
UPTIME MAGAZINE
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Reliability Excellence for Managers	General Managers, Plant Managers, Design Managers, Operations Managers and Maintenance Managers	Build a business case for Reliability Excellence, learn how leadership and culture impact a change initiative and build a plan to strengthen and stabilize the change for reliability.	SESSION 1 DATES: Mar 10-12, 2015 (CHS) Aug 25-27, 2015 (CHS) (Sessions 2-4 dates are available on the website)	12 days total (4, 3-day sessions) 8.4 CEUs	$5,995
Risk-Based Asset Management	Project Engineers, Reliability Engineers, Maintenance Managers, Operations Managers, and Engineering Technicians.	Learn to create a strategy for implementing a successful asset management program. Discover how to reduce risk and achieve the greatest asset utilization at the lowest total cost of ownership.	Apr 14-16, 2015 (CL) Sep 15-17, 2015 (CHS)	3 consecutive days 2.1 CEUs	$1,495
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*LOCATION CODES: (CHS) = Charleston, SC | (CL) = Clemson University in Greenville, SC | (UA) = University of Alabama

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Editorial

GREAT LEADERS ASK GREAT QUESTIONS

Anyone who is following our work with Uptime Elements – A Reliability System for Asset Performance Management and our goal of creating 1,000 Certified Reliability Leaders knows we approach the work as an inquiry.

Questions are powerful leadership tools to create awareness and understanding, which in turn, create empowerment and engagement.

As soon as a child has language, questioning is the primary way he or she learns about the world. An average 4-year-old asks hundreds of questions per day, but that curve reduces steeply as we integrate our children into today's institutionalized educational system where kids are forced to memorize answers to questions they do not have. As you may sense, I have some disdain for traditional approaches to education; however, I am encouraged by much of the work being done by some very smart people to change this paradigm. I do my own work to prepare my children for the challenges of the modern world.

Make no mistake about it, many smart people have also gotten at the issues around reliability and some powerful insights have developed as a result. The paradox is that our research still shows 70% of these proven approaches still fail to generate sustainable business results. Questions may help improve those odds.

Questions disrupt established processes and systems. Asking questions can begin to shift your results and you might want to start with these:

1. Do you have any time for questions?
2. Who comes out ahead at your company – the person who asks the question or the person who says nothing?
3. Is questioning dangerous to your career?

We invite you to join us in our inquiry and consider how you might use these and other questions in your work. Questions open up possibilities, while answers sometimes close them down. Understanding is the booby prize in life!

Questions require you to think in an entirely different way.

Here is an exercise I want you to try. For the next week, each night before you go to sleep, have a piece of paper next to your bed and list your most important reliability challenge. Then join me in my primary inquiry by asking:

1. What is reliability?
2. Where does reliability come from?

I am 55 years into a 99-year inquiry called my life and the last 30 years of that experiment has been spent asking these core questions.

Your brain is wired to solve problems by asking questions and the committee of neurons that is your brain is just waiting for its next assignment. I predict that many of you will solve some big problems if you follow this assignment. I would like to hear from you personally about your experience.

There is a corner office waiting for the person who asks the right question.

Warmest regards,

Terre O'Hanlon

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IN THE NEWS

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Just Announced at RELIABILITY 2.0 Las Vegas

Women in Reliability Roundtable

Moderated by: Maura Abad and Kelly Rigg O'Hanlon (reliabilityweb.com)

The 2015 Women in Reliability Roundtable focuses on the leadership challenges for women in reliability. There are four targeted areas of discussion. Together, they are designed to explore the wide range of challenges in providing secure and effective project value delivery:

- Empowerment
- Leadership
- Accomplishment
- Achievement

A balanced agenda and experienced facilitators provide focus and an effective platform for networking and discussion. Those who attend can expect a stimulating event, innovation and concrete results. Women in Reliability Roundtable participants will exclusively receive white papers describing key results from the discussion – a unique source of timely, peer-reviewed content.

This intimate, candid and highly interactive global event is professionally managed by Reliabilityweb.com.

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The working committee for event development for IAM USA - Northeast Chapter
Left to right: Joe Kessler (guess Keynote), Kelly Rigg O'Hanlon, Mike Salvato, Matthias Ebinger, Harvey Urbieta, Lenny Caputo, Agnes Harris

IAM USA New York Meeting

The inaugural event of the Institute of Asset Management (IAM) USA New York Branch was attended by 100 asset owners, (in the Northeast region of the United States) including Reliabilityweb.com's Co-Founder and member of the IAM USA working committee, Kelly Rigg O'Hanlon, bringing together local leaders to share ideas and questions about the practice of asset management. Joe Kessler, Senior Vice President, Power Generation, at the New York Power Authority (NYPA), the nation's largest state electric utility, discussed the role asset management plays in his vision and in the operation of the NYPA. Following the keynote was a panel discussion regarding the effective use of data to support management functions through the asset lifecycle.

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Adapting to Being a Better Leader

by Dan Pontefract

When thinking of IBM and Xerox, one tends to think of paradoxical leadership. In the blue corner, we have a company — and a leadership model — that superbly enacted the attribute of adapting. In the red corner, we have a company that was highly innovative and thought-leading, yet for a period of time didn't possess the adapting attribute and suffered for years thereafter as a result.

Back in 1993, newly appointed IBM CEO Lou Gerstner had been parachuted in to salvage a beleaguered, if not bankruptcy-destined, organization from the verge of collapse. The instructions given to him by the board of IBM were clear: "Help us adapt to the new world of business." Gerstner wasn't an engineer, nor was he a technology expert; at his core, he was an adapting change agent who could help Big Blue with its transformation needs. Drawing on similar experiences from his days at Nabisco, American Express and McKinsey, Gerstner successfully brought in an adapting leadership attribute to the organization.

It permeated throughout all facets of the company. Through his leadership and a willingness and perseverance to push the company into a new way of thinking — a more adaptive way of operating — IBM trimmed anything that wasn't working and evolved into the technology idea factory it is known for being today. Through Gerstner's nine-year reign, IBM's value and revenues grew by more than 40 percent, and the company radically transformed from a monolithic, rigid giant to a flexible and adapting organism. As he left his post, Gerstner underlined the point of his belief in adapting and in people in general by saying, "In the end, an organization is nothing more than the collective capacity of its people to create value." By instilling the behavior of adapting, IBM has gone on to be a role model organization.

In the 1970s, things were as positive and rosy as can be if you were a member of the Xerox team. The world was gobbling up Xerox technologies everywhere, from photocopiers to highly sophisticated laser printers. Today, we take these technologies for granted, but it's Xerox and its innovative culture we have to thank.

It's this innovative mind-set throughout the organization that also saw the launch of Xerox Palo Alto Research Center (PARC), a facility instituted by CEO Charles McColough to cook up even more cool gadgets. But this is where our adapting attribute story takes an unfortunate twist.

Imagine a research center that developed the technology we use today, like the mouse, or electronic file folders, or the graphical user interface, or what-you-see-is-what-you-get (WYSIWYG) software. Yes, all of these were born at Xerox PARC. But, due to a culture that was very territorial, less entrepreneurial than its Silicon Valley counterparts and absolutely lacking the adapting gene, Xerox squandered the opportunity to bring these magnificent inventions to mass market. Instead, because it was lacking the adapting gene, the innovations Xerox PARC developed were sold to budding (and adapting) leaders like Steve Jobs, who ran wild with their functionality. Why didn't McColough, or his successor David Kearns, see the inherent opportunity in PARC-related technologies? Why didn't they adapt to the changing societal and business needs? It's most likely because they did not have the adapting attribute like Lou Gerstner did. And we know full well what Jobs did with the technology afterwards, don't we?

What is evident in the business world is steadfastly simple to some and eerily overlooked by others. A failure to adapt, to anticipate, or to possess continual flexibility in previous decisions will be the unnerving undoing of an organization. The company formerly known as Research in Motion (RIM), makers of the iconic BlackBerry smartphone line, is a classic example. Former co-CEOs Jim Balsillie and Mike Lazaridis were innovation machines, producing technology products that were snapped up in droves by their customers. But an unwillingness to adapt or to look ahead and better the organization ultimately led to their resignations in early 2012. RIM's board and the company (with new at the time CEO Thorsten Heins) attempted to hastily play catch-up to the likes of Apple and Samsung. It was a desperate quest to gain a stronghold in the consumer space. It eventually led to the departure of Heins a short year later and the installation of long-time, high-tech veteran John Chen to steer the Blackberry ship to safe passage. Only time will tell if it's too late for the company.

What of Digital Equipment Corporation (DEC) as well? In 1977, founder Ken Olsen quite famously said, "There is no reason for any individual to have a computer in his home." This oft-used quote nicely illustrates the adapting attribute. DEC was a market leader in technologies, such as the minicomputer, data processors, mainframe computers and networking, yet didn't see the benefit of personal computers until it was far too late and others had flanked, outwitted and adapted much earlier.

Unsurprisingly, the company was pared back and bit parts were sold off until eventually what remained was sold to Compaq. If only DEC had a better adapting attribute, perhaps it would be the world's most valuable company and not Apple as it is today.

The words of Alexander Graham Bell nicely summarize the adapting attribute for a connected leader: "Don't keep forever on the public road, going only where others have gone."

If leaders understand they can both adapt *and* better their leadership capabilities to fuel the growth of the organization itself, why aren't more doing it?

At the 2012 Democratic National Convention held in Charlotte, North Carolina, First Lady Michelle Obama gave a rousing speech, some argue, for the ages. It poetically painted her husband, President Barack Obama not as the President of the United States, but as a true connected leader of the people. She depicted a graceful, loving and empathetic man. One line in particular stuck out and it went as follows:

> "Success isn't about how much money you make, it's about the difference you make in people's lives."

How to be adapting as a leader

- The future happens every day; get used to it. Leaders need to be continually uncomfortable with the status quo.
- No road is ever smooth. Anticipate bumps and barriers so others can succeed in changing business conditions.
- Uncertainty is not a negative. Explore options, dig into possibilities, get creative and be relentless to improve.
- Do not stay on the white line. Shift priorities or approaches to address needs of today and the future.
- Perfection is not the goal. Adapting to change and progressing forward is how to be perfect.
- Others don't own the future. Be accountable to yourself. No one will adapt for you.

We might take some creative license with her words and suggest the attribute of being better as a leader is as follows:

> "Success isn't about how many direct reports you have, it's about how well you are bettering your team and the organization whatever the situation."

Who cares how big your team is or your organization's girth?

The goal is not a larger team, it is making that team — whatever the size — the best it can be. It is the responsibility of the leader to assist team members in hitting their professional or career pursuits. And the true connected leader will take interest and provide counsel on personal endeavours, as well. Likewise, it is incumbent upon connected leaders to refrain from invoking a culture of status quo. Jim Collins, author of *Good to Great: Why Some Companies Make the Leap…And Others Don't*, in quoting Voltaire, said, "Good is the enemy of great" and it is this phrase that leaders should tattoo on their foreheads.

Bettering is improving. This is the essence of moving beyond status quo leadership. Euan Semple, author of *Organizations Don't Tweet, People Do* and the former Director of Knowledge Management at the BBC, states to "do whatever you can" and "encourage a shared sense of ownership" and "keep adapting and be willing," all of which help us understand the importance of consistently demonstrating the behavior of bettering your people and the organization.

In a sense, bettering is much like good parenting. The term helicopter parenting — coined by Dr. Foster Cline and Jim Fay in 1990 — is the act of over parenting or child smothering and it's an awful way to raise children. Of course, the same can be said of leadership. When you are helicopter leading, you are micromanaging, which no one cares for in this day and age. The other end of the spectrum is absent parenting, those moms and dads who have checked out of the process, leaving the child to fend for his or her own well-being through life's crucial decisions and actions. The latter can be thought of as those leaders who just don't care about the growth of their team, who have checked out and simply fill in the performance review once a year. That is as ugly as it gets. But when a parent gets it right, when he or she knows the fine balance between assisting and letting go, it is, in fact, the act of bettering the child. In the workplace, why can't leaders find the right balance, too?

How to be bettering as a leader

- Territorial piss-posts are akin to hoarding your employees. Look out for the betterment of the organization and stop thinking you own your team.
- Being close-minded only punishes the employee and the organization. Start an open dialogue with team members about wants, needs, wishes and expectations.
- You are a member of the organization, so openly encourage your team to better themselves by being open to other career opportunities in the organization.
- Performance reviews are a formality. By bettering, you should be conducting a running conversation with team members about their development and goals.
- The head in the sand ostrich effect won't work either. Get out in front and initiate the bettering actions with your team members.
- No one is irreplaceable. Holding on to talent for selfish reasons is the antithesis of bettering. Be brave and think holistically for the sake of the employee and the organization.

Bettering the team helps in so many different ways. For example, in December 2008, it was evident that TELUS had a number of team members who were in need of some bettering action. To be clear, bettering isn't about sending people off to a training course. It is about improving the situation of the employee, with the employee, team and organization all equally in mind. Two individuals in particular, Rob Sharpe and Marguerite Behringer, were learning and collaboration consultants working on various projects. They were rock stars and the company was lucky to have them. When they were approached separately about their portfolios, ambitions, likes, dislikes and traits, it became evident that they were in need of some bettering action. For example, there were numerous conversations with Rob about his passion and ways we could tap into that outside of our team to better his skills and experiences. We found a three-month job shadowing opportunity in a completely different part of the organization, fully paid for by his current role, which then led to other bettering opportunities outside of our team.

Rob is still a highly contributing member at TELUS on a different team and now has a team of his own that he is leading. The act of bettering helped Rob in his career at TELUS, and more importantly, kept him at the company as well. Through many conversations with Marguerite that focused on bettering her skills, career options and talents, we shifted her portfolio on the team from one that focused on a single deliverable to one that supported an entire business unit. From there, we continued our bettering dialogue and she happily graduated from our team to go on and become a highly successful HR business partner for the TELUS enterprise sales team. It's another example of how the act of bettering can help both the employee and the organization as a whole.

The act of bettering is nicely encapsulated in the book, *30 Reasons Employees Hate Their Managers: What Your People May Be Thinking and What You Can Do About It*, by Bruce Katcher and Adam Snyder:

> "Such support for employees is not merely altruistic. It will further the goals of the organization by keeping a cadre of highly motivated, accomplished, and upwardly mobile employees who refuse to become complacent slaves. It will also be attractive to potential new employees to know that the organization supports employee growth and development."

As a leader, ask yourself what you're doing to adapt to the times, but don't stop there. Also ask yourself how you're bettering both your own leadership skills and those you are supporting. It is this type of leader who understands what a *FLAT ARMY* is all about.

***Dan Pontefract** is the author of "FLAT ARMY: Creating a Connected and Engaged Organization," and Chief Envisioner at TELUS, where he runs the future of work consulting shop, TELUS Transformation Office. www.danpontefract.com*

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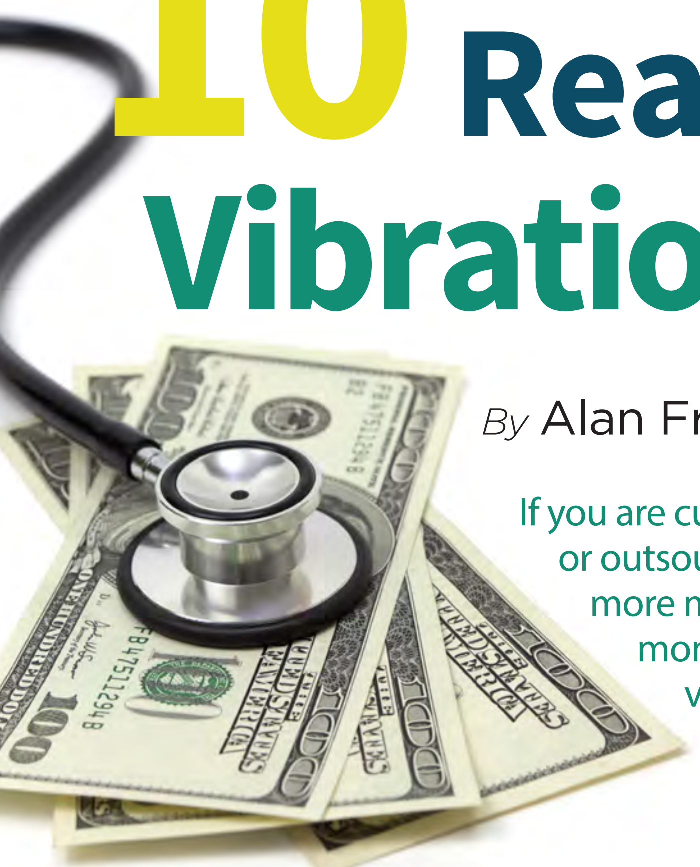

By Alan Friedman IMC Presenter

If you are currently running a vibration monitoring program in-house or outsourcing it to a consultant, before you potentially throw any more money in the toilet, you really need to audit your vibration monitoring program and ask yourself if you are getting any value out of it.

If you do not know what benefits you are getting from a program, you are probably not getting any benefits at all! On the other hand, if you *are* getting benefits but not documenting them, then your program is at risk for being cut. Either way, you need to know what is going on with your program and document it if it is good or fix it if it is not.

All too often, people come to work every day and do their jobs without ever stepping back to ask if what they are doing is beneficial. Furthermore, many people cannot verbalize the goals of their program, no less demonstrate its benefits in financial terms. For example, one company has been using a consultant for a long time to test machines on a quarterly basis. The consultant was providing a report that was just graph after graph that no one ever looked at. Nowhere did the report show how many machines were tested, how many defects were detected, what defects were detected and how bad they were. On the client's side, the company never asked, "What is the benefit of this?"

People often have problems on the technical level as well. Vibration tests are often configured in such a way that the analyst is not going to find a fault unless it is really bad. And if it is really bad, then you don't need a vibration program to find it! When you buy a digital camera, it has a bunch of settings, like flash on or off, aspect ratio, number of pixels, f-stop, etc. Vibration data collectors also have a bunch of settings that need to be configured correctly for each test. The difference is when you set up the camera wrong, perhaps by taking a picture in the dark with the flash off, it is immediately obvious that you goofed because the photo doesn't come out. With a vibration test, it is not so obvious. You may very well be collecting useless data without realizing it.

Q Questions

1. How many machines are being tested per quarter?
2. How many diagnoses are being made?
3. How many of these diagnoses are accurate?
4. How many of these defects would have been discovered even if you did not have a vibration monitoring program?
5. How much money is being spent on the program?
6. How are vibration reports helping you make better repair decisions?
7. What return on investment (ROI) are you getting from your program?

A Answer

If you do not have answers to these questions, then you really need to audit your vibration monitoring program NOW!

How you take the readings also matters. In some cases, people take readings on too many test points and money could be saved by taking fewer. On the other hand, some people don't take enough data, or they don't take it in the right place, like a doctor trying to listen to your heart by placing a stethoscope on your head; you might not be getting the data you think you are getting! Not only do you need to put the sensor in the right place, but since no sensor measures everything perfectly, you also need to use the correct sensor for the application. How you mount the sensor (e.g., two-pole magnet, flat magnet, sensor pad, etc.) also makes a difference and this also depends on what you are trying to measure.

