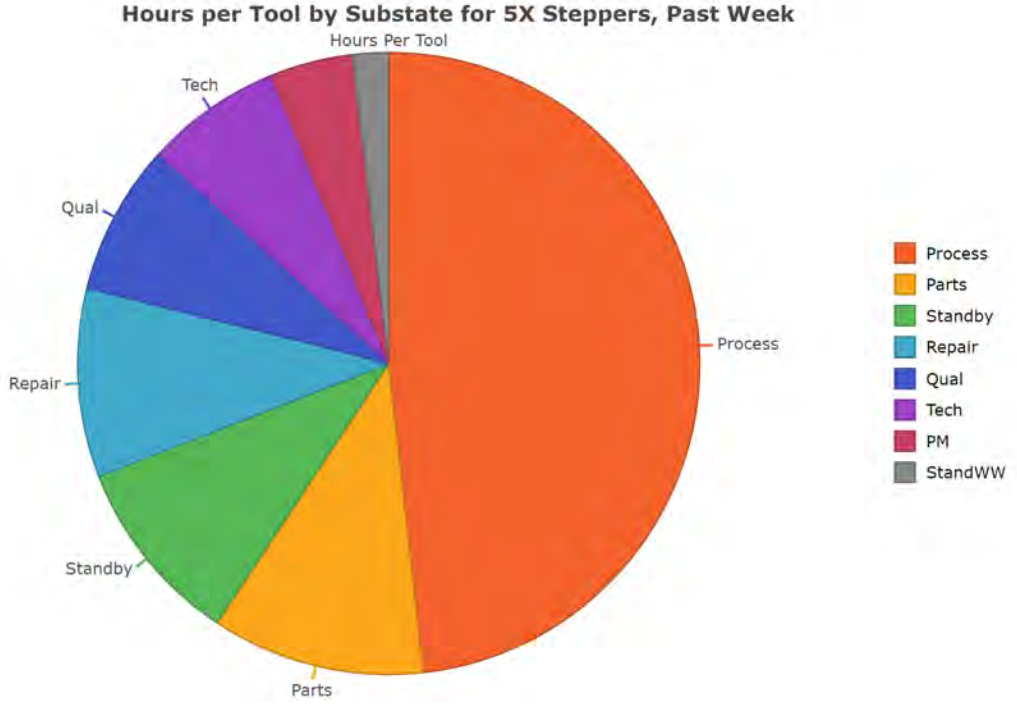
FabTime welcomes the opportunity to publish community announcements, including calls for papers. Send them to newsletter@FabTime.com.

FabTime® Software Tip of the Month

Use Ag-Grid to Generate Different Types of Charts

Our new Customer Success Manager, **Elaine Jacobson**, suggested a tip that she thought our software users would find useful. You can select a set of data in one of the Ag-Grid data tables in FabTime and display it using your chart format of choice, as you might do in Excel. To do this in FabTime:

1. Generate your chart of interest. For example, we generated a Tool Hours Pareto chart for the 5x Stepper tool group in our demo model and sliced it by sub-state (waiting for parts, processing, etc.). We set the time for the chart to be the past week.
2. Select the columns you would like to plot in the data table (you may need to drag to expand the data table first). Continuing our example, we selected the SubState and Hours Per Tool columns (just the data rows, not the column headers).
3. With your mouse in the selected range, right click. Select "Chart Range" near the bottom. A menu will pop out to the right showing available chart selections. For this example, we selected the "Pie" category and then the "Pie" chart from the next menu (vs. "Doughtnut"), also available in the pie chart category.
4. Ag-Grid generates a pie chart displaying the selected data. Drag to re-size as needed. To add a title or other formatting, mouse over the chart and click the menu icon with three horizontal lines that appears in the upper right-hand corner of the chart window.
5. You can use "Settings" to change the type of chart or click the "Format" tab. Under "Title," check the box for "Enabled." Double-click on the resulting dummy chart title to edit.
6. Once you are happy with the chart, click inside the chart image to close the "Settings" menu. Click the "Download chart" icon in the upper right corner to download the chart as a PNG file. The name of the file will reflect your chart title. You can also right-click to save or copy the image.
7. Experiment as you wish with other chart formats. Depending on your FabTime version, you may be able to save these Ag-Grid-generated charts to your home page tabs. Enhancements to this functionality are underway.



We hope you find this tip useful.

