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Operator Care DELIVERED BY JOEL LEVITT	Production Supervisors, Operations Managers and Personnel, Maintenance Supervisors and Personnel, Team Leaders, Lean Implementers	Improve production performance and asset reliability with an Operator Care program. Make data-driven decisions to create effective Operator Care tasks and achieve operational stability.	Feb 25-27, 2014 (CHS) Apr 8-10, 2014 (CL) Sept 9-11, 2014 (CHS)	3 consecutive days 2.1 CEUs	$1,495
Planning for Shutdowns, Turnarounds and Outages DELIVERED BY JOEL LEVITT	Members of the shutdown or outage teams, planners, plant engineers, maintenance engineers	Save time and money on your next shutdown by learning how to effectively plan for and manage such large projects. Learn processes and strategies for optimal resource allocation.	May 20-22, 2014 (CHS) Oct 21-23, 2014 (CHS)	3 consecutive days 2.1 CEUs	$1,495
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Reliability Excellence for Managers	General Managers, Plant Managers, Design Managers, Operations Managers and Maintenance Managers	Build a business case for Reliability Excellence, learn how leadership and culture impact a change initiative and build a plan to strengthen and stabilize the change for reliability.	SESSION 1 DATES: Mar 25-27, 2014 (CHS) Jun 10-12, 2014 (CHS) Sep 16-18, 2014 (CHS) (Sessions 2-4 dates are available on the website)	12 days total (4, 3-day sessions) 8.4 CEUs	$5,995
Reliability Excellence Fundamentals	Personnel involved in applying or are impacted by Reliability Excellence, and people who influence business process improvement.	Experience the fundamental concepts of Reliability Excellence in order to drive performance improvement efforts within your organization.	Feb 25-27, 2014 (CL)	3 consecutive days 2.1 CEUs	$1,495
Risk-Based Asset Management	Project Engineers, Reliability Engineers, Maintenance Managers, Operations Managers, and Engineering Technicians.	Learn to create a strategy for implementing a successful asset management program. Discover how to reduce risk and achieve the greatest asset utilization at the lowest total cost of ownership.	Apr 29-May 1, 2014 (HOU) Nov 4-6, 2014 (CHS)	3 consecutive days 2.1 CEUs	$1,495
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***LOCATION CODES:** (CHS) = Charleston, SC | (CL) = Clemson University | (HOU) = Houston, TX | (UA) = University of Alabama

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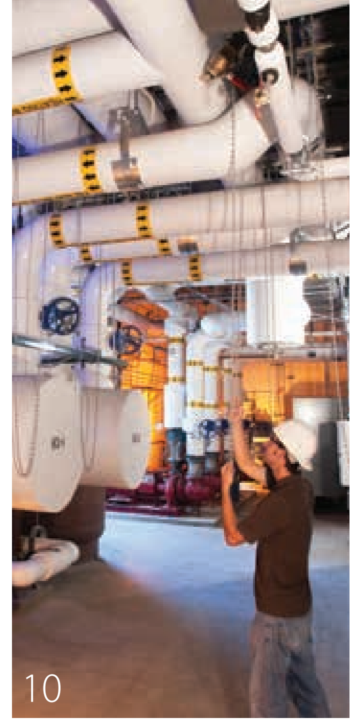
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Elements

Editorial

Innovations and Top Trends for 2014

Over the past 18 months as I recovered from Guillain-Barre Syndrome and was blessed with a second chance together with the wonderful love and support of my family, friends and coworkers, I spent time traveling the world, listening and learning. The trends and innovations I discovered are nothing short of astonishing.

ISO55000 Asset Management - In a shift from delivering function to delivering value, organizations will consider a new managing system for asset management that is expressed in ISO55000.

Better Decision Support - The Internet of Things (IoT), 3D scanning, asset information models that serve every user perspective, Big Data, asset analytics, reliability modeling and evidence-based decision tools are evolving quickly, providing organizations like Southern Company and UK-based Crossrail with data and evidence to make great whole life asset decisions.

Imagine Reliability - The Next Element is here - In a recent Abraman conference presentation in Brazil I looked out to an audience of hundreds of young energetic future leaders who see the 2014 World Cup and 2016 Olympics as an opportunity to create Brazil as a global leader with a bright economic future. Our own Maura Abad with Co-founder Kelly Rigg O'Hanlon are leading a new Imagine Reliability group of future maintenance reliability leaders in North and South America. Log onto www.maintenance.org to join.

Reliability Leadership - Reliability leadership is based on the concept that everyone who enables reliability is a leader who will deliver results. The Certified Reliability Leader (CRL) exam is designed to provide a simple, yet deep awareness of the interconnected elements required for sustainable reliability and asset performance aligned perfectly in support of the ISO55000 asset management standards.

C-Level Interest - I just returned from a London meeting with 40 chief information officers (CIOs) of the largest organizations in Europe and they are listening for new ways to deliver value with new and existing assets. They understand that there is a perfect storm brewing that includes aging assets, technology obsolescence, retiring workforce, skills shortage, appetite for reduced risk, lack of new capital investment and increased expectations.

Innovations are wonderful, but they mean nothing without high integrity leaders who are willing to take committed people on the journey with them. Are you going to dive in and learn these new ideas, processes, technologies and strategies, or are you going to sit on the sidelines to see how it all works out? Are you a driver or a passenger? Are you a hedgehog or a fox (Google it)? What are you committed to delivering for yourself and your organization today?

Listening carefully,

Terrence O'Hanlon, CMRP
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PO Box 60075, Ft. Myers, FL 33906
1-888-575-1245 • 239-333-2500 • Fax: 309-423-7234
www.uptimemagazine.com

Uptime Magazine
is a founding member of

Uptime® (ISSN 1557-0193) is published bimonthly by Reliabilityweb.com, PO Box 60075, Ft. Myers, FL 33906, 888-575-1245. In the U.S., Uptime is a registered trademark of Reliabilityweb.com.

POSTMASTER: Send address changes to:
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Reliabilityweb.com Participates in Florida Polytechnic University's Inaugural Industry Partner Summit!


Kelly Rigg O'Hanlon, Co-founder, Reliabilityweb.com and John Couch, Vice President of Education, Apple

Florida Polytechnic University is Florida's high-tech jobs university set to open in 2014. Reliabilityweb.com Co-founder Kelly Rigg O'Hanlon joined Apple's Vice President of Education John Couch for a robust discussion on cutting-edge degree programs. Florida Polytechnic University's mission is to educate students by emphasizing science, technology, engineering and mathematics (STEM) in an innovative, technology-rich and interdisciplinary learning environment. The University collaborates with industry partners to offer students real-world problem-solving, work experience, applied research and business leadership opportunities. Florida Polytechnic prepares students to assume available leadership positions in the dynamic technological landscape in Florida, the nation and the world.

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2013 Be Inspired Award

Bentley Systems announced ScottishPower's Strategy for Asset Management and Process Safety as the winner of a 2013 Be Inspired Award. Special guest keynoters included Sir John Armitt, chairman of the Olympic Delivery Authority for London 2012 and chairman of National Express; Andrew Wolstenholme, CEO of Crossrail Ltd.; Peter Hansford, chief construction adviser to the U.K. government; Pedro Miranda, corporate VP, Siemens AG, and head of the Global Center of Competence Cities; and Terrence O'Hanlon, CEO and Publisher, Uptime Magazine. The award was presented at a ceremony during the Year in Infrastructure 2013 Conference, held October 29-31 in London, United Kingdom. This global gathering of leading executives in the world of infrastructure design, construction and operations featured presentations and interactive sessions exploring the intersection of technology and business drivers, and how they are shaping the future of infrastructure delivery and investment returns.


Sandra DiMatteo, Marketing Director, Bentley
Jon Osborne, Generation Business Chief Engineer, ScottishPower
Eddie Launhardt, Generation Business Integrated O&M Specialist
Alan Kiraly, Senior Vice President, Bentley

Terrence O'Hanlon, CMRP of the Year Award


Terrence O'Hanlon, CEO/Publisher, Uptime Magazine

Uptime Magazine's Publisher received the top honor in the Veteran Professional category for the inaugural CMRP of the Year Award.

In addition to earning the Certified Maintenance and Reliability Professional (CMRP) certification, Mr. O'Hanlon was selected as the award recipient by the SMRP Award Committee due to his demonstrated leadership, professional development and accomplishments in the M&R industry. "World-class organizations recognize that success is achieved through leadership," said O'Hanlon. " However, they also realize that results are only delivered through engagement and empowerment of everyone in the workforce. Leadership does not come from one person – it comes from everyone. This is especially true for reliability." Mr. O'Hanlon has spent more than 30 years in the M&R industry. He is co-founder of Reliabilityweb.com and publisher/founder of Uptime Magazine, based in Ft. Myers, FL. He has served many volunteer positions within SMRP, including the Board of Directors, Certification Committee and Exam Development Team.


HX-4
HX-1

ISO 55000

It's All About the Value

Rhys Davies

Asset management has been a rapidly growing discipline in a variety of industries around the world for a long time now. In 2004, BSI PAS55 was published in the UK defining requirements for an optimal asset management system. It was followed in 2008 by a revised version of PAS55 drawing on input from more industries and reflecting a greater international input. Work has been progressing for the past three years on formal international standards for asset management in the form of the ISO55000 suite of standards to succeed PAS55. The ISO55000 series is due for publication in early 2014.

So what is this suite of standards all about? The key issue to bear in mind from the start is that organizations have been managing assets for a long time. In most organizations, there are enthusiastic and competent groups of engineers seeking to improve their assets and contribute to their business. However, for most of them, they are bombarded by initiatives for safety, the environment, cost reduction and a myriad of other important ideas. The trick to a successful organization is in bringing all of these well-intended initiatives together with excellent reliability engineering to deliver organizational value. And there lies the challenge for most organizations.

Back in 2004, BSI PAS55 defined a management system framework for asset management. It outlined a number of core themes that helped organizations to separate the 'management of assets' from 'asset management.' They included:

- Aligned objectives from senior management at the top of the organization down to the technicians working on the smallest assets.
- Transparent and consistent decision-making to better balance potentially conflicting demands for resources between asset groups, but also between initiatives that impact the assets, such as safety, the environment, corporate social responsibility and many others.
- Using risk to help make those decisions so they are focused on delivering required organizational outcomes and managing the uncertainty associated with those outcomes.
- Balancing long-term asset needs with short-term business planning cycles.

A management system is the framework of processes and procedures used to ensure that an organization can fulfill all tasks required to achieve its objectives.

From Wikipedia

These themes were structured into a management system that allowed organizations to embed good management of assets and good decision-making processes sustainably into the way they do things in their organization.

In late 2008, with BSI PAS55 growing in acceptance, the UK's Institute of Asset Management, which had led the development of PAS55, started working to enhance international and cross-sectoral input to a series of international standards for asset management. This led to the formation of ISO/PC251 which, over the past three years, has brought together experts in asset management from 31 countries to develop its work.

ISO/PC251 Participating Countries:

1. Argentina
2. Australia
3. Brazil
4. Canada
5. Chile
6. Columbia
7. Czech Republic
8. Denmark
9. Finland
10. France
11. Germany
12. India
13. Ireland
14. Italy
15. Japan
16. Republic of Korea
17. Mexico
18. Netherlands
19. Peru
20. Portugal
21. Russia
22. South Africa
23. Spain
24. Sweden
25. Switzerland
26. United Kingdom
27. United States of America
28. United Arab Emirates
29. China
30. Belgium
31. Norway

ISO55000 AND GETTING TO GRIPS WITH VALUE

With ISO/PC251, the experts were charged with developing three international standards that would define a management system framework for asset management.

With BSI PAS55 being one of the core base documents, the aim of ISO/PC251 was to grow the understanding of what delivering asset management within an organization really means. This raised a number of big questions at the outset:

What do we mean by an asset?
What do we mean by asset management?
What do we mean by an asset management system?
What do we mean by value?

On the face of it, these should be simple questions to answer, but when you lock 50 experts in a room to discuss these simple questions, they very quickly become more complex.

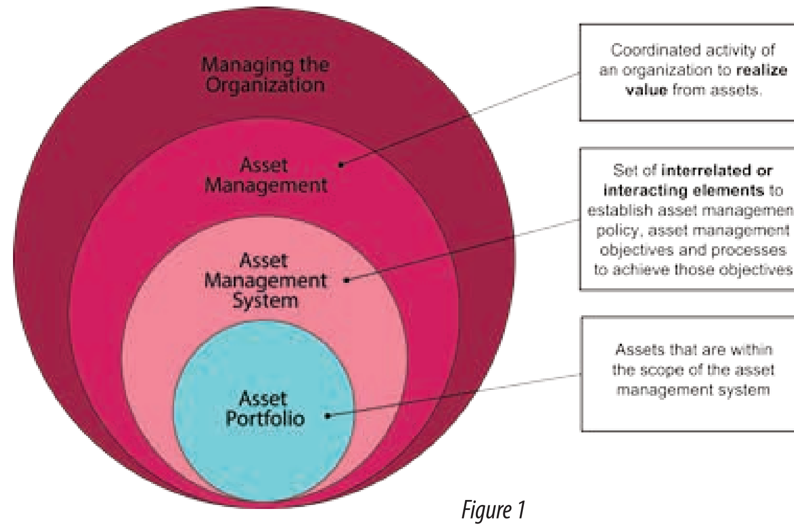

Figure 1

ISO/PC251 - Deliverables

ISO55000 - Asset management – Overview, principles and terminology

ISO55001 - Asset management – Management systems - Requirements

ISO55002 - Asset management – Management systems - Guidelines on the application of ISO55001

Figure 1 is extracted from the ISO55000 overview document and provides a view of how the management system framework sits when considered with the assets themselves and also the wider discipline of asset management.

So, let's start with what an asset is and what constitutes value. If we look to ISO55000 , value is highlighted as one of the fundamentals of asset management. It goes on to highlight that asset management does not focus on the asset itself, but on the value that the asset can provide to the organization. It also makes a strong point that value can be tangible or intangible, financial or non-financial and the concept of value needs to be determined by the organization and its stakeholders. For example, value could be a straightforward need to deliver profit from an asset base, but if we consider the case of a municipal government looking after public parks, value could be defined as a mix of ambience, safety and low cost.

ISO55000 Standards

The Standards will be published in early 2014. To purchase a copy visit:

www.iso.org

Note that at no point is ISO55000 saying that we have to have the most reliable assets or the greatest level of production. We need to be clear on what we are trying to achieve in terms of value and which assets we are trying to manage.

So what does ISO55000 say about assets? An asset in BSI PAS55 was very clearly a physical asset, but in ISO55000, the definition has been broadened to include any things that have the potential to add value to the organization. This very clearly still addresses physical assets (and indeed much of ISO55000 has been written from the perspective of physical assets), but could also include less tangible items, such as contracts, licenses, brands, or concession agreements. The word 'physical' has been deliberately removed so industries that are less focused on physical assets (for example, those with a high software content) will find it more relevant to them.

ISO55000 also reminds us that value can change during the lifecycle of an asset and that we need to consider the management of risks and liabilities, as well as opportunities throughout the lifecycle.

So you can start to see that ISO55000 has a broader view of assets and a stronger focus on delivering value. In fact, asset management has been defined as the activities that derive value from assets, which can be quite wide reaching. But in principle, the core themes that were successful in PAS55 have remained key elements of ISO55000, namely aligned objectives, transparent and consistent decision-making, and the use of risk and consideration of long lifecycle issues in making those decisions.

WHY IS ASSET MANAGEMENT MORE THAN JUST A MANAGEMENT SYSTEM?

In Figure 1, it is clear to see that ISO55000 is telling us that asset management is more than a management system. The definition of a management system at the beginning of this article defines it simply as a collection of processes and procedures. We might wish to refer to that as the parts of asset management that we can capture in a structured way to make them consistent and repeatable in a sustainable way.

This leaves lots of other elements of asset management still to be delivered by the organization and its leadership. ISO55000 highlights the following areas that are clearly important beyond the management system: Leadership, culture, information or knowledge about the asset base, to name but a few. It is important to remember that the ISO/PC251 group was tasked with developing international standards relating to management systems for asset management, so they didn't seek to expound upon the whole discipline.

As such, it is important to remember that simply implementing ISO55000 will NOT solve all your asset management problems. In fact, my personal experience with organizations implementing an asset management approach who simply think that a collection of processes can solve their issues always results in failure. So, strong leadership, a developing culture that has asset knowledge at the core and good solid engineering are all important factors to keep in mind as you make your asset management journey.

WHERE DOES THIS LEAVE RELIABILITY ENGINEERING?

Assets are at the core of asset management and for those industries focused on physical assets, reliability engineering will remain a core element of their work. Just as good knowledge about assets and how they impact on delivering organizational objectives and managing organizational risk are key to good asset management, core competences of good reliability engineering remain key to successful asset management.

This invites the question of what additional value does asset management bring over and above good reliability engineering? For me, this is an easy question to answer. I have worked in so many organizations where engineering teams have not been provided with the necessary clarity on what they should be achieving. This results in enthusiastic and capable engineers trying to improve things in a world where they are fighting for resources among a myriad of other initiatives. It is not always possible to see how our reliability initiatives fit into the bigger picture, nor how we can defend our positions.

When combined with strong leadership and an emerging asset management culture, the management system framework defined by ISO55000 provides a structured view of what the organization is trying to achieve and how to balance things, like performance, the environment and safety, to achieve organizational value. As a reliability engineer, this gives us clarity on how to apply our skills within the wider business to not only communicate better with the rest of the organization, but ultimately achieve much better outcomes.

ISO55000 PROVIDES A STRUCTURED VIEW OF WHAT THE ORGANIZATION IS TRYING TO ACHIEVE AND HOW TO BALANCE THINGS, LIKE PERFORMANCE, THE ENVIRONMENT AND SAFETY, TO ACHIEVE ORGANIZATIONAL VALUE

CONCLUSION

The enthusiasm that has developed for BSI PAS55 has already transferred and expanded to a much greater level for ISO55000. When it is published in early 2014, ISO55000 is going to impact our industries, particularly where we work in an international context or for multinational organizations. Asset management is not just reliability engineering re-badged, nor is ISO55000 the whole solution to the problem. However, good reliability engineering, coupled with good asset knowledge and strong leadership, can be combined with the management system processes defined by ISO55000 to make our lives much easier and allow us to deliver value more consistently.

Rhys Davies is the Chairman of ISO Committee PC251, leading 31 countries in developing International Standards for Asset Management that will lead to the publication of the ISO55000 series in 2014. He was fundamentally involved in the development of PAS55 and was Vice Chair of the Steering Group for PAS55:2008. Rhys is President of eAsset Management Limited and eAsset Management Inc., registered in the U.S. Rhys, a Chartered Engineer, holds a BEng (Hons) and MEng in Electronic Engineering from UCNW and completed an MBA. Rhys has developed his career as an asset management specialist.

Q&A with 3 Industry Leaders on ISO55000

As a member of the U.S. Technical Advisory Group to ISO PC251 that drafted the soon-to-be published standard titled ISO55001 Management Systems for Asset Management, Uptime Magazine's Publisher Terrence O'Hanlon worked with a group that included thought leaders Scott Morris, Terry Wireman and Ramesh Gulati. This special group has agreed to provide early guidance for those who seek to optimize value delivery from more effective asset management.

IMC 2013 Presenters

Scott Morris

Associate Director, Genzyme, A Sanofi Company. Mr. Morris is the Vice Chairman of the U.S. delegation for the development of the ISO55000 series documents on Asset Management.

Terry Wireman

Senior VP of Strategic Development, Vesta Partners. Mr. Wireman is a member of the US Technical Advisory Group to ISO PC251.

Ramesh Gulati

Asset Mgmt & Reliability Planning Mgr, Aerospace Testing Alliance, Arnold Engineering Development Center (AEDC). Mr. Gulati is a member of the US TAG PC251/ ASTM/ANSI Committtee which is supporting development of ISO55000. Member of the U.S. Technical Advisory Group to ISO PC251.

How would you describe the new ISO55000 - Asset management systems standard to maintenance reliability leaders?

ISO55000 is a holistic approach to enable assets to provide maximum value to an organization. The standard specifies that an organization have transparency and accountability, from top management through to the operator level. This means that the entire organization is responsible for doing their part for asset care, not just the maintenance reliability functions.

The asset management systems standard focuses on setting up a management system to manage the assets of a company. While that sounds like double-talk, let me explain. Asset management focuses on maximizing the value that an organization can realize from its assets. An asset management system assures that the company puts the "management" structure in place to ensure the business objective of maximizing the value received from the asset can be realized.

"If we can't describe what we are doing as a process, we don't know what we are doing." Some wise man said that. This is true in every sense. In fact, this is what a standard does for us. Asset management standard ISO55000 is a disciplined approach to do asset management.

First, we need to understand the term "asset management." Most of us have come from a maintenance background and are more concerned with repairs and fixes. Asset management is a much broader term and deals with the whole life of an asset, not just repairing assets when they fail. It's a proactive approach of managing assets through concept, design, build, install/commission, operations and end of life-disposal phases to reduce total cost of ownership. This ISO standard 55000 helps us set up the process to do that.

Can you explain the BIG concepts of how this new standard will help organizations deliver value from their assets?

This standard makes organizations 'think' about their assets and how these assets affect organizational objectives. This may sound obvious, but a majority of organizations take their assets for granted and look at keeping them in optimum condition as a cost. By changing the perspective to how assets provide value to the organization, the cost conversation is looked at in context. This also requires organizations to review their asset management strategy, with associated risks, when changes in organization context occur (e.g., customer demand changes, new market opportunities, etc.).

One key element is that this standard is for an asset management system. This means it is not a performance or technical standard. It will tell you what elements or processes you need in place, but not the details.