It also matters what the machine is doing when you test it. When using vibration analysis in the context of a condition monitoring program, the key is to trend the data. Imagine waking up in a hospital bed and having a nurse take your pulse. Now imagine jogging to the doctor's office and getting it taken. Does your higher pulse rate mean that you are sick? Of course not. But if we can't compare the two tests, then how do we know which pulse rate is normal for you? Bottom line, if you are not testing your machines under similar conditions (e.g., speed, load, etc.) each time, then your trends are probably useless and so are your alarm settings – that is, if you have any alarms set up!

Assuming you are lucky enough to have all the test parameters set correctly and you know you are getting quality data, what about analysis? Are you just getting an alarm, or are you getting a concise report, such as: "Stage 3 motor bearing wear is indicated by a peak at 7.2x with harmonics and shaft rate sidebands. I recommend a bearing replacement during the next shutdown." And who gets this report and what do they do with it?

Does anyone calculate the financial value of knowing well in advance that the motor bearings are entering a failure mode? Does anyone open up the bearings after the repair to verify that they were, in fact, damaged? Does anyone track how many diagnoses are accurate? Does anyone track how many failures are not diagnosed? Does anyone follow up to figure out *why* they were not diagnosed? When failures are detected, does anyone do a root cause failure analysis (RCFA) to determine what caused the failure? Does anyone follow up to redesign the asset or change procedures to prevent the same failure from happening again in the future?

The best advice to remember is:
Audit it. Improve it.
Get the most from your vibration monitoring program NOW!

Why is it that so many people have these sorts of problems with their programs? One reason is that the people running them are not adequately trained or have the skills required for the job. Many people put in charge of the vibration program are just given a data collector or software manual to read. After taking even a basic Category I vibration course, they discover they have been doing things backwards for years. What is difficult to understand is how anyone can think that running a program backwards for years is less costly than sending someone to a training class or having someone come in to audit the program. Lastly, it is one thing to take a class and pass an exam. It is another thing to be confident that your program is set up correctly and that you are getting the benefits that you should, and this is yet one more reason to.

In conclusion, at least 10 reasons why you should audit your vibration monitoring program NOW have been presented in this article. Can you find them? Can you come up with 10 more reasons to audit your vibration monitoring program now? If you think about it a bit, you more than likely can!

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SALVO Project: Scottish Water

Determining and Proving Which Projects or Maintenance or Asset Replacement Tasks Are Really Worthwhile and When

Like most organizations, Scottish Water, a Scotland company providing water and sewerage services, faces major challenges in determining what interventions are really worthwhile, and when, in the management of aging assets. The rate of technological change, infrastructure age profiles, differing functional demands, new legislation, financial constraints and competency concerns all combine to create a perfect storm for critical asset management decision makers.

by Bill Reekie, Karen Whitehall and Andy Hunt

There are many solutions, methodologies and tools already available to assist organizations in making these decisions, but none really provide the business case for what to do and when.

Enter Salvo

The strategic assets lifecycle value optimization (SALVO) project has been a three-year, cross-sector research and development program that combines the best of existing methods with highly innovative solutions for targeting, evaluating and optimizing interventions in lifecycle value optimization of aging assets.

It has generated new processes, decision-supported software, a range of field proven case studies (several already implemented with major benefits quantified), and extensive guidance to enable a broad variety of personnel to make better decisions about what is worth doing, when and why.

Scope and Objectives

The scope of the SALVO project is to provide a clear line of sight between business priorities and practical options, ensuring the right things to do are selected and the right amount or timing of the interventions is identified and proven with hard numbers for cost, risk, performance and asset lifecycle value impact.

The objectives are that the resulting methods must be understandable and applicable to frontline decision makers in real time, and be able to handle any realistic mix of data, uncertainties, risks, competing business drivers and asset knowledge sources.

Systematic Decision-Making Approach

The SALVO team built an end-to-end process for decision-making in six fundamental steps, comprising of a top-down targeting of the key decisions to be made and interventions to be evaluated/optimized, and a bottom-up justification, optimal timing and total program coordination of the solutions. The steps are illustrated in the SALVO smiley (Figure 1- see page 14) and full process mapping of these steps was performed, supported in each step by examples and guidance documentation, and, where appropriate, either existing best practice tools/methods or, where no practical solutions existed, freshly designed and developed decision-supported solutions. A management summary and illustrations of these processes will be published in an upcoming SALVO guidebook.

The individual process steps, their use of existing technology or methods and areas of SALVO innovation are described on page 14.

Scottish Water Experience

Scottish Water is one of the core sponsors of the SALVO project. For Scottish Water, participation in SALVO has provided the foundation for the development and rollout of all its asset maintenance strategies, with a framework that has senior management buy-in. The diagram in Figure 2 provides an overview of the Scottish Water planning system.

Within the Scottish Water planning system, asset master plans are key to the lifecycle asset management approach. An asset master plan is an optimized lifecycle plan that defines the inspection, monitoring, maintenance, refurbishment and replacement strategies for selected critical asset types. These strategies are the building blocks that demonstrate a clear line of sight from corporate objectives to how assets are managed.

One of the challenges facing Scottish Water is to determine which interventions are the most worthwhile on its critical assets and at what frequency. SALVO has helped Scottish Water provide these answers. Following the SALVO process steps, an asset master plan was developed in a workshop environment using expert knowledge from Scottish Water subject matter experts, including mechanical, electrical and instrumentation technicians, maintenance planners, asset planners and operators.

To date, Scottish Water has completed a number of these facilitated workshops and SALVO studies on a diverse range of assets and equipment types, including chemical dosing, sewage pumps, rapid gravity filters and sludge plate presses. The structured, analytical approach of the SALVO process has enabled Scottish Water to make the most of the extensive knowledge and experience of its staff, and present the results in a clear and concise format that is easy to understand. Outputs from workshops held to date have also been used to develop planning guidance to support the preparation of the Scottish government funded SR15 (2015 – 2021) investment plan at Scottish Water.

Scottish Water Case Study – Salvo Step 4

This case study shows the simplified version of a decision made on the overhaul frequency of a vertical shaft drive centrifugal sewage pump of 205Kw. The case study is based on the outputs of a cross-functional workshop that took just a few hours to complete.

With the first element of Step 4 identifying a potential intervention option, the scope and cost of the intervention option being considered needs to be determined. The next step is to determine the reasons for doing the planned intervention (overhaul) and these set out the storyboard guidance (shown on the left in Figure 3) that leads the workshop team through a step-by-step guided process, ensuring the right questions are asked in the right way.

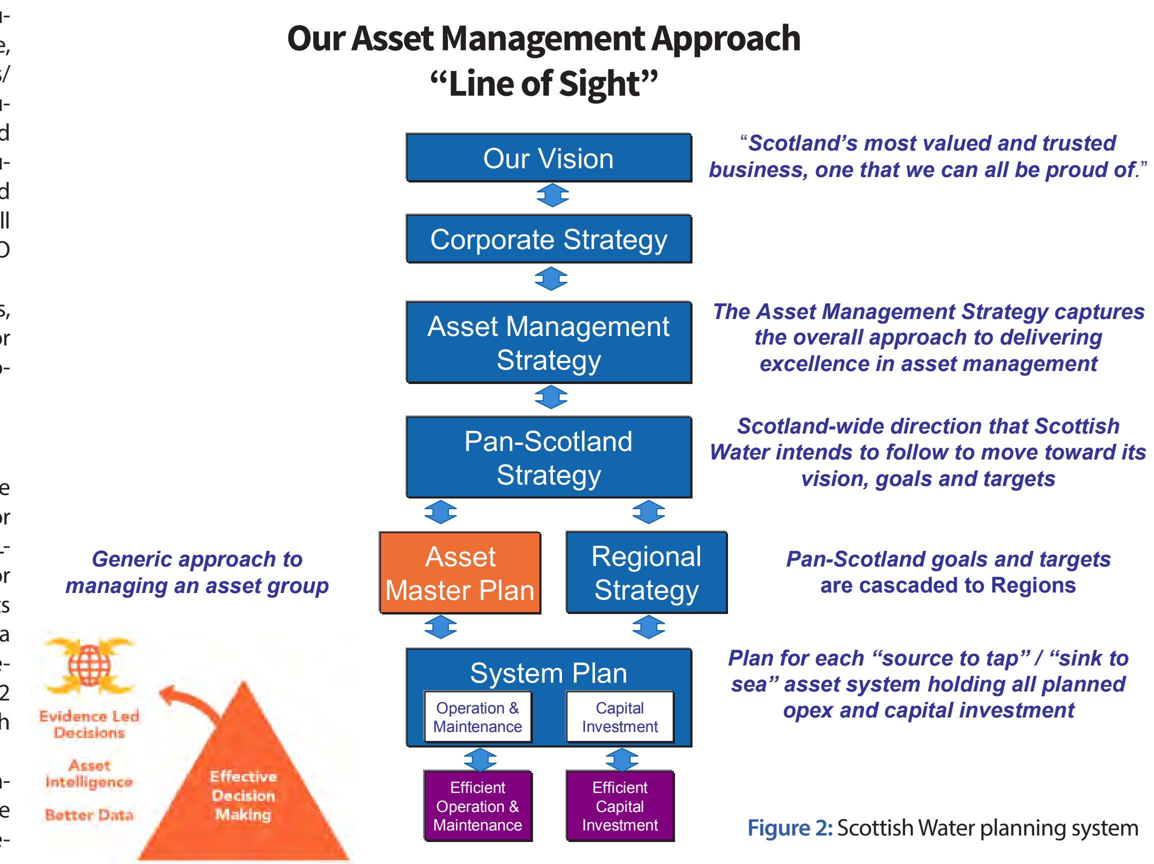

Figure 2: Scottish Water planning system

The Salvo Process Steps

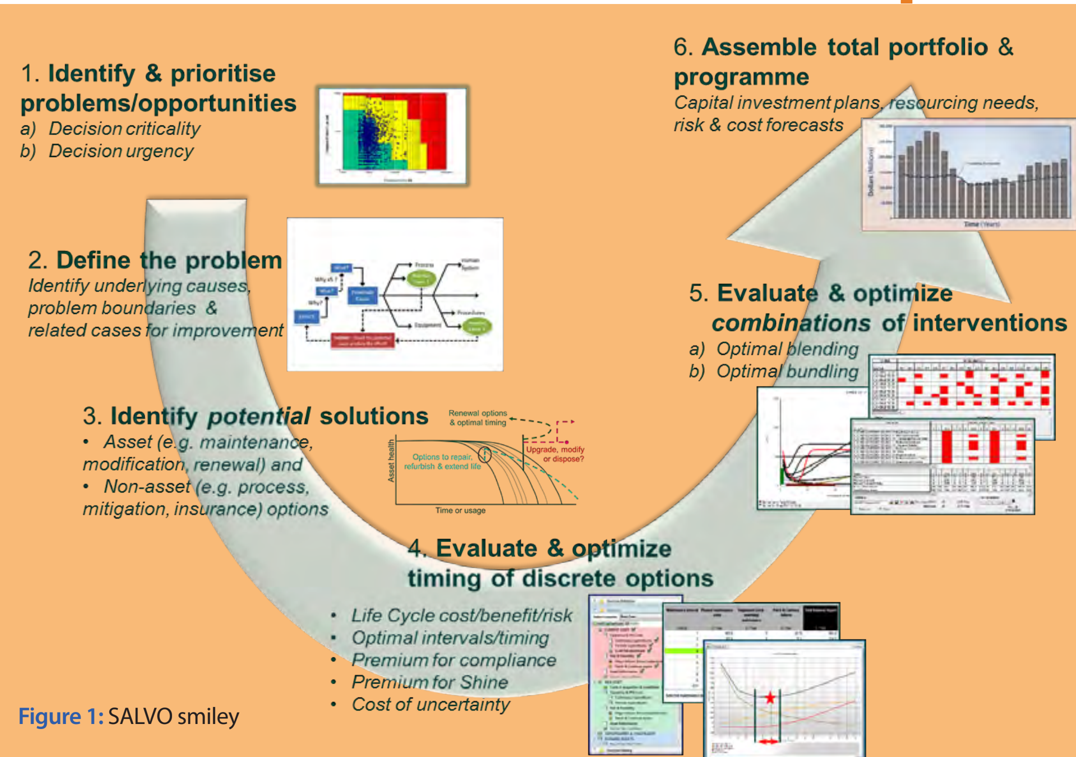

Figure 1: SALVO smiley

STEP 1 Recognizes that an asset portfolio is often large and very diverse, and competing priorities often will be unclear and volatile. Therefore, the first priority is to identify the asset groupings or subgroupings that can and should share a common strategy through their commonality of type and functional role, age, health, etc. This is not just risk and criticality analysis; SALVO has researched and revealed over 40 potential factors that can be used to distinguish between asset needs.

STEP 2 Drills down into these issues to ensure that the problems/opportunities are genuinely understood and root causes are addressed.

STEP 3 Triggers the identification of potential interventions or asset management options. SALVO broadens this a great deal by identifying over 50 option types that might be considered, including non-asset/technical solutions, such as insurance and operator competency or incentives. Stimulation of such lateral thinking reveals potentially high value ideas that would not necessarily have emerged from traditional strategy development tools, such as reliability centered maintenance (RCM), failure mode, effects and criticality analysis (FMECA), or risk-based inspection (RBI).

STEP 4 Is a big area of SALVO innovation and the area of the case study for this article. It provides the objective business case evaluation and optimized timing of the different intervention options. It involves a toolbox of methods since the cost/benefit appraisal of a design modification, or an operator training course, is very different to the evaluation of optimal inspection intervals or asset replacement timing.

This step introduces a number of existing and SALVO-developed new techniques that work in combination, including cross-disciplinary discussion/workshop facilitation; tacit knowledge elicitation techniques; high-speed, sophisticated what-if calculations; scenario modeling; data sensitivity testing methods; and audit trail capture. This process of intervention appraisals and business case justified results can be constructed from scratch by a relevant small team within just two to three hours.

The participants in SALVO have already applied these methods to a wide range of asset and problem types, and they have proven practical and effective, with full transparency in the selection of the optimal strategy.

STEP 5 Begins once individual options have been evaluated and the ones with the best value identified and optimally timed. This step explores the combinations of such interventions and optimization of the overall, whole lifecycle strategy. This includes two stages in particular:

The Blending of Multiple Activities on the ***same*** asset for optimal whole life value. For example, high frequency maintenance may extend asset life, but also introduce other damage, so what is the best mix for whole life value?

The Bundling of Multiple Activities across ***multiple*** assets for delivery efficiency and shared costs, access, or system downtime. For example, shutdown strategies or remote site visits where tasks can share downtime or logistics costs if they are grouped into bigger work packages, even if this involves cost/risk compromises.

STEP 6 Assembles the total asset management program of optimized strategies to see the combined capital expenditure (CAPEX) and operating expense (OPEX), resources, performance and risk implications, including residual justified risks.

In a cost or resource constrained environment, this enables the least valuable or least timing critical tasks to be identified. Step 6 ensures that the best value combination tasks are funded and done at the right time.

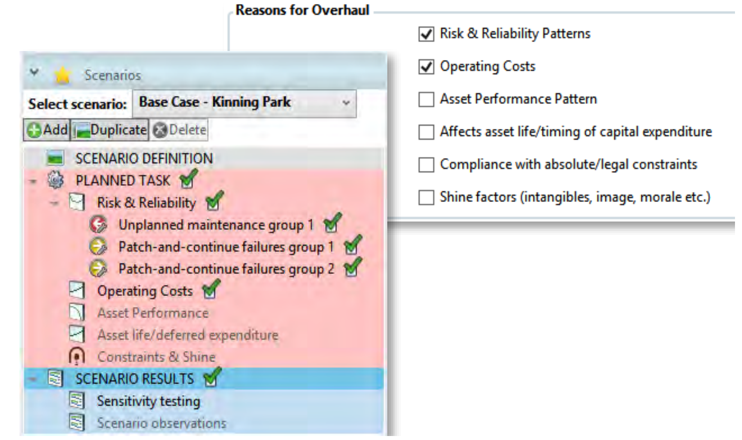

Figure 3: The storyboard reason for doing the planned intervention

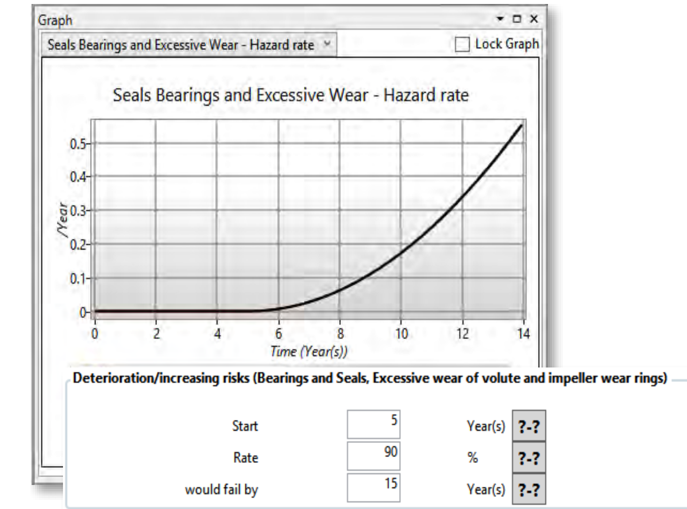

Figure 4: Unplanned maintenance failure pattern and hazard curve

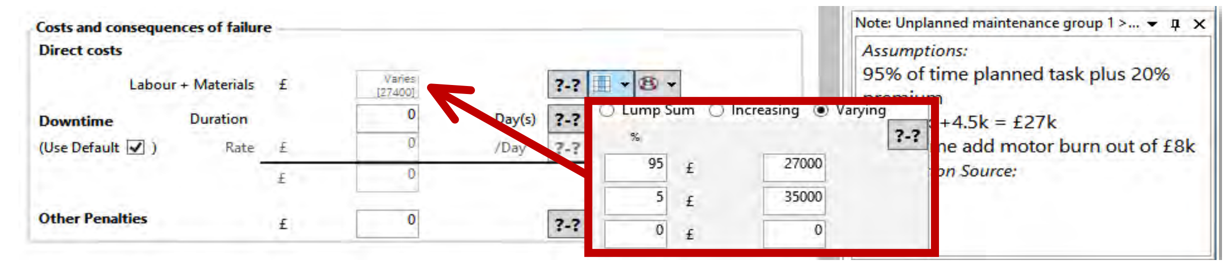

Figure 5: Variable costs of failure

For the risk and reliability elements, failure mode and effects analysis determined several potential failure modes, allowing for the interactions of individual failure modes. These were assigned to three different failure patterns covering pump trips due to blockages, minor repairs, such as couplings, and major failures, such as bearings, seals and volute/impeller wear out.

The unplanned maintenance group 1 (pattern), comprising of failure modes associated with bearings, seals and volute/ impellers, was estimated from a basic analysis of maintenance data that showed the earliest failure at age five and an approximated 90 percent failure probability by age 15. The resulting data entries and derived hazard rate curve are shown in Figure 4.

The costs associated with these failures included the potential risk of additional damage, such as motor burnout if the pump fails. These costs are not fixed, so a variable cost was entered based on past experiences as shown in Figure 5.

The operating costs associated with running the pump, including efficiency losses estimated at one percent per 1,000 hours of operation, were calculated for run hours of six to 9.6 hours per day, allowing for different demand rates and duty/standby/assist operating regimes.