FabTime software customers can subscribe to the separate Tip of the Month email list (with additional discussion for customers only) here: http://www.fabtime.com/tip-of-the-month.php. Thanks!

Subscriber Discussion Forum

Cycle Time and Holds

We received a detailed response from longtime subscriber **David Carmichael** to the last issue's main article about cycle time and holds. Dave said: "Great article on holds. Holds are among the most abused of MES functions and I think I have seen ALL the possible abuses during my career.

The most egregious abuse that you did not mention is the incomprehensible practice of placing a lot on hold in order to SPEED IT UP. I know this sounds crazy, and it is, but the reason is simple. Someone wants extra attention to be given to this lot and since the list of on-hold lots tends to be closely watched, users think they can best communicate the urgency of the lot in question via this mechanism. Obviously, this is certifiably insane, but it happens more than you might think. How effective it is I cannot say, nor can I say how damaging. Clearly another communications tool is needed, and one would think with the universal availability of cellphones, it could be managed.

As you said, placing lots on hold because the one tool that can process them is unavailable at present is definitely a practice to be avoided at all costs. However, I feel that linked to this is the idea of flagging lots as idle for the same reason. The idle lots tend to be ignored, and as they do not return to an available (wait) state automatically when the tool does become available again (unless some smart software is watching), it can cause the same problems as the hold state does. It is especially annoying because the lot's idle state can be deduced easily from MES data without the need for an actual lot state change.

Those who have read my comments in the past will know how I hate to bang on at length about the Theory of Constraints and how it can solve pretty much all your manufacturing logistics problems, but here goes anyway. In a fab that has been properly characterized (taking into account the existing and future product mix) and has set up WIP buffers of sufficient size ahead of all of the constraint tool sets (they really don't move around much despite what everyone thinks), routine holds will not have much of an effect. The buffer has enough WIP in it to handle the likely upstream holds, and the dispatch system is always looking for lots to accelerate to keep the buffer filled up. The dispatch system will of course ignore on-hold lots for a reasonable amount of time until they become a problem. After that, it should let EVERYONE know about the issue. Holds that occur after the last of the fab constraints are an issue, but any good planning system should flag these as likely OTD misses providing production control plenty of time to sort them out."

FabTime Response: Thanks for sharing, Dave. We had not previously heard of putting lots on hold to speed them up. We certainly agree that this is a counter-productive practice that should be avoided. We also agree that changing a lot's status to idle isn't a good idea, because of the lack of automated systems to return lots to active status. When we have recommended the use of idle or inactive lot lists to manage a fab, we've assumed that these lots are identified through reporting (e.g., display a list of all lots that have been in queue at this tool for more than 24 hours). We would not advocate for changing a lot's status to idle. Thank you for expanding our understanding of real-world fab behaviors in this area.

Managing Operations Under Lean Staffing Conditions

Another **longtime subscriber** is seeking feedback from other sites about the best way to manage operations under lean staffing conditions.

FabTime Response: We wrote about staffing constraints last December, in Issue 22.05, and shared some ideas from a subscriber in Issue 23.01. Nearly a year later, we continue to hear from people at a variety of fabs that they are struggling with staffing constraints: operators, technicians, process engineers, etc. We

thought that it would be worth raising the subject again in this forum to try to spark additional discussion/information sharing.

- How do you manage your operators when you can't find enough of them?
- Where are you looking now for new people (in terms of backgrounds?
- What metrics do you use for operators when you're understaffed? Are they the same ones you would use normally, or have you made changes?
- Are you seeing improvements now, as the job market is cooling a bit?

We welcome any feedback on this topic and will consolidate responses for the next issue.

Responses to the First Cycle Time Tip of the Month: Look for and Eliminate Process Restrictions

FabTime launched a new supplemental feature for newsletter subscribers in September: a brief cycle time tip of the month. The full newsletter will continue to be sent every other month. On the off months, we will offer a concrete tip for reducing fab cycle time.

Last month's inaugural tip was FabTime's number one recommendation for improving cycle time in an existing fab. It applies to any fab that has at least some redundancy in the toolset.

Tip: Look for and eliminate process restrictions leading to single or dual path operations. Start today.

We won't repeat the full tip text here, but if you didn't receive it, please write to Jennifer to request a copy.

Feedback for the addition of this new cycle time tip mailing was uniformly positive. Many thanks to all who took time to reply. We also received two responses to this specific tip and are sharing those here.