The two largest impacts for most companies will be the true lifecycle approach to managing assets and the alignment of the organization to maximize the value received from the assets.

Many companies talk about lifecycle management of assets, but few have the "management system" and/or integrated asset data to achieve this. Most companies are still in organizational silos where the engineering organization does not share asset design information with the operations organization and neither shares the asset information with the maintenance organization. In addition, finance has information (such as the expected value delivery of the asset) that is not shared with any of these three organizations. Achieving ISO55000 certification will require these silos and the information they contain to be integrated.

Value delivery, what does it mean? It means that assets are producing or providing services as designed, cost effectively. It cannot be achieved without a proper system – well designed processes with the right culture. A standard, such as ISO55000, helps to achieve that. This standard requires us to set up a process that uses strategic, as well as tactical, approaches to manage our assets. It also forces us to have a third eye, an outside view of our progress or improvements that we need to make via external audits.

In the past, most of us did our best to perform maintenance to ensure that assets worked when they were needed. We use all kinds of tools to perform those tasks effectively. But usually, we are working in isolation or silos to do our job. There are several other stakeholders in managing assets effectively, such as operations, capital projects managers, design, etc., and they need to be involved. I believe a good asset management process implemented with ISO55000 principles would be an excellent approach.

What "next steps" would you recommend?

I feel this standard can be transformational if embraced by an organization. Educate personnel throughout the organization, including employees, peers and management. Be an advocate by breaking down institutional silos. Unlocking and aligning the knowledge within your organization benefits all parties.

Also, compare existing processes to the standard. You will be surprised at how much you already have in place that aligns to the management system.

This answer is easy – education. Every maintenance reliability leader should educate themselves about asset management. There is a considerable body of knowledge that currently exists about asset management. It is simply a matter of collecting this information, much of which can be found at the Institute of Asset Management (http://uptime4.me/assetman-org). In addition to reading documents, it is also important for maintenance reliability leaders to attend conferences where asset management is a discussion topic. This will allow for open dialogue with other maintenance reliability leaders who are pursuing asset management and thought leaders in the asset management field.

Once maintenance reliability leaders feel comfortable with their knowledge of asset management, they should begin to share that information with peers and executives in their respective companies. Once there is a common understanding of asset management, the organization will be ready for their journey.

I suggest a three-pronged approach.

First, we need to find organizations, such as Motorola, GE, etc., and look at what they did with the Six Sigma initiative back in the 90s. They adopted and really and truly implemented the Six Sigma approach at every level of the organization. We have to find these organizations who can lead the ISO 55000 implementation and show others the benefits. My personal experience in implementing a tailored ISO9001 for quality management since 2003 at Arnold Engineering Development Complex (AEDC), U.S. Air Force's aerospace R&D facility, is that a standard approach can truly benefit a lot in creating the right culture and reducing operating costs.

Second, let us find some champions at "C" level for this cause, similar to what Jack Welch did with Six Sigma. He became the sole champion and the driver for implementation across industry, not just GE.

Third, we need to get media support. We need the continued support of Terrence O'Hanlon, CEO/Publisher of Uptime Magazine and Reliabilityweb.com, to help us spread the gospel. We need our other media friends to help us. We may need a campaign to get others, such as *Industry Week* and the *Wall Street Journal*, to get on board with this initiative.

Recent Advances and Trends in Predictive Manufacturing in Industry 4.0 Environment

Jay Lee and Edzel Lapira

IMC 2013 Presenter

The manufacturing industry continues to be a pillar of the U.S. economy, underpinning its essential role in ensuring national security. It contributed to 11.9 percent of total U.S. gross domestic product (GDP) in 2012, and when compared to other industries, manufacturing provides the largest multiplier effect — every $1 spent in manufacturing generates $1.48 in additional economic activity.[1] Manufacturing also provides direct employment to nearly 12 million Americans.[2]

Essential as it is, the U.S. manufacturing industry is experiencing challenges that threaten its sustainability. Despite claims of a rebound from the last economic recession of 2008-2010, the U.S. market share in the global export of advance technology products still dropped by six percent in 2011[3] and only a small portion of the five million jobs that were lost has been recovered. Furthermore, the U.S. manufacturing industry faces strong and increasingly capable competition from emerging economies that are positioning themselves to lead markets in high value-added products. Other nations have invested to strengthen their manufacturing competitiveness with intensive research and development (R&D) efforts[4] more aggressively than the U.S. A report[5] by the National Science and Technology Council recognizes this gap between R&D activities and the deployment of technological innovations in domestic manufacturing. The Obama administration has proposed a $1 billion investment in a National Network for Manufacturing Innovation to address the aforementioned gap[6]. However, the question remains: What innovative technologies should be developed in order to sustain the competitiveness and leadership of the U.S. manufacturing industry?

The aggressive adoption of the "Internet of Things" ideology has helped in laying the foundation of predictive manufacturing by setting the foundational structures of smart sensor networks and smart machines

The globalization of the world's economies is a challenge to the local sector and it is pushing the manufacturing industry to the brink of its next transformation. This metamorphosis is aided by current advances in sensing, instrumentation, automation, communication and other emerging technologies. This article describes the evolution of manufacturing, and introduces the concepts and principles of predictive manufacturing and how it can mold next generation production assets and their auxiliary systems to improve manufacturing competitiveness.

EVOLUTION OF MANUFACTURING STRATEGIES

From the early adoption of mechanical systems to support production processes, to today's highly automated assembly lines, manufacturing has always been a vibrant industry with an ecosystem that is highly reli-

ant on innovation and ingenuity. The discovery of new technologies has enabled numerous transformations and technological developments to occur (and will continuously be expected) in order to be responsive and adaptive to dynamic market requirements and demands.

At the turn of the 20th century, mass production was made popular by Henry Ford to generate large volumes of standardized units using assembly lines designed for the systematic and sequential organization of laborers, machines and parts. Production costs are minimized by utilizing interchangeable parts to build the final product. However, the early implementations of mass production were laden with numerous sources of waste, such as overproduction, waiting (idle time), transport, processing, inventory, redundant or unnecessary motion and defects. Then came the Toyota Production System in the early 1970s, the prime directive of which is to reduce production costs by minimizing and ultimately avoiding the sources of waste. This manufacturing strategy entails an organizational-wide operation evaluation to determine the different sources of waste and identify necessary changes to processes in order to avoid them. Such philosophy eventually trickled into the Western nations with the development of lean principles and Six Sigma techniques. Then, the start of the computer age brought forth numeric controllers that provided automation and flexibility to equipment, such as industrial robots, machine tools and other engineering assets. With such capabilities, manufacturers are able to institute mass customization or agile manufacturing and supply consumers with products they want. The last two decades saw astounding growth in the advancement and adoption of information technology and even social media networks that have increasingly influenced consumers' perception on product innovation, quality, variety and speed of delivery. This scenario led to the establishment of reconfigurable manufacturing, wherein a plant structure can be easily and systematically modified so production capacity can scale up rapidly and functionality can adapt more quickly.

Manufacturing organizations can only take full advantage of the aforementioned strategies if there is a good fit between the principles

Prognostics and health management deals with the assessment of the condition of a manufacturing asset, the discovery of incipient failures and an inference of the next failure event so proactive maintenance activities can be performed to avoid catastrophic and costly machine breakdowns

of the paradigm being adopted and the company's corporate goals, and if implementing guidelines are faithfully observed. However, even a strict compliance does not ensure maximum potential benefits due to uncertainties that can be found in machines, the people and even processes.

TRANSPARENCY – SHOWING THE UNCERTAINTIES IN MANUFACTURING

In manufacturing, there are many uncertainties that may not be quantifiable or even known to decision makers, making them unable to form sound judgments and conclusions about the efficient operation and usage of their assets (see Figure 2).

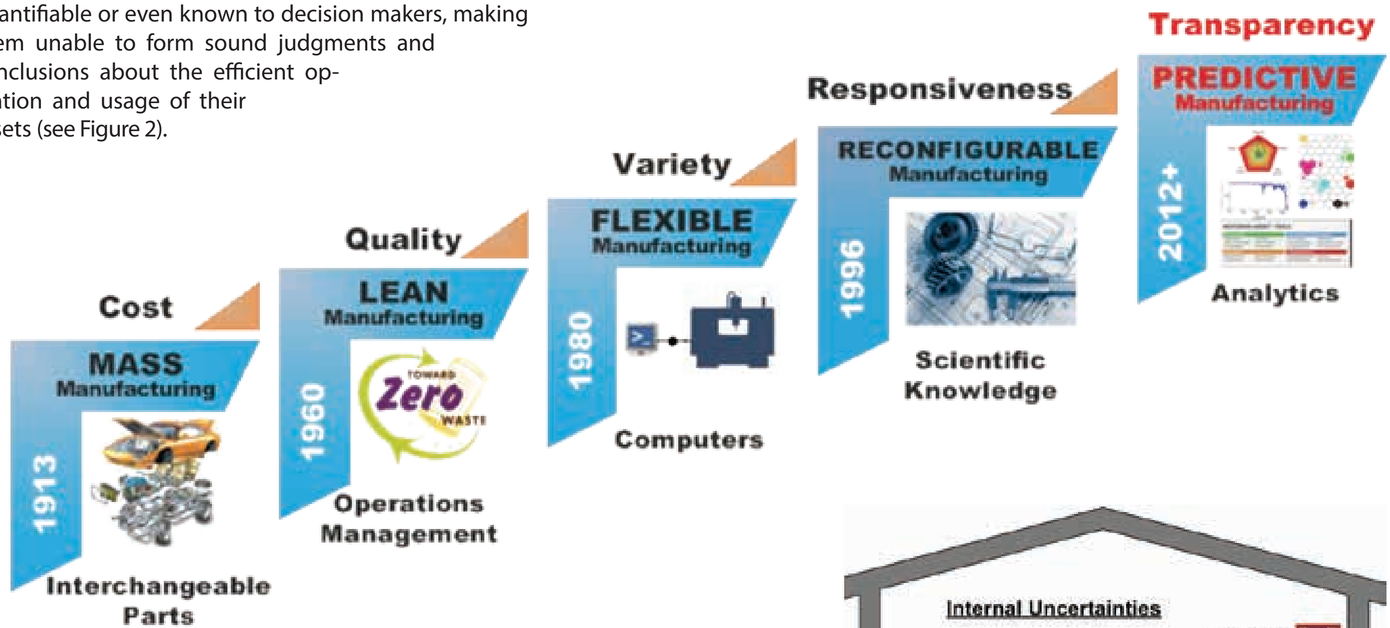

Figure 1: Evolution of manufacturing paradigms

These uncertainties persist both internal and external to the factory. Examples of internal uncertainties include degradation of the machining processes and the occurrence of failure events without any recognizable symptoms (component level); and variation of cycle time due to inconsistent operation, unplanned breakdown of systems and the presence of scraps and rework that may lead to difficulties in production planning and scheduling (system or production process level). Meanwhile, external uncertainties, typically stemming from product development all the way through the supply chain, can manifest as: 1) unreliable downstream capacity, 2) unpredictable variation of raw materials or parts in terms of delivery, quantity and quality, 3) market and customer demand fluctuation, 4) incomplete product design due to the lack of accurate estimation of product state during production and usage, and 5) random warranty claims and demands for replacements, etc.[7]

The internal manufacturing issues can be further mapped into two domains: visible and invisible. Examples of visible issues include machine failure, product defects, poor cycle times, long time delays, drops in overall equipment effectiveness (OEE), etc. These are very obvious conditions and information retrieved from analyzing visible issues is primarily after the fact. On the other hand, invisible issues may occur as machine degradation, component wear, etc. These uncertainties can have adverse effects on manufacturing operations if no predictive analytics and control strategies are judiciously implemented.

In each of the domains, issues are treated in both deterministic and uncertain levels (see Figure 3). Pertaining to deterministic issues (Q3), tools using best practices and standard work are normally utilized to handle these issues systematically. Then as a potential countermeasure, companies work with their equipment suppliers to utilize new knowledge from their internal problem-solving exercises and develop technologies that will be integrated to their equipment as a value-added improvement (Q2). Meanwhile, on uncertainty issues, efforts have been made, such as in the prognostics and health management (PHM) research area, to formulate more advance predictive analytics and detect problems at an early stage

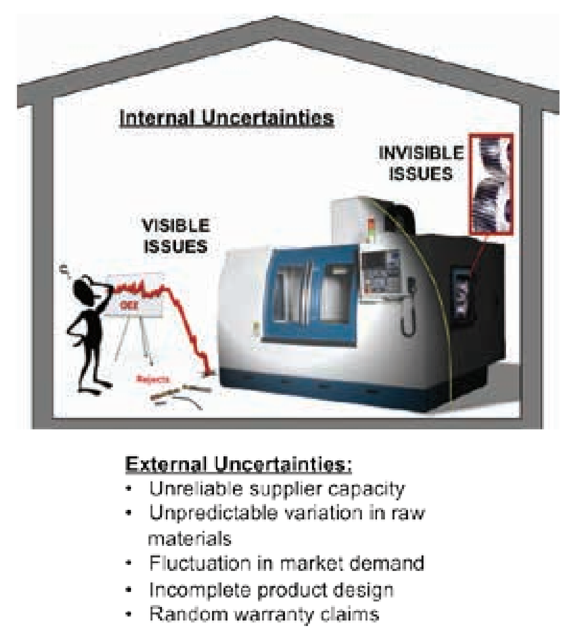

Figure 2: Illustration of manufacturing issues in a factory

(Q3). The unmet need, therefore, is to replicate what has been done in the invisible space and further define how issues are addressed from the problem-solving level to the problem avoidance level (Q4). Utilizing predictive tools and techniques will unravel many new value-creation opportunities that will exploit the new information (unknown knowledge).

What are needed then are tools and technologies that can provide transparency, which is the ability of an organization to unravel and quantify such uncertainties to determine an objective estimation of its manufacturing capability and readiness.[8] The manufacturing strategies described earlier have haphazardly assumed continuous equipment availability and sustained optimal performance during its every usage, yet such assumptions do not hold true in a real factory. In order to achieve transparency in the plant, the manufacturing industry has to take the plunge and transform itself into predictive manufacturing. Such evolution requires the utilization of advance prediction tools and approaches so data that is continuously generated by factories can be systematically processed into information. This information can help explain the uncertainties, thereby allowing asset managers and process supervisors to make more "informed" decisions.

The aggressive adoption of the "Internet of Things" ideology, even in the manufacturing industry, has helped in laying the foundation of predictive manufacturing by setting the foundational structures of smart sensor networks and smart machines. The use of advance predictive tools has become more prevalent across different market segments. An area that has leveraged on such predictive analytics is prognostics and health management. It deals with the assessment of the condition of a manufacturing asset, the discovery of incipient failures and an inference of the next failure event so proactive maintenance activities can be performed to avoid catastrophic and costly machine breakdowns.

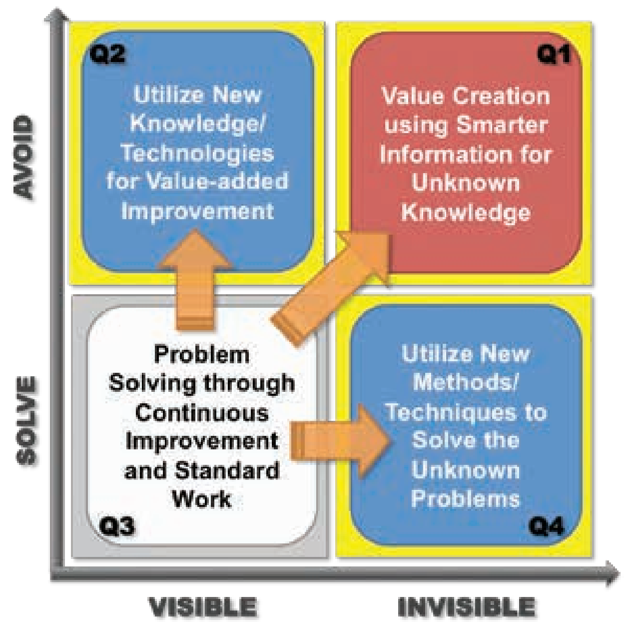

Figure 3: Problem solving and avoidance in both visible and invisible spaces

THE PREDICTIVE MANUFACTURING SYSTEM

A predictive manufacturing system provides machines and systems with "self-aware" capabilities, thereby giving greater transparency to users and ultimately avoiding potential issues concerning productivity, efficiency and safety.

The core technology of a predictive manufacturing system is the smart computational agent that contains smart software to conduct predictive modeling functionalities. The predictive analysis of equipment performance and estimation of the time to failure will reduce the impacts of these uncertainties and give users the opportunity to proactively implement mitigating or even countermeasure solutions to prevent productivity/efficiency loss in manufacturing operations.

Predictive manufacturing systems allow users transparency in operations with information, such as actual health condition, a trajectory of the equipment's performance or degradation behavior, and insights as to when and how the equipment, or any of its components, is likely to fail.

Some benefits of a well designed and developed predictive manufacturing system are:

- *Cost reduction* – By knowing the actual condition of the manufacturing assets, maintenance activities can be provided at a more appropriate condition (not too late that a failure has occurred and not too early that a perfectly good part is being unnecessarily replaced). This is also known as just-in-time maintenance.
- *Operation efficiency* – With knowledge when equipment is likely to fail, production and maintenance supervisors can prudently schedule their activities, thereby maximizing equipment availability and uptime.
- *Product quality improvement* – Degradation patterns and near real-time machine condition estimates can be integrated with process controls so product quality is maintained while accounting for equipment or system drifts over time.

PROGNOSTICS AND HEALTH MANAGEMENT

Prognostics and health management (PHM) is a critical research domain that leverages advanced predictive tools. PHM is becoming more popular primarily due to the need to have a mechanism to obtain objective assessment on the true condition of manufacturing assets, as well as auxiliary systems. In the past, reactive maintenance has been adopted widely due to its practical approach, wherein a machine is repaired only when it is needed (i.e., when it fails). However, as production throughput rates have soared to meet growing consumer demands, unplanned downtime has become prohibitively expensive and must be avoided. Then came preventive maintenance strategies that require maintenance activities (such as conditioning and replacement) to be accorded either on a time- or usage-based interval. Although the preventive maintenance approach can provide the highest level of availability (assuming a reasonable time interval), it has two major drawbacks: (1) implementing a preventive maintenance program is expensive, especially if the time interval is very short and (2) since components are being replaced before failure or even before symptoms start to show, there is no insight gained about the degradation behavior of the asset. Condition-based maintenance, meanwhile, utilizes machine signals (either from the controller or from sensor installations) to detect the occurrence of a fault or anomaly. In some implementations, even the location of the fault can be isolated and the type of fault event can be recognized. PHM is a natural extension of condition-based maintenance by using prediction algorithms so future performance of the equipment can be inferred. By monitoring health metrics (confidence value or CV, failure mode, remaining useful life, etc.), the user can observe the temporal behavior of the machine and be warned of the incipient signs of failure before the actual fault event. With such information, manufacturing transparency is then achieved because plant managers and supervisors are now capable of identifying machines that can optimally finish a production job order (mission readiness) while prioritizing equipment for repair without interfering with production schedules.

By monitoring health metrics (confidence value, failure mode, remaining useful life, etc.), the user can observe the temporal behavior of the machine and be warned of the incipient signs of failure before the actual fault event

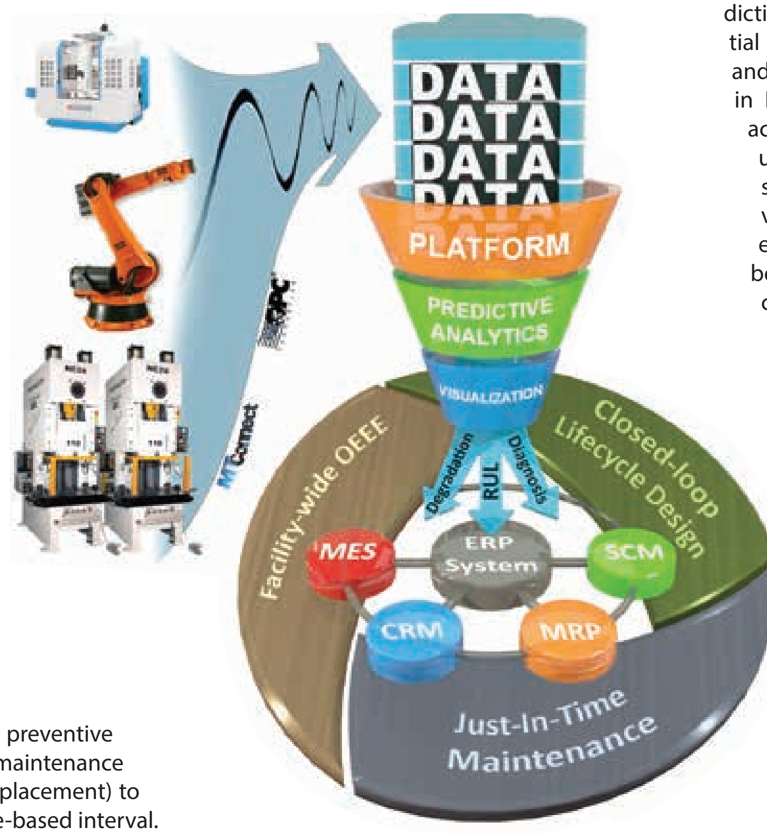

Figure 4: Predicting a manufacturing system framework using predictive analytics

Illustration by Behrad Bagheri

A FRAMEWORK FOR A PREDICTIVE MANUFACTURING SYSTEM AND PHM

In order to reap the benefits of a predictive manufacturing system, essential components should be present and effectively utilized as illustrated in Figure 4. It starts out with data acquisition of appropriate signals using the applicable sensor assemblies to extract data, such as vibration, temperature, pressure, electrical signals, etc. It also may be useful to apply data mining and correlation to historical data to augment the incoming data. Moreover, there are industry-grade communication protocols, such as MTConnect and OPC (OLE-DB for Process Control) that can aid users to store status signals from the machine's controller. Such data can provide context information when the sensor data is being simultaneously recorded. When all the data from the different sources (historical, sensors and controllers), multiple components and units are aggregated, then the big data predicament needs to be addressed. Such phenomenon poses the challenge of how to effectively manage and extract useful information only. An example of an effective transforming tool to manage big data is the Watchdog Agent™, developed by the National Science Foundation's Industry/University Collaborative Research Center (I/UCRC) for Intelligent Maintenance Systems (IMS, www.imscenter.net) in 2001. It is a suite of predictive tools and algorithms that can be categorized into four sections: signal processing and feature extraction, health assessment, performance prediction and fault diagnosis. With prudent selection and use of visualization tools, health metrics, such as current condition, remaining useful life, failure mode, etc., can be effectively conveyed in terms of radar chart, degradation curve, risk chart and health map. With integration to the manufacturer's enterprise resource planning (ERP) system, the health metrics can trickle into the company's other corporate wares, such as supply chain management

(SCM), manufacturing execution system (MES) and customer relationship management (CRM), allowing for a more holistic enterprise control and optimization. With manufacturing transparency, management has the right information to compute facility-wide OEE. Equipment can then be managed cost-effectively with just-in-time maintenance. Finally, historical health information can be provided to equipment designers for closed-loop lifecycle redesign to improve next generation production systems.