Results

The results of this analysis showed that the optimum time to overhaul the pumps was five years. However, analysis of the results reveals that the intervention timing is not driven by the higher cost of failure (consequential damage to the impeller, shaft, rotor and motor) when compared to planned overhauls, but by the rising operating costs due to pump efficiency losses.

This is clearly shown in the results graph in Figure 6 where the blue line shows the cost impact of efficiency losses and the orange and red lines show the risk and reliability costs.

The planned intervention at five years is a significant shift from Scottish Water's current strategy, which is driven by condition monitoring, as well as routine visual checks that are based on risk and reliability issues only. As a result, Scottish Water is planning to intervene at five years for these large pumps and is now building this into its asset lifecycle plans. However, this decision analysis has also allowed for costed options to intervene earlier or later (note the relative flatness or the total impact curve between four and six years in Figure 6), depending on asset observations, such as monitoring of pump efficiency and condition. This decision also means that budgets for both planned and unplanned overhauls are costed since these ratios are available in the SALVO results based on the proportion of the population that would have failed before the planned intervention at five years.

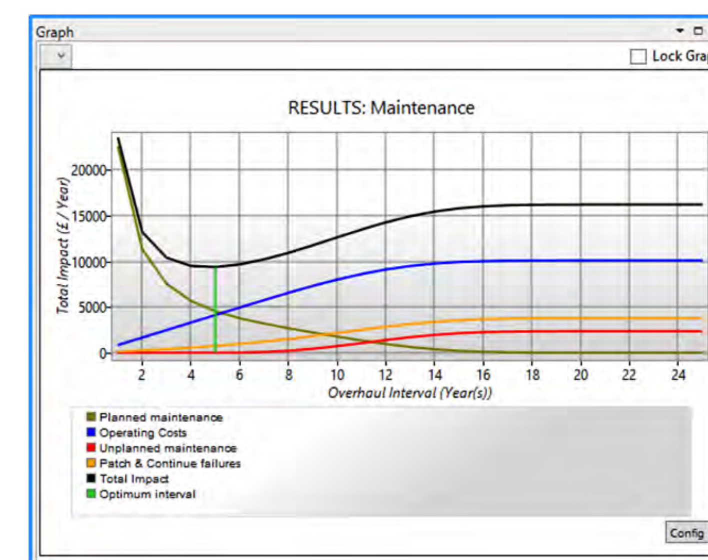

Figure 6: Optimum overhaul timing results

To close the loop, Scottish Water also will conduct validation tests to confirm the estimations on efficiency losses, and as part of the continuous improvement cycle the option of continuous efficiency monitoring is being considered. Most importantly, Scottish Water now has a fully costed (total impact) business case based framework for determining its maintenance strategies with senior management buy-in and an understanding to ensure sustainability.

Conclusion

The SALVO process helps to identify and demonstrate the optimal timing for asset replacement, and helps to identify the optimum frequency for interventions. The structured, step-by-step approach of SALVO provides a road map to ensure the correct elements are considered in the decision-making process.

The SALVO collaboration project provided participants with an opportunity to be involved with a diversity of leading asset management organizations in the development of best practice guidelines in asset management decision-making. It continues to provide access to an invaluable network of industrial partners, enabling participants and process licensees to gain knowledge and experience in asset maintenance and management.

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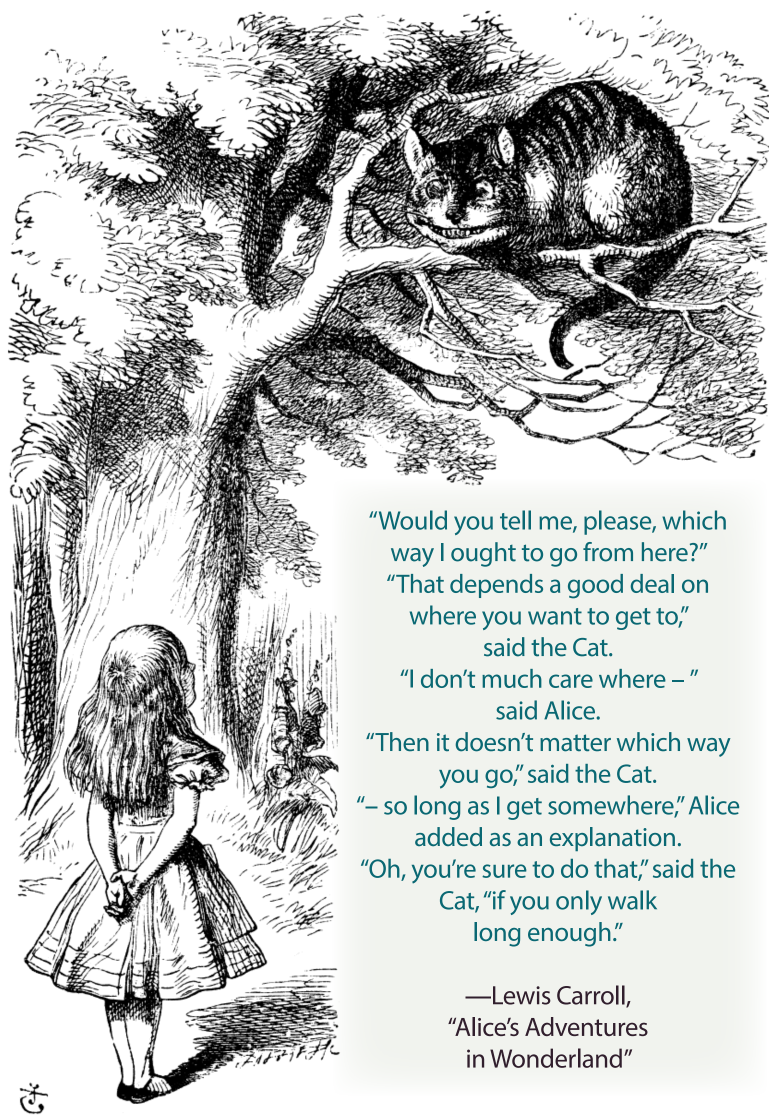
Metrics VS KPIs:

Lessons from "Alice in Wonderland"

by G. Lance Jakob and Anthony Honaker



"Would you tell me, please, which way I ought to go from here?"
"That depends a good deal on where you want to get to," said the Cat.
"I don't much care where – " said Alice.
"Then it doesn't matter which way you go," said the Cat.
"– so long as I get somewhere," Alice added as an explanation.
"Oh, you're sure to do that," said the Cat, "if you only walk long enough."

—Lewis Carroll, "Alice's Adventures in Wonderland"

We can learn wonderful lessons from the clever literary characters Lewis Carroll created. The exchange between Alice and the Cheshire Cat illustrates the need for purpose and context in the decision-making process. We often face pivotal decisions at work, but without empirical insight, we're left aimlessly chasing white rabbits.

The terms metric and key performance indicator (KPI) have been overused to the point where they've lost much of their differentiation and are often used interchangeably. In an environment where we have access to an unprecedented breadth of data, we can easily feel overwhelmed in knowing where to focus. It's important to understand, however, that just because we have the ability to measure something does not mean it will inherently provide value.

A metric is simply a data point. Without context, this number does not communicate whether we are doing well or underachieving and therefore, whether or not we should act. A KPI, on the other hand, applies strategic context to a metric to deliver meaningful information from which fact-based decisions can be made.

When viewing a metric, we immediately try to determine if the number is good or bad. Should the number be higher or lower? Sometimes the answer is not that straightforward. Take the monthly critical spares growth metric as an example. It is a measure of the month-over-month relative growth of value for inventory identified as critical spares for a given storeroom. Generally speaking, the value should be close to zero and remain highly stable. But under some circumstances, a higher number is not only expected, but desired. In other cases, current initiatives and operations should deliver a number less than zero. So, how do we define whether this is a metric or a KPI? Perhaps the best way to define a KPI is by deconstructing its three elements: key, performance and indicator.

Key

Organizations are unique and each matures at its own pace, so it is expected that each organization would focus on goals specific to its environment. In that vein, a metric must be ***key*** to the organization. Not all metrics can be key. There must be a clear understanding why this number is important, why the established targets and thresholds should be met, and the consequences of not meeting the targets and thresholds. At executive levels within an organization, these can be straightforward measures, like revenue, earnings, margins, etc. At lower levels, however, it is more difficult to correlate measures with strategic objectives.

"…it's no use going back to yesterday, because I was a different person then," said Alice.

—Lewis Carroll, "Alice's Adventures in Wonderland"

In the previous metric example, what's the impact of high monthly critical spare growth? The root cause may be that warehouse managers are circumventing stocking policies by labeling more items as critical, or there is truly a strategic necessity to invest additional resources in critical spares. If growth is tied to a specific strategy, what is the goal the strategy is intended to support and how does that correlate with higher level measures, such as earnings? We should strive to define measures that support lower level, operational improvement, while retaining relevance at the enterprise level.

KPIs inherently have a lifecycle. As organizations mature, they must reevaluate what they're measuring, how and why. Some organizational objectives are finite, so it doesn't make sense to manage all KPIs perpetually. But even KPIs tied to perennial objectives must be reviewed periodically for relevance and accuracy. In other words, does it make sense to continue measuring performance in this area and is the current calculation still valid? As Alice points out, we're different than we were yesterday. We shouldn't continue to measure our performance with the same metrics we've always used.

"Now, HERE, you see, it takes all the running YOU can do, to keep in the same place. If you want to get somewhere else, you must run at least twice as fast as that!" said the Red Queen

—Lewis Carroll, "Alice Through the Looking Glass"

Performance

The Red Queen understands that we can't expect to improve if we continue to operate status quo. A KPI must serve as a catalyst for action to improve the business through three primary channels:

1. Validation of business objectives by visualizing performance that directly supports specific goals.
2. Exposure of process risks by actively comparing planned versus actual performance.
3. Identification of coaching opportunities by detecting and alerting the right people of non-conformance events or trends.

In order for a metric to be a KPI, it must provide a means to measure and impact ***performance***. To accomplish this, there are two key factors necessary to associate with the metric: a goal and a time frame. This can manifest itself as a target and date (e.g., lower monthly critical spare growth to .5% by the end of July) or a threshold and date range (e.g., maintain monthly critical spare growth between -0.5% and 0.5% for the summer months). With a goal and time frame, an organization can determine if it is underperforming and can react appropriately. Better yet, the organization can proactively implement initiatives and monitor its progress in pursuit of the goal.

Applying trends to metrics provides meaningful, directional context and can potentially highlight correlations to initiatives (e.g., the number has risen consistently over the last 12 months, the summer months are always 15% higher, etc.). But looking in the rearview mirror is not a stand-alone strategy for driving continuous performance.

Indicator

"'and what is the use of a book,' thought Alice 'without pictures or conversation?'"

—Lewis Carroll, "Alice's Adventures in Wonderland"

Finally, in order for a metric to be a KPI, it must be an ***indicator***. Alice understands that being *shown* something provides much greater context. The metric must be aligned with the business by having a consistent and agreed to definition that indicates the state or level of a process. A measure, such as monthly critical spares growth, does not mean much unless we know how critical spares are defined; and means even less if that definition is not consistently applied across the enterprise. It's that consistency that fosters confidence in the results. Without confidence in the data, one can never expect to achieve pervasive user adoption.

Perhaps most importantly, an indicator must communicate some degree of insight. Simple record counts are the starting point for many organizations, but in reality, they convey very little. Ratios, durations, effort and costs provide much greater insight and potentially allow for pragmatic comparisons between different parts of the organization.

Indicators generally fall into one of three categories:

1. Capacity Indicators, which measure throughput or generation of deliverables for the organization, such as units produced.
2. Process Indicators, which can trend organizational maturity in areas, such as safety or process adoption rates.
3. Outcome Indicators, which measure the end result, such as increased revenue, decreased costs, or improved customer satisfaction.

Understanding the category of the indicator can help define the visualization components and techniques needed to best convey the desired message.

Conclusion

It's not uncommon for an organization to fear openness and transparency, but we can all learn from the March Hare's advice. KPIs, unlike metrics, must clearly identify where we want to go, when we expect to get there and how we are currently performing, all while providing actionable opportunities along the way to ensure we reach our destination.

Metrics are indeed the central components of KPIs. Even if they are not worthy enough to be a KPI, they still provide intrinsic value when leveraged appropriately. Metrics can be used to both establish baselines and identify opportunities for improvement. Through leveraging a structured performance management methodology, a metric can evolve into a KPI when:

- It clearly ***indicates*** progress (or lack thereof), accomplishment, a problem area, an opportunity, or something meaningful.
- The relationship of the measure to ***key*** objectives is identified.
- A target or threshold is identified and the actions and planned reactions necessary to drive ***performance*** are established.

If an organization is not based on a culture of fact-based conclusions, decisions will continue to be derived from a gut feeling. But rather than focusing on hitting the numbers, metrics should genuinely reflect the business processes themselves. Organizations should leverage KPIs from the top to the bottom of the decision-making hierarchy, replicating successes throughout the organization.

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Keep It Clean, Keep It Dry, Keep It Tight!

by George Frey

With the many types of maintenance techniques available to the industrial professional, there are many tools to provide a great deal of information on the quality and workings of electric motors and their processes. However, if maintenance basics are ignored, all the techniques are like three drops of rain in a drought – ineffective and futile. If the three basic rules for proper motor operation and upkeep are not followed, why bother investing in advanced technologies to confirm known problems? These three rules are keeping a motor clean, keeping it dry and keeping it tight. Without these rules, fancy equipment simply doesn't matter! This is perhaps the oldest maintenance story of them all.

Keep It Clean

There are many examples of how keeping equipment clean can provide great reliability benefits. Electrical circuits are designed with specific insulation thickness across coils, phase conductors, inside relays, circuit boards, etc. One element that is important for these applications is the concept of electrical leakage and/or tracking. Electricity, analogous to water, always seeks the path of least resistance in any circuit. When there is an insulation system keeping the electrical current flowing where it should be, there is always a certain electrical stress. The electrical stress is across insulated conductors and through cracks, flaws, thin points in insulation, or circuit areas where inadequate clearance exists. This stress forces the current to flow across, over surfaces, or through the electrical insulation. A circuit board in electronic equipment may become extremely heavily packed with dust, hair, or foreign particles and these items deposit on electrified surfaces. The result is a protective system breakdown and failure. Coils and cooling passages in a motor may be plugged with debris. A major culprit is the operation of cooling fans. When filters are inadequate or not present, they can pull large amounts of material right into the interior spaces. **Result = In Service Failure.**

Keeping these areas clean can be accomplished in several ways. In the realm of electric motors/generators and insulators, cleaning is usually performed when the motor is switched off, locked out and after a visual inspection. It also may be performed based upon hours of operation or years of service. Visual inspection can reveal the presence of surface contamination that may be possible to remedy by one or more of the following steps:

1. Vacuuming out the material, which usually prevents you from driving it further into the apparatus.
2. Removal with a special cleaning apparatus, such as those on the market that use CO_2 pellets or dry ice. This can protect surfaces and interior spaces by removing surface contamination without leaving abrasive residues or leftovers inside the cabinet/enclosure.
3. Removal by solvents or wiping away the material with cleaning towels and/or manual removal. Because of their sticky nature, oil and other types of lubricants and grease may have to be dealt with by this method. Large motors or generators may have access panels that can be removed to allow access.
4. Removal with compressed air can be used, but special consideration should be taken. You can easily drive foreign substances further into the electrified spaces and aggravate the problem versus mitigating it.

Paper Pulp Plant Case Study

During routine periodic testing at a manufacturing facility, the ideal practice is to do a visual inspection of the motors when the test route is performed. After all, it may be six months to a year or longer between inspections. In this case, a lot of paper pulp had escaped from its vessel and was found when the motor testing/maintenance professional went into the area to test motors.

It can be a challenge to keep things clean when material is deposited about like this pulp.

Keep It Dry

The old expression, "water and electricity don't mix," is the main subject for this section. Motors can be, and are, designed to operate properly underwater or in other liquids. When designed to operate underwater, they will perform flawlessly for many years. The kicker is that not all motors are designed to be operated underwater.

When water penetrates the inside of an electric machine, what happens? Aren't these motors sealed very well with a vacuum pressure impregnation process and other measures, like waterproof seals? The fact is NO! Not all motors are designed to be impervious to water. Extra types of sealing measures drive up the cost of a motor's design and often drive down the manufacturer's profit margins.

A much less expensive type of enclosure is standard. These come in many shapes, sizes and applications. Even totally enclosed fan cooled (TEFC) motors can be penetrated by foreign substances. One of the most common, undesirable substances is water. Water can be absorbed by electric machines in several ways. One way is by condensation. The thermal mass of the motor causes it to lag behind ambient temperature. A motor is always trying to achieve equilibrium with the ambient temperature, but because it has quite a bit of mass, it may not totally catch up. When the motor is cooler than the dew point, water droplets condense out of the air and deposit on the motor, including the interior spaces. Why? Because the interior space's temperature lags behind the furthest, leading to the greatest delta in temperature. Once inside, it is difficult to get out.

Wind-driven water or torrential rain by tropical conditions can be forced through seals. Processes, such as pulp and paper production, generate a lot of wet pulp and other by-products. These can penetrate connection boxes and conduits, be sprayed about by shaft mounted fans, or achieve ingress via weakened or worn seals. The net result is water gets inside and stays inside, especially when drain plugs are clogged by debris.

Power Plant Case Study

A coastal power generating station was flooded during a hurricane. Many parts of the station, including a pair of large electric motors, were penetrated by ocean water. This extremely difficult cleanup process took several months, but hard work paid off and eventually normal operation was resumed.

It is tough to keep things dry in any plant when water overflows, such as this one did.

A few years later, the plant went into a planned maintenance outage. The large motors were turned off and cooled down, and electrically tested that day with passing results. Afterward, the motors immediately began to accumulate water in their interior spaces. Eventually, over the outage of several weeks, these water droplets began to pull residual flood salt down into the electric coils. When it came time to restart the motors, they were found to be ground faulted, simply from water penetration. The motor heaters had failed to operate properly and did not keep them dry. Emergency efforts at driving out the salty contamination failed. The motors had to be pulled and completely rebuilt at great expense and time delay.

When a motor is properly designed and perfectly sealed with vacuum pressure impregnation, a barrier to water penetration is established. A defect in the sealing requires at least two flaws in the insulation system to exist for an electrical tracking problem to occur. One flaw would have to be on the insulation on the surface of an electric coil. The second flaw would have to be in the insulation on a second strand or phase, or in the insulation between the electric coil and stator steel, where electric potential exists during operation.

Keeping water out in the first place is usually the most effective strategy. It's better to keep the inside of the apparatus warm and dry versus trying to force out water after the fact. Space heaters or winding heaters are designed in either from the start or retrofitted after real-world conditions affect motor and machine reliability. It is important to check for the presence of current flow through the space heaters periodically. The breaker may be energized, but if the fuses have blown, the heater has burned open, or other problems exist, the heater could be nonfunctional.

Keep It Tight

Items in an electric motor that are susceptible to tightness related problems are the ring lugs under the taped connections at the motor's leads. Periodically taking off-line measurements can help determine if they are operating effectively. In motor testing circles, this is known as the resistance test.

