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SUPPLIER PERSPECTIVE

Fourth-Generation Maintenance

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ABSTRACT

From the beginning of mechanized world maintenance, the initial focus was to fix equipment only when it broke. As equipment became more and more complex and the costs associated with keeping it running escalated, new approaches to maintenance were formulated. Maintenance has evolved from the initial "fix it when it is broke" reactive form, through preventive, predictive, and proactive approaches. Today, we are seeing a better approach that uses the best of all of these methods and integrates them into a balanced format. We use what has been learned and take it a few steps further. By integrating and using the best parts of each approach, a maintenance team can provide additional value to an organization by adding process improvement as well. This article is not a guide to each of these maintenance paths. Our focus here is to explain that there is a better way that will help an organization "keep the lights on" while always addressing the future. In some cases, this takes expertise to guide you along the correct path to success.

The Evolution of Maintenance

Your latest grain bill is ready to go, you're about to start making your next seasonal, you hit the start button, and the $5 drive belt on your mill tears apart. Or, you're pushing wort into your heat exchanger and the $0.25 gasket springs a leak. Surely, you have the replacement part in stock. How long will you be down for? Will you run out of your customers' favorite brew? If this situation sounds familiar, it's time to look at your maintenance strategy, identify your critical failures, and put plans in place to avoid situations like the ones described above.

The first mistake most people make is to think that failures are time driven. That is to say that, the older a part gets, the more likely it is to fail. That is simply not true. Data and experience show that 85% of all failures are random. Figure 1 shows all the demonstrated failure patterns and the evolution of our understanding of failure modes since the beginning of mechanization.

How can you prevent failures, and their consequences, efficiently when age is not a good predictor of when a failure will occur? In order to answer this question, we'll first review how the practice of maintenance has evolved and then look at how developing and implementing a balanced maintenance strategy will allow you to turn maintenance into a contributor to your profitability rather than letting it be a necessary evil.

Until the 1950s, maintenance was mostly reactive. The old adage "if it ain't broke, don't fix it" prevailed. With the advent of mechanization and mass production, managers realized that downtime was expensive and, between 1950 and 1975, preventive maintenance started to appear. From 1975 to the early 2000s, as asset managers realized that systematically replacing parts that had not yet failed could also be an expensive proposition, they started to implement predictive maintenance. Finally, with the advent of computerized maintenance management systems and the proliferation of sensors, resulting in readily available equipment condition data and maintenance history data, proactive maintenance started in the early 2000s.

The next chapter in maintenance evolution will surely be deeply influenced by industry 4.0 and Big Data. For the sake of brevity, this article will not be able to dig into these aspects in depth.

Reactive Maintenance

As the name implies, reactive maintenance, from its inception, has consisted of performing repairs in reaction to a failure. With mechanization and all the way through the two great wars, machines were mostly run to failure. The newness of machines and the fact that early machines were simple partly explain why a strategy based on reactive maintenance could be successful in the first generation of maintenance, up to 1950. However, as machines became more complex and their maintenance required more specialized knowledge, running to failure became inefficient and costly.

Preventive Maintenance

During the period from 1950 to 1975, the second generation of maintenance, preventive maintenance, became the prevalent maintenance mode in the industry. Time-based maintenance tasks were implemented with the goal of replacing components, in a planned manner, before a failure occurred and resulted in an emergency. These tasks included scheduled overhauls and systematic replacements, as well as fixed-interval inspections. This was the beginning of maintenance planning.

This maintenance philosophy is based on the understanding that repairing a failure in an emergency fashion is typically three to four times more expensive than performing the same work in a planned fashion. This does not include the cost associated with a fully staffed production line idling. Given that, in these early times, the data were not readily available, the cost of replacing a component before the end of its service life was not well understood.

Soon enough, however, managers realized that there were costs associated with systematically replacing components: the remaining useful life of the components themselves and the

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cost of performing the work. Imagine that a systematic replacement is carried out five times per year and that every time 20% of the component's life remains; this means that, once every year, the job is performed for nothing and the money for the labor, the parts, and the line downtime associated with this job are wasted. Out of this realization, predictive maintenance was born.

Predictive Maintenance

Predictive maintenance is mostly associated with condition monitoring. Therefore, instead of replacing a part because it has been in operation for a given number of hours or cycles, as is the case with preventive maintenance, parts get replaced only when the symptoms of an impending failure appear.

