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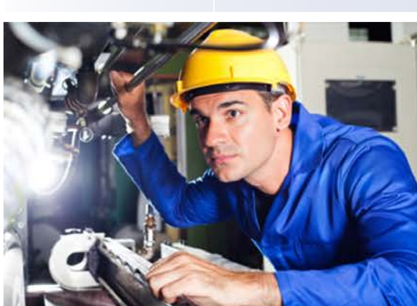

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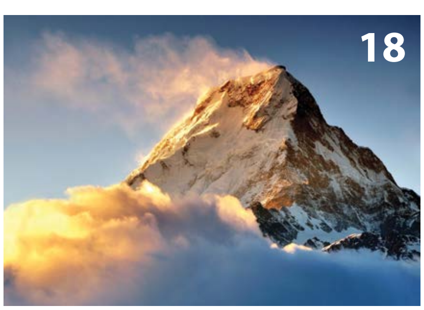
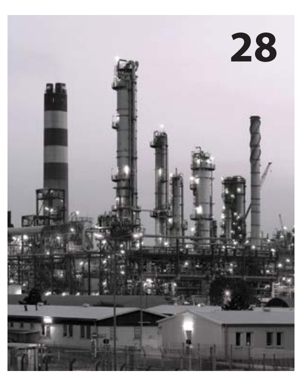
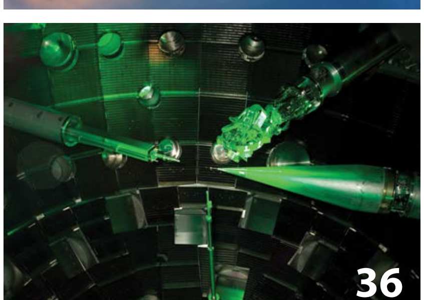
Special Edition







Features

Elements

Editorial

A Decade of Uptime

Ten years is not that long of a time but when Jenny Brunson, Editor at Uptime Magazine, stopped in my office to discuss this special issue, I began to look back at the journey from the first issue to today.

I begin by acknowledging my Uptime co-founder, Kelly Rigg-O'Hanlon. Many business owners are content to play it safe and the magazine business is anything but safe. Each issue is a roller coaster of risk with very little reward. Even though as an online publisher, we had struggled with two previous attempts at magazine publishing, she encouraged the team and worked to ensure Uptime was everything we wanted it to be.

The Uptime team of writers, editors, cover artists, graphic artists, layout experts, sales staff, support personnel and digital specialists has created an impressive body of work both in print and at the iTunes app store.

A lot of maintenance reliability leaders and asset managers have been incredibly generous with their knowledge and experience by contributing Uptime articles and case studies over the past decade. If you are reading this, please make a goal to see your name in print as an author during our next decade.

No part of the Uptime story would have been possible if it were not for the high level of advertising support from the enlightened solution provider community who fully support our aim of creating a proactive culture of reliability in the organizations Uptime readers represent. Bill Partipilo is responsible for advertising sales; however, I say that he really partners with the supply community for value and he never really "sells" anything.

I know of no other community that works together in this way to evolve and advance practices that not only deliver economic prosperity but improve safety, environmental sustainability and social responsibility. We are honored to have the special role we serve.

As I optimistically look ahead to the next **ten years** I see Uptime playing a major role in defining the Industrial Internet of Things (IIoT), Asset Performance Modeling, Predictive and Prescriptive Analytics, IT/OT Convergence, Reliability in the Cloud, Drones, Build Information Management (BIM), 3D and the continued evolution of Uptime Elements Reliability Framework.

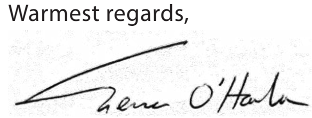
In our travels around the world, we are reaching out to some of the best subject matter experts where we find them, both inside and outside the United States, to discover and deliver innovation that can help you be safer and more successful.

We know time and attention are in short supply; however, we hope that you think Uptime rises above the clutter and noise.

We exist because of you and we thank you for being a reader and subscriber.

We do not ask for much but as this is a special time for us as we celebrate **ten years**, please consider taking a picture of yourself or your team holding Uptime Magazine, in front of your plant or a piece of equipment, or on a hunting/fishing trip or just hanging out in your backyard. The team loves seeing reader photos and we may post it on our Facebook. Twitter, Instagram, Flickr or LinkedIn pages.

Warmest regards,



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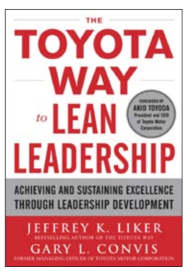
The 30th International Maintenance Conference

Best-selling business author, Dr. Jeffrey K. Liker, will be a keynote speaker at the 30th International Maintenance Conference held December 7-11, 2015 in Bonita Springs, Florida. Dr. Liker is Professor of Industrial and Operations Engineering at the University of Michigan and President of Liker Lean Advisors—a network of top-notch practitioners who consult, coach and teach in The Toyota Way. He is the author of several books with his original work, *The Toyota Way: 14 Management Principles*, being the best selling book on lean management in 27 languages with over 650,000 copies sold.



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CRL Workshop and Exam
London, England

November 10-12, 2015
Uptime Elements
CRL Workshop and Exam
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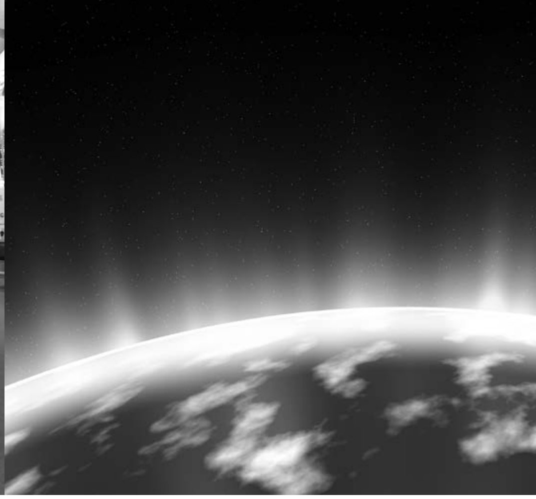
We often get positive feedback from readers about the innovative Uptime Magazine covers and it is a thrill to see them all assembled here for the 10th Year edition. We know we have had an impact because of the changes we see on all of our industry magazine friends' covers! It's OK to look good in reliability.

We reached out to some good friends for the special articles in this issue and our only regret is not being able to produce an issue with 1,000 pages so we could include everyone we wanted to.

Uptime is nothing without our readers and our writers. You complete us and this issue was made with a renewed commitment to you.



Reliability:
65 Years of History and Counting

by Anthony M. Smith and Samuel R. Paske

Reliability is a recognized engineering discipline that has progressively upgraded and improved the makeup of the world for all of us to use and enjoy. It has been the primary force behind the currently acceptable performance of virtually every product in our homes, as well as those that we take for granted every day in areas such as transportation, power, water supply and communications. This is the story of how this technology came about and what you must learn from the journey. There are essentially three distinct periods of development and innovation in the evolution of reliable technology that occurred since the end of World War II. This article provides an overview of all three and closes with some thoughts on where to now.

PHASE I – LATE 40s AND 50s

Reliability as a formal engineering technology emerged in the post-World War II period with the introduction of microelectronic piece parts (e.g., transistors, capacitors, etc.) and their assembly into circuit boards, modules and electronic Components, more commonly referred to at the time as Black Boxes. This type of hardware offered significant functional advantages for the U.S. Department of Defense (DoD), providing reduced weight, power and space requirements for electronic equipment in aircraft, missiles and the emerging interest in space vehicles. But these Components lacked the required reliability for military use and essentially introduced serious maintenance concerns for manned programs and similar challenges for long life reliability for unmanned missile and space projects.

Several data analysis programs were formulated to measure and track this electronic equipment reliability, but it became painfully obvious that there was insufficient recorded failure histories to make these measurements meaningful. Hence, the DoD sponsored a variety of projects to institute failure data collection and analysis across industry and government facilities. This effort led to the birth of what is known today as a Computerized Maintenance Management System (CMMS). Similar concerns surfaced about improving the inherent design reliability of these Components, leading to the birth of Failure Mode and Effects Analysis (FMEA) as a design and later, in the 1960s, as a maintenance reliability tool. A natural progression from these beginnings also led to some early realizations that reliability engineering and project requirements went beyond the Component level of assembly, and that reliability at the System and Vehicle level of assembly was as equally important, if not more so, than the Component's reliability efforts. You will see this progression develop and mature in Phase II and III.

PHASE II – 60s TO 80s

The successes realized in Phase I slowly led to a keen interest in Reliability as a discipline, not only with the DoD, but also with the commercial sector. The nuclear industry, with urging from the U.S. Nuclear Regulatory Commission (NRC), plus lessons learned from the Three Mile Island Unit 2 (TMI-2) core melt accident on March 28, 1979, undertook very extensive and costly reliability and statistical studies at the Plant level called Probabilistic Risk Assessments (PRAs). These studies, done at U.S. nuclear plants throughout the Phase II and III periods, proved to have not only pertinent safety findings, but also an Availability/Economic payoff for the non-nuclear balance of plant Systems.

The Phase II period also saw two other not to be forgotten events that provided increased emphasis on reliability, namely the first flight of the 747 airplane on February 9, 1969 and the Space Shuttle Challenger disaster on



January 28, 1986. The 747 Type Certification was the tipping point for the development of the Reliability Centered Maintenance (RCM) methodology that today is an element of many product maintenance strategies. The Federal Aviation Administration (FAA), somewhat unknowingly, released the creative talents of Boeing and United Airlines (UA), especially Tom Matteson, vice president for maintenance planning at UA, and his colleagues, F. Stanley Nowlan and Howard F. Heap, to discover the RCM methodology that focused maintenance resources where it was important to preserve product Functions. The system-based approach espoused by RCM also increased recognition of the role of the Operator and the implications of human error in assessing risk and reliability. In the case of the Space Shuttle tragedy, NASA and the world learned the importance of management and technician teamwork to make correct decisions, especially when lives are at stake.

Organizations have learned that reliability practices contribute value to their bottom line and promote improvements to their culture.

Also during this phase, the U.S. nuclear submarine force, under the command of Admiral Hyman G. Rickover, developed innovative portable condition monitoring technologies that led to significant improvements in fleet availability. Overall, industry and government alike also learned during Phase II that economics and safety requirements can frequently be met with regulatory inputs from Agencies, such as the NRC and the FAA.

PHASE III – 90s TO PRESENT

Events of the 70s and 80s, like TMI-2, the 747 airplane and its RCM legacy, and the Challenger disaster, continue to be major considerations in how the DoD structures its projects. But such considerations have also motivated the Commercial and Industrial communities on a global scale to apply Reliability technologies to their products and production facilities. Phase III has seen the birth of Reliability Engineering degrees at U.S. universities, including Arizona, Tennessee and Wisconsin, and dramatic increases in the number of RCM practitioners and their influence in structuring Corporate Reliability and Maintainability strategies.

In the past 25 years, Reliability technologies have also grown far beyond Phase I and II achievements. Now, there are supporting techniques in the toolbox, such as Predictive Maintenance (PdM), increasingly known as Asset Condition Management, Root Cause Failure Analysis, Total Productive Maintenance, etc. But most of all, the last 25 years have seen many large Reliability/RCM programs conducted across the DoD and Industrial landscapes. From the authors' experience alone, over 50 Classical RCM projects have been successfully completed in organizations, such as Westinghouse, Eaton, NASA, United States Air Force (USAF), Boeing Commercial Airplanes, Georgia-Pacific, United States Postal Service (USPS), TMI-1, Tennessee Valley Authority (TVA), MidAmerican Energy, Tesoro Refineries, and The Metropolitan Sewer District of Greater Cincinnati.

Reliability success stories are recounted annually at professional meetings (e.g., annual Reliability and Maintainability (R&M) Symposium, International Maintenance Conference, annual Society for Maintenance and Reliability Professionals (SMRP) Conference) and publications (e.g., *Uptime*, *SMRP Solutions*, *Maintenance Technology*). Reliability success stories abound as organizations report increased production output, decreased costs, improved safety and accommodations to challenging regulatory requirements.

Organizations have learned that reliability practices contribute value to their bottom line and promote improvements to their culture. RCM stands out because it uniquely benefits organizational know-how by building broad-based human understanding and buy-in to new innovations through multidisciplinary teams.

Looking ahead, the greatest challenge may be the ability to sustain the use of tried-and-true Reliability methods, like RCM, as well as emerging technologies. Despite a better understanding today of organizations and change, it has yet to be demonstrated that consistent SUSTAINABILITY is a hallmark of the efforts of the past 65 years. But organizations are learning. Testimonials from successful programs strongly suggest that an empowered Reliability Champion significantly improves sustained results. While the future is unknown, don't be surprised to see successful advances that build on the tremendous reliability legacy of systems thinking, multidisciplinary teams and empowered champions.


Anthony M. "Mac" Smith, P.E. and Samuel R. Paske, P.E., CRL, *worked closely together as a team during much of Phase III and Mac was closely involved in his work with Phases I and II after his discharge from the Army in 1956. Thus, most of the historical perspective described in this article is drawn from personal experiences and contributions to this evolving discipline. (See Uptime April/May 2013 issue to read more about Mac Smith and his contribution to the reliability industry.)*

The Future of Asset Condition Monitoring[1]

by Jack R. Nicholas, Jr. and Elsa K. Anzalone

INTRODUCTION

There is a fourth paradigm shift developing in the way organizations handle asset condition monitoring (ACM), formerly called predictive maintenance (PdM) before the ISO55000 asset management standards series was issued in 2014. This shift follows previous major changes in ACM/PdM programs, with the first being when equipment went from heavy, cart transportable packages for data collection and some analysis (1980s) to microprocessor-based, handheld packages. The second significant change was when desktop personal computers with robust software programs and substantial memory capacity and portable laptop computers for field use came into use (1990s). Together, they transformed collection, storage and analysis of data for asset condition monitoring and prediction. The third shift began with the application of wireless technology to condition data collection and the introduction of highly sophisticated analysis software programs and integration of data from multiple technologies for management, reporting and focusing of maintenance actions on improving asset performance and availability. The fourth and latest shift involves the use of the Internet of Things (IoT), cloud computing, big data management, analytics and communications using tablet computers and cellular fourth generation (4G and in a few years 5G) long-term evolution (LTE) technology.

TRADITIONAL FIRST AND SECOND GENERATION PdM PROGRAMS

Predictive maintenance and condition monitoring have been around for almost 60 years. For most of those 60 years, routine data collection was performed using what was then called "portable" equipment, including paper and pencil. In the earliest days of almost all technologies, such as vibration analysis and infrared thermography, portable meant that a team would lug or cart various components of a monitoring suite weighing 30 to 50 pounds into areas of plants where monitoring was required. This was cumbersome and time-consuming, even before data collection could be performed. The advent of microprocessors in the 1980s reduced these data collection tools to handhelds. Data could be collected and analyzed in situ (i.e., at the machine) to some degree.

In the 1990s, the introduction of electronically cooled sensors allowed infrared thermographers to retire their liquid nitrogen cooled equipment. This development, combined with ever increasingly capable integrated circuits and digital technology, enabled PdM practitioners to create much more vivid, intuitively interpreted images in both visual and infrared spectra that even a novice could understand.

At the same time, the introduction of personal computers in the late 1980s and battery powered laptop computers with sufficient memory in the early 1990s further enhanced the PdM technician's ability to perform detailed analysis in the field with the help of increasingly sophisticated software. Most notably, this enabled the collection of a vastly greater amount of data needed to do motor circuit analysis economically and to do analysis in situ right at a motor control center, pump, or any other location in a plant.

THIRD AND FOURTH GENERATION ACM/PdM PROGRAMS

What is described in the previous last few paragraphs sounds thoroughly modern, and it was in the first decade of the 21st century. But it is going to change and/or expand much more. The change is going to be as much a paradigm shift as the one from heavy suites of equipment to handheld devices and/or wireless sensors linked via networks and from individual analysis to live and automated computer-supported, sometimes expert system supported, analysis and reporting from remote sites by cadres of experts serving multiple facilities.

In a May 2004 editorial in *Sound & Vibration* magazine, Nelson Baxter made the following points concerning the future of predictive maintenance and condition monitoring:

- There will be fewer people collecting data and performing analysis due to global competition, skyrocketing health care costs, deregulation and other factors.
- Where it is possible, data will be brought to the analyst, not the other way around.
- Data from similar machines will be archived and used to simplify problem identification across a fleet of like machines wherever possible.
- The combination of wireless networks and the Internet will enable the easy movement of data from the plant to the analyst.
- Large manufacturing organizations will have hybrid programs where more critical equipment is monitored daily or more frequently and less critical equipment less often.[2]

Advanced analytics and cloud-based big data management will be the basis for new and better ways of monitoring machine condition and performance, worldwide.

In addition to these predictions made over 10 years ago but still valid today, and which focused mainly on the application of sound and vibration monitoring, the following developments are actually happening or beginning to happen in the field of asset condition monitoring management for multiple technologies, including lubricant and wear particle analysis:

- New and different sensors, robust communications links, power sources, such as ambient harvested, and analytic methods are being developed and employed that will have application in the utility, commercial and industrial markets.
- Mobile platforms, manufacturing plants, commercial buildings, utility plants and their associated distribution networks, as well as infrastructure for many other applications, will be monitored in ways that are significantly different and more extensive than what is being done today. This is made possible by the Internet of Things, as well as private, radio-linked monitoring stations, such as those used by commercial airlines for in-flight monitoring of planes.
- Monitoring systems will be cheaper, faster, more capable and easier to use, redeploy and configure than the systems in use today. New, inexpensive, easy to learn (i.e., one day on-site training) instruments are already on the market that broaden applications in the field for those using hand tools to make repairs. Highly trained ACM specialists will be called upon less frequently to confirm that a defect exists or that quality repairs have been performed.
- While the amount of labor required for monitoring machines in a facility or platform will decrease because of increased productivity of ACM systems and support tools, the number of applications requiring monitoring will increase for a wide variety of reasons, mainly economic-related.
- While the number of individuals engaged in ACM/PdM per site or fleet of vehicles will decrease, the number of ACM skilled knowledge workers will increase as a percentage of total workforce and as the value of ACM becomes more known by managers intent on competing effectively in the global marketplace. However, these workers will get their knowledge from places outside their workplace, such as the Internet or somewhere in the Cloud.

ACM/PdM IN THE FUTURE

It is becoming easier and more inexpensive for almost anyone to have a role in this rapidly changing field of ACM/PdM. Already, smartphones and commercial tablet computers can be adapted with plug-in sensors (US $250 or less) and free downloadable applications to become infrared imagers. Similar arrangements are available for ultrasonic analysis, laser alignment, balancing and vibration analysis. With the next generation of wireless communications, such as 5G LTE with download speeds 10 to 100 times faster than today's 4G capability,[3] more advanced analytics and cloud-based big data management will be the basis for new and better ways of monitoring machine condition and performance, worldwide.

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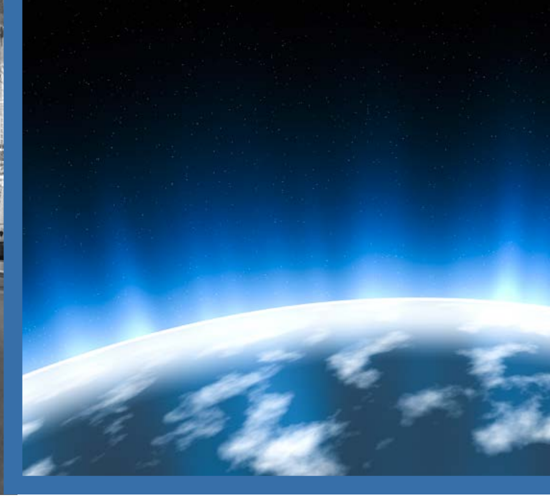
Jack Nicholas, Jr., *CRL, CMRP, has over 45 years' experience leading, teaching, training and consulting in the fields of maintenance and reliability in government, military, utility and commercial venues in Asia, Australia, North America and the Caribbean. He is author, co-author, editor and major contributor to many books, professional papers and magazine articles on R & M subjects.*

Elsa Anzalone *has been involved in the area of asset condition management for over 25 years. Her focus has been on the sales of products relating to ferrographic oil analysis, vibration hardware and software, stress wave analysis, wireless vibration analysis, and software and instrumentation for operator-directed reliability programs.*



Work Execution Management

Time to Move Forward

By Terry Wireman

Work execution management (WEM) is the domain where the work activities on assets identified in other domains, such as reliability engineering for maintenance (REM) or asset condition management (ACM), are actually performed. For example, when reliability engineering (RE) or root cause analysis (RCA) identifies activities that need to be performed on an asset to allow it to meet design performance specifications, those activities are planned and scheduled in the WEM domain. Similarly, if out of tolerance conditions are detected through the ACM domain, the work is properly identified and then planned and scheduled in the WEM domain. The interdependencies between the WEM domain and the other domains have a dramatic impact on the overall lifecycle costs of an asset, which ties into asset management.

What has been the progress over the years in WEM? Unfortunately, progress has not been as positive in the WEM domain as it has in the REM, ACM and leadership for reliability (LER) domains. Let's take a look at each of the elements in the WEM domain and evaluate the extent of progress over the past 30 years.

PREVENTIVE MAINTENANCE

The most effective preventive maintenance (PM) programs concentrate on the basics of maintaining the equipment, such as good visual inspections, good lubrication practices and good fastening procedures. While these seem basic, a survey in the book, "Maintenance Management for Quality Production," published in 1984 by the Society of Manufacturing Engineers, states that only 22 percent of the 2,500 organizations surveyed were satisfied with their PM program. That survey was conducted over 30 years ago, but PM activities are still producing substandard results. Organizations still have equipment failures, sometimes just days after basic PM inspections were performed. When a root cause analysis is performed on the failure, it is determined that the cause is due to a problem that should have been found during the PM inspection that was just performed.

While the technology-driven inspections from the ACM domain can assist in proactively finding degrading equipment conditions, a good PM program focused on basic care is key to a cost-effective solution for premature equipment failures.

MRO SPARES MANAGEMENT

The maintenance, repair and operations spares management element (MRO) deals with the cost-effective procurement and utilization of spare parts. Since MRO can comprise 40 percent to 60 percent of an organization's maintenance budget, this is an important area to consider.

How has the overall MRO function matured in the past few decades? Similar to the PM element, not much progress has been made. In organizations today, there are still an incorrect number of spare parts being stocked, whether too many, which results in excessive costs, or too few, which results in excessive equipment downtime. Organizations simply do not know how to correctly value their MRO.

PLANNING AND SCHEDULING

Planning and scheduling (PS) comprises activities that allow maintenance to be completed efficiently and economically. PS confirms that all logistics for the particular job are completely controlled before the job is executed. This ensures little or no waste as the work is performed. By eliminating waste, the work is now executed at the lowest possible cost.

Planning and scheduling has improved over the years, due to the increased utilization of planners. Companies have progressed from not even having planners to developing a good job/role description and allowing the planners to contribute to increase labor efficiencies and effectiveness. While there is still work needed in the area of the proper ratio of planners to maintenance technicians, as an organization continues to mature its planning and scheduling program, expect to see improvements in this area.