A high quality milli-ohm or micro-ohm meter is used to perform this resistance test. Use an instrument that offers at least 3.5 digits or greater resolution. Less capability means less effective results. These devices are also known variously as ductor, Kelvin bridge, digital low resistance ohmmeter (DLRO), or 4-wire resistance meters. The general idea is that measurements are taken when the motor is turned off, locked out and tagged out. The most time-effective practice is to test from the motor starter through the feed cables to the motor. In this way, the entire circuit can be evaluated relatively quickly. Results can be viewed and interpreted easily by trained maintenance professionals.

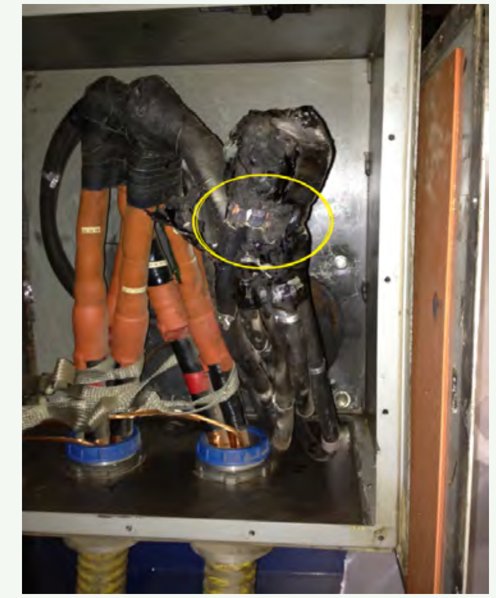
Just how much resistive imbalance is too much? Table 1 shows some of the guidelines, developed through experience of many years, for a three-phase induction motor. These targets give a good baseline or starting point on how to proceed and urgency actions based on trending results.

Table 1 can be easily interpreted as: The smaller the imbalance, the better!

Table 1: Three-Phase Induction Motor

% Imbalance	Recommended action(s)
<1% line to line imbalance	New motors, motors in stores; The ideal, trend
1-2.5% line to line imbalance	Used motors, motors through feeds; Trend
2.5-5% line to line imbalance	Investigate if time permits; Attention to trend
>5% line to line imbalance	Investigate immediately; Do not ignore

Resistive Imbalance Case Study



A motor test was performed from the bucket on a medium voltage motor during periodic maintenance activities. The test was performed from the switchgear through the feeder cables to the motor. The motor technician, who was operating the resistance meter, noted an imbalance of greater than two percent. Since the test device being used had a memory bank for test results, the technician was able to look at the trend history. During the past few years, the results were better balanced, averaging less than one percent. The technician decided the best course of action was to go to the motor connection box and untape the motor leads from the feeder cables.

Upon untaping, a visual inspection was performed first. The first thing noticed was discoloration of the ring lugs, nuts and bolts. The color suggested overheating of the leads, ring lugs, nuts and bolts. The leads were repaired and cleaned, new lugs and bolts were installed and torqued to specifications. The resistance test was performed again and less than 0.05 percent imbalance remained. The motor was returned to service. This action prevented a potential in service failure.

On the right side of the photo, failing lugs are visible. These lugs were replaced and connections at the motor leads were reestablished, which repaired the resistance issue.

Summary

The three basics of motor operation and upkeep are vitally important. Without them, the investment in advanced maintenance technologies is moot. By keeping your motors and machines clean, dry and tight, they will always perform better. By investing in technologies that help perform the basics well, a plant's operation will be more effective and outages less catastrophic. After all, the old saying, "keep it simple," remains in full effect.

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The Importance of Single Point Lessons in the Workplace

by Martin Tauber

Single point lessons, or SPLs, taken in the context of total productive maintenance (TPM), are defined as lessons or subjects that can be described in a page or less and explained in five minutes or less.

For a TPM Kaizen event, from where SPLs are mostly known, they are utilized to outline a specific operation that is performed by the machine operator to make the equipment more reliable and efficient. Whether it is how to calibrate a scale, change fonts on a printout, or the safe removal of a plastic wrapper, the SPLs are all short, concise and to the point.

But why do we limit ourselves to only Kaizen events for SPLs? Standardizing an operation in every facet of the manufacturing operation will have a positive influence on the amount of success the company achieves or expects to achieve.

SPLs, while having a lot in common with written maintenance procedures, differ in a few aspects. An SPL, as previously mentioned, is only on ONE operation that will be performed. It outlines the steps necessary to perform that one operation in a standard fashion. On the other hand, a maintenance procedure can be best described as a series of SPLs combined into one procedure, with the complete description of a procedure often being hours long. A maintenance procedure is performed in a standard fashion as outlined in the procedure's details and can be many pages long, or as few as three.

In everyday usage, the SPL plays an important role in assisting the operator to successfully execute a commonly performed task. For example, there may have been a concern raised about the many different ways a task is done by different operators. With all operators following the specific SPL for the process, there is an achieved state of standardization and optimization. The operators and machine will perform more efficiently, thus becoming more productive for the company.

So why don't all companies utilize SPLs? A lot has to do with the cultural mind-set of a past generation. In the past, operators were allowed to slowly learn an operation and make mistakes along the way. Today, in the fast-paced manufacturing world where downtime is counted in minutes and line success is dependent on the piece count each day, the equipment must run constantly at the optimum speed. Operators have to do it right the first time because if too many second or third attempts are needed to correct a problem, it could spell a sudden career change for that operator. Also, some more experienced operators believe that if they write down their secrets, they will have no job security!

With the advances in mechanization occurring at such a fast pace, it is impossible for companies to totally retool their plants every few years with the latest and greatest. Rather, they employ the equipment that has served them very well for a long time and improve on its design to maximize their output.

The Bureau of Labor statistics show the average age of a skilled operator is in the 50- to 60-year range, meaning that in 10 years or so, the now skilled operators will retire, taking all the expertise they have gathered over the years with them. There needs to be a program to instruct new, younger hires in the skill set and knowledge required to work with some degree of success on the older equipment that is still in use. Without such a program in place, a steady increase of downtime and frustration on the part of the operator or mechanic will be evident. The days of "take your time and learn it" are gone, replaced by the fast-paced production line where seconds count and operators need to know exactly what has to be done and how to be able to do it competently.

A single point lesson is invaluable for accomplishing this transfer of knowledge to the newer, less experienced operators. But take it out of the TPM context and it now can be several pages long, while still focused only on the one aspect of the operation that has proved itself over time to be a matter of conjecture on exactly how it should be performed or how the equipment should be set.

Writing an SPL with a degree of accuracy first begins with a talk with a supervisor to determine if the company already has a procedure for the applicable task that can be done efficiently and still be safe. If none is known, move on to the operators who perform that task. Ask how they do it and record their method completely. After talking with the operators and watching them all perform the task, talk with maintenance to see what the operator's manual has to offer. If you are seeing just some steps from the manual being performed by the operators, this is a good thing. It is a case of tribal knowledge being verbally passed down to new operators and something always being left out or changed in the teaching is common. Once a decision is made on standardizing a single operation, ask a maintenance and operations supervisor to verify it to be correct and complete.

Pictures are a universal language. Take pictures of critical steps in the lesson (e.g., screenshots or pictures of controls). These can be invaluable to operators who use English as a second language.

Writing the descriptions for the steps in the lesson can be challenging. They need to be written clearly, using words that are easy to understand, and be short in explanation and to the point. The last thing you want is unnecessary verbiage in a description that might confuse the reader in understanding what you are trying to get across to them.

When designing the page, do NOT make it all technical. Remember, your audience are operators, not engineers. Design the page in a manner that is easy to follow and understand. If necessary, take the lesson from applying your lockout-tagout (LOTO), by using a sequential, logical progression through the entire single point lesson. Remember, it is called a single point lesson for a reason, so only focus on that one particular task or aspect you want to achieve. You should be able to give the written SPL to anyone to follow and, if written correctly, will result in the optimum outcome.

When you are satisfied with your SPL, give it to a supervisor for a test run with a group of operators. If all is well and no further value-added information needs to be included, print copies for every operator and go over it with them to be sure they understand it. Laminate one copy to be left on the machine, either attached to it or placed in a binder that is kept by the machine for reference.

Given time, this method will begin to standardize all aspects of a machine's operation. It will decrease downtime, eliminate personal preferences and ensure optimum settings and methods are in consistent use.

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Lifelong Learning:

A New World for Asset Management Training

by Darrin Wikoff and Shon Isenhour

In a recent research study of the asset management landscape conducted by Reliabilityweb.com, 90 percent of survey participants communicated that their asset management strategy is directly linked to their organization's ability to achieve economic goals. Forty-four percent said they have an asset management policy they plan to implement in the next 12 months, but 40 percent said organizational culture would be a major obstacle. Finally, 43 percent told ReliabilityWeb.com that asset management training in 2014-2015 is critical to their ability to drive short-term results.

As reported by the Bersin by Deloitte (formerly Bersin Associates) report, "The Corporate Learning Factbook 2013: Benchmarks, Trends and Analysis of the U.S. Training Market," mature industrial companies still focused on creating an adaptive and competitive organizational culture spend between $700 and $800 per competency – a set of skills like performing root cause analysis – per employee. This is nearly half the pre-2008 $1,300-$1,500 budgets. Learning and development professionals agree that the training focus in industrial sectors is no longer on continuing education, but instead on lifelong learning in order to scale skills at the pace of improvement while maintaining a reasonably low cost per employee.

Since 2010, medium-sized companies (1,000-9,999 employees) are spending less than 28 percent of their training budgets on public, instructor-led classes as their sole source of skills training. Lifelong learning shifts the organization's focus from singular continuing education events, like a public training class, to a behavior-based professional development model that grows as the organization's needs grow.

Asset management plans created as a result of ISO55000 will most certainly challenge existing skills and may require the introduction of new core skills or advancing skills – competencies that are intended to be used in the future as organizational maturity and strategic needs evolve. Once the management plans, associated technology, practices and systems have been defined, professional development planning begins with the selection or development of basic education requirements.

Can training be an effective tool used to drive business transformation short term?

Here's how lifelong learning works:

Basic Education Requirements outline the learning objectives and formal qualifications that each role must demonstrate in order to execute the desired management plans. Instruction in core skills is most effective when delivered face-to-face and incorporates opportunities for simulation and hands-on learning to bridge the gap between theory and practical, relevant application. The design of curriculums is less abstract and more focused on providing what the employee needs to know in order to demonstrate the desired skill. Skills are defined based on role responsibility and their connection to the asset management plans, in turn making the success of each management plan the measure of Level 1 training success.

Continuing Education Requirements are what most think of in regards to training in industrial spaces. As adults, we have become accustomed to the term so much that there is little accountability for achievement. It's just ongoing, so what's there to achieve? Continuing education requirements in mature learning organizations that routinely demonstrate an ability to rapidly adapt new skills and practices are often associated with higher education institutions, such as state universities or local community colleges, in order to reach a larger group of professionals and leverage lessons learned from other local industrial companies. Continuing education in the lifelong learning model maps organizational challenges, such as resolving a chronic asset-related problem, or features courses designed to teach the techniques that are meant to resolve the problem. At this level, it is common to see a blend of instructional methods emerge that requires very little time away from the learner's core role and begins to utilize social media, webinars and virtual classrooms to engage students in scenario-like discussions. Continuing education should refresh infrequently used core skills while driving application to a known problem within the business or management plan.

What level of effort and investment must an organization make in order for training to effectively drive organizational change?

Practical Application Requirements create opportunities for the application of knowledge in the work environment. The U.S. Navy, and many craft skills training organizations as a result, refer to this level of instruction as PAR. Who better to replicate when developing an asset management training model than the world's largest asset management company, the U.S. Navy? This lifelong learning level is designed to provide systematic, programmed opportunities for each learner to demonstrate proficiency in a single learning objective or skill. Similar to on-the-job (OJT) training, the learner accomplishes a specific task under the watch and supervision of a more experienced colleague. To advance the learning in this phase, the colleague must be proficient enough to facilitate an immediate evaluation of the skill being performed and provide coaching to enhance the learner's ability to reapply the skill correctly. Practical application requirements are especially valuable for learning skills that may be used infrequently or when a significant period of time has passed after basic education. The objective of PARs is to encourage skill application and proficiency beyond simply task qualifying the learner, which often can be done in a classroom setting. PARs should be measureable and to ensure a greater success rate, it is recommended that training plans incorporate on-demand eLearning modules less than 10 minutes in duration to refresh core concepts prior to skill application.

Personal Learning Environments are one of the greatest breakthroughs in adult education. They began initially many years ago as communities of practice, constructed out of sheer necessity to engage cross-functional teams in problem solving and continuous improvement activities. Today, the model has evolved in an effort to virtually pair together learners with industry and subject matter experts to advance the collective body of knowledge and increase the rate of new skills in tune with the rate of organizational improvement. Today's innovative learners are engaged in multiple personal learning environments based on the variety of role responsibilities, the speed of change within their organizations and the abundant availability of social media outlets. Advancements in learning technologies, referred to as Tin Can, stretch our ability to measure and record learning in these environments. Whether it's YouTube, Facebook, Vimeo, or even Outlook, learning happens everywhere and collecting experiences in order to grow from them is the most powerful way to accelerate change.

What level of effort and investment must an organization make in order for training to effectively drive organizational change? By using a blended learning approach, as described by the lifelong learning model, that requires no more than 30 percent instructor-led training, it would be realistic to budget between $700 and $800 per skill or competency, per employee. For example, training a crew of 20 technicians to identify asset-related risks and deploy asset management plans using traditional techniques, such as criticality analysis, planning and scheduling, condition monitoring best practices and failure mode and effects analysis, would cost nearly $150,000 if fully administered using only the face-to-face classroom. This estimation assumes a cost per technician of $1,495 per class and that these skills can be taught in five instructor-led classes. For close to $96,000, the lifelong learning model ensures that these same 20 technicians understand the core concepts, provides a structured approach to apply these same techniques with the help of a coach and provides a virtual group of problem solvers to help them overcome obstacles when applying these skills. The cost of this level of effort is based on six competencies at $800 per competency, per person.

Can training be an effective tool used to drive business transformation short term? Absolutely! Focusing the learning process on the specific skills required based on asset management plans and reinforcing those skills through hands-on coaching, virtual learning communities and web-based forums will certainly accelerate an organization's ability to drive change.

4 Levels of Lifelong Learning

1. Basic education to acquire the formal qualifications and core skills.
2. Continuing education offered by higher education institutions to refresh core skills.
3. Practical application requirements that include on-the-job coaching and performance feedback.
4. Personal learning environments or self-directed learning using online applications to advance the knowledge base.

Download Reliabilityweb.com's Research Report on Asset Management Practices, Investments and Challenges 2014-2019: www.reliabilityweb.com

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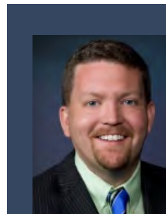

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2015 Revisions to NFPA 70E & CSA Z462

Change: The Only Constant

by Tim Rohrer

"The only thing that is constant is change."
-- Heraclitus (500 BC)

There are a few universal truths in life:

- The sun will rise in the east every morning.
- There is nothing in the world as cute as your baby… except maybe your dog.
- Politicians will always disappoint us… always.
- And, just when you think you really know the latest revision of a standard, the new revision is ready for print.

And so, the world turns. As new research is conducted, old topics debated and best practices refined, the world's most influential electrical safety standards evolve to keep pace. And now, sometime before the golf season ends and deer season begins, NFPA 70E and CSA Z462 are set to release their latest revisions.

The following is a brief summary of some of the more significant changes and evolutions with some insight regarding the reasons for the revisions. This overview is *not* intended to be all-inclusive, nor is it intended to be a replacement for reading the standards in their entirety. At best, it is an attempt to provide readers with an indication that they will need to:

(A) Purchase a copy of the new revision,

(B) Study the modifications to the text,

(C) Consider how the changes might influence their documented electrical safety programs.

It is also important to note that the changes anticipated herein are based on the most recent drafts and final committee balloting, however, the final revision could differ based on the results of final edits, approvals and votes that could affect the final text.

(Note: Because CSA Z462 is harmonized with NFPA 70E and the differences are minimal, this article will focus primarily on NFPA 70E.)

Concepts of Hazard and Risk

The 2012 revision of NFPA 70E and CSA Z462 made several changes to separate the concepts of hazard and risk. The two concepts deserve to be separate and are, in fact, distinct concepts in other occupational heath and safety (OHS) standards. The 2015 revisions of NFPA 70E and CSA Z462 continue this effort to separate and clarify these important, foundational concepts.

Hazard, hazardous, risk and risk assessment have all been added to the *Definitions* section, further delineating and separating the use of those terms.

Whereas a *hazard* is the source of potential injury or damage to a worker's health, *risk* is a combination of the *likelihood and potential severity* of that injury.

Consequently, any references to the hybridized hazard/risk categories (HRC) have been replaced with the more accurate and descriptive personal protective equipment (PPE) category.

The various forms of hazard analyses have been changed to risk assessments, which:

- *Identify* the hazard(s),
- *Estimate* the potential *severity* and *likelihood* of injury/harm,
- Determine what, if any, *protective measures* are appropriate.

These changes might not appear significant at first glance, but they are significant in the way they bring these standards in line with other safety standards. And as you will see, they have a great deal of impact on the task tables in NFPA 130.7(C)(15).

Other Global Changes

The term *harm* has been clarified to read, "injury or damage to health." Because *probability* has the connotation of a mathematically derived calculation, the 2015 revisions of 70E and Z462 will refer to the "likelihood" of an event.

In a continuation of the effort from the 2012 revision, all references to flame resistant (FR) are changed to arc resistant (AR). It is an important detail that seeks to eliminate any potential confusion with regard to PPE that is appropriate for use around a potential arc flash hazard.

Scope

Traditionally, the scope of NFPA 70E has seen very few changes over the years. This cycle, however, brings about a few notable exceptions. For consistency with related standards and industry best practices, and to emphasize the importance of safety-related maintenance and administrative controls (e.g., training), the revised scope will also include safety-related maintenance requirements and other administrative controls. The committee also added an informational note warning that the highest risk of electrical-related injury "for other workers involve unintentional contact with overhead power lines and electric shock from machines, tools and appliances…" The addition of this note to the scope continues the efforts to emphasize that electrical safety is something that affects workers across the organization, not just the electrical group.

The most significant change to the scope, however, resulted from a Mine Safety & Health Administration (MSHA) decision to accept the NFPA 70E standard in much the same way that OSHA does, making it a de facto electrical safety standard for the mining industry. Consequently, the exemption for mining applications previously found in the scope [Section 90.2(B)] will be removed in 70E-2015.

Prohibited Approach Boundary

The prohibited approach boundary (i.e., the distance from a conductor that was considered the same as making contact) has been eliminated from the definitions after some interesting debate.

Those who advocated for its continued inclusion in the standard generally thought that it underscored the difference between working in contact with the conductor versus working in proximity that would require shock protection.

The committee determined that previous changes to the standard have made the prohibited approach boundary obsolete since it no longer triggers any behavior on the part of the worker or manager. Generally speaking:

- The limited approach boundary defines the boundary for unqualified workers.
- The restricted approach boundary defines the area in which qualified personnel are required to utilize PPE to prevent shock.
- The arc flash boundary defines the area where arc resistant PPE is required.

