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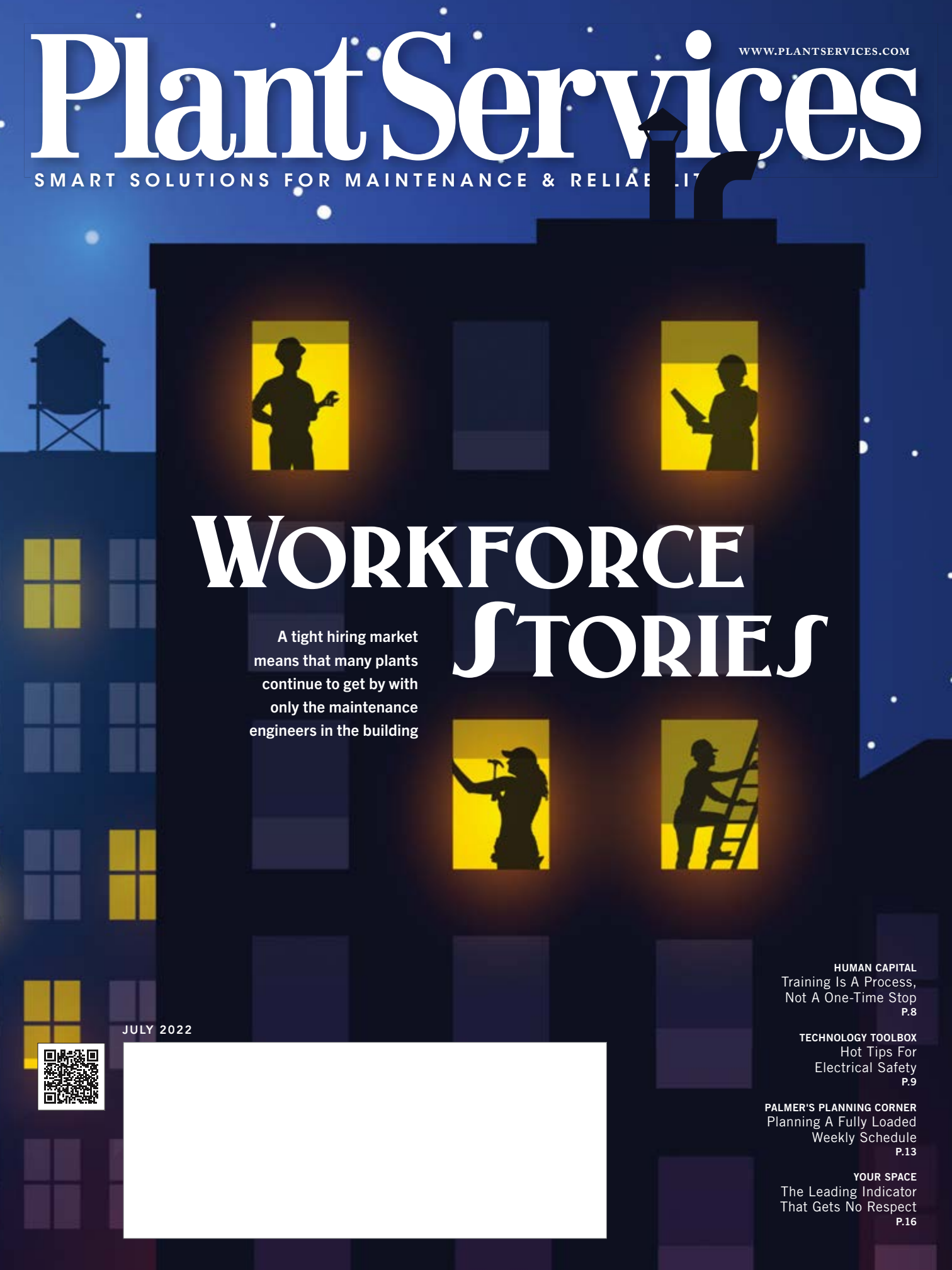

WORKFORCE STORIES

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JULY 2022

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Policy paradoxes

How much space exists between what your plant says and does?

Are you familiar with the acronym "ESG"?

It stands for Environmental, Social, and Corporate Governance (ESG), which is an approach to evaluating the extent to which a corporation works on behalf of social goals that go beyond the role of a corporation to maximize shareholder profits.

The three criteria commonly break down as follows: *environmental* criteria consider how a company safeguards the environment, including corporate policies addressing climate change. *Social* criteria examine how the organization and its teams manage relationships with employees, suppliers, customers, and the communities where it operates. Finally, *governance* deals with a company's leadership, executive pay, audits, internal controls, and shareholder rights.

These criteria are increasingly used by investors to screen their investments and to encourage companies to act responsibly. This was made very clear at the recent ARC Industry Forum in Orlando FL, which focused on the theme of "Accelerating Industrial Digital Transformation and Sustainability." During his keynote address, Michael Guilfoyle of ARC explained that energy transition and industrial sustainability are the largest disruptors of our lifetime, and that ESG risk portfolios—those which prioritize optimal ESG factors or outcomes—are currently where investment capital is flowing. He added that these investments are expected to reach $41 trillion by end of 2022, or 1 of every 3 dollars managed.

ESG policies are presenting new challenges to companies across all functional groups, from the C-suite and finance office to operations and security. Perhaps chief among these is ensuring that the company is doing what it says it is doing, and then backing those statements up with relevant data. After all, the pathway to ESG can be quite vague; each organization is unique, and there may not be much guidance available on actions that organizations can take to improve both environmental performance, for example, and business net-positive results. This year's ARC Industry Forum went a long way toward building cross-industry connections and knowledge sharing.

Are you familiar with the acronym ESG? If not, get ready to put it on your mental map.

ESG criteria also are being used by hiring teams to attract the best candidates, and by job seekers to determine for whom they would like to work and for how long. The U.S. unemployment rate in June was just 3.6%, and was even lower in manufacturing (3.0%) and in mining, quarrying, and oil & gas (1.6%). It's a tough hiring market in maintenance and reliability, so consider ESG an opportunity to help your company stand out from the crowd.

For more information on ESG be sure to check out our new infographic on p.22, built from a survey jointly conducted by Plant Services and Augury that explores the degree to which ESG policy is being executed at the plant floor level, and follow that with Managing Editor Anna Townshend's industrial workforce cover story on p.24.

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Training is a process, not a one-time stop

Employee training exposes new staff to the expectations, but leaders ensure those expectations are met

I was asked recently to help a plant with improving the maintenance performance. I looked over the plant's work management process to see what the plant management wanted its planners to be doing. It was a well written document. It covered all the best practices with a few minor items for improvement.

Next, I asked the planners what their job was and how they spent their days. It was no surprise to me that their daily and weekly tasks did not line up with the work management process that I had reviewed. I soon realized that most of the planners had not read the document.

We lead and manage in a dynamic environment. However, we can't provide training once every four years, while there is more than 20% annual turnover.

I mentioned this to the maintenance manager, who was surprised, and the corporate reliability leader, who said: "Everyone was trained on the process!"

There were four planners. One, the most experienced and retirement ready, had been in the plant for decades. Planner One had been doing what the plant had called planning well before the 2014 process was designed and implemented. Planner One was trained in 2014 on the new process, but it's unclear (and unlikely) that the change was ever really embraced by Planner One.

Planner Two has been on the job for less than a year with lots of good experience in operations and maintenance. However, Planner Two was never trained on work management process and didn't know of the existence of the process documents. When provided with a copy, Planner Two was excited to see clear guidance, and specifically guidance that would enable the planners to stop doing things they were not accountable or responsible for.

Planners Three and Four had only been on the job for less than two months. When showed the work management process documents their response was, something like, "Oh geez, we just started getting comfortable with what we were told to do. Now we have to learn something new." Not the response I was hoping for. But they were honest.

What are the real problems?

The corporate reliability program put forth the effort, at considerable cost no doubt, to create a best-practice work management process and documentation. The plant personnel were trained. But that was in 2014 and 2018. Based on Planner One, the effort probably never really took hold. Since then there had been a huge amount of turnover.

The maintenance manager had been in that position for about two years. In fairness, that two years has been dominated by the COVID era and lots of trouble keeping employees and filling open positions. Open positions meant that there may not have been enough people to carry out the work management process as defined.

So, what's the way out of this problem? As leaders we have many challenges. We lead and manage in a dynamic environment. However, we have to keep our eye on the ball. It's the maintenance manager's responsibility to educate their team on roles, responsibilities, and accountabilities. It starts with orientation for new employees. It continues with watching for and correcting deviations from guidance and reinforcing the correct processes and procedures.

We can't provide training once every four years, while there is more than 20% annual turnover. Did you check the training records? Are the people now in the plant the same people that were trained?

When a new person joins your team, do you provide him or her with the policies, plans, processes, procedures, and measures, and the time to actually read them? Do you explain roles and responsibilities and how this employee fits within the greater organization? Do new staff know what others are responsible for?

As a leader are you attentive to check on compliance with your processes? If you find deviation from guidance are you assertive? Do you address deviations?

Don't make assumptions about what people know. As leaders the onus is on us to make clear and support our expectations. Go forth and do great things.

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Hot tips for electrical safety

Innovative tools and accessories help protect against serious industrial hazards

Electric shock, electrocution, and arc flash hazards are top of mind for industrial workers dealing with electricity. Ensuring that personnel are fully qualified, using the right tools, and following the appropriate NEMA safety standards is the best way to protect against the risk of injury or death. Modern safety devices and wearable solutions help to achieve this vital goal.

SAFETY DEVICES

Ground-fault circuit interrupter (GFCI) technology is improving. The new SB5000 Industrial Shock Block GFCI from Littelfuse reduces unnecessary tripping using DFT filtering and the full UL 943 inverse time curve. Its ground-check capability with a Zener termination option monitors the ground wire for continuity between the Shock Block and load, and trips if it is compromised.

Ensuring that personnel are fully qualified, using the right tools, and following the appropriate NEMA safety standards is the best way to protect against the risk of injury or death.

The SB5000 Shock Block is "putting the best/latest safety technology into a smaller, more functional package," says Richard Dale, product manager for relays at Littelfuse's Industrial Business Unit. The new packaging is IP69K-rated, making it well-suited for equipment washdown environments, and the SB5000 series is fully certified to meet Class A or Class C/D requirements, he adds.

The 1000 VAC/VDC Safe-Test Point from Grace Technologies is a permanent electrical safety device (PESD) designed to allow absence of voltage testing (AVT) from outside the electrical cabinet. The self-powered device, which can be combined with a voltage indicator, enables AVT with a multimeter through high impedance protected test point jacks, without wearing special personal protective equipment (PPE).

"The development of this new Safe-Test Point will bring optimized electrical safety to more doors and, consequently, more people," observes Drew Allen, president and CEO of Grace Technologies. "Our team is very proud to provide a safer and more productive method of performing lockout/tagout (LOTO), which is critical for minimizing injuries in the workplace and maximizing equipment uptime."

External oil sampling devices for cabinet transformers avoid de-energizing the transformer or opening the cabinet door. SampleSafe ST and the new SampleSafe Essential from SDMyers are valve extensions for cabinet transformers that are designed for this purpose. SampleSafe ST has the added benefit of a steel powder-coated lockable enclosure. Available dual configuration provides the ability to complete online oil processing services such as top-offs or reinhibiting.

All SampleSafe kits come standard with a viewing window, Schrader valve, and relocation of the pressure vacuum gauge, says Kyle Johannes, product manager at SDMyers. "These features allow for the critical step of a visual inspection on the cabinet, adding of nitrogen (if necessary), and

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checking the pressure of the unit prior to sampling," he explains.

The Safe-Connect product line recently acquired by IRISS complements the company's other electrical maintenance safety devices. "Safe-Connect offers the advantage of thermochromic science for visual indication of asset health," says Martin Robinson, founder and CEO of IRISS Group. The thermochromic technology causes a color change based on temperature ranges, enabling 24/7 safety monitoring and the ability to detect overheating before an electrical fire or equipment failure occurs.

For instance, Safe-Connect ThermoClips used in tandem with large-format infrared (IR) windows from IRISS enable visual inspections for overtemperature conditions in electrical equipment before and between IR and ultrasound inspections, even in intermittently loaded systems. Thermochromic cable wrap and label solutions are also available.

WEARABLE PROTECTION

Knowing where people are located is crucial, especially in emergencies. The new Safety Watch industrial real-time location solution (RTLS) from Honeywell improves safety, security, and compliance monitoring and accelerates mustering and search and rescue operations. Its small, battery-operated RFID tags can be integrated into employee badges or affixed to critical assets, including in hazardous areas. Honeywell's OneWireless network infrastructure and RTLS software platform complete the solution.

RTLS helps users "do more in the safest and most productive way possible with real-time data, and safeguards your most valuable assets, thus improving the overall effectiveness of your workforce," says Nisha Lathif, safety solutions business director at Honeywell Process Solutions.

The Bussmann series of arc flash PPE recently launched by Eaton marks a milestone for the company. "Eaton is now the only manufacturer that can partner with customers through every step of their electrical safety journey, from conducting arc flash risk assessments and personnel training to recommending a PPE portfolio and now providing the PPE itself," says Thomas Domitrovich, Eaton's vice president of application engineering for the Bussmann division.

Available as a kit or in components, Bussmann arc flash-rated clothing meets or exceeds all related standards, and the shields or hood window panels achieve 100% color acuity with clear true gray color, notes Domitrovich.

Email Contributing Editor Sheila Kennedy, CMRP, managing director of Additive Communications, at sheila@addcomm.com.

Easy-to-implement CMMS modules

These two simple modules will move you toward planned maintenance and maximize equipment uptime

Although management is well aware that spending thousands if not millions of dollars on a CMMS does not in and of itself guarantee a return on the investment, it is rather surprising how few companies can boast full benefits realization. Even years after implementation, many companies struggle to get the most out of their CMMS.