Condition-based maintenance, meanwhile, utilizes machine signals (either from the controller or from sensor installations) to detect the occurrence of a fault

CONCLUDING REMARKS

The aggressive adoption of the "Internet of Things" ideology by the manufacturing industry has ushered in the unique opportunity to unravel and quantify uncertainties in assets and processes, ultimately improving manufacturing competitiveness. A predictive manufacturing system is presented here as the next phase in the industry's evolution that can provide transparency in the factory. Through the use of advance predictive tools and techniques, such as those found in the PHM practice, users can objectively and confidently deal with invisible uncertainties.

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Leadership for Reliability

Int

integrity

Integrity

Terrence O'Hanlon

I do not want you to read this article. Let me restate that…as the author of this article, I do not want you to *simply* read it. I want you to actually DO something as a result.

As you read this article, please identify one area where you would like to realize a significant breakthrough in the performance of your team or your organization. I hope you will find something useful for that purpose in the information presented.

According to research conducted by Reliabilityweb.com and Uptime magazine, and now confirmed by numerous other sources, more than 70 percent of change efforts and new reliability strategies fail to create a sustained result.

There are a number of factors that contribute to the low success rate, including:

1. A lack of understanding the elements of reliability as a holistic system and the ways these elements interact and interrelate.
2. A lack of appreciation for the roles that culture and leadership play in the delivery of performance.
3. A lack of awareness of the nature of the journey from one operating domain or maturity level to another (e.g., the transition from the reactive domain to the planned domain).

Uptime Elements were created to provide a simple way to understand a holistic, system-based approach to embedding reliability into an organization's practices and culture.

Like safety, reliability is as much a way of thinking as it is a set of actions and it must involve all stakeholders at all levels, from top management to plant floor.

Uptime Elements detail a reliability leadership system for asset performance that includes:

- Reliability Engineering for Maintenance,
- Asset Condition Management,
- Work Execution Management,
- Leadership for Reliability, and,
- Asset Management.

Uptime Elements as a system resulted from, and has been validated, by observations and assessments conducted at over 400 organizations and completed as part of the Uptime Awards, an annual event since 2006 that acknowledges and celebrates the "BEST" programs for maintenance reliability and asset management.

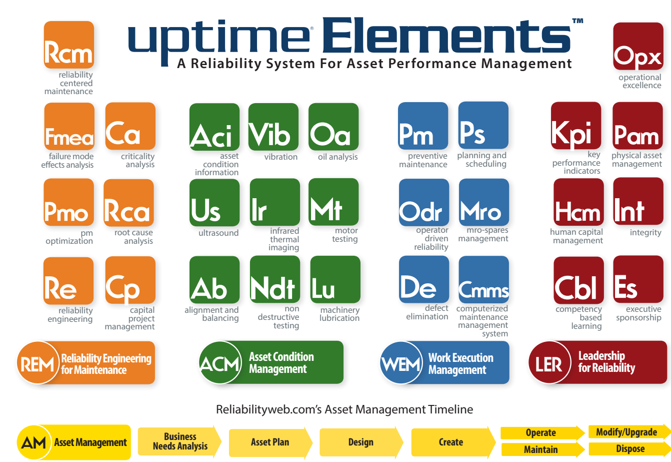

Figure 1: Uptime Elements – A reliability leadership system for asset performance management

Aligning people in aim and understanding creates a new paradigm of engagement and provides a foundation for a high-performance culture. At their highest purpose, Uptime Elements are designed to generate alignment and create enlightened awareness and understanding for:

- Top management who drive/demand asset performance;
- People who directly lead reliability improvements;
- People who manage aspects of reliability improvement projects (Figure 2);
- Individual contributors to reliability improvement.

Although these people typically have different job titles, roles and responsibilities, each one should be educated and encouraged as a reliability leader.

World-class organizations understand that performance is generated through leadership. They also understand that results require an informed, engaged and empowered team. Leadership is not one person's job; it is everyone's job.

The Uptime Elements reliability leadership system is designed to align three value drivers, each creating results that eventually intersect and replace the default future of inaction or ineffectiveness (Figure 3).

The system is also designed to develop an understanding of the current operating domain characteristics so they may reach a point of stabilization that supports transition to a more effective operating domain (Figure 4).

There is one theme that threads though all the Uptime Elements and that is **integrity**.

- Integrity enables reliability;
- Without integrity, reliability does not work.

As we move from the integrity of the inputs to criticality analysis in the reliability engineering for maintenance domain, through the integrity of the sampling of oil in the oil analysis of the asset condition management domain to the integrity of the data in the computer maintenance management system of the work execution management domain, we see that having integrity is fundamental to success. This is seen, no more so, than in the fourth Uptime Elements domain, leadership for reliability, as, simply put, without integrity there is no leadership.

South African reliability expert Grahame Fogel of Gaussian Engineering adds the following perspective:

All of asset management revolves around integrity. For an asset to perform within its design capacity over its entire life, it should:

- *Be planned, designed, built and commissioned with integrity.*
- *Ensure that the structure and accuracy asset data has integrity.*
- *Ensure that equipment is operated with integrity.*

Figure 2: The leaders required for a high-performance reliability system

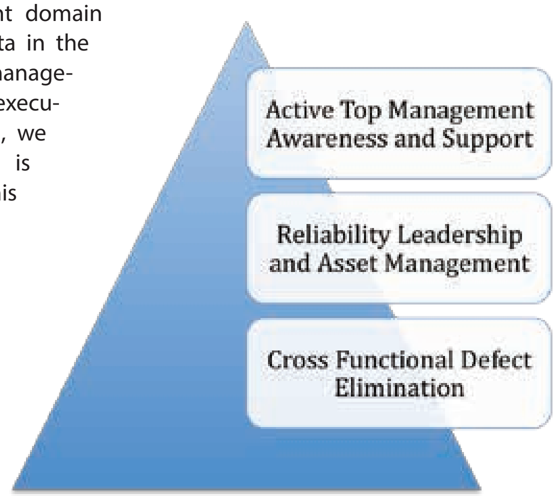

Figure 3: Intersecting value drivers

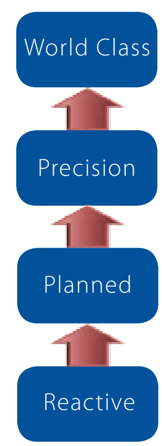

Figure 4: The operating domains

Source: Don't Just Fix It, Improve It, A Journey to the Precision Domain; Ledet/Abshire

An object has integrity when it is whole and complete.

Think of a gear with a crack or a bicycle wheel that is missing spokes. They are not whole or complete. Over time, performance will be reduced and failure is more likely. When an object is out of integrity, it becomes less workable. Conversely, a system has integrity when it is whole and complete.

As integrity declines, workability declines, and as workability declines, value (or more generally, the opportunity for performance) declines.

Whatever performance measure you choose requires integrity. Violating the ***Uptime Elements Law of Integrity*** generates undesirable consequences, just as certain as violating the law of gravity.

Operate as if the Uptime Elements Law of Integrity is true and the results that you and your organization can produce increase dramatically. The potential impact on performance is huge: 100 percent to 1000 percent! No software or hardware required.

Even if you do not know a clear definition of integrity, you know when someone or something does not have it. If you do not know a clear definition of reliability, you know when

Uptime Elements Law of Integrity

Integrity increases performance. When something is whole and complete, it has integrity. When something has integrity, it is capable of greater performance than when it lacks that wholeness.

Figure 5: Lack of integrity = lack of reliability = lack of potential performance

someone or something does not have it. Like reliability, integrity must be earned and it cannot be purchased. There is no "easy button" to achieve it and no check in an amount large enough to procure it.

Integrity and reliability are closely linked, not only in definition, but also in action. Table 1 draws your attention to the close relationship between integrity and reliability.

Table 1: Relationship between integrity and reliability

INTEGRITY	RELIABILITY
The integrity of the system	The reliability of the system
The integrity of the structure	The reliability of the structure
The integrity of the brand	The reliability of the brand
The integrity of the data	The reliability of the data
The integrity of the company	The reliability of the company
The integrity of the person...	*The reliability of the person...*

How will reliability work if the bicycle wheel is missing a spoke or the gear has a crack?

How will reliability work if you, your manager and/or the corporate leaders do not have integrity?

INTEGRITY IS A RELIABILITY PERFORMANCE TOOL

Of course we want mechanical integrity, but that is NOT the focus of this article. Robert DiStefano, co-author of "Asset Data Integrity is Serious Business" and CEO of Management Resources Group, Inc., puts it in context by quoting his grandfather instructing him as a young man: *"Integrity is always doing the right thing – especially when it is hard to do; especially when no one is looking."*

In a performance context, integrity is keeping your word. You are your word. People trust you or doubt you based on your word or your lack of word. People follow you based on their experience of your integrity.

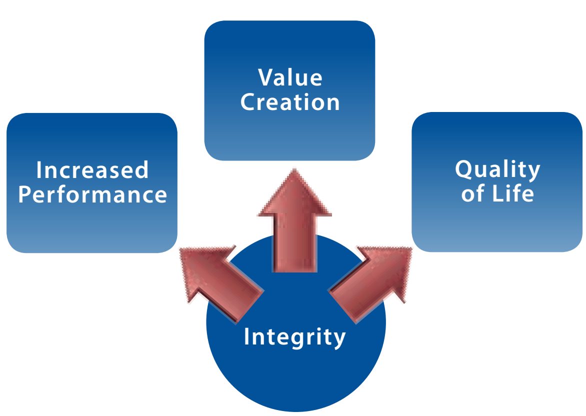

Figure 6: Integrity supports performance

Do not make commitments lightly; do not say you will do something and then not do it. Do what you say you are going to do.

On the other hand, if you NEVER break your word, you are probably playing it "safe" and not living to your fullest potential. When you live your life big and stretch your capabilities by leading reliability in your organization, there will be times when things happen and you cannot, or choose not, to keep your word. When this happens, you need to earn integrity back by HONORING your word.

How do you honor your word when you break it?

We honor our word by cleaning up the mess we made when we broke our word – at the earliest possible opportunity – NOT AT THE LAST POSSIBLE MOMENT.

Honor your word by cleaning up the mess you made and then keep your word moving forward.

Integrity builds trust and people will follow leaders they trust. Conversely, people will not follow someone they do not consider to be operating from a place of integrity. Management authority comes from title. Leadership authority comes from integrity and example.

Uptime Elements is not a system for ethics or morals, nor are we explaining integrity in that context. When something has integrity, it is whole and complete. When something is whole and complete, it is capable of greater performance than when it lacks that wholeness. Therefore, it is logical to state that when something lacks integrity, it has less potential for high performance.

You are whole and complete (with integrity) to the extent that you keep your word and to the extent that you honor your word by cleaning up any mess you made when you do not keep your word. You are capable of higher performance when you are in a state of being whole and complete. *Lack of integrity is a failure mode.*

We often hear management extol virtues they want to see in you, things like, "Be a good worker," or "Do it right the FIRST time," or "Take pride in your work." Can you imagine management's reaction if they saw posters on the factory floor that said, "Do what you say you are going to do," or "More management follow through," or "Leaders Honor Their Word?"

As the topic of integrity is rarely discussed in relation to reliability, peer review and critiques were solicited for this article. A number of highly respected colleagues responded with positive suggestions that have been incorporated into this work.

In reviewing this article, reliability expert Heinz Bloch stated, *"We are in charge of keeping our word, not someone else."*

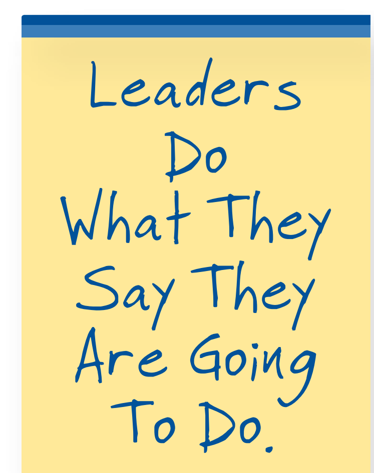

Figure 7: What reaction would this banner create?

University of Stellenbosch (South Africa) Professor P.J. Vlok added, *"Integrity in reliability is somewhat like oxygen – you do not really have to think about it until you do not have it."*

Author and reliability leader Winston Ledet commented, *"Thank you for the understanding of integrity. John Bennett (author of "The Dramatic Universe") says that 'understanding is the course of freedom and the molecule of will.'"*

Friend and reliability expert Henry Ellmann added a new depth by asking us to consider that, "the relationship between integrity and safety may add an additional dimension to this discussion."

In a lecture on the topic of integrity, Werner Erhard, founder of Erhard Seminars Training, asked: *What would your life be like and what would your performance be if the following were true:*

1. *You have done what you said you would do and you did it on time?*
2. *You have done what you know to do, you did it the way it is meant to be done and you did it on time?*
3. *You have done what others would expect you to do, even if you never said you would do it, and you did it on time, including meeting all relevant ethical, moral and legal standards, or you have informed all others that you will not meet those expectations and standards?*

4. *You have informed others of your expectations for them and have made explicit requests to those others?*
5. *Your being, actions and words are consistent with what you say you stand for, who you hold yourself out to be for others and who you hold yourself out to be for yourself?*

What kind of a world would we have if everyone functioned with that level of integrity? Now imagine what kind of organization you would have if everyone in the organization functioned with that level of integrity. Now imagine how you would perform if you lived in that level of integrity.

The people who deliver results want to be empowered and engaged. They want to work in an environment of integrity. If you accept that things of integrity are, by their nature, whole and complete, and that whole and complete things have better performance potential, it is likely that your organization could benefit from creating a high integrity environment.

INTEGRITY HOW-TO:

1. Integrity begins with you – make a declaration to live a life of integrity.
2. Give your word only when you have an intention and ability to keep it.
3. Recognize and acknowledge all instances when you do not keep your word.
4. Honor your word by cleaning up the mess you made by not keeping your word.
5. Clean up the mess you made at the earliest possible opportunity and earn your integrity back.
6. Repeat.

KEY PERFORMANCE INDICATORS FOR INTEGRITY

1. Percentage of time life works (increases up to 100 percent).
2. Percentage of time your performance and abilities improve (increases up to 100 percent).
3. Number of times you did not keep your word (reduces – approaching zero*).

*If you achieve zero, it may indicate that you are playing it too safe and not living life as "big" as you could be. It is okay to take risks and reach for extremely high goals.

Please consider this question as you reach the final words of this article: What are you committed to producing for yourself and your organization today?

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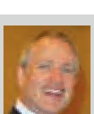
This paper was influenced by Kelly, Erin and Ian O'Hanlon, Ramesh Gulati, Bart Jones, Ron Moore, Terry Wireman, Cliff Williams, Bill Partipilo, Jenny Brunson, Jeff Smith, Derek Burley, Henry Ellmann, Grahame Fogel, P.J. Vlok, Werner Erhard and Dave Logan.



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Retrofit Monitoring with BIG Payoff Results

Jim Cerda and Greg Lee

AES Southland provides power to Southern California from a multitude of power resources. In 1998, AES Southland acquired the Alamitos natural gas power plant from Southern California Edison. Since that time, AES has undertaken a number of programs to modernize the generating station and improve the reliability of the Alamitos facility.

Figure 1: Monitoring system

In 2010, AES Alamitos' Units 3 & 4 boiler circulating pumps and Units 5 & 6 exciters were identified as having reliability issues. These machines were never equipped with vibration probes and only the metal temperatures of the exciter pedestal bearing and common lube oil drains were monitored by the control room recorders. Due to low cost of implementation and software compatibility, it was decided to purchase and install a monitoring system (see Figure 1) to improve the reliability of the AES Alamitos Units 3 & 4 boiler circulating pumps (see Figure 2) and the Units 5 & 6 exciters.

Figure 2: Boiler circulating pump

THE RUPTURE WOULD GROUND THE MOTOR, CAUSING A CATASTROPHIC MOTOR FAILURE - THE REPAIRS WOULD TAKE UP TO NINE WEEKS AT A COST OF OVER $150,000 PER PUMP/MOTOR

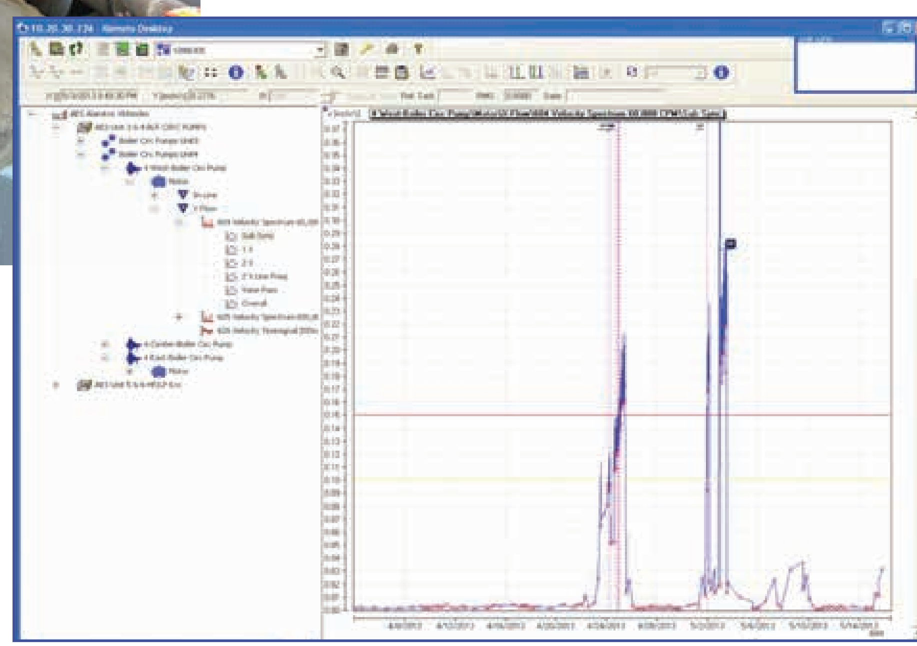


Table 1

BOILER CIRCULATING PUMPS

The vertical boiler circulating pumps have a carbon coated bearing and seal that are cooled and lubricated with water. As the seal fails due to normal wear, it allows hot boiler water to enter the pump bearing, in turn causing it to fail (see Figure 3). The failure mode causes the pump's upper bearing to have a subsynchronous vibration (see Table 1). In the past, the seal failure (see Figure 4) would go undetected until the motor's liner, which separates the windings from the pump, ruptured. The rupture would ground the motor, causing a catastrophic motor failure. The repairs would take up to nine weeks at a cost of over $150,000 per pump/motor. With the new monitoring system, they can now detect an impending bearing seal failure at its earliest symptoms and shut down the pump/motor before it ruptures the Inconel liner. The pump can then be removed and the seal and bearing repaired in less than three weeks for a total cost of $30,000, a savings of about $120,000 per pump.