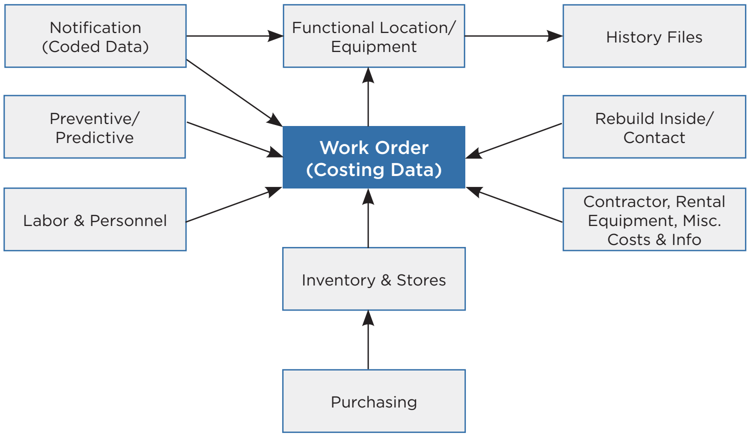


Figure 1: Equipment Information Management

COMPUTERIZED MAINTENANCE MANAGEMENT SYSTEM

The computerized maintenance management system (CMMS) is a specially designed database for tracking all equipment maintenance information (see Figure 1). The CMMS has been used by maintenance organizations since the mid-1970s. So what has been the result of CMMS utilization? According to the "CMMS Best Practices Study" published by Reliabilityweb.com in 2011, *"work order management was cited by 91 percent of respondents as the most important feature of a CMMS."* Yet, upon close scrutiny, the accuracy of the data in most CMMS databases is severely lacking. In informal surveys, the vast majority of maintenance reliability managers feel the data in their CMMS is too inaccurate to use for financial decision-making.

OPERATOR DRIVEN RELIABILITY

Operator driven reliability (ODR) is the element where operators are utilized to increase the capacity of the equipment they operate or to free up maintenance resources to be utilized on higher level maintenance reliability activities. The goal is to have the operators take ownership for 10 percent to 40 percent of the organization's PM program. What has been the result of ODR initiatives? Overall, they have proven to be successful in a small number of organizations.

DEFECT ELIMINATION

Defect elimination (DE) is a powerful element that builds on the five other WEM elements. The DE element uses cross functional teams to eliminate equipment-related defects, thereby increasing the capacity of the equipment. How successful has DE been for most organizations? Since DE focuses initially on the basics of maintenance and reliability, some organizations have had initial success. However, when the organization is ready to realize the true power of DE and it is applied by trained, cross functional teams, most fall well short of the goal. There are several reasons for this, including lines of jurisdiction between the various departments and proper training for all employees involved.

THE FUTURE OF THE WEM DOMAIN

What is the future of the WEM domain? After briefly reviewing the six elements of WEM, it is clear that if they are utilized correctly, they add great value to an organization's maintenance reliability functions. But why do the WEM elements fail to achieve their true potential? There are two main reasons:

1. Lack of understanding the financial impact of the elements.
2. Lack of proper skills to implement and execute the elements.

When equipment/assets are out of service longer than required for repairs, it is a loss to the company. It impacts the capacity of the equipment/asset. If the organization is in a sold-out market, the lost capacity is a lost sale and, ultimately, lost revenue. Even if the organization has a capped market, the inefficiency in wasting maintenance and operational resources is still an unnecessary expense. It is necessary for all organizations to have a clear understanding of the losses in this area to ensure losses are minimized or avoided completely.

If organizations lack the skills necessary to implement and manage the elements of this domain, they will fail to execute the elements in the most efficient and economical manner. Not only does this lead to labor and material losses, but also prolonged downtime and repetitive delays. These unnecessary losses will impact the profitability of organizations, again from an expense and lost revenue perspective.

If organizations are going to make improvements in the WEM domain in the future, they will need to overcome the two reasons previously noted. If they can resolve these issues, their respective companies will see increased profitability and value delivery from their assets/equipment.

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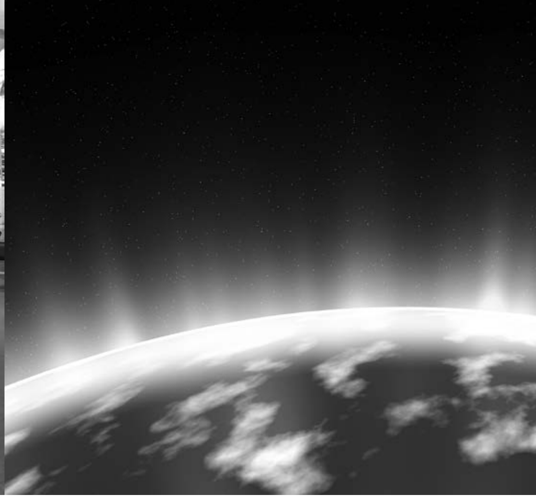


LER

Leadership and Reliability

by Ron Moore

For essentially all business objectives, top management's leadership and active support is vitally important for achieving any single objective. Reliability is no different. However, it seems that top leadership in most organizations has little understanding of reliability principles. Of course, they understand the concept of reliability at some level, but most immediately think maintenance and delegate the responsibility to a corporate maintenance manager and expect reliability will simply happen. This view is only reinforced by organizations and service providers that provide so-called reliability services. For example, the Society for Maintenance and Reliability Professionals (SMRP) has maintenance and reliability in its name, implying that if you do good maintenance, you'll have good reliability. This mentality of intimately linking maintenance and reliability and thinking if you do maintenance really well, you'll have good reliability is seen far more often than not. It seems especially prevalent in the senior leadership of most organizations. *And it's flat wrong* for a host of reasons! Let's explore this fundamental issue.

LEADERSHIP – WHAT IS IT?

Leadership is an essential and even dominant element in any company's business success. But what is leadership? How do you get it? Can you buy it by attending "leadership school," or get it by using leadership mentors or reading the latest books on leadership? Actually, leadership is simultaneously simple and complex, and it's likely to be context dependent. What works in one situation, may not work in another. It's a bit like the phrase that U.S. Supreme Court Justice Potter Stewart once offered: "It's hard to describe, but I know it when I see it."

This author's personal definition of leadership is: *The ability to inspire ordinary people to consistently perform at an extraordinary level*. This is not to suggest anything pejorative in the use of the word ordinary, but rather the opposite. Ordinary in this context is more in line with the principles illustrated in the book "Citizen Soldiers," where ordinary citizens became soldiers during World War II and defeated professional armies. These citizen soldiers, including this author's father, won because they were inspired by a higher sense of purpose related to freedom and the American way of life. Many sacrificed everything, much the same as our founding fathers.

Leaders set the example by creating an environment for this, one of pride, enjoyment and trust. Leadership begs the question: "How do I get people to genuinely look forward to coming to work every day?" The answer is simple. Give them work they like to do by: 1) training them in developing the appropriate skills; 2) creating a structure to involve them in improvement activities and teams; and 3) asking them about the problems encountered and then working with them to solve those problems, among other activities. Leaders engage the workforce in process improvement, giving them the freedom to be successful for the company with work that is challenging, rewarding and calls them to a higher purpose. The leverage in a company's success is in getting hundreds, even thousands of people working to improve the company's performance.

> "People own what they create."

Of course, there are other leadership models. Warren Bennis, a pioneer of the contemporary field of leadership studies, characterizes the difference between leadership and management in which leaders challenge status quo, trust, innovate, develop and do the right things, whereas managers accept status quo, administer, maintain and do things right.

Peter Koestenbaum, who developed a leadership awareness program, describes leadership as being the four points of a diamond, with each point characterized by the concepts of *Vision, Reality* tied to the current situation, *Courage* to make the changes and *Ethics* to treat people honestly and with dignity and respect. Jim Collins, a student and teacher of leadership, describes Level 5 leaders as those who build enduring greatness through a paradoxical combination of personal humility and fierce professional resolve. Larry Donnithorne, author of "The West Point Way of Leadership," identifies the key components of leadership as being courage, determination, integrity and self-discipline. Some common traits among all these leadership models include:

- Having a vision or a greater sense of purpose, albeit grounded in reality.
- Putting people first and treating them with trust, dignity, respect and appreciation.
- Being demanding and supportive simultaneously.
- Being trustworthy and true to your word and principles.
- Having a passion for excellence and setting high work and ethical standards while creating a caring, disciplined and proud environment.
- Setting the example in basic values and principles for others to follow.

RELIABILITY AND OPERATIONAL EXCELLENCE – WHAT IS IT?

Let's start by identifying what it is not! It is NOT maintenance! Of course, maintenance excellence is a requirement for reliability and operational excellence, but if that's all you do, you will only do more efficient work that you should be doing in the first place! To be more technical, a common definition of reliability is the probability that plant or equipment will perform a required function without failure under stated conditions for a stated period of time. A very simple definition is: "Stuff works when you want it to."

Moreover, reliability is essential for operational excellence and it is far more dependent on excellence in design, procurement and operating practices. This is where most of the defects occur that create the maintenance requirements and result in additional costs, lost production, incidents and injuries, as illustrated in Figure 1.

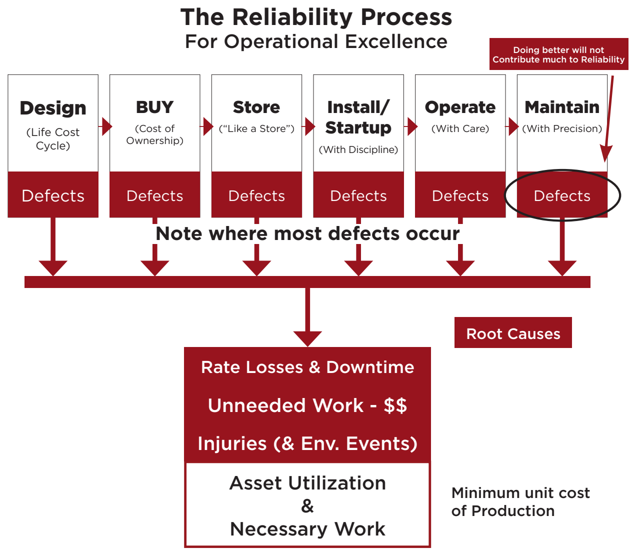


Figure 1: The reliability process for operational excellence

RELIABILITY AND OPERATIONAL EXCELLENCE – HOW DO YOU GET IT?

Experience has shown that four elements are key. If you miss any one of them, the odds become increasingly stacked against your success. Miss all of them and you have little hope. The four elements are:

1. Leaders ***must*** be actively involved as sponsors for reliability and have an excellent understanding of Figure 1. Sponsorship is more than permission. Senior leadership frequently give permission – just go do it – but then fail to provide the visible support necessary for developing and sustaining it. Or, they fail to provide the resources to assure reliability and operational excellence is inculcated in the organization or fail to provide the incentives for supporting its implementation. Reliability should be like safety – a top priority. A reliable plant is a safe plant and a cost-effective plant, and operating plant data supports this.
2. Production and maintenance ***must*** work in partnership, even having a partnership agreement outlining how they will support each other. They should meet periodically to review their relationship and support, and foster teamwork and alignment to a common set of goals related to operational excellence.
3. There ***must*** be shared measures that foster that partnership and balance competing interests for the greater good. For example, production and maintenance are both held accountable for on time delivery and maintenance schedule compliance. These are often in conflict and more often than not, on time delivery (short term) wins over maintenance schedule compliance (longer term) to the long-term detriment of the business. Similar measures could be applied to procurement and maintenance, or to design and production.
4. There ***must*** be a process for structured improvement time and shop floor engagement. According to management consultant Margaret Wheatley, "People own what they create." If you want ownership within the organization, then people must participate in problem-solving and creating solutions. If you want to understand the problems with the work, ask the workers. Get them involved in problem-solving, giving them a sense of control, ownership and purpose. You'll also get cultural change!

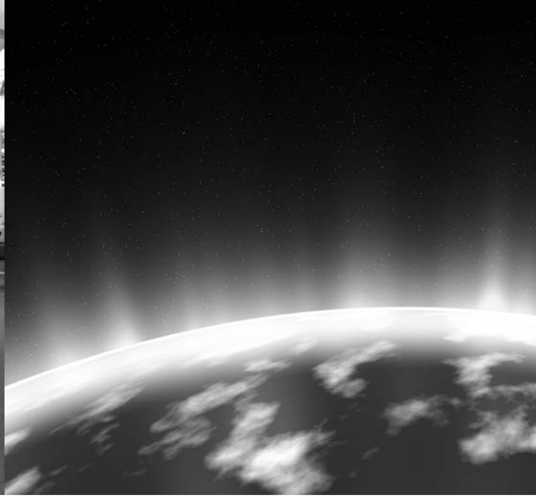
RELIABILITY, SAFETY, COSTS AND ENVIRONMENTAL PERFORMANCE

Finally, it's appropriate to close with a comment on reliability, safety and costs. Leaders in most companies frequently state that safety is a top priority. If they truly believed this, they would sponsor and demand reliability, and put in place the systems, processes, measures and rewards to align the organization for reliability and operational excellence that would yield improved process and personal safety, lower costs and better environmental performance. There is compelling operating plant data to demonstrate clearly the relationship between reliability and safety, and costs and environmental performance. A reliable plant is a safe plant is a cost-effective plant, is an environmentally sound plant.

If leaders truly believe safety is a top priority, then reliability must be a top priority.

***Ron Moore** is the managing partner of The RM Group, Inc., in Knoxville, TN. He is the author of "Making Common Sense Common Practice – Models for Operational Excellence," 4th edition; "What Tool? When? – A Management Guide for Selecting the Right Improvement Tools," 2nd edition; "Where Do We Start Our Improvement Program?"; "Business Fables & Foibles;" and "Our Transplant Journey: A Caregiver's Story," as well as over 60 journal articles.*





Asset Management Past and Future

by Thomas W. Smith

The ISO Standard 55000 for Asset Management, which was released in January 2014, represents the culmination of a series of activities going back several decades. Its most immediate predecessor is the British Standards Institution (BSI) Publicly Available Specification (PAS) 55, which was released in 2004 and updated in 2008. Before that, however, there were numerous national and sector level standards providing specific guidance for asset management.

ISO55000 focuses on asset value. The critical features of the ISO standard are its adaptability to all sizes and types of organizations, its focus on a comprehensive and integrated approach across the asset lifecycle, and its recognition of the importance of the influence of the organizational context on assets. Context in this case includes the physical, social and economic environment in which the organization operates. The impact of this new standard with its very broad approach is just beginning to be felt, and there are many opportunities for organizations to take advantage of the building momentum.

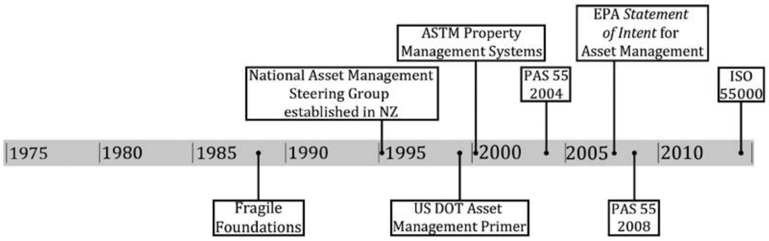


Figure 1: Asset management standards timeline

TALKING ABOUT ASSET MANAGEMENT

It's not hard to strike up a conversation about asset management within the communities to which most of us belong. The growth of interest in ISO55000 and an increased emphasis on asset productivity have made asset management a topic of presentations and publications, as well as everyday conversation.

The real issue is making those conversations productive. The pressures on assets and the need for effective asset management are going to continually increase. Adversarial discussions and one-sided approaches are not going to help the cause. No one industry sector or organizational function owns asset management.

WHAT CAN BE DONE TO ENSURE PRODUCTIVE CONVERSATIONS?

1. The ISO55000 standard for asset management is involved in many conversations. Use of the standard is not limited to third-party certification. Many organizations are currently using the standard as a framework for development or renewal of an asset management program. These organizations may or may not transition to a formal asset management system for purposes of certification. The standard itself recognizes this difference. It also recognizes the difference between a management system for asset management and the many software systems that are used to support the asset registry and the maintenance system. Precise and conscientious use of these terms will go a long way in improving discussions.

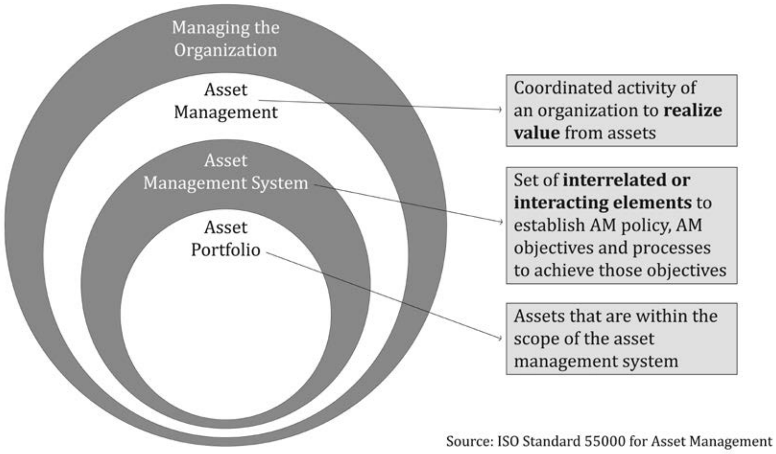


Figure 2: Relationship of key terms

2. Third-party certification is done by an accredited certifying body. The first national accreditations for certifying bodies were issued by the United Kingdom Accreditation Service (UKAS) in the spring of 2015. Other national accreditations are soon to follow. Organizations may also self-certify, though this does not carry the same weight in international commerce as third-party certifications. As with other management systems standards, the organization may certify a business unit and not the whole organization. When discussing certification, it is important to recognize what is being certified and by whom.

   It is also important to distinguish individual certification from organizational certification. The Institute of Asset Management (IAM) offers a certificate and a diploma for individual practitioners of asset management. The World Partners in Asset Management (WPiAM) offers a certified asset management assessor qualification.

3. Asset management occurs at multiple levels: strategic, tactical and operational. The standard is meant to be integrated, comprehensive and adaptable. It is hard to address all levels and functions in one conversation, and it is easy for working asset managers to assume that the operational level is all that really matters. The question posed by the standard, however, is about asset *value* and asset *performance,* which includes measures, such as uptime and reliability, that are only two components of value.

   The strategic approach begins with a clarification of the organizational mission, vision, values, goals and objectives, and then an analysis of what assets are needed to meet those objectives. It takes into account the organizational context in terms of external environment and stakeholder needs. It is capability-based and considers, but is not driven by, the placement and condition of current assets.

   The tactical approach considers how to meet the defined assets' needs. Development, acquisition and outsourcing are all tactics. The management of asset portfolios occurs at the tactical level.

   Operational decisions are often thought of as utilization and maintenance activities, but should include creation and disposal. Those involved in utilization and maintenance are key stakeholders in development activities.

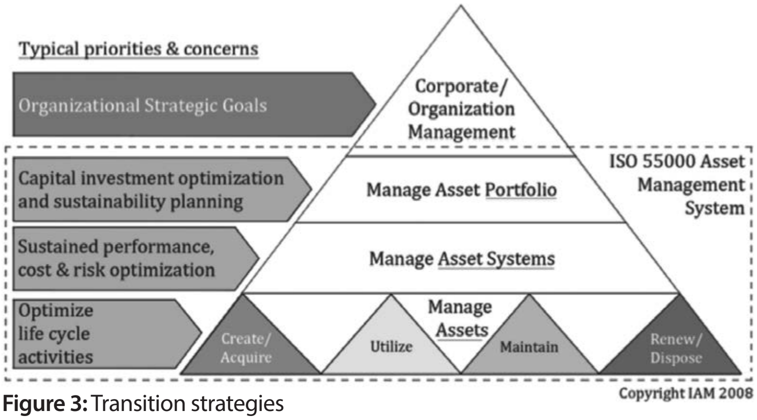


Figure 3: Transition strategies

GROUND RULES FOR ASSET MANAGEMENT DISCUSSIONS

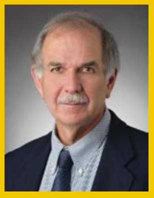
Asset management discussions should begin on a solid foundation. The easiest way to do this is to quickly work through the: Who, What, When, Where, Why and How of the discussion.

- Who is involved? What department, division, or function are you talking about?
- What is the level of the discussion? Is it strategic, tactical, or operational? Is it multilevel, which requires additional clarity and a more extensive discussion?
- What is the subject of the discussion? Is it asset management in general, the asset management program or system, or a particular set of asset management tools?
- When will things take place? Asset management issues may be long term and also driven by current needs. The discussion should include a time frame for information, decisions and action.
- Where is the asset, asset system, or portfolio located? Are you talking in specifics or generalities?
- Why are you having this discussion? Is it because of current events or long-term needs coming to a head? If so, what exactly is driving the need?
- How are you going to complete the discussion, make a decision and follow through?

A common problem occurs in discussion of lifecycle management. It may be assumed that end of life is a wear out issue, but more often than not it is a result of technological obsolescence. And there may be a series of technical renewals or updates that are part of the lifecycle. Without these clarifications, a discussion of lifecycle management can be very frustrating.

A more fundamental problem is related to the "what business are we in" discussion. For example, upper management at a consumer products company may be focused on marketing and distribution, while those engaged in production are frustrated by the lack of attention to their role.

It all comes down to productive discussions. They are critical to the advancement of asset management and clarity of purpose, while approach is fundamental to those discussions.



Thomas W. Smith, MS, *is a Program Director in the Department of Engineering Professional Development, University of Wisconsin-Madison. He served as an U.S. Delegate and Task Group Leader for the International Standards Organization (ISO) Program Committee on Asset Management and serves as a member of the Faculty of the Institute of Asset Management, UK.*
www.epd.engr.wisc.edu/2015assetmanagement

Evolving **Ideas** &

Some of the smartest people in industry share the dream of enabling the triple bottom line of economic prosperity, environmental responsibility and social responsibility with the *Uptime* team.

When I meet *Uptime* readers in the field, one of the first questions I get is, "How do you keep bringing information that actually helps me do my job? It sometimes seems like you know just what I need to learn or think about."

The secret? The Uptime team shares the same dreams as you do.
Here is a look under the hood to acknowledge some of the people who continue to shape where this framework and *Uptime* Magazine is heading.

REM ACM WEM LER AM

RELIABILITY ENGINEERING FOR MAINTENANCE

In 1978, Nowlan and Heap released the report that changed everything titled reliability centered maintenance and the world began to shift to a more proactive approach to asset maintenance management. There has been a combination of extraordinary successes and extraordinary failures in the application of reliability engineering for maintenance, but *Uptime* thinks it is the MOST important knowledge domain because it is the only one that systemically reduces failures or its effects.

We mourn the passing of RCM great, John Moubray (RCM2 and leader of the Aladon Network), and we remembered him in the Aug/Sept 2014 issue of *Uptime*. We continue to celebrate his life work and move to the future with the "Reliability Centered Maintenance Project Manager's Guide" (www.uptime4.me/rc-managers-guide) available as a peer-developed implementation methodology for those who wish to use it. We are fortunate to still have access to our other RCM pioneer, Anthony "Mac" Smith, who would have certainly left us if not for the quick thinking and action of his wife Mary Lou, who discovered Mac shortly after he suffered a heart attack but, used CPR and a calm call for emergency help to bring him back.

We continue to examine solutions to the CAPEX to OPEX value divide brought forward by Bentley Systems' CEO, Greg Bentley, during past CIO Roundtable events in Amsterdam and London, as well as Emerson's Robert DiStefano. Two organizations stand out in the area, including Southern Company in the United States (see Uptime Oct/Nov 2013) and Crossrail in the United Kingdom (see Uptime Oct/Nov 2014).

The REM section is not complete without mentioning our Guru/Teachers, Dr. Bob Abernethy (translator of the work developed by Waloddi Weibull of Weibull Analysis fame and the reason the Lockheed SR-71 Blackbird ever flew) and Paul Barringer, the smartest reliability engineer alive today. He has been both patient and generous with his time and knowledge.

ASSET CONDITION MANAGEMENT

Allied Reliability Group's leader, John Schultz, who is a visionary for all things that used to be called predictive maintenance and has transformed this entire subject, deserves special recognition. *Uptime* Magazine would like to make it clear that all work we have done in this area begins with the work

Sharing the Dream

by Terrence O'Hanlon

of Mr. Schultz and his direct protégées, Andy Page and Carey Repasz – three people who moved asset condition monitoring and management thinking ahead by at least a decade and linked it with reliability.