There is so much pressure on North American industry to reduce costs, through better planning and less fire-fighting. This must translate into higher efficiency and utilization of maintainers and operators, as well as lower equipment downtime from greater reliability and performance of equipment. The CMMS is an essential tool used in support of this objective.

In this column we turn to two of the simplest and most fundamental CMMS modules, Work Management and Equipment History, to get at the low hanging fruit.

WORK MANAGEMENT MODULE

Moving to 100% planned maintenance of assets through the Work Management module is an easy sell—conceptually—yet so few companies fully embrace it. There are only three ways maintenance of assets can be triggered, namely maintenance policies as follows:

1. failure-based maintenance or run-to-fail
2. use-based maintenance where maintenance is done on a regular basis whether it needs it or not (e.g., changing the filter each month)
3. condition-based maintenance where maintenance is triggered upon regular inspection by reaching an upper or lower control limit (e.g., changing bearings upon inspecting vibration on rotating equipment every quarter when levels exceed a given value).

To understand the resistance to establishing a work program that embraces an optimal mix of these three maintenance policies for each asset, one need not look farther than your family car. Most of us agree that, when done on a regular basis, changing the oil, inspecting the belts, and ensuring proper tire pressure can significantly extend the life of your car.

Why then do so few people do these very simple routines even though they know it is good for them? Instead, the default is allowing systems and components to run to failure rather than planning what maintenance policy should be implemented for which asset. One problem is that there are no immediate consequences, therefore planning appropriate maintenance policies becomes low priority. It is not surprising to find top management espousing the virtues of planned maintenance. However, the demands of production, and the expense in time and money in establishing and maintaining a work program, cause an indefinite delay in the implementation of streamlined work management.

Because of its simplicity, the work management module of CMMS packages are fairly similar. All of them give you the option of triggering work orders based on calendar and meter readings (i.e., use-based maintenance policy). Most CMMS packages allow users to trigger maintenance based on events or condition readings taken directly from equipment on the shop floor on an online, real-time basis (i.e., condition-based maintenance policy). These readings are compared to the allowable upper and lower control limits and can even spot an alarming trend before downtime occurs. Herein lies the power of the work management module to achieve the objective of minimizing downtime.

One problem is that there are no immediate consequences, therefore planning appropriate maintenance policies becomes low priority.

The calendar feature differs slightly from one software package to another, in terms of ease of use and level of detail. High-end packages use graphics to display calendars showing holidays, vacations, shift hours, and scheduled overtime for an individual maintainer. Low-end packages dispense with the fancy graphics and may only provide calendars by crew or plant, not by individual. The calendar feature is important to achieve the objective of maximum maintainer utilization.

Another significant difference between CMMS packages with respect to their work management modules lies not within the module itself, but the ability of the package to interface with other software such as document imaging, workflow, predictive maintenance, ERP, shutdown maintenance, and project management software.

With the purchase of an optical scanner, and/or using CAD software, document imaging allows users to attach either scanned or CAD images to a piece of equipment,

work order, or inspection record. These images can then be retrieved within the work management module or other maintenance management modules for viewing, printing or editing. Thus, a maintenance worker can prepare a free-hand sketch of lubrication points on a piece of equipment, scan it, and the system will automatically print it each time the appropriate use-based or condition-based work order is printed. This translates into greater efficiency and effectiveness of maintainers when performing maintenance.

First and foremost, maintenance is responsible for maximization of equipment uptime. That is why downtime reporting is an essential part of equipment history.

The interface with ERP (i.e., production planning software), shutdown maintenance and project management software provides a means of coordinating equipment downtime with production, and managing the planned overhaul of equipment. This interface can dramatically reduce the amount of unplanned downtime experienced, as well as the length of downtime required for conducting maintenance.

EQUIPMENT HISTORY MODULE

The Equipment History module, if it is properly designed and used, provides the greatest source of savings and benefits to the maintenance department in terms of minimizing downtime and maximizing maintainer utilization. Let us examine why this is so, and how CMMS packages differ in their treatment of this important module.

First and foremost, maintenance is responsible for maximization of equipment uptime. That is why downtime reporting is an essential part of Equipment History. Vendors offer a variety of analysis tools to help understand the nature and cause of downtime, as well as optimal solutions. Advanced features include reliability-centred maintenance, activity-based management, troubleshooting database, asset performance and reliability (e.g., mean time between failure), total cost of asset ownership, and so on.

Many vendors are improving their budgeting capability and variance reporting. Also, some CMMS vendors offer serialized component tracking including detailed repair history. This is an important feature for companies that have considerable repair/replace activity, and where repaired components are not necessarily replaced into the original equipment.

Maintainer utilization answers the question, "What is the company paying for the current level of service to production?" If the number of maintainers was cut by say 25%, how would it affect the level of equipment downtime in the short to long term? In my experience, the average maintainer utilization in North America is approximately at least 45%. This can be calculated for your company through Industrial Engineering work measurement techniques such as work sampling.

Maintainer utilization can also be derived through the CMMS by analyzing time sheet data. By maintainers reporting each day on the breakdown of hours spent on each activity, the Equipment History module can summarize by day, week, month, and year for each person, crew, trade, cost center, or the entire maintenance department.

The types of activities include failure-based maintenance, use-based maintenance, condition-based inspections, condition-based maintenance, emergency reactive maintenance, capital projects, standing work orders, administration, and training. As well, the breakdown can be in terms of regular hours, overtime hours, contracted hours, and percentage, and can then be compared to same time last year or to budget.

These reports, used in conjunction with the work backlog report, are essential for measuring the efficiency and effectiveness of a maintenance department. Suppose the mechanical tradespeople booked for last year, 40% of their payroll hours on emergency reactive maintenance, 10% on failure-based maintenance, 40% on standing work orders (e.g., minor lubrications and inspections, and jobs under 30 minutes), and 10% on capital projects, including a 20% overtime premium. If the backlog of work for the mechanical trade is estimated at one person-year, and there are only six mechanics in the department, then certain conclusions may be drawn.

First, too much time is spent fighting fires. This is not a feeling—there are figures to support your claim. Second, little use-based and condition-based maintenance are done. Third, overtime is a chronic problem. Fourth, more people or contract maintenance is required to eliminate the overtime and clear the backlog of planned work, since only 10% of six people are available to do one person-year of backlogged work.

Finally, 40% spent on small jobs is very high, and could be caused by workers charging idle time (e.g., waiting for parts, waiting for instructions, excessive walking, extra time spent on jobs) to the standing work order "slush account". Once corrective action has been taken, further reports are generated to highlight whether problems have been addressed.

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Planning a fully loaded weekly schedule

Planned work should do more than keep crews busy; 100% schedule loading gets more work done

The absolutely most controversial part of planning and scheduling is fully loading weekly schedules for each maintenance crew to 100% of its forecasted labor availability. Only with fully loaded schedules do crews reach superior productivity. But management faces an enormous obstacle of supervisor fear in enacting such an approach. Loading schedules fully makes the whole program work, but is rare in industry. Let's make the case for full schedules being the best strategy and then talk about two of the mechanical aspects.

In the *Maintenance Planning and Scheduling Handbook*, I state the fourth principle of scheduling as "The 1-week schedule assigns work for every available labor hour. Preference is given to scheduling higher-priority work by underutilizing available skill levels over scheduling lower-priority work. Normally, the schedule inherently contains a sufficient amount of work hours on tasks that could be interrupted for new emergencies and high-priority jobs that cannot wait until the next week."

There are three schools of thought in loading schedules. One school says to overload the schedules, say 120%. A crew with 400 hours of available labor (10 mechanics with no vacation, training, special meetings, or carryover that works a 40-hour week) would receive 480 hours of work orders for the next week. Another school of thought says to underload the schedule, say 80%. A crew with 400 hours available would receive 320 hours of work orders. A middle school of thought is to load the schedule 100% with the 400-hour crew receiving 400 hours of work orders.

The idea of the 120%, 480-hour schedule is to provide a "stretch goal" to increase productivity and give the crew some extra work "just in case" some of the work cannot be cleared or has other problems that cannot be resolved. The idea of the 80%, 320-hour schedule is to achieve high schedule compliance, foster a good relationship with operations from completing scheduled work, and easily be able to handle new reactive work that always surely arises at every plant. Both overloading and under-loading schedules have valid points and perhaps simply splitting the approaches and scheduling 100%, 400 hours, would make sense.

Nonetheless, both overloading and under-loading have serious flaws in accomplishing the purpose of scheduling. The purpose of scheduling is to help us complete more work than we would normally complete. Normally, crews keep busy, but crews that have a properly loaded schedule complete a bit more work than normal. (This extra productivity is because of the "sense of mission" we discussed last month.) That's the type schedule we desire.

Over-scheduling provides a stretch goal that is often daunting to crews. In the face of knowing reactive work will surely interrupt a full schedule, going further to overload the schedule merely keeps the crew supervisor in a mindset of keeping everyone busy. Over-loading a schedule does not increase crew productivity. On the other hand, under-scheduling does not provide any more work to be completed that could increase productivity. In fact, Parkinson's Law (the amount of work assigned expands to fill the time available) practically guarantees that under-loading a schedule will not increase productivity.

Parkinson's Law (the amount of work assigned expands to fill the time available) practically guarantees that under-loading a schedule will not increase productivity.

Furthermore, over- and under-loading both obscure management analysis. "How come you did not complete the overloaded schedule?" "Because it was more than we could do." "Did you have any problems with the under-loaded schedule?" "No, we completed all the work." Compare these discussions with the fully loaded schedule: "How come you did not complete all the work?" "We had ten new reactive work orders interrupt us. We really need to do something about that unreliable sump system."

The fully loaded schedule increases productivity beyond the normal "keep busy" rate. A great example is a plant in Fernandina Beach, FL, which increased its work order completion rate from 170 work orders per week to 225 work orders per week simply by increasing its schedule loading from 80% to 100%. Parkinson's Law is real, but can be simply defeated. Imagine completing an extra 200 work orders per month, for free.

Even so, the management obstacle is huge. The fully loaded schedules result in lower schedule compliance because reactive work does exist. Yet, it is better to fully load the schedule and break it, than under-load it and meet it. But an immature culture fears "looking bad" with lower schedule

compliance. (We will discuss schedule compliance in a soon to be written future article for Scheduling Principle 6.) It is very scary for a scheduler to give a supervisor a 100% loaded schedule for the upcoming week. We are not trying to make the supervisor look bad. But the fear is there. I find it helpful to refer to the scheduling as "backlog research." We are not trying to give you (the supervisor) more than you can do. In fact, we are not telling you what to do. We are simply having the scheduler dig through the backlog to find a good batch of work for the upcoming week as a service. Supervisors should not be trapped in offices digging into backlogs.

Two mechanical aspects of building the schedule are worthy of mention. First, it helps to have a somewhat multi-craft capability. For example, can we use a welder as a helper? Consider: We have a lot of fairly urgent work that requires only helpers, but we have no more helpers. And we have little welding work and many welders. We would want to use welders as helpers for the upcoming week because completing more urgent work is more critical to plant availability and reliability than not completing it. Of course, we abide within union and cultural policies. Second, there is always work that can be skipped in a fully loaded schedule. Not doing some of the work in a fully loaded schedule is preferred to under-loading the schedule to allow labor for reactive work that pops up.

Fully loading weekly crew schedules is a critical step in achieving productivity. Such schedules require management leadership to understand the purpose of scheduling of increasing productivity. The purpose is not simply to achieve high schedule compliance. Be a great plant!

Doc Palmer, PE, MBA, CMRP is the author of McGraw-Hill's Maintenance Planning and Scheduling Handbook and as managing partner of Richard Palmer and Associates helps companies worldwide with planning and scheduling success. For more information including on-line help and currently scheduled public workshops, visit www.palmerplanning.com or email Doc at docpalmer@palmerplanning.com.

Force field mindset drives plant reliability

Most machine failures originate from careless work, so do your best to insulate assets from human error

In any industrial setting, it is essential to prevent errors from occurring during the maintenance and operation of the assets. After all, even a tiny mistake can have serious consequences, ranging from production downtime to safety hazards depending on your processes and products.

In his work at DuPont and other activities, Winston Ledet determined that 84% of failures originate from careless work habits. Contrast that to the typical myth that equipment is more likely to fail as equipment gets older. Winston found that 4% of failures could be attributed to equipment aging, and 12% to basic wear and tear. With reliability-centered maintenance (RCM II), John Moubray found that more than 70% of failures are self-induced, with 40% of that number being human error. To that end, we are our own worst enemies in ensuring equipment availability. If the numbers are that bad, don't you think we should do something about it?

To start, envision a simple conveyor, gearbox, and motor system on your plant floor. With an Avengers or Hunger Games movie approach, surround that system with a force field where no errors penetrate the shield. Any error that attempts to reach the system ricochets off the shield back to the sender. Taking this mindset, it becomes easy to see how the focus is not about finding more issues with inspections and then planning and scheduling more work. It is about eliminating the introduction of new errors into the system, errors that create failures, and eliminating the need to plan and schedule corrective work.

Sure, maintenance planning and scheduling do play a role. Standardized work is critical in both maintenance and operations. The maintenance planner should create reusable job plans that detail the task steps using a level of specification (i.e., gaps, fits, fastener torque, belt and chain tension). Using the motor in our system, the job plan should specify the grease, the quantity required, removal of the purge plugs while greasing, and so on. Using ultrasound would provide a better precision approach for greasing activities to ensure the right amount of grease is used. No doubt over-greasing is a more significant issue than under-greasing for many organizations. On the gearbox, provide the right oil, and fill level. Use desiccant breathers if needed.

