uptime®

feb/march16

for maintenance reliability and asset management professionals

How to Develop an Industrial Internet of Things Solution

uptimemagazine.com

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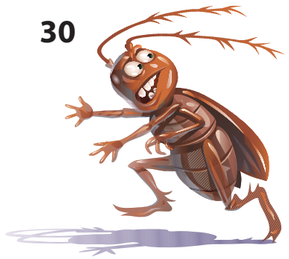
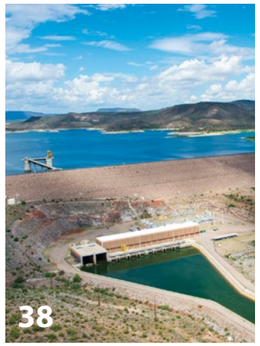
feb/march 2016

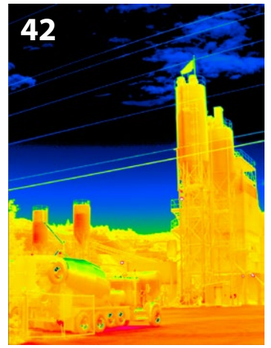
uptime® for maintenance reliability and asset management professionals

ON THE COVER
Can you find the Uptime logo on the cover?

Features







Editor's Correction:

In the Dec/Jan 2016 issue of Uptime, we made an editorial error in the article, "Ultrasonic Superheat Bypass Valve Inspection," by Jim Hall and Jim Cerda. In our edits, we inadvertently altered text so it indicated that Mr. Cerda needed help finding a superheat bypass valve leak. The correct statement is as follows: Jim Cerda, a process engineer at AES Southland with ultrasound training, had been requested to "help" find a superheat bypass valve leak or "leak-thru" that may be leaking within the facility's Unit 3 superheat steam bypass system.

Mr. Cerdia is a well-trained, experienced and talented engineer who would not need help finding a leak of this nature. Our apologies go out to Mr. Cerdia and his co-author, Mr. Jim Hall.

Elements

Editorial

Embracing Epic Failure

The small energetic and focused team at Reliabilityweb.com and Uptime Magazine does some mighty big work. We stick our necks out and take chances in our quest to discover and deliver our mission, to make you safer and more successful. We are alive and vibrant because we are encouraged to take chances. We fail often, recover quickly and move to the next potential breakthrough as fast as we can. In fact, the quicker we fail, the quicker we innovate.

We took some BIG hits in 2015 with failures at every level of our organization in every operating area. I would like to thank the entire team for its bravery in creating and facing failures. We always work to restore integrity by cleaning up the mess we cause as well as it can be cleaned.

For most people, failure shows up as a threat. Something that makes them "not right" and threatens their very survival. Our team has learned to stand and look out from the middle of failure and realize that which showed up as a threat can be viewed as a clearing for something new and as an opportunity. Not in a Pollyanna or patsy fashion, but as a possibility for a new, created future. I am not talking about positive thinking; I am talking about the powerful domain of generation.

One of my favorite quotes, "The best way to predict the future is to create it," teaches us that the future is not preordained; it unfolds as a result of the actions we take. I follow Steve Jobs's advice to put a dent in the universe and the only thing I know that does that is *action*. And when you generate action, sometimes you fail. I think it beats the heck out of staying locked in place.

Out of these epic failures, we are doing some fantastic and innovative things, like the new Solutions 2.0 Virtual Conference, Reliability and Asset Performance (RAP) Talks, ReliabilityTV On-demand video library, Uptime Elements Academy Online Learning Management System and our first Reliability Bar Camp (un-conference) sessions at The RELIABILITY Conference in Las Vegas, and of course, our continued development of the transformative Uptime Elements Reliability Framework.

The team is honored and delighted as industry trade magazines, training companies and even not-for-profit associations try to look like us, act like us and sound like us. We hope they get it right because we need all the help we can get to change the world, and the more, the merrier.

I extend my sympathies if you and your team were unable to experience failure in the same way we did in 2015 because it likely means you were not stretching yourself or your team. If you are not failing, then you are not growing, advancing or evolving. You are playing it safe. Good luck with that strategy, as 40% of the companies that exist today will be gone in 10 years.

There are many businesses that are easier, more profitable and much less risky than a publishing and conference company. That does not matter to us because we get to work to our mission.

I am so thrilled that this team permits me to lead – because there is nothing finer than leading a team of leaders.

We hope you like what you discover in the pages of this issue of *Uptime* Magazine and online at Reliabilityweb.com. It was created out of failure.

Thank you for being a subscriber.

Warmest regards,

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LER Leadership for Reliability

RELIABILITY®

IN THE NEWS

CHECK IT OUT!