We would also like to call out Mapped Services and Training (MSAT) Providers, Lubrication Engineers, Ludeca and SDT Ultrasound, for developing some powerful new paradigms in the asset condition management supply community based on delivering successful outcomes for clients rather than just selling a product or service.

Authors and subject matter experts, Jack Nicholas (*Asset Condition Management*) and Alan Friedman (*Audit It: Improve It.*), cultivate new thinking in program management for effective use of condition monitoring.

Our thanks also go out to Jim Hall of the Ultrasound Institute, Dr. Ronald Eshelman of the Vibration Institute, Jim Berry of Technical Associates, Wayne Ruddock of Advanced Infrared Resources, Dr. Howard Penrose (better known as Motor Doc) and lubrication trainer, Ray Thibault.

WORK EXECUTION MANAGEMENT

Uptime Magazine is very fortunate to have the time, attention and contribution of Mr. Terry Wireman, who we consider to be the absolute master of all things work execution management related with his six book series, *Maintenance Strategy Series,* published by Reliabilityweb.com. He is also a successful trainer for the Certified Reliability Leader courses.

Our other prime inspiration is Life Cycle Engineering's Joel Levitt, who has produced an equivalent WEM body of knowledge to Mr. Wireman's. He continues to amaze us with his zen-like enlightened teachings about performance in life and work.

The team of Jeff Shiver, Dave Bertolini and Tammi Pickett keep us connected at the equipment level, where the rubber meets the road in reliability, maintenance planning and scheduling, and effective CMMS use.

LEADERSHIP FOR RELIABILITY

There is an interface between reliability, work execution management and leadership, and there is no one whose work bridges it more than that of Winston Ledet, author of *Don't Just Fix It, Improve It!* and *Level 5 Leadership At Work*. He has provided us with the insight to empower teams for defect elimination and teaches us the direct connection to and from leadership and asset reliability.

Cliff Williams woke us up to the culture created with leadership in *People: A Reliability Success Story* and if you have ever seen Cliff's non-traditional keynotes, you can see why I used the term "woke up."

Filling in the reliability leadership gap is Ron Moore, whose best selling books, *Making Common Sense Common Practice* and *What Tool? When?,* lead all maintenance reliability titles in terms of sales volume. If you have ever read them or had the good fortune to hear Ron speak, you will understand why.

In the real world, I would like to thank two people who live it, George Williams and George Mahoney, who have taught me that performance is the result of leadership and that by generously empowering those around you as leaders, everyone benefits. The performance that these two have created, each in their own way, will serve as my own lighthouse in my attempts to improve in this area.

ASSET MANAGEMENT

It is all about value at the end of the day and the people showing us how to create and deliver performance through asset management include ISO TC-251 Chairman Rhys Davies, IAM CEO David McKeown, MTA's Michael Salvato, University of Wisconsin's Thomas Smith and US TAG Chairman Jim Dieter. You can watch for more thought leadership in this area as we expand our coverage to learn from organizations like Pacific Gas and Electric that earn ISO50001 Certification.

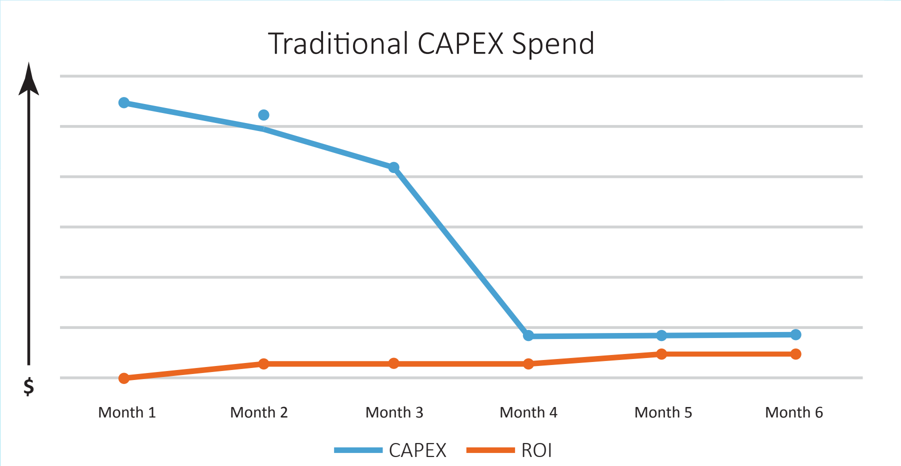
And finally, we like to say you are known by the associations you keep, so we stay plugged into dozens of the societies, groups and associations who are part of a larger community of practice called The Asset Management Alliance, who are engaged in creating guidance for the rest of us. These groups include The Association of Asset Management Professionals (www.maintenance.org), The Institute of Asset Management (www.theiam.org), MIMOSA (www.mimosa.org), The Industrial Internet Consortium (www.industrialinternetconsortium.org), BEMAS (www.bemas.org/en) and STLE (www.stle.org) and will continue to rapidly expand in 2016.

So, when I do meet readers who want to know how we manage to publish such high quality information, we hope this short acknowledgment, that leaves out hundreds of great contributors (sorry about that), provides a glimpse of the rarified air we get to do business in.

Captial vs Operational Expenditures

Companies that follow a traditional CAPEX model when implementing ultrasound to their reliability strategy face high risks, big up-front investment, and longer wait times for ROI. The risks are 100% borne by the customer with no guarantee for success.

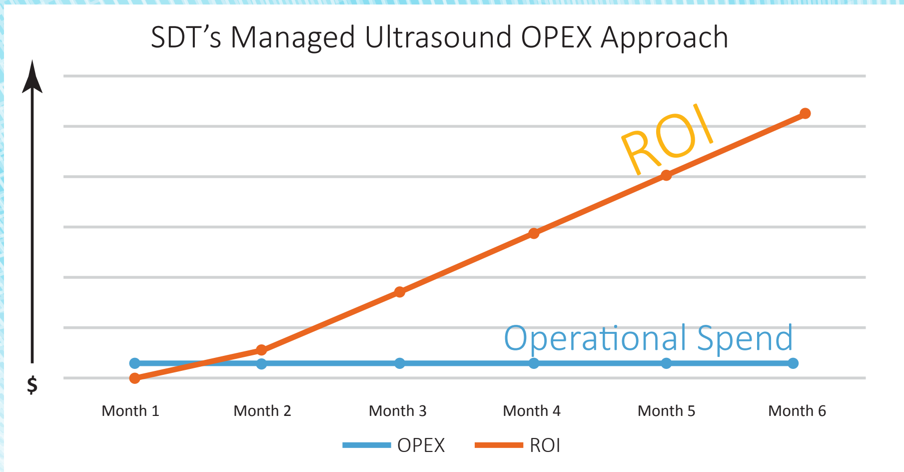
Without SDT's roadmap to world-class, up to six months may pass before your team even finds its first air leak or acoustically greases their first motor bearing. The chart "Traditional CAPEX Spend" illustrates how ROI is still below CAPEX six months after deployment. That's unacceptable.



With SDT's MANAGED ULTRASOUND approach no CAPEX is required.

SDT shares the front-end burden of start up by providing all the hardware, sensors, software, training, and mentorship you need. Program costs are spread out over low, all-inclusive monthly fees pulled from your OPEX budget.

Progress is marked by 3 major milestones and scorecarded to track your progress. Regular site visits by your dedicated customer success representative ensures that you program stays on track. We help you document your success and highlight the ROI that you have achieved.



A New Way of Thinking

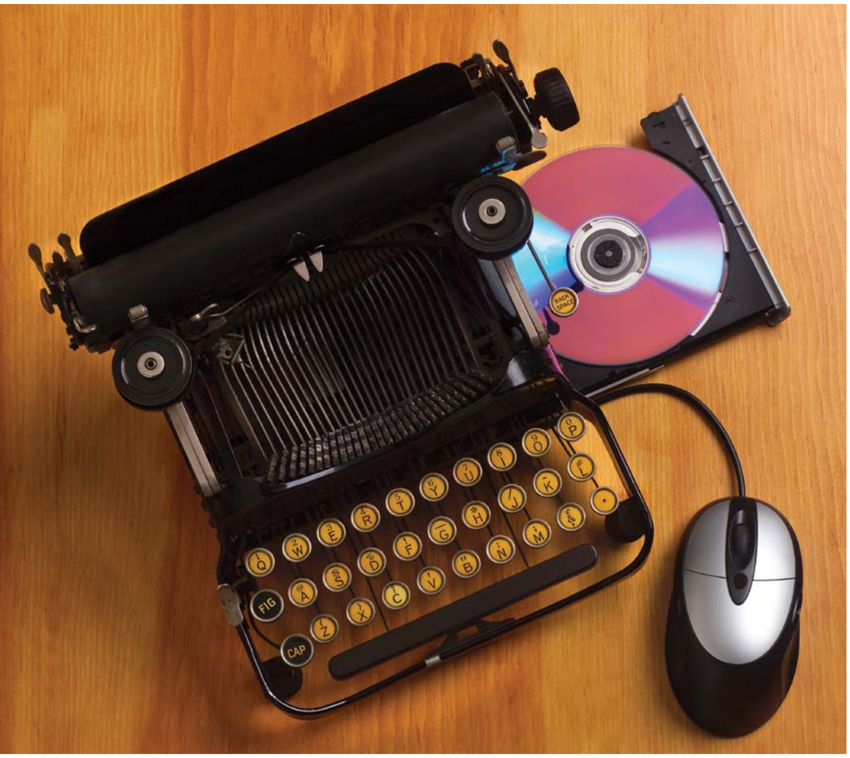
Managed ultrasound represents a new way of thinking to be sure. Even if you are already getting results from your ultrasound initiative, you know you can be doing better. As ultrasound testing takes its place as a key element of your asset condition management strategy you know you need to do more… to hear more.

Managed Ultrasound offers something different. A new approach. A partnership which is only available when you pair yourself with a technology leader.

Talk to an SDT Representative to Hear More

sdthearmore.com/managed-ultrasound

> "Sometimes I wonder if the maintenance reliability community (and now the asset management community) are making any progress at all."
>
> – Reliability Guru, Terrence O'Hanlon



What has changed in last 10, 20, 50 years? Have you noticed any changes? There are some things that have changed and some that have stayed the same.

We live in a digital age now. Babies are playing with tablets and smartphones instead of dolls and building blocks. Technology is making us change big time. It is changing our lives, but there are some things it will not change. They are the fundamentals. We are re-branding them and giving them different names, but the basic principles did not change.

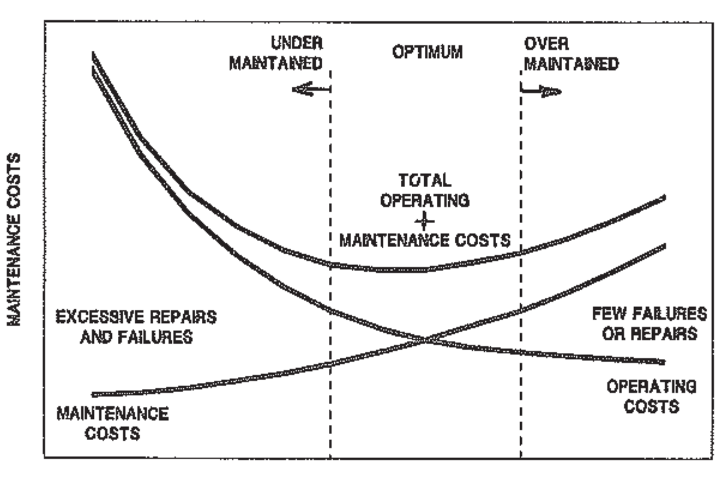
Let's take preventive maintenance (PM) as an example. We invented or learned the hard way back in the 1960s that we need to check or inspect the machinery and fix it accordingly so it does not fail. Technology is helping us do that more efficiently, but the basic principles remain the same. But the question is: Are all of us doing PM? Unfortunately, the answer is no. Many companies still live in a REACTIVE, run to failure mode.

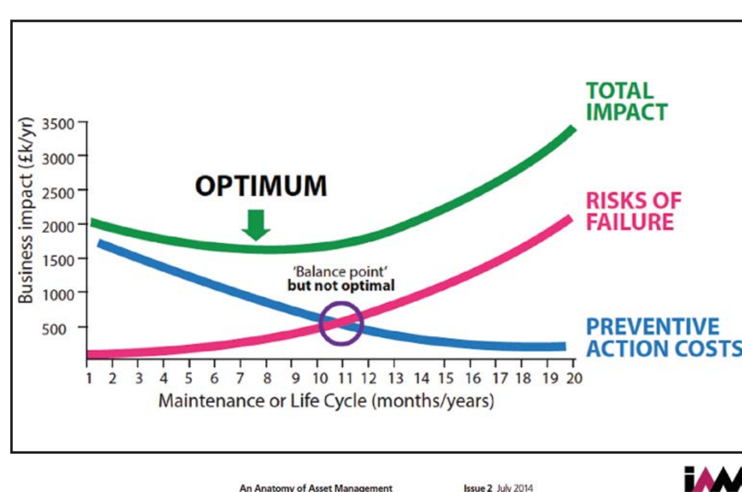
Let's take another example, planning and scheduling. We started planning the tasks and scheduling them to eliminate waiting time – waste – inefficiencies over 40 to 50 years ago. Do we do planning and scheduling in a proper way? Again, the answer is no. Many organizations are still struggling to implement planning and scheduling. They may have a planner in namesake only, since what he or she does is just scheduling.

I wrote and presented this paper almost 30 years ago. I accidentally found it and was surprised to read that we are still struggling to implement some of the things I talked about in the paper. We still don't understand basic fundamentals. We have a long way to go.

The More Things **Change**, the More They Stay the **Same**

by Ramesh Gulati





Notice the similarity between Figure 3 on optimized maintenance (from the paper, "Optimization of Maintenance" by Ramesh Gulati, 1988) and Institute of Asset Management (IAM) Anatomy 2014 Figure 3 on optimized asset management.

Ramesh Gulati, CRL, CMRP CRE, *is an Asset Management and Reliability Planning Manager with Aerospace Testing Alliance at Arnold Engineering Development Center (AEDC), Arnold AFB, TN.*

OPTIMIZATION IN MAINTENANCE . . . *a survival strategy**

Ramesh C. Gulati, P.E.
Manager, Industrial Engineering
Sverdrup Technology Inc.
Arnold Engineering Development Center, Tennessee 37389

ABSTRACT

Maintenance costs can't be ignored in today's environment. They have direct impact on the "bottom line ". This paper describes a program, based on optimization concepts, to reduce maintenance costs and to improve plant/facility operating effectiveness, resulting in higher productivity.

PRESENT SITUATION

The maintenance function has become a critical element in today's environment. Its impact on the "bottom line" is much more visible today than it has been in the past. Only a few years ago, management felt little obligation to concern itself with maintenance costs because they were a relatively small part of overall costs. This situation has now changed drastically since maintenance costs are no longer a small number. They constitute a major portion of the total facility operating expense. A recent survey in the manufacturing segment of the industry by the Society of Manufacturing Engineering (SME) indicates that maintenance costs now range from 3 to almost 16 percent of the total sales dollars where previously they had been in the range of 2 to 8 percent.

There are several factors contributing to the upward trend in maintenance costs:

- Higher labor cost
- Complex and state-of-the-art equipment
- Higher downtime cost
- Specialized training cost
- Low maintenance effectiveness

To increase maintenance productivity and reduce costs, changes must be made in the traditional way of managing maintenance. An objective approach, using optimization techniques described below, may be used to achieve the desired results.

MAINTENANCE OBJECTIVES

Maintenance is any activity designed to keep equipment or other assets in working condition. Poorly maintained equipment can be unsafe to operate and can create high costs in the form of delays, defective products, and idle time. Maintenance usually deals with servicing equipment, replacing worn-out parts, and doing emergency repairs.

The objective of maintenance is to keep equipment and other assets in a condition that will best facilitate organizational goals. This does not necessarily mean that everything must be in the best operating condition with all new parts so that failures (breakdowns) never occur. This would be nice from a theoretical standpoint, but unfeasible from a practical point of view, and may be cost prohibitive to achieve. Maintenance activities should be evaluated in light of the total operating system and optimized to reduce the total cost. Therefore, maintenance goals should be to:

1. Improve equipment/facility availability, and

2. Optimize maintenance activities (costs) to reduce total cost.

IMPROVING EQUIPMENT AVAILABILITY

Availability is a measure of the degree to which an item is in an operable and committable state at the start of a mission when the mission is called at an unknown (random)time. In simple terms, it may be stated as the probability that equipment will be in operating condition whenever needed.

Availability is also a function of reliability and maintainability. Reliability is usually defined as the probability that equipment or a system will give satisfactory performance for a specified period of time when used under stated conditions. It is usually expressed in terms of mean time between failures (MTBF), or mean life. Maintainability usually refers to those features of equipment or a system that contribute to its ease of repair. It is

*The effort reported herein was performed at the Arnold Engineering Development Center (AEDC), Air Force Systems Command. Work and analysis for this effort were done by personnel of Sverdrup Technology, Inc./AEDC Group, operating contractor of the AEDC propulsion test facilities. Further reproduction is authorized to satisfy needs of the U. S. Government.

This paper was presented to 1988 International Industrial Engineering Conference at Orlando, Florida.

usually expressed in mean time to repair (MTTR). Mathematically, availability can be expressed as

Availability = Uptime/(Uptime + Downtime)

= MTBF /(MTBF + MTTR)

MTBF = Mean Time Between Failure

MTTR = Mean Time To Repair

To improve availability, uptime (or MTBF) has to be improved. In other words, the number of failures must be decreased, which will cause the MTBF to go up. Also, downtime, or MTTR, needs to be reduced. MTBF and MTTR are essential parameters for tracking to improve availability.

To establish MTBF and MTTR, an equipment history data base is required. This data base helps in the decision making process for maintaining the facility in a cost effective manner. The equipment data base should contain the following information:

- Failure - Breakdown Events
- Preventive Maintenance (PM) Performed
- Planned/Scheduled Repairs
- Operating/Usage Hours
- Repair Time and Cost

In addition, it could have

- Equipment Name Plate and Specifications
- Spare Part/Component Data
- Drawings Data

Information from the equipment data base can be used to perform failure analyses to identify problem areas. This allows cost effective corrective actions to be taken to reduce failure rates and repair time, thereby increasing plant/facility availability.

The results of a failure analysis using an equipment data base are shown in Fig. 1. Failure data from 45 hydraulic systems in a facility were analyzed. Four major failure modes were identified and the number of failures in each category were plotted to show trends. As the data indicate, failures due to "leaks" and "contamination" show an upward trend along with "out of adjustment."

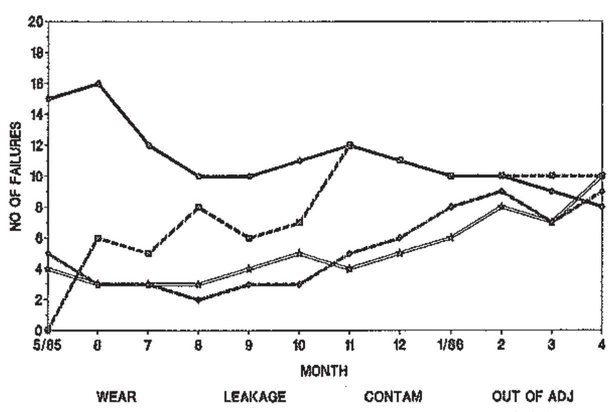


Fig. 1. Hydraulic failure trend analysis.

On investigation, it was found that "leaks" and "out of adjustment" were caused by vibration (probably by hydraulic hammer effect and faulty motor coupling), and a workmanship problem created by some new employees in the maintenance crew. To correct the workmanship problem, a training program was instituted to improve the skill of the craft employees working in the area. Vibration problems are being corrected by redesigning some of the systems.

The facility system engineer had some knowledge of the contamination problem, but not the magnitude of it. However, with the aid of a well-organized data base, he was able to easily justify a new filtration system.

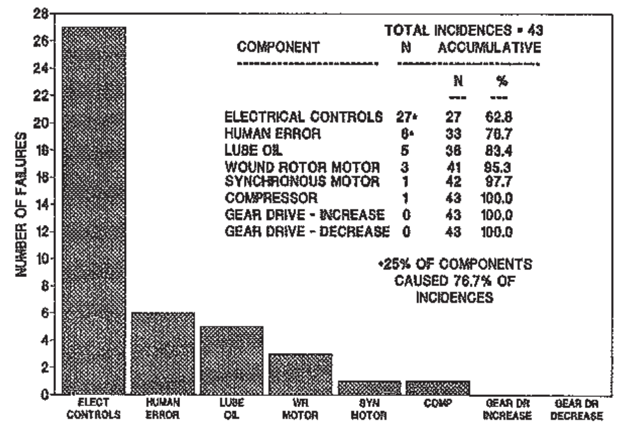


Fig. 2. Pareto analysis - compressor system.

Results from a second failure analysis, using a simple Pareto approach, are shown in Fig. 2. The number of failures for seven major subsystems of a large compressor system, along with those due to human error, are plotted and tabulated in the above figure. As data indicate, 74 percent of the problems are contributed by two subsystems, "electrical controls" and "lube oil." Problems in these two subsystems should be addressed; reducing system failures should be the first consideration. Pareto analyses guide in prioritizing the work in order to reduce failures. In fact, it supports an overall maintenance resources optimization.

MAINTENANCE ACTIVITIES OPTIMIZATION

Are we maintaining the facility cost-effectively? Are we doing the right amount of PM's? What is the optimum level of maintenance? The impact of level of maintenance on total cost can be significant, and is illustrated in Fig. 3.

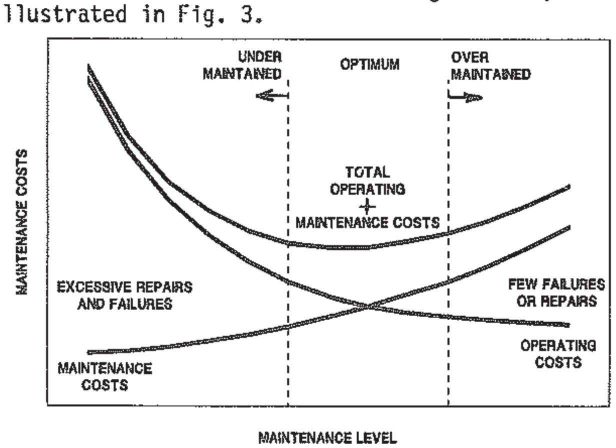


Fig 3. Maintenance level versus costs.

Maintenance repair activities can be classified into two major categories; planned and unplanned. "Unplanned," also known as "failure" or "breakdown," is usually of an emergency nature and is performed when equipment fails to operate, often at a premium cost. Planned repairs can be further divided into two classifications: preventive maintenance (PM) and scheduled or corrective repairs.

Preventive vs Breakdown (Failure)

Traditionally, PM programs are set up to carry out equipment maintenance on a regular calendar schedule or hours of operation based on equipment manufacturers' recommendations. These recommendations are usually based on an average operating environment. However, questions the plant engineer should ask include: Is my operating environment different? What is the failure rate of equipment? Is it cost effective to perform PM's? Figure 4 shows a PM and breakdown (Failure) cost scenario.