For PM inspections and adjustments, standard procedures should include cleaning rollers to reduce product buildup and belt stretch, ensuring belt alignment and the proper belt tension. Tighten fasteners and remove loose materials that may create a belt tear or jam. In my previous column, I shared ways to develop PM tasks that identify equipment in the act of failing. Leverage those concepts to prevent additional secondary damage. Ensure the inspection procedures detail any steps needed to return the equipment to an operational level. On the operations side, procedures and training are necessary to ensure the proper operation of the assets. Items include not overloading the conveyor belt, clearing jams to prevent stretching and tracking issues, cleaning the belt and rollers, appropriate changeover setups, and more.

> Any error that attempts to reach the system ricochets off the shield back to the sender.

As you consider other plant equipment, it is easy to identify many more ways to introduce errors to your assets. With more complex assets such as a cartoner, incorrectly made (i.e., out of specification) packaging materials can cause excessive machine adjustments, downtime, and significant waste. Yet, the operator still attempts to run it rather than rejecting the packaging material and running a different lot with the correct specifications. Continuing with the cartoner example, simply resetting the machine to its "home" timing position weekly can prevent excessive adjustments and downtime. Machine changeovers are another event that can trigger the introduction of errors. Ensure that standard work adequately documents the actions needed. Use fixed adjustments (pinning) over infinitely adjustable slots and color-coding to eliminate human error—coach and train personnel on the correct adjustments.

Again, the goal is to prevent introducing new errors into the equipment and identify and correct mistakes before they occur. Implement quality control procedures like audits. Use the force field concept and consider how errors are introduced. Use critical events (downtime of two hours or more) and review the potential root causes. Teach plant personnel to constantly ask, "How can we prevent introducing new defects or faults in the asset?" Taking steps to ensure they don't occur using a combination of procedures and training can significantly impact plant reliability and reduce your frustrations.

Jeff Shiver CMRP is a founder and managing principal at People and Processes, Inc. Jeff guides people to achieve success in maintenance and reliability practices using common sense approaches. Visit www.PeopleandProcesses.com or email JShiver@PeopleandProcesses.com.

The leading indicator that gets no respect

Even if you know your reactive maintenance rate, you probably would rather not talk about it

Most manufacturing organizations measure lagging indicators such as units produced and Overall Equipment Effectiveness (OEE), which measures uptime, rate, and yield. To improve production volume, most plants use the gold standard of Pareto (also known as the 80/20 rule) to identify and mitigate the top five chronic losses.

The other typical lagging indicator is cost. It's nearly universal practice for an accounting function to measure and trend total manufacturing cost, along with the sub-category of maintenance cost.

When Reactive Maintenance is correctly measured, meaning that it is probably a larger percentage than we like to admit, the result should be viewed as an opportunity.

When it comes to leading indicators, many plants deploy standard metrics such as overtime, schedule compliance, and PM compliance. One leading indicator that's rarely used is Reactive Maintenance, even though the Society of Maintenance and Reliability Professionals (SMRP) considers it a best-practice metric. At Life Cycle Engineering (LCE), we call this metric Maintenance Break-In Work (MBIW).

Whether the metric is called Reactive Maintenance or Maintenance Break-In Work, when it is used, it's typically measured incorrectly. MBIW is calculated as follows:

MBIW = (Total labor hours spent on break-in work / Total craft labor hours) × 100

It is important to define what work order priorities account for break-in work:

- Emergency Work: work hours that result from a breakdown causing lost production or service
- Urgent Work: not the result of a breakdown, but work hours that require breaking the weekly work schedule to avoid a possible breakdown, or work that should have been scheduled but was not.

For example, one plant LCE recently worked with had most of their work orders categorized with a routine priority. Their metric for breakdown maintenance, which used work order count as the measure, was in the 12% range. After improving their priority structure to assign priorities based on time, the maintenance manager did not want to redefine and report MBIW based on labor hours, per the best-practice definition. When asked why, he said it would make him look bad.

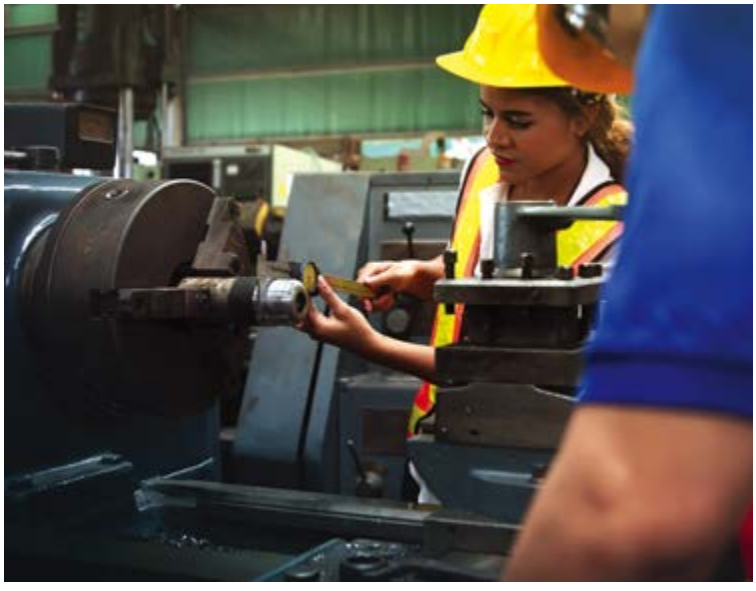
When the correct definition was configured into the reporting software based on labor hours and included all shift maintenance hours spent on reactive work, the weekly results averaged 28%:

- Maintenance consisted of 50 skilled tradespeople
- 50 people × 40 hours available per week = 2,000 hours
- Emergency and Urgent work hours = average of 560 hours per week
- Reactive work = 560 hours/week divided by 2,000 hours/week = 28%

WHY DOES MBIW GET NO RESPECT AS A LEADING INDICATOR?

One reason is that it is a measure of a negative performance. By correctly measuring Reactive Maintenance, the negative is highlighted for all to see.

A second reason follows: no one likes to present negative results to their boss. We are trained that when one identifies



a problem they are now accountable to fix it.

We should all challenge this paradigm. When Reactive Maintenance is correctly measured, meaning that it is probably a larger percentage than we like to admit, the result should be viewed as an opportunity. It's important to measure reactive maintenance correctly and trend it weekly, and to include it in monthly communication reports. A plant should also Pareto the common causes of break-in work.

In my experience, these are common lessons learned:

1. True plant emergencies (where a production unit is down or there's a significant EH&S event) and the associated maintenance labor hours are not as numerous as people perceive.
2. Plant personnel will over-utilize this priority to get their issue resolved, regardless of the correct lower priority.
3. Urgent work accounts for the majority of MBIW events and hours. Many of these are good use of this priority to prevent problems like a line going down.
4. However, many urgent events are the result of last-minute poor decision-making and planning.

HERE'S HOW YOU CAN USE MBIW AS AN EFFECTIVE LEADING INDICATOR

Develop Reactive Maintenance Pareto data and charts to identify problem equipment and assign them to reliability engineers to mitigate. Also, use the data to change behavior and improve decision-making through education and training. When you can convince your team to commit to this expression, you'll be able to improve Reactive Maintenance: "We are going to expose reality, we are going to own it, and act on it."

John Cray is a principal consultant with Life Cycle Engineering (www.LCE.com), working with public and private enterprises to improve performance by implementing reliability excellence, continuous improvement, lean/six sigma, and organizational change management. You can reach John at jcray@LCE.com.

Optimizing grab sample quality and safety

Maximizing profitability during large-scale facility construction requires a uniquely designed system

by Matt Dixon, Swagelok Company

Building large-scale industrial facilities like chemical refineries, wastewater treatment plants, manufacturing sites, or oil and gas platforms is complicated. Industrial construction often includes pre-approved schematics of fluid systems that are then built by subcontractors on-site, which does not allow contractors to fine-tune the system as it is built. Leaks of potentially harmful fluids not only put the operators at risk but can also lead to costly environmental damage. In addition, correcting any potential shortcomings that exist because of improper system design could require taking the system offline for an unknown period of time. Such downtime can be damaging to a plant's operations, not only costing money in the short term but potentially harming a facility's competitiveness over the long term.

For these reasons, careful planning of industrial fluid systems should be at the forefront of any industrial facility construction. Though every fluid system is unique to a facility's specific circumstances, there are some universal considerations that must be examined before a system is built to avoid issues in the future.

Careful planning of industrial fluid systems should be at the forefront of any industrial facility construction.

ESTABLISHING EFFECTIVE GRAB SAMPLING SYSTEMS

Grab sampling is a process by which a sample is extracted from a fluid system for remote laboratory analysis (see Figure 1). Plant operators use sampling to ensure the fluid meets critical quality standards throughout a facility. Common grab sampling points include near storage containers, on long transport lines, and on process lines at flare locations. In addition, samples may be analyzed before and after a commodity is transferred to determine the value of the cargo, particularly if there is a custody change.

It is especially important to pay close attention to the construction of grab sampling systems when building large-scale facilities. The key to avoiding simple grab sampling system errors is to build them using criteria specific to each facility. Standardized approaches may save time in the short term but may lead to unforeseen problems down the road.

Advancements in grab sampling systems have helped make the process simpler, safer, and more repeatable. For plants that have been following the same grab sampling process for years, it is worth considering making improvements that could drive greater sampling efficiency and accuracy.

For example, grab sampling panel designs must account for flushing and purging to ensure that transport lines are clean and free of contaminants. Flushing the lines may take an excessive amount of time if the design is not optimized, especially for longer transport lines. Also, it is important that purge gases not be introduced back into the system where they could potentially contaminate or otherwise impact the quality of the process fluid. Modern panels incorporate safeguards to ensure purge gases stay within the confines of the sampling system.

Elsewhere, some new sampling panels have been designed with heightened user convenience in mind. Obtaining samples, venting, flushing, and purging are all accomplished by operating a series of different valves. Today, some geared valve assemblies are designed to activate the necessary valves in the proper sequence, helping the operator more easily control fluid routing through the panel. Additionally, technicians can more easily isolate gauges when performing maintenance. Geared valve assemblies also help minimize the chance of operator error by preventing valves from being activated out of sequence.

THE IMPORTANCE OF PROPER GRAB SAMPLING DESIGN

Given the importance of accurate sampling on overall plant operations, it is important to minimize the external factors that can affect samples and possibly taint the results. To be useful, samples should reliably reflect the quality or true process conditions of the systems. That is why it is vital to design grab sampling systems properly, with accurate analyses in mind. Even seemingly simple variables in a system's design can have an outsized effect on sample quality and therefore negatively impact the results. Ultimately, your system design should ensure your samples are:

1. Timely: The more time it takes for a sample to reach the sample container from the process line, the more opportunity there is for contamination and degradation to take place. During the design process, this calculation must be taken into account and adjusted accordingly to keep those times as minimal as possible.
2. Representative: Samples should be representative of the process fluid in the system at any given time. Unneces-

sary variation can render the eventual analysis moot and can be mitigated through well-designed systems.

3. Compatible: As the system is constructed, care should be taken to choose system materials that are compatible with the sample being taken. Selecting compatible materials will help reduce the amount of maintenance and repairs necessary over the life of the system.

Additionally, proper design of sampling systems can help prevent waste and minimize unnecessary danger to the operator and the environment.

To ensure the grab sampling system is built to provide samples that are timely, representative, and compatible, it is helpful to enlist the support of experienced advisors to help in the following areas:

Selecting the Appropriate Sampling Vessel: Choosing the appropriate sample container during the design stage—one that can handle the process pressures and temperatures without leaking—will help enhance safety for operators. Choosing between sample cylinders or bottles is one of the first decisions to be made for liquid grab sampling and is largely dictated by the type of sample being collected. Sample volatility and toxicity may necessitate the use of sample cylinders. Sample bottles can be effective for collecting nonvolatile, nontoxic liquids.

Assisting With Probe Selection: To achieve the optimal level of accuracy, it is important to extract the sample from the process tube or pipe from the ideal location. Bringing in an external advisor from a trusted supplier to identify the best location can make the process easier. They may also be able to give advice about which probe size is appropriate for the application in question. Finally, advisors can help by performing specific calculations to establish the system design, including the right tubing lengths and component diameters. Having this assistance at the beginning of the design process will prevent problems from occurring once the system is operational.

Determining Grab Sample Location and Grab Sample Panel Placement: To ensure the most accurate sampling results, grab sample points should be located on the process lines at strategic points. In addition, the grab sample panel should be placed in an easily accessible area so operators can collect samples safely. It should not be too high or difficult to reach. For maximal performance, operators should be able to safely retrieve samples and transport them to the laboratory for offline analysis.

Conducting Temperature and Pressure Calculations: Standardized system designs often overlook the need to make specific calculations to maintain sample quality. Specifically, temperature and pressure calculations like the Joule-Thomson (JT) calculations should be conducted to predict the temperature effects of pressure changes. These parameters allow operators to monitor the sample and ensure it does not change phase during the sampling process. For example, if pressure drops, which could cause the gas to cool past its dew point, liquid will form and change the composition of the sample. This can prevent an accurate analysis from being done at the off-site laboratory, skewing how the facility maintains its system.

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Figure 1. With grab sampling, operators extract a sample from a fluid system and take it away for remote laboratory analysis.

Conducting Purge-Time Calculations: It is essential to ensure that sample nozzles, probes, transport lines, and panels be purged completely between uses. Otherwise, residual fluids may compromise the next sample. Operators must be able to perform the proper calculations to determine how long the system must be purged to ensure a fresh sample the next time the equipment is used. There are several other calculations an advisor can assist with, including time-delay calculations and phase-change calculations for different fluid mixtures.

Before doing any large-scale industrial construction, proper heed should be given to the design of the fluid and grab sampling systems. Finding suppliers who can advise on best practices for the layout of the system can be a significant help. The earlier the advisors are brought into the project—including during facility construction—the more easily they can make the complex process run smoother and ensure the completed fluid system will follow best practices for quality, safety, and profitability.