Figure 3: Bearing melted carbon coating

Figure 4: Pump impeller seal/bearing wear area

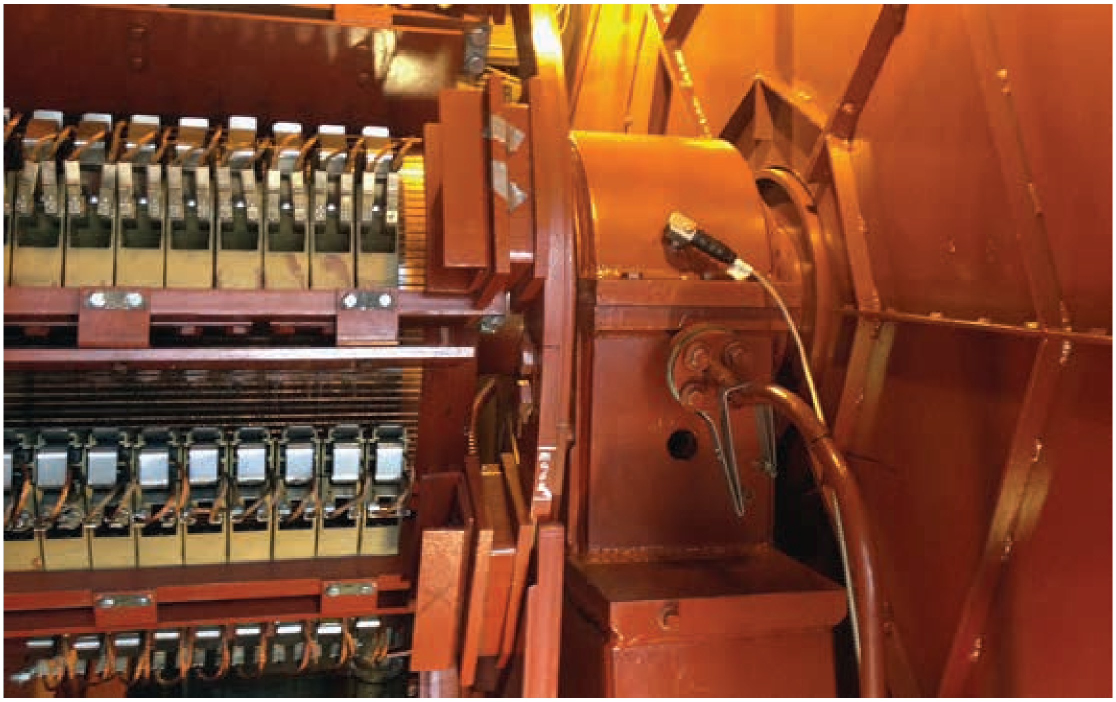


Figure 5: Exciter bearing accelerometer

RECENT CATASTROPHIC FAILURES OF THESE UNITS CAUSED MAJOR OUTAGES WITH THE RESULTING REPAIRS AND LOSS OF UNIT AVAILABILITY COSTING OVER $1 MILLION

HP & LP EXCITERS

The Units 5 & 6 HP and LP exciters (see Figure 5) are directly coupled to the turbine/generators with a reduction gearbox using a ratio of 5 to 1 and 2 to 1, respectively. These exciters were not equipped with a monitoring system other than lube oil temperatures wired to recorders in the control room. Some of the reduction gearbox bearings are not accessible with the data collector due to the placement of the exciter housing. Recent catastrophic failures of these units caused major outages with the resulting repairs and loss of unit availability costing over $1 million. With the success of the monitoring system on the boiler circulating pumps, it was decided to place one system (see Figure 6) on each exciter and gearbox. Both the vibration and temperature are monitored with dual mode accelerometers. A new problem was first identified when starting up the new monitors. The vibration was instantly in alarm with the captured spectrum, indicating mechanical looseness on the exciters. During the next outage, the exciter base bolts were checked and found to be loose, saving the company another costly outage and repair.

Figure 6: Monitor being wired

DATA PATH TO ROSEMOUNT CMMS AND PI HISTORIAN:

The monitors use an Ethernet connection and IP address to communicate with the software. The software is used to define the measurements taken for each input channel and create frequency bands that trend the vibration of critical frequencies representing machine faults. For example, on the boiler circulating pumps, a subsynchronous band is monitored. The subsynchronous band usually trends with low amplitude until the pump seal begins to fail. Any of the bands monitored along with their alarms are automatically assigned a Modbus address in the monitor. Using the Modbus TCP protocol, this data can be accessed through the same Ethernet connector that is used by the software to communicate with the monitor. In our case at AES, we use a server to retrieve the band data via Modbus TCP from the monitor on the different units. The band and alarm data is then moved to an OPS server where the Rosemount CMMS and PI Historian (see Figure 7) systems pick up the data for archiving and analog display in the control room. This provides us with a clean and efficient method of getting data from the monitor to the plant control environment.

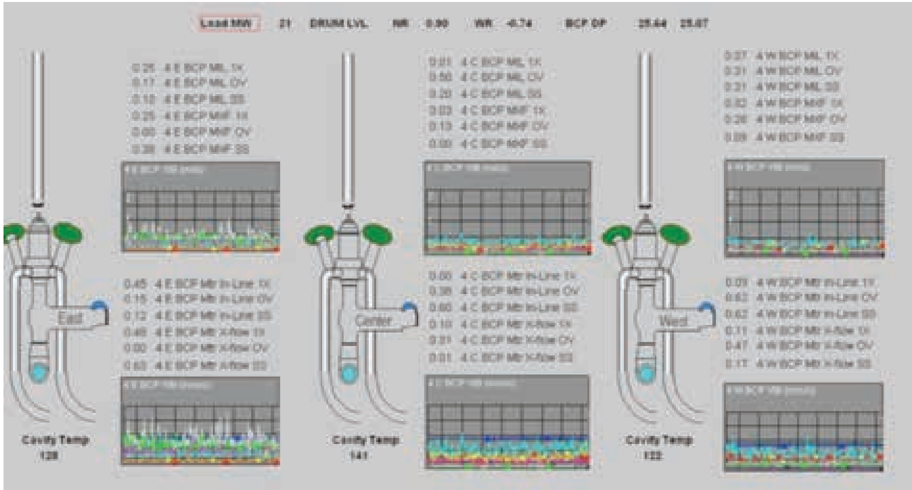


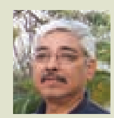
Figure 7: PI Historian – Unit 4 boiler circulating pumps in operation

A BRIEF SUMMARY OF THE MONITORING SYSTEM

We are using Ludeca supplied Pruftechnik VIBNODEs with Omnitrend software for the online monitoring system. Our software serves as the platform for our portable data collection program, as well as our online vibration monitoring systems. The monitoring systems are connected to the Alamitos LAN system via the plant's Ethernet. The software can display trends, spectrums, and overall frequency band specific alarms. The Units 5 & 6 exciters' vibration probes also have temperature outputs. As previously mentioned, the band amplitudes and associated alarms are displayed on the Rosemount CMMS or PI Historian screens. Monitoring software can be installed and viewed on any plant computer by users with appropriate access rights.

CONCLUSION

To date, AES Southland has successfully saved six boiler circulating pumps at Units 3 & 4, generating savings of over $100,000 each. In addition, it has identified two serious vibration problems on Units 5 & 6 exciters with preventive savings in the millions of dollars for each event. AES estimates a potential overall savings since 2010 of about $2.6 million on a capital outlay of under $75,000.00. Not a bad return on investment!



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Greg Lee is a Senior Application Engineer at LUDECA, Inc. Since the 1980s, he has worked in the field of vibration and field balancing, running programs for IRD, SKF, Prüftechnik and LUDECA. His activities have included product development for hand-held and online hardware and software. www.ludeca.com

Project group from left, Jacob Smith, Damarco Chapman, Andy Inman, Tyree Harper and Kendell Brinson

Reliability Awareness

through a Toyota Sponsored Mentorship

IMC 2013 Presenter

Andrew Inman

Maintenance reliability careers are not well known these days among today's youth. It became most evident to me at IMC 2012 last December when Terrence O'Hanlon was giving some inspirational words about the number of young maintenance professionals being too few. He narrowed the room of approximately 1,000 people in the maintenance reliability profession incrementally by age, decreasing every tenth year starting at 50. By the time he got to age 30 and below, only three or four people, including myself, were standing, additionally proving his point.

THE SCHOOL

At the time of the conference, I had already been involved in a capstone project mentorship program for high school seniors at Woodward Career Technical High School in Cincinnati, Ohio, through my position at Toyota. This high school is part of Cincinnati's public school system and is predominantly African-American in population. To give you an idea of the area, from January to August 2013, there have been two separate gun violence incidents in the area involving two different Woodward high school students as victims; one of whom was killed.

The program I was given the opportunity to be part of is called Advanced Technology in Manufacturing. The high school has two other programs, Building Technology and Health Technology, that allow students to have a choice in selecting a major.

In each program, students can become certified in career readiness in these particular areas. According to the teacher, Mr. David Hapner, the advanced technology program uses the ACT National Career Readiness

Certificate by requiring students to take three assessments in applied mathematics, locating information and reading for information. Once certified, this gives the students a way to promote themselves to potential employers immediately out of high school.

THE PROJECT

The Advanced Technology in Manufacturing program requires a capstone project where students work in groups with a locally assigned sponsor company. In addition to my company, there were six other companies from Cincinnati working with students in this program. The students become familiar with a process within the company and help solve a problem given to them from that process. At the end of the semester, they are required to present information about the company, the process they witnessed, what the problem was and how they solved it.

I was asked to present to four students working as a group with a manufacturing process and a problem with that process. Before presenting them with the process and problem, knowing that they would not know any proactive maintenance processes like reliability centered maintenance (RCM) or failure mode effects analysis (FMEA), I taught them about what I do.

WHAT TO TEACH?

Before actually meeting the students I was to work with, I had to come up with some sort of way to teach them about what maintenance reliability is and how to use reliability processes as a structured way to solve problems. I knew I could never teach them the same way I was taught maintenance reliability because when I began learning, I already had five years of experience in the industry. I had to bring myself to their level.

I asked myself, "What things made sense to me when I was about to graduate high school?" I knew I liked money when I was a teenager. I also knew I liked the freedom of being able to drive my car where I wanted to go. These two thoughts were exactly what I based my summary of reliability on. Toyota makes cars and sells them for money. Toyota can't have the freedom to make cars without a means…the machine.

YOU JUST GOT TAUGHT!

I created an A3 (11x17 for you non-Toyota folks) with all the information they needed to know about reliability and taught one-on-one right off that sheet without a presentation. They didn't need to take notes because they had it all on one sheet.

First off, they needed to know some definitions and acronyms, otherwise they would be lost as soon as I got to MTBF and MTTR.

DEFINITIONS

Down Time: Time that the machine is NOT running.

Failure: Any event that causes the machine not to work the way we want it to work.

Maintenance: Tasks that we do to a machine that ensure the machine continues to work the way we want it to work.

MTBF: Mean Time Between Failure - The average time between failures.

MTTR: Mean Time To Repair - The average time it takes to fix the machine.

RCM: Reliability Centered Maintenance - The process of answering the seven questions that develop the maintenance tasks that ensure the machine continues to do what we want it to do.

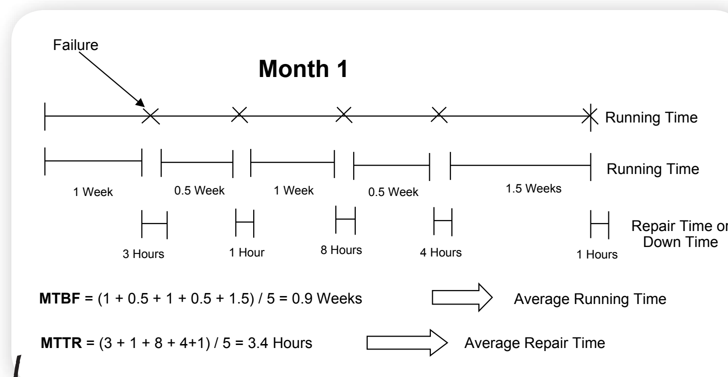
Running Time: Time that the machine IS running.

Figure 1: A3 definitions

Next, I explained to them how I have to report on key performance indicators (KPIs) of MTBF and MTTR. They needed to know, in all simplicity, what that means. I remember learning terms and acronyms when I first did my co-op and thinking about how complicated everything was when, in actuality, it was very simple.

LONGER MTBF and SHORTER MTTR Equal MORE Running Time – This is a typical heading to describe the goals of uptime, but to make the main goal as simple as possible for my students, the major heading in my A3 is: MORE Running Time Equals MORE Cars Built $$$. This also shows the students where this type of role stands within the company and why it's important.

Then, they learned the improvement process. The process I showed them was a very simple version of reliability centered maintenance. Without getting into risk management or the 80/20 rule, I basically had to explain to them that when a machine is failing so frequently that you inhibit your main goal, you have to improve it. RCM is one structured way of improving a machine to enhance your main goal of producing cars.



RCM 7 QUESTIONS

1. What are the functions of the equipment?

2. How does it fail?

3. What causes it to fail?

4. What happens when it fails?

5. Does it matter if it fails?

6. What can be done to predict or prevent each failure?

7. What if the failure cannot be prevented?

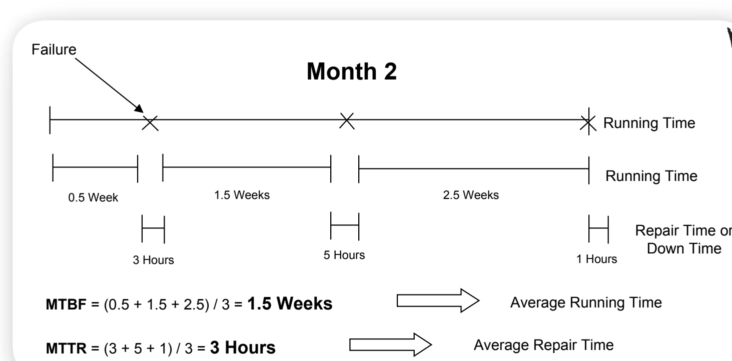


Figure 2: RCM as a maintenance improvement process

When improving a machine or process, you have to show the problem. In this case, a short MTBF and long MTTR is the problem. Once the improvement is complete, then you must show how the improvement enhanced your main goal. Figure 2 shows simply that by using an improvement process like RCM, you can improve your main goal.

The students at this point were just listening to me ramble on. My next point is where I related this process to something that made sense to them -- the fact that they each liked or wanted the freedom to drive wherever they wanted to go. Figure 3 shows the actual thought process of the students when looking at their car as a machine whose function needed to be maintained. They answered the seven questions of RCM.

They were also given information on tools they might be able to use to predict a future failure. They can use tools, such as infrared thermography, oil analysis and vibration analysis, to countermeasure their failure modes. One day in class, I let them operate an infrared camera, which turned out to be very exciting for them.

THE PROCESS

Once I taught them some basic concepts of reliability improvement, I showed them a process in the assembly shop at Toyota's Georgetown, Kentucky, plant. It was a simple process of filling the vehicle on the assembly line with coolant. They were to take what they saw from the process and use what was taught previously to improve the machine's reliability or MTBF/MTTR (given that this machine needed the improvement). They performed their own RCM analysis with just a few questions that needed to be asked of me, but for the most part, they did it on their own.

RCM 7 ANSWERS

1. **Get from Point A to Point B**
2. **Unable to get from Point A to Point B**
3. **Flat tire - Due to thin tread**
4. **Car shakes - Thumping noise - Pull over and inspect wheels. Two hours to replace tire.**
5. **Yes, continued running with a flat tire will cause further damage to the car.**
6. **Check tire tread depth before driving. If tread is less than 5mm, schedule tire replacement.**
7. **It can be prevented. Do the above task.**

Figure 3: Actual student thought process using the RCM 7 questions on a car

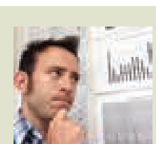
THE PRESENTATION

On presentation night, they had a poster board, with each student taking a section and speaking about it. They also borrowed the infrared camera connected to a screen and a video of the process as props to enhance their presentation. The students did very well and presented the entire project as experts. Everyone (parents, teachers and the principal) was very impressed with how well they put it together.

As I was walking around looking at other presentation boards, a woman came up to me and asked if I was the one who worked with the students at the table with the colorful camera. She looked very serious as if she was about to tear my head off for doing something wrong. I hesitantly answered, 'Yes.' I did not expect her to tell me how thankful she was that I made an effort to work with her son and getting him excited to go to college.

Figure 4: Student's presentation table

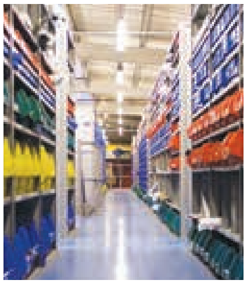
Hearing that I helped her son get excited about college was probably the most rewarding moment of this activity. I really encourage readers to get involved with a program like this. It is rewarding to not only get someone excited about a career in maintenance or engineering, but to get them excited about something. If not maintenance and engineering, at least they were educated on opportunities they might not have otherwise known about. This program made a big impact on these students. For the sake of maintenance and engineering, I can now say we can count four more young people who found the field exciting.



Andrew Inman has been with Toyota for almost nine years, including three years of co-op. He graduated from the University of Cincinnati with a bachelor's degree in mechanical engineering. While at Toyota, he has specialized in Reliability and Maintenance.

Work Execution Management

Mro mro-spares management



The Role of Critical Spares Analysis in Validating Spare Parts Recommendations

Chris Endrai

One Monday morning, I arrived at the daily production meeting and joined a tense discussion about the three-stage, recycle compressor that had failed over the weekend. It had been a fairly reliable machine, but it was going to result in a lot of downtime while we repaired it. Being a world-scale polymer production facility, this translated to a couple of million dollars of lost economic opportunity. It was going to be a long week, but at least we had all the parts.

The day went from bad to worse an hour later when the mechanical foreman reported that several key parts weren't on the shelf in the storeroom. The damaged ones were beyond repair and the original equipment manufacturer (OEM) was quoting eight weeks on expedited delivery. Best case was a local machine shop offering to reverse engineer and manufacture the needed parts in two weeks. After the dust settled, one of the corrective action items I was assigned by the site leader was to investigate why the part wasn't on the shelf.

Management of spare parts usually generates a spirited discussion, especially when the critical ones aren't on the shelf when they're needed most. Sometimes the part has been consumed and not replaced, or perhaps it wasn't set up to be stocked in the first place. The latter could be because a strong reliability program is either not in place at the facility or it has not identified the need to have the spare part on the shelf. I've even found that a part I set up on the shelf was not there because someone deleted it from inventory.

Management of spare parts usually generates a spirited discussion, especially when the critical ones aren't on the shelf when they're needed most

All of these situations are frustrating and illustrate the need for a robust and well-designed spare parts management process. This begins with an asset criticality analysis and a failure mode and effects analysis (FMEA) that identify the critical assets and the parts you are going to set up in maintenance, repair and overhaul (MRO) stores. Other elements of spare parts management include a process for issuing and reordering parts, and an approval step for adding/deleting stock items. During the process of approval of spare parts recommendations for critical assets, one of the tasks performed is a critical spares analysis (CSA). Since these are usually also very expensive parts, a more in-depth economic evaluation is necessary. But first, let's understand FMEA a little better so we understand the inputs to the CSA.

When your company starts the journey from reactive and urgency-based maintenance to reliability excellence, your decisions on what spare parts to keep on the shelf will no longer be arbitrary. Instead, the decisions will be guided by a risk-based strategy. Best-in-class plants usually start with a failure mode and effects analysis to identify and make recommendations to mitigate risks to production, maintenance costs, and environmental, health, and safety (EH&S) incidents. As each of these risks is analyzed, it is assigned a risk ranking or risk priority number (RPN). This risk assignment is based on the consequences (or severity) of the failure and the likelihood (or probability) that it will happen. A scale or matrix with 1-5, 1-10, or some other relative index, is often used to associate these risks with dollars, pounds of production, etc. The calibration of this scale or matrix is usually approved ahead of time by site leadership or corporate engineering.

Spare parts is a common recommendation from a FMEA to mitigate risks. Other well-known categories of recommendation include preventive maintenance, predictive maintenance or condition monitoring, calibrations, equipment redesigns, changes or additions to operations standard operating procedures (SOPs), or formal defect elimination studies.

As mentioned earlier, a best-in-class MRO stores management program will include a process for additions, as well as approvals to do so. This is facilitated by a stock request form. While many of the tasks associated with setting up MRO stores inventory, such as price, delivery, vendor source, etc., will be done by materials management and procurement, the reliability engineer should provide technical input for the justification to stock the part. Spare parts for critical assets are usually the most expensive ones, so the need for (risk of not having) the part must be compared to the actual usage and costs of stocking this spare part. More importantly, this justification needs to be calculated in actual dollars and cents rather than a subjective assessment that "it's important." MRO inventory costs can quickly get out of control if this is not done consistently. This alone could put you at a competitive disadvantage if your plant operates in a market where profit margins are small. This process is what we referred to earlier as the critical spares analysis.

One key piece of data the reliability engineer usually provides for the CSA is the risk ranking from the FMEA that was discussed earlier. This credible piece of information should surely provide the clout needed to justify keeping the spare part for a critical asset, right? When the CSA is done, the results may sometimes indicate that the cost to procure and carry the spare part in MRO stores inventory may exceed the justification for it. For example, we may be mitigating a production loss valued at $300,000, but the spare part may cost $300,000. I've oversimplified the analysis for this example, but the point is that we must decide how to reconcile this. Was the risk assessment in the FMEA erroneous? Would we really accept a $300,000 loss because the mitigation recommendation wasn't economically justified? These were just some of the questions I had when I first encountered this corrective action item.

There are a couple of answers. First, when we did the risk assessment in the FMEA, we may not have had hard data on the consumption rate of parts to verify our prediction of failure likelihood. More understandable, we may not have accurately known what that spare part was going to cost when we made that recommendation. And to some degree, when we're conducting a FMEA, we can subconsciously get in a mindset that any recommendation is better than no recommendation and cost sometimes gets forgotten. It's easy to say the FMEA team should have made better estimates or not relied on a single recommendation to mitigate a failure mode. But if you're doing a full-scale assessment of a world-scale facility, you may be doing hundreds of FMEAs on tens of thousands of assets and under pressure to complete them in a short time, not years. So it's not always practical to stop and gather all of that detailed information. This is acceptable at the moment because a CSA is a second-pass look at high-value spare parts on critical assets.

Depending on the criticality of the asset, the CSA process considers several possible avenues. Let's just say, for example, the CSA determines that you should not stock this item at your facility. One of the options is to consider a partnering arrangement with a supplier or vendor to keep the part on consignment in its inventory to avoid or reduce your inventory holding costs. This could be plausible if the vendor has many other customers who also use that part and, therefore, turnover rates justify keeping the part in its inventory. In any case, accounting and procurement should be included in this discussion to ensure best practices are followed with regards to inventory taxes and any regulations that may be involved.