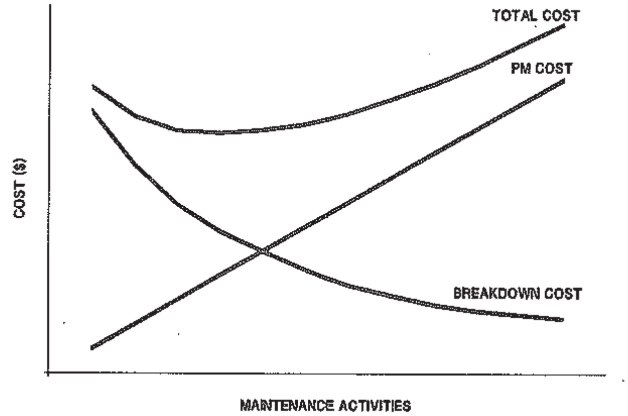


Fig. 4. Preventive versus breakdown costs.

To develop an optimum level of maintenance, repair activities cost should be collected and tracked by:

a. Breakdown (Failure) Repair cost
b. PM Inspection/Repair cost
c. Scheduled Repairs cost

Typical maintenance repair cost data is shown below:

TYPE OF MAINTENANCE	CURRENT MONTH		YEAR TO DATE	
	LABOR - MH	COST - $	LABOR - MH	COST - $
BREAKDOWNS (FAILURES)	1,028 (18.6%)	25,560 (19.2%)	7,204 (18.3%)	177,716 (17.5%)
PREVENTATIVE MAINTENANCE	829 (14.9%)	17,580 (13.2%)	7,042 (17.9%)	160,920 (15.9%)
SCHEDULED REPAIRS	3,682 (66.5%)	89,840 (67.6%)	25,135 (63.8%)	673,493 (66.6%)

A cost analysis would indicate impact of PM cost on failure and total maintenance costs. Ideally, the failure cost should be the driving factor of an effective PM program. The cost analysis should help in developing an optimum level of maintenance.

A multi-year maintenance cost analysis is shown below in Fig. 5 indicating an upward trend in PM cost and a downward trend in failure cost. The failure cost has been higher than PM cost, but the trend reversed in 1987 when PM cost went up slightly more than the failure cost. However, the total maintenance cost is still down and holding at a steady level. It is a very desirable trend. Maintenance activities costs need to be tracked to arrive at an optimum level of maintenance.

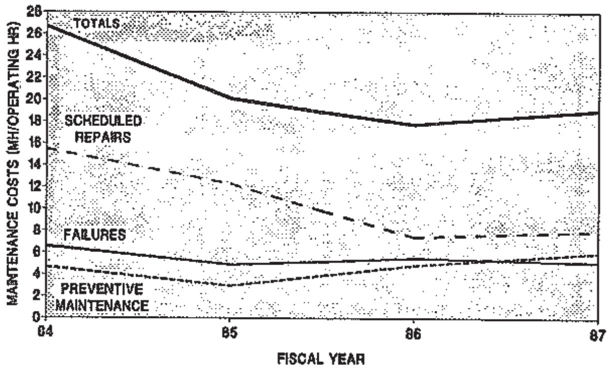


Fig. 5. Maintenance activities analysis.

MAINTENANCE COST OPTIMIZATION MODELS

PM and Breakdown Cost Model

Preventive Maintenance (PM) can be most effective when service/repair needs are well known or breakdowns (failures) can be predicted with some degree of reliability.

A well-organized equipment data base can provide information to develop a cost model using the concept of expected value. This model helps in the decision process used in estabilishing cost-effective maintenance policies. In the following example, the mentioned concept is used to determine the cost advantage of a PM policy.

A typical equipment history data base has the following repair cost information on a machine for the last 20-month period.

MONTH	BREAKDOWNS (SERVICE CALLS)	REPAIR COST $
1	1	500
2	0	0
3	3	1230
4	2	900
5	2	800
6	1	650

Continued on next page.

MONTH	BREAKDOWNS (SERVICE CALLS)	REPAIR COST $
7	3	2250
8	1	400
9	1	150
10	2	480
11	4	800
12	2	1200
13	2	750
14	1	600
15	0	0
16	2	860
17	3	1600
18	1	400
19	3	850
20	2	600
TOTALS	36	15,120

The plant engineer is in the process of developing a PM program for the machine. It is estimated that it would cost $225 to perform the PM that would reduce the breakdowns (service calls) to one per month. Is PM proposal cost effective?

The above data can be grouped by number of breakdowns (service calls) and number of months they occurred. The average cost of a breakdown is also calculated.

NUMBER OF BREAKDOWNS	0	1	2	3	4
NUMBER OF MONTHS OCCURRED	2	6	7	4	1

AVERAGE BREAKDOWN COST = $15,120 ÷ 36 = $420

Breakdown frequencies can now be converted to probability distribution to determine expected cost/month of breakdowns.

NO. OF BREAKDOWNS (X)	NO. OF MONTHS OCCURRED f(X)	PROBABILITY OF BREAKDOWNS P(X)	MEAN NO. OF BREAKDOWNS X.P(X)
0	2	.10	0.00
1	6	.30	.30
2	7	.35	.70
3	4	.20	.60
4	1	.05	.20
	20		1.80

The average service cost/month
= $420 x 1.8 = $756.0

Maintenance Cost/month with PM proposal:
PM cost = $225
Cost of 1 service call = $420
Total = $645

Cost advantage/savings from PM
= $756 - $645
= $111

Crew Size Model

The following example illustrates how the modeling technique can be used in establishing optimal crew size.

There are approximately 40 machines in an area of a plant. The maintenance analyst is attempting to establish size of maintenance crew to meet the servicing needs in the area. The plant equipment history data base has the following information for this area:

Mean Breakdown(service call) rate = 4/Hour

Mean number of machines
that can be serviced/worker = 6/Hour

Average Machine downtime cost = $200/Hour

Average Labor cost = $20/Hour

In developing a model, it is assumed that machine breakdown rate follows a Poission distribution and service rate follows an exponential distribution Using the concepts of queuing theory, the data are analyzed and the total cost, including failure cost is calculated.

	CREW SIZE			
	1	2	3	4
MEAN ARRIVAL RATE	4	4	4	4
MEAN SERVICE RATE	6	12	18	24
MEAN NUMBER OF MACHINE IN SYSTEM WAITING FOR SERVICE	2	1/2	2/7	1/5
CREW COST/HR	$20.00	$40.00	$60.00	$80.00
DOWNTIME COST/HR	$400.00	$100.00	$57.10	$40.00
TOTAL COST/HR	$420.00	$140.00	$117.10	$120.00

The analysis indicates that a crew size of three will be most cost effective.

PROGRAM RESULTS

The discussed practices have been implemented with a high degree of success. Significant reductions in downtime and maintenance costs have been achieved. The program has created a new awareness among plant personnel. The downtime data in Fig. 6 indicate a downward trend for the total facility and a plant within the facility as shown below. The reduction in downtime and number of failures has resulted in approximately a 3-percent improvement in plant availability.

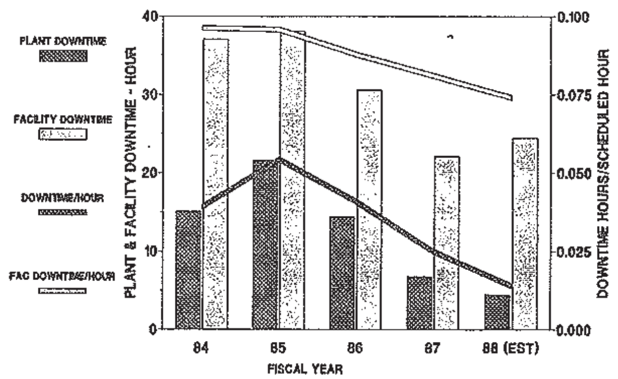


Fig. 6. Plant/facility downtime data.

The maintenance cost data for the plant shown in Fig. 7 indicate that cost/month is remaining at the same level for the two previous years after showing a significant downward trend. However, cost/scheduled hour had an appreciable jump in 1987 after a steady decline. An analysis of data revealed that this was caused by reduction in scheduled hours (production curtailment) in 1987. Overall, there is a positive trend in maintenance cost reduction.

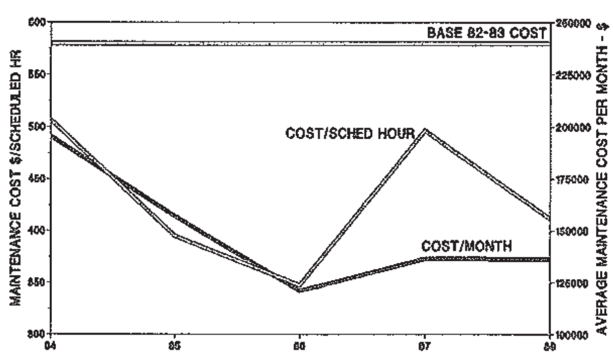


Fig. 7. Plant maintenance cost analysis.

CONCLUSION

Maintenance costs can't be ignored in today's environment. They have significant impact on operating effectiveness. The bottom line maintenance objectives should be to improve equipment/facility availability and to reduce maintenance costs.

Optimization concepts can be applied to improve plant/facility effectiveness, resulting in higher productivity and a reduction in maintenance costs, and thereby reducing overall product/service cost.

SURVIVING LOW OIL

What Producers Can Do to Weather This Storm

by James Nesbitt

The first half of 2015 has seen a dramatic drop in the price of crude oil. Six-year lows are being seen and there is uncertainty about where or when the market will bottom out.

There is a lot of speculation as to the causes of this situation. The current environment is even more impactful since it comes on the heels of record highs for oil prices driven by increased oil consumption in growing nations, such as China, coupled with unrest and conflict in key oil supplying nations, such as Iraq. This caused conventional producers worldwide to struggle to keep up with demand. As a result, prices spiked and $100/bbl oil was the norm since 2010.

This increased demand, coupled with record, seemingly sustainable prices, made traditionally cost prohibitive methods of extraction viable. Shale or tight oil extraction in North Dakota and steam-assisted gravity drainage (SAGD) in the heavy oil sands of northern Alberta are now attractive to producers and investors eager to exploit the high market value of oil. In the U.S. alone, production has risen by four million barrels a day since 2008.

Capital project budgets reached record limits and finding human capital (i.e., skilled and experienced people to operate, maintain and manage these facilities) became increasingly difficult. Competition for employees drove salaries ever higher, supported by the need to produce and the high margins available.

All this was stable until demand started to taper off and supply was able to outpace it. This resulted in unsold oil being stockpiled until later and a worldwide surplus or glut of oil supply.

The Organization of the Petroleum Exporting Countries (OPEC) has typically been the balance in this equation. As the process of oil production is threatened, the curtailment of supply through OPEC nations ensured the supply side of the equation was in check and the price remained stable. However, this time, OPEC has refused to cut supply, citing a loss of market share to higher cost producers, such as shale and SAGD.

Now, producers have seen their margins reduced to razor-thin levels. Costs that were justifiable in a higher return environment are now threatening the viability of the business. Furthermore, cash reserves are quickly being consumed as organizations try to reduce their workforces to adapt to this economic reality.

One thing that hasn't changed is the need for organizations to fulfill their regulatory and social requirements to operate. They must ensure they remain vigilant in controlling risks that could endanger the health and welfare of their employees and the community, as well as ensure they do not create an event that could have an irreparable impact on the environment.

PHYSICAL ASSET MANAGEMENT

The importance of managing physical assets has grown as a strategic lever in asset-intensive companies over the past several decades. It is driven by a range of factors, including the need to ensure sound safety and environmental stewardship, obtain solid financial returns, apply advanced technologies and demonstrate value to the shareholders and the communities in which they do busi-

The elimination or control of unplanned events is the greatest financial return that asset management can yield for your organization.

ness. In early 2014, this culminated in the publication of the ISO55000 standard for physical asset management.

Asset management is defined in ISO55000 as "the coordinated activity of an organization to realize value from assets." Instead of a cost to be managed, asset management has become a strategic element for helping organizations weather uncertain economic times and ensure they are at the head of the pack in terms of competitiveness. But beyond all this, asset management ensures that owners and operators have the systems, policies, practices and people in place to ensure safe, reliable and environmentally responsible operations.

THE NEW IMPORTANCE OF ASSET RELIABILITY

One aspect of asset management that is particularly powerful in a low margin oil environment is the implementation of business-focused equipment reliability programs. Reliability took root in low margin industries, such as paper production, where global competition, coupled with dramatically lower demands, meant only the lowest cost, most efficient producers would survive. Reducing the unit cost of production was essential, and re-

liability was one way to remain both competitive and viable. Oil production is not facing an alternative to its product, as was seen in the paper industry. However, the need to remain reliable will have a direct impact on profitability.

Unplanned equipment downtime erodes profit. It is a common mistake to think that unplanned downtime is less important when product margins are low. People think, "We are only making $18/bbl, therefore, the equipment does not need to be as reliable because the consequences aren't as severe." In fact, the opposite is true. The need to provide raw material, labor and energy to processes to produce products does not change. The best strategy for becoming a low cost producer of any product is to produce greater volumes at the same cost. Reliability accomplishes this. Unplanned, unreliable operations cause unrecoverable loss of salable goods and increased costs of labor, energy and materials, and will quickly result in an unsustainable business model.

The elimination or control of unplanned events is the greatest financial return that asset management can yield for your organization. By understanding the causes of unplanned events and focusing efforts on eliminating or avoiding preventable losses, organizations can quickly increase production values while lowering overall cost per barrel.

Historically, high margin producers were often lucky. In the new environment, low margin producers must be smart.

REDUCING COSTS

Reducing overall costs must be done, however, broad-brush cost-cutting measures will not ensure viability given that the timing of a return to higher margins is not guaranteed and the damage done by taking such an approach will be felt for years to come. Instead, the need is to ensure that the integrity of the operation remains intact and there is no increase in the risk associated with less maintenance. Robust reliability centered maintenance techniques, as outlined in SAE JA1011, are suitable to help understand the appropriate maintenance strategy for complex or tightly coupled operations. However, if the goal is to reduce cost while maintaining current performance and you need to do this quickly, a maintenance program optimization (MPO) review may be the answer.

Over time, maintenance programs tend to grow. Often the genesis of the program is an original equipment manufacturer's recommended maintenance program that has had a cursory review by the Engineering, Procurement, Construction (EPC). From here, the addition of new technology, techniques and responses to poor asset performance cause the maintenance program to grow. Experience shows that about 30 percent of the existing maintenance program is of low or no value. This is often for a number of reasons:

- The cost of the maintenance task often exceeds the cost of the failure it is trying to prevent. It is simply not worth doing.
- There are duplicate tasks, for example, changing oil based on a time schedule or cycles, as well as performing a lube analysis program.
- The tasks are inappropriate for the equipment. Often, legacy tasks remain in the system after component upgrades or capital improvements to the system, resulting in work that cannot be completed. This becomes an annoyance to the maintenance staff, who simply close the work as completed. This work is especially costly, as it still goes through the planning and scheduling processes and, in some cases, requires the purchasing of spare parts that will not be used. It is not technically feasible to do the work.
- The work does not reduce the risk of equipment failure. The work is not effective.
- Work that is poorly planned or too vague. For example, maintenance on an elevated motor that requires scaffolding or work that is simply labeled "inspect and repair as required."
- Work that is currently performed based on a schedule can be migrated to a condition, allowing your organization to increase the life of its equipment, yet still plan the repair in enough time to avoid the consequences of the failure.
- The identification of the risk associated with not performing preventive maintenance work. In most organizations, there is not enough personnel to do all the work. By understanding the risk associated with the work task, the organization can defer or cancel low risk tasks and focus on those that are the most effective.
- Reduction of reactive work. When the work is categorized based on risk avoidance and effectiveness, the amount of reactive work will decline. Reactive work is usually two to four times more costly to perform than proactive work.

Risk management provides a framework to ensure that:

✓	All levels of the organization understand the tolerance for risk and make decisions based on that known value.
✓	The identification of risk is consistent and based on the goals of the company (e.g., safety, the environment, production, etc.).
✓	Decisions to spend or defer money have a rational basis and consider the organization's exposure to risk.
✓	The development of mitigation, elimination and acceptance strategies are based on their impact on the organization.
✓	The organization allows capital spending decisions to be better planned.
✓	Senior management understands the current risks facing their business and provide the information needed to make critical business decisions.

RISK MANAGEMENT

UNDERSTAND RISK

When operating budgets shrink and resources that were limited before become even scarcer, understanding where to spend limited dollars is critical. Unfortunately, in many organizations, this decision is more emotional rather than quantitative.

CONCLUSION

No one knows how long low oil will last or how bad it will get before it stabilizes. However, producers need to react now. Cutting fat is the first logical step, but it must be done with care and precision. Asset management will help weather this storm while maintaining a profitable, competitive business that is ready to capitalize when the markets begin to turn.

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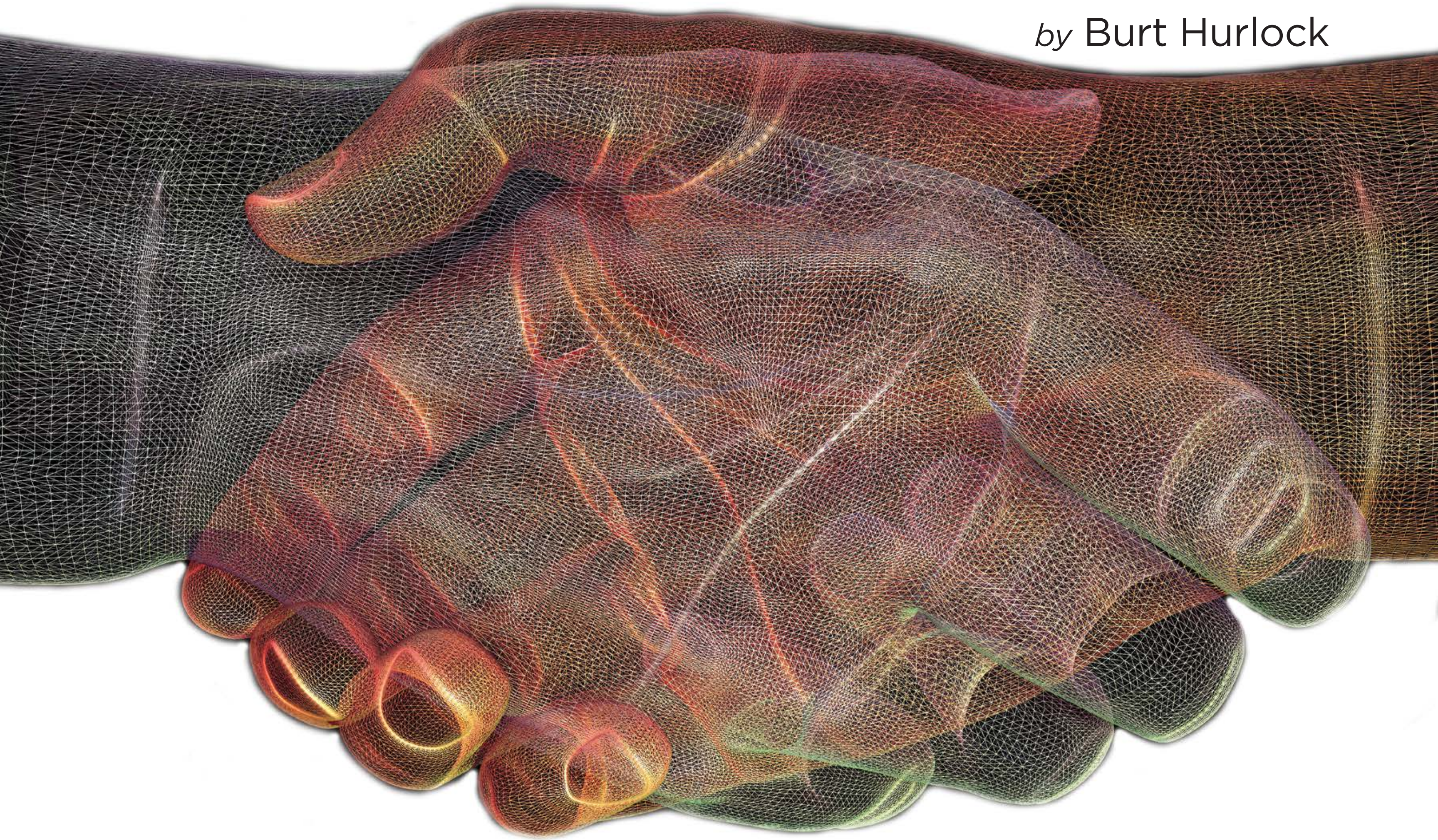
Human Capital and the Internet of Things

Managing talent and leveraging experience

by Burt Hurlock



If you have children aspiring to attend college, then you know that somewhere between the time of their birth and the present, the world changed. It went from valuing being well-rounded to valuing specialization. Whether that's a healthy development is a worthy debate, but not the purpose of this article. This article explores the role of the connected world in propagating specialization and how specialization has the potential to supercharge the value of old-fashioned human judgment.

Technical visionaries often invoke terms like the Internet of Things, smart machines and machine to machine (M2M) to ease our fears about managing the upcoming brain drain that accompanies the graying American industrial workforce. The theory goes that one day, self-learning machines and massively parallel computing may replace the operator. Perhaps, but not in the foreseeable future. That's because smart machines are very good at keeping us from doing dumb things, like stalling a commercial airliner, or pushing a gas compressor beyond safe tolerances. In the realm of black and white, the value of artificial intelligence is unassailable. But what about the rest of the time?

MYOPIC INTELLIGENCE

The Internet has accomplished little if not the ability to perform research and gather massive amounts of information quickly. Industrial automation combined with smart sensing technologies and advanced analytics have compounded the potential for knowledge and insight far beyond anything imaginable just ten years ago. What isn't known is whether these technologies will ever account for enough variables to achieve sufficient situational awareness to best human judgment.

This author once stood on the floor of a nuclear power generation control room simulator and tapped on the glass of an analog meter to see if reenacting the famous scene from the movie *The China Syndrome* would mean anything to the guide. He said, "We really do that, you know. Sometimes the humidity makes the gauges stick." He had never seen the movie. So what should be done until the Internet of Things and smart systems can anticipate and address all possible scenarios, situations and outcomes and become all-knowing? And how likely is that to happen so long as humans make mistakes and mechanical designs have flaws?

Scarcity may be a defining attribute of talent

WHEN LAMENTING THE BRAIN DRAIN IS CRYING CROCODILE TEARS

Technology vendors never hesitate to invoke the graying of the industrial workforce to underscore the need for interconnectedness, smart machines and even offshoring skilled industrial knowledge workers. From one perspective, the sales pitch is a slightly cynical exploitation of fear. From another, the solution being offered solves the brain drain problem by not displacing experienced American workers, but by making them more powerful, possibly indispensable.

Using massive connectedness to enhance visibility, disseminate knowledge and support collaboration accelerates situational awareness and improves the collective judgment of all manner of line workers, management, and arguably, faster than the systems themselves can ever catch up. Why? Because addressing the mundane, the black and white through automation frees up intellectual bandwidth to focus on increasingly complex problems associated with even more subtle variables that intelligent systems have yet to resolve. These variables may be so intermittent, uncorrelated, or local that they never submit to a universal rule base. It is these intelligence gaps in the connected world that will perpetually propagate specialization.

INTERNET OF THINGS OR INTERNET OF PEOPLE?

Terrence O'Hanlon, the publisher of *Uptime*, recently coined the phrase, the Internet of People, which nicely diffuses the fear and uncertainty that brain drain is sometimes used to provoke. The Internet of People may even envision organizational change and new business models that could eventually emulate the modern medical system, with its hub-and-spoke care delivery systems that depend on highly specialized satellites of expertise supporting centers or hubs of total care. Just like medical specialty practices are the healthcare world's method of rationally allocating scarce skills and knowledge, networks of highly experienced machine health analysts can virtually achieve in the industrial world what the medical world has achieved locally. In this scenario, the demise of the industrial workforce, as author Mark Twain warned, may be greatly exaggerated, but only on two conditions: 1) that the workforce recognizes and seizes the opportunity, and 2) that there are rewards for doing so.