Matt Dixon is application commercialization manager for Swagelok Company (www.swagelok.com), and has extensive experience in sampling systems.

Simulation training is catching on

Troubleshooting simulations provide a systematic approach to tackle issues and get machinery working

Michael McKenzie
VP Products, TPC

TPC (www.tpctraining.com) leads the industry in training and workforce management solutions by offering a best-in-class learning management system (LMS), 200 instructor-led training courses (virtual or in-person), thousands of digital training options, cloud-based workforce management solutions, consulting services, and continuing education and safety programming. TPC has helped more than 40,000 client sites globally to train over 3.5 million skilled workers, and most recently has extended their simulation module library to include VFDs and PLC-based industrial sensors.

We recently caught up with **Michael McKenzie, VP Products at TPC**, where he manages TPC's cloud-based 3D electrical troubleshooting simulation products. Michael is a training and development professional with over 20 years of experience, and we asked him about the role of simulations in best-in-class maintenance and reliability training.

Q: In a general sense, what makes simulation training so valuable for businesses?

A: What makes simulation training so valuable is that it saves time and money for businesses. It saves time as learning is done virtually. The learner does not have to take the time to physically get the parts and set up equipment. It saves the business money since simulations:

- Do not require downtime of equipment while the trainee is learning
- Enforce safe working habits that can prevent costly downtime due to accident or injury
- Teach best practices and efficient techniques that speed up the troubleshooting process.

Q: What qualities set simulation training apart from other training options?

A: Simulation training employs a learn by doing model that engages the student on a much deeper level than other training options. In our simulations, the student is given increasingly difficult faults where it is up to the student to fix the problems. Using our five-step systematic troubleshooting process, the trainee develops the skills to take all of the necessary actions to diagnose and resolve issues.

Q: What are the key benefits that simulation training can drive at a facility?

A: Learning to anticipate, troubleshoot and solve issues in an environment that closely resembles reality contributes to a worker population that is more efficient, and accurate in the identification and resolution of issues at a facility. In addition, the simulation stresses the importance of safety and best practice requirements. Our simulation training develops the critical skills necessary to repair electro-mechanical equipment accurately, safely, and efficiently resulting in reduced downtime and repair costs.

Q: Specifically, how can simulation training help plant teams achieve meaningful reductions in downtime, whether planned or unplanned?

A: Simulation training decreases downtime in four ways.

1. Trainees are learning on simulated equipment and not tying up equipment on the plant floor. Machine downtime for training is significantly reduced.

2. Trainees gain experience during the troubleshooting process. Following the five-step approach instills though processes that result in efficient decision making. When machines go down, trainees have a systematic approach to tackle the issue and get the machinery up and working in a timely and safe manner.

INDUSTRY PERSPECTIVE
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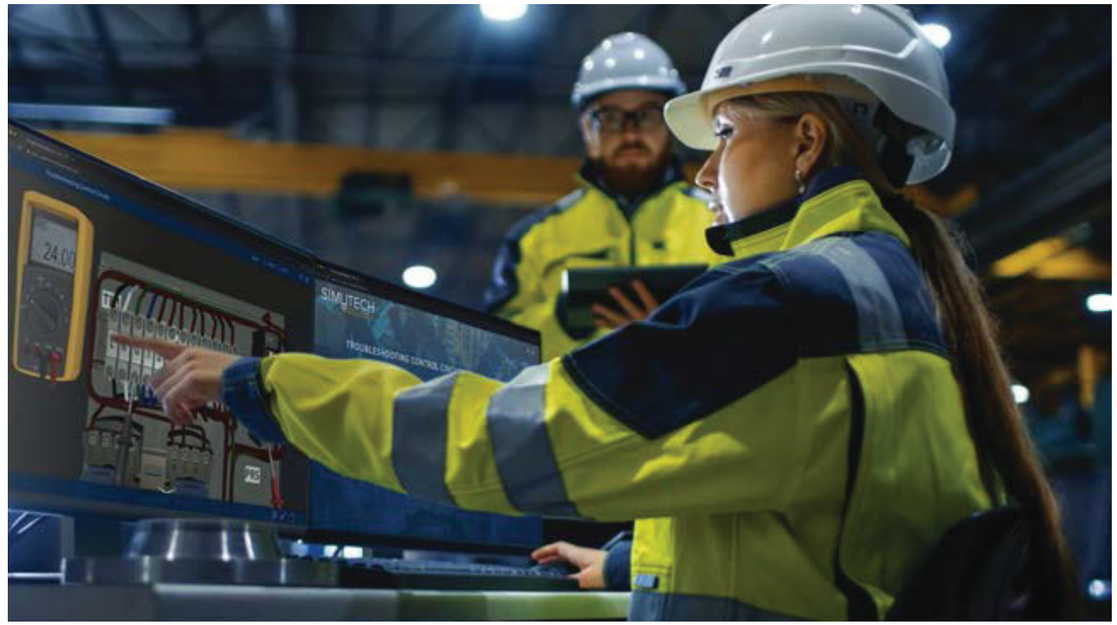


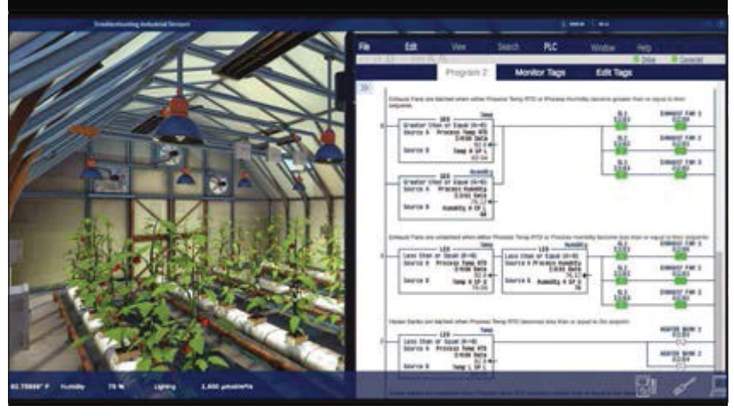
3. With the large number of faults available to the trainees, trainees become more confident and proficient in diagnosing issues as they are exposed to a wide variety of potential problems. This increased confidence can inspire them to anticipate scenarios and to look for patterns in equipment behavior, addressing issues before they become a problem.

4. The simulation training reinforces safe work practices which leads to a safer environment with less chance of accident-related downtime.

Q: Beyond the cost savings associated with reduced downtime, where else does simulation training have a positive impact on the financial bottom line?

A: Another cost saving opportunity that simulation offers is reduced repair cost. Our simulations track the cost of repairs, which include the technicians' time, and the replacement part costs. Trainees are penalized when good parts are unnecessarily replaced or when they take too long to resolve an issue. The cost of reordering and managing excess parts are an additional cost saving that can be reduced through increased accuracy in troubleshooting issues.

TPC SIMULATION — TROUBLESHOOTING INDUSTRIAL SENSORS



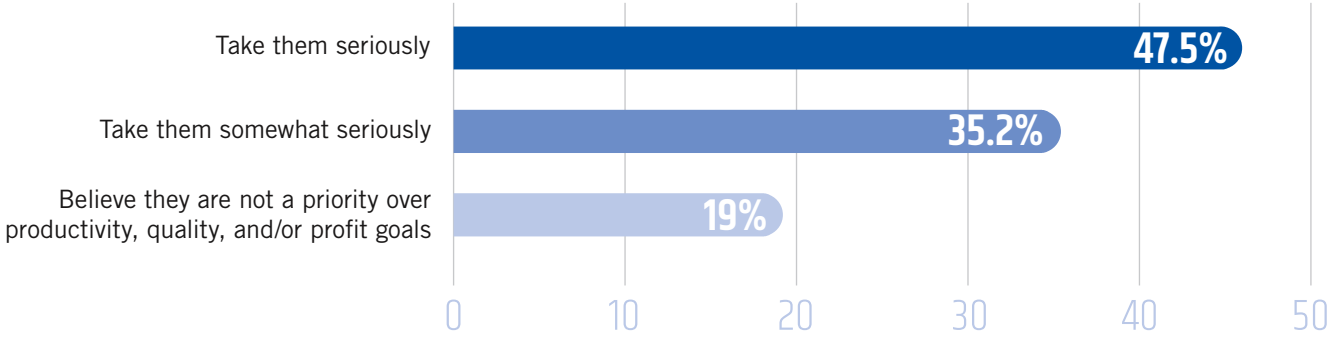
To watch video: www.youtube.com/watch?v=j1dj8-42-vI

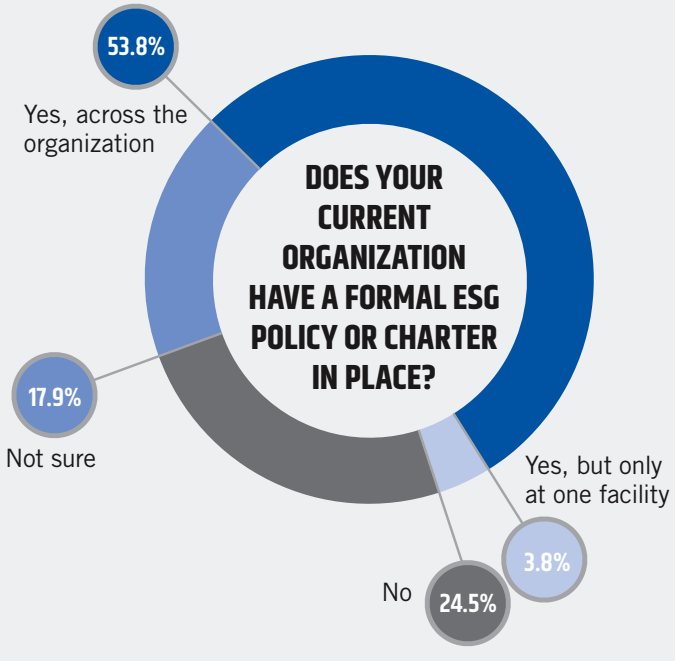
Readers interested in learning more can request a no-obligation demonstration of TPC's online simulation training systems at https://plnt.sv/2207-TPC.

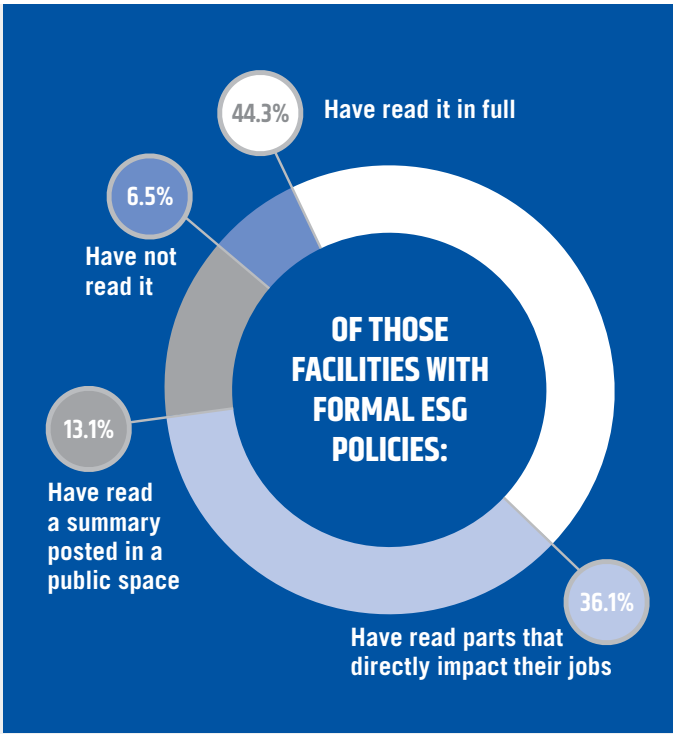
The ESG paradox: policy vs. practice

Overall, the majority of organizations support environmental, social and governance (ESG) practices with formal policies and standard practices, but research indicates this policy message is not being executed at the plant floor level. A high number of employees unengaged on a daily basis with ESG policies indicates a discrepancy between what companies outline as their ESG goals and how those practices are supported across the company and within individual job requirements. Is your company stuck in the ESG policy paradox?

WHAT IS THE PERCEPTION OF ESG GOALS AND OBJECTIVES WITHIN YOUR ORGANIZATION?