Predictive maintenance can be high-tech: for example, using technology to analyze the alignment or the vibration on a rotating assembly to decide if the bearing requires replacement, or oil analysis to determine if it is time to change the oil and to detect contaminants that indicate that something is wrong with the components being lubricated. It can also be low-tech: hearing the sound of a drive belt slipping, indicating that it needs to be replaced, or touching a gearbox to determine that it is running hotter than usual, which would indicate a problem.

Entire articles have been written on predictive technologies and their application; this article does not go into these technical details. The goal of this article is to point out that these technologies exists and that, moreover, there are low-tech predictive technologies, such as your five senses, and they are all part of the predictive maintenance arsenal. In both cases, decision-making is based on the P-F curve (Fig. 2).

The P-F curve illustrates the fact that symptoms of a failure appear at a certain point in time (P on the curve) and that failure will occur at a reasonably predictable point in the future (F on the curve). The effectiveness of predictive maintenance is based on the ability of the maintainers to detect the symptoms when they appear and on their capacity to prepare the work and schedule in time to prevent the failure. In order to predict when a failure will occur based on the appearance of specific symptoms, effectively charting the P-F curve, one needs experience—both with general maintenance and with the specific component being evaluated—and also good maintenance and failure history, as well as good information from the original equipment manufacturer.

Using a bearing as an example: Bearings are a great example of the usefulness of predictive maintenance because they are as likely to fail early as a result of poor installation as they are to fail as a result of all other causes. This means that it is counterproductive to replace a bearing before it is absolutely necessary. Therefore, one could measure bearing temperature on a continuous basis, using a sensor, or at given intervals, using handheld tools. Given experience with the equipment and available data for the specific bearing, a temperature threshold could be set to decide on the optimal time to replace the bearing. This allows the maintenance planner to schedule the work and ensure that it is ready to execute at the scheduled time, without disrupting the maintenance or production schedules.

In the same way that preventive maintenance was an improvement over reactive maintenance, predictive maintenance is also an improvement over preventive maintenance. How-