Talent and experience have always been scarce. In fact, scarcity may be a defining attribute of talent. So the problem is not new, nor is it without its merits for both talent and those seeking to employ it. In most commercial endeavors, talent is rewarded with outsized returns. From Hollywood actors to great Wall Street traders, talent gets paid commensurately with the value it contributes to the enterprise. Lamenting the industrial talent exodus begs the question of whether American industrial workers are being rewarded commensurately with their contribution. It's a question that will become more poignant as interconnectedness accelerates specialization and specialists acquire more leverage by achieving efficient production. Why should industry expect more for less when that paradigm isn't commercially viable anywhere else? And does that expectation explain the brain drain? Industry has its role to play in rewarding big value-generating diagnostic insights or all that hand-wringing about the graying workforce and the disinterest of the millennials rings hollow.

NATURE ABHORS A VACUUM

The Internet of People arrives just in time to fill whatever experience vacuum may be developing in industrial America and at the very moment that industrial enterprises have both the tools and the need to correlate value with knowledge and experience. Whether or not specialists emerge through and by the Internet to supply that demand remains an open question. However, free market theory suggests it's less a question of *if* than *when*. Until machines get smart enough to trump judgment, specialists on the end of scalable, connected solutions will dominate.

The graying industrial workforce is not the work of a malevolent universe, rather, it is a sign of change, evolution and transition of human capital. Like aging Air Force pilots for whom there is no substitute for a person in the cockpit with their hand on the stick, the new generation of drone pilots replacing them can't possibly bring to bear the knowledge, experience, or character required to do the job. It just isn't so. The remote world is everywhere for a generation where gathering information, analyzing it and acting on it remotely is second nature.

Perhaps it is connectedness and its power to concentrate and accelerate knowledge that is to blame for academia's pivot away from being well-rounded. Whatever the reason, specialization is the currency of the day. Moreover, specialization is the best way to play scarcity as an advantage, whether you're applying to college or carving out a sustainable role or business niche. Be it a response to the Internet or because of it, there has never been a better time than the era of connectedness for people from all walks of life to amass experience and knowledge of all kinds to leverage scarcity. Yet, the question remains whether industrial professionals will seize the opportunity to improve their own positions as employees or third parties for the benefit of the industries they serve.

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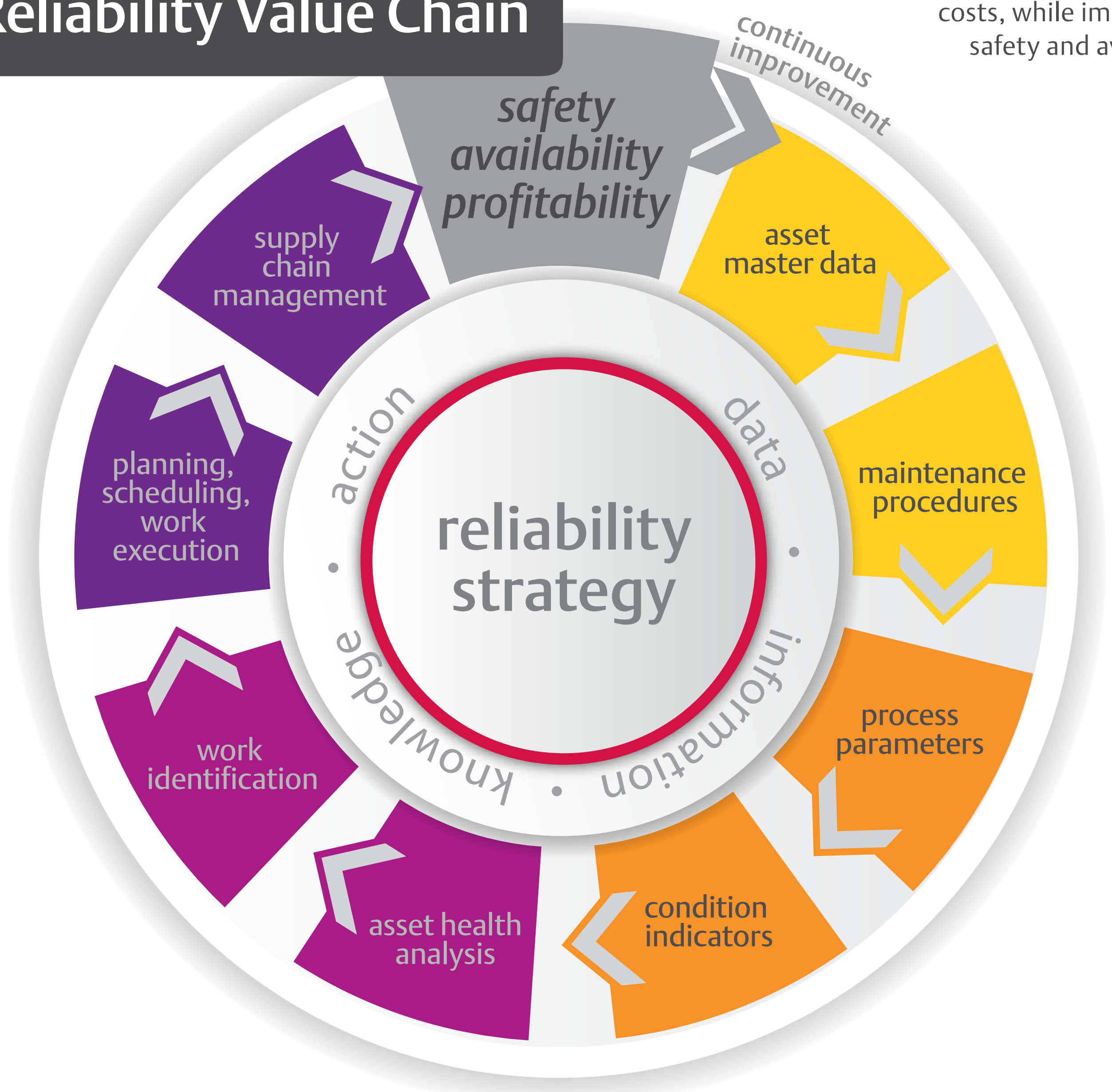
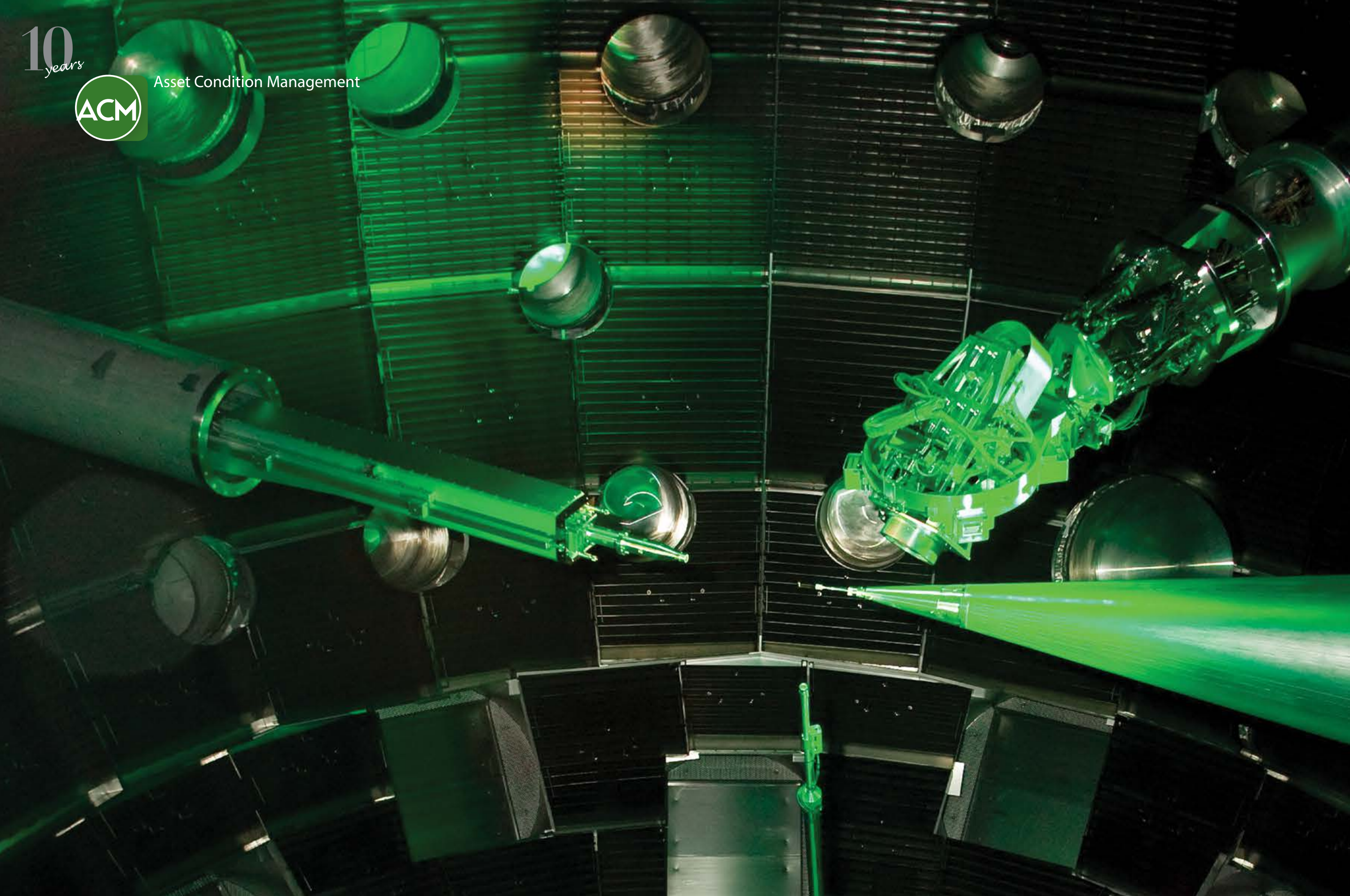
4 STEPS TO
IMPROVE YOUR

The Reliability Value Chain – Top performing companies understand that reliability is a chain of activities that reach across the organization. Transform your reliability program to drive down maintenance costs, while improving safety and availability.

Reliability Value Chain





PROACTIVE MAINTENANCE

Saves NIF Shot Time and Money

by Nick Jize

At Lawrence Livermore National Laboratory's National Ignition Facility (NIF), the world's largest laser system, we treat our assets the way a good medical doctor treats patients. We are proactively keeping tabs on the health of the equipment using asset condition management (ACM) techniques. We do not perform any intrusive maintenance until asset conditions require it.

NIF's product is the physics data derived from the experiments performed at the facility. Our goal is to maximize NIF's availability to do experiments and consequently its data output by predicting and preventing equipment failures before they occur. We want to be in control of the equipment, not let the equipment be in control of us.

NIF focuses 192 of the world's highest energy lasers on peppercorn-sized targets to create unprecedented conditions of temperature and pressure for a wide variety of cutting-edge scientific experiments. We use reliability centered maintenance (RCM) and other industry best practices processes and tools to keep NIF running at an ever increasing pace. NIF completed over 300 target experiment in Fiscal Year 2015 while also saving millions of dollars in avoided downtime and unnecessary maintenance. Since 2011, RCM and a companion program called condition-based maintenance (CBM) have saved more than $2 million. They are projected to save nearly $3.5 million by 2017. The programs use non-intrusive techniques, such as vibration analysis, oil analysis, ultrasonic lubrication and the elimination of ineffective preventive maintenance tasks.

The RCM program is a decision process to determine what needs to be done based on the function of the equipment. In other words, our decisions are function-based, not equipment-based. We look at the failure modes and effects of each asset and the criticality of the function it performs to determine the best maintenance path to follow.

We have determined that using a template process based on equipment type alone leads to wasted time and effort. For example, we now have a completely different preventive maintenance (PM) procedure for two identical pumps because one has a primary function and the other serves as a backup pump. While we maintain the primary pump with all essential PMs, we perform a different set of PMs to assure the backup pump is in a ready state.

A key asset condition management tool used by our facility operations and maintenance (FOM) group is vibration analysis. We use it to assess the health of critical pumps and motors to mitigate failures and plan for repairs with as much early notice as possible. Vibration analysis has allowed us to predict what's failing and how it's failing. We also keep historical records of this analysis and plan to potentially determine how much longer we have before a failure may occur.

We also use our vibration analyzer and precision laser alignment tool to perform alignment and balancing whenever we replace motors or fans. The vibration analyzer provides information about our critical rotating machinery, measuring the condition of bearings, co-alignment of motors and pumps, adequacy of equipment mounting and proper balancing, all of which affect the reliability of our rotating equipment.

When we install new equipment, we get a baseline of the vibration signature, make the necessary adjustments and take the baseline again until we're satisfied that we've installed the equipment properly. Then, we go out every quarter or so and take another vibration signature. Based on how the vibration spectrum is changing, we can tell whether a bearing is failing, if the motor has some imbalances and so forth.

The RCM program paid big dividends toward the end of last year when a routine monthly vibration analysis detected incipient failures on one of the motors in the laser amplifier cooling system. The motor was placed on a watch list and scheduled for weekly vibration analysis. Subsequent tests revealed a significant rise in low frequency vibrations, indicating further bearing deterioration and looseness. At that point, the FOM team received management approval to replace the motor before it failed.

Vibration analysis told us that the motor bearing was beginning to wear out and it wasn't worth the risk to extend the operation of the motor any longer. If it failed at an inopportune moment, it could impact facility costs a lot more than the cost of replacing the motor.

Vibration analysis allowed sufficient time to have a well planned replacement strategy using NIF's "Formula 1" operational approach based on the quick teamwork of Formula 1 race car pit crews. NIF's FOM and transport and handling (T&H) teams used pre-coordinated plans to replace and commission the motor in an available four-hour window between shots, taking less than three hours to complete the task. Prior to Formula 1 evaluation, the process in a reactive mode could have required a full eight-hour shift.

Figure 1: Facility operations and maintenance technicians perform precision alignment on the NIF central plant motor and pump set

This proactive approach prevented at least eight hours of shot delays had the motor failed while we were preparing for a shot. The Formula 1 process avoided at least two hours of shot delays, for a onetime savings of about $80,000.

We think of ACM in the same way a doctor thinks about using lab results prior to treating a patient. Our CBM differs from time-based preventive maintenance by taking into account the condition of the equipment in determining the need for additional maintenance. We use oil analysis to monitor the health of our rotating equipment and as a way to confirm any diagnoses from our vibration analysis data. For example, if vibration analysis indicates that we are seeing some bearing deterioration, we should be able to confirm this with an increase in the metallic contents of the oil. With these types of confirmations, we can then make informed decisions on performing the appropriate maintenance.

Figure 2: FOM electrician installs an accelerometer on a NIF power amplifier circulating fan motor

Lubrication for motors is another example. We use precision ultrasonic lubrication for all our motor bearing lubrication. This technology alone has doubled the life of our laser amplifier cooling motors. Based on the manufacturer's recommendations, we used to pump in three to six pumps of grease per bearing every quarter. It turned out that was much more than was needed for this operation. Now, we use ultrasonic oil analysis to determine if lubrication is needed.

The ultrasonic device is attached to a Zerk fitting and allows the technician to listen to the bearing while applying the lubricant. By doing this, the technician can determine how much lubricant to add and when to stop adding it. In the past, we used to find the windings full of grease during post-failure analysis. Now, we are no longer filling our motor windings with grease and eliminating that issue has extended the life of our motors.

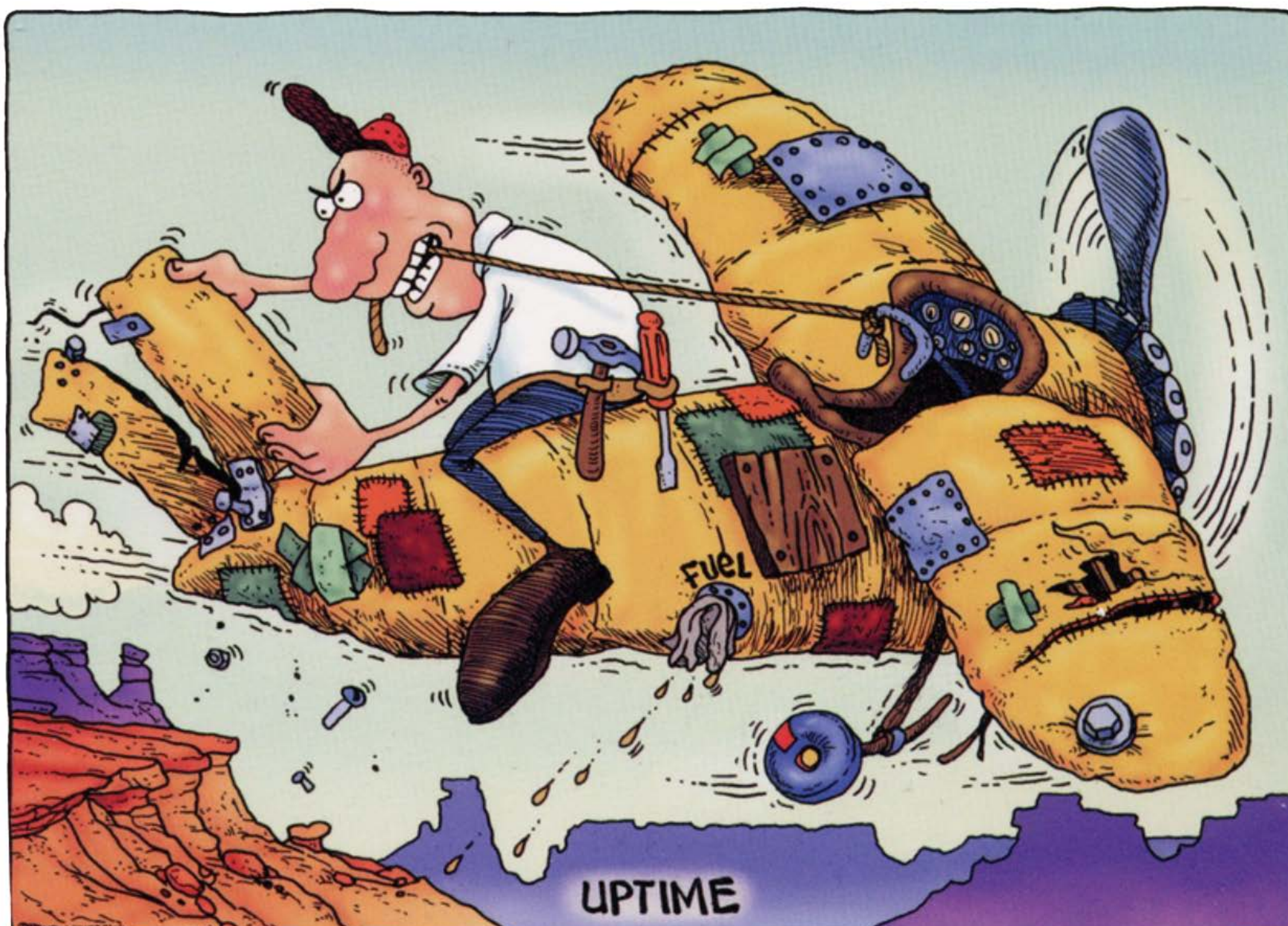
We also started using a paperless process, utilizing tablet computers to streamline our checklists and track our work orders. One hundred PM work orders are now being performed using the mobile platform and this number is increasing each week. Environmental stewardship is one of our goals and going mobile not only saves trees, but has saved time as well. Data from the field is seamlessly stored in our enterprise asset management (EAM) database and we get automatic alerts when inspections find parameters that are out of spec.

The FOM team performs about 6,000 PM work orders a year at an estimated average of four hours per work order. About 25 percent of all maintenance tasks have gone through a rigorous RCM analysis to evaluate cost-effectiveness and value, resulting in the elimination of hundreds of hours of ineffective preventive maintenance. In addition, the team has reduced the time spent doing reactive maintenance by 50 percent. RCM evaluations for the remaining maintenance tasks are in progress, but the reviews already are saving several hundred thousand dollars a year. Expansion of NIF's RCM and CBM efforts are planned for 2015 and the years to follow.

***Nick Jize** is the NIF facilities and utilities manager. He has more than 20 years of experience in reliability management and is considered an industry leader in reliability centered maintenance and asset condition management. His job is to ensure that all conventional facility equipment and utilities at NIF are ready for laser shot operations 24 hours a day, seven days a week.*

How to Build a High

by Mike Stonecipher



Warning: Leading a maintenance turnaround is not for the faint of heart.

It takes guts, vitamins and a lot of prayers, in addition to a good plan.

Performance Maintenance Team

A few years ago, this author inherited perhaps the world's most underperforming, unreliable, unpredictable, unacceptable and all other antonyms that are an antithesis for anything positive, maintenance team. The extreme lack of performance left all sorts of carnage piled up at the front door of the unemployment office. Maintenance managers did not last longer than 18 months before quitting or getting fired. To be fair, it was the result of long-term neglect and a few bad decisions by upper management. Nonetheless, the requirements of the job was to roll up the shirt sleeves, do a deep dive and fix it.

At the bottom of Maslow's hierarchy of needs are food and shelter. Simply put, SURVIVAL. That was exactly where the company was and its maintenance department was not helping the situation. However, this author's personal goal went beyond survival. It was to reclaim a higher quality of life by eliminating the late night and weekend calls that started out like, "Boss, you ain't gonna believe this!" Conditions were so bad that the author personally helped extinguish two fires in one year that could have burned down the facility, which, at the time, did not seem like a bad plan.

Just in case you or someone you know is experiencing a similar undesirable work environment, the author shares this brief recap of the maintenance turnaround plan that was used.

FIRST THINGS FIRST:

DELIVER a State of the Union Address

Pull together the facts, no matter how ugly they are, and present them to the entire maintenance team in a clear and succinct message. It is best that all team members hear it at the same time. This is a message that you cannot afford to have delivered secondhand or get misconstrued. Once the bad news is delivered, which is probably old news, begin painting a picture of the future and call it the "target condition." Demonstrate passion and convey what a critical role the maintenance department plays in the execution of the business strategy, achievement of operational performance targets and safety. Next, highlight some of the initial steps that will be taken to get the turnaround process started. No need to communicate a long, boring comprehensive plan. Just stick to the key areas that will receive a laser focus so the journey and dedication to achieving the target condition is crystal clear.

This meeting is not about searching for agreement or reaching a consensus. It is about setting a new direction and establishing a starting point for the turnaround. It is about encouraging those that want to change, converting those that are on the fence and firing a warning shot to those who are dead set on maintaining status quo. Will there be teamwork, employee feedback and participation? You bet! It is impossible to reach target condition without a fully engaged workforce.

DEVELOP a Code of Conduct and Daily Standard Work

This is the first team assignment. Pull together a mix of formal leaders and informal leaders. Why informal leaders? Because often they are the ones that others are going to follow. On a flip chart, begin documenting the characteristics of a high performance maintenance team. At this point, nothing is too basic. In fact, most of the items on the list should be fundamental and include such things as: start and stop times, protocol for shift hand off, documenting work performed, providing feedback to operators, behaving in a courteous and professional manner, and so forth. Take the feedback and create two formal documents: a code of conduct and daily standard work. Each document should be no more than one page in length. Once completed, ask the sub-team to present the documents to the team. It is critical that everyone hears the message, understands the documents and signs a training record. Post the documents in very conspicuous places throughout the maintenance shop. It is also a good idea to have some of the maintenance team members report on the new mode of operation at a monthly all employees meeting or at operational team meetings.

Now that expectations are clear, all future group meetings will be conducted with a sense of urgency and in a celebratory manner for each accomplishment achieved, even the small ones that look like baby steps. Long-term success is going to be built by putting points on the scoreboard, not by a single silver bullet. Will there be tough discussions? Yes, but probably with only a small percentage of the group. From this point forward, those discussions will be held in private and on an individual basis. Everyone else will be receiving praise and encouragement.