Read the full market insight report at: **info.plantservices.com/ESG-2022**

Rules for Plant Engineers

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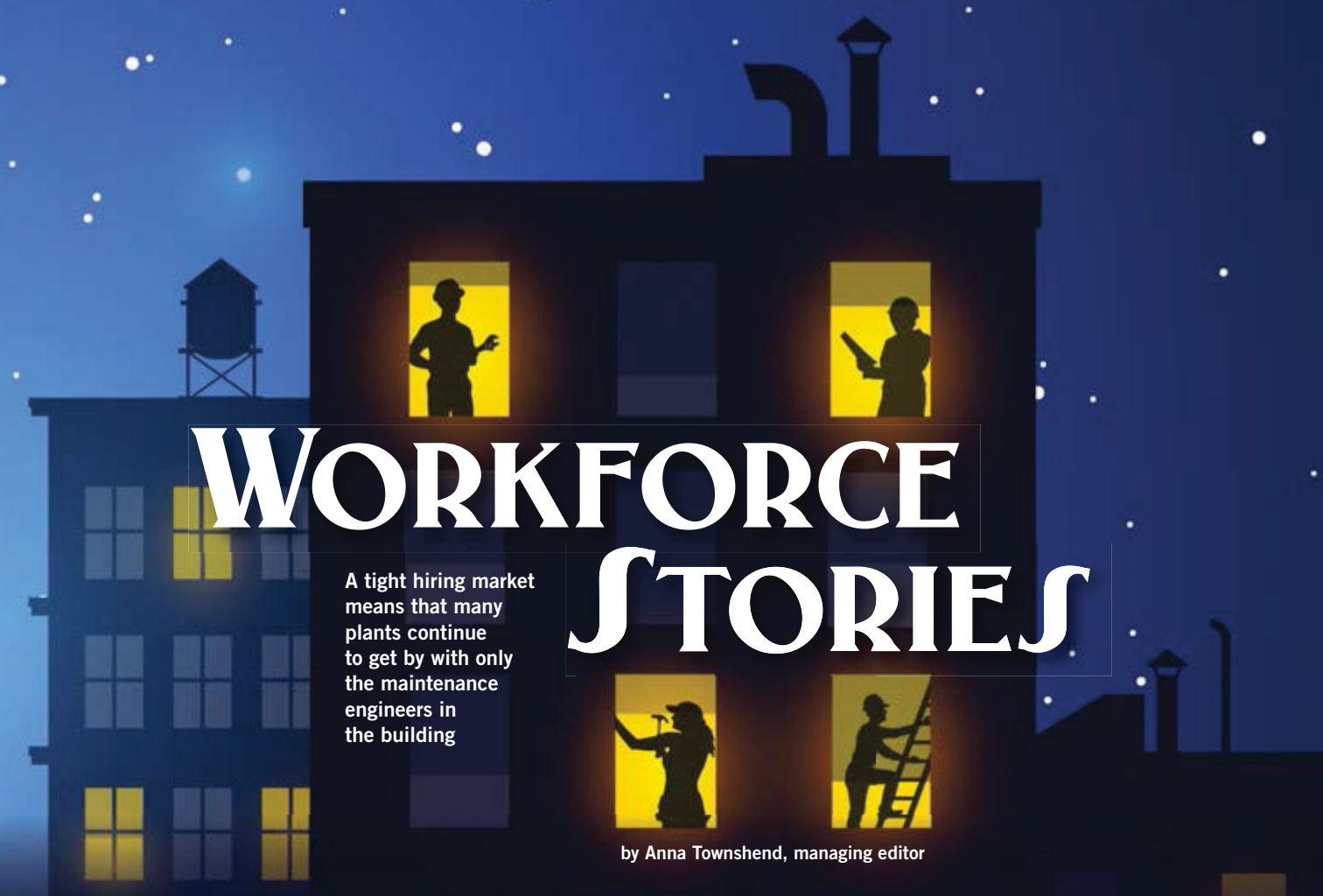


Workforce Stories

A tight hiring market means that many plants continue to get by with only the maintenance engineers in the building

by Anna Townshend, managing editor

Manufacturing is not alone in its struggle to meet workforce needs. Many industries are fraught to replace retiring workers with a new, younger workforce, but manufacturing, in particular, has some other unique and potentially damaging impacts affecting its thriving workforce. From 1945 to 1975, the United States dominated the world in technology development. We had the world's highest productivity economy, and GDP growth was close to 4%. Over the next three decades, as global competition grew and Germany and Japan established themselves in the manufacturing economy, U.S. GDP dropped to 3% with some periods as low as 2%. Following the 2007 recession, GDP fell to a dismal 2.1%.

The country made some slow economic recovery since then, but its diminished presence in the global economy has mirrored diminishing jobs in manufacturing. And the jobs left largely remain unfilled. Now, as new technologies demand a more skilled workforce, industry is scrambling to make up for decades of lost investment to develop the next industrial workforce.

HOW U.S. MANUFACTURING REBUILDS WHAT IT HAS LOST

The U.S. manufacturing machine once changed the course of a world war and dominated global enterprise. So what happened and how did the world's manufacturing leader fall from its throne? William B. Bonvillian and Sanjay E. Sarma explore this backdrop and what created the current workforce and its problems in their book *Workforce Education: A New Roadmap*. They explore solutions for employers and the education system, as well as new education technologies that can boost the scale of adoption.

The vast research for the book grew out of the Workforce Education Project, an effort started in 2018 at the Massachusetts Institute of Technology (MIT) Office of Open Learning program. Bonvillian is a lecturer at MIT in the Program in Science, Technology and Society and senior director of special projects at MIT's Office of Digital Learning. Sarma is the Fred Fort Flowers and Daniel Fort Flowers Professor of Mechanical Engineering at MIT.

The authors focus in large part on industry because the successes and failures of U.S. manufacturing reverberate far beyond factories and its suppliers. Manufacturing is intrinsically tied to the U.S. economy, they argue. Three sectors account for more than 30% of the workforce: retail, healthcare, and manufacturing. That includes 12.8 manufacturing workers, according to 2019 data from the Bureau of Labor Statistics. Manufacturing has long been understood as the economy's largest job multiplier. "Growth in manufacturing output encourages additional output and growth in other sectors, both directly and indirectly, in terms of jobs, investment, and innovation," Bonvillian and Sarma wrote. Considering the entire industry value chain, manufacturing could account for up to one-third of GDP

and employment. When manufacturing thrives, so does the U.S. economy.

In the summer of 1791 in Philadelphia, Alexander Hamilton drafted his "Report on Manufacturers," for Congress. "Hamilton was arguing that American independence from the era's contending great powers, and ultimately its liberty, would depend on building a strong manufacturing sector," Bonvillian and Sarma said. The United States did achieve this liberty and established itself as a global manufacturing power, yet why have we fallen so far?

Bonvillian and Sarma argue that just as the country's weakened presence in the global economy reflects diminishing manufacturing jobs, this decline is also mirrored in falling U.S. incomes and a widening gap between classes. U.S. median household income has been stagnant since the 2007 recession, a time which also resulted in dramatic losses in manufacturing jobs.

To make sense of the changing class dynamics, the authors describe a model introduced by their MIT colleague David Autor, which graphs occupational employment. The data takes on a barbell shape, indicating a thriving upper middle class and a growing service sector with lower-end, lower-paying jobs on each end, leaving a thinning out of the middle class, represented as the handle of the barbell. His analysis also examines where the declines are taking place: in middle skill jobs.

"Examining a third of a century, Autor identified ten broad occupational categories and found that four core middle-skill occupations—production worker, sales, office worker, and machine operator—accounted for 60% of American jobs in 1979. By 2012, these categories had fallen to 46%," Bonvillian and Sarma said. Manufacturing used to be a common path to the U.S. middle class, but the erosion of the middle class and growing wage inequality, the authors argue, are leaving the working class behind.

Middle skills jobs are becoming more and more technical, and workers without some advanced education can often no longer follow that career path. The discussion around the semantics of workforce characterization even tell an interesting story about how this country views industrial work. In 2017, the National Academy of Science, Engineering and Medicine's "Building America's Skilled Technical Workforce" report urged dropping the term "middle skills," which it said carried a pejorative connotation, for "skilled technical workforce."

Bonvillian and Sarma also introduce a term from IBM CEO Ginni Rometty, who describes those with the skills needed in areas such as cybersecurity analysis, app development, and cloud computing implementation, as "new-collar" workers. "They are a far cry from blue-collar workers doing rote assembly in Henry Ford's River Rouge Ford plant, but they don't require four-year degrees," Bonvillian and Sarma said. Their research aligns U.S. manufacturing workers into three categories: lower-skill assemblers and basic production workers (which once dominated but no longer); middle-skill workers, such as machinists, technicians, welders, and other skilled workers (which have seen significant growth in the last two decades); and high-skilled workers, including engineers, researchers, and scientists.

The lack of focus on training and education programs to funnel workers toward manufacturing jobs in those areas that are expanding has exacerbated the economic problems for industry, as it now tries to play catch up. Bonvillian and Sarma argue that not only does the U.S. lack a unified workforce education system, the labor market information system to connect workers and employers is also broken. The building blocks for a meaningful system exist, but they remain disparate and difficult to scale. It's a regionally influenced problem that needs a national answer.

Many successful workforce education programs are thriving across the country in small pockets, but the current workforce needs require a more organized, wide-scale effort. Online, on-demand technologies hold great promise for scaling workforce education, and other education technology (or EdTech) can get upskilling programs and new education paradigms in front of more new and younger workers. These online tools are also particularly effective for hands-on learning or learning by doing techniques, which are prevalent in middle skills training.

Their book outlines the tools this country already has in place and what we need to revitalize the U.S. industrial workforce, but none of it is a quick solution. There is urgency to scale these solutions, but it will still take time, attention, and funding to coalesce. But many companies have staffing issues that need to be solved in the short term, so what can they do now? In the chapter about how to frame new educational content for competency-based programs or certificates, the authors make mention of something important, a theme that was also reverberated throughout recent industry discussions on workforce issues and represents a small step that employers can take now to strengthen their workforce.

In addition to technical skills, workers need what are referred to as soft skills or social skills. The National Network of Business and Industry calls them personal skills: integrity, initiative, dependability and reliability, adaptability and professionalism; and people skills or interpersonal skills: teamwork, communication and respect. The Center for Third Space Thinking at the University of Southern California identified five core soft skills: adaptability, cultural competency, empathy, intellectual curiosity, and 360-degree thinking.

According to David Deming, a professor at Harvard University and expert in social and educational policy, the labor market is rewarding social skills more and more. Expanding team production means more jobs require high levels of social interaction, and employers need flexible workers that can adapt to changing work conditions.

SOFT SKILLS FOR MAINTENANCE AND RELIABILITY PROFESSIONALS

The discussion around interpersonal or soft skills was a part of the panel discussion on workforce development at the Society of Maintenance and Reliability Professionals (SMRP) Denver symposium in May. "Curiosity, I think it's a key attribute for good operators and maintenance techs," said Jason Bolte, CMRP, CMRT, continuous improvement manager at Ardent Mills. "They're going to be curious about the business we're in." He is also a big fan of transitioning qualified operators into maintenance positions. "I think what makes a good operator makes a good maintenance technician. You're curious, you're hands-on, you know your equipment and you take ownership in it," Bolte said. A special soft skill for maintenance, stubbornness, as in a persistence to fix difficult problems, Bolte said, can also be a virtue for reliability engineers and technicians.

The panel also discussed many small and simple suggestions to implement for employee training and mentoring, attracting new workers, retaining good workers, and enhancing knowledge transfer.

While training as a whole is lacking in industry for new and incumbent workers, Bolte suggested that plants also need training for senior workers to help give them direction on how to transfer their knowledge to younger workers. Train the trainers, and likewise, make sure younger employees have a clear career path.

The Ardent Mills training program includes in-house developed video training and some high-quality training material from YouTube. "I think you can find plenty of junk out there," Bolte said. "But I think if you're looking for something specific, like setting the gap in a bearing, there's a lot of valuable stuff out there [on YouTube]."

The two-year training program at Ardent Mills is a combination of video training and traditional textbook and worksheets. "I think keeping it simple but having a strategy is a good start," Bolte said. You don't need a long, complicated assessment. "Don't let perfect get in the way of good, and stop you from doing something that will build up the skills to make your technicians feel valued," Bolte added.

The industry brain drain from the retiring workforce requires mentoring in the field as well classroom training. "I see it over and over again when people retire," said Dave Reynolds, owner of Midlands Reliability & Consulting. "There's no mentoring of his skills to that next person. It's assumed that with the training that the young person will attend, he will be able to pick up right where the last employee left off, and that's not necessarily the case." But mentoring is not easily done at facilities, Reynolds added. Finding the time for one-on-one training or sitting down off the floor can be difficult. The process also needs to involve some type of skills assessment, Reynolds suggested. "Anybody can hook a laser alignment machine and push buttons," Reynolds said. "But when it tells you to do something, you have to understand what to do. What's causing this problem?"

Training should also include information about the employee's career path and the company and its products. "All of those things help in that attitude of the employees because now they have a clearer picture of what the objective is," Reynolds said.

Flexibility is another big theme for new workers. The double-edge sword is that maintenance teams are short-handed, so those techs that companies do have are often asked to work extra shifts and long hours. "You have a tendency to potentially burn them out, and then they're more apt to leave," Bolte said.

In addition to technical skills, workers need soft skills or social skills. Expanding team production means more jobs require high levels of social interaction.

He thinks it's also important to recognize that maintenance and reliability is a skilled position. "Not everybody is wired for maintenance and troubleshooting," Bolte said. Promote individuals for the right reasons, but make sure they're suited for technical work, or dedicate the time and resources necessary to develop them.

At some Ardent Mills sites, operators can work overtime hours with maintenance to observe and practice. "It allows our company to see if maybe they have some potential and this might be somebody we want to consider for a new maintenance position," Bolte said. "The sites that are successful with that are the ones that aren't super lean, because the last thing that you are able to do is double up people for training, especially when you're already short staffed."

A standardized skills assessment for workers is also an on-going project at Ardent Mills. Starting in 2020, the team identified 100 maintenance skills, and they're working on how to assess or rate those skills. The ratings will form a skills matrix to assess current skill levels, but ultimately guide a personal training plan for each employee.

JOB SEEKER MARKET DRIVES A REFINED HIRING PROCESS

Chris Pepin, founder of Progressive Reliability, a talent acquisition firm for maintenance and reliability professionals, and Adrian Messer, CMRP, vice president of executive services at the company, help facilities find and hire qualified candidates, but also help companies upgrade their hiring process. "It's not just about having the right talent, but getting the talent through the door, and through the process with an offer letter in hand ready to start faster than everybody else," Pepin said. Companies need to think about the candidate experience, he added, even amongst

the perfect storm of overwhelmed managers facing understaffed facilities.

Not only are companies strapped to fill positions, but candidates also appreciate a fast and fluid process, especially in a competitive market. For example, Pepin said they have helped companies combine hiring process steps, such as a written test and on-site interview, which might typically be done in two visits.

In the current market, Messer said they coach hiring managers or decision makers to act quicker. "As we know, right now, it's a job seekers market," Messer said. "If they've got somebody highly qualified, they've got to act quicker than ever on that candidate in order not to lose that candidate."