But the prohibited approach boundary had no actual instructional value within the standard and no requirements associated with it. It had essentially become an answer to a trivia question. The committee ultimately decided that the term added a layer of complexity and was a possible source of confusion without actually adding any direction to the user.

Maintenance and Your ESP

The *electrical safety program* (formerly 110.3) is being moved to the beginning of Article 110, *General Requirements for Electrical Safety-Related Work Practices*, to provide clarity since the implementation of an electrical safety program (ESP) would naturally be the first element of the section an employer would address, followed logically by the other section considerations, such as training, relationships with contractors, etc.

As with the 2012 revision and as seen earlier within the scope, maintenance is once again being placed front and center as a keystone of electrical safety. After the mandate that the employer must implement an ESP, the first consideration listed [110.1(B) *Maintenance*] is that the ESP must give consideration to the equipment maintenance.

Because improperly or poorly maintained electrical equipment can result in failures and longer clearing times, personnel safety is directly affected by the condition of the equipment in their proximity. It only makes sense that the standards would continue to focus attention on the condition and maintenance of the equipment. This will be evident again in the task tables in Article 130.

Auditing and Training Intervals

Auditing the ESP [110.1(I)] will continue to be required at intervals of three years or fewer. But the audit of field work to verify that workers and managers are following the ESP procedures now will be required at least annually. Previously, there was no prescribed interval.

Annual auditing of field work actually brings the section in line with various training intervals required in Article 110.2 (*Training Requirements*) of the standard. The annual training or refresher is required for aspects of emergency response training, including contact release, CPR and AED, as well as for training verification.

Normal Operation

Do you wear a full bomb suit when plugging in your laptop or walking past a motor control center (MCC)? Then you will be very interested to learn about the normal *operations* clause to the *Energized Work* [130.2(A)] section.

Past revisions added informational notes to indicate that enclosed electrical equipment that has been properly installed and maintained and is under normal operating conditions is "not likely" to pose a hazard. NFPA 70E-2015 will move this concept to the body of the standard, giving the reader clear direction that *normal operation* of equipment will be permitted as long as the equipment is properly installed and maintained, doors and covers are closed and secured, and there is no evidence of pending failure. These points are echoed in the task tables in Article 130.

Energized Electrical Work Permits

The requirements around *energized electrical work permits* (EEWPs) have been loosened and clarified. No longer are the *limited approach boundary* or the *arc flash boundary* triggers for requiring an EEWP. Instead, the permits will be required when working inside the *restricted approach boundary* and, as previously, when conductors are not exposed, but there is an increased risk of injury due to arc flash.

The *exemptions to work permit* also saw clarifications. As before, a permit is not required for testing and troubleshooting. Thermography, visual inspection, general housekeeping, access and ingress with no electrical work are all exempt when done outside the *restricted approach boundary*. An exemption also exists for tasks that a risk assessment determines has no arc flash hazard.

Selection of Arc Flash PPE

The committee has added additional language to stop the all too common practice of mixing the method of selecting appropriate PPE. Users may use either the *incident energy analysis* method or the *arc flash PPE selection categories* method (formerly referred to as the hazard/risk categories method), **but not both** on the same piece of equipment.

Furthermore, sites that perform an *incident energy analysis* to generate the arc flash hazard analysis labels are not permitted to compare the calculated cal/cm^2 value to the arc flash PPE levels from the tables and then list the *arc flash PPE level* on the labels. Instead, PPE selection based on specific cal/cm^2 requirements would be appropriate.

Similar restrictions are repeated in the labeling requirements, stating that the incident energy or PPE category can be listed on the labels, "but not both."

No "Bling" Zone

Jewelry wearers take note: The standard has clarified an ambiguity with regard to when conductive articles, such as watches, necklaces, etc., can be worn. Quite simply, leave the bling in your locker when you are going to be working within the *restricted approach boundary*.

Arc Flash Hazard Identification Table

Gone are the traditional hazard/risk category classification (HRC) tables. The former table method for selecting PPE was based on classifications of equipment, which, in turn, is based on the voltage, available fault current, clearing time and minimum working distance, and the risk associated with the task. Consequently, lower risk tasks required less PPE than higher risk tasks despite the fact that the thermal energy produced in an arc flash incident is in no way affected by the risk of the task. The potential result was a worker being under protected.

It is worth pointing out that there has been no evidence to indicate that workers have been injured as a result of being under protected when using the table method. However, the potential was there and the committee addressed the potential issue proactively.

The new table method for PPE selection separates the tasks and arc flash PPE selection into two discrete tables.

The new *task table* identifies whether the task requires arc flash PPE. The determination is based on whether the task increases the risk of triggering an arc event and whether the equipment condition should be trusted using the same criteria as that under *normal operation* (i.e., properly installed, properly maintained, covers secured, no evidence of impending failure). The *task table* combines the previously separate AC and DC tables into one table.

After the *task table* indicates that the task or equipment condition requires personnel to utilize arc flash PPE, the user is instructed to consult the *arc flash PPE categories* table to determine what level of PPE is required. PPE requirements are based on the equipment parameters similar to previous revisions (i.e., voltage, available fault current, clearing time and working distance). Whereas, previous revisions listed various levels of PPE for a category of equipment, now there is simply one level of PPE prescribed for each category of equipment.

Arc flash boundaries is a new column in the *arc flash PPE categories* table. The *arc flash boundary* has been rounded up to the nearest foot for equipment falling into Category 2 or higher. Gone is the column indicating the requirement for rubber gloves. Similarly, the column for insulated tools no longer exists, but the *Insulated Tools and Equipment* section was modified so the trigger to utilize insulated tools is now the *restricted approach boundary* as opposed to the *limited approach boundary as with the 2012 revision*.

PPE Category 0

Category 0 PPE, formerly HRC 0, is no longer listed in the PPE tables.

Because users only consult the *arc flash PPE categories* table when they require arc flash PPE, any PPE listed in the table would have to be arc resistant. The former Category 0 was not actually arc resistant since the cotton could ignite, it simply didn't melt. Eliminating Category 0 ensures that personnel who are at risk of encountering an arc flash will be dressed in materials that are arc resistant, which Category 0 never was.

One common complaint that people have with the elimination of Category 0 is that personnel will see it as a green light to begin wearing meltable fabrics when working with electrical applications. However, it should be pointed out that a facility's ESP can require personnel to wear more conservative attire by making it part of its ESP and site-specific policies. Furthermore, there are numerous references to the prohibition of wearing meltable fabrics as or with PPE.

Thermography

The task of performing infrared thermography outside the *restricted approach boundary* does not require the use of arc flash PPE, as long as the equipment is properly installed and maintained, with secured covers and no impending failure. This will make performing infrared (IR) scans far more comfortable and easier for those who do not yet have IR windows to make the task safer and more efficient.

However, there are two important points to be made:

1. If for any reason the equipment condition is suspect (e.g., not properly installed, not properly maintained, covers not secured, or evidence of impending failure), the thermographer would need to wear appropriate arc flash PPE.
2. The workers who are opening the hinged doors or removing bolted panels to expose the conductors for the thermographer's inspection are engaged in an inherently high-risk task, one that could trigger an arc flash event. Therefore, the workers who are opening the equipment still need to wear PPE appropriate to their potential exposure.

Barricades

A clarification was also made with regards to barricades. They are to be placed at the distance defined by the *limited approach boundary* or the *arc flash boundary*, whichever is greater.

Safety-Related Maintenance Requirements

NFPA 70E-2015 and CSA Z462-2015 consistently bolster references to maintenance and continue to drive home the importance of properly maintaining electrical equipment as an integral aspect of electrical safety. As indicated earlier, the electrical safety program must now give consideration to equipment maintenance and, for the first time, users of the tables are required to consider equipment condition as part of their arc flash risk assessment. Maintenance is truly taking center stage in the 2015 revision.

Article 200: Safety-Related Maintenance Requirements continues that emphasis. A new informational note refers readers to the Institute of Electrical and Electronics Engineers' IEEE 3007.2-2010 *Recommended Practice for the Maintenance of Industrial and Commercial Power Systems*. Then, under *general maintenance requirements*, it makes the point that the equipment owner or its representative is responsible for maintenance of the electrical equipment.

A new informational note was also added to suggest a system of labels to indicate calibration, condition and inspection status, again providing the worker with critical information about condition and maintenance.

Finally, an informational note was added to point out that improper maintenance of protective devices can result in increased clearing times, which results in higher incident energy.

Conclusion

This latest revision to NFPA 70E contains several changes that are significant enhancements for safeguarding workers who may encounter electrical hazards on the job. The committee's members should be applauded.

There is no substitute for studying the standard in its entirety. This summary is not an all-inclusive detailing of the standard. Anyone who works with electricity or who manages those who do are strongly encouraged to purchase and study this important, life-saving standard.

Tim Rohrer is Founder and President of Exiscan LLC, a manufacturer of industrial electrical safety products including infrared windows, visual inspection windows and ultrasound ports. Tim has over a decade experience in the predictive maintenance industry and is a Level 2 Thermographer. He is a member of IEEE Industrial Applications Society, a committee Chair for the IEEE IAS Electrical Safety Committee and a committee Chair for the IEEE IAS Electrical Safety Workshop. www.exiscan.com

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The Journey to Reliability Uncovers a 'Hidden Plant' Within the Walls

by Darren Booth

Those working in the field of maintenance know how important it is to the success of any organization to maximize reliability and minimize or eliminate unscheduled downtime. This can be a daunting task and often requires professional collaboration, a change in organizational culture, and the willingness and ability to make decisions that are not always popular.

Lubrication Engineers (LE) is no different than any other manufacturing facility in the world. It can only make a profit if it is producing quality product and shipping it to customers in a timely fashion. If the facility experiences unscheduled downtime with its production equipment, it causes a ripple effect throughout the entire operation. When this happens, the organization seeks to learn from it and get better to minimize the risk of it occurring again.

LE manufactures its own high-performance industrial and automotive lubricants in its 200,000-square-foot manufacturing and warehouse facility. Its products are distributed and used by companies all over the world (Figure 1). As a batch process manufacturer – as opposed to a continuous process manufacturer – LE is able to give each product an intensive care approach during the cooking and blending steps. It formulates its products to meet the needs of the application and not just to meet minimum specifications.

After the finished product is approved by quality control, the product handling department fills containers ranging in sizes from pint bottles to tanker trucks. Product is stored in three warehouses across the United States, which helps lessen the delivery times to customers in various regions.

All this may sound good, but LE is never satisfied with the status quo. The company works continually to maintain or improve mechanical uptime in order to provide quality product and reliable service to its customers. Seven years ago, LE had some challenges to overcome. The biggest challenge was the need to change the reliability culture in the entire facility. While LE was already very good at helping its customers improve lubrication reliability and mechanical uptime, the company knew it could do better in its own facility. The organization needed to walk the walk, not just talk the talk.

Advanced Lubrication Strategies Help Company Increase Uptime, Reduce Costs

Figure 1: LE distributes products to customers all over the world out of its warehouses in Wichita, Kan., Knoxville, Tenn., and Las Vegas, Nev.

LE needed to focus on managing its assets at a higher level than ever before. The company initiated plant-wide meetings to discuss reliability topics. Discussions focused on reliability in terms of how it relates to its employees, as well as its customers. LE determined that it could do better in its reliability efforts and save money by doing so.

Getting Started

The beginning of a reliability journey can seem overwhelming, but that is why it is so important to be patient and take one step at a time. Although it would seem easy for a company like LE to get started because it already partners with reliability-minded product and service providers, its reliability journey still sputtered, at best, in the early stages, even with this built-in advantage.

Top-Down Support

It was imperative that senior management recognized that good lubrication practices would protect assets and keep them generating products and profits, positively affecting the bottom line. LE also needed its leaders to place equal importance on both human and mechanical assets.

Figure 2: Continuing education is a priority, as evident by the many LE employees with advanced certifications.

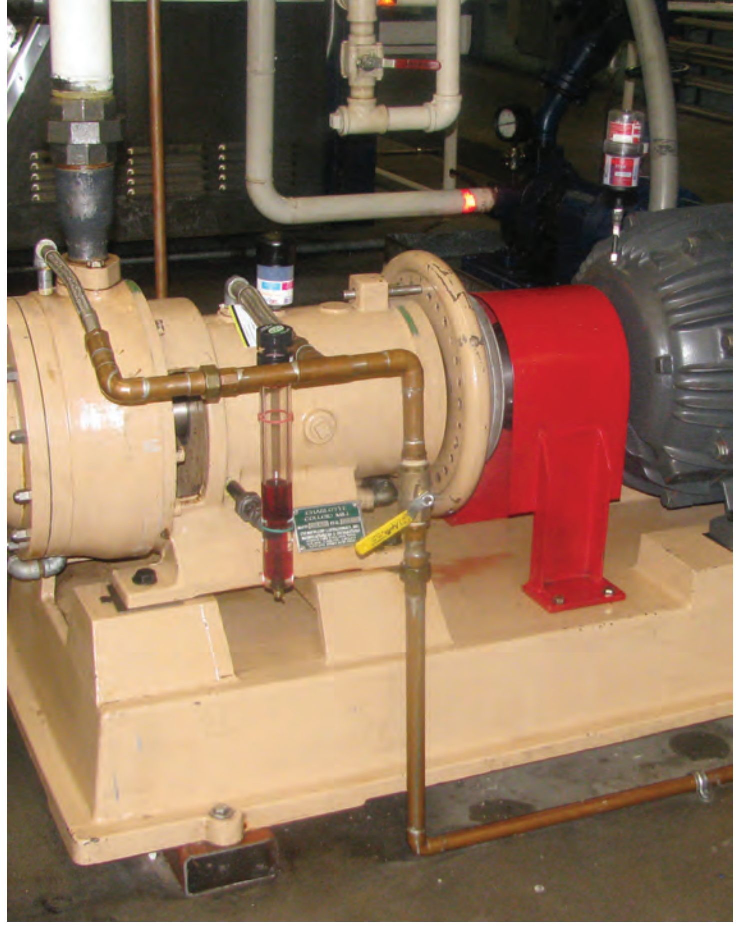


Figure 3: LE installed breathers and sight glasses on critical equipment to exclude or remove water and other particulates

Education & Training

LE chose to spend money on its people to get them the training they needed. The maintenance team and senior management attended maintenance reliability conferences and as many training opportunities as possible. Many were able to earn certifications, including Machinery Lubrication Technician Level I (MLT), Oil Monitoring Analyst Level I (OMA) and Certified Lubrication Specialist (CLS), which further increased their confidence and ownership of the process (Figure 2). They then began implementing what they learned into their operations.

Figure 4: LE's new lubrication system keeps lubricants clean and dry with filtration into and out of each tank, and everything organized and color-coded for a smarter, more efficient process

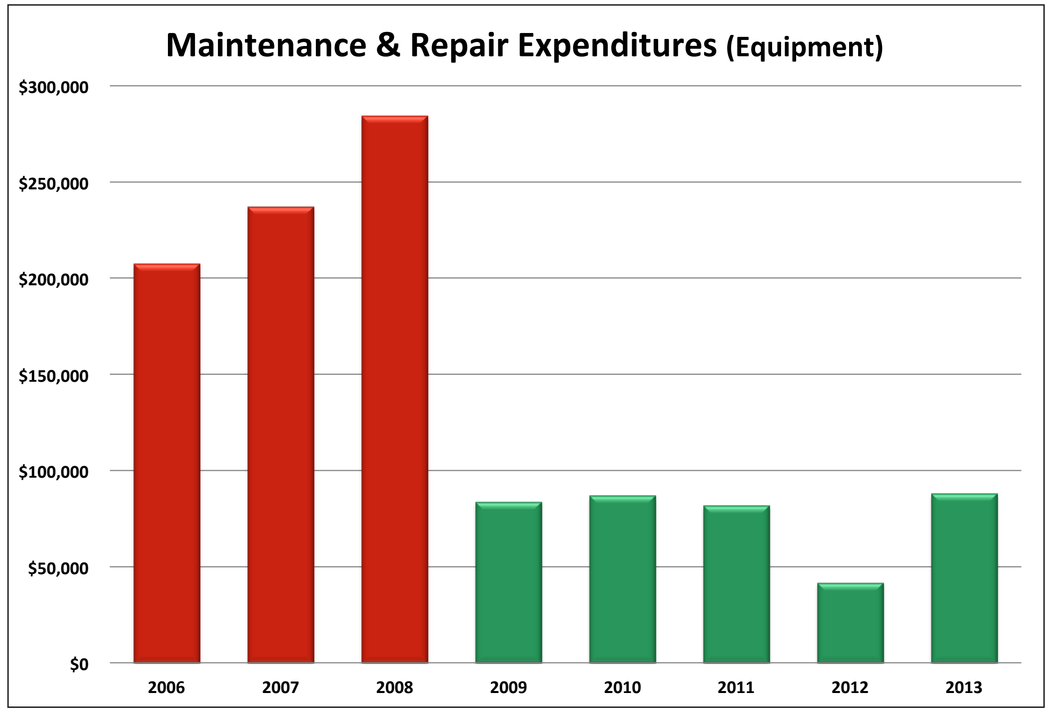


Figure 5: In five full years after implementation of its lubrication reliability program, LE's average annual expenditures on repairs and maintenance dropped 68 percent, from $243,000 to $76,000

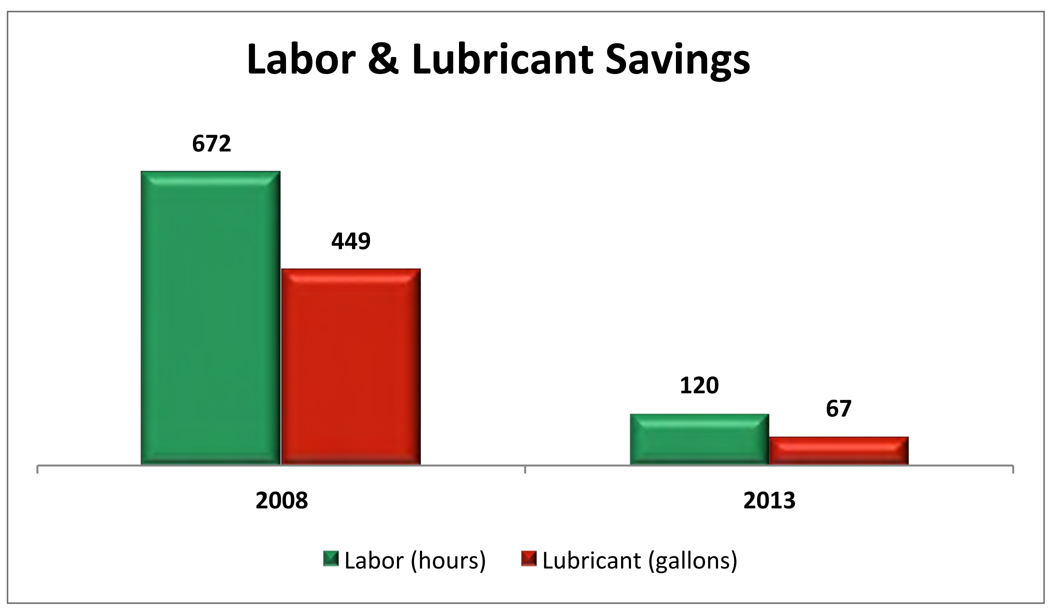


Figure 6: From 2008 to 2013, LE reduced lubricant-related labor hours by 82 percent and lubricant usage by 85 percent, which added another $21,000 in savings

Reliability Products

One of the first changes made was installing desiccant breathers and sight glasses on many of the assets (Figure 3). Top-down support was crucial for this investment to happen. It was understood and agreed upon that increasing the reliability of each asset would lower the total cost of ownership. LE later incorporated other reliability products, including automatic lubricators and filtration devices.