The NEW Reliabilityweb.com Website

With over 15 years of deep knowledge and shared experiences from some of the best practitioners in the field, the new website is custom-built to make discovering resources easier than ever. A new design, streamlined navigation, improved search, and more are waiting for you at the new **Reliabilityweb.com.**

WIRAM Women in Reliability and Asset Management

Women in Reliability and Asset Management (WIRAM) held their first meet-and-greet at IMC-2015 in Bonita Spring, Fla. The group had the opportunity to share experiences and discuss the role of women in the industry. The event featured speakers, Marie Getsug, Senior Consultant at Maintenance & Reliability Services, and Cathy Wilson, Reliabilty Technology Manager at Sunair Company, who spoke on the urgency of attracting women to the field of reliability and asset management.

International Maintenance Conference Celebrated 30 Years!

Celebrating its 30th anniversary, IMC-2015 was the event's biggest year yet with over 1,100 attendees. The annual event took place in Bonita Springs, Fla. from Dec. 7-11, 2015. On hand to deliver a rousing keynote was Dr. Jeffrey Liker, author of "The Toyota Way." Other highlights from the week were the Uptime Awards, which recognize the best of the best maintenance reliability programs, 150+ presentations, endless networking opportunities and the chance to meet some of the industry's leading experts and authors.

Just Announced!

CRL Reliability Engineering for Maintenance (REM) Leader Review Course

April 15, 2016 • The RELIABILITY Conference

The objective is to demonstrate an understanding needed to develop effective and efficient maintenance strategies to ensure that the asset delivers the functions and performance standards specified by the asset owner within agreed upon levels of service. For example, the person seeking the certification should understand the value and deliverables of each of the seven questions of reliability-centered maintenance as expressed by Nowlan and Heap.

This review course is followed by a (no-cost) Beta Exam to earn an Association of Asset Management Professionals (AMP) REM Leader Badge. The AMP REM Leader Badge requires a current Certified Reliability Leadership status.

More information: reliabilityconference.com

Congratulations to the newest CERTIFIED RELIABILITY LEADERS!

Mahmoud Al-Juhani
Yansab - Chemical Maintenance
Jorge Alarcon
Tekniker
Mousa Ali
Jordan Bromine
Anthony Armeli
Palm Beach County Water Utilities
David Armstrong
Bentley Systems Inc.
Francisco Ballesteros
Preditec/IRM
Jonathan Barron
Honda
Matthew Berg
The Mosaic Co.
Donnie Billings
Continental Cement
Terry Blackman
Mobius Institute
Michael Blanchard
Life Cycle Engineering
Victor Blanco
Cementos Progreso, S.A.
Lawrence Bouvier
Fuss & O'Neill Mfg Solutions
Gilberto J. Carrera Loaiza
AVINTIV
Dan Charlebois
Mosaic
Thomas Coombes
Pruftechnik Inc.
Jim Davids
Barrick Gold
James Davidson
Rio Tinto
Robert Dent
SDT Ultrasound Solutions
Frank Dowthwaite
Independent Consultant
Gary Einarson
Yara Belle Plaine
Mahmoud El-Manakhly
Methanex
Leonard Ellis
Iluka Resources Inc.
Pablo Figueroa
Bristol Myers Squibb Company
Jason Garrett
Honda of America Mfg., Inc.
Kerry Hancock
Salt River Project
Robert Haroldsson
LJT & Associates
Brian Harrison
EDI
Doug Harvey
Graphics Packaging
Malcolm Hide
Strategic Maintenance Ltd
Clint Johnson
Barrick Gold
Johnathan Jones
Jacobs
Shayne Jones
Salt River Project
Gary Josebeck
Owens Corning
Teri Kitzmiller
Honda of America Mfg., Inc.
Alan Knight
Mueller Co.
Kent Knight
Fluid Life Corporation
Jesus Laboy
VibrAnalysis, Inc.
Felix Laboy
VibrAnalysis, Inc.
Laura Lamb
Leprino Foods
Matt Maini
Honda Manufacturing of Alabama
Armando Marina
Bristol Myers Squibb Company
Donald Mendes
Concord Foods
Jayaram Menon
BP
Elizabeth Minyard
CH2M
Timothy Mitchell
Iluka Resources Inc.
Paul Moreau
Iluka Resources Inc.
Julio Motta
Bristol Myers Squibb Company
Cheryl Norris
Portland General Electric
Georges Ouellette
Honda of Canada Mfg
Joe Patton
Honda of America Mfg., Inc.
William Peck
Honda of America Mfg.,inc
Don Penney
LJT & Associates
Chris Power
Continental Cement
Steve Righton
Rio Tinto
Enid Rivera Calderon
Bristol Myers Squibb Company
Werner Roberts
Fortescue Metal Group
Ryan Roomsburg
HECLA Greens Creek Mining
Dave Ross
JM Smucker Company
Zaid Salhi
Jordan Bromine
Francisco Santiago
JLL
Matthew Scully
Evolution Mining
Ismael Solis
Pall
Perry Steele
The Mosaic Company
Jamieson Stevens
Post Consumer Brands
Kevin Strader
BP
Phil Swanton
Honda North America
Marco Van Veen
Endress+Hauser
Luis Vazquez
PharmaBioserv
Cesar Vega
Duke Energy
Gustavo Velasquez
SDT Ultrasound Solutions
Steve Welch
Honda of America Mfg., Inc.
Steve Welch
Mueller Co.
Scott Werling
Honda of America Mfg., Inc.
Ron Whitson
Bentley Systems Inc.
Johnson Wilkie
Chevron Nigeria Limited
David Yazzie
Barrick Gold
Gaston Zanco
Metales del Talar