Pepin likes companies to hire within three candidates. Across the maintenance and reliability industry on average, he estimates that the ratio is closer to one out of seven candidates. With a tight process and filtered, qualified candidates, "It only takes three people to fill the job," Pepin said.

Once companies get new candidates in the door, it takes continued work to make them long-term employees. Culture, training, and access to growth are key factors for attracting new employees, Pepin said. Some companies also need training on building that culture, so they know how to give employees an environment for career growth. He also said that experienced, niche candidates in maintenance and reliability want a developed preventive maintenance culture too. "There has to be opportunity to grow," Pepin said. "There has to be room to learn."

Many companies fear that if they train employees, they will leave with that training. But a culture that promotes training and development and the proper tools to develop the right skills will retain good talent, Pepin said. "As technology changes, new skills are going to be needed," Messer said. "We've got to continue to develop the workforce and train them to the current skill level that's needed to do their jobs effectively and reliably."

Who bears the burden of technical skills education, schools or industry? While the onus is often put on schools to bring back skilled trades, companies need to have involvement in identifying the needed technical skills and the training gaps, Messer said. "Companies have got to get more creative on developing their own programs to identify kids at an early age who have an aptitude for electrical and mechanical type work and begin to work with those kids and develop those skills at an earlier age," Messer said.

THE GENERATIONAL CULTURE CLASH AND COMPETITIVE MARKET FUEL THE STAFFING WAR

Joel Crawford, sales officer at I-care Reliability Inc., also presented at the SMRP Denver symposium. In his presentation "Maintenance and Reliability Hiring Managers, Enough is Enough," he said the number one challenge facing plant managers is recruitment. "That's what keeps plant managers up because they're going day to day, week to week with positions that are going unfilled," Crawford said.

Ten years ago when Crawford began in the maintenance and reliability industry, he was primarily helping companies develop reliability positions and programs. Certification programs have helped advance the reliability and maintenance industry, and companies are less concerned with the basics of program development. They know best practices and what they're looking for, Crawford said. They just can't find the staff they need.

Another problem with reliability engineers is attrition, Crawford said. Companies plan and hire a reliability engineer to focus on preventive maintenance and then that engineer is constantly pulled away to deal with emergencies. "I've learned that reliability engineers will last a very short amount of time working in a reactive plan. If they signed up to build something, if they want to go build a reliability / proactive maintenance department, there's a lifespan to that, if they're constantly pulled back into reactive work," Crawford said.

For some companies, it's a dramatic change in culture. "Because of the way plants have historically run, and then now the new generation is coming in with expectations on what they want that job to look like, there's this culture clash," Crawford said. "And it's affected the way plants are operating." It's also affecting attrition rates, which are at an all-time high, he said.

In talking with reliability engineers that left the field for something else, Crawford said, usually it comes back down to company culture and the maintenance program budget and support. Be upfront with candidates about the plant's current state, Crawford said. If the maintenance program is a mess and 90% reactive, let them know. "Also let them know what you're doing as a leader to move the needle and find new candidates to make change over a period of time," he said.

According to the U.S. Staffing Association, retirement is ramping up, on average 10,000 per day in 2019. By 2025, Crawford said it's predicted 2.5 million technical positions will go unfilled. In 2019, according to Indeed.com, the U.S. had 100,000 reliability engineering job openings.

All of this has led to a "hyper competitive market," Crawford said. The pandemic has only heightened the Great Resignation, as more workers got a taste of working from home and more flexible schedules.

Of the open positions today, 94% of those are going to be filled by word of mouth, Crawford said. "It's not going to be through recruitment; it's not going to be by going to job career fairs; it's not going to technical schools; it is going to be working with your employees, working their networks, engaging them, and pulling in people they've worked with in the past," Crawford said. And companies are realizing this now, he said, as evidenced by the vast use of LinkedIn

and recruiters. "Most companies right now, most Fortune 500 companies, most of their messaging on social media platforms is around people. It has nothing to do with the product," Crawford said. "It's all based around their people, the people working at the plants. They highlight a plant manager or they highlight an engineering manager or operator because they're trying to show what the culture is."

"It's very, very competitive in today's landscape," Crawford said. Selective candidate engagement is a big mistake; instead, "try to find those people out there that you think you can make into rockstars over a period of time if you put the right training curriculum behind them, and the right support and mentor," he said.

Similarly, where many workers and industries have been affected by economic downturns or more recently, the pandemic, companies often found reasons to cut training programs or apprenticeships or cut maintenance budgets. "Companies now are scrambling. Now it's a war for talent because they did nothing during the last 20 years for succession planning, for knowledge transfer, for mentoring," Crawford said.

Just as potential workers are looking for more flexibility, companies need to welcome more flexibility in the job application process and even, the final job description. Why do companies write a job description for each opening describing the ideal candidate? It's likely that position has been open for a long time, and they need someone to hit the ground running. The job description goes to human resources, who will post for the job and review candidates. "They're going to live and work in the job description that you create," Crawford said. "You're setting the expectation right out of the gate with that very first job description." In some cases, you may be extending the time that job will remain open.

Maintenance teams need to work closely with human resources. "Because they have very similar jobs as you do, where they're doing a little bit of everything at all different times, they get pulled in a million different directions. And you're going to want to build some sort of unified approach with them," Crawford said.

Hiring and training employees the way you've always done won't work anymore, Crawford said, like this common hiring misnomer: we don't want anybody that's jumped around from job to job. "Why?" Crawford asked. He's seen many examples of tragic circumstances, personal and global, that have affected employment across the country. More and more, workers are interested in contract work, or the gig economy, where gig workers make their living with multiple part-time jobs over one full-time job. "So again, it's living in the reality of what's happening in this market," Crawford said. This will require new ways of thinking and new practices.

Company culture, hiring processes, and employee training also need to consider generational changes and adjust to some of the new ways of living. Twenty years ago, Gen-Xers were driven by career growth, working their way up the proverbial job ladder. For Millennials and probably even more so for Gen-Z, it's work flexibility that drives their career choices.

It can be difficult for older workers who have worked the overtime hours and weekends and emergency work, and they're watching a newer generation in the plant that won't work like that. "That starts to hurt the culture," Crawford said. "If you think that they can't feel that tension at a plant, and they can't feel frustration from a maintenance manager or a plant manager, you're wrong. Because I could feel it." Sometimes Crawford can feel it on a day visit, watching how employees interact and the way they talk to each other. Too much tension and frustration can create a closed-door culture, where people leave and knowledge dies.

Companies need a more streamlined hiring process, and communication is key, Crawford said. Build transparency and show the candidate what to expect in the process. Don't go weeks without communication. The hiring process needs the same standardization that they seek in reliability programs. "Standardize all the activities from job description, creation, all the way down to onboarding and find out who's responsible? Who's accountable, who supports and who informs and who does what, and what's the established timeline to get each item done?" Crawford said.

"Onboarding is your last chance to make a first impression," Crawford said. "Working in your culture, you have a chance to give them a really good experience and a thorough onboarding and a lot of added communication and make them feel comfortable and motivated moving into their job."

OLD MODEL, NEW VERSION: FESTO'S FOUNDATION IN EDUCATION AND TRAINING

Education and training are part of the foundation of Festo, which began as a woodworking machinery manufacturer. The company introduced a pneumatic cylinder in the early twentieth century, which used compressed air to provide force instead of traditional clamps.

Festo Didactic Inc., the industrial workforce development brand of Festo, sells training equipment and curriculums to technical schools to educate the workforce of the future, and it works directly with companies on custom training solutions. When companies purchase automation equipment from Festo, Festo Didactic can also perform on-site and personalized training on the new technology.

One of Festo Didactic's flagship products is a cyber-physical (CP) factory. "It's basically a miniaturized, laboratory-sized version of complete factory processes," said Sean O'Grady, director of operations for Festo Didactic. "So assembly and machining or storage and sensor technologies and PLCs interface with industrial networks and safety and robotics and security." The classroom-sized, factory process simulation allows students to work with actual industrial equipment.

"The sophistication of those products continues to evolve, and where we are right now, and where most of the skill evolution that we see taking place over the next couple of years, are taking folks with traditional factory maintenance backgrounds and helping them to become experts at Industry 4.0 technology," O'Grady said.

In June, Festo Didactic announced a new partnership with PMMI, the Association for Packaging and Processing Technologies to provide advanced technical education and hands-on training for the industry. The packaging and processing machine builders are at the cutting edge of many different factory automation technologies, he added. PMMI also plays an active role in supporting education surrounding its industry technology and different certifications on a wide array of highly technical topics. "Since that's exactly in line with our mission, it was just a natural partnership," O'Grady said.

Certification programs have helped advance the reliability and maintenance industry, and companies are less concerned with the basics of program development. They just can't find the staff they need.

PMMI works to evaluate the talent level throughout the packaging and processing industries, with training and development opportunities and connecting employers to the workforce. The PMMI Mechatronics Certification program was developed to help education institutions create industrial maintenance programs that align with the technical needs of manufacturers, preparing students for careers in advanced manufacturing. Festo Didactic's mechatronics learning solutions will provide lab equipment and education content for PMMI's mechatronics certifications.

Festo Didactic also specializes in customized training programs because the amount of time that employees have for training is quite limited. "We have to be very targeted in how we use that time," O'Grady said. "Our programs are very customized to exactly what topics they need."

Festo Didactic has several products that use augmented reality technology, which can overlay fault information on equipment images via a tablet or cell phone. "Understanding how to access those technologies and interact with them is something that not many factories are doing yet. And then the skills required to actually develop and deploy those applications so that the factory worker can pull their phone out of their pocket and tell what's wrong with the machine, rather than even having to get a maintenance person involved is where that part of the industry is going," O'Grady said.

O'Grady thinks industry is also still fighting the image of manufacturing as a dirty, dark and dangerous place. Parents don't encourage their kids to work in those environments. "Once people actually tour a modern factory and see what it's actually like to work in them and get to meet people that are doing those jobs every day, some of the jobs themselves are very interesting," O'Grady said. But often, students and workers realize the potentials of manufacturing too late, before they can capitalize on training in their early years.

This spring semester Festo Didactic ran its first pre-apprenticeship program with students about ready to graduate high school. "One kid said, 'I always thought I was just not a good learner. I always struggled with things, but being in this factory and doing things hands-on with machinery just made sense to me'," O'Grady recalled. The program hopes to reach those students earlier.

Traditionally, Festo Didactic takes a three-pronged approach to its education programs. It works with schools on turnkey package curriculum and training for incumbent workers on specific gaps in their current training. The company also works with industry directly to assess what issues the facility is having and form a foundation list of technologies to solve those problems. This includes assessing the current knowledge level relative to applicable standards for the plant's operation and design a training program to close the gap.

"And then the third prong, this is where there's so much potential to be the marriage between the school and the company," O'Grady said. This apprenticeship-like program or dual enrollment education system, which is very prevalent in Europe, is seeing more interest in the U.S., O'Grady said. As an example, a typical student would go to a local community college one day a week for classroom work, then spend one day a week at Festo doing hands-on technical training with the equipment, and then the other three days a week working with their employer practicing new skills.

"It's very clear that dropping the 100% German model into the U.S. market does not work," O'Grady said. "But we're finding that employers are very willing to be flexible about how they apply apprentice programs. Frankly, sometimes the term itself gets in the way a little bit."

Funding still remains an issue for many apprenticeship programs. O'Grady was talking with a German colleague about the lack of adoption of the dual enrollment program here. In Germany, the government essentially pays for the program. German companies cover the cost of apprenticeships but essentially receive tax cuts to cover costs. For now, companies in the U.S. aren't receiving the same kind of government support.

"If an employer has a strong employee who meets their values and wants to grow and learn new things, they love the opportunity to work with an apprentice program that is tailored to their needs," O'Grady said. "And so we're finding a lot of support, even from the government, to certify these apprentice programs to exactly what it is that local industry wants."

Part Two: Preventive Maintenance like the military

Many industry practices have a similar U.S. Army standard program to use as a guide

by Craig Cotter, P.E., CRMP

This is Part Two of a two-part article on performing preventive maintenance like the military. The purpose of the article is to demonstrate how to develop a preventive maintenance (PM) program for your organization using principles similar to those employed by the United States Army. Part One appeared in the June 2022 issue of Plant Services, and is available online at: https://plnt.sv/PM-MILITARY-01

DEVELOP THE TRAINING

The Army uses a phased approach to train personnel on each piece of equipment as follows:

- classroom (crawl)
- hands-on (walk)
- testing in classroom and field as applicable (jog)
- perform PMs on the job (run).

Military training uses a structured process that covers task, condition, and standards along with performance measures for each PM. Training is structured and consistent throughout the military (not including local Standard Operating Procedures or SOPs). PM training and certification allow seamless transfers from unit to unit. Some additional training is carried out for site-specific requirements, such as temperature, altitude, and local regulations. Such training enables the soldier to go from the street to service in six months (although some skills take longer). This provides a good model for industrial sites to use to develop both craft task training and PM training that is consistent and can be used at multiple sites.

The classroom PM training would be set up using tasks, conditions, and standards. Figure 1 shows a side-by-side comparison of tasks, conditions, and standards for the protective mask and a PM for changing oil on an over-hung pump. From the standards in its technical manuals, the military develops a performance sheet to test the soldiers after the training.

Using the same task, conditions, and standards format for an industrial PM (changing oil in a pump), the PM performance sheet would look as shown in Figure 2. The training would include classroom instruction, hands-on training in the classroom with an actual pump, and then a performance evaluation in the field, evaluated either by the instructor or by a qualified craftsman chosen to evaluate training tasks.

This process is a good model to use to develop a training program for each PM at your site either to train new personnel with no skills (part of a journeyman program) or re-certify current personnel. A recertification program is a necessary part of the PM process to ensure your personnel remain qualified to perform the work in your organization.