However, if it's a unique item or one with a long manufacturing lead time, this isn't any more justifiable for the vendor. There may be no incentive for the vendor to assume the financial burden of carrying the part. In this case, the reliability engineer could revisit the FMEA. The intent of this is not to work backwards from the answer and fudge the risk rankings until the justification comes out in the FMEA's favor. Rather, a less expensive alternative recommendation might be found that could be implemented and still mitigate the failure mode adequately. Or an existing recommendation could be modified. Perhaps vibration monitoring or eddy-current testing frequency could be increased. An inexpensive redesign could be implemented, or an operations SOP could be revised that would reduce the likelihood of failure.

In conclusion, as you take control over spare parts management, implement risk-based asset strategies with spare parts recommendations and deliver fiscally responsible counter responses to critical spares analyses, you move around the roadblocks and arrive closer to your destination of reliability excellence.

Chris Endrai is a Reliability Engineering Subject Matter Expert with Life Cycle Engineering. He is based out of their Houston office and has over 20 years of direct, hands-on experience in petrochemical plant maintenance and reliability, including several world-class facilities that maintained 99%+ equipment availability. Chris holds a degree in mechanical engineering from Purdue University. www.lce.com

Are Your Engines NESHAP Compliant?

Karrie Williams

As part of an effort to reduce engine emissions, the U.S. Environmental Protection Agency (EPA) adopted new national emission standards for hazardous air pollutants (NESHAP) in 2010. The new regulations apply to existing stationary compression ignition (CI) and spark ignition (SI) reciprocating internal combustion engines at area and major sources of hazardous air pollutants (HAPs).

This regulation, known as RICE NESHAP, NESHAP Subpart ZZZZ, Quad-Z, or RICE MACT, will require sources to achieve emission limits reflecting the application of the maximum achievable control technology (MACT) consistent with Section 112(d) of the Clean Air Act.

Under RICE NESHAP, facilities with stationary engines are required to meet stringent emissions standards, verify compliance, perform maintenance activities and report their continued compliance to the EPA. The procedure for achieving compliance will require the implementation of new processes, methods and systems, each unique to the respective operator, operating conditions and locations. EPA set the following start dates for compliance with the national emission limits and operating limits:

- Non-Emergency Diesel (compression-ignition or CI) Engines by May 3, 2013.
- Non-Emergency Gas (spark-ignition or SI) Engines by Oct. 19, 2013.

With nearly 1.5 million stationary engines in the U.S. affected by this new ruling, there are lots of people searching for knowledge on the requirements. However, as with any federal regulations, the reading can be extensive, confusing and the process for achieving compliance quite intimidating.

SOME BACKGROUND ON THE RULE

On February 17, 2010, EPA finalized portions of the National Emission Standards for Hazardous Air Pollutants (NESHAP) for Reciprocating Internal Combustion Engines (RICE). The rule was promulgated into existing RICE standards located in 40 CFR Part 63, Subpart ZZZZ on March 3, 2010. The newly incorporated standards were originally proposed on February 25, 2009, and apply only to stationary RICE. The proposed standards included provisions for RICE located at area sources of hazardous air pollutants (HAPs) and RICE with a site rating of ≤ 500 brake horsepower (bhp) located at major sources of HAPs. In addition, the proposal included standards for existing non-emergency compression ignition (CI) engines with a site rating of > 500bhp at major sources and revised provisions related to startup, shutdown and malfunction (SSM) events for engines previously regulated under the rule.

Under these new regulations, many previously unregulated engines, including those designated for emergency use, are subject to federal regulation, including emission standards, control requirements, or management practices

Under the NESHAP, a major source is defined as a site that emits > 10 tons per year (tpy) of any single HAP or > 25 tpy of combined HAPs. An area source is a site that emits HAPs, but is not considered a major source. A list of pollutants considered to be HAPs can be found at epa.gov/ttn/atw/orig189.html.

Under these new regulations, many previously unregulated engines, including those designated for emergency use, are subject to federal regulation, including emission standards, control requirements, or management practices.

DO YOUR STATIONARY ENGINES FALL UNDER RICE NESHAP?

To determine if your engine(s) must comply with the new regulations, you need to know the following information:

- Horsepower of the engine(s).
- Annual hours of operation.
- Annual hours of operation for non-emergency purposes.
- Annual hours of operation for maintenance checks and readiness purposes.
- Date of engine manufacture.

Using this information, you can determine if your engine is classified as either an emergency or non-emergency engine, as well as its source group. The engines are distinguished as either a major source or area source of HAPs. A major source is an area that produces over 10 tons of carbon monoxide (CO) annually, while an area source is any engine not classified as a major source. Once you have this information, you need to identify specific requirements for your specific engine/application.

WHAT ROLE DOES OIL ANALYSIS PLAY?

Following public comment on the proposed rule, EPA made a number of significant changes to the promulgated rule, including adding an option to the management of implementing oil analysis to extend the oil change frequencies listed in the final rule.

For those engines that require periodic oil changes, the schedule for changing engine oil can be extended if the oil is part of an oil analysis program. However, the oil analysis must be performed at the same frequency as specified for oil changes.

The oil analysis program must include the following parameters in order to qualify: Total base number (diesel engines), total acid number (natural gas engines), viscosity and percent water content. If certain limits are met during the analysis, then the owner or operator is not required to change the oil. However, if any of the limits are exceeded, the oil must be changed within two business days. The limits are shown in Table 1.

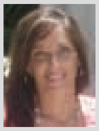
TABLE 1 - OIL ANALYSIS PROTOCOL

Parameter	Condemning Limits
Total Base Number (TBN) (CI RICE only)	<30% of the TBN of the oil when new
Total Acid Number (TAN) (SI RICE only)	Increases by more than 3.0 mg of potassium hydroxide per gram from TAN of the oil when new
Viscosity	Changed by more than 20% from the viscosity of the oil when new
% Water Content by Volume	>0.5

RECORD-KEEPING AND REPORTING REQUIREMENTS

The EPA and state environmental agencies have the authority to request compliance records for a period of up to five years, so owners/operators must validate that management practices have been implemented and be able to supply accurate substantiating records in a timely fashion should a request be made by a regulatory agency.

It is not possible to address all applicable aspects of RICE NESHAP or the nuanced compliance issues related to it. It is highly recommended that you review the regulations in detail and seek professional assistance if necessary. For more information or to view a copy of the final rule, go to epa.gov/ttn/oarpg/new.html.



Karrie Williams is the Marketing Director for TestOil headquartered in Cleveland, Ohio. In addition to overseeing the company's marketing initiatives, she has written several educational papers and recently co-authored the book, Oil Analysis for Dummies, which was developed to help readers better understand oil analysis and lubrication fundamentals. www.testoil.com

3D Scanning:
Moving Beyond Movies to a Factory Near You!

Alan France

3D scanning is used extensively for industrial design and in the production of movies and video games, but does it have value for use in a factory?

In the ideal world, every factory would have accurate, fully dimensioned, 2D/3D drawings of every part of the facility so new plant modifications can be easily designed. While this would be in place for new plants, in reality the first step in plant remodeling to meet demands for new products is often a time-consuming measurement and drawing process.

For complex plants, this takes too long and it can be difficult to attain high levels of accuracy. This lack of visibility often means that initial discussions of new layouts at a senior level are delayed or made worse by relying on inaccurate layouts.

HOW DOES 3D SCANNING WORK?

The most common scanners for this purpose are tripod based with a rotating scanner and camera, with the camera there to color the scan points. The laser scanner uses phase shift to measure the distance between points from the scanner location. At each position, the scanner captures hundreds of thousands of measurement points per second in a full 360 degree data capture, creating a complete sphere pattern of dot positions. As equipment within the room obscures the scanning process, multiple scans from different positions are required to obtain information from all sides of the area's contents.

Once multiple scans for a single area are complete, post-processing stitches together millions of data elements into a "point cloud." The process is then repeated for other factory areas with post-processing joining individual point clouds together to create a "project point cloud" of the entire site.

THE OUTCOME

The results of the process permits a 3D "walk through" of the "as installed" plant to a measured accuracy of up to 2mm, with the ability to dimension and add annotations to any 3D element.

THE MOST COMMON SCANNERS FOR THIS PURPOSE ARE TRIPOD BASED WITH A ROTATING SCANNER

LISTED
NO. MH47936

That means plant remodeling is based on accurate data making the design process much quicker. It also means that reverse engineering of assets and components is possible. While 3D computer-aided design (CAD) users are likely to have powerful workstations to access files, standard users are supported by a secure web application that allows unlimited views within the organization from standard desktop personal computers.

The accuracy is so good that at a recent exhibition, many visitors thought the 3D scanned images were videos until they were shown how to "walk-through" and measure elements.

3D scan to CAD is 12 times faster than manual measurement.

TYPICAL APPLICATIONS

Although 3D scanning for video games and the entertainment industry may be exotic, there are many uses that could be considered for factory use.

Import to 3D CAD: This is probably the most obvious requirement for project engineering and maintenance teams. The 3D scan to CAD process is 12 times faster compared to manual measurement with much higher accuracy rates. The point clouds are imported into software that sections the point cloud and uses the points to create a geometric configuration, a bit like tracing in 3D. The days of tape measure, paper and camera to create CAD layouts must surely be coming to an end. The three-step process of 3D scan – point cloud – to 3D CAD means that by step two, the 3D walk-through and ability to dimension and annotate is available within a few hours. That means benefits are gained while work continues on the final step, the import to 3D CAD for further design work. Although import to CAD is important, it is estimated that as much as 60 percent of the benefit for the factory team could be gained once the point cloud has been created in step two.

ALTHOUGH 3D SCANNING FOR VIDEO GAMES AND THE ENTERTAINMENT INDUSTRY MAY BE EXOTIC, THERE ARE MANY USES THAT COULD BE CONSIDERED FOR FACTORY USE

Supplier Review: Want a potential supplier to quote for plant modifications, but don't want him or her to see the full site? Don't have time for the supplier to arrange a site visit? Give the supplier secure web access to a restricted part of the plant from his or her own location. The ability to walk-through and dimension allows both parties to view simultaneously and compare ideas and thoughts online. This allows more potential suppliers to be involved and reduces project quotation time.

Reverse Engineering: Have failed asset components from obsolete equipment, or missing CAD files from an old project? Use 3D scanning to quickly digitize a part and create a fully surfaced CAD model that can be then used to reproduce a local copy. There is no effective limit in terms of size, with larger and more complicated items just needing more scans.

Plant Reviews: The regional management team wants to quickly review plant layouts. Of course, a Gemba (or Genba) visit to the manufacturing floor is better, but for an initial check or quick safety review, a 3D walk-through will be quicker and much more realistic. The ability to dimension also means that initial assessments can be made to see if the new kit could possibly fit in that position.

Asset Register: Creating an asset register from scratch takes a long time and it's not unusual for the process to take months. While a 3D scan won't identify the plant nameplates or serial numbers, it's a great start and will speed up the equipment identification process. Database links can be made in both directions with the 3D scan point cloud able to load an asset register and the asset register, in turn, able to load the 3D scan point. The is no reason why the process cannot be part of maintenance checks with the inspection content linked to, and taking the engineering to, a precise location in the 3D scan point cloud for a physical review.

Incident Investigation: One final application you may hope not to use is forensic crash investigation, which allows data to be recorded for office-based analysis and supports vehicle deformation comparisons against standard measurements. Could those techniques be used for industrial incidents? Almost certainly.

Being able to walk-through an accurate 3D layout increases plant visibility significantly. It's as close as you can get to actually being there in the room. 3D scanning is here to stay with more uses being identified daily. Try it out and you'll wonder how you managed without it.

Alan France, OEE Business Manager of Olympus Automation, has extensive experience in lean manufacturing with a background that includes several years as Engineering Systems Manager for the largest food company in Europe. www.olympus-automation.co.uk

Capturing Ultrasound Time Waveforms

Pictures vs. Numbers

IMC 2013 Presenter
Jim Hall and Randy Stiver

The ability to look at the audio signal adds a wealth of information about the original ultrasonic signal and can be summarized as "pictures" versus "numbers." The waveform reveals the instantaneous value of the signal. The wave shape reveals signal strength, transient impacts, frequency of cyclic phenomena, beats and harmonic content.

WHY CAPTURE WAVEFORMS?

1. Signals too small for dB reading
2. Slow speed bearings
3. Training
4. Human factor – we all hear differently
5. Critical equipment history/baseline/fault analysis

Sometimes, more than just a number is needed. Time waveform capture and PC software offer the ability to look at the captured waveforms and apply signal processing effects to them. Effects applied to the time displacement waveform ranges from rate of change for velocity and acceleration to fast Fourier transforms (FFTs) and spectrograms for frequency analysis.

Recording the sounds to play back the audio later allows sharing of information with others for training and further analysis. Some industrial plants require double hearing protection that makes on-site listening difficult. But audio signal recording is not affected by the noise and allows listening and analysis later in the office. The amplitude of some ultrasonic signals, such as slow speed bearings, can be too small for a stable dB reading, but can be heard, recorded, amplified and analyzed.

The one drawback (sometimes major benefit) to PC audio software is you have to go back to the office for listening and analysis.

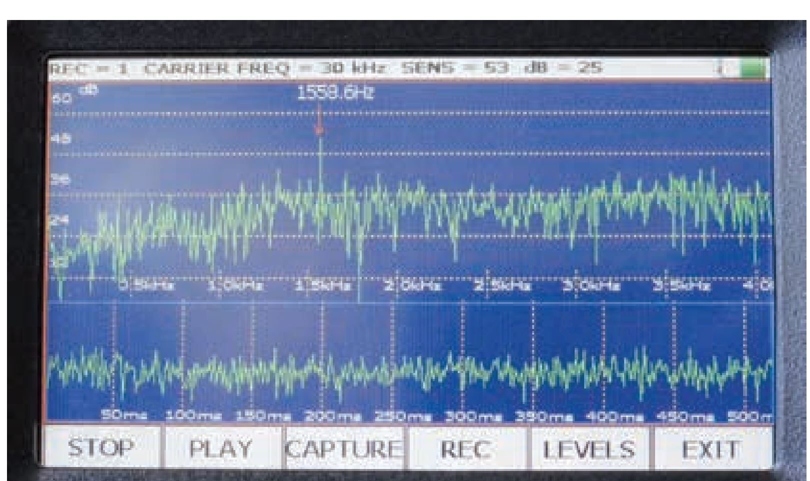


Figure 1: UE Systems 15,000 displaying time waveform and FFT

AUDIO CAPTURE DEVICES

Today, some of the top-of-the-line ultrasonic devices have onboard recording and display capabilities.

There are also third party add-ons for capturing the time waveform for audio playback, visual display and signal processing. These choices include: digital voice recorders, oscilloscopes, vibration spectrum analyzers, and PC-sound-card-software combinations. There are pros and cons to each hardware and software combination.

BUILT-IN RECORDING CAPABILITIES

Some manufacturers of ultrasonic detectors include the capability for on-site time waveform display and recording of the output audio signal with the capability of processing the time waveform to the frequency domain. Other equipment makers' devices can capture the waveform internally, but must be taken back to the office PC for viewing and software manipulation.

EXTERNAL RECORDING DEVICES

For companies that cannot afford the latest equipment or who already have existing ultrasonic detectors, there are several external devices that can plug in to the headphone output jack to display and capture the audio signal for analysis. There are advantages and disadvantages to each method, such as whether the waveform can be viewed on-site or taken back to the office, whether the captured audio can be replayed and emailed, and whether the maximum recording time length is measured in seconds or hours.

The four devices commonly used to record the audio headphone output are: vibration spectrum analyzers, oscilloscopes, digital voice recorders and PC-soundcard-software.

THE AMPLITUDE OF SOME ULTRASONIC SIGNALS, SUCH AS SLOW SPEED BEARINGS, CAN BE TOO SMALL FOR A STABLE dB READING, BUT CAN BE HEARD, RECORDED, AMPLIFIED AND ANALYZED

VIBRATION SPECTRUM ANALYZER

Most maintenance departments performing ultrasound scans already have vibration spectrum analyzers (VSAs) in their possession. The analyzer can be connected to the ultrasonic detector output to display the time waveform and convert that to a spectrum in the frequency domain. Spectrums present a complex sound waveform in terms of its component frequencies. The sensor input settings of the VSA are important. The VSA normally supplies power to accelerometers. This power must be disabled (turned off) when connecting to an ultrasonic detector.

OSCILLOSCOPE

An oscilloscope is an instrument for viewing a graphical representation of how a signal's amplitude changes over time. The waveform is graphed on an X versus Y axis. The horizontal X-axis represents time. The vertical Y-axis represents voltage. The graph illustrates how the signal changes over time. There are adjustments for the scaling of both axes and triggering of the waveform. Today's handheld portable oscilloscopes offer an affordable and easy alternative for viewing the time waveform on-site for analysis.

DIGITAL VOICE RECORDER

What's beneficial about using a digital voice recorder is the long recording times possible (hours), the ability to play back the audio for others and the ability to dictate notes directly into the audio recording. A few of the most important settings for repeatability are the microphone setting (e.g., low or high), sampling rates, and audio recording format (e.g., wav, mp3, wma).

PC - SOUND CARD - SOFTWARE

A PC and a sound card can be used with audio recording software to capture the ultrasonic detector headphone output. The PC recording volume input slider makes repeatable amplitude mea-

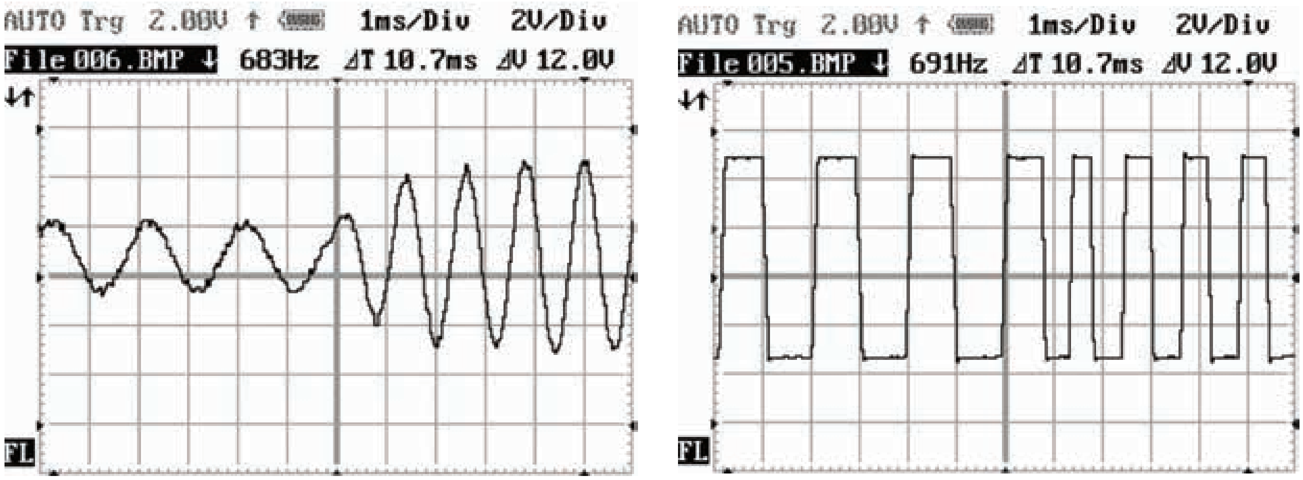


Figure 2: The display to the left shows the two sine waves of a tone ultrasonic generator. The display to the right shows clipping because the amplification of the ultrasonic detector is set too high.

surements difficult. We use precise voltage dividers to interface between the detector output and the PC input and then set the recording volume slider to maximum. Environmental concerns must be addressed when using a PC in the plant and must be weighed against benefits, such as audio playback and nearly unlimited recording times.

INTERCONNECTING CABLES

Four areas must be addressed in the connection and setup of external equipment. They are: cabling and interconnecting hardware, voltage levels, equipment settings and calibration/testing.

Custom-built cables are often required to interconnect the ultrasonic detector output to the input of the various capture devices. Depending on the manufacturer of the ultrasonic equipment, you may need a 1/8-inch or 1/4-inch phono connector for the ultrasonic detector output. The input of the vibration spectrum analyzer may be a BNC connector. The input to digital voice recorders or PC-sound card-line in/microphone input are 1/8-inch connectors.

The maximum output voltage of the ultrasonic detector must not exceed and should be matched to the maximum input voltage of the recording device. For example, if the maximum output of the ultrasonic detector is 8 volts peak-to-peak (p-p) and the maximum input voltage of the VSA is 2 volts p-p, then a 4:1 voltage divider is needed and can be constructed with resistors. A digital voice recorder may need a 500:1 or a 1000:1 voltage divider.

If the signals are not matched, clipping of the signal can result or the signal may be too small to be usable. Both situations render any post processing results, such as FFTs, unreliable.

Ultrasonic equipment settings, such as sensitivity/amplification/volume control and frequency tuning, must be recorded for repeatable and comparable measurements.

An ultrasonic tone generator is an invaluable tool for testing and calibrating. We use an ultrasonic tone generator before and after any serious waveform recording to ensure all equipment is connected and working properly. The tone generator transmits alternating bursts of two different frequencies. The time waveform will display two repeatable sine waves and the frequency domain will show distinct lines.

COMPUTER SOFTWARE FOR ANALYSIS

Add-on PC software offers a wide range of prices and capabilities for analysis, from simple displays of the time waveform to applying sophisticated signal processing effects. These effects can include taking the first and second derivative of the time displacement waveform and converting to velocity and acceleration waveforms. Other effects include transformation to the frequency domain for spectrum plots and spectrograms. A spectrum plot takes the audio in blocks of samples, does the FFT and averages all the blocks together to produce one picture. A spectrogram shows how the amount of energy in the different frequency bands change over time and can be described as video versus a photo.