Computer System

As the workforce's knowledge level increased and reliability improved due to the small changes put in place, improvements began to accelerate. LE began looking into a computerized maintenance management system (CMMS) because, up to this point, maintenance reliability technicians were working from computer-generated asset cards to do lubrication activities. Maintaining this archaic system was not easy.

During its review of several CMMS packages, LE realized that a CMMS would be more time-consuming to implement than a simple computerized lube route system. At the time, the main goal was to quickly get a better handle on lubrication reliability practices, however, many of the CMMS packages reviewed did not incorporate lubrication, or their lubrication components would have been cumbersome to implement. After many discussions, LE came to the conclusion that adopting a CMMS system did not make sense at that time for its five person, one shift maintenance department. Having made this decision, LE was able to proceed more rapidly with the rest of its journey.

Plant Survey

LE's mechanical assets include 177 gearboxes and gear reducers, 119 electric motors, 51 pumps and 21 stirring vessels, as well as compressors and additional miscellaneous equipment. The entire facility was surveyed and each lubrication point on each asset was identified. This helped the facility visualize the amount and type of equipment it was performing maintenance on and gave it a blueprint to start managing the equipment more efficiently. This is a critical step in the process and should not be skipped.

Lube Room

Lubricants are the lifeblood of mechanical assets throughout any facility. LE regards them as assets, not consumables. In fact, LE looks at lubricants as its number one asset. Just like any other asset, lubricants need to be maintained properly and used properly for specific applications. A well-equipped lube room will protect these fluid assets so you can sleep at night.

LE purchased a new lubrication storage system and created a dedicated lube room (Figure 4). This made it evident to all employees that the company was serious about reliability. The maintenance team took ownership of this new lube room and storage system, and they are very proud of it.

Figure 7: With top-down support, the five-man maintenance crew at LE took ownership of the changes and embodied the new, stronger reliability culture

This created momentum in the lubrication reliability journey, which became increasingly evident as the maintenance team began to think of more ways to improve machine uptime.

Lubricant Identification

All lube points were tagged according to product number and color-coding that matched the storage system tanks was implemented. This helped make lubrication a smarter, more streamlined process for the team and it raised the knowledge level of each team member.

Lube Route Software

After a search of available software solutions, LE purchased lubrication reliability software to manage all its lube tasks. The quick turnover to this system enabled LE to keep its mechanical assets running and minimize downtime. With the software, LE was able to assign lubrication routes and schedules to team members who took ownership of the process to ensure "their" equipment was maintained properly.

The software significantly improved LE's ability to manage the lubrication of its mechanical assets and helped the facility organize its approach to handling maintenance activity.

Results

By implementing all these steps on its reliability journey, LE has seen a major reduction in the cost of equipment repairs and maintenance. From 2006 to 2008, LE documented an annual average expenditure of $243,000. In 2009, the first full year after lubrication reliability changes, this annual number dropped dramatically to $83,000. LE spent an average of $76,000 annually in the five years since the program was implemented on repairs and maintenance of equipment (Figure 5).

Using condition-based monitoring and oil analysis, LE also drastically decreased its oil usage. From 2008 to 2013, annual lubricant usage dropped from 449 gallons to 67 gallons, for a savings of more than $11,000.

Reducing lube change-outs, as well as repair and maintenance tasks, contributed to significant labor savings. In 2008, 672 hours of labor were dedicated to maintenance and repair tasks; in 2013, that dropped to 120, for a savings of nearly $10,000 (Figure 6).

Looking back, the main drivers that helped LE on this journey were:

- Supportive top-down leadership;
- Willingness to invest equally in both people and mechanical assets;
- Detailed plan of attack;
- Patience (organizational stamina);
- Quantification of results.

With similar drivers in place, your organization can achieve the same positive results. The most important thing to do is take that first step and get started. Soon, you will be on your way to finding the hidden plant within your facility.

Software System Gets Lubrication Right Every Time

It is critical to get the right lubricant in the right place at the right time using the right procedure or technique – every time – to ensure equipment reliability.

And yet, many companies still rely on the all too fallible memory of employees. Other companies turn to spreadsheets or computerized maintenance systems. These systems are effective, but don't provide detailed tracking and streamlining of lubrication tasks and costs.

Performing lubrication seems elementary, but can be quite complex when you consider that a single plant can have thousands of pieces of equipment, multiple lubrication points per piece of equipment and multiple activities per lubrication point, each done at different intervals. From daily lubing to semiannual oil sampling to yearly tank draining, the required lube tasks can number in the hundreds of thousands per year. A software system dedicated to tracking, managing and documenting lubrication will cut costs, improve efficiencies, eliminate guesswork and extend the life of plant equipment.

A lubrication reliability software breaks the cycle of reactive maintenance, frees up time and resources, helps ensure the success of other maintenance initiatives (e.g., vibration and infrared), minimizes capital equipment replacement and helps companies do more with less.

A software system takes responsibility for hundreds of thousands of lubrication tasks annually, essentially ensuring that none are left behind. Each week the software generates a list of tasks for each route so lubrication responsibilities are always known. These lists can be synchronized to mobile devices and contain full details for each lube point, including precise location and the quantity and type of lubricant to be applied.

***Darren Booth,** CLS and vice president of Manufacturing Operations, has worked for Lubrication Engineers, Inc. for 25 years. Darren currently oversees plant operations, consisting of manufacturing, product handling, traffic and maintenance. Through his role in helping implement lubrication reliability throughout the operation, he has been a catalyst in lowering LE's total cost of ownership of its mechanical assets. www.LElubricants.com*

3 Keys to Improved Bolted Flange Joint Integrity

"That all important clamping force which holds the joint together — and without which there would be no joint — is not created by a good joint designer, nor by high quality parts. It is created by the mechanic on the job site, using the tools, procedures, and working conditions we have provided him with . . ."

"The final, essential creator of the force is the mechanic, and the time of creation is during assembly. So it's very important for us to understand this process."

—John Bickford, "Handbook of Bolts and Bolted Joints"

by Michael Kessel

In 2008, *Pumps & Systems* magazine published an article by Jim Drago of Garlock Sealing Technologies that reviewed 100 failed gaskets in a variety of industrial applications. Of the 100 failures, 68 were attributed to under compression and 14 to over compression. These results point directly to the importance of the informed mechanic and the availability of tools to execute flange assembly according to best available practices.

In 2010 and 2013, the American Society of Mechanical Engineers (ASME) updated its PCC-1 Guidelines for Pressure Boundary Bolted Flange Joint Assembly. The document is geared toward maintenance engineers and doesn't easily translate into a mechanic's field manual. There are, however, a few general guidelines that will contribute greatly to achieving improved bolted flange joint reliability.

ASME PCC-1 Joint Component Approach

Every component of a bolted flange joint has a *maximum* allowable stress level. The mating flanges will begin to rotate or warp at a defined stress threshold. The studs or bolts of a given specification also will yield or be stressed past their elastic properties at a defined level. Non-metallic and semi-metallic gaskets will crush under excessive applied stress loads.

Likewise, gaskets and bolts or studs have a *minimum* stress level. For gaskets, it's the minimum force that will affect a seal. For bolts and studs, PCC-1 suggests 40 percent of yield, which is the lower end of the elastic range for most industrial fasteners. ASME suggests a target of 40 percent to 70 percent of bolt yield as a range for fastener preload.

The essence of the data provided by PCC-1 and borne out by the Garlock study suggests accurate bolt preload is the most critical element in reliable flange joint assembly. The elastic interaction between the flange, fasteners and gasket compensates for various forms of relaxation of all the components.

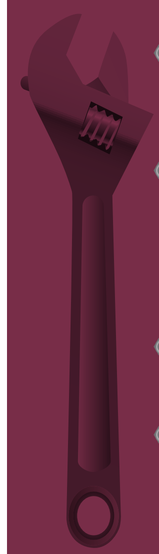
PCC-1 also suggests that the gasket manufacturer supply necessary data for proper stress levels for specific materials. Ultimately, with a little guidance, an acceptable range of bolt stress can be determined for a specific application. Once this range is defined, it's imperative to compensate for variables in the assembly process.

There are three keys to improving bolted flange joint reliability in the vast majority of industrial flange gasket applications where the turn of the nut method is used as the tightening procedure.

1 Measured Force

The most common method for achieving fastener preload is turn of the nut. This method is riddled with opportunities for variables in accuracy. Simply put, turning a nut radially to create axial stress along the bolt or stud is an exercise in overcoming several kinds of friction and resistance. Using hand, slug, or striking wrenches will result in huge variations in achieved stress. These methods by feel have proven to be highly inaccurate, largely dependent on the strength of the mechanic and the length of the tool's handle.

ASME PCC-1 has made recommendations on tightening methods in ascending order of accuracy. Implementing this hierarchy depends on the critical nature of the application and the practical nature of using certain methods to obtain preload. In most pressurized systems, the minimum acceptable method should utilize torque measurement.



ASME PCC-1 Recommended Tightening Methods

- Tightening with hand or impact wrenches. Hand wrenches are practical only for bolts approximately 25 mm (1 inch) in diameter and smaller.
- Tightening with hand operated or auxiliary powered tools with torque measurement. Hand-operated torque wrenches are practical only for bolts with an assembly torque less than approximately 700 nm (500 ft-lb).
- Tightening with tensioning tools that apply an axial load to the bolt with force measurement.
- Any tightening method used with bolt elongation (stretch) or load control measurement. Bolt materials and properties vary within bolt types and this must be accounted for when using these methods.

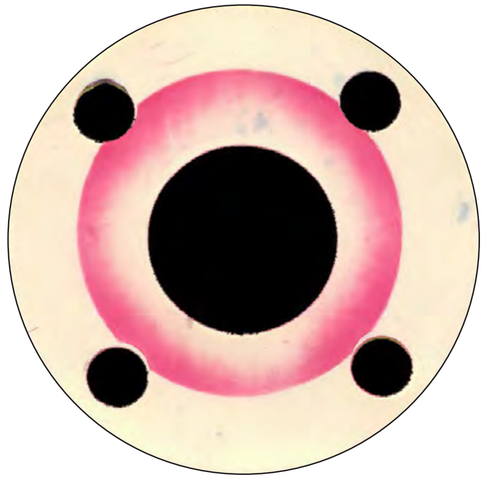


Figure 1: Pressure-sensitive film shows effective gasket stress in deeper shades of red; example utilizes hardened washers and shows uniform compression around the outside diameter of the gasket surface

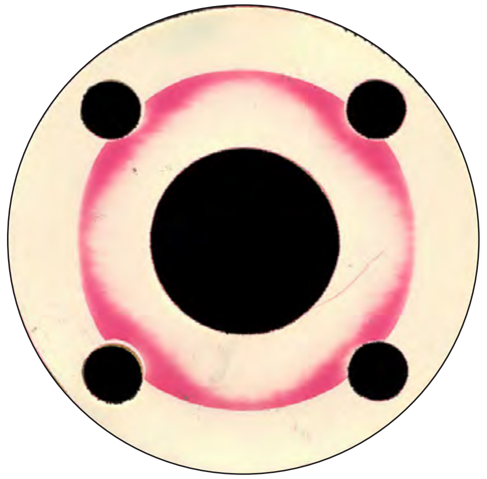


Figure 2: Using the same compressive force, the effective gasket stress is significantly reduced between the bolts when no washers are used; potential leak paths or failure points are clearly evident at the midpoint between the bolt holes

2 Through-Hardened Washers

As amazing as it seems, the function of the washer may be the most important component in bolted flange joint reliability. Overcoming friction through turn of the nut procedures is critical in terms of realized bolt load. The interface between the nut and the washer becomes a crucial bearing surface.

If a washer is not through-hardened, it is also susceptible to cupping, resulting in inaccurate torque readings versus actual bolt stress. Another benefit of using through-hardened washers is the prevention of the nut becoming embedded against the flange face, or with a nut flat embedded inside the bolt hole. This will result in a large variable between applied torque and actual preload.

Utilizing through-hardened washers also disperses the applied load of the fastener assembly across the face of the flange. This allows for more uniform stress applied to the gasket contact area and reduces potential leak paths of the contained media.

3 Lubricating Threads & Contact Surfaces

Friction is the enemy of accuracy in bolting applications. Significant variables exist between different types of lubricants and anti-seize compounds. Care should be used to select a lubricant that avoids contamination of the process system or oxidation to the hardware and flange assembly. Never apply any lubricants to the gasket contact area of the flange.

Table 1 - 14" 150# ANSI Flange Utilizing 1" A193 B7 Bolts (Klinger®expert program)

Friction (Nut Factor)	Target Bolt Stress	Required Torque
11	60.00%	484 ft/lbs
12	60.00%	522 ft/lbs
13	60.00%	560 ft/lbs
14	60.00%	599 ft/lbs
15	60.00%	637 ft/lbs
16	60.00%	675 ft/lbs
17	60.00%	713 ft/lbs
18	60.00%	751 ft/lbs
19	60.00%	789 ft/lbs
20	60.00%	827 ft/lbs
21	60.00%	866 ft/lbs
22	60.00%	904 ft/lbs
23	60.00%	942 ft/lbs

The benefit of pre-coated bolts is primarily to protect against oxidation. While they will assemble with reduced friction initially, coated hardware should be lubricated if reused.

Apply lubricants liberally after inserting the studs or bolts through the flange to avoid contamination. After assuring the nut rotates freely to the point of contact with the flange, apply lubrication to the stud threads and interface between the nut and washer.

The nut factor, also called the K factor or friction factor, is available from most manufacturers of anti-seize products. This factor has a large impact on the effectiveness of applied torque. Table 1 shows the variations in required torque using different friction factors. Imagine the effects of using rusty or non-lubricated hardware!

Summary

In general, ASME suggests tightening to a preload of 40 percent to 70 percent of bolt yield. If this is within the tolerable stress ranges of the flange and gasket, torque guidelines can be readily developed for the specific application. Accurately measured force using turn of the nut methods is crucial for improved reliability. However, torque readings can be misleading without using a known friction factor or through-hardened washers to reduce variables in the assembly process.

Developing a target stress level, measuring applied force when tightening, using through-hardened washers, and lubricating fastener threads and interfaces are protocols that should be used at every industrial facility in the world. Lost production, increased energy usage and downtime associated with gasket leakage and failure should override any expense of implementing these exceptionally simple procedures.

This article is limited to turn of the nut methods for a bolted flange joint assembly. Axial tensioning uses a vastly different procedure to attain bolt preloads, which are not applicable here. Ultimately, ultrasonic strain measurement and other more refined technologies allow for greater levels of bolted flange joint reliability. However, at the end of the day, measuring bolt stress is only an assurance of tightening accuracy, not a method of obtaining tightness.

These recommendations are taken from ASME PCC-1, 2010 and 2013. The ASME document contains a vast amount of non-mandatory recommendations that are not addressed here.

***Michael Kessel** is a 30-year veteran in the fluid sealing industry, primarily as a technical sales specialist and manufacturer's representative. During the past several years, he has concentrated on maintenance protocols as they relate to bolted flange integrity. Michael is the managing partner of Pro-Torc LLC and a regional representative for the TORC LLC line of hydraulic torque tools and accessories. www.protorc.net*

BLAME Complacent Engineers for Bad Management Decisions

by Heinz P. Bloch

Figure 1: Whatever the cause, the result is anguish.

Author's Note: While I'm solely responsible for this article, I am also entirely indebted to a process hazard analysis and loss control engineer (PHA/LCE) at a major refinery. In his contributed material, he is not disclosing anything of a proprietary nature. Still, it's a sign of the times that he has to remain anonymous. Perhaps it's because his expressions contain a measure of mild irony as he invades the comfort zone of equipment reliability engineers (REs). He quite obviously takes issue with their custom of limiting their work to mere analysis and recommendations. The REs, he notes, then consider their job done and let managers make decisions, some right and some wrong. This PHA/LCE alerts us to a stack of serious problems that can result from engineers' reluctance to pursue certain issues beyond just recommendations. He pleads with management to develop a challenge culture, a collaborative effort that benefits all sides.

A Defective Challenge Culture

In reality, management seldom understands what seems obvious to the technical staff. Try to reset your memory and recall the space shuttle disasters. In the first of two instances, canceling a launch was viewed as a multimillion dollar decision, one that only could be made if management thought they could explain their rationale to President Ronald Reagan, who would certainly give *them* (management) a courtesy call to find out why *they* (management) had canceled the launch and sent Christa McAuliffe home. But management didn't understand the information they were given. And because of their defective challenge culture, questioning it didn't help either. So, they launched the spacecraft. For as long as it takes to say, "See? We told you so!" the technical staff felt vindicated. But then the anguish set in over what they had allowed management to do. There can be no question that management would have acted responsibly on the information if they had understood it. Clearly, some agency or management group had failed to develop a healthy challenge culture. This is one of the reasons why seven (and, ultimately, 14) astronauts died.

We see this defective culture everywhere in industry today. It's easy to spot in news reports that portray the technical staff as the victim and management as the villain. We saw it on the deck of the Deepwater Horizon structure and a few years ago in the hallways of Apple Inc., where technical competence abounds. No reasonable person could be persuaded that Steve Jobs was a ruthless autocrat bent on intentionally releasing a defective phone despite the engineers' pleas to fix an antenna problem. Indeed, buying into the "deaf dictator scenario" just doesn't make sense.

Whatever the cause, the result is anguish

Tough decisions are tough for a reason. The reason is, well, because they are not *easy*.

We all have similar and parallel stories to tell about machines and other assets in major process plants. There have been incidents and near misses, and many of these are repeat events because of a defective challenge culture. As noted before, a defective challenge culture creates a deep chasm between management and technical staff.

Considering the potential process safety consequences that a defective challenge culture represents to the process industries, both engineers and managers should take time to reflect on the purpose of their respective job functions. Are you managers really smarter than your technical staff, just keeping them around for inflicting torture and throwing away money? Probably not. Like most managers, you recognize that the technical staff represents a certain skillset that you need to make good decisions. You expect them to protect you from making bad decisions that would interfere with your business commitments and objectives.

Shouldering Accountability

Reliability engineers must shoulder this accountability. You, the RE, expect management to act responsibly on the information you provide. But this may require reordering and rephrasing your information in ways that management can understand. (Remember, you more than likely have an intellectual advantage over them.) If management challenges your data, don't retreat or try to read between the lines. Request more time, if needed, to fine-tune your analysis and then make your case again. At the end of the discussion, both you and management should be satisfied that good engineering judgment has prevailed. Both sides must be comfortable with the decision and, remember, both sides share common accountability.