Will there be tough discussions?

YES

PURGE the Junk

This is not glamorous work. In fact, it can be extremely nasty. However, the result will make a huge impression, improve efficiency, safety and morale, and generate a cleansing feeling. It is like a new beginning. Don't be surprised that when you start purging the junk, you end up with over 14 flatbed trailers full of scrap steel and obsolete equipment for the recycler – no kidding!

Start with the red tag process. Expect some pushback because someone will insist that you keep that "one-of-a-kind inoperable 1968 strain gauge that was made by a company that no longer exists." Target purging the junk in the maintenance department first, then attack all other hidden areas scattered throughout the factory. Tackle the maintenance, repair and operations (MRO) tool crib, red tagging all junk and obsolete parts. Be sure not to forget or overlook cabinets and drawers.

During this process, keep the finance department or controller informed so assets can be properly accounted for. Before hauling everything to the recycler, pull a team of engineers, operators and maintenance technicians together to review the red tag area just to make sure there is nothing expensive, unique and still vital to maintenance and/or operations in the hold area. When completed and the junk is on its way to the recycler, the accomplishment will feel refreshing. Make a point to give the team positive feedback and celebrate! But don't stop there, because this is only the first step in the 5S process.

CONDUCT a Skills Assessment

This is optional based on the demonstrated strengths and skills of the individuals within the department. But if you suspect that the skills are insufficient, then they probably are insufficient. Do not swing at this assessment alone. Team up with human resources and your local technical or community college. There are several great resources and tools already developed, tested, validated and ready to use. This assessment is the starting point for building a strong, competent team. If you work in a union environment, the skill assessment still can be accomplished by working closely with the union leadership, sharing the vision and getting their buy-in to the plan.

START the Training Process

Once the job requirements have been determined and individual capabilities assessed, provide individual feedback in a confidential manner, along with a prescribed training plan. Again, this is best done through human resources and outside support. Establish a fair and reasonable time frame for completing the prescribed training plan. There will be pushback, but there also will be those who are trailblazers and set the course of action for being the first to complete the training. The good news is that course work is now conveniently available online and lab work can be conducted on-site or possibly at a technical school.

DEVELOP a Critical Equipment List

Identify the key equipment that can bring operations to a halt. It can be a single piece of equipment that is part of the process in which most of the products manufactured flows through it, or it can be equipment that does not have a backup or alternate process. Do not overlook infrastructure when evaluating critical equipment. If the facility or process is dependent on a boiler, compressor, cooling tower, or electrical substation, then be sure to include those items on the list of critical equipment. A substation that has been ignored or overloaded can be dangerous, create costly repairs and cause significant downtime.

A good approach for dealing with critical equipment is to: 1) have a robust preventive maintenance (PM) plan; 2) inventory critical spare parts; and, 3) have a backup plan for a catastrophic failure. For example, identify and pre-approve a contract manufacturer for temporary outsourcing. Redundant equipment is also something to consider, especially if outsourcing options are unavailable or control of intellectual property is critical.

CONSTRUCT a Capital Plan

Now that the junk is purged and a critical equipment list is constructed, identify the equipment that needs to be placed on an intensive care list. This list is for equipment that is currently on life support. Engineering support or an equipment technical representative from the original equipment manufacturer (OEM) should be able to help evaluate the options (e.g., invest in repairing and upgrading the equipment or purchase new equipment and unplug the life support). The costs and return on investment (ROI) for replacing or upgrading equipment on the intensive care list are the beginning of the capital plan. Depending on the company's health, a short-term repair may take precedence over replacement until funding can support a long-term solution.

Based on the size of the operation, equipment condition, complexity and advances in technology, the capital plan may be a three- to five-year outlook. This type of planning and detail will help with budgeting and eliminating surprises. There are other options to consider if capital is limited or non-existent, such as vendor financing. This is more common for very expensive equipment, like machining centers, lasers, etc.

HIRE a Reliability Engineer

A reliability engineer is extremely valuable, especially if sophisticated or complex equipment is involved. The ability to evaluate machinery, identify its weaknesses, develop a thorough PM plan and make engineering modifications to improve reliability will break the chains of unpredictable performance and reactionary maintenance. It is not unusual for a good reliability engineer to generate a savings of six to eight times his or her salary in the first year.

TOSS the Spreadsheets and Flash Cards – Go With CMMS

There are many low cost options for a computerized maintenance management system (CMMS). The ability to track and measure performance in real time is critical to achieving the target condition. A CMMS enables the maintenance team to optimize the usage of replacement parts, properly assign resources, plan for performing PMs and evaluate the effectiveness of the work being performed. If your company can afford it, install a wireless system and purchase tablets so entries and pictures can be made at the point of service. This is a big time-saver versus going to a computer terminal and getting in line to make entries.

IMPLEMENT the Right Metrics

It is not unusual to jump right to an overall equipment effectiveness (OEE) metric and wonder why performance is not better. Although OEE is an excellent metric, it is better to start off with basic metrics and master the simple things. For example, understanding equipment downtime and reason codes will provide guidance to root cause evaluation and corrective action. Understanding where resources, both people and parts, are consumed can help with determining if there is a skill deficiency, equipment misuse, design issue, or some other assignable cause. Once these metrics are clearly understood, posted and discussed daily at the equipment, add metrics like mean time between failures (MTBF) and OEE to gain a deeper understanding on how to improve performance. The target condition should be great uptime (i.e., 100 percent) and a strong, favorable ratio of time spent conducting preventive maintenance versus performing reactionary maintenance for unplanned downtime.

DEVELOP a Lean Maintenance Methodology

What applies to operations applies to maintenance. Methodologies, such as 5S, single-minute exchange of dies (SMED), standard work and kanban, all can be exemplified in the maintenance department. For example, with 5S, everything should have a designated place and be in its place. Therefore, if you implement a parking lot for maintenance buggies with clear visuals and signage, it sends a message that everything you do matters and should be done in an organized and efficient manner. This simple idea makes it very easy to determine who is at work and who isn't. It prevents a traffic jam at shift change and makes it convenient to conduct a 5S inspection. Other simple ideas and techniques include quick disconnects for hydraulic units, standard work for tool maintenance, visuals for total productive maintenance (TPM) plan and a kaizen schedule for targeted areas of improvement. Value stream mapping events can be used for processes like the MRO procurement cycle. If there is a tool crib, implement a kanban system for spare parts and consider vendor-managed inventory (VMI) for small parts like nuts and bolts. Converting to VMI can reduce time spent managing small parts and swap inventory on the balance sheet for cash.

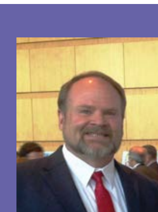
ENGAGE the Operators

You've probably said or heard the phrase, "Please treat the equipment like you would your house or car." Many folks, in fact, do treat the equipment they operate exactly the same way they treat their house or car – very poorly! So change your approach to, "Please treat the equipment in a way that our target condition of being ready to run, clean and well maintained is achieved." This can be a major cultural change. So the onus is on leadership to work with the operators to establish and achieve the target condition. It can be a challenge and requires a lot of training, auditing and follow-up. The best tools to use are a good TPM plan and 5S check sheets. Eventually, the behavior will change, new habits will form and the target condition will be achieved on a daily basis. Make it fun! Have a competition and reward the shift or team that does the best job achieving and maintaining target condition.

SUMMARY

Building a high performance maintenance team is not a three-month undertaking. It is not a part-time initiative or approach. Depending on where the department is on the maturity curve, the age and deterioration of equipment, and the overall health of the business, it can be a three- to five-year journey. However, significant improvements are often realized in the first three to six months by being relentless, firm and encouraging.

The author's company did survive and posted some impressive profits during its third year in the turnaround. However, perhaps the biggest reward during the turnaround was the bond and respect the operators and maintenance team developed for each other. It is a behavior that becomes contagious based on a common purpose of making the equipment better today than it was yesterday.



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Systematizing Your

Asset Management Operation

Management Systems for Your Physical Assets

by Tracy Smith

In the movie *Deliverance*, Burt Reynolds's character says, "Sometimes you have to lose yourself before you can find anything." That statement is never truer than in discussions about asset management. When you're focused on what you already know, it's easy to miss a better way of doing things.

When it comes to asset management, most companies focus on maintenance, repair and operations (MRO). In theory, this makes sense. You would think that focusing on MRO would be the most effective way to improve equipment performance and reduce downtime. But in fact, it can compromise the effort. Too much focus on MRO prevents people from taking a step back and seeing the big picture.

If a company wants to see consistent, measurable improvement in asset performance, costs and risks, it must stop viewing its business functions — MRO, storeroom, procurement and the rest — as isolated units and start treating its asset management operation as a unified system that relies on the cooperation of all elements for success. This is the basic premise of asset management systems.

Creating synergy is at the heart of what an asset management system does.

THE ASSET MANAGEMENT CHALLENGE

Conventional MRO solutions treat individual components of an operation as separate entities. If a company wants to improve asset performance, it focuses on a single aspect of it operation. The company may implement a reliability centered maintenance (RCM) program, purchase a software system, or seek out supply chain solutions. The trouble is, it does this without a sense of the larger perspective, or how the separate pieces of its operation should fit together.

As a result, many organizations suffer from a haphazard, stop-and-go, whack-a-mole approach to asset management. They make improvements piecemeal without con-

Figure 1: Asset management functional matrix

sidering the larger context. For example, they implement maintenance planning and scheduling without considering MRO supply chain performance, or install information systems without establishing consistent and insightful software content. They focus too much on maintenance operations or software applications and ignore other elements that drive success.

Yes, maintenance and software are critical to the success of an asset management operation, but they can't do it alone. They are key players, it's true, but they are still only two players on a much larger team, a team that includes storeroom operations, procurement, operations, project management, accounts payable and many others. Neglecting the other players on the team is a fatal mistake because maintenance and software depend on key support functions, like storeroom and procurement, for their success.

The results of this mistake are all too familiar. Parts aren't available when needed, maintenance job plans aren't detailed enough, materials catalogs don't match actual inventories, procurement costs are too high, equipment is down too often, and so on. Despite a company's best attempts, it ends up with inefficient operations and frustrated management. Often, companies blame the software or the culture that implemented it rather than addressing the root of the problem.

The Big Picture

What is missing is a consolidated effort, a comprehensive strategy that addresses all the variables in the asset management equation. The truth is, asset performance is determined by many factors interacting across multiple internal business functions. Operations must coordinate with maintenance to keep equipment in good condition; maintenance depends on the storeroom for parts and materials; the storeroom relies on procurement to obtain supplies; and procurement is at the mercy of project management and accounting when it comes to authorizing purchases and paying vendors. Understanding and leveraging these interdepartmental dependencies is the key to getting the most out of a company's physical assets. For an asset management operation to be successful, all the associated business functions must be integrated like puzzle pieces to create a single, seamless operation.

Asset management is a team effort. This is where asset management systems shine. They provide the strategy and structure necessary for coordinating large-scale MRO operations.

ASSET MANAGEMENT SYSTEMS

An asset management system is a holistic program for directing and controlling all aspects of equipment and infrastructure management, from planning and investing to operations, maintenance and disposal. An asset management system is not a software system. Rather, it is a set of policies, strategies, practices and processes that govern all activities affecting a company's physical assets. Software is a powerful asset management tool, but it does not replace a comprehensive asset management system.

An asset management system establishes clear, documented processes for every activity that affects an asset's lifecycle, from purchasing a piece of equipment to creating a work order to contracting a vendor. It dictates procedures to ensure that all asset lifecycle events, including maintenance work orders and supply chain transactions, are captured and tracked within the software system to ensure accurate data and reporting. It lays out clear guidelines for dividing responsibilities and coordinating activities between departments. In short, it provides a complete program for managing physical assets across the entire organization and throughout the full asset lifecycle.

Figure 2: Sample of an asset management system

System Components

An asset management system unites organizational vision and structure with practices, content, information systems and assessment tools to create efficient and effective operations. These components represent all the different factors that must be directed and coordinated to create a successful asset management operation. They encompass the organization's overall objectives, asset management strategy, team roles and responsibilities, operational activities, technology requirements, master data libraries, coding structures and performance measurement tools.

Figure 2 represents a sample asset management system. Specific components and their contents will differ from one organization to another, but the basic structure is the same for any operation.

- **Organization & Management** is the first component of a successful system. It includes the asset management policy, objectives and strategy determined by upper management, as well as role descriptions and responsibilities that help define organizational structure.
- **Practices** are the second component of an asset management system. They include processes and procedures for all maintenance, storeroom and procurement activities, plus business rules and guidelines for coordinating with project management, accounting and other functions. Practices are the heart of an asset management system; they keep things running. The other parts of the system cannot function effectively without solid, consistent, clearly defined practices.
- **Content** is the third component of a system. It comprises master data, such as asset registries, equipment hierarchies, materials catalogs, vendor catalogs, as well as coding structures, naming conventions, classification systems and other tools for grouping and filtering data. Good content is the foundation of good data management.
- **Information Systems** constitute the fourth component of an asset management system. This component specifies the requirements for all technology associated with asset management, including enterprise asset management (EAM), enterprise resource planning (ERP), computerized maintenance management system (CMMS), supervisory control and data acquisition (SCADA), data historian system, distributed control system (DCS), predictive maintenance (PdM) technologies, and production control and monitoring systems.

- **Performance Improvement** is the fifth and final component of a system. It contains assessment tools, such as key performance indicators (KPIs), performance targets and audit scoresheets, to measure the system's effectiveness and find new ways to improve.

Together, these five components provide the tools needed to effectively manage an organization's physical assets, starting at the top with large-scale policy and objectives and working down to detailed guidelines for specific roles, practices and technologies.

An asset management system provides the big picture for maintenance operations. Once in place, it serves as a framework for implementing smaller programs, such as reliability initiatives, supply chain solutions and software systems. An asset management system ensures that programs like these are integrated seamlessly within the rest of an operation to ensure maximum performance and return on investment (ROI).

Why Use Systems?

Asset management is about making sure a company's physical assets are helping it accomplish its business objectives. The only way to ensure this is to maintain a clear line of sight between upper management and the folks in the trenches, aligning the organization from execs to techs. An asset management system does this by providing a clear directive from upper management regarding the company's asset management policy and defining management-approved practices and procedures to govern day-to-day activities.

This top-down approach also allows a company to define the interrelationships between its various business functions from the very beginning, delineating specific roles and responsibilities at the outset to avoid problems later on. Moving across a broad front like this helps ensure success because it takes all variables into account, avoiding surprises that pop up halfway through an implementation. This might happen, for instance, if an organization tries to implement maintenance plans and schedules without an effective storeroom operation.

By defining how different business functions will interact and providing a unified set of guidelines for the organization as a whole, an asset management system helps to unite an organization around a common cause. This produces synergy, a whole that is greater than the sum of its parts. Creating *synergy* is at the heart of what an asset management system does.

SOFT DOLLAR PROGRAMS, HARD DOLLAR SAVINGS

Numerous organizations have seen firsthand what systematizing can do for an operation. One organization, for example, has been implementing an asset management system over the last 18 months and is already seeing significant, measurable improvements in performance, reliability and bottom-line costs.

An asset management system provides the **big picture** for maintenance operations.

A representative from the organization's upper management reports that the company has realized a significant ROI on the system in less than two years. "We are increasingly becoming a more reliable organization and minimizing costs in the process," the representative says. Unplanned maintenance is down, productivity is up, emergency maintenance has been cut in half and callout work has been significantly reduced.

THE BENEFITS OF SYSTEMATIZING

Systematizing an asset management operation improves more than just equipment reliability. The rewards stretch across the entire organization, from operational productivity to bottom-line profit to stakeholder relationships. Done right, an asset management system:

- improves asset performance and reliability;
- increases ROI on equipment and software purchases;
- facilitates better record keeping and reporting;
- standardizes practices and procedures;
- improves coordination between business functions;
- increases operational efficiency and productivity;
- minimizes costs and improves the bottom line;
- facilitates the realization of business objectives;
- minimizes health, safety and environmental risks;
- demonstrates compliance with legal, statutory and industry standards;
- signals to regulators and stakeholders that assets are in good hands;
- facilitates better performance measurement and analysis;
- formalizes commitment to continued improvement and provides a clearly defined path forward.

The system also has generated downstream benefits for the organization in the form of reduced insurance premiums, netting it significant hard dollar savings. The organization's contact explains:

> "Insurance regulators like management systems, especially ones that focus on improving safety, reducing environmental impact and minimizing risk. Large manufacturing companies like ours pay a lot of money for insurance. By demonstrating good stewardship, our asset management system has actually reduced our insurance premiums, providing us with significant hard savings that directly impact our bottom line."

This organization chose to take a comprehensive approach to managing its assets because it wanted to create value in the long term. The company's representative put it best:

> "We are an asset-intensive organization. Our physical assets are critical to helping us accomplish our business objectives. We felt the implementation of an asset management system provided a top-down, comprehensive approach to improving performance that addressed all variables and could create value across a broad organizational front on a long-term, sustainable basis."

A Standard for Excellence

Companies aren't the only ones talking about the benefits of systems. International experts increasingly agree that asset-intensive organizations need process-centric systems to manage their operations. In 2004, the British Standards Institution published PAS55, the world's first international asset management standard. It states that an organization shall "establish, document, implement, maintain and continually improve an asset management system."

ISO55000, the internationally recognized asset management suite of standards published in 2014 by the International Organization for Standardization (ISO), agrees. According to Section 4.4 of ISO55001, an organization shall "establish, implement, maintain and continually improve an asset management system, including the processes needed and their interactions." Together, ISO55000, 55001 and 55002 provide complete guidelines for creating and implementing an asset management system.

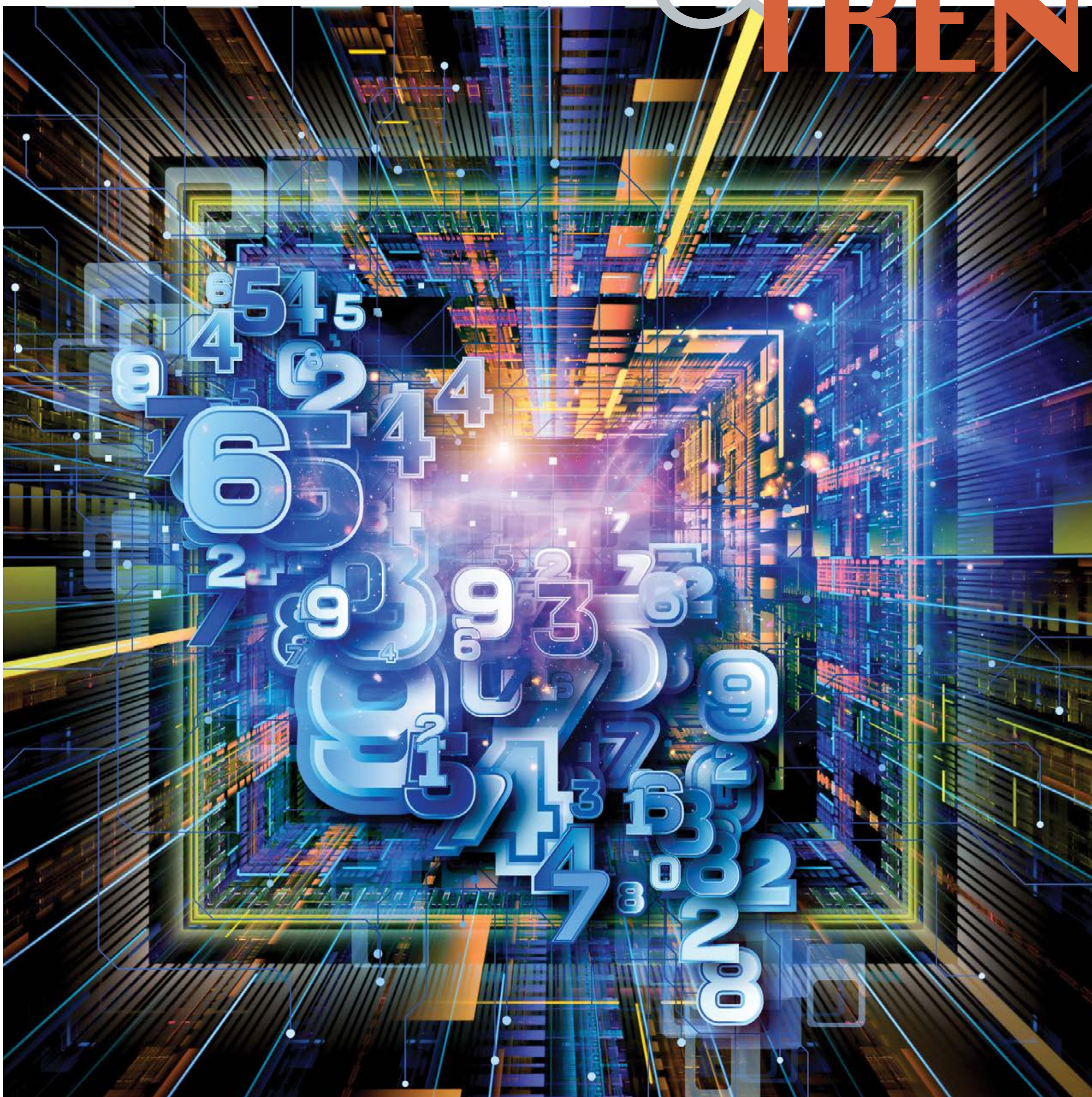
CONCLUSION

Why are asset management systems so important? The answer is simple: asset management systems represent a comprehensive approach to asset management. Asset management systems provide the holistic perspective and large-scale strategy necessary for managing large maintenance operations. They lower costs, improve asset performance and reduce risk.

The systems themselves may be as complex as the operations they manage, but the results are simple. Asset management systems make asset-intensive organizations run better.

__Tracy Smith__ is a veteran asset management developer, strategist, and consultant. He is the president of AMS Engineering, a leading asset management consulting firm, and has 18 years of experience building and improving asset management systems for some of the world's largest manufacturing organizations. www.assetmanagementsystems.org

RELIABILITY CONCEPTS & TRENDS



by Carlos Perez

While the word reliability is frequently used, unfortunately, the way it is used ignores its true context and real implication. With the various improvement techniques in asset improvement, the use of the reliability word has created a constant advertising siege.

The most known concept to define reliability is: "Probability that an asset or system operates without failing during a given period of time under some operation conditions previously established."

Sometimes, this concept is wrongly used due to the particular use given to the word *failure*. For many, failure only means shutdowns, so they construct complex mathematical formulas to calculate shutdown probability without taking into account that a failure also occurs when being inefficient, insecure and costly, having a high rejection level, or contributing to a bad image.

Other factors to be taken into account are shutdown causes that may occur for numerous reasons, so comparing apples and oranges, as the expression goes, should be avoided. An example is comparing shutdowns due to bearing lubrication with shutdowns due to errors in bearing mountings. It is not the same changing an item because it is going to fail versus changing it because it failed versus changing it because a frequency was met before it failed. Specifying an item that failed due to wearing is not the same as another that failed due to an improper installation or one damaged by an accident.