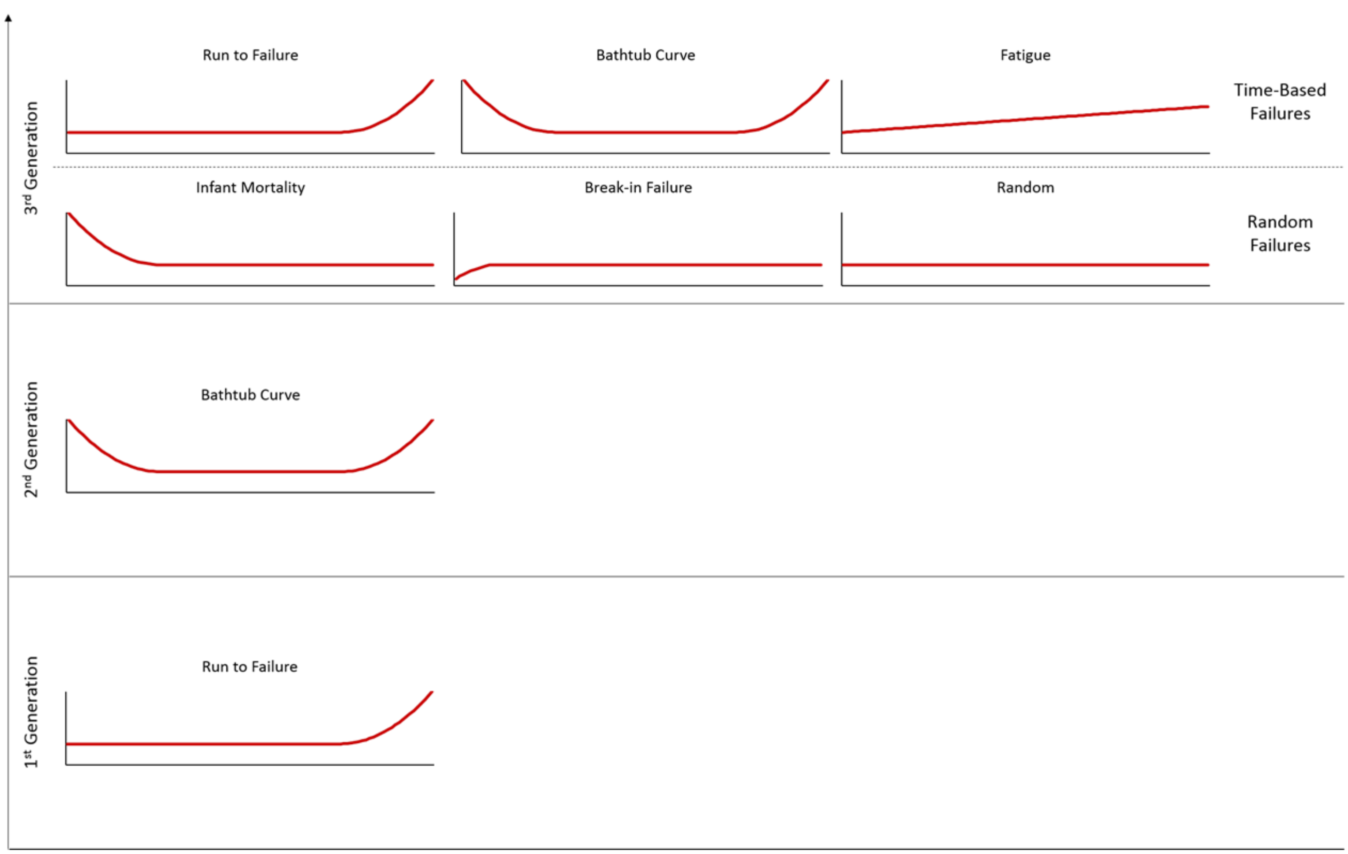

Figure 1. Evolution of equipment failure understanding (1).

ever, in the early 2000s, managers realized that predictive maintenance was also suboptimal. One could easily waste money performing unnecessary predictive tasks. For example, if your oil analysis comes clean every other time, it is being analyzed, at a cost, twice as often as it needs to be. This led to fourth-generation maintenance.

Proactive Maintenance

In order for maintenance to become a profit contributor, the global cost of operating equipment throughout the entire lifecycle has to be taken into consideration. Furthermore, fourth-generation maintenance takes into account the fact that downtime is not the only consequence of a failure. Failures can have a multitude of consequences related to safety, the environment, product quality, your ability to serve your customers, and the morale of your employees as well as cost. Therefore, lifecycle optimization and risk management are the two major drivers behind proactive maintenance. As such, proactive maintenance did not bring about technical advances in the same way that predictive maintenance did. Rather, it made use of technologies to optimize maintenance task planning over preventive maintenance.

Fourth-generation maintenance is also the understanding that reactive, preventive, and predictive maintenance all play a role in optimizing the reliability, availability, and cost of industrial assets. In this case, the technical advance comes from the availability of the data through sensors, data historians, and analytical software. As such, it is based on hard data, maintenance history, and failure history, and it makes use of the knowledge that 85% of all failures are not time based to appropriately leverage reactive, preventive, predictive, and proactive maintenance.

It is through understanding this data that a balanced maintenance strategy can be designed and implemented, thereby optimizing equipment performance. Furthermore, in fourth-generation maintenance, the development of the maintenance plan begins much earlier in the life of the equipment. In fact, operational readiness and the design for maintainability methodology allow the user to evaluate the maintenance requirements during the design stage and make the cost of maintaining a piece of equipment and operating it throughout its entire lifecycle a part of the procurement decision. For example, it is not rare for a brewer to ask bidders on major capital projects to present the failure modes and effect analysis of their proposed solution as part of the bidding process. Operational readiness is another topic altogether, and it is not treated in any more detail in this article.

A Balanced Maintenance Strategy

How does one go about implementing a maintenance strategy that takes advantage of fourth-generation maintenance? This is accomplished by implementing a proper mix of reactive maintenance, preventive maintenance, and predictive maintenance while using the tools of proactive maintenance to apply each of them properly and at the right time.

Typically, a successful maintenance strategy includes less than 2% of the technicians' time spent on emergency work and 8% on unplanned work. This means that 10%, or less, of the available maintenance labor hours must be spent on unplanned work (Box 1).