Georg Seidel from Infineon Technologies wrote: "It's always good to see that you are working on the same topics that we are. We constantly monitor process restrictions. There will always be the question how many tools you qualify, however, because engineer time is unfortunately limited."

FabTime Response: We do think that people all around the industry face similar issues – we're glad to be able to provide a forum for people to talk about them. It is unfortunate that engineer time is limited (especially now – many fabs are having staffing shortages). But the good news is that we don't think you need to go above 3-4 qualified tools to get most of the cycle time reduction benefit. It's not a matter of needing to continue adding more and more qualified tools – the benefit definitely levels off. See the chart below: Cycle Time X-Factor for Different Levels of Dedication for an illustration of this.

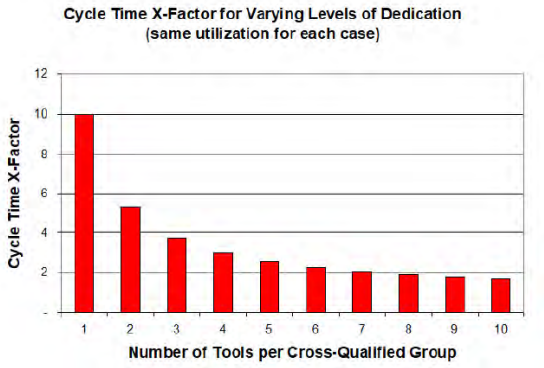
Another anonymous subscriber wrote: "Just to share, one of the methods I used in my fab to reduce cycle time was to reduce utilization with line balancing. We would offload demand from highly utilized routes to less utilized routes. For example, as in the diagram below, Process 2 is the constraint operation. Part B and Part C can be processed on two different routes. In this case, I would push Part B and Part C through Process 2AA as is not fully utilized. By doing this I will be able to balance the line. However, I could expect push back from process engineering, as this might impact process sigma."

Qualified Part: Part A, **Part B** and **Part C**	Process 1	Process 2 (constraint operation)	Process 3	Process 4	Process 5
Qualified Part: **Part B, Part C** and Part D	Process 1	Process 2AA	Process 3AA	Process 4	Process 5

FabTime Response: We think that your method could make sense as long as it doesn't affect yields significantly, and as long as the reliability for Process 2AA is reasonably good. Otherwise, you might pay a price in cycle time for processes B and C even though the average utilization through Process 2AA isn't very high.

One-of-a-Kind Tools and Cycle Time

Another **longtime subscriber** wrote: "After your excellent article about 10 recommendations for Fab Cycle Time Improvement and especially the part about the effects of "single path tools" on cycle time, you kindly sent me an excel spreadsheet with one tab that showed this. I'm now in a start-up fab, and had a couple of questions:



1. I wanted to double check your definition of X-Factor. I'm presuming that it is basically whatever the current cycle time is of the operation of interest and the X-Factor shows the effect on the current operation for a change in the variable – in this case single vs multiple paths.
2. I don't know if you have discussed this, but what would the X-Factor variation for the entire Fab be if you had just had single path tools?"

FabTime Response: X-Factor is total cycle time divided by theoretical cycle time (realistic best case theoretical cycle time). At the tool level, people usually use either planned or actual process time in the denominator and time between step move outs in the numerator. In the figure above, the bars show the X-Factor for different levels of dedication, with the average utilization across each group set to 90%.

What Part 2 of your question made us realize is that although we've written frequently (including in our first cycle time improvement tip) about eliminating single path operations via tool qualification, we haven't written much about managing true one-of-a-kind tools. We remedy this in the main article below.

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

Main Article: Managing One-of-a-Kind Tools

Introduction

We have talked often in this newsletter and our cycle time improvement course about why cycle time is higher for single path tools and operations. When a lot is in queue for a single tool, the lot is subject to all the variability that affects that tool. If the tool goes down for extended downtime, the lot must wait until the tool comes back up, because there is nowhere else to process it. If there are two like tools available for processing, the chances are reasonably good that they won't both be down for extended downtime at the same time. On average, at the same utilization, cycle time X-Factor per visit is roughly twice as high for one-of-a-kind tools than for tool groups with two tools. More details are available in Issues 20.05 and 22.04.

For this reason, our top cycle time improvement recommendation for fabs that have tool redundancy is to identify and eliminate single path operations. We stand by that recommendation. But what about fabs that have true one-of-a-kind tools? These fabs might include:

- Pilot lines, even if within a larger site.
- Start-up fabs.