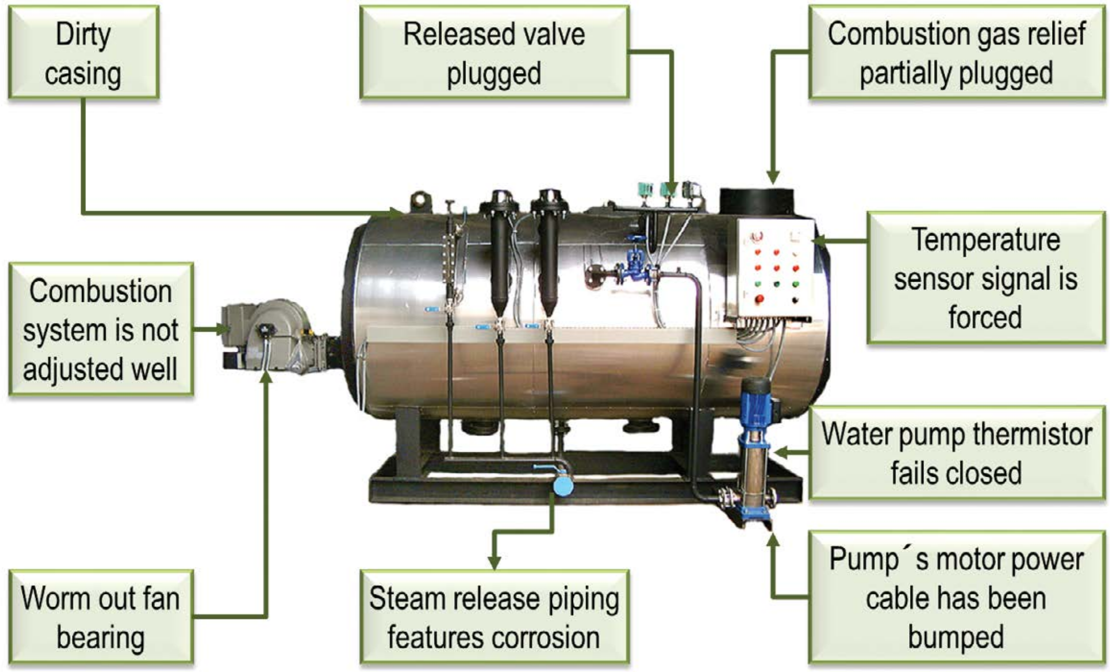


Figure 1: Boiler failure causes

IS IT A STATISTIC ISSUE?

A common discussion is whether or not reliability is a statistic issue. Managing data has an undeniable usefulness in the company's management and direction. It is necessary to distinguish if statistics are used to manage real data to see its behavior or to support forecasts and estimations that sometimes border on daring and irresponsible speculations.

Some authors adhere to defining mathematical postulates as an absolute truth about failures and deny the fact that numbers of analyzed failures mix effects with causes. In addition, they deny that having failure data to analyze is accepting that failures occur and with more data come more failures.

The most common misconception of reliability is that it is like the average time between failure occurrences. This statement has several connotations to consider. The first is to remember that the cipher is an average and the failure concept is associated with more shutdowns than with unconformities, such as spilling, a nonconforming product, or increased risks, which are failures too.

Datum as such, is an average cipher. There's a big difference between probability and reality, thus generating confusion. A probable failure is a possible failure and an occurred failure is a real failure, but a calculus logarithm doesn't necessarily assure its occurrence at a given point.

Therefore, using calculated, desired, estimated, arbitrarily fixed, imagined, recommended by manuals and even invented ciphers may carry error percentages, inaccuracies and deficiencies requiring responsible handling.

For example, Figure 1 shows the various failure causes of a boiler.

If failures are analyzed, Table 1 (see page 54) shows the various results.

It is clear that not all failures affect availability, therefore, they should not be used in calculating mean time between failures (MTBF) as it is repeatedly done.

Getting back to boiler failures:

- Assume that 10 failure modes are produced within 720 hours (one month).
- Only two of the failure causes listed in Figure 2 produce a shutdown, generating a total of 20 shutdown hours.
- According to the traditional failure concept, the calculation of MTBF for the boiler would be: MTBF = (720 hours – 20 hours) / 2 failures = 350 hours.
- If the company's MTBF goal is 300 hours, the goal would be met.
- The probability that the boiler does not fail before the MTBF goal would be calculated this way: e-(300/350) = 42.5 percent.

Thus, analyzing numbers may only give peace of mind to some people since there are other reasons an asset may fail, such as:

- Non-compliance of cleaning standards;
- Inoperative protections;
- Harmful situations for security and the environment;
- Greater fuel consumption, which is a greater cost.

If the asset does not perform all required functions as desired, it is also considered a failure.

Therefore, if the real failure concept is applied, calculations would be different:

- MTBF = 720 hours – 20 hours / 10 failures = 70 hours.
- Since the company's MTBF is 300 hours, the purpose would not be met.
- With the current failure concept, the probability that the boiler does not fail before the MTBF goal would be calculated this way:
  Probability = e-(70/350) = 1.37 percent.

Very few companies have data on MTBF; what they really have is datum on mean time between shutdowns.

Very few companies record failure occurrence using the failure mode scope and those that do, their information systems make the MTBF calculation difficult.

So, what's the solution? The time being used for mathematical calculation of MTBF or failure probability would be better spent defining failure consequences and devising an action plan to mitigate those consequences.

HOW TO IMPROVE RELIABILITY

Currently, the issue facing maintenance staff is not only learning what the new techniques are, but also being able to decide which ones are useful for their companies.

If properly chosen and used in an integrated manner, maintenance practices and outputs will likely improve. Likewise, costs will be optimized. If improperly chosen, more problems will be created which, in turn, will worsen existing ones.

Table 1

No.	Failure Cause	Effect	Generates shutdown?
1	Dirty casing	Increases fuel consumption	No
2	Release valve is plugged at "closed"	In case of pressure increase, steam would not be released, thus increasing risk	No
3	Combustion gas relief is partially plugged	· Increases fuel consumption · Non-compliance with environmental legislation	No
4	Fuel system is badly adjusted	· Increases fuel consumption · Increases gas issuance · Non-compliance with environmental legislation	No
5	Bearing on the burner fan is worn out	Combustion air is not supplied and boiler turns OFF	Yes
6	Steam release piping features corrosion	· Piping is ruptured and if there's a leak, someone may get burned · Associated damages	No
7	Pump's motor power cable has been bumped	Pump stops so water is not supplied and boiler turns OFF	Yes
8	Water pump thermistor motor fails; it is closed	Upon a surcharge, engine would burn	No
9	Forced temperature sensor signal (bridged)	Upon temperature increase, boiler would not turn OFF, increasing risk	No
10	Dirty boiler	Company's standards are not met	No

Some companies have gone beyond statistics and have reviewed their internal practices, carrying out benchmarking with those that are outstanding. These organizations came to the conclusion that it is impossible to talk about reliability as a unique cipher. Therefore, it is necessary to use several measurements as fundamental indicators of inputs/outputs of the processes.

The need for reliability in installations is as old as humanity, but undeniably, the growing relevance of environmental issues and their security have led to the need of changing orientation of some markets and niches due to:

- More complex products.
- Greater pressure to reduce costs to be more competitive.
- A greater number of operational functions carried out by equipment and machines.
- Requirements to reduce products' weight and volume, and maintaining and improving performance and security standards.
- Requirements to increase or reduce operation duration of products to increase or reduce demand.
- Greater difficulties to carry out maintenance interventions due to asset utilization increases.
- Trends to use software, electronic, pneumatic, or hydraulic components having different wearing behavior in response to components failing in function of age.
- Current legislation that is increasingly more demanding and less tolerant.
- Greater impact of shutdowns and operational losses on sales and products.
- Growing demands for quality in services and products.
- New perceptions of a company's image or commitment.
- Commitments to reduce the human life loss risk.
- Requests to reduce the spilling risk or affectations of the equipment on the environment.

These new demands drive the use of strategies that have been successfully applied in many companies, strengthening global performance, optimizing costs, reducing risks, improving corporate image, lowering environmental impact and consolidating business results.

Successful companies have made a concerted effort to incorporate their maintenance improvement strategies into other corporate initiatives, avoiding or preventing the syndrome of the campaign of the moment, peak of the wave, or the promotion of the month. The best indication that this effort produces satisfaction is when it turns into a durable and stable policy.

Among the most successful tools being used consistently are:

- Reliability as a global concept instead of reducing costs or downtime.
- Carrying out diagnoses, audits and evaluations of maintenance practices.
- A development strategic plan describing and establishing a corporate vision related to reliability and asset good performance.
- Extensive utilization of performance measurements with appropriate goals.
- Benchmarking to identify opportunities and barriers for improvement.
- Sharing knowledge and achieving consensus among areas typically separated; using teams with different functions and specialties who work together during a specific period of time to analyze problems and opportunities aimed at a common output.

CONCLUSION

To achieve reliability, maintenance is not the only responsible area. It requires responsible designs, consistent and trained operators, professional purchasers and stable policies. In other words, several responsible actors take part during an asset's lifecycle.

Maintenance is considered an action; it is more of a joint responsibility than a function. Maintenance starts with selecting equipment and follows with installation. It is supported by the right operation and good maintenance, with support provided by purchases and inventories.

Those responsible for whether assets will be reliable or not are: design; selection; manufacturing; suppliers; installation; environment; operation; maintenance; stores; and purchases.

As you can see, improving MTBF is not enough.

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SMART Vibration Analysis

It's a commonly known fact that machine faults can be detected by changes in the vibration of the machinery. It's also apparent that non-fault related conditions are also detectable in the vibration data. This means that everything related to a machine, good or bad, will show up in some way. Leading indicators, at very low amplitudes, show up in the vibration spectra. As a fault condition worsens, the damage rapidly becomes more obvious and easier to identify in the vibration signature. Once a fault is positively identified, an analyst can sometimes sort through the historical data and often identify the leading indicator that eventually led to the fault condition.

by Richard Bierman

Figure 1: Typical overall vibration trend of a standard piece of rotating equipment

Since leading indicators at inception are not yet typical "wall chart" fault conditions, finding them as they happen requires a really close look at every spectra and a comparison to historical signatures to distinguish them from normal, transient conditions related to load, temperature, process rates, accelerometer data, etc. This could be done by hiring a large team of analysts dedicated to doing only that, however, the room for error is high and the associated cost and effort is extremely impractical. Alternatively, your vibration software can automatically do this for you by using trend-based narrowband envelope alarms. Setup is easier than using band alarms and the results are much more accurate. Furthermore, findings are discovered sooner, allowing your facility to drastically reduce the amount of points monitored and the frequency at which they are taken. Optimizing your vibration analysis program to find leading indicators will also allow you to relax, but not eliminate, your other predictive maintenance efforts, including oil analysis, ultrasound detection and thermography **(see Figure 1)**. With less data to collect and analyze, a large facility containing over 2,000 machines can easily be monitored by a single analyst.

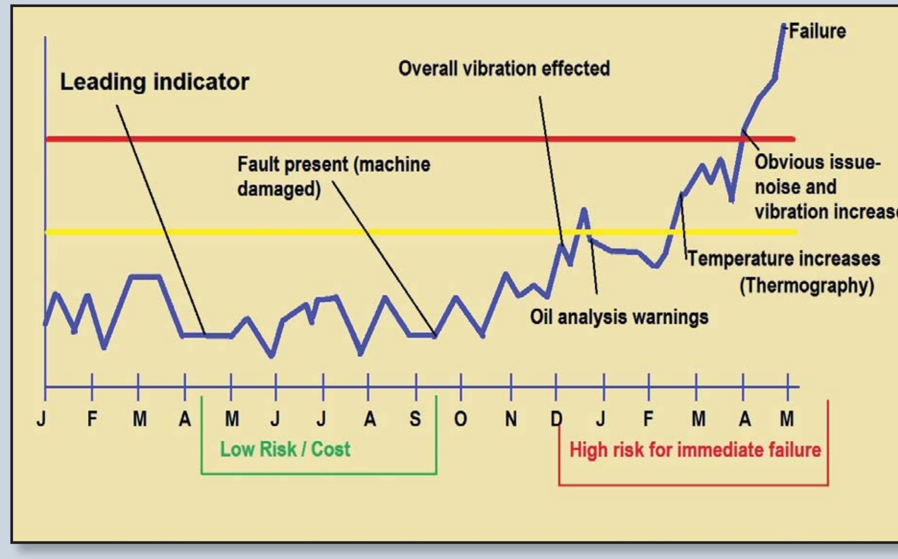
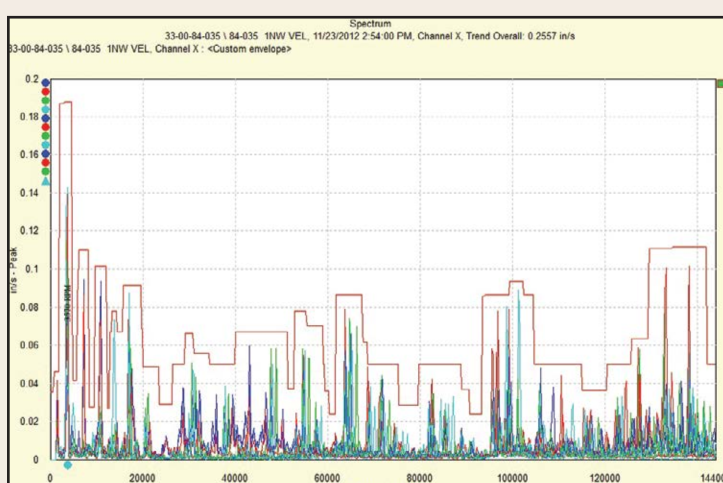


Figure 2: Trend-basing the narrowband envelope alarm by overlaying several fault-free spectra collected under various conditions

A narrowband envelope alarm is an alarm level that monitors the absolute, not overall, amplitude of every peak in a spectrum. Unlike spectral band alarms, often called power bands, there are practically no limits* to the amount of narrowband envelopes that can be displayed on a spectrum. This eliminates the problem with overall and spectral bands where low amplitude noise, such as slightly elevated noise floor, triggers the alarm. Because of this phenomenon, overall and spectral bands must be set at a higher amplitude offset to reduce the amount of false alarms. Unfortunately, this pushes the alarm limits beyond the sensitivity needed to detect leading indicators. With narrowband envelope alarms, this problem doesn't exist. The set point is unique to each frequency, so the sensitivity can be much closer and false alarms caused by broadband noise are eliminated. With a tighter offset, important forcing frequencies will never go undetected due to the higher amplitudes of the surrounding frequencies. Simply put, the narrowband envelope will stay out of alarm unless a legitimate issue presents itself.

As complex as they may sound, narrowband envelope alarms are very simple to set up. Basically, the narrowband envelope alarm is a line drawn above the outline of the spectrum collected. Most vibration software will automatically generate the alarms using an existing spectrum. If any peak breaks this line, the next time data is uploaded, the alarm is triggered, regardless of its amplitude. Hence, even very low amplitude changes at any specific frequency will be immediately detected and pointed out by the narrowband envelope alarm. To avoid these from being triggered every time the signature changes, the narrowband envelope alarms should be trend-based. This, too, can be simply done by overlaying several pieces of good data and adjusting the line drawn (i.e., the narrowband envelope) to allow for non-fault related conditions **(see Figure 2)**. Once again, the process is simple compared to setting spectral bands or overalls. You do not have to define a frequency minimum (Fmin), frequency maximum (Fmax), specific amplitude for alert, or another for danger. All you need to do is redraw the line, which can be done by simply clicking on the line and dragging it to where it needs to be. Doing so also creates variable offsets, allowing you to compensate for the limitations of the particular type of data being collected (e.g., acceleration, displacement, or velocity). The more data you have overlaid and the more these are adjusted for different running conditions, the more accurate they become. Eventually, they will stay in the green under any previously seen condition and be triggered the first time something new shows up on the data. At that point, the analyst can see exactly what's new and decide whether it is a leading indicator of a fault or something that is normal. If it's unclear, the alarm can be adjusted to just slightly above its current amplitude at the suspected frequency and the next time the data is collected, if it stays the same, it stays green and if it worsens or anything else changes, it alerts the analyst to look at it again. This way, at the very moment the leading indicator is identifiable, the machine goes into alert status and if all is as it has been in the past, it stays clear. It sounds like a lot of work, but the software does it all, freeing up time for the analyst.



* The number of narrowband envelopes matches that of the resolution of the spectra. It takes about five fast Fourier transform (FFT) lines to build a frequency in a spectrum, depending on the resolution and frequency maximum (Fmax). If a spectrum has 6,400 lines of resolution, it will allow approximately 1,280 envelope alarms.

Figure 3: Envelope alarms not only detect small changes in the vibration signature, but also quickly point out the change

Figure 3a shows a historical trend of overall velocity collected from a steam turbine. The amplitude levels and spectra are constantly changing due to variances in speed, load and random white noise seen in the noise floor from steam and cooling water flowing through the turbine. At the indicated point on the trend, a leading indicator exists. If the analyst were to monitor the overall levels, he or she would be unable to detect it. Since the machine is not in alarm, it is unlikely and impractical that the analyst would spend the time analyzing the detailed data shown in the spectrum in **Figure 3b**. If by chance the analyst did look at the details of every piece of data collected, the primary question in Figure 3b would be, "Does this spectrum indicate a problem?" When comparing this data with the variances found in historical signatures, it is unlikely that any abnormality would stand out. Since there is no mechanical fault yet and anything that looks like a fault is at an almost null value, the diagnosis would most likely be that this machine is in excellent condition. In **Figure 3c**, however, the same data is displayed showing the trend-based, narrowband envelope alarm. The alarm is referenced and immediately anyone can tell that there is some strange new detail in the vibration signature. A closer look at the frequencies in question will reveal that these are the natural frequencies of the installed bearing. The low amplitude peaks seen in the lower frequency range match the ball spin frequency, the white noise is shown as an elevated noise floor and other filtered data collected from the machine (not shown) confirms a lack of lubricity. The recommendation was to drain and fill the oil in the bearing housing to "sweeten" the oil. A visual inspection of the oil drained showed the oil was dirty and discolored. After partially draining the reservoir and refilling it a few times with clean oil, data was collected again. **Figure 3d** shows that the data is now out of alarm. Even though the overall vibration is significantly higher than before and the spectrum has greater amplitude activity in the lower frequency range, the data has returned to within its typical historical trend. Lubrication related leading indicators are very common, especially in facilities with a less than world-class lubrication program, but they are not the only type of leading indicator that is discoverable using this alarming method.

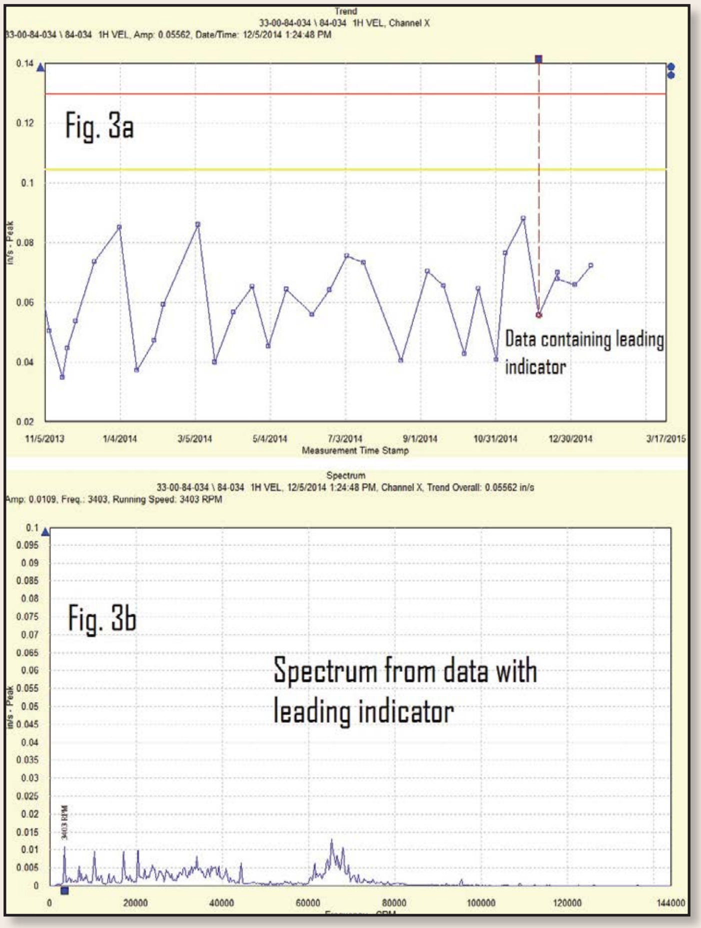
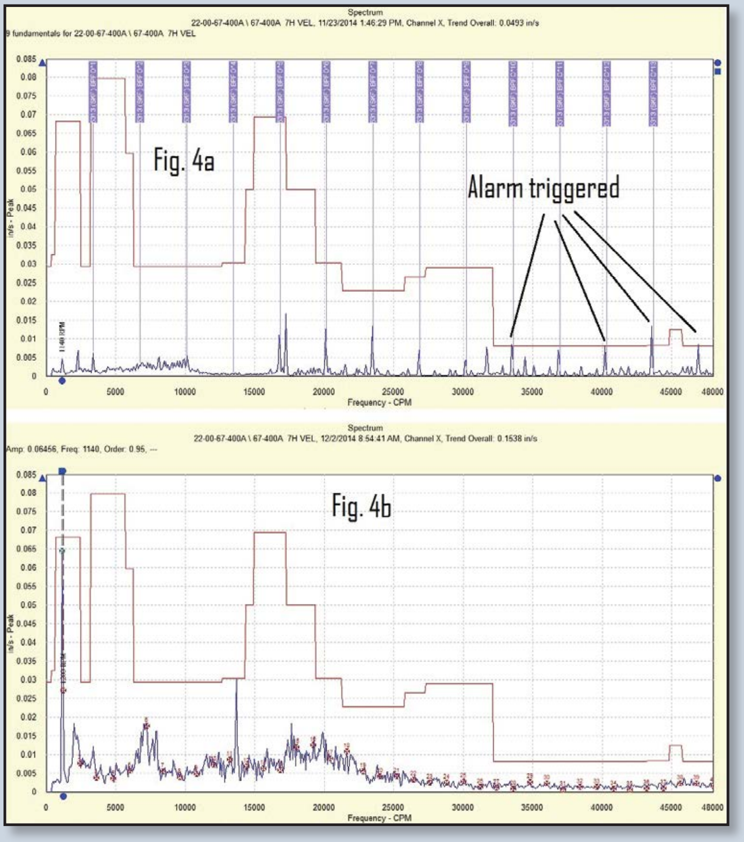
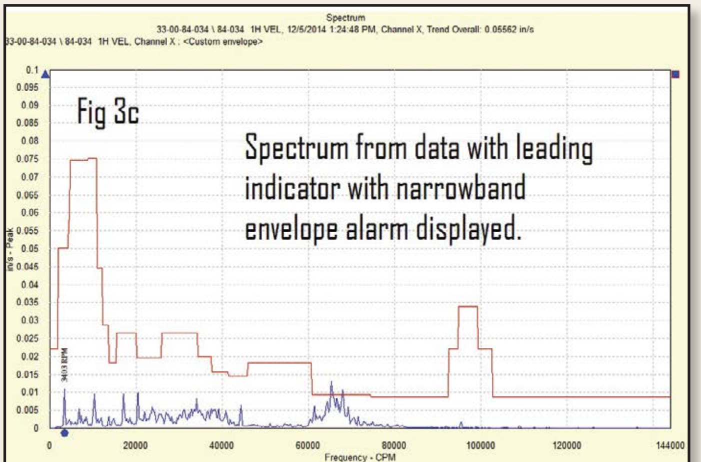


Figure 4: Trend-based narrowband envelope alarms free up the analyst's time to focus efforts on seemingly insignificant abnormal conditions, detecting the first sign of a potential fault-creating situation



In **Figure 4a**, low amplitude high frequency peaks again can be seen in a spectrum collected from the bearing housing on a split case pump. These peaks are of insignificant amplitude and line up with the sound the harmonics of the outer race of the installed bearing create. Since there are no fundamental fault frequencies, sidebands, or other indications of an issue, and the amplitudes are low, it is safe to say this is just the sound of the bearing turning. This is a true statement and there is no fault. However, further investigation shows the peaks have never been there in the five-plus years of historical data. With the tremendous amount of time saved by using the narrowband envelope alarms, the analyst can go investigate this seemingly insignificant singularity. In this case, the data was found to be repeatable and was seen in other orientations at the same location. A closer look beneath the coupling guard showed that the packing was leaking. The leak from the packing and a plugged drain had filled the bearing housing frame adapter with water. The water was drained out and the data collected afterwards returned to its normal looking signature, consistent with the five-plus year trend in which the alarm was based **(Figure 4b)**. To satisfy curiosity, the adapter frame was allowed to refill and the data collected confirmed that the water filling the bowl-shaped frame adapter had amplified the sound (i.e., vibration) of the higher frequencies, similar to how filling a drinking glass changes the pitch of the higher frequencies as you fill it with water. Had this dirty water been left in the adapter frame, it eventually would have entered the bearing housing, causing a failure. Having this documented, if the issue recurs, the analyst can create a report stating that, according to the data, the drain on the bearing adapter is plugged. Findings like this do a lot for the credibility of the program. This type of finding may not be typical, but is a good example of how trend-based narrowband envelope alarms take analysis far beyond finding faults seen on the wall chart.