Preventive maintenance should account for 20–25% of the total maintenance hours, as should the corrective maintenance hours. This is because every hour of preventive maintenance should result in one hour of corrective work. If an hour of pre-

Box 1. Emergency versus Unplanned Work

Emergency work is work that must be performed immediately. Production cannot continue until the repairs are performed. It is the most costly type of maintenance work.

Unplanned work is work that cannot wait until the next planning window but does not need to be performed immediately. The production line may be able to continue running to the end of the current run while the maintenance work is being prepared. While this is still very expensive and needs to be minimized, it is slightly less costly than emergency work.

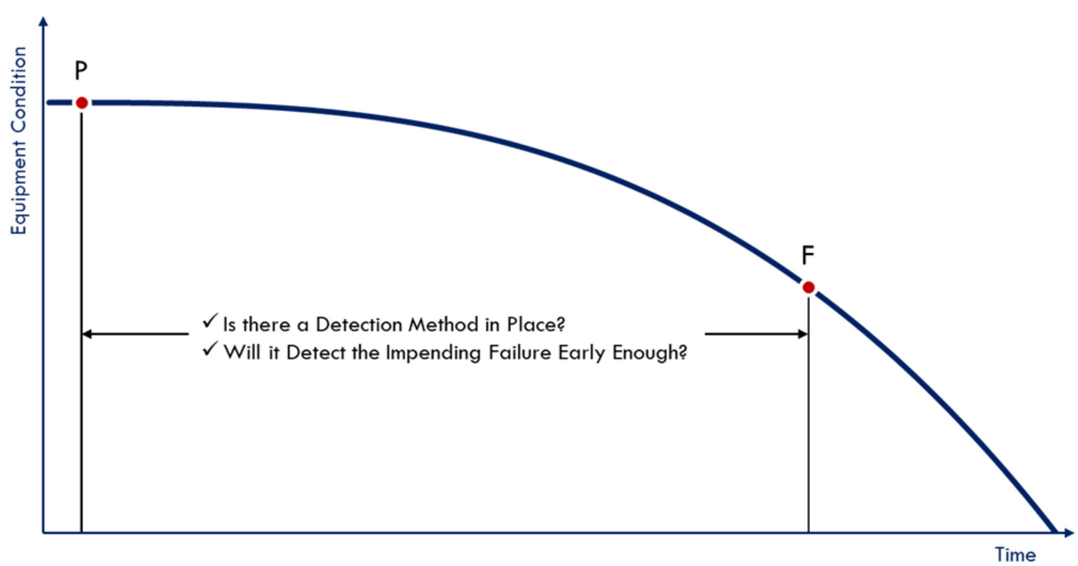

Figure 2. The P-F curve.

ventive maintenance at your facility yields less than an hour of corrective work, it means that too much preventive work is being done or that it is not effective. Conversely, if each hour of preventive maintenance yields more than one hour of corrective work, the frequency of the preventive work must be adjusted to reduce the amount of corrective work being identified.

Predictive and proactive maintenance should account for another 20–25% of the maintenance labor hours. This leaves approximately 20% of the available maintenance hours to perform improvement work. This last point highlights the importance of moving out of a reactive mode and into a proactive mode: the only way to get better is to adjust your maintenance strategy to minimize reactive work and maximize work that enables improvement. The balanced maintenance strategy is presented in Figure 3.

Implementation

How to implement your strategy greatly depends on the current state of your assets and your team's maturity with respect to asset performance management and operations management, as well as your overall strategy, or plan, to run a successful brewery. Ideally, it would start at the design stage, when you still have a brewery-in-planning. Including funds to follow the operational readiness methodology as you design and build your facility will not only save you up to 3% in lifecycle operational costs but will also improve your equipment production potential by as much as 10% over its service life. The investment, typically 0.5–1.0% of the total investment in equipment, pays for itself in the first few years.

If you are already past the design or even building stage, it's still not too late. It is slightly more complex, however, and it is likely that you will need professional help to assess your current situation. That assessment, combined with a thorough knowledge of best practices, is then used to design a maintenance strategy and implementation plan that are aligned with your operational objectives. The process is illustrated in Figure 4. This is valid whether you are a beginner or an expert at asset performance management.