- Small government fabs that have no plans to expand.
- Small to mid-size fabs that have redundancy in most of the tool groups, but not all of them.
- Fabs that have redundancy normally, but have key tools in an extended downtime state, with no backup.

In this article, we discuss the impact of one-of-a-kind tools on fab cycle time, and ways to manage and improve cycle time in their presence.

Understanding the impact of one-of-a-kind tools on fab X-Factor

The subscriber quoted in the discussion forum above asked what the cycle time X-Factor (cycle time / theoretical cycle time) would be for a fab consisting entirely of one-of-a-kind tools. We can use queueing models to estimate the X-Factor for a one-of-a-kind tool, as shown below. Under medium variability, the estimate for X-Factor is 1 / (1-Utilization), where utilization is defined as productive time out of the time that the tool is available to manufacturing. A slightly more complex version of this equation that incorporates different levels of variability can also be used and is available in our Operating Curve Spreadsheet (available from our newsletter archive).

Unfortunately, there's no obvious way to scale up from tool level to fab level in terms of the spreadsheet / queueing models. We did experiment with a spreadsheet that used the queueing models for each step, and then added up the estimates across the flow, with tool utilization at each step as a fixed input. However, this approach doesn't capture the interaction between the tools, or the effect of operators. It's also necessarily a snapshot in terms of the utilization and variability values for each tool. You lose the educational benefits of looking at the shape of the operating curve.

It's possible to build a simulation model of the fab to estimate the overall X-Factor in the presence of a one-of-a-kind toolset. However, adding sufficient detail for accuracy (particularly in terms of the impact of operators), and maintaining that level of detail, tends to be prohibitive.

Our real-world experience has been that smaller fabs with multiple one-of-a-kind tools often operate at 4-5X overall (compared with larger fabs with more redundancy that can operate closer to 2.5-3X). However, the actual X-Factor could certainly be higher with many (or all) one-of-a-kind tools and/or if the fab is highly loaded. The full fab X-Factor doesn't directly scale up from the bottleneck X-Factor(s) in practice because not all tools are equally utilized. You make up cycle time at the less utilized tools, while experiencing high X-Factors on the bottlenecks.

We have come to believe that it's more useful to measure your actual X-Factor, at both the overall fab and the tool level, and then look for the largest improvement opportunities.

Mitigating the impact of one-of-a-kind tools

If you have true one-of-a-kind tools in your factory, there are three primary ways to mitigate their effect.

1. Buy more tools.
2. Increase buffer capacity.
3. Reduce variability.

We will discuss each of these in turn.

1. Buy More Tools:

If you just have a couple of one-of-a-kind tools in your factory, you may find that they disproportionately affect cycle time, even if they are not heavily utilized on average. This is far from the case everywhere, of course, but if any budget is available for capital purchases, you should consider adding redundancy at the

one-of-a-kind tools. If you're deciding which tools to add first within the one-of-a-kind tools, consider tools that:

- Have relatively high utilization.
- Have poor and/or highly variable reliability.
- Are batch tools.
- Have short and/or predictable lead times. (This is true in the current supply chain-constrained environment. It may be better to add redundancy somewhere now than to wait 18 months.)