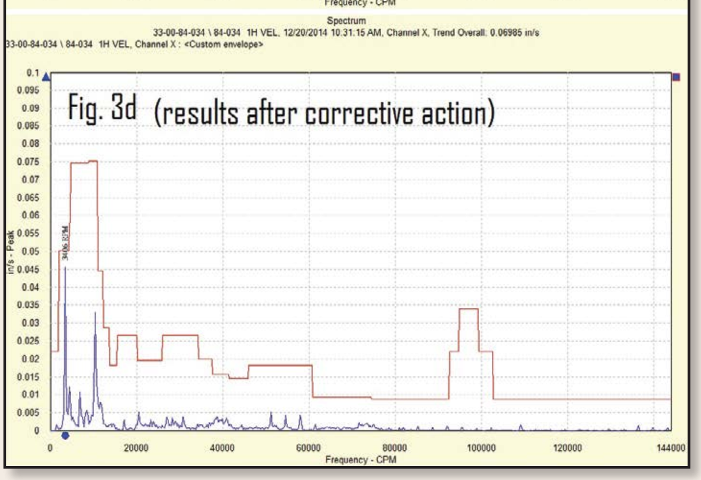
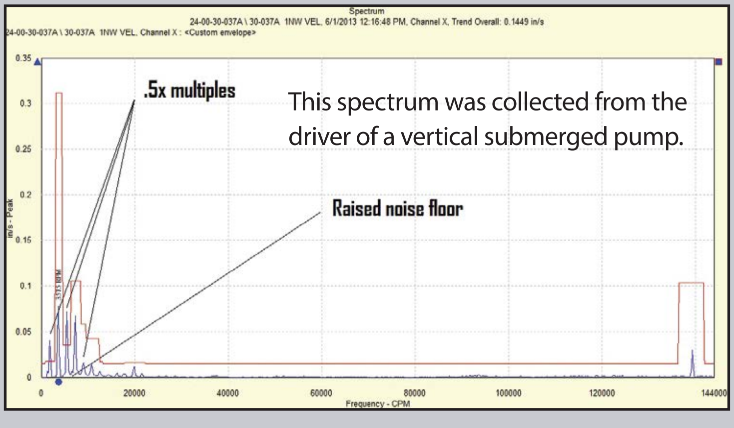


Figure 5: The narrowband around 1x allows for normal variances in the imbalance of the machine while the looseness condition caused by worn sleeve bearings below grade are detectable above in the motor before the overall velocity is affected

It takes very little imagination to envision what an actual machine fault will look like using this alarming method **(Figure 5)**. If your narrowband envelopes are properly set up, which, again, is very simple to do, a genuine fault condition will light up terrifically. Every data point on the machine with an issue will be in red. At this point, you may be able to detect a problem with properly set overall or power band vibration alarms, but not if the machines have a wide range of normal overall amplitudes. With even a trivial fault condition, the vibration signature details all over the machine will be affected. Each narrowband envelope alarm will point out exactly what's wrong and the diagnosis will be quick and accurate. If, for some reason, the machine has to continue to run with the fault, the alarms can be quickly and easily adjusted to prompt the analyst again when the condition worsens. While finding machine faults is not the primary focus of this article, trend-based narrowband envelope alarms drastically improve that capability as well.



Finding faults early means the types of corrective actions will change. Instead of planning to shut down a machine to make repairs, corrective actions would be in the form of adding grease, tightening a bolt, changing the speed of a motor, or changing process rates. Depending on what is discovered, more times than not, a leading indicator can be addressed without shutting down the machine. The entire approach changes from a somewhat predictive but reactive one to truly preventative.

Since the problems getting fixed are not obvious, it is essential that the supporting data is shared with other departments. Data collected before the corrective action should point out the frequencies of concern. This will justify performing the corrective action. It is also equally important to show the result of the data after the corrective action has been completed. This not only proves that the issue was resolved, it also shows the rest of the facility that what is being done works and is worth doing. No matter how many machines are saved or how effective the program is, if it does not get the proper exposure, the program will not get the support it needs.

So, if this method is so effective and not new, then why isn't it being widely taught? The answer is simple. Most vibration certification companies focus on teaching the general concept of vibration analysis. They center on how to tell if a machine is good or bad, how to make sure the proper data is collected, how an analyzer works, common machine fault characteristics, standardized overall vibration limits and a grip of other things that are vital to the understanding of the craft. Most of them mention narrowband envelope alarms as well. This isn't new or exclusive technology. In an attempt to improve their vibration program, companies wanting to improve will quickly spend the money to certify their analysts to a higher level or buy more equipment. This is effective and a good practice, as well as very common. Hence, the result is a company with a very good analyst with a typically good program. It is less common for that same company to encourage its analyst to attend training from the vibration hardware and software manufacturers so he or she can learn to really optimize the company's program based on what it uses. Companies are even less likely to send their staff to conferences where analysts can network with other companies and learn from what they are doing beyond advanced early fault detection. Networking events are where these types of things are discussed, yet even the few analysts that utilize this type of technology stay at home and don't often share information outside their facility. Recognition awards are based on metrics used by the status quo, so again, they are not widely publicized. Eventually, they will make their way to certification training in a generalized capacity, but not until they are more commonly practiced in the industry. Until then, one can only learn about them at conferences and read about them in publications like this one.

The fact is, in order to have a world-class vibration program, you do not need a huge team of experts to constantly analyze large amounts of data. You do not need a lot of expensive tools, or to outsource your efforts. Additionally, you should not settle for the discovery of damaged equipment and the constant firefighting mode of taking quick action to avoid downtime just because it's what everyone else is doing. When you basically have an arrow pointing to machines that have an abnormality and then pointing out exactly what that abnormality is, it radically simplifies the whole process. All you need is to use the existing tools most programs already have. Then, simply relax and address the leading indicators when time allows, well before faults occur.

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by
Obaidullah A. Syed

UNLEASH the Potential of Your Reliability Function

It is a resounding fact that the need for advancement in the plant maintenance field gave birth to the function of reliability. But isn't it about time we disconnect this child from its umbilical cord and allow the reliability function to stand on its own feet, independent from maintenance? Shouldn't we now let this child unleash the true potential it has to offer to the industry by being an autonomous external entity, focusing on asset reliability at every level of asset lifecycle management (ALM)?

There is no doubt early reliability techniques evolved to strategically handle plant maintenance. Predicting failures in advance and allocating sufficient resources helped the industry mitigate the impact of unexpected failures and unplanned outages. The early techniques also prevented maintenance folks from patching up the failures and demanded detailed root cause studies so problems leading to failures are fixed once and for all. But after many years, the function of reliability is still so tightly married to maintenance that it is often perceived to be the only combination that can unlock all challenges related to an asset. But can maintenance alone handle all aspects of reliability throughout the lifecycle of an asset? What if the asset has inherent design flaws or inadequate commissioning procedures? What if it is being operated outside of its operating parameters? Such issues are related to engineering and operations, which are outside of the maintenance scope.

> [The primary function of maintenance, which takes precedence over all other roles, is "**firefighting**."]

The primary function of maintenance, which takes precedence over all other roles, is "firefighting." When equipment breaks down, the maintenance team is expected to return it to service immediately so production can be restored. The function of reliability has nothing to do with this firefighting approach. Thinking of reliability as an improved maintenance practice does not do justice to this function and limits the imagination to what it can truly deliver. It is very common in the industry to interchange the term maintenance engineer with reliability engineer without much thought. The majority of reliability engineers are still perceived as "smart" maintenance engineers or engineers who deal with maintenance-related issues of high dollar value assets, such as compressors and large rotating equipment. It almost seems inconceivable, even to many industry professionals, that a reliability engineer has a much broader goal and is better off being an independent entity overseeing engineering, operations and maintenance (EOM) to embed reliability at every level. Just as the safety group is effective in incorporating its policies and programs within EOM's routine business, the notion of having an independent reliability group doing the same for reliability programs and initiatives should not be alien at all.

Think of it this way: If you want a reliable car, you must first ensure that the car is built to be reliable. You then make sure it is operated as it was intended to be during its design. Lastly, you focus on maintenance and take measures to do it right and on time. All three, the designer, the operator and the maintainer, must adhere to reliability to have a reliable car. The same philosophy applies to the plant's assets. Maintenance alone should not be deemed responsible for their reliability. Just like a car, equipment only can be truly reliable if the engineering team ensures reliability during the procurement and commissioning phases, the operations crew operates it as per the standard operating procedures without exceeding the operating envelope, and the maintenance folks exercise due diligence in maintaining reliability with quality workmanship.

The single entity that can ensure the collaboration within these three disciplines and oversee reliability throughout the entire lifecycle of an asset is the function of a reliability engineer. The reliability engineer does not necessarily have to be a mechanical engineer. This role also can be performed by an electrical or instrumentation and control (I&C) engineer having sufficient industry experience and sound knowledge of reliability engineering tools and techniques. However, for a reliability program to be effective in a plant, one must realize this is not a one-man show. Establishing an independent group to launch a comprehensive reliability program is recommended. The group must consist of several reliability engineers who are preferably a mix of mechanical, electrical and I&C engineers; computerized maintenance management system (CMMS) experts; senior technicians; and at least one representative each from EOM. The group must report to the entity having authority over EOM. This is important since reliability mandates changes and enhancements in the traditional style of work and, as commonly known, the change is always resisted and often counterattacked. Trying to accomplish this change laterally by having the reliability group part of maintenance will only make this task difficult and longer, if not implausible.

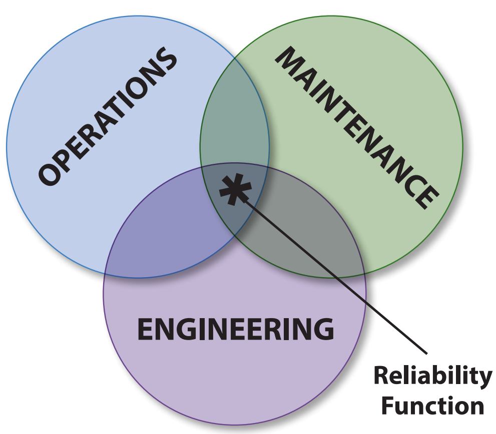

Figure 1: Reliability function as an independent external entity focusing on the niche areas of Engineering, Operations, and Maintenance (EOM) to improve asset reliability throughout its lifecycle (depicted from the book "Good to Great" by Jim Collins)

The reliability group must focus on strategic programs and management must realize that such programs require long-term commitment and support in order to produce expected results. Some recommended strategic programs and analytical activities that are labor-intensive and can be undertaken by the reliability group include:

- Reliability centered maintenance (RCM) program covering seven questions of RCM methodology.
- Develop preventive maintenance (PM) procedures and optimize utilizing failure modes.
- Implement predictive maintenance (PdM) technology and develop a continuous monitoring program. Some examples are online/off-line vibration monitors, ultrasound measurement devices, thermographs, oil condition monitoring and smart instrumentation online diagnostics.
- Operator driven reliability (ODR) program focusing on the operations role to enhance asset reliability. This may include detailed operators' checklists for visual, audio, smell and feel tests, review and enhancement of standard operating procedures (SOP), accurate integrity operating window (IOW) for all equipment, simple handheld devices to collect data for off-line predictive maintenance and minor maintenance tasks, like tightening up loose bolts with basic tools.
- Failure mode and effects analysis (FMEA) or failure mode, effects and criticality analysis (FMECA).
- Root cause analysis (RCA) or root cause failure analysis (RCFA) covering effective failure reporting and close tracking of recommendations until fully implemented.
- Develop standard job plans (SJP) for better planning and scheduling of work orders with accurate resource handling.
- Participation in process hazard analysis (PHA), like a hazard and operability study (HAZOP).
- Layer of protection analysis (LOPA) or other qualitative analyses for safety instrumented systems.
- Safety instrumented system (SIS) lifecycle management covering all phases from cradle to grave and compliance with industry and company standards. Safety instrumented function (SIF) performance, like actual demand rate, detected failure rates, proof test compliance, diagnostics, etc., also should be part of this program.
- Functional testing procedures and relevant documentation for non-SIS related equipment.
- Initiation and tracking of a lessons learned database for reliability.
- Review of capital project packages with reliability enhancement recommendations.
- Bad actors identification, tracking and replacement program.
- Advanced reliability analyses, including, but not limited to, Weibull analysis, Markov modeling, lean and/or Six Sigma study and reliability, availability and maintainability (RAM).
- Obsolete equipment tracking and systematic replacement program.
- Ad hoc site visits to witness the operations and maintenance work with the intention of issuing recommendations for identified gaps.
- Random checks for CMMS or systems, applications and products (SAP) data entry and quality.
- Single point of failure (SPF) identification and enhancement.
- Design for reliability (DFR) program and related studies.
- Reliability performance metrics for developing, tracking and enhancing leading and lagging key performance indicators (KPIs). Examples include mean time between failures (MTBF), mean time to repair (MTTR), overall equipment efficiency (OEE), equipment availability and equipment probability of failure on demand (PFD).

Several programs listed are considered "living" and require a twofold approach to be fruitful.

This is by no means a comprehensive list, but each organization can customize it with additional programs based on its size and resources. Several programs listed are considered "living" and require a twofold approach to be fruitful. First, develop a detailed scope of work covering the feasibility and implementation requirements for management support and approval. Second, execute the program and be on the lookout for areas of improvement while constantly bridging any gaps identified.

In conclusion, the function of reliability has evolved immensely over the years. Allowing reliability to operate independently, focusing on its core strengths without getting consumed by daily firefighting work from maintenance will take this function to another dimension of ingenuity. Empowering the reliability group to have jurisdiction over engineering, operations and maintenance will ease and expedite the part of change management while shortening the implementation period through improved collaboration. This is essential since many reliability initiatives fail during the execution phase when management does not see results for an extended period and loses interest. When placed correctly in an organization, along with the necessary expertise, resources and authority, the function of reliability will demonstrate the true potential it has in improving asset reliability during its lifecycle and achieving a robust reliability culture throughout the facility.

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From Fighting Fires to Achieving World-Class Reliability

By Douglas Plucknette

The faces on the group that showed up for my training today look rough, weathered and exhausted. As they walk into the classroom wearing the standard deep blue version of the maintenance uniform with their name over the pocket, each is carrying a cup of coffee and their emergency lifeline: the walkie-talkie. As we make our way through introductions, I let them know I started my career as a tradesperson, went through an apprenticeship program and worked as a journeyman while going to night school for reliability engineering.

I let them know I have walked in their shoes, but I was lucky enough to work with a group of young guys who were driven to change and improve the way we did maintenance reliability on our equipment.

"We could have left things just the way they were when we started at the site, but no one really wants to work on the same failures over and over again. So, we started taking some time to figure out why things failed and some extra time to make sure we installed things correctly," I explain to the group.

Randy (I know this is his name because it's on his shirt) points a finger at me and says, "Well, you never worked here. We don't have any extra time to think about why things fail and we have even less time to play around with precision alignment and torque wrenches. From the time I put my lock on a piece of equipment, I have an operations supervisor tapping me on the shoulder asking me when I am going to be done."

Randy is the oldest in the group and he isn't at all angry as he shares what life is like in their world. He is simply stating the facts.

What It Takes to Change an Ingrained Culture

He goes on to say, "We have tried almost anything and everything you can talk to us about in the 32 years I have worked here and while some things worked for a short time, as soon as we get something good going, they give us a new manager or supervisor who has his own thoughts on how things should be done. We've just learned to go along for the ride; they pay us by the hour and we work lots of 'em."

I smile, look him in the eye, and ask, "And you like this, working lots of hours and overtime?"

Randy leans back in his chair, takes a sip of his coffee and replies, "We are worn out. Most of us have grandkids, sore knees, sore backs and plenty of things to do at home. If you got a better way, share the secret because we want to learn it."

The secret to changing Randy's work culture isn't a technology, like vibration analysis or airborne ultrasound, and it isn't a tool, like failure mode and effects analysis (FMEA), reliability centered maintenance (RCM), or root cause analysis (RCA). It's called a business case. While these technologies and tools work, what causes them to fail is that very few people take the time to show the business case for change.

It's the only way to drive change and it's the only way to sustain change because the data/numbers you use to help drive the change and the data/numbers you use to show that the change was a solid business decision will help sustain the change.

So, if Randy's team wants things to change, they have to get into the game and start using facts and figures to drive change. I have been in this business myself for going on 35 years and I can honestly tell you that I have yet to meet a single manager who changed anything because the maintenance guys were complaining about it.

Let's use airborne ultrasound as an example. If I was a maintenance technician and I thought our plant should be using airborne ultrasound as a technology to detect potential failures, I would take the time to build a business case that detailed where I thought the technology could provide a return on investment. You don't have to spend five days doing this, simply look through your maintenance history.

- How many air leaks have you repaired in the last year?
- How many pneumatic instruments have you repaired/replaced year to year over the past three years?
- How many work orders and how much money have you spent on the compressed air system year to year over the past three years?
- How much has the plant, building, or site spent on energy year to year over the last three years?

Put a simple two or three page business case together with these facts, along with other uses for airborne ultrasound. Show management the potential cost savings and who you think might be best suited for training to use it.

> The business case is, indeed, the most important tool in the box.

Now here comes the big secret, the one everyone really needs to learn and hang on to because this is where most people mess it up.

Once you have the new ultrasound tool – and remember this works for everything you want to change and sustain – *measure the success of the change*. For example, you now have airborne ultrasound and because you have the technology, you have identified and repaired 342 air leaks over the last six months. As a result, utility bills have gone down an average of $4,124 per month over the last four months, the number of pneumatic instrument failures is down seven percent, and you are now using the technology to identify bearing failures and to detect corona, tracking and arcing on electrical panels. Continue to do this and show the business advantage for having the tool and you will continue to use it.

It works on everything. Bring in a new manager who wants to change things and you now have a very clear before and after shot of why you need to continue to do this. I have used it to justify torque wrenches, precision alignment tools and three different technologies, and even to stop one of our young engineers from making programming changes to our programmable logic controller (PLC). You want to change the program, show the business case and prove it.

As class ends on the first day and Randy is leaving the classroom, he stops to shake my hand and says, "I can't wait to go home and tell my wife the most important tool I have is math I was taught in grade school. She's a teacher who's been telling me for years that I work too hard."

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Q&A with an Industry Leader

Uptime Magazine is honored to share a special conversation between John Day, one of the most well-known proactive maintenance management advocates in the world, and *Uptime* Contributing Author, Ricky Smith, CMRP, who also worked for Mr. Day back in the 1980s. Mr. Day was formerly the maintenance and engineering manager for Alumax Mt Holly. Mr. Day designed one of the first proactive maintenance organizations in the world. He titled his vision and process to maintenance in 1979 as:

STRATEGY TO ACHIEVE WORLD-CLASS PRODUCTION THROUGH RELIABILITY.

Companies that have adopted John Day's philosophy and strategy have achieved results beyond what was known and expected within a company. Mr. Day has spoken all over the world about his model of proactive maintenance.

Q: What is the single biggest improvement you have seen when it comes to today's approach toward maintenance?

There has been very little movement forward because proactive maintenance has not been embraced and implemented by most organizations. Reactive maintenance still rules in most companies and corporations. Some companies have made great strides to move toward a more proactive maintenance environment and thus have seen the rewards. If a maintenance organization is not proactive, however, it tries new techniques to solve its reliability problems. But it needs to step back and get the basics right first: preventive/predictive maintenance focused on the reduction of unacceptable failures, disciplined maintenance planning and scheduling, a well organized and proactive stores function, work execution using repeatable procedures with specifications and the elimination of defects at their source.

It is frustrating to see companies who think they are doing great, but they are deceiving themselves. I challenge companies to compare themselves to the results my maintenance organization displayed over 20 years.

Best In Class Maintenance Benchmark Data

Category	Best in Class
Maintenance Spending/Replacement Asset Value	2.0-2.5%
Budget Compliance	+/- 5.0%
Overtime/Straight Time	6-8%
Number of Crafts	4 or less
Planners per Tradesperson	1:20
Absenteeism	1-2%
Backlog in Crew Weeks (Per Tradesperson)	2-3 weeks
Schedule Compliance	90-100%
Percent of Urgent (Interruption) Work	<10%
Percent of PM/PdM to all Work Orders	>30%
PM Accomplishment	95-100%
Inventory Accuracy	95-100%
Inventory Turns	2-4
Maintenance Training $'s as % Total Payroll $	>6%

John Day

Q: Do you see a closer tie between a maintenance manager and a reliability engineer these days? Do you see the role being combined into one more often?

Many organizations today are nowhere near where we were back in the 1990s. Our reliability engineers were focused on defect elimination (failure elimination) through development and execution of defect elimination teams made up of operators and maintainers. The reliability brings the data to the team and facilitates this process. There are a few organizations that follow this same philosophy, but most do not.

Q: Looking back on your career and your model for proactive maintenance, where do you see this strategy going in the next few years? Any significant changes that you foresee?

I quote: Over the past 30 years, there has been progress toward proactive maintenance, however, most organizations are looking for a quick fix. It is our generation of I want it now. But with proactive maintenance, you can't have "now" and cannot be dictated by corporate. It is a process that takes structure, discipline and alignment of everyone on a site, with assuring capacity to production the focus and everyone supporting it. It is time the boardroom is educated in the true value of "maintenance."

Q: What do you believe is the biggest stumbling block for maintenance departments these days to get to the "next level" and out of a reactive mode?

Lack of effective leadership and not knowing the lost opportunity (e.g., capacity and money) from the top down.

Q: Preventive maintenance (PM) activities are living documents that require periodic review and revisions. Why do think this step seems to be missed by so many organizations still to this date and do you have a preferred method for preventive maintenance optimization (PMO) or review?

PMs must be seen as living documents that require adjustments as failures occur. I review all failures we have daily and ask these questions of the team: "Why did this failure occur?" "What is the true root cause of the failure, human, reliability, or production?" and "Is our PM or predictive maintenance (PdM) program effective or not?" Next, I tell my team this failure will not happen again. I know it sounds harsh, but we are talking about managers accepting substandard performance from the maintenance and production leaders to their team members. Discipline and focus to keep equipment maintained to specification and operated to specification are missing in many organizations. Everyone seems to do what they want to do.

My preferred method of PMO is reliability engineers sitting down with operators and maintainers to review past failures and the current maintenance strategy we are applying to specific equipment. I do not need PMO software to manage my PM program; I need everyone helping in managing the PM program.

Q: If you could offer a single piece of advice to a maintenance team that is struggling to get to a more proactive mode, what would that be?

Listen and hire the right consultant. Identify a consultant who has a reputation for success. Hire him or her and lay out a plan with site leadership that will move the site forward to proactive maintenance. To be successful in this effort requires solid leadership from the top down and some people may need to find another job. Identify leading and lagging metrics so everyone knows if their contribution to reliability is working and if not, recommend changes to adjust reliability in the right direction.