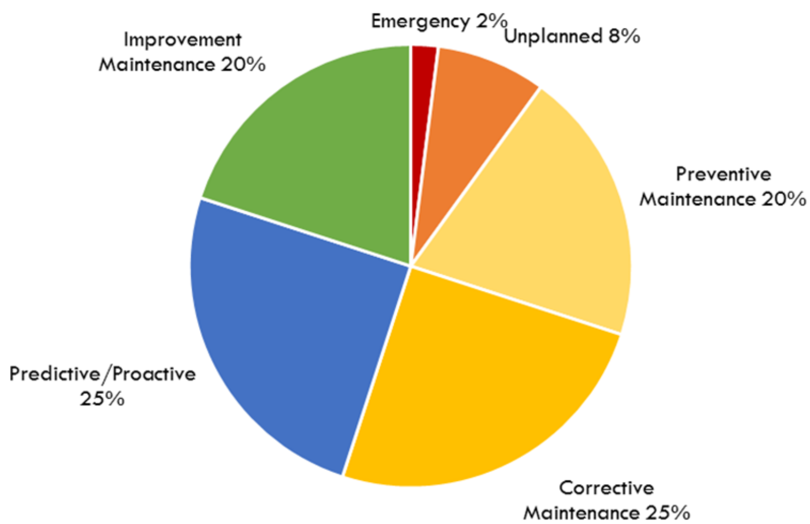

Figure 3. Balanced maintenance strategy.

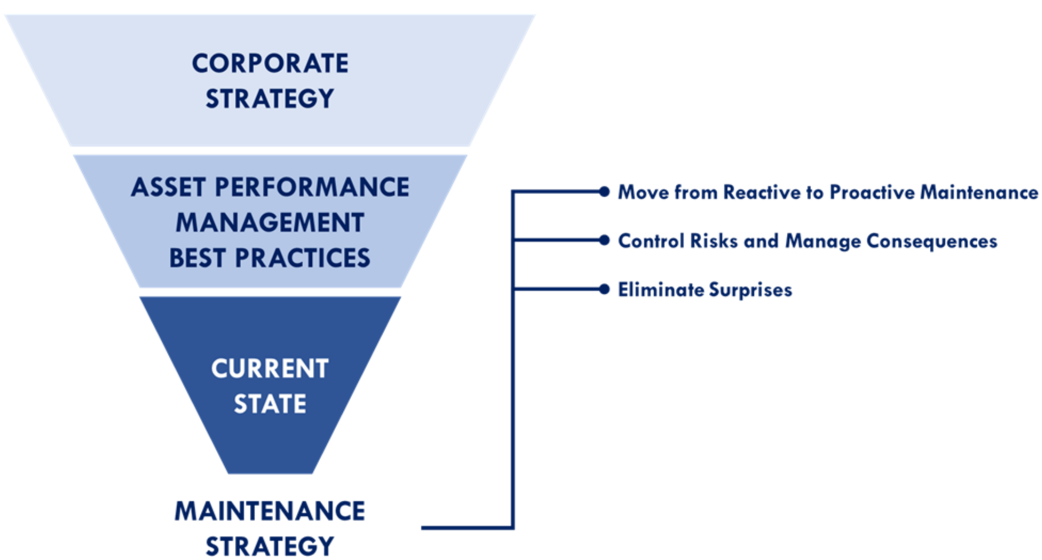

Figure 4. Maintenance improvement methodology.

Summary

Maintenance has evolved from a reactive form through preventative, predictive, and proactive forms as complexity and demand for cost saving and performance have escalated. Today, we are suggesting a new, more balanced, approach. The realization causing these changes is the cost of maintaining equipment and the cost of that equipment downtime. Each stage in the development of maintenance strategies has been focused on eliminating failures or mitigating their consequences. Each new development in maintenance strategy (reactive to preventative and preventative to predictive) added value and, independently, each change brought savings in its approach to maintenance. What we have learned from all of this is to take each of these strategies and integrate them in such a manner as to complement each other, producing the highest savings and creating the most aggressive, balanced approach that best complements your maintenance staff. This approach blends the best parts of each strategy, leading to a process that keeps the business running at the lowest cost while adding time and a framework to allow for improvements, always looking for opportunities to keep moving forward.

REFERENCES

1. Moubray, J. 1997. Page 4 in: Reliability-Centered Maintenance, Second Ed. Industrial Press: New York, NY.