Good managers ask their employees to logically explain "concerns" and require follow-up to turn them into "non-concerns"

Tough decisions are tough for a reason. The reason is, well, because they are not *easy*. Easy decisions are usually straightforward enough so they don't need much technical support. In other words, even a manager can make them. A dedicated professional adds value by helping management convert a tough decision into the right decision. Thankfully, we are not left to our own devices in helping management understand the information they need to make the right decision. As a reliability professional, it's your responsibility to provide all pertinent information in a manner that others can understand. Others have done so long before you; they have mapped the way and described the tools. Do you have all the tools you need to help management wisely think through the tough decisions? Maybe it's time for you to do more reading, work with a mentor, or uncover other responsible ways of conveying to management the risk associated with allowing repeat failures, or whatever else that has the potential to cause anguish.

Accelerating Desperately Needed Change

Here, then, are action steps that good managers are, or should be, actively pursuing:

- Good managers insist that technical employees go beyond guesswork and always substantiate their concerns. In other words, good managers ask their employees to logically explain "concerns" and require follow-up to turn them into "non-concerns."
- The best managers abandon the destructive short-range-profit view and take a longer-range approach. Thus, they make conscious and consistent efforts for knowledge progression and successor planning. They keep their best technical employees from seeking employment elsewhere by implementing a dual ladder of advancement---one administrative and the other technical. They recognize that claims of always being able to hire an outside contractor may be true for your office interior painting and lawn care program, but are fallacious and untrue for many technical issues or disciplines!
- Top companies stretch the tenure of their in-house experts and future executives. In other words, cycling a talented individual through fourteen departments in five or six years is almost certain to produce extremely shallow areas of expertise and superficial thinkers. Good managers groom talent, not arrogant generalists.
- Top managers offset the benefits of past cultures with the need to forge a new culture. They will not allow employees to interact by way of a flood of e-mails alone. Good managers know that hours spent in posturing and responding to internal e-mail is rarely--if ever--adding value.

Indeed, then, better management is needed at many facilities to achieve long-term equipment reliability and its related plant profitability objectives. "Reliability initiatives" and similar pursuits will fail where there is no trained or highly experienced workforce. Claims that you can always hire a competent outsider are simply not supported by the facts. Competent outsiders are a dying breed, and the few that are left will not accept the pay that an unqualified individual will accept.

Plants where training is an afterthought, or where training is conducted by individuals whose "know-how" is simply not up-to-date, are unable to reach their true safety, reliability and profitability potential. Some of these trainers spend all too much time on discussing maintenance philosophies. What is needed are the explanation and implementation of discrete steps that must be taken on the component and work procedure level. Regrettably, only the very best facilities are implementing the right steps.

Finally, broad communication across functional disciplines is needed. Such seemingly autonomous groups as operations, maintenance, project, purchasing and reliability/technical can obviously affect equipment reliability, safety and profitability. However, none of these groups should ever be allowed to make far-reaching decisions without input from the various related (or affected) disciplines or functional areas. Holding people accountable is of extreme importance here. So, why not start with asking your reliability professionals to explain why the mean time between failures (MTBF) of pumps at your facility differs so much from that of the competition? Will you let these professionals guess or will you compel them to read? The answers are out there! Make your technical staff challenge managers by submitting solid facts and by mapping out logical remedial steps and intelligent alternatives. That's what one expects from medical professionals and should demand from one's equipment or maintenance-technical professionals.

***Heinz P. Bloch** is a practicing consulting engineer with over 50 years of advising process plants worldwide on failure analysis, reliability improvement and maintenance cost avoidance topics. He has authored or co-authored 18 textbooks on machinery reliability improvement and over 600 papers or articles dealing with related subjects. His two most recent books, "Pump Wisdom" and "Compressors: How to Achieve High Reliability & Availability," were published in 2011 and 2012, respectively.*

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Lubrication FMEA: The Big Picture

by John Cummins

Failure mode and effects analysis (FMEA) has been used for over 60 years to determine the cause and effect of equipment and process failures in an effort to improve equipment and systems reliability. The big picture of equipment failure modes is illustrated in Figure 1.

The global failure modes are:
- Obsolescence (10%)
- Breakage (10%)
- Surface degradation (80%)

The surface degradation causes are:
- Corrosion – Why we paint and use protective coatings
- Wear – Why we lubricate
    - Adhesive wear
    - Abrasive wear
    - Surface fatigue
    - Corrosive wear

Obsolescence at 10 percent appears to be growing with rapidly changing technology and increasing government regulations. Do you remember the U.S. government's Cash for Clunkers program? If you operate a coal fired power plant, can you see obsolescence on the horizon?

Breakage, also at 10 percent, is for the design engineers to use FMEA to determine how to handle today's increasing power densities and lighter weights while improving reliability in future process systems and equipment.

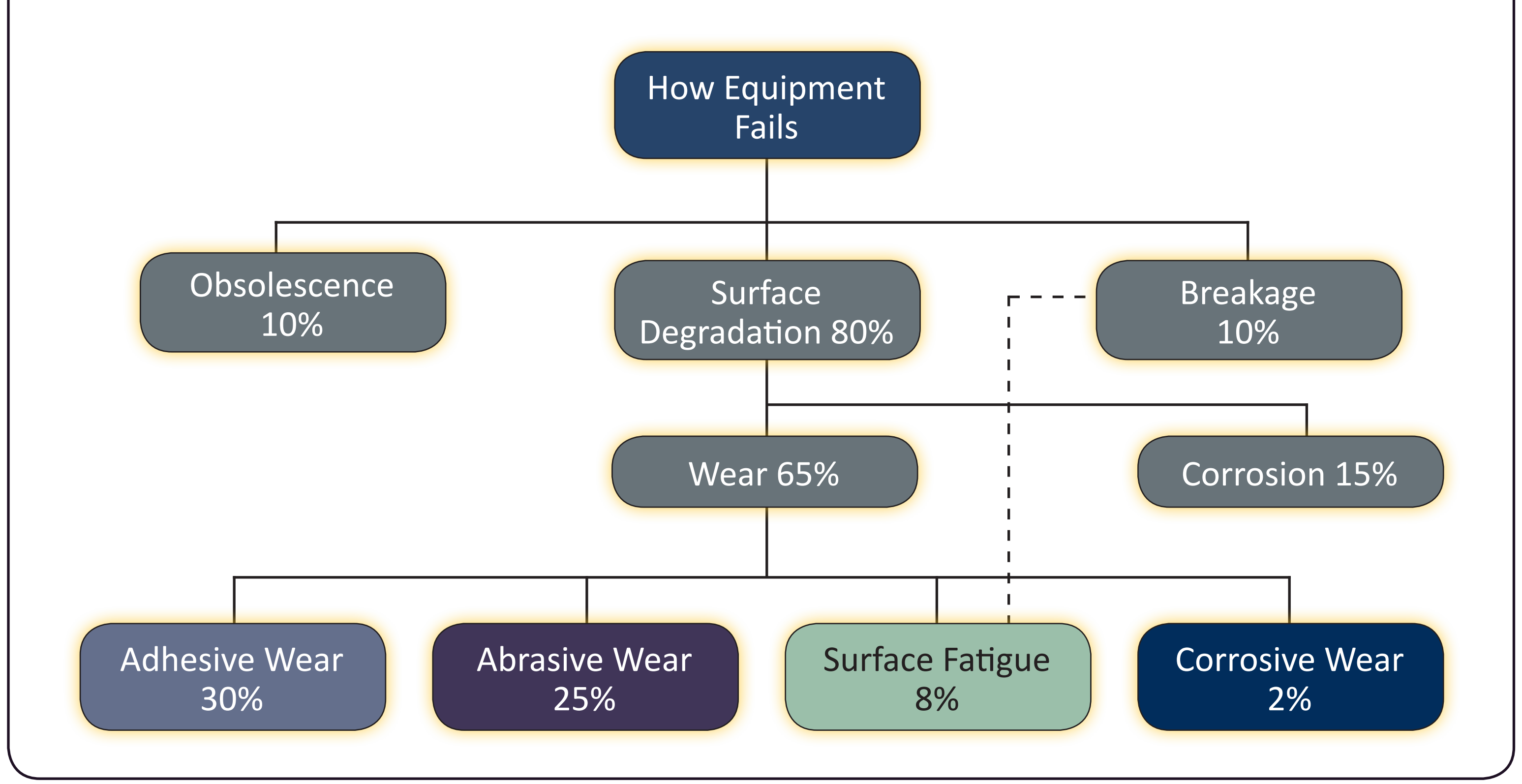
Surface degradation at 80 percent is further divided into wear at 65 percent and corrosion at 15 percent. With respect to lubrication, corrosion can be eliminated at this level because paint and protective coatings or stainless steel and other corrosion resistant alloys are used to protect equipment surfaces against environmental damage.

By eliminating 35 percent of the global failure modes, a Tribologist or lubrication engineer can focus on wear when using FMEA. If you don't have a lubrication engineer on your FMEA team, get one! Many organizations do not have an engineer with any formal training in lubrication or tribology – the study and application of the principles of friction, lubrication and wear.

Table Keys

SEV – severity factor on a scale of 0 to 10
OCC – occurrence factor on a scale of 0 to 10
DET – ease of detection factor on a scale of 0 to 10
RPN – the Risk Priority Number = SEV x OCC x DET

Figure 1: Equipment Failure Modes



Adhesive Wear

Adhesive wear is a direct result of metal to metal contact. Surface asperities contacting under load while sliding will generate heat, friction and wear due to insufficient or loss of the lubricating film. The range of adhesive wear can be as low as running-in wear with a poorly specified break-in oil up to catastrophic damage with surfaces welded together due to total loss of lubrication.

The most important physical property of a lubricating fluid is viscosity. Viscosity measures a fluid's resistance to flow as it relates to load, temperature and speed. Viscosity determines the ability of the lubricant to enter the contact zone of the moving surfaces and remain in the contact zone under the applied load for the necessary time to prevent metal to metal contact.

Today's equipment design engineers now see the lubricant as an integral component to improve reliability. That is why it is important to read the original equipment manufacturer's manual and review the recommended oils and greases. However, when an existing process or machine is being applied in a new way, any change to the operating load, temperature, or speed must be analyzed to maintain the proper oil film.

Figure 2: FMEA for adhesive wear

Function or Process Step	Failure Type	Potential Impact	SEV	Potential Causes	OCC	Detection Mode	DET	RPN
Lubricant Provides Correct Oil Film Thickness to Prevent Metal to Metal Contact	Mild Adhesive Wear	Component Runs Hot	3	Improper Lube Viscosity Selection for **Load, Speed, Temperature**	7	Measure Operating Temperature With Laser Thermometer or Thermography	1.4	29
Lubricant Provides Correct Oil Film Thickness to Prevent Metal to Metal Contact	Catastrophic Adhesive Wear	Component Seizes	10	Improper Lube Viscosity Selection for **Load, Speed, Temperature**	.10	Detect Noise, Heat and Smoke	1	1

Abrasive Wear

While the saying, "*cleanliness is next to godliness,*" does not appear verbatim in the Bible, it certainly needs to be a commandment for proper lubrication practices. Abrasive wear is caused by suspended hard particles in lubricants. These particles are a combination of wear particles generated by adhesive wear, dirt and other abrasive particles from the process or environment and, in some cases, from the degradation of the lubricant itself. Abrasive wear is why we use filtration and seals.

Never assume a new hydraulic system or piece of machinery is clean and never assume a new lubricant is clean. New machinery and systems must be flushed to remove contaminants that entered during manufacturing and assembly. If you want clean new lubricants, then you must specify the International Organization for Standardization's (ISO) cleanliness requirements for new lubricants and even then, use filtration to transfer the new lube from its container into the reservoir or sump.

Using dirty lubricants affects the entire system or machine because abrasive particles circulate throughout until they are filtered or settle in the reservoir.

Figure 3: FMEA for abrasive wear

Function or Process Step	Failure Type	Potential Impact	SEV	Potential Causes	OCC	Detection Mode	DET	RPN
Clean Lubricant (Low Particulate Count) Prevents Abrasive Wear Inside Machinery	Mild Abrasive Wear	Machine Internal Tolerances Increase Over Time	2	Improper Filtration Program for Machinery or Environment; Ruptured or Leaking Seals	7.5	Lube Elemental Wear Analysis and/or Lube Particle Analysis	1	15
Clean Lubricant (Low Particulate Count) Prevents Abrasive Wear Inside Machinery	Severe Abrasive Wear	Mean Time Between Failure Is Shorter Than Designed	10	Improper Filtration Program for Machinery or Environment; Ruptured or Leaking Seals	1	Filter Plugging, Magnetic Drain Plug	1	10

Surface Fatigue

Machinery components do not last forever; they have a designed life for their useful purposes. Premature surface fatigue is usually the result of over-speed or overload of the equipment, especially in the case of bearings and gear surfaces. Even in a perfectly lubricated bearing, if you double the speed, bearing life is reduced by 50 percent and if you double the load, the life is reduced by 87.5 percent.

We are a nation of tinkers and profit-driven to increase system production by making things faster (speed) or doing more work (load) in the same amount of time. By our own actions, surface fatigue has a dotted line impact on why equipment breaks.

Surface fatigue is extremely difficult to detect in operating systems because it is easily masked by catastrophic adhesive wear or catastrophic abrasive wear caused by large chunk spalling. Detection in operating equipment is difficult and typically requires partial disassembly and bore scoping by a trained technician, or direct reading ferrographic analysis of wear particles. In many cases, surface fatigue is only confirmed by complete machine disassembly and inspection of the failed component using magnetic, X-ray, ultrasonic, or scanning electron microscope devices.

Figure 4: FMEA for fatigue wear

Function or Process Step	Failure Type	Potential Impact	SEV	Potential Causes	OCC	Detection Mode	DET	RPN
Both Proper Operating Parameters and Correct Lubrication Achieve Designed Life of Equipment	Surface or Subsurface Damage Caused by **Overload**	Affected Component Life Is Reduced by 87.5%	9	Increasing Power Density Without Design Change or Purposely Overloading	.10	Bore Scoping, Ferrographic Analysis, Disassembly, X-ray, Magnetic, Ultrasonic or SEM	8	7.2
Both Proper Operating Parameters and Correct Lubrication Achieve Designed Life of Equipment	Surface or Subsurface Damage Caused by **Overspeed**	Affected Component Life Is Reduced by 50%	5	Speed or Rev Limiter Failure	.02	Bore Scoping, Vibration Analysis, Disassembly, Ferrographic Analysis, X-ray, Magnetic, Ultrasonic or SEM	8	0.8

Corrosive Wear

Over time, oxidation causes lubricants to become acidic. Acidic lubricants are responsible for most surface corrosion. This can be measured by the increase in the total acid number (TAN) of the used oil compared to the new lubricant's referenced TAN. In most cases, if the used oil TAN number is 2.5 higher than the new oil's referenced TAN, then the used oil is sufficiently acidic to cause surface corrosion. Oxidation reactions with the lubricant also cause internal deposits of gums, varnish and sludge. Surface corrosion caused by additive reaction is rare. It is generally found in additive reactions with copper or silver surfaces. This is easily detected using elemental oil analysis.

Figure 5: FMEA for corrosive wear

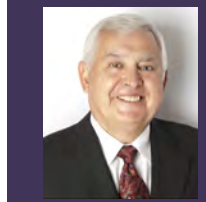
Function or Process Step	Failure Type	Potential Impact	SEV	Potential Causes	OCC	Detection Mode	DET	RPN
Lubrication Provides Rust and Corrosion Protection to All Contacted Surfaces	Surface Damage Caused by Acidic Lubricant	Surface Finish Is Damaged, Formation of Gums, Varnish and Sludge	4	Oxidation of Lubricant, Oil Drain Extended	.5	Oil Analysis: Total Acid Number (TAN)	1	2
Lubrication Provides Rust and Corrosion Protection to All Contacted Surfaces	Surface Damage Caused by Additive Reaction	Surface Finish Is Damaged	5	Improper Lubricant for Application, Additive Is Incompatible With Component Metals	.001	Oil Analysis: Elemental	1	0.005

Table Keys

SEV – severity factor on a scale of 0 to 10
OCC – occurrence factor on a scale of 0 to 10
DET – ease of detection factor on a scale of 0 to 10
RPN – the Risk Priority Number = SEV x OCC x DET

In conclusion, by adding the above risk priority numbers (RPNs) in Figures 2-5, the sum is 65.005% representing the global percentage of equipment failure modes caused by surface degradation. The best way to reduce this global failure mode percentage in your processes and equipment is to improve your lubrication program.

The lubrication program should emphasize the selection of lubricants that must be application driven based on the load, environment, temperature and speed of the process. The lubrication program also must ensure the five basic rights of machinery, which are the *right lubricant* of the *right quality* delivered in the *right place* at the *right time* in the *right amount*. Formal lubrication training is needed to establish a truly effective lubrication program. Most organizations require a cultural change in the way they view lubrication fundamentals.



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ISO4406:99 ISO11171

A Twist on Particle Evaluation: Redefining the ISO Cleanliness Code

by Matt Spurlock

For over 20 years, users of oil analysis have used the ISO cleanliness code to help determine solid contamination levels in both new and used oils. The current ISO standard for reporting cleanliness is ISO4406:99. Using this standard, analysts and end users alike have managed to establish cleanliness goals and develop key performance indicators (KPIs) with the expectation to allow for preemptive action to avoid early machine damage. While this has produced some success, relying specifically on the ISO code as it is currently reported has its limitations.

This is a proposal to rethink how industry uses particle count data in oil analysis for condition monitoring purposes. This article will focus on the vagaries of the ISO4406:99 reporting standard and review the difference between a reporting and a calibration standard, present the weakness of the reporting standard as it is currently used and consider the weaknesses via a case study.

Calibration vs Reporting Standards

Particle counters are delicate instruments and their precise performance can be a challenge to maintain. Accordingly, frequent and careful calibration is necessary to validate the instruments' continued accuracy. Automatic optical particle counting calibration follows an established standard, which is ISO11171. This standard dictates that automatic particle counters are calibrated to accurately measure particles in accordance with the following values:

≥4 microns;
≥6 microns;
≥10 microns;
≥14 microns;
≥21 microns;
≥38 microns;
≥70 microns.

Figure 1: Current ISO code table (per ml)

Greater than	Including	ISO Value
640000	1300000	27
320000	640000	26
160000	320000	25
80000	160000	24
40000	80000	23
20000	40000	22
10000	20000	21
5000	10000	20
2500	5000	19
1300	2500	18
640	1300	17
320	640	16
160	320	15
80	160	14
40	80	13
20	40	12
10	20	11
5	10	10

Figure 2: Exponential calculation results

ISO Value	Actual Max
27	1342177.28
26	671088.64
25	335544.32
24	167772.16
23	83886.08
22	41943.04
21	20971.52
20	10485.76
19	5242.88
18	2621.44
17	1310.72
16	655.36
15	327.68
14	163.84
13	81.92
12	40.96
11	20.48
10	10.24

When reporting particles at the size ranges listed, it warrants noting that the particles measured at greater than or equal to four (≥ 4) microns include ALL particles four microns and greater in size. For the next level, ≥ 6 micron, only those particles five microns and less are excluded. Those particles that are six microns and greater are counted and reported. This holds true up the entire ISO calibration range.

By measuring and reporting these values, the end user can have an overall understanding of solid particles lingering in the oil. Monitoring these values also can help confirm the potential presence of large wear particles that cannot be seen through other standard test methods. Of course, particle counting alone simply indicates the presence of particles and does nothing to indicate the type of particles present.