A SPECTRUM PLOT TAKES THE AUDIO IN BLOCKS OF SAMPLES, DOES THE FFT AND AVERAGES ALL THE BLOCKS TOGETHER TO PRODUCE ONE PICTURE

Documenting the various settings involved with time waveform recordings are required for proper analysis. You may want to document and build a library of waveform signatures and measurements for future reference and comparison purposes. Having a reference to compare can prove invaluable with future troubleshooting. Capture reference waveforms:

- Before and after installation.
- After changes or additions.
- After repairs or upgrades.

Remember, it all starts with assessing which equipment is worth the time and effort of capturing waveforms. One of the benefits of ultrasonic detectors is the simplicity of use. Sometimes, a number is all that's needed for comparison. But there are other times when a picture is worth a thousand words.

Jim Hall is the president of Ultra-Sound Technologies, a "Vendor-Neutral" company providing on-site predictive maintenance consultation and training. Jim has provided airborne ultrasound training for several Fortune 500 Companies. A 17 year civil service veteran, Jim served as an aerospace engineering technician. UST provides a two-day Ultrasound Time Waveform Capture class. ultra-soundtech.com

Randy Stiver is currently the Technical Director and one of the principals of ASTAR LLC. He has over 30 years experience maintaining, repairing, operating, and teaching computer controlled equipment. He also has over 19 years experience in Customer Service, Field Engineering, and Training and Education.

Applying Lean **Six Sigma** Principles to Lubrication

IMC 2013 The 28th International Maintenance Conference Presenter
Mark Barnes

In 2010, it was reported that as many as 43 percent of U.S. manufacturers were deploying some form of business improvement strategy centered around lean manufacturing principles, Six Sigma, or the original Toyota production system (TPS).

While the lines between these different strategies have been blurred over the past 10 to 15 years, at their core, they all focus on one fundamental tenet: Create efficiencies by improving business processes that eliminate waste. In this context, waste can mean anything from wasted time, wasted effort, or wasted raw materials.

Fundamental to waste elimination is the concept of 5S. Originally developed in Japan as a way for frontline workers to provide feedback on process improvements, the 5S concept was originally represented by five Japanese words, each starting with the letter 'S.' Today in North America, 5S is most often transliterated into five English words that have become the cornerstone of any lean-Six Sigma initiative. Those words are: Sort, Set in Order, Shine, Standardize and Sustain.

APPLYING 5S TO LUBRICATION

At its core, 5S is a methodology by which technology (engineering) and psychology (people) are optimized to achieve an efficient set of business processes. A business process is simply a set of steps, rules and practices required to complete any specific task. In this context, lubrication, like any other activity in a manufacturing plant, is just another process. It is the process of selecting, purchasing, storing, dispensing and applying the lubricant to the machine while maintaining (sustaining) the quality and cleanliness of the lubricant.

As such, 5S principles can and should be applied to the process of lubrication for maximum efficiency. So let's see how we can 5S our lubrication program, starting with *sort.*

LEAN SIX SIGMA - 5S

1. Sort
2. Set in Order
3. Shine
4. Standardize
5. Sustain

SORT

With respect to lubrication, sort has two phases. The first is to organize which lubricant needs to be used based on application and operating context. The goal is to minimize the number of lubricants in use without compromising equipment reliability or performance. For plants that have been through a 5S process, the number of lubricants used have been optimized with a concerted effort put in place to consolidate to a single lubricant supplier and, where applicable, to eliminate unnecessary types or grades of lubricant through technical consolidation. 5S plants typically have a database (spreadsheet) listing each asset and the lubricant to be used, with this information readily available and published, often as a poster or wall chart. It may seem obvious, but knowing which lubricant is used in which machine is fundamental to future success, but so few plants even get to first base!

The second phase of sort is to create organization in how lubricants are stored, handled and made available throughout the plant. 5S is a highly visual process; everything in place where everything has its place. Lubricant storage areas need to be organized and ergonomic, with clear visual workplace management tools, like color coding, charts, shadow boards etc., used to denote what the desired state should be. Designating an "owner" of the lube room and other designated lubricant storage areas is often an effective means of making sure standards don't slide over time and creating a sense of accountability while promoting pride in doing a good job.

SET IN ORDER

Central to the principles of 5S is efficiency. Requiring an operator or lube tech to walk several hundred yards or more to access the oil or grease they need is, at best, creating inefficiency in work processes and, at worst, encouraging lubricants to be stored behind the machine or for the wrong oil to be added since it's closer. Lubricants and the tools necessary to do the job right need to be at hand. This may require satellite lube lockers at point of use or portable lubrication carts that can be moved around as work is performed. Visual workplace management needs to extend to all designated remote storage, with the same 5S principles used in the lube room. Accountability is the key for remote storage, with weekly inspections and check sheets used to ensure standards remain consistent.

More often than not, errors, like adding the wrong oil or applying the wrong grease, happen by mistake. To minimize the likelihood of mistakes happening, a highly visual workplace is a fundamental part of any lubrication 5S process at all levels. The lube room, lube locker, tools, machine etc., all need to be tagged with a color and shape to designate which lubricant is in use. Tags should be placed at all critical control points where lubricants are transferred from one point to another or to the machine. Ideally, lube tags should not specifically state the manufacturer or brand lubricant in use. While this may seem counter to 5S principles, including the brand name lubricant will cause problems if you decide to switch suppliers in the future. With product brand names on lube tags, you're just one vendor change away from violating the last "S" in 5S – Sustain!

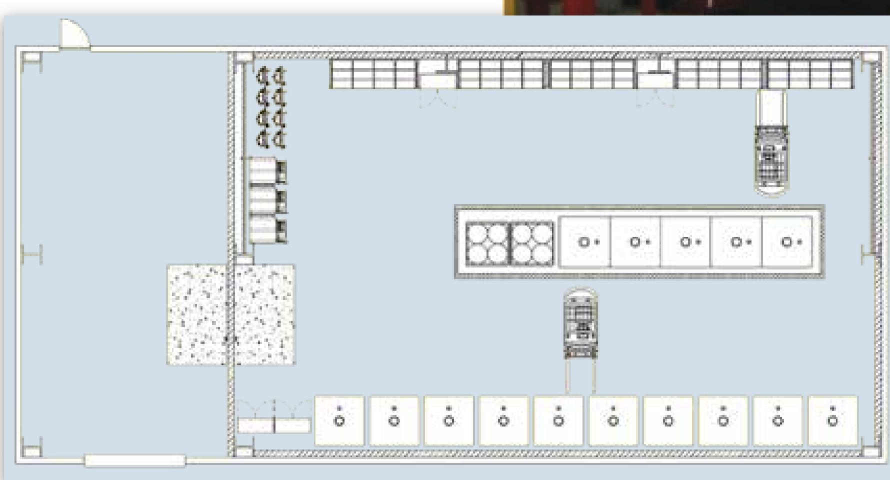


Figure 1: Lube storage areas need to promote ergonomic work flow while promoting best practices through visual work management (labels, color coding, shadow boards, etc.)

Finally, machines need to be configured to allow preferred practices to be deployed. Denoting that all new oils need to be pre-filtered before use without setting up the machine with quick connects or a proper breather defeats the purpose. Making the easy way the right way (transfer oil from the barrel using a portable filter cart and quick connects on the barrel and machine versus open the fill port and use a hand crank oil transfer pump) is a critical step towards making sure buy-in occurs at all levels.

SHINE

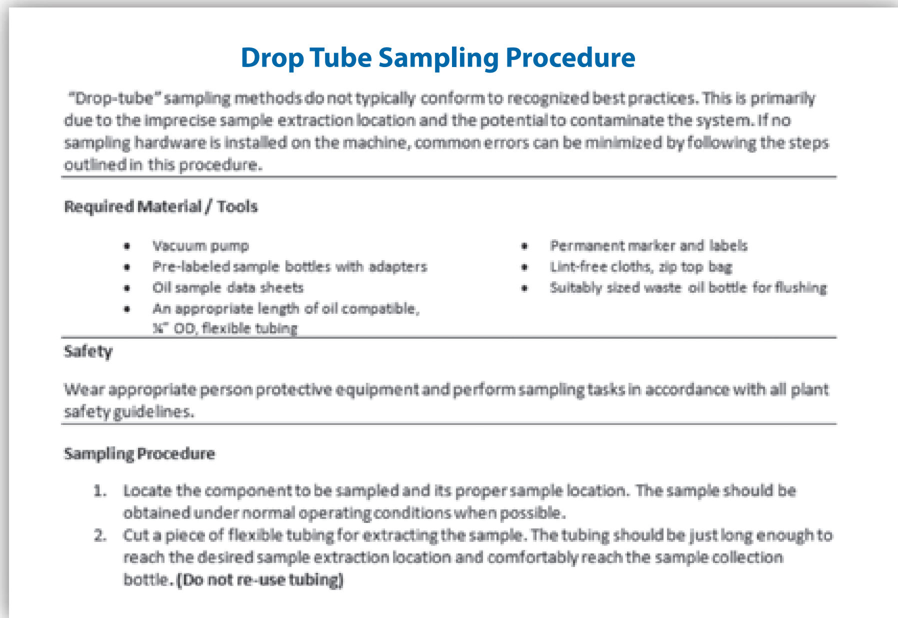
Cleaning and inspections are important in creating consistency and continuity. In addition to assigning responsibility to keep lube storage areas clean through weekly inspections, machines need to be kept clean, free from leakage and routinely inspected. Any leaks that are found should be noted and immediately put into the work management system for corrective action. Basic lubrication inspection should be included as a daily task. Oftentimes, operators can be trained to do these basic checks. Make inspections simple and easy to do and they get done. Allow opportunity for individuals to interpret what you want and shortcuts will happen. Lube inspections need to include simple, basic questions and binary answers (e.g., oil level: high or low?; desiccant breather: blue or pink?; filter differential pressure <20 psi: yes or no?).

More often than not, errors, like adding the wrong oil or applying the wrong grease, happen by mistake

STANDARDIZE

Having standard work procedures is a must for any maintenance team. I often get asked how a company can get 50 different mechanics, technicians and operators all functioning at the same level. The answer is standardization. Commercial aviation is by and large an efficient, safe business process that works because every task from pre-flight checks to refueling, baggage loading and flight plans is choreographed on checklists and standard operating procedures. If United Airlines can do it with hundreds of people all capable of influencing the success of flying from Chicago to Houston in a multi-million dollar machine flying at 37,000 feet, surely adopting a similar approach can work for us on the ground. While we may not need quite the same degree of rigor, a standard work process, checklist and documentation all feature heavily in successful 5S plants.

But it's not just about having documents that serve as preventive maintenance (PM); it's how the PM is written that counts. Having a PM worksheet that states "lubricate the motor" is not a standard operating procedure, it's a wish! The PM should include specific details, such as which lubricant to use, basic steps to ensure compliance with best



Drop Tube Sampling Procedure

"Drop-tube" sampling methods do not typically conform to recognized best practices. This is primarily due to the imprecise sample extraction location and the potential to contaminate the system. If no sampling hardware is installed on the machine, common errors can be minimized by following the steps outlined in this procedure.

Required Material / Tools

- Vacuum pump
- Pre-labeled sample bottles with adapters
- Oil sample data sheets
- An appropriate length of oil compatible, ¼" OD, flexible tubing
- Permanent marker and labels
- Lint-free cloths, zip top bag
- Suitably sized waste oil bottle for flushing

Safety

Wear appropriate person protective equipment and perform sampling tasks in accordance with all plant safety guidelines.

Sampling Procedure

1. Locate the component to be sampled and its proper sample location. The sample should be obtained under normal operating conditions when possible.
2. Cut a piece of flexible tubing for extracting the sample. The tubing should be just long enough to reach the desired sample extraction location and comfortably reach the sample collection bottle. **(Do not re-use tubing)**

Courtesy of Des-Case Corporation

Figure 2: PM procedure should include enough instruction to ensure the task is completed consistently each time

practices (e.g., clean the grease fitting, allow three to five seconds/shot, etc.), as well as task specific details, such as the quantity of grease in shots or ounces.

SUSTAIN

I visit a lot of plants each year in many different industries. But no matter the plant or industry, they all have something in common: basic metrics for safety ("we have worked 243 days without a lost time accident") or production ("OEE year-to-date = 94.7%"). Do we really need reminding to work safe and hit production quotas? The answer is an emphatic "yes!" Without standards by which we're measured and consistent reinforcement of those standards, it's inevitable that things will slip over time.

For lubrication, basic metrics like lubrication PM compliance (ratio of completed lube PM on time/total number due), compliance with contamination control targets (ratio of machines that meet our targets vs. the total number of machines), or compliance with lubricant health (number of machines "in the green" from oil analysis vs. the total number sampled) serve as the "scoreboard" by which lubrication success or failure can be measured. By tracking metrics and posting them conspicuously, the message is clear. We expect everyone to take seriously a set of performance standards around lubrication, with clear, actionable remedies if we're in noncompliance.

PUTTING IT ALL TOGETHER

Having taught literally hundreds of lubrication classes over the past 20 years, it always amazes me the number of companies that send good people to training classes expecting that simply sitting through three-days of lubrication training will turn the plant's performance around. While it's true having knowledgeable and committed people is key, it's only with a proper system in place built around solid 5S principles of sort, set in order, standardize, shine and sustain that we can maintain performance over the long haul. True competitive advantage comes when great people work in a great system. When that happens, great things occur!

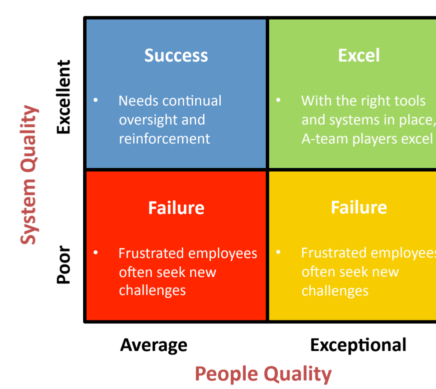
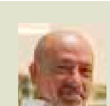


Figure 3: While having knowledgeable and committed people is important, true competitive advantage only occurs when exceptional people work within an exceptional system. 5S is the key to build the system.


Mark Barnes, CMRP, is Vice President of the Equipment Reliability Services team at Des-Case Corporation. Mark has been an active consultant and educator in the maintenance and reliability field for over 17 years. Mark holds a PhD in Analytical Chemistry. www.descase.com

Analysis of a Mechanical Seal Failure

Umeet Bhachu

Weibull analysis is an important statistical tool in the realm of reliability engineering. It helps in the modeling of increasing, decreasing and constant failure rates.

In maintenance organizations where time and cost of repair are crucial elements, it is of paramount importance for a reliability engineer to determine swiftly and accurately the failure modes and root causes underlying a particular issue to avoid further machinery breakdowns. This translates into cost savings because a pro-active approach, rather than a reactive maintenance attitude, forms a basis for implementing advanced programs, such as reliability centered maintenance (RCM), in the operating organization.

It is prudent, however, to assess the data (in our case time between failure) for randomness and distribution prior to performing such an analysis. Data following a renewal process is independent and identically distributed (iid), which means the data arises from a single population. If the failure data does not follow a renewal process, the Weibull analysis leads to incorrect predictions about the nature of machine reliability. This often causes inappropriate action on the part of maintenance, resulting in costly and unwarranted repairs. Improving or degrading trends in reliability leads to failure data that does not follow a renewal process. There are various methods, both graphical and analytical, to assess this data before inputting it for a Weibull analysis. We will use one such method called the Laplace trend test.

Consider the case of an API 610-compliant centrifugal pump, one of the most common and critical pieces of rotating machinery in a refinery. Mechanical seal failures are often the initial reason such pumps are brought down for maintenance or repair. Usually, this is not because of an incorrect seal design selection or a faulty seal, but simply because of the way the mechanical seal is operated. Mechanical seals are one of the weakest links in pumps and turbomachines. They fail due to vibration, misalignment, changes in process conditions, incorrect settings on the seal flush plans and various other reasons. Weibull analysis, when properly used in this context, helps the reliability engineer determine and qualify the failure mode without having to stop the machine or wait for the next failure to happen. By using the past failure and maintenance history of the machine logged in the plant's computerized maintenance management system (CMMS) to calculate Weibull parameters, such as the shape parameter Beta (β), Weibull can help in determining why the failure occurs.

As a related case, consider a charge pump in a hydrocarbon service, pumping volatile gas oil as the finished product. The pump has a pressurized dual mechanical seal with an API Plan 02/53B. The normal pumping temperature is 85 degrees C, with a maximum temperature of 120 degrees C. The seal experienced multiple failures in the past that have subsequently caused the unit to shut down for seal replacement on both the inboard and outboard ends of this critical pump. Thorough scans of the CMMS system revealed various work order (W/O) and seal failure histories that helped in determining the time to failure (TTF) during each event. TTF provides the input for analysis that will then help to understand and draw meaningful conclusions on why the seal is failing.

We first use the Laplace trend test to determine if the data is suitable for Weibull analysis. Detailed information on computing and using Laplace testing can be found in the various references provided at the end of this article.

$$L = \frac{\sum_{i=1}^{n} (ti) - \frac{nT}{2}}{T\sqrt{n/12}}$$

Where:

T = Total observation time

n = Number of failures, if the last failure is at the end of the observation time (tn = T), then use n-1 in all places having n.

ti = Time from a common start point to each failure event.

Using the Laplace equation data yields the following values:

	Laplace Score (L)	Observation Period (T) (dd/mm/yy)	Failures (n)
Before Upgrade	-0.14	12/01/10 – 09/18/11	4
After Upgrade	0.42	04/10/11 – 06/06/13	3

When the score is greater than +1.96 or less then -1.96, we are 95 percent confident that there is a statistically significant upward or downward trend. This disqualifies the data from being iid and coming from a single population, leading to a non-qualification from further analysis using Weibull.

However, in our case, the Laplace score is closer to 0, showing that no discernible upward or downward trend exists and the data is essentially random failures qualifying it for the Weibull analysis. So let us now proceed to performing a Weibull analysis on our failure data.

Weibull distribution can be created for any data and is flexible in modeling a wide range of data. In our example, we use only failure data to model this distribution without incorporating non-failure (also called censored or suspended) data. While the inclusion of suspended data provides a more accurate distribution, we chose to ignore it due to the quality and accuracy of the data from the CMMS. Table 1 shows the filtered data and the time to failure for each of the failure events. The red line item shows seal upgrade from a different seal vendor performed during April 2011.

WO Number	Order Date	Work Order Description	WO Type	Time to Failure (Hrs)
XXX	1/12/2010	REPLACE SEAL	4	
XXX	9/29/2010	REPLACE ALL SEALS 2 BEARINGS	3	6240:00:00
XXX	11/11/2010	NEED TO TROUBLESHOOT AND REPAIR SEAL	3	1032:00:00
XXX	11/22/2010	REPLACE SEALS	4	264:00:00
XXX	9/18/2011	REPAIR PUMP INBOARD SEAL	3	7200:00:00
XXX	11/4/2011	INSTALL UPGRADED MECH. SEALS (Dif. Seal Vendor)	3	
XXX	10/4/2012	LEAKING MECANICAL SEAL	2	8040:00:00
XXX	10/12/2012	UPGRADE SPARE MECHANICAL SEAL	3	192:00:00
XXX	11/6/2012	NDE PRIMARY SEAL IS LEA	3	600:00:00

Table 1 - CMMS data on W/O and failure histories

In order to plot the Weibull distribution, a free online service called statgraphics (www.statgraphicssoftware.net/SGLive.aspx) was used with the TTF derived from Table 1. Rank regression estimation was used for plotting the distribution.

In reliability engineering, the bathtub curve is used to represent failure rates with passing time. The shape parameter, also called Beta (β), helps us in understanding if the failure rate is increasing (wear out conditions) where β>1, constant (random failures) where β=1, or decreasing (infant mortality) where β<1.

In Figure 1, prior to the upgrade, and Figure 2, after the upgrade, it is seen that β is less than 1, pointing to the fact that these seals are failing in the infant mortality zone. It should be noted that we have a small sample size (failures) for both situations. However, it has been observed by Dr. Robert B. Abernethy, a leading expert in Weibull statistics, that the Weibull method works well for performing engineering analysis, even with such small sample sizes.

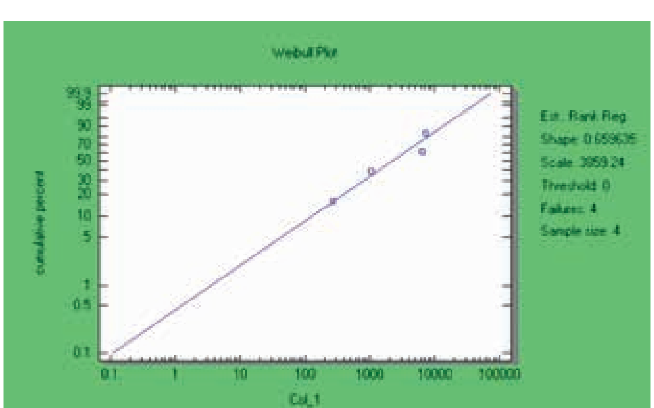


Figure 1: Weibull plot showing failures prior to the mechanical seal upgrade, β<1, η=3859.24, p value of 0.96808 and a sample size of 4

It is interesting to note that despite the upgrade on the mechanical seal, the failure pattern was not significantly altered. The seal was unable to clear the infant mortality zone successfully. One of the reasons leading to infant mortality in mechanical seals is connected to the incorrect design and application of the seal. When a mechanical seal is incorrectly designed or selected for a given application, there seems to be an increase in the number of failure incidents during the early life of the seal. The Weibull plot helps draw our attention to the fact that careful consideration needs to be implemented when selecting the right seal design for the application.