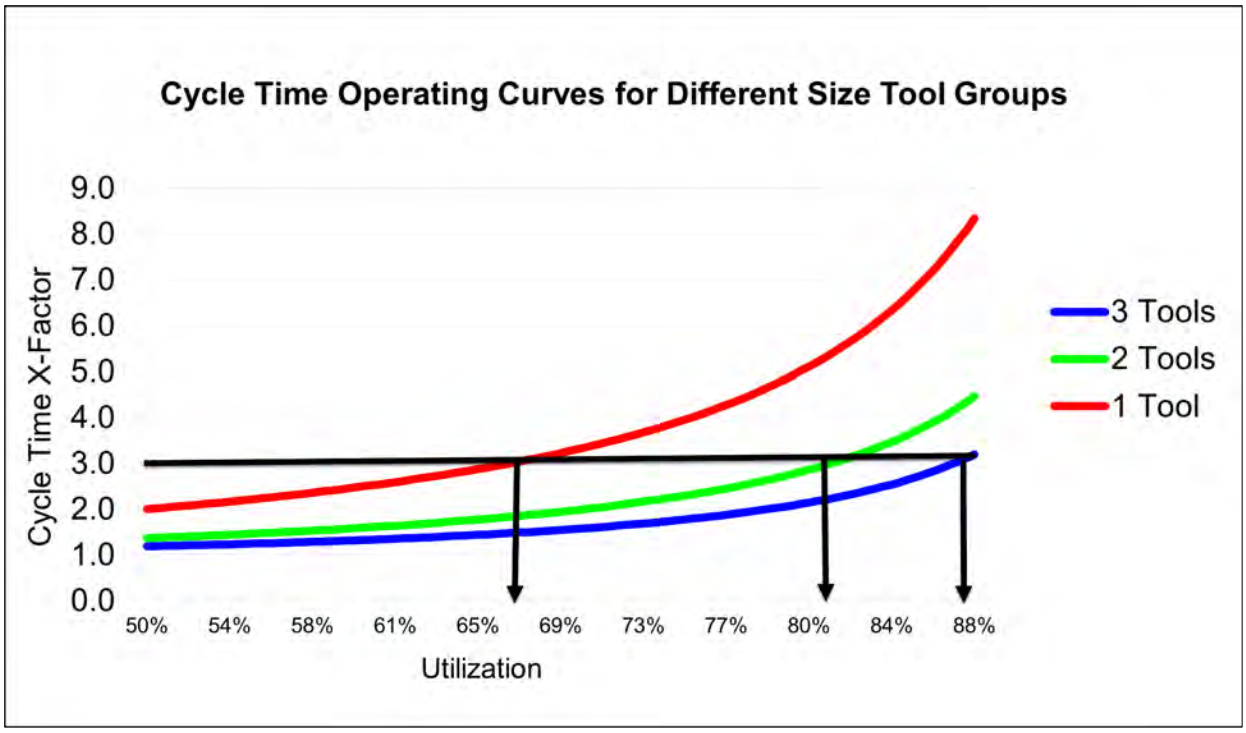
Regarding batch tools, we worked on a project many years ago with Seagate (see Grewal et. al.) that found batch tools tended to be high value in terms of overall cycle time reduction per dollar. This is because running smaller batches smooths flow to downstream steps, reducing arrival variability.

2. Increase Buffer Capacity:

With one-of-a-kind tools, it's vital to stay away from the steep part of the operating curve. Using our 1 / (1 – Utilization) formula, if we want to achieve 3X cycle time through a one-of-a-kind tool, under moderate variability, we need to keep the utilization to ~67% of available time:

(1 / (1 – Utilization)) = (1 / (1 – 2/3)) = 3

That is, we need about 1/3 of the time that the tool is available to manufacturing to be standby time, or buffer capacity. When planning capacity for one-of-a-kind tools, many fabs plan for a lower utilization than they would for a tool group with redundancy. For example, the chart below shows the operating curve for tool groups with one, two, and three tools where the target is a 3X cycle time. For three tools, under the specified variability assumptions, an 87% utilization target could be set (13% buffer capacity). For two tools, the utilization target drops to 81% utilization (19% buffer capacity), and for one tool it drops to 67% utilization (33% buffer capacity). If we try to run the one-of-a-kind tool at 87% utilization, the X-Factor will be close to 8.



Here again we note that it's not necessary to achieve a 3X cycle time on all tool groups to achieve a 3X cycle time for the fab. For fabs that have a mix of sizes of tool groups, it's likely that they will accept a higher X-Factor on the one-of-a-kind tools and expect a lower one on the tool groups with more redundancy.

Regardless of what the planned utilization is for a one-of-a-kind tool, the goal should be to increase standby time on the tool by using capacity more effectively. There are two broad ways to do this: by increasing the efficiency of the process time and by reducing the amount of time spent in non-value-added states.

Increase Efficiency of Process Time: The goal for all tools, but especially one-of-a-kind tools, should be to produce the targeted number of wafers in the minimum amount of time. Two things that can help with this are:

- Increase actual units per hour (UPH) rates on the tool. To do this, reduce delays due to alarms and setups and improve processes to be more efficient. This will lower the utilization of the available time without reducing the throughput rate and convert wasted process time into buffer capacity.
- Reduce rework rates. Running rework lots on tools drives up the process time without improving throughput. Efforts to reduce rework, including reprocessing lots due to missed time windows, should focus especially on one-of-a-kind tools.