Starting with your critical equipment, you can review the PMs to determine if they are set up correctly. Standardize the PMs as needed, validate with your senior or experienced personnel, and then develop training for each PM to cover all skill levels of your organization. One training course can cover all personnel for that PM, but the more skilled craftsmen should be re-qualified on the hands-on or field execution of the skills on a periodic basis. I have used an interval ranging from one to three years, depending on the criticality and difficulty of the PM.

OPTIMIZE THE PM PROGRAM

Keeping track of the PM work performed on equipment is important for several reasons. One is to ensure com-

pliance with respect to the PM program. Another is to review and optimize the PM program itself. The military uses forms to record the data and digitizes that information to assist in recordkeeping and for ordering repair parts. I have worked at facilities where PMs are performed, but no records of the work or issues found were kept, making it nearly impossible to gauge the effectiveness of the PM program.

An additional benefit of tracking PM work done is being able to establish the proper stocking levels of spare parts based on actual work performed. Tracking what part (object) was worked on, what the issue was (damage), and what the cause of the failure/issue was (cause) over time will provide valuable failure data and information to help optimize the process.

Continuous improvement will lead to PM optimization. The reason for optimizing your PM program is to ensure reliable operation of your equipment. If your reliability is not improving and the same failures are occurring, you may want to consider the following in your program:

- The PM interval may be too long, and potential failure is not being identified during the PM, so failures are occurring before the next PM.
- The PMs are not set up to identify the potential failures by asking the wrong questions, or looking for the wrong potential failure mechanisms. Object damage cause (ODC) codes from repair WOs will assist in this review.
- PMs are not repeatable or consistent and are performed inconsistently by different technicians.
- The wrong tools are being used or the technician is using tools improperly.
- Human error is induced into the equipment during the PM.

The ODC information data from PMs and work orders can provide insights on reliability and fitness for service of the equipment, allowing for reliability improvements.

	Mask	Pump
Task	Maintain Your Assigned Protective Mask	Change Oil On An Overhung Pump
Conditions	You have used your assigned protective mask or must conduct a scheduled mask inspection. You are given your assigned protective mask (with authorized accessories and components); a container of warm, soapy water; soap; a container of warm, clear water; cheese cloth or clean rags; a small cleaning brush; alcohol; optical lens cleaning compound, the applicable suppty bulletin, the applicable technical manual (TM): TM 3-4240-279-10 and DA Form 2404 (Equipment Maintenance and Inspection Worksheet), spare parts for the masks; and a set of replacement filters (Mt 7-series mask) or a replacement canister.	In a field environment, given an overhung pump, shut down and LOTOed, 5 gal of synthetic ISO 68 R/0 oil, set of millwright field tools, all required PPE. One had spare sight glasses and spare TRICO oiler.
Standards	Maintain your assigned protective mask, ensuring that: Preventive-maintenance checks and services (PMCS) are performed on the mask according to the applicable TM. The mask is cleaned and dried. No damage is done to the mask. Record uncorrected deficiencies on DA Form 2404 or DA Form 5988-E, and report them to your supervisor.	Change oil on an overhung pump: LOTO Pump and confirm zero energy Drain oil from pump Inspect oil for and note contamination or bearing material Inspect drain plug for damage / contamination. Clean threads and reapply pipe tape. Insert drain plug, and torque to OEM value. Inspect/clean sight glass/TRICO Oiler or replace as needed. Refill oil tvo 1/2 sight-glass level with synthetic ISO R/0 68 Oil. Refill TRICO Oil. Prepare pump for operation, start and ensure oil is 1/2 level in sight glass.

Figure 1. Side-by-side comparison of tasks, conditions, and standards for an Army and Industrial task.

Task	Standard	Pass/Fail
LOTO pump and confirm zero energy.	Pump is locked out with confirmed zero energy.	
Drain oil from pump. Inspect oil for and note contamination or bearing material. Flush housing with oil to 1 quart of oil.	Oil is drained, housing is flushed. No contamination is found. If contamination is found, flush until cleaned. If excessive contamination, pull pump for repairs.	
Clean threads and re-apply pipe tape. Insert drain plug and torque to OEM value.	Oil drain plug is replaced and torqued to correct value.	
Inspect / clean sight glass / TRICO Oiler or replace as needed.	Sight glass and oiler (if equipped) are cleaned.	
Refill oil to 1/2 sight-glass level with synthetic ISO R/O 68 Oil. Refill TRICO Oil if equipped.	Proper oil is used and filled to correct level. (1/2 of sight glass or at indicated level on housing.)	
Prepare pump for operation, start and ensure oil is ½ level in sight glass.	Pump is returned to operation and oil remains at correct level. (1/2 of sight glass or at indicated level on housing.)	

Figure 2. Example of industry PM performance measure.

Here are some actual PMs I reviewed and modified to make them more specific, repeatable, and effective. Figure 3 shows a PM assigned to an instrument technician to perform on a level switch on a sump pump. This PM is used on more than 100 pumps at various sites by eight different technicians. From discussions with the technicians, I learned there were several different methods used for performing this PM. The worst case was from one technician who said he would check the set point of the system in the PLC, and the PM was done.

The review of the PM provided the following:

- the PM was not performed in the same manner.
- the results of the PM varied among craftsmen.
- many key objectives of the PM were missed based on the interpretation of the PM.

I discussed the goal of the PM with the technicians, and we determined the following goals:

- Check the functionality of the transmitter.
- Check to see if the pump:
  - starts when required
  - has high level indication
  - initiates high-high level test and shutdown sequence
  - stops when required; doesn't run the pump dry
  - points are within a specified tolerance.
- Perform visuals on the system for wear and tear.
- Ensure a repeatable process.
- Record the results.

From the above results, we reworked the PM and developed a new PM form. The new form had information on the transmitter to allow the technician to verify that it was the correct transmitter, and to determine if the transmitter has been replaced since the last PM. Next, there are four level checks (not one) performed, which are actual level filling checks to confirm the functionally of the transmitter, pump, and PLC and ensure they are all working together. There are also tolerances for each check with instructions on actions to perform if there is a functional failure. Finally, there is a section to place the system back into operation.

Once this PM was reworked, we field-trained the technicians and tested the procedure, made some final adjustments, and then placed the PM into our CMMS, allowing us to perform the PM on a tablet with results uploaded into the CMMS upon completion.

During the field verification of this PM, I noted that one of the supervisors kept finding the transmitter he was working on in a failed condition. As I observed his actions, I noted he was using the test equipment incorrectly. I asked a senior technician I trusted to assist the supervisor on the correct use of the test instrument, allowing the transmitter to pass and the PM to be completed. Why did I have the supervisor performing the PM in the field? By being part of the process, including performing the PM, the supervisor will be more in tune with the work the personnel perform,

		PASS / FAIL CONDITION			REMOTE INDICATION (Y/N)
DEVICE DESCRIPTION	SET POINT		AS FOUND	AS LEFT	
SUMP #1 HIGH LEVEL	36°				

Figure 3. Example of a poor PM.

and the bonus was that I determined the need for additional training on the test equipment.

PM PROGRAM REVIEW AND GRASS ROOTS SETUP

If you have a PM program you want to revamp, or no program at all, a good place to start at is with an equipment class versus PM comparison. First, sort the equipment into classes of equipment along with their criticality. Next, for each class of equipment, sort by subclass. The example in Figure 4 shows pump codes and the subclasses. For each subclass, review the boundary for the analysis (see Figure 5). Next, the different failure modes are reviewed, along with the severity and consequences of each failure, and PM/PdM strategies are developed to reduce the severity and/or the occurrence of the failures.

Figure 6 shows an example from a grassroots PM program developed at a new site. This example shows only 3 out of 43 equipment classes with a total of 67 PM/PdM routines. There were close to 4,000 hours of work assigned to maintenance and more than 1,500 assigned to operations. All this work needed to be set up in the CMMS, including training and field verification. Due to this being a new program, a PM optimization was performed after one year of operation.

Although this is an example at a new facility, this same process can be used to evaluate any existing program. By organizing your equipment by class and subclass, performing an FMEA on each class and subclass, and developing the corresponding maintenance and operations routines to address the failure modes, a structured review can be performed. From this list, we can determine training needed for the PMs before beginning or continuing the program. As the PMs are performed and data are captured in the CMMS, we can then perform a PM optimization.

A PM optimization is an essential part of a PM program. Without a review of our PM program, how do we know if it is effective? Some ways to measure PM effectiveness is through the following KPIs:

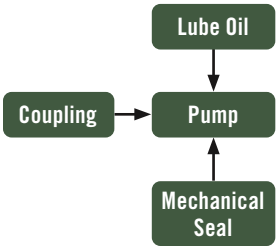
- MTBF (mean time between failures) or MTBR (mean time between repairs)
- preventive maintenance vs. breakdown labor hours (follow-on work)
- review the comments from PMs: Are there issues being found?

If your MTBF/MTBR is not improving, you should review the failures of the equipment to determine if PMs/PdMs can reduce the number or severity of failures. You should also review the follow-on work orders from PMs and the comments and observations about the PM work being performed. If you conduct a review and your current PMs are not developing follow-on work or there are no comments listed on your PM forms after the work is performed, you have issues with your PMs.

Now let's review two examples of PM optimizations performed at different sites. The first example will focus on the electrical side (although the optimization covered the entire PM program). A review of the program discovered some PMs had been set up to benefit the contractor performing the work, not the company or the equipment. Thermography was being performed on electrical equipment every three months, but the hands-on PMs were performed on the equipment regardless of the thermography results. Part of the review included the changes shown in Figure 7.

• PUCE	Pump – Centrifugal
• PUGN	Pump – General
• PUDI	Pump – Diaphragm (Controlled Volume)
• PUGE	Pump – Gear
• PUGN	Pump – General
• PUHN	Pump – Hand
• PURE	Pump – Reciprocating
• PURO	Pump – Rotary
• PUSC	Pump – Screw

Figure 4. Pump codes with subclasses example.



Items not considered in this FMEA:

- Driver or driver unit/lube oil/seal
- Control and instrument system
- External relief valves
- Pulsation dampener

Figure 5. Subclass boundary review.

These changes in the electrical area alone resulted in a reduction of 21 full-time equivalent contract employees. Further review and PM modifications resulted in a reduction of 2,210 mechanical tech hours, 2,683 electrical tech hours, and 853 instrument tech hours. In general, the PM program at this site involved working on the equipment. The review reduced the overall PM program by 50% and provided focus on the work that needed to be done. We modified the remaining PMs that were generic and created specific and focused plans that were mapped back to the failure modes of the equipment. The process we used was to develop a list of equipment by class, and list the PMs assigned. Next, we mapped the tasks back to applicable failure modes and removed tasks that were not needed. We also added tasks to PM or added PMs to ensure all feasible failure modes were covered by a PM.

At another site, we reviewed the current PM program and

Equipment Class		Maintenance Routine	By Who	Equipment Count	Time	X YR	Maint	Read Sht	ODR	Vendor
							3989	**91**	**1464**	**0**
BLOWER		ODR-PDMVIB-001 (performer on reading sheet)	ODR	0	0.17	52	0			0
		ODR-ROT EQUIP-004	ODR-R	13	0.17	1	0		0	0
		OEC-LUBE-005	MAINT	13	2	2	52		0	0
	NTD	ODR-Visual	ODR-R	13	0.17	52	0		0	0
COMPRESSOR		ODR-PDMVIB-001	ODR	3	0.17	52	0		0	0
		ODR-ROT EQUIP-004	ODR-R	3	0.17	1	0		26	0
		OEC-LUBE-005	MAINT	3	2	2	12		0	0
		ODR-Visual	ODR-R	3	0.17	52	0		0	0
CONTROL LOGIC		OIEC-CSAUTM-002	MAINT	0	2	2	0		0	0

Figure 6. Excerpt from a FMEA/PM developed for a new plant

Description of work	Original frequency	New frequency
Thermography	3 Months	12 Months
Circuit Breaker Detailed Inspection and Testing	3 Months	48 Months
HV/MV and LV Equipment Detailed Inspection and Testing	3 Months	48 Months
Protection Relay Testing	3 Months	48 Months
Molded-Case Circuit Breaker (MCCB) Mechanical Operation Test	3 Months	48 Months

Figure 7. PM optimization example, frequency modifications.

were able to reduce the PM work by more than 70% due to unnecessary work and to re-focus the remaining work on applicable failure modes. For example, pump PMs had more than 94% of the work removed because it was unnecessary. One 12-month PM for all pumps was to perform an alignment check.

Although the facility had an active vibration condition monitoring program that would identify misalignment, they ignored the vibration program and would check alignment of all pumps on an annual basis. This site was another example of where most of the PM work being performed was unnecessary and had been added over the years without a proper review of the system. Both examples show the need to optimize PMs to ensure they are focused on failure modes, and they highlight importance of a review process to ensure the PMs are fit for purpose.

LEADERSHIP

Finally, an organization with an excellent PM program will still fail in execution without the proper leadership. All successful PM programs require engaged, hands-on leadership to support the program and the optimization process. Without committed and engaged leadership, the PM program will be marginally functional or even ineffective.

Leaders should spend up to 75% of their time with their maintenance techs. Without being in there where the work is being done and understanding what the technicians do on daily basis, how can a leader provide true direction and motivation and understand the issues that confront the technicians? Leaders can only lead by being involved at the point of action, not from the office.

Craig Cotter is an engineer with more than 30 years of experience in refining, chemical, and E&P organizations in the areas of reliability engineering and maintenance management. He was responsible for setting up training, certification, and qualification processes for millwrights, pipefitters, and boilermakers at a refinery and setting up formal training programs for non-hourly personnel at several sites. He has a BS in Mechanical Engineering from the United States Military Academy, West Point, NY, and an MBA from Lamar University, Beaumont, TX. He is a retired U.S. Army Colonel, Infantry, with 20 years of active and reserve service.