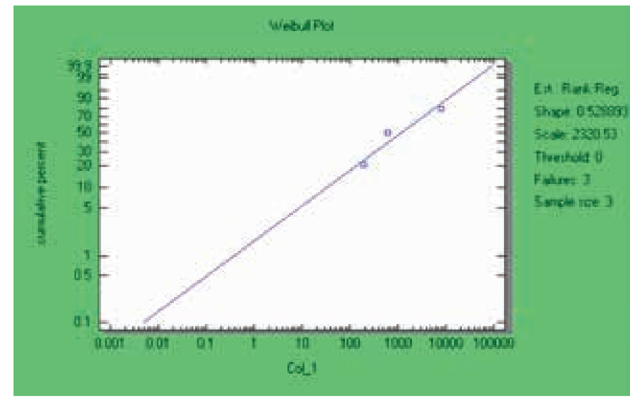


Figure 2: Weibull plot showing failures after the mechanical seal upgrade, β<1, η=2320.53, p value of 0.92837 and a sample size of 3

Further assessing the probability of failure for these seals given the two-parameter Weibull equation:

$$F(t) = 1 - e^{-(t/\eta)^{\beta}}$$

Where:

F(t) = Probability of failure at time (t)

η = Scale parameter or characteristic life, this gives the time when 63.2 percent of the parts are expected to fail

β = Shape parameter or the slope, as discussed previously

t = Time period selected for calculating probability of failure (hrs)

e = Exponential function

Results of calculations using this equation are tabulated in Table 2.

From Table 2, the reliability of the seal actually dropped further after performing the seal upgrade by the new vendor. This reflects the fact that the upgrade did not have the desired effect on improving seal reliability in this particular application.

Based on the root cause analysis performed on these mechanical seals (both prior and after the upgrade), we have seen them running at higher temperatures and causing face distortion and other issues leading to early

	Beta	Eta (hrs)
Before seal upgrade	0.659635	3859.24
After seal upgrade	0.528693	2320.53

Before seal upgrade			After seal upgrade		
Time (hr)	Survival Probability	Reliability (%)	Time (hr)	Survival Probability	Reliability (%)
500	0.2288	77.1246	500	0.3586	0.6414
1000	0.3366	66.3438	1000	0.4731	0.5269
1500	0.4150	58.5002	1500	0.5479	0.4521
2000	0.4770	52.2999	2000	0.6032	0.3968
3000	0.5713	42.8728	3000	0.6819	0.3181
5000	0.6946	30.5354	5000	0.7770	0.2230
10000	0.8465	15.3516	10000	0.8853	0.1147
100000	0.9998	0.0192	100000	0.9993	0.0007

Table 2 - Seal reliability values before and after upgrades

failures. The higher running temperatures were attributed to cooling limitations during operation, resulting from the inability of the selected seal flush plan to cool the seal sufficiently in conjunction with the seal design. The initial seal design selected for the pump prior to upgrade was not an effective design, particularly in regards to the seal face orientation for this application. Weibull modeling is a good tool in predicting reliability and determining gross failure modes for many simple and complex engineering and maintenance related equipment breakdowns. The distribution finds prominent use in implementing maintenance strategies in many world-class organizations by quantifying failures. When failures are random (β=1), a good condition monitoring program coupled with effective preventive maintenance practices help prolong equipment life. When failures are in the infant mortality zone (β<1), as we have seen with the mechanical seals, then careful attention needs to be given to the design, fabrication, operating procedures etc. And finally, when failures belong to the wear out zone (β>1), then a decision has to be made to either run the equipment to failure or develop a proper program for maintenance and overhaul of such equipment, which would include availability of spares as required. It is noteworthy that Weibull modeling information also acts as a valuable asset in project engineering by giving the project team important information during design and selection of machinery based on past equipment performance.

Plenty of papers dealing with Weibull do not stress the importance of pre-qualification testing of the data before performing analysis.

This article demonstrates the importance of using a pre-qualification test, such as Laplace, prior to performing a Weibull analysis. Negligence in performing a pre-qualification of the data can lead to incorrect analysis, subsequently causing costly and unwarranted repairs. Plenty of papers dealing with Weibull do not stress the importance of pre-qualification testing of the data before performing analysis. Detailed root cause analysis should have been the key focus after the initial failures on the first seal. However, in the absence of this approach, the second seal upgrade was also found ineffective due to potential incorrect seal/elastomer design and selection, consequently resulting in repeated failures in a short span. The second upgraded seal failed again in the infant mortality zone due to the similar reasons that caused the first seal to fail. The Weibull method is not the be-all and end-all solution to maintenance reliability problems. However, it is but one tool, and an important tool, in complementing other analysis and empirical methods used to troubleshoot and proactively ensure a higher uptime for the plant.

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PART 1

Why Single-Source Supply Contracts Can Disappoint

Selecting from among the many equipment or component manufacturers requires forethought. Experience shows that picking the right bidders is an important prerequisite for choosing the best machine, or selecting critically important components, such as bearings and fluid sealing devices. Let's take a look at several examples to support this contention.

Heinz P. Bloch

By way of generalization, it has been said that all manufacturers operate with business models that emphasize either quality, low price, or innovation. Rare indeed is the entity that simultaneously and consistently achieves all three, or even only two of the three. Plain logic should convince us that if a manufacturer truly reached pinnacle status in all three, it would soon become the only surviving provider of the asset in question.

That does not imply there aren't any capable, experienced vendors, but we have to find them and invite them to bid. Three principal characteristics[1] identify such capable, experienced vendors.

1. They are in a position to provide extensive experience listings for the equipment or components offered and will submit this information without much hesitation. (That is to say, beware of vendors hiding behind the smoke screen of "that's proprietary" whenever we ask questions).
2. Their machines or devices enjoy a reputation for sound design and infrequent maintenance requirements. Potential buyers must ascertain that a previously good reputation still holds true today after the provider has perhaps struggled through periods of mergers, downsizing and rightsizing.
3. Their marketing personnel are thoroughly supported by engineering departments. Also, the marketing and engineering departments are willing to provide technical data or details beyond those customarily submitted with routine vendor proposals.

Vendor competence and willingness to cooperate are shown in a number of ways, but data submittal is one of the most discernible tests. When offering fluid machinery or components in compliance with the standards of the American Petroleum Institute (i.e., the latest editions of API-610, 617, 618, 682 or any other standard), a capable vendor will make diligent efforts to fill in all the data requirements listed on the API data sheets. However, the real depth of technical know-how will show in the way a vendor-manufacturer explains exceptions taken to either an existing API clause or a user's supplementary specifications. Most users are willing to waive some specification requirements if the vendor is able to offer sound engineering reasons or meets the design intent, but only the best qualified vendors can state their reasons convincingly. Buying from best qualified vendors should not, however, be misinterpreted as an encouragement to single-source or standardize just for standardization's sake. And, of course, there are the occasional (but rare) exceptions when common sense directs us to consider deviating from the rule.

> THAT IS TO SAY, BEWARE OF VENDORS HIDING BEHIND THE SMOKE SCREEN OF "THAT'S PROPRIETARY" WHENEVER WE ASK QUESTIONS

WHY THERE'S RISK IN SELECTING ONLY A SINGLE-SOURCE OF SUPPLY

Not all equipment purchases entail the same risk; occasionally single-sourcing may be appropriate. Still, single-source vendor alliances require carefully worded contractual agreements between user and supplier. Moreover, any such agreement must be fair to both sides. The agreement also must be enforceable and must later be actively enforced by the main parties. We will start out by using mechanical seal partnerships (or "seal alliances") as our first example.

CAVEATS IN SEAL PARTNERSHIPS

Many mechanical seal alliances or partnership agreements are made by an owner's purchasing department. Unless a competent reliability engineer is involved, contracts usually end up being awarded to the lowest initial cost bidder. In those instances, seals get cheap and everything else gets costly. Safety and reliability are among the first victims.

Therefore, leading user companies choose to involve their most knowledgeable seal specialist and, ultimately, a perceptive legal adviser. The user's team recognizes its primary options and then moves in one of two possible, but different, directions:

Option (a): The parties enter into a performance-based contract. Seal life extensions (fewer failures) are rewarded and both sides hope to benefit.

Option (b): The owner-purchaser buys only about 80 percent of its seals from reputable Vendor "A" and 20 percent from reputable Vendor "B," or Vendors "B" and "C."

In the single-source situation described as Option (a), some alternative flush plans historically have not received wide acceptance. There may be a need for elaborate cooling auxiliaries in old-style seals. In these, flush circulating devices or elementary pumping rings are still applied by the average single-source provider. Therefore, not all seal manufacturers are able or willing to provide the best solution from the seal user's vantage point.

However, modern, computer controlled manufacturing methods have helped implement superior sealing technology and it's in the user's interest to capitalize on that. Purchasing from two or three vendors, as described in Option (b), makes the agreement with principal provider "A" self-enforcing. Each manufacturer knows that the purchaser's reliability engineers have other choices. This gives manufacturers "A," "B" and "C" an incentive to put their best talent to work. Competing manufacturers or vendors tend to provide better service and product quality, accordingly, the user benefits. Competing vendors are more receptive to implement well-engineered and highly innovative solutions.

As an example, review the high performance pumping rings in dual seals in Figure 1. Suppose an owner-purchaser deals exclusively with Vendor "A" and assume that Vendor "A" does not offer this type of pumping device. Unless the owner-purchaser uses the approach described as Option (b), superior products may not easily find their way into the facility.

This is why a number of best-in-class users prefer Option (b), the 80/20 approach. Option (b) keeps these users and their reliability engineers informed about technology advances and lifecycle costs. The two or three providers of sealing components, bearings, or gaskets participating in Option (b) become the user's technology resources and networking partners. If one of the providers does not perform well, the others will step in to fill the gap. The user and competent partner companies benefit from this open networking arrangement.

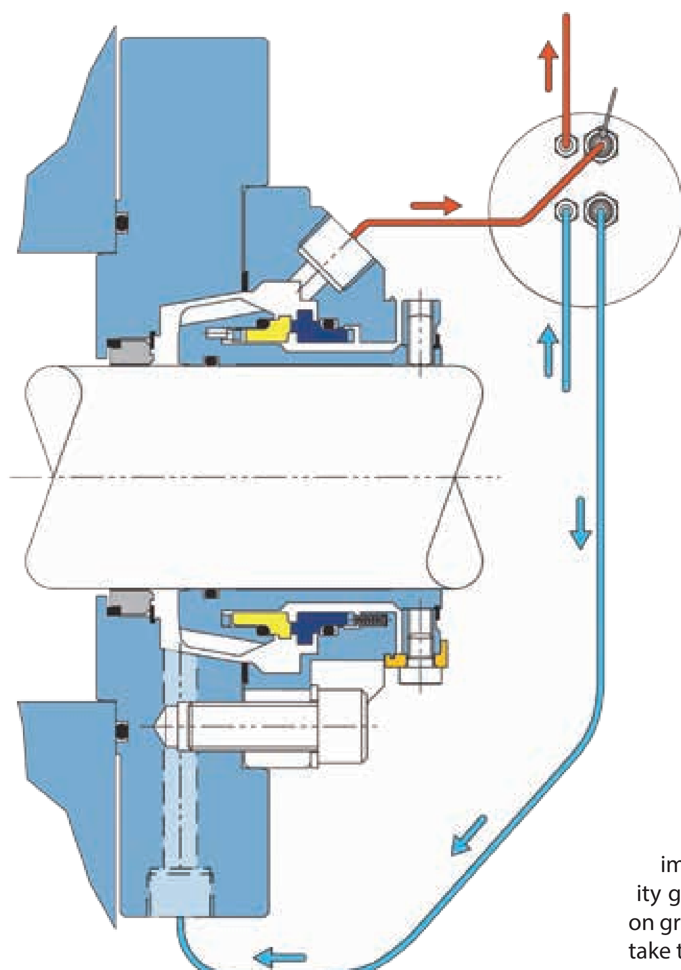

Figure 1: Plan 23 cross-section of a seal cavity with a bi-directional (tapered) pumping device. The flush fluid is product that passed through the throat bushing on the left. After being cooled in a small heat exchanger (upper right), this product re-enters the seal. A bi-directional tapered pumping device promotes relatively high flow rates and thus cooler face temperatures. (Source: AESSEAL Inc., Rotherham, UK and Rockford, TN)

While often used, single-source, performance-based contracts described in Option (a) are not always easy to interpret or enforce. In the eyes of the provider's management, the user-partner is in it for the long term. Accordingly, the provider may give priority to cultivating other potential customers and the long-term user-partner will suffer in the process. The seal provider often sets up a resident seal specialist at the user's site. But perhaps the supplier-partner's resident representative does not meet all of the user's expectations and the resident specialist's influence at the seal manufacturer's factory or the provider's principal engineering offices is often rather limited.

As an example, after finding many new seals that leaked from the day they were commissioned in 2011, a very large U.S. refinery began testing every mechanical seal before installation. Fortunately, there was a performance clause that allowed flawed products to be rejected. The seal manufacturer's quality subsequently improved. Single-source contracts without performance clauses and routine procurement from a single-source vendor can burden the purchaser with even more serious quality control issues.

Another example involves electric motor lube issues and purchaser's indifference plays a role here. At a 2013 reliability conference, a user related a situation where several, large grease lubricated 13.2 kV electric motors required bearing replacements after a single year of operation. While much more detail would be needed to zero in on the root causes of this unacceptably high failure frequency, the feedback illustrates what happens when lowest bid price is of paramount importance. At certain speeds, grease lubrication may impede reaching a user's projected reliability goals. And at all speeds, excessive pressure on greases and non-optimized grease paths will take their toll.

Users with true reliability engineering expertise understand all and will specify most of the items listed on motor nameplates. The motor winding life effects of buying a 100 hp motor with a service factor of 1.15 versus a 115 hp motor with a service factor of 1.0 are understood by good reliability engineers. Also, whenever bearing data on motor nameplates are incomplete, competent reliability experts seek clarification. To manage an effective lubrication program, one needs to know grease entry and exit locations, whether or not there are shields and where these shields are located relative to the grease reservoir. The issue at hand is illustrated in Figures 2 and 3, although many more configurations are available.[2]

Serious failure risk exists if, in Figure 2, grease is injected at Point 1 without first removing the plug from exit Point 2. High-pressure "new" grease is almost certain to push some spent

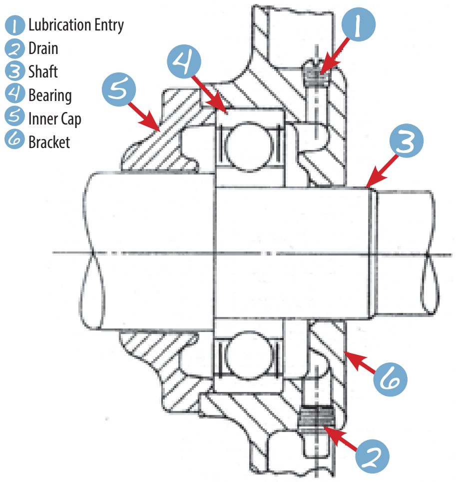

Figure 2: Grease injection at Point 1 without first removing the plug in exit Point 2 is almost certain to (a) push spent grease into the bearing and (b) force the shield into troublesome contact with the rolling elements.

grease into the bearing and force the shield into contact with the rolling elements. This vulnerability did not escape ARCO Alaska who, over 30 years ago, opted to remove the drain plug and replaced it with a length of pipe, as see in Figure 3. The drain pipe terminates in an elbow and a short nipple. The threads on the open side of the pipe nipple must be mangled so as not to allow capping. In Figure 3, a plug of spent grease is always located in the drain pipe and over-pressuring the grease reservoir is no longer a threat.[3] The "old plug" gets expelled at the time of regreasing (grease replenishing).

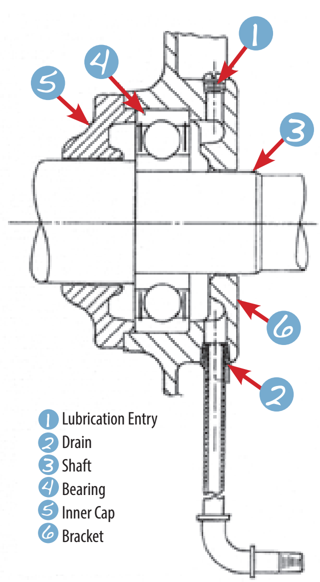

Figure 3: An inexpensive and very effective way to prevent over-pressuring the grease reservoir.[4]

Understanding the design intent of shielded bearings is of paramount importance. Shielded bearings are to be used in housings where grease resides in the adjacent reservoir. The oil contained in the grease is supposed to "bleed" from its soap matrix past the small annular gap into the bearing. Greases have different bleed points for different applications and, for long life, superior motor greases should not be exposed to pressure for more than just a few minutes. Although homogenous at the point of original manufacture, most greases under pressure will separate into their soap and oil constituents.

Different bearing housing types or directions of grease flow are shown in Figure 4. On single shielded bearings, the shield should face the grease reservoir. Installing the shield away from the grease reservoir causes 100 percent of the bearing to be filled with grease. Bearing manufacturers are unanimous in recommending bearings to be filled only 30 to 35 percent to prevent churning and overheating of the grease.

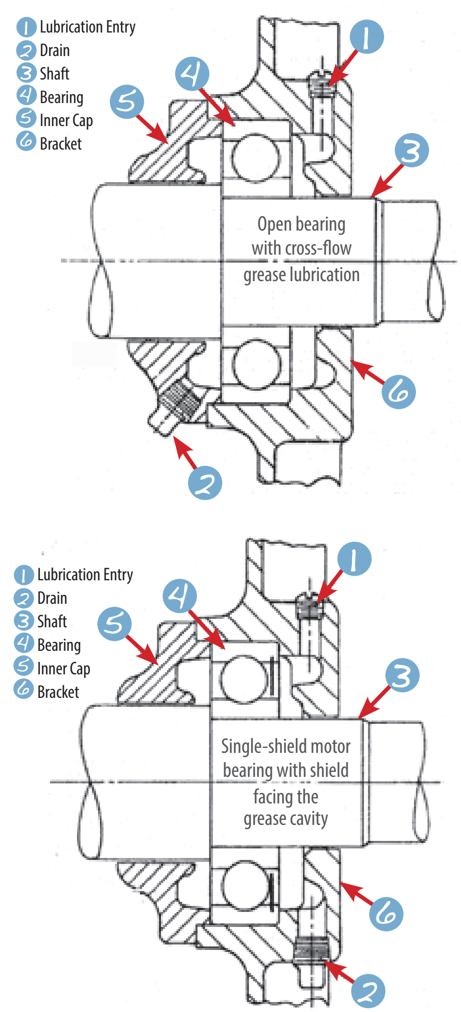

Figure 4: Different types and directions of grease flow. Understanding the design intent of shields is of paramount importance: Grease resides in the adjacent reservoir and oil is expected to "bleed" from its soap matrix past the small annular gap into the bearing. Greases are compounded with different bleed points for different applications; superior motor greases should not be pressurized.

Chances are that single-sourcing electric motors from the lowest bidder will deprive diligent users of a comparison basis. Having electric motors from more than one source also provides an excellent learning opportunity for grooming newly-hired personnel to become the diligent reliability engineers of the future. Diligent engineers know how things work; they never confuse facts with mere opinions. That said, understanding why some reputable motor manufacturers went through the trouble of adding a separate shield in front of shielded bearings (see Figure 5) is of interest. The Reliance Electric Machine Company called it a "metering plate" and hoped that no attempt was made to squeeze grease through the gap between shields and bearing inner rings. Oil was to bleed through that gap and no grease -- an oil-soap mixture -- was to be introduced by brute force. Having this understanding then reemphasizes the three important points of (1) not making the lowest bidder your only source, (2) incorporating lubrication details in the motor purchase specification, and (3) learning and teaching facts instead of opinions.

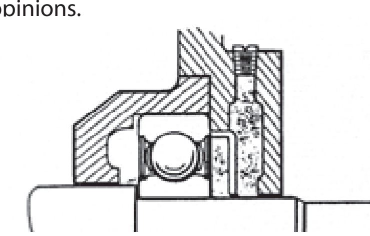

Figure 5: In this 1970s vintage bearing housing, the electric motor manufacturer placed a metering plate in front of a double-shielded bearing. The motor manufacturer thus reduced the risk of applying excessive pressure to the bearing shield adjacent to the grease reservoir.

The message is this: Why lock yourself into the wrong bearing style? Pursuing Option (b) will likely prove highly informative. The key is to work with only the most competent manufacturers. Understand who they are and do not get wedded to the one who claims to be both best and cheapest.

Another aspect of our topic, why single-source supply contracts can disappoint, is the subject of a follow-up article in the next Uptime issue.

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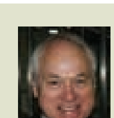

Heinz P. Bloch is a consulting engineer and ASME Life Fellow with over 50 years of industrial experience. He advises process plants worldwide on maintenance cost reduction and reliability upgrade issues. Many of his 18 textbooks on reliability improvement subjects are completely up-to-date or leading edge. They can be obtained from the MRO Bookstore or from Amazon.com.

Machinery Health Monitoring Depends on Accelerometers

PART 2 Signals from Accelerometers

Wayne Tustin

This is Part 2 of a five-part, series. Part 1 (Uptime Oct/Nov 2013) **dealt with the mechanical aspects of using accelerometers, while Part 2 will cover the electronic aspects of dealing with those small signals. Part 3 will discuss calibrating accelerometers to determine their sensitivity. In Parts 4 and 5, we will attach accelerometers to various machines so they can report on machinery health.**

DATA ACQUISITION - AVOIDING ERRORS

Part 1 told you that accelerometers convert motion into electrical signals. Part 2 warns you against certain electrical errors.