The reporting standard, as previously mentioned, is ISO4406:99. In accordance with this standard, the values used from the particle count data are related to the >4, >6 and >14 micron levels. The raw data at these micron levels are compared to a standard table and then translated to a code value. (Figure 1). By using the code, it is much easier to develop target values and report KPIs.

It's important to understand the concept behind the ISO code table, referred to as the Renard's series table. The maximum value of each level is approximately twice the value of the preceding level. This means the minimum value of each level is also nearly double the minimum value of the preceding level.

This is accomplished by using the ISO code, which is a value that is an exponent of two, dividing that result by 100 and then doing a bit of rounding. Figure 2 shows the actual exponential calculations for each code value. This provides the maximum number of particles that a given code value can contain. For example, consider the code of 15.2 to the 15th power equals 32768. This value divided by 100 equals 327.68. For the purposes of simplicity, this value was rounded to 320. So, for any micron level with a code of 15, there will be a number of particles greater than 160 up to and including 320, as shown in Figure 1.

By following this method, it is easy to understand why the rule of thumb is: For every increase in an ISO code value, the possible number of particles doubles. At face value, it appears the code provides the user with a convenient grip on the nature of changes in the solid particulate concentrations in the oil.

There are some characteristics about the code that can create a false sense of security. For instance, due to the discrete range of values at each code level, the actual number of particles can increase significantly without ever registering a code change. At the same time, there also can be just a slight increase in raw data that causes the ISO code to increase, giving the appearance that the contaminant level has doubled. It also should be noted that an increase in nearly four times as many particles can result in an increase of only a single ISO code value.

It is this reason that the current ISO code, as written and reported, has limited usefulness for proactive data evaluation. In the current format, the ISO code is a useful performance indicator and reporting tool, however, the lack of structure for true particle trending allows for a less than robust proactive contamination monitoring tool. Until now, the only true way to monitor cleanliness trend is via the raw data itself, which can be daunting given the amount of raw data and numerical ranges that are sometimes provided. This can be especially true for those laboratories that report particles per 100 milliliters of sample versus reporting particles per milliliter of sample.

The Solution

While the intent of the ISO code is to allow for easy reporting and tracking by aggregating data, the reduction has gone too far. As previously suggested, it is important to understand how far into the next ISO range the samples have progressed. This can be accomplished by dividing each range into 10 parts and inserting a single decimal point into the code, thus providing a better view of change in the particle count volume without having to look at the actual raw data. Taking this very simple approach can help drive the decision of whether corrective action is warranted.

Let's look at this proposition as it relates to the ISO code level of 20. In its current form, if the number of particles at a given micron size is greater than 5000 particles/ml up to and including 10,000 particles/ml, for that particle size, there is a range of 5000 and it is assigned a value of 20. If the range is divided by 10, there are 10 equal parts that have a 500 point value difference.

Figure 3: Proposed new breakdown at ISO 20 (ISO code value 20: (10,000 – 5000)/10=500)

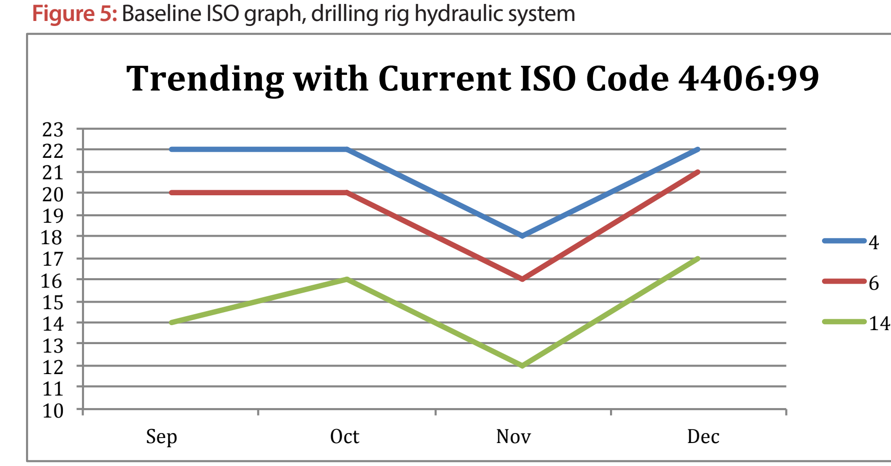
ISO Value (X)	
X=20	
X.0	5001
X.1	5500
X.2	6000
X.3	6500
X.4	7000
X.5	7500
X.6	8000
X.7	8500
X.8	9000
X.9	9500

For example, assume target ISO code value at the >6 micron level is 20. If there are two samples in a row that report an ISO code value of 20 at >6 microns, then there is a perception that the system is fine. Most people wouldn't even look at the raw data because the 20 would not be at any alarm level. But what if the first sample is a 20.2 and the second sample is a 20.9? Would it warrant taking proactive action at this point? As this is a significant increase in particle values, it would, indeed, warrant some type of corrective action.

Figure 4: Offshore hydraulic system particle count data

	13-Dec	13-Nov	13-Oct	13-Sep
PC >4	39322	2396	27713	22426
PC >6	13544	532	9500	7235
PC >14	663	38	585	127
PC >21	174	18	68	19
PC >38	10	5	2	6
PC >70	1	1	0	1
ISO Code	22/21/17	18/16/12	22/20/16	22/20/14

Figure 5: Baseline ISO graph, drilling rig hydraulic system



Let's look at the following real-world lab data to understand the significance of this proposed process.

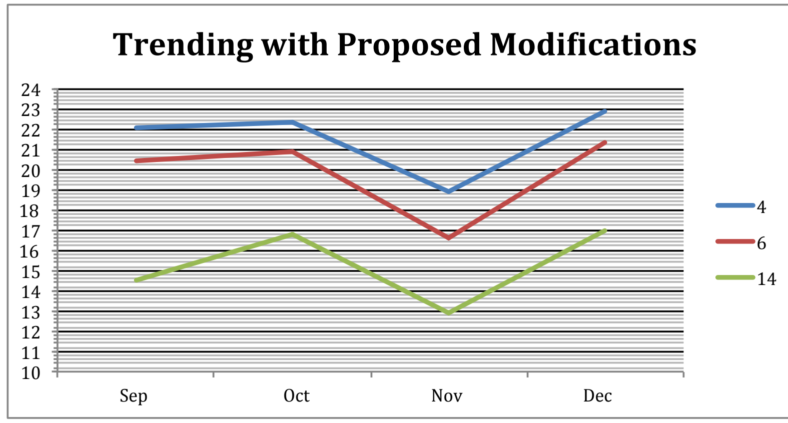
Case Study

A drilling platform has been consistently sending oil samples for several months. The overall program is considered to be at mid-level quality. The data shown in this study is from a hydraulic system powered by a gear pump. For the purposes of this study, only the data related to particle count and the ISO cleanliness code for the last four samples are required.

Using the data in Figure 4 and reviewing Figure 5, it is easy to see that there was a significant change in the November 2013 sample. In the December sample, it appears that the particle count values came back to the historical trends at the lower micron levels. What isn't evident, however, is the actual trend of those lower micron levels and the overall severity of the >14 micron level.

When you refer to Figure 6, which is consistent with the new proposed reporting structure and breakdown, you can quickly see that it is possible to report the true trend of contamination without the need to monitor the raw data provided by the particle counter. By using just the ISO code as it stands today, it is evident that there was an increase in particles, but it is only evident at the >14 micron levels. By subdividing the ISO code values, you can see that the increase in particles is much more pronounced than the current ISO code indicates.

Figure 6: Proposed ISO code graph, drilling rig hydraulic system



How This Affects You

By breaking down each code range and adding just a single decimal place, condition monitoring professionals gain the ability to accurately track where the trend is going without having to manage what could be an extraordinarily large amount of raw data.

Conclusion

The goal of particle contamination measurement is to monitor the condition of the oil for corrective action before the lubricated components reach point P on the P-F Curve. The ISO cleanliness code, as it stands today, provides a means for partially achieving this goal. However, with this simple modification, the technician will be able to see changing directions clearly and quickly, and do so without becoming overwhelmed by numerical data. The value of the cleanliness coding system for KPI target setting and trending would remain, and its utility as an analysis tool would be markedly improved.

Particle count sample data courtesy of Fluid Forensics
Particle count ranges developed by M. Spurlock

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Table 1- PROPOSED RANGES FOR REPORTING CLEANLINESS (per ml)

ISO Value (X)	Each 10	X.0	X.1	X.2	X.3	X.4	X.5	X.6	X.7	X.8	X.9
27	66000	640001	706000	772000	838000	904000	970000	1036000	1102000	1168000	1234000
26	32000	320001	352000	384000	416000	448000	480000	512000	544000	576000	608000
25	16000	160001	176000	192000	208000	224000	240000	256000	272000	288000	304000
24	8000	80001	88000	96000	104000	112000	120000	128000	136000	144000	152000
23	4000	40001	44000	48000	52000	56000	60000	64000	68000	72000	76000
22	2000	20001	22000	24000	26000	28000	30000	32000	34000	36000	38000
21	1000	10001	11000	12000	13000	14000	15000	16000	17000	18000	19000
20	500	5001	5500	6000	6500	7000	7500	8000	8500	9000	9500
19	250	2501	2750	3000	3250	3500	3750	4000	4250	4500	4750
18	120	1301	1420	1540	1660	1780	1900	2020	2140	2260	2380
17	66	641	706	772	838	904	970	1036	1102	1168	1234
16	32	321	352	384	416	448	480	512	544	576	608
15	16	161	176	192	208	224	240	256	272	288	304
14	8	81	88	96	104	112	120	128	136	144	152
13	4	41	44	48	52	56	60	64	68	72	76
12	2	21	22	24	26	28	30	32	34	36	38
11	1	11	11	12	13	14	15	16	17	18	19
10	0.5	5.1	5.5	6	6.5	7	7.5	8	8.5	9	9.5

Q&A with an Industry Leader

Uptime Magazine recently caught up with Paul Crocker, Supervisor of Maintenance at Kansas City Board of Public Utilities (BPU), Nearman Water Treatment Plant in Kansas City, Kansas. BPU is a nationally recognized municipal utility plant, much of which can be attributed to its philosophy regarding maintenance reliability and attitude toward the communities it serves.

Paul Crocker

Q: What is your career background?

Paul: As a kid, I remember taking broken things apart to see how they worked; still something I do as an adult. I've had a lifelong fascination with technology and seeing how things work. With regards to technology, I got my first computer, a Texas Instruments TI-99/4A, when I was in my early teens. I learned how to program BASIC and that learning eventually led to running a computer repair business years later as a second source of income.

Just out of high school, I completed a two-year course in automotive machine shop to rebuild internal combustion engines. That led to an interest in heavy equipment, like bulldozers, railroad switch engines, skid steers, etc., which I ran for years for the Kansas City Board of Public Utilities in its power plant's fuel handling group. That ended up being a dead end job and I wanted to improve myself, so I went back to technology, pursuing and completing an accelerated bachelor of science degree in network and communications management at DeVry University and graduating with honors in 2004.

Q: How did you come to be in your current role at the Kansas City Board of Public Utilities (BPU)?

Paul: Several things happened at just the right time. God has a way of opening doors that would otherwise be closed. I had been given the opportunity to visit Argentina several times in 2004 as a graduation present from my parents. On one of those trips, there was an opportunity to provide clean drinking water to indigenous people and it all revolved around a one-foot wide by three-feet tall concrete box filled with sand called a biosand filter. I learned everything I could about it on my own via the Internet, eventually taking a week-long implementers course on it through the Centre for Affordable Water and Sanitation Technology (CAWST) in Calgary, Alberta, Canada. I learned how to weld and build several steel molds for producing biosand filters that have made their way to Kazakhstan and Africa for producing filters in those areas.

Meanwhile at BPU, I bid down from fuel handling to utilities storerooms as a warehouseman. I was trying to bid on several IT jobs that my recently earned bachelor's degree qualified me for. But it was in not getting an IT job and that learning about water treatment that a job opened up in the water treatment plant for which I was qualified. I bid on it and was awarded the utility operator position at Nearman Water Treatment Plant.

While in that position, I earned my State of Kansas Water Supply System Class IV Operator Certification. Through some transitions in upper management, a position opened for the supervisor of maintenance position and one of its essential functions was to "administer, use and maintain a computerized maintenance management system (CMMS) for corrective and preventive maintenance, spare parts inventory, linked documents and lockout/tagout ticketing." Everything I had learned up to this point in my life just came together and I've been at it ever since.

Q: As the supervisor of maintenance for a public utility, how much focus is there in maintenance to provide reliable service to the customer?

Paul: There's a tremendous focus. The job bid for the maintenance supervisor had a cover page listing the BPU's mission, vision and values. While all of them apply, the following three are most specific to the question:

- **Our Mission:** To be the utility of choice and the workplace of choice while improving the quality of life in the communities we serve.
- **Responsive:** Awareness of who the customer is in every situation. Proactively anticipate the needs of others. Take initiative to offer assistance. Seek continuous improvement. Offer alternative courses of action and actively seek solutions. Share information and keep others informed.
- **Customer Focus:** Respect our customers and give them our best efforts.

My most immediate customers day in and day out are the senior system operators who work around the clock to meet the U.S. Environmental Protection Agency (EPA) standards in producing high quality drinking water for the residences and businesses in Kansas City, Kansas. For me, there's a huge responsibility in keeping the equipment running at steady state so the operators can do their job without encumbrance.

Q: Does your organization use any root cause or reliability centered maintenance (RCM) tools to help ensure reliability of your assets?

Paul: Speaking strictly from my department, no formal RCM tools or procedures are used. That being said, we do use our CMMS for calendar and run hour based preventive maintenance (PM) tasks. We do some asset condition monitoring, such as oil analysis, infrared thermography, vibration analysis and alignment. The senior system operators take readings on equipment and are on the front line of noticing and reporting problems with equipment through our CMMS program. We know that no amount of maintenance can improve a poorly designed asset or process, so we recognize that a formal RCM program would be nice to have in place.

BPU celebrated its 100 year anniversary in 2009

Q: Seeing that you have recently achieved the Certified Reliability Leader certification, (a) How do you keep yourself constantly challenged to increase your skills and (b) How do you encourage your employees to increase theirs?

Paul: (a) I read *Uptime* Magazine and all the trade magazines I can and that helps me a lot. I study for other related certifications that improve my skills and knowledge. I also hold a Plant Maintenance certification for Class 3 Technologist awarded through the Kansas Water Environment Association (KWEA) in conformance with the Association of Boards of Certification (ABC). I'm also studying for and planning to take the Certified Maintenance & Reliability Professional (CMRP) exam administered by the Society for Maintenance and Reliability Professionals (SMRP) in 2015.

(b) I leave copies of *Uptime* and trade magazines with my staff and when I find a particularly relevant article concerning something we're already working on, I make a special point to share it with them. Vendor lunch and learn training is popular with the guys and we do that whenever the opportunity presents itself. I would love to see my staff work towards lubrication certifications or CMRP certification. What a great way to show off what you know.

Q: Do you see a skills shortage developing in your field and if you do, how do you think organizations should begin to change to cope with a skills shortage?

Paul: Yes, I do. It seems to me the public school systems have removed the majority of the shop type classes from the junior and senior high school curriculums in favor of science, technology, engineering and mathematics (STEM) which, in and of itself, isn't a bad thing except it leaves the more physical, skill-related programs, like carpentry, metal working and automotive sciences, out of sight, out of mind for students who would otherwise gravitate towards and excel in those fields. And to me, that's a problem.

Our utility has in the past and is currently working with the trade unions, like the International Brotherhood of Electrical Workers (IBEW), Local 53, to supply apprenticeships for linemen and electricians and that's a plus. Another thing organizations should do is proactively fill jobs when they know someone will be retiring so some cross-training can occur before that person leaves the job.

Q: In the future, do you foresee pursuing some type of asset management credential, such as ISO55000, for the public utility and, if so, how would BPU begin to pursue accreditation?

Paul: Most definitely! Take the following into consideration: BPU is recognized as one of the top municipal utilities in the nation. It is one of only 83 of the more than 2,000 public utility companies to receive the Reliable Public Power Provider (RP3) award from the American Public Power Association (APPA). BPU is also one of only seven public utilities in the country to receive the Gold Award for its water system from the American Water Works Association (AWWA). In addition, it's the only utility in the Kansas City metropolitan area and in Kansas to receive the National Partnership for Safe Water Award developed by the EPA. And BPU was previously voted as having the *Best Tasting Water in the State of Kansas.*

Not only that, but in the Water Division, we've embraced asset management and have been working with the Kansas Department of Health and Environment (KDHE) and the Southwest Environmental Finance Center to work through the A.M. Kan Work! program. Doing that has resulted in the following: Starting with the 2013 program year, KDHE has modified the project ranking criteria for the Kansas Public Water Supply Loan Fund (KPWSLF) Intended Use Plan (IUP) to award up to 10 extra points for systems that have implemented an asset management plan. KDHE is required to provide available funding according to the IUP ranking. Historically, the cutoff for project funding has been at 10 to 13 ranking points. Having an extra 10 points added to a project's categorical ranking would almost assure the project to be above the cutoff for funding.

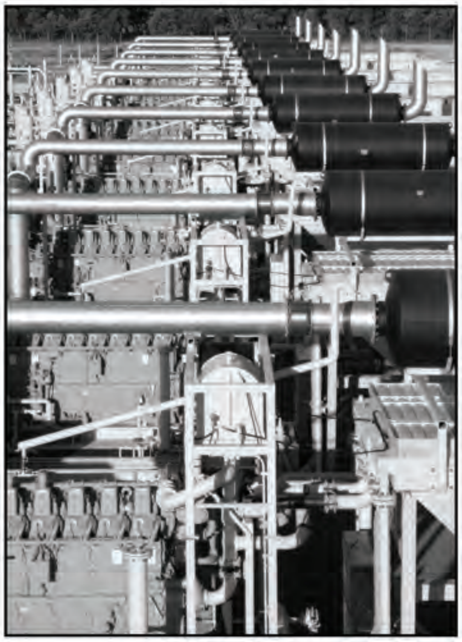
KDHE's Capacity Development Program determines the degree of asset management plan implementation and encourages systems to use the asset management IQ score tool developed through the A.M. Kan Work! program. The Kansas City Board of Public Utilities was the first and only (so far!) public water supply system to submit projects to the KPWSLF, in which KDHE determined a significant asset management plan was being implemented and qualified to receive these extra points. KDHE also determined the Kansas City Board of Public Utilities should receive the maximum extra ranking points allowed.

The next step is to get this train moving from the front end. Pushing from the back end of the train isn't very effective for getting the whole train moving, but being pulled from the front by the board and general manager will be significant for long-term results. Hopefully, those results would manifest in more businesses wanting to relocate to Kansas City, Kansas, because of lower rates and more reliable service, and lower the burden of cost for the average ratepayer.

> *"You can never cross the ocean until you have the courage to lose sight of the shore." - Christopher Columbus*

Q. Any last thoughts you would like to share with *Uptime* readers?

Paul: Christopher Columbus is quoted as saying, "You can never cross the ocean until you have the courage to lose sight of the shore." With respect to asset management and reliability, you must get away from the "this is the way we've always done it" mentality and move towards becoming a world-class, best practice organization by pursuing all the benefits asset management and reliability provide.



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