Reduce Capacity Losses: Capacity losses on a tool can quickly push performance to an unacceptable location on the operating curve. While important on all tools to identify and avoid such losses, it is particularly important to do this for the one-of-a-kind tools. Suggestions include:

- Avoid starving the one-of-a-kind tool. Consider having dispatch rules at upstream tools that prioritize feeding downstream one-of-a-kind tools. If you have a handful of one-of-a-kind tools in your fab, particularly if they are operating above the planned utilization value, it may be worth giving these tools special consideration in your dispatch rules. In cases where all the tools are one-of-a-kind tools, focus on those with high utilization.
- Look for standby-WIP-waiting time when the one-of-a-kind tool is available but not being run. Often this indicates a lack of operators. Consider adding operators (if you can find them in the current environment) or modifying staffing patterns to ensure that the one-of-a-kind tools have better operator coverage.
- Focus availability improvement efforts on highly utilized one-of-a-kind tools. Work to reduce the duration of downtimes on the one-of-a-kind tools, particularly time waiting for parts or waiting for technicians. One-of-a-kind tools are one of the first places you should consider investing in spare parts. Technicians should know (for fabs with a mix of one-of-a-kind tools and larger groups) to prioritize fixing the one-of-a-kind tools.
- Minimize hand-carry hot lots, where you hold tools ahead of the hot lot, in your fab. If you have discretion over which tools to hold, try not to hold the one-of-a-kind tools for as long.
- Don't hold batch tools idle while you wait for full batches to form.

3. Reduce Variability:

One-of-a-kind tools are disproportionately impacted by variability. Therefore, they benefit most of all the tools in your fab from variability reduction efforts. Some specific ideas include:

- Break up maintenance events instead of grouping them (see Issue 22.01).
- Release lots into the fab in smaller, more frequent batches.
- If you use carts to transport lots between tools, encourage operators not to wait until they are full before delivering lots downstream, especially if delivering to a one-of-a-kind tool.
- Minimize periods of non-scheduled time on tools.

We once worked with a fab that had a high-capacity one-of-a-kind tool that they only ran every other shift. A pile of WIP would build up during the off-shift. The pile would be quickly worked off when the tool was run, but the arrival variability to tools downstream of that tool was high. Making a change to run that tool on both shifts reduced cycle time for the entire fab.

Conclusions

Single path operations in wafer fabs should be avoided wherever possible. They have a disproportionate effect on cycle time. Sometimes, however, single path operations can't be avoided because the fab has one-of-a-kind tools. A pilot line or startup fab might have all, or nearly all, one-of-a-kind tools, while a slightly larger fab might have only a few. As our friend Thomas Beeg proposed in a recent article, a "Golden Rule" for capacity planning in fabs should be: "avoid one of a kind tools as much as possible – or plan with very low tool utilization for these situations." But, of course, this "Golden Rule" is a luxury in many real-world situations.

In this article, we have made recommendations for where you should consider buying capacity to add redundancy at one-of-a-kind tools, if that is an option. Where that's not an option, all you can do is focus on fundamentals: avoid high utilization, especially from forced idle time, on the one-of-a-kind tools and do everything in your power to reduce variability in arrivals and process times at those tools.

Closing Questions for Newsletter Subscribers

Do you have any one-of-a-kind tools in your fab, even temporary ones? Are there other things that you do operationally to mitigate their impact on cycle time? What strategies have you used that we missed?

Further Reading

- Thomas Beeg, "Fab Size Does Matter," Factory Physics and Automation Blog, 2022.
- N. S. Grewal, A. C. Bruska, T. M. Wulf, and J. K. Robinson, "Integrating Targeted Cycle-Time Reduction Into The Capital Planning Process," *Proceedings of the 1998 Winter Simulation Conference*, Washington, DC, 1005-1010, 1998. Download PDF from FabTime's website.
- J. Robinson and F. Chance, "On Breaking Up PMs and Other Unavailable Periods," *FabTime Newsletter*, Vol. 22, No. 1, 2021.
- J. Robinson and F. Chance, "Fundamental Drivers of Wafer Fab Cycle Time," *FabTime Newsletter*, Vol. 22, No. 4, 2021.
- J. Robinson and F. Chance, "The Impact of Tool Qualification on Cycle Time", *FabTime Newsletter*, Vol. 20, No. 5, 2019. Available from the FabTime Newsletter Archive. The current password is "FabTimeCommunity" (no quotes).

Subscriber List

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