READOUT INSTRUMENTS

Figure 1 suggests some readout instruments. Identify the domain (time or frequency) in which each functions or displays:

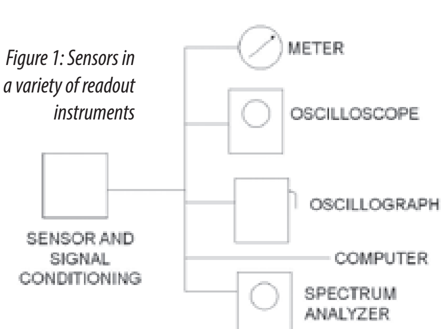

Figure 1: Sensors in a variety of readout instruments

The first three? The time domain. The last? The frequency domain. The computer? In both domains. Let's focus on the computer and spectrum analyzer.

Never introduce a millivolt-level sensor electrical signal directly into electrically noisy environments of desktop/laptop computers. Instead, route it through an electrically quiet front-end amplifier.

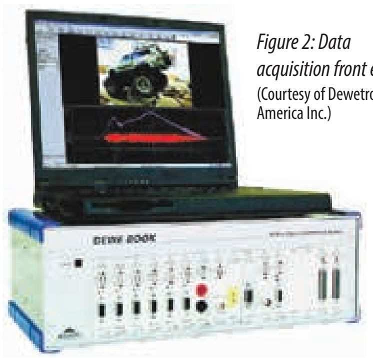

Figure 2: Data acquisition front end (Courtesy of Dewetron America Inc.)

THE FREQUENCY DOMAIN – SPECTRUM ANALYSIS

In Parts 4 and 5 of this series, we are going to look for changes in the signatures or the spectra of machines. Spectra?

Figure 3: Handheld mechanical spectrum analyzer contacts motor turning at 1750 rpm

Mentally hold the mechanical spectrum analyzer shown in Figures 3 and 4 against a 1750 rpm motor. Each reed was factory tuned to resonate at a specific frequency. One, tuned to 1750 rpm, is responding strongly.

Figure 4 suggests the internal construction.

Hold the analyzer quietly, all reeds at zero. Knuckle strike the analyzer bottom. If Figure 5

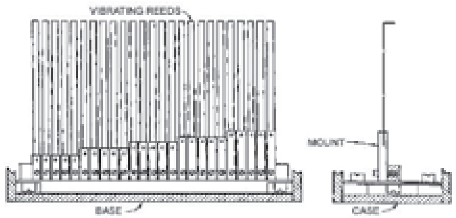

Figure 4: Internal construction of reed device

Figure 5: Multi-reed tachometer just struck

were a video, you'd see all the reeds responding simultaneously, each at its own frequency.

Agree? The shock event contains energy at many frequencies. If each reed could record how vigorously it responded, we'd have a spectrum of that event. (It's called the shock response spectrum (SRS.) We're preparing to use machinery spectra in Parts 4 and 5 of this series.

ELECTRONIC SPECTRUM ANALYSIS

Let's move on. In Parts 4 and 5, we'll determine how much of our machine's overall vibration (accelerometer-sensed) occurs at various frequencies. We interpose numerous fixed electrical filters between our accelerometer and our readout instrument.

Back in the 1920s, the first fixed audio filters were an octave wide. Example: 37.5 to 75 Hz, showing little detail (see Figures 6 and 7).

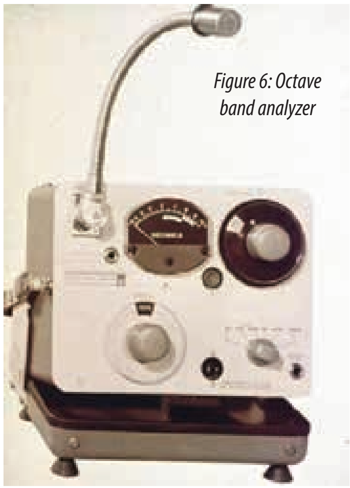

Figure 6: Octave band analyzer

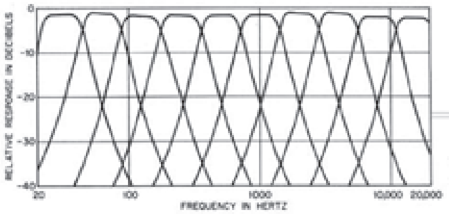

Figure 7: Set of octave band filters

One-third octave analyzers (see Figures 8 and 9) suffice for noise code enforcement. As machinery speeds and vibration frequencies have increased, early analyzers have become technically obsolete, although many are still in use.

One-third octave filters plus microphone, amplification, weighting networks and readout meter are combined in Figure 9 into a sound level meter (SLM).

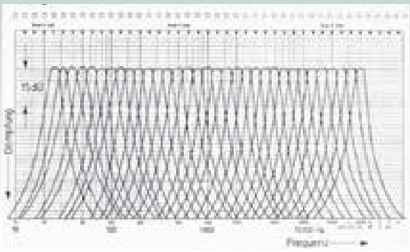

Figure 8: Set of 1/3 octave filters

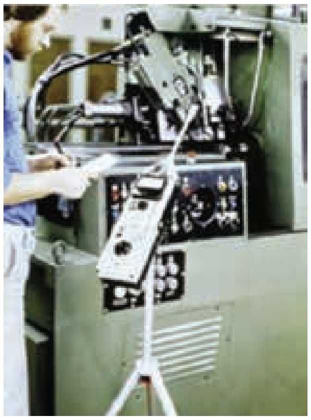

Figure 9: Sound level meter

NEED FOR DETAILED SPECTRUM ANALYSIS

How can we accurately determine the magnitudes and frequencies of the several vibrations our machine generates simultaneously? Sometimes, these are very close together in frequency.

Figure 10's historic technician manually tunes his analog analyzer across a pump's range of vibration frequencies. When he identifies a spectral peak, he writes down its height and frequency. Very time-consuming.

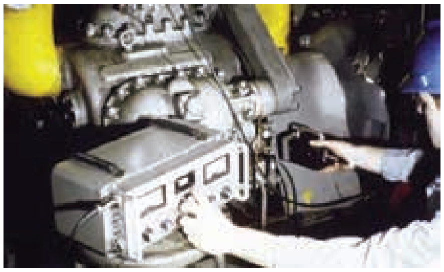

Figure 10: Example of analog analysis

Figure 11: Example of a dedicated spectrum analyzer (Courtesy of Ono Sokki)

Today's digital sound and vibration spectrum analyzers are much faster. Perhaps your vibration band of interest is 0 to 500 Hz. If your analyzer provides 500 windows or 500 lines, your resolution is 1 Hz. That is, you can measure and plot what vibration is occurring in each of the windows, 398-399, 399-400, 400-401 Hz., etc.

ELECTRICAL MEASUREMENT ERRORS

Reasonable accuracy is important. But errors can and do creep in.

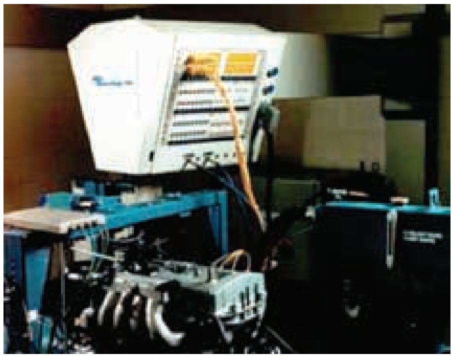

Figure 12: Engine test cell suggests some sources of electrical noise

Most measurement and analysis of vibration signals are done digitally using computers. Analog signals from accelerometers, force sensors, etc., must be digitized or sampled. If we are not extremely careful, we can get wrong data. We will consider aliasing and leakage in Part 4.

But plenty of other error sources exist. Electrical error sources mentioned here affect both analog and digital analysis.

Avoid noise or unwanted signals that can contaminate your measurements. Figure 13 suggests the idea that noise or unwanted signals make information gathering difficult.

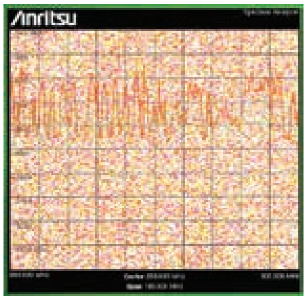

Figure 13: Electrical noise makes information hard to read

SIGNAL CONDITIONING

The first piezoelectric (PE) accelerometers (circa 1955) fed signals into vacuum tube (later solid state) voltage amplifiers. Most of today's PE accelerometer signal conditioners are called charge amplifiers or, more accurately, charge to voltage converters.

Signal conditioners used with pressure (PR) and specific gravity (SG) sensors must also supply DC excitation to the resistive bridge elements in the sensors. Figure 14 suggests the functions needed for each channel of instrumentation.

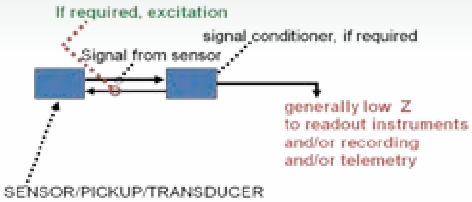

Figure 14: One channel of instrumentation

In-line charge amplifiers (Figures 15 and 16) have given way to today's inside the accelerometer amplification.

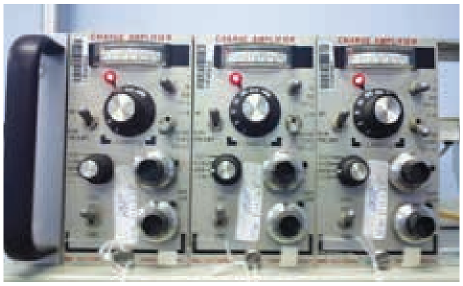

Figure 15: Charge amplifiers (Courtesy of Element & Steve Brenner)

Figure 16: In-line charge amplifier

GROUND LOOPS

The concept of troublesome ground loops is illustrated in Figure 17. A PE accelerometer feeds a signal conditioner and readout device, here called measuring instruments. They are connected to local ground at different locations on an electric power distribution system or water piping. Unfortunately, those two grounds are some millivolts, or volts different in potential, because of unknown circulating currents in various conductors.

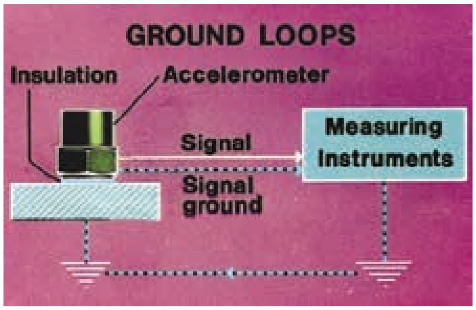

Figure 17: Ground loops

If your situation resembles Figure 17, unground either your sensor or your measuring instrument.

Never allow your cables to become kinked, twisted, or knotted. Never stress them or flop them loosely around. Don't step on or drive over them. Don't contaminate them with chemicals, dirt, oil, or grease.

If you suspect a cable is bad, destroy it and obtain a new replacement. Your data is so expensive that you can't risk its validity by using suspect cables.

Don't leave your entire cable (and accelerometer) inventory available to just anyone. Keep new equipment hidden until needed.

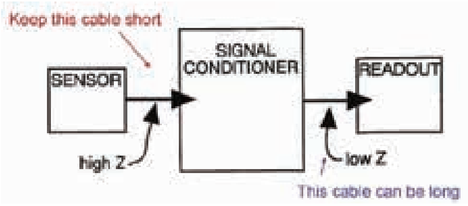

Figure 18: Keep high Z wiring short

Correct cable routing lessens electrical interference. Don't run cables close to AC power lines. If crossing a power line, do so at 90 degrees.

Any high electrical impedance signal lead from sensor to signal conditioner is vulnerable to electrical noise, so keep it short. Put the signal conditioner close to the sensor. It's okay to have a long lead after the signal conditioner because that lead is at low electrical impedance, perhaps 100 ohms.

AMPLIFICATION INSIDE SENSOR CASE

Carrying Figure 18 to a long-awaited conclusion, manufacturers have been placing microcircuit amplifiers inside accelerometer housings for some years (see Figure 19).

High impedance circuitry is sealed inside the sensor case, untroubled by contaminated environments and by electrical interference. It can drive long cables without signal degradation or loss of resolution. It works directly into modern fast Fourier transforms (FFTs) and data collectors.

THERMAL EFFECTS

Unfortunately, most such sensors can only operate at -65 to +250 degrees F.

CONCLUSION

In the first article of this series, we looked at several accelerometer types that currently are popular. Our concern was mostly on mechanical aspects. In this article, our emphasis is on the associated electronics. In the third article, we will consider calibrating these sensors and systems.

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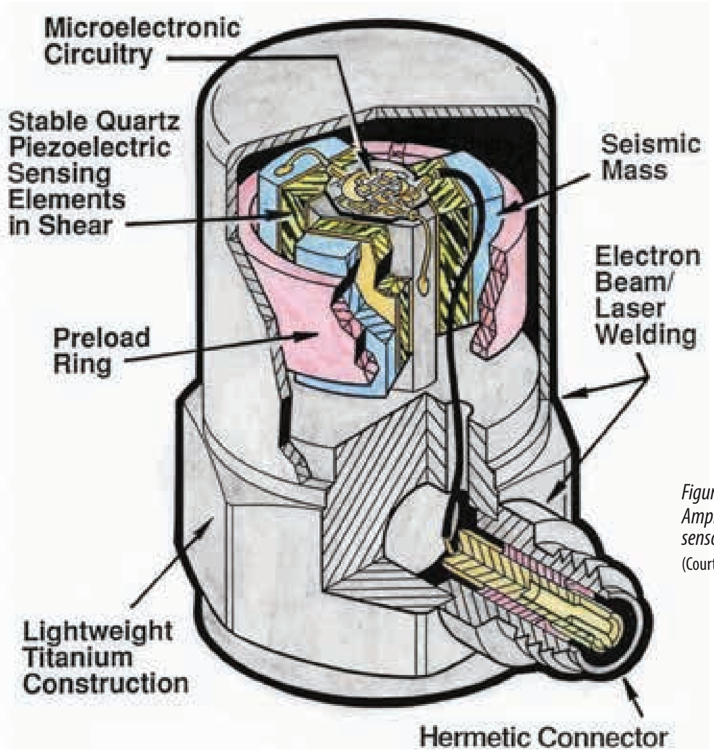


Figure 19: Amplification inside sensor case (Courtesy of PCB)

The Application of Strategic Reliability Principles

Jay Shellogg

Since the discovery of modern asset reliability principles, first detailed by F. Stanley Nowlan and Howard F. Heap in the mid-1960s, up until the latest evolution in the 1990s by John Moubray, some 30 odd years have passed, but with little rigorous adoption of these principles into the asset management strategies of North American industry. This article is intended to help explain why the adoption of these truths has been so hard to come by over these past 30 years and what it will take for the adoption of these reliability principles to occur.

In North America, organizations have continually passed through the endless cycle of reliability despair due to a lack of understanding of the fundamental principles of strategic reliability that Nowlan & Heap and John Moubray have outlined. Organizations frequently pass from good reliability to poor performance and back again, never understanding why this cycle occurs or how to break it. The most important question for today's reliability leaders is: Why have we failed to sustain reliability efforts of the past in the presence of clear and tangible results of our past efforts? Until we can answer this question, we cannot break the cycle of despair.

The answer must be a lack of knowledge and understanding of these reliability principles by the entire organization attempting to establish reliable asset performance. What else can rationally explain why someone would ignore something to be true unless that person did not really know the truth in the first place? Basically it boils down to this: Most leaders within North American industry today do not understand (or even know about) these principles of reliability, how the principles were derived and how to implement them into a strategic plan. Most of North America's industrial leadership is ignorant of what is required to achieve meaningful reliable asset performance. This ignorance is not necessarily of their making. Asset reliability is not taught in business academia and only occasionally taught in colleges of engineering. Often, today's organizational leaders have never been exposed to these reliability principles in a direct and fundamental way. Consequently, today's organizational leaders have learned false principles that they believe to be true and giving up those false ideas is difficult to overcome.

So what are these principles of reliability? Basically, the principles set up the cultural aspects of how an organization should view reliability. Culture is a shared system of beliefs that an organization uses to solve its problems because they have worked well enough in the past to be taught to others as the correct way to act. An example of this is when you hear someone say, "That's not how we do it here." The individual making the statement is reinforcing the company's system of beliefs on how to act. The person is reinforcing the culture. The principles of reliability set out a new paradigm of reliability, a new way to think and act. Adoption of these principles is not easy, but the steps are basic. The first step is learning these principles.

By my count, there are NINE PRINCIPLES OF RELIABILITY that must be understood in order to achieve a full understanding of reliable asset performance. They are as follows:

1. Eighty percent (±) of all equipment failures occur randomly with respect to time. The age of an asset does not increase the conditional probability of failure.

2. Indication of pending functional failure (the failed states) follow a predictable degradation curve known as the P-F interval. As an asset moves towards functional failure, the asset will give off detectable signals at definable time intervals, thus giving an organization time to react proactively.

3. The human senses are capable of detecting 80 percent (±) of failed states. A dependence or focus on technological devices is unwarranted. Most failed states can easily be detected using sight, hearing, touch, smell and taste.

4. Those working closest to a problem are the best equipped to solve the problem. They are the subject matter experts (SMEs).

5 There is no need for the collection of data first in order to achieve asset reliability. The data we think we need to collect will be prevented from collection if we have a strong reliability program in place. The data we think we need already exists; it is in the minds of the SMEs.

6 There must be an understanding of the meaning of failure consequences (safety, environmental, production and non-operational). Further, there must be an understanding that 30 percent of the failure consequences occur hidden under normal operating conditions.

7 Risk is inherent in everything we do. It is not possible to eliminate risk, only to identify what level of risk is acceptable (tolerable). Not to define a tolerable level of risk leads the organization to a default position of ignoring risk altogether. We must be brave enough to talk about risk in terms of acceptable injuries per year and how that leads us to an acceptable risk calculation for every task one may be asked to perform. For example: If an organization sets as its goal not to have injured more than five workers over a one-year period and there are 1,000 employees, then the acceptable injury rate is one injury per 200 years worked (5:1,000 or 1:200 employee-years). In a calendar year, 1,000 employees will work 1,000 years. Once the acceptable injury rate is known (1:200 employee-years), the next step is to determine the number of tasks/events within an organization that could injure someone. A detailed discussion of this type of determination is not practical for this article, however, it might be as simple as taking an organization log of safety incidents (e.g., near misses, need for first aid, OSHA recordable) and determining the average number per year. This would give an organization a good idea of what its number of tasks/events that could lead to an injury would look like. To illustrate:

Let's assume a 1:200 employee-year injury rate is tolerable.
Let's assume that from our safety logs we have determined that we have 240 tasks/events per year that could lead to an injury.
We know we have 1,000 employees.
1: (200 employee-years/1,000 employees) = one injury for every 0.2 calendar years. Or one injury about every 2-1/2 months.
1: (0.2 X 240 tasks or events) yields 1:4 years.
Multiplying the 1:4 years by a safety factor (SF) accounts for errors in determining the number of events per year (200).
Let's assume a SF of two.
1: (4X2) = 1:8 years.
This means that for any of the tasks/events that could result in an injury, the probability of occurrence must be below 1:8 years.

No doubt this is a tough conversation to have, but to ignore this discussion is to leave risk at an undefined level, which cannot be tolerated.

8 Assets can only perform as well as they are designed, installed, operated and maintained. We must understand what our assets can do versus what we want them to do.

9 Failure mode identification must be categorized into three categories:
a. Suddenly b. Over a period of time c. Hidden

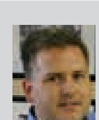
Until all nine principles of reliability are understood by an organization, it cannot move on to the second step.

The next or second step is for an organization to become open to these principles. Often, this is driven by a need for change, either from external pressures of competition or internal pressures to improve performance, like safety, environmental, quality, or production. But this is a conundrum – what comes first, the understanding of the principles or the openness to learn the principles? The answer is both and is dependent on the individual and/or organization. In today's organizations, as stated previously, the majority of leadership is ignorant of these principles, so the openness to new principles is limited. Change for these leaders is only driven by pressure, external or internal. However, people attending school, whether professional or trade, are open to new ideas and will accept these principles without pressure to change because for them, there is no change. The key to the second step is understanding who needs to change. If it is leadership, then they will first need a compelling reason. If it is employees new to an organization or still attending school, they will accept the principles without the need for a compelling reason.

The most important question for today's reliability leaders is: Why have we failed to sustain reliability efforts of the past in the presence of clear and tangible results of our past efforts? Until we can answer this question, we cannot break the cycle of despair

The third step is a commitment by the organization that the principles of reliability should be used to govern the way an organization makes its decision about asset management. When questions arise, organizations should look to these principles to solve their problems and improve asset performance. Far too often, organizations fall into the trap of tactile application of reliability elements rather than strategic application of the principles of reliability. Organization are tempted to focus on an element of reliability, such as planning and scheduling, equipment history, predictive tools and many others, rather than focusing keen attention to the principles of reliability. It is the tactical application of these elements without a strategic understanding of the principles that has led us to the endless reliability cycle of despair. It is more important that the right job be done than doing the job right. Organizations are often overly focused on performing work correctly, rather than understanding if the work needs to be done in the first place. Without first mastering the principles, one cannot move on to the application and if questions or challenges arise, one must be ready to fall back on the principles for guidance. The principles of reliability are the foundation to all elements of a reliability asset management strategy.

The last step puts the focus on today's reliability leaders. Our task is to educate ourselves on what the principles of reliability are; then we must educate everyone else. The work begun by Nowlan & Heap and carried forward by John Moubray is now in our hands. It is the duty of today's reliability leaders to move the work through to its next phase – the education of business and engineering professionals, as well as the trade/craftspeople, on these principles of reliability. Not until everyone from the shop floor to the boardroom understands these principles of reliability can the work of the next phase begin – the work of establishing proactive asset management plans with lasting effects.



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