Advanced APM 4.0

How new tools can and should meet companies where they are on their digital transformation journey

by Mike Brooks, AspenTech

Contrary to popular opinion, a digital transformation journey to improve maintenance and asset performance need not be an ordered, strict, logical set of steps that symbolize the typical maintenance maturity pyramid. It also should not take the form of a rip-and-replace and complete re-engineering approach.

Technologies such as condition-based monitoring and product inspections are a critical part of asset performance management (APM) and can be augmented and improved, not entirely replaced, with new technologies. Also, digital transformation is rarely achieved with a decision to implement a large data lake, gather all kinds of indiscriminate data, and then figure out what to do with the data. A more assertive approach isolates a specific and important problem and then organizes to solve it.

Today, an advanced detection and mitigation strategy for improving performance is not based on fixed hierarchical steps. Rather, it is about starting with the right APM issues to solve, and doing so with applications that are important to the business at an individual site.

APM 4.0: ALIGNING INDUSTRY 4.0 WITH ASSET MANAGEMENT

APM 4.0 can be defined as more than mechanical equipment maintenance and the avoidance of unplanned downtime. It is an approach that aligns Industry 4.0 technologies with maintenance best practices in order to extend asset life and improve asset reliability. APM 4.0 must ensure the highest equipment availability along with peak equipment performance that is fully aligned with the business goals for any manufacturer. That means preventing reductions in asset performance that affect losses in quality, yield, and off-spec product.

Also, it must ensure that asset strategy and decisions made on equipment, fully account for the cost and risk for each asset and the full system delivering to bottom-line profit and sustainability. For example, a manufacturer may have issues with process operations affecting the full performance of assets and resulting in declining yields, accelerated catalyst decay, excessive waste products, or off-spec product. Again, these are critical items in achieving superior APM 4.0 performance – the equipment must be available and perform well.

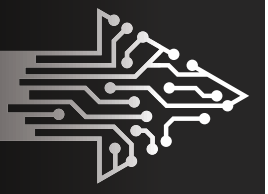
As always with APM 4.0, the place a company must start is not determined by its maintenance maturity. It begins with an assessment of the critical issues that a company faces. Generally, but not always, the critical element is availability. For example, total energy use and yield of most valuable products does not matter if the equipment does not keep producing. But such is not always the first and most critical issue. Some manufacturers have more pressing needs for quality, yield improvements, and reductions in waste product.

Other manufacturing operators feel that current tools give them insufficient comfort in the strategic and tactical decisions they need to make on equipment operation, spare parts inventory, criticality assessment, and asset interactions that

affect overall asset performance. It's important to note that assets are combinations of process and mechanical equipment – after all, one cannot separate the machine from the process, or the process from the machine. One machine can behave very differently in a different location and with a different task, and this dynamic may contradict widely held internal opinions about how to manage that asset. When assessing criticality, the combination of machines and manufacturing process must be considered together for ultimate performance.

PdM: value regardless of maintenance maturity. Digital transformation, especially advanced predictive maintenance (PdM), can and should start where a company is today. PdM can bolt on and bring benefits with little effort, regardless of a company's maintenance maturity. The only requirement to start is the PdM application and a maintenance planner who can receive the alerts and determine the best mitigation options.

As always with APM 4.0, the place a company must start is not determined by its maintenance maturity. It begins with an assessment of the critical issues that a company faces.



Modern PdM technology can deliver true, measured, pattern matching using artificial intelligence and machine learning (AI/ML), and will always deliver earlier warnings about emerging degradation and failure patterns. Modern PdM saves time, and ultimately money. The earlier the warning, the smaller the risk, since a company can plan to mitigate the issues in a coordinated, controlled, and safe manner.

Rather than an unplanned shutdown, an orderly transmission likely means avoiding such mishaps as when leaks and emissions occur. For example, in a petrochemical plant on an unplanned shutdown, one accidental lifting of the flare valves can issue more carbon into the atmosphere than the entire rest of the year. Equally, the extra lead time before a failure may offer the opportunity for different feedstock sourcing to minimize disturbances and losses.

PrM: taking digital transformation to the next level. For those ready for more digital maturity, the availability of current advanced PdM applications called prescriptive maintenance (PrM) take the functionality to a higher level. They can offer advice on the precise failure mode, the likely cause, and the mitigation options of process adjustments, minor repairs, or service/repair details. These, too, are simple extensions to PdM with very clever internal capabilities.

The superior solutions are not limited, but allow users to select such advice in three configurable ways. They include advice from an asset management system, input from manually-entered instructions, and/or assertions from a Failure Modes and Effects Analysis (FMEA) data store. The predominant issue is that some changes indicate clear degradation and failure issues, but others merely signify anomalies in equipment performance. Such anomalies always need human intervention to understand the causation, which can be due to equipment degradation or due to changes in process behavior that can damage equipment.

PdM & PrM: TEAM ALIGNMENT ON WHAT TO FIX FIRST

PdM/PrM technology applications offer detailed, thorough, and more frequent inspections every few minutes, as opposed to operation rounds and maintenance inspections happening once per shift or once a week. These applications offer a faster, cheaper way to inspect and, excepting any mandated physical inspections, can reduce the burden and cost of employing users for such rote tasks.

Furthermore, many approaches to identify risk and criticality often are misunderstood and misapplied when determining equipment inspections and service. These tools can be very complex, time consuming, and a financial burden, to provide only limited results. Some elements, such as risk priority number (RPN), are completely specious, based on pure opinion, and give widely different rankings based on minor changes in one parameter.

More modern and comprehensive approaches offer faster and cheaper results, and a more inclusive feel for the true risk and criticality. They execute based on data, rather than opinion. After all, the loudest voice in the morning meeting isn't always the right one. Instead, a tool with hundreds of simulations can point out the combinations and relationships between machines, the effects of weather, logistics of supply and delivery, all with indicators of what is really affecting the bottom line. It'll be clear what to fix first.

Modern analytical applications can meet a company on its digital transformation journey today, without disruption. Constant process monitoring and state of the art AI analysis can give warnings before things go awry. They offer immediate advice on what to adjust and in what order, to achieve the appropriate cost, risk and performance in terms of availability, quality, and yield from the assets.

This leads back to one important question: where should you start? It's up to you. Digital transformation tools that improve total productivity at a company's plant can be applied now. Significant, early results are possible. You just have to start.

Mike Brooks is Global Director of APM Solutions at AspenTech (www.aspentech.com). He was previously President and COO at Mtell, the company that pioneered condition-based monitoring using machine learning. Brooks has 25+ years of experience at Exxon, Chevron, and start-ups in process operations, planning and scheduling, control, and industrial IT systems.

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Accelerate your APM program

The stage is set for plant teams to more efficiently crowdsource asset management tools and strategy

Tracy Swartzendruber is VP of Marketing for Power Generation and Oil & Gas at GE Digital (www.ge.com/digital), connecting industry with software that solves some of industry's toughest problems. In her own words, "a better run plant is a more efficient plant, which is actually a more sustainable plant." At the ARC Industry Forum in June, she presented an update on several GE Digital initiatives including the use of "Accelerators" to help plants scale APM across the enterprise. Listen to her full podcast interview at: **https://www.plantservices.com/voices/the-tool-belt**

PS *One of the things you launched at the June event were GE Digital's Accelerators, can you introduce them to our readers?*

TS Accelerators are really, if you think about it, they are downloadable content that collapses your time to value with our applications. They might be analytics, it could be a dashboard, can be an asset strategy, that have deep domain expertise because not only as the software developer, but as in many cases, the implementer, within industry. We know the best practices and we have seen time and again, dozens if not hundreds of times, customers needing the same type of configuration. So some smart people within the organization said, "Hey, we keep seeing the same requests. Why don't we package these? Why don't we productize these services that we are doing?"

That's really what an Accelerator is. It's a way to get faster time to value, so that instead of making 27 different decisions and the work behind setting up an asset strategy, we can give you those prepackaged strategies. Instead of just deploying APM against the most critical assets in your facility or enterprise, you can go ahead and deploy it against all the tier-two and tier-three assets that you always say, "We'll get to it." And we all know what happens there, right? You never do get to it. This is a way of really ramping up and bang, you get to now apply it to hundreds of other assets.

The easy way of explaining it to those who still don't quite understand this, is that APM is like Minecraft. I have a 13-year-old son who still plays Minecraft. I know a lot of adults do too. And for those who aren't familiar with it, Minecraft is a "sandbox" video game. It's creative, and people create in it. You can be given a world, but you can go into creator mode where you create your world.

I like to think of Accelerators as just that: you can go into Minecraft and have a sort of blank canvas, if you will, but there are now all kinds of downloadable content packages from the owners of Minecraft, which I think these days is Microsoft, as well as other creators out there so that you don't have to spend hours of work building a texture for something – you can just go ahead and download that.

PS *Let me switch over to another announcement that you made at the ARC event, which was that GE Digital has achieved Amazon Web Services or AWS Energy Competency status.*

TS We submitted for it with the basis of our APM solution in the cloud of course, and it was thoroughly vetted and put under a microscope. We believe that APM is this foundational bedrock of energy transition. If you do not have solid foundation in your current operational excellence, right, whether you're in oil and gas or whether you're a power generator, for example, you're not going to be able to take those next steps; you have to have those initial items in order.

And even for a power generator, being able to produce reliable, affordable, and sustainable power has everything to do with reliability. Traditional power plants were designed to run at base load continuously with maybe a ramp-up / ramp-down once or twice a day. That is not the case anymore. As we bring more and more renewables online, those plants are having to more rapidly react, and turn-up / turn-down all over the place. There's even this notion of the duck curve, where you can really see as the renewables come on and it takes a dip, and then it takes a huge spike up. Reliability is everything because they need to know that they can generate when needed and quickly. That's really the basis for the AWS competency status, and why our APM solution is that foundational piece for us.

Personally, I think sustainability, net-zero, energy transition, however you want to frame it, is the most pressing issue of our generation, and more importantly, of future generations. I think that's what's going to keep it at the forefront for the foreseeable future until we do hit that goal, and I think the pressure is on.

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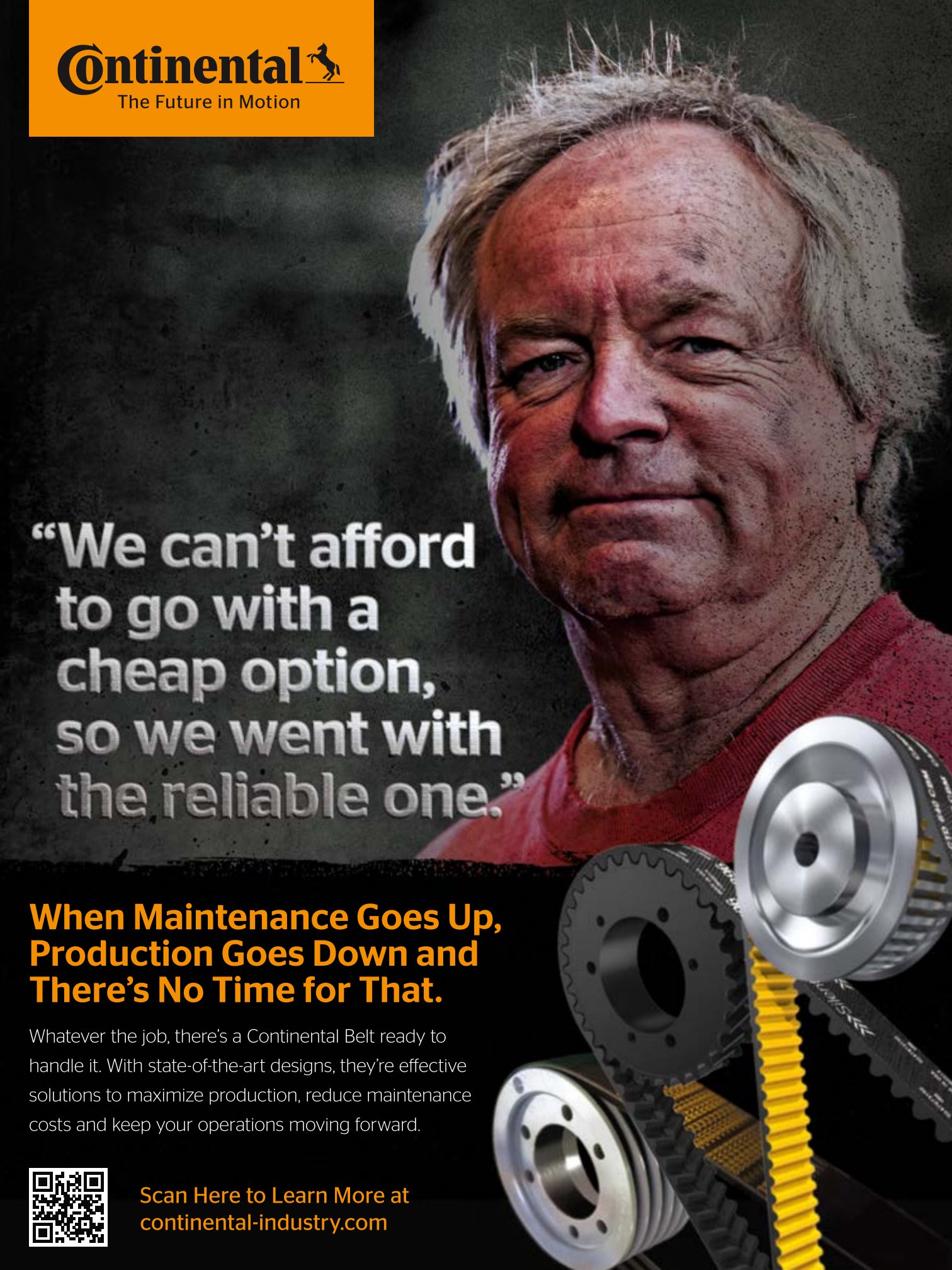

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