2016 Upcoming Certified Reliability Leader Events

CRL Workshop and Exam

February 15-19
Uptime Elements
Fort Myers, FL

February 23
MARCON
Knoxville, TN

April 7
Reliable Plant
Louisville, KY

April 11-15
The RELIABILITY Conference
Las Vegas, NV

May 9-13
Uptime Elements
Fort Myers, FL

June 20-24
Uptime Elements
Fort Myers, FL

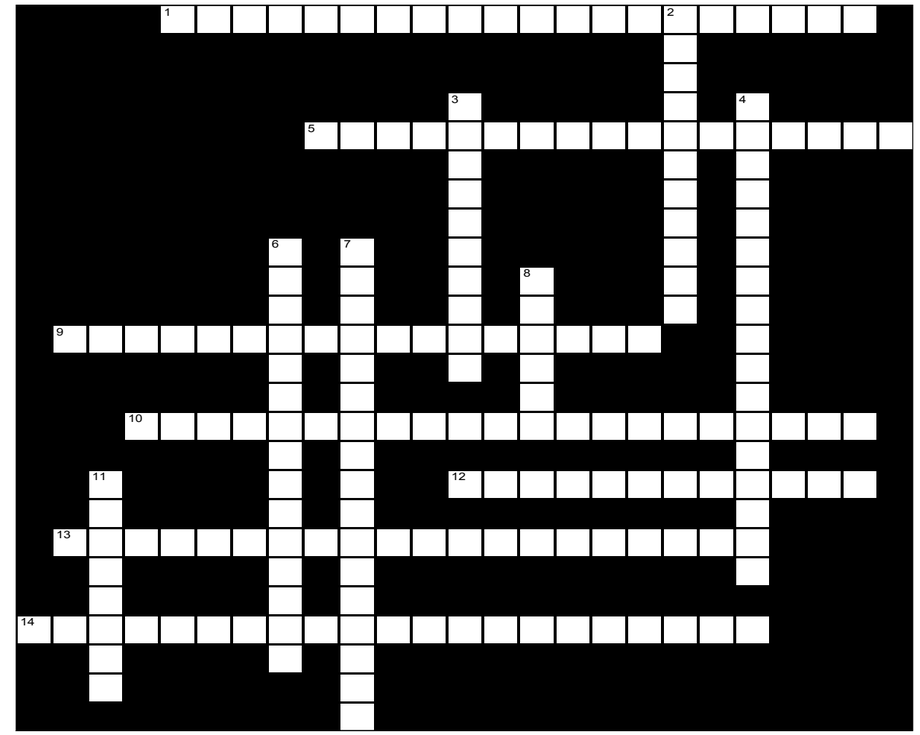
September 12-16
Uptime Elements
Fort Myers, FL

October 10-14
Uptime Elements
Fort Myers, FL

uptime® Elements™

Created by Ramesh Gulati

Crossword Puzzle



ACROSS

1 Support required from the management to implement a sustainable change

5 A methodology that leads to the discovery of the cause of a problem

9 The identification of a nonconformance and its removal

10 A philosophy of leadership, teamwork and problem-solving resulting in continuous improvement throughout the organization

12 Encompasses several predictive maintenance technologies to monitor and assess motor health

13 Performed to reduce friction and heat

14 Key techniques to minimize effects of vibration in rotating equipment

DOWN

2 A predictive maintenance technology used to determine the quality of the lubricant oil and/or condition of equipment being lubricated

3 A process of determining which jobs get worked on, when and by whom based on priority, resources and asset availability

4 A predictive maintenance technology used to detect leaks and other defects in assets

6 An organizational process to maximize value from an asset during its life

7 Anyone who helps another person, a machine or a gadget to do a better job

8 The time during which an asset or system is either fully operational or is ready to perform its intended function

11 A process of determining the resources and method needed, including safety precautions, tools, skills and time necessary to perform maintenance work efficiently and effectively

See page 64 for answers.

Uptime Awards

Best Maintenance Reliability Programs

Recognizing the Best of the Best!

2015

Uptime Magazine congratulates the following outstanding programs for their commitment to and execution of high quality Predictive Maintenance and Condition Monitoring Programs.

To read more about each company, download the Uptime Award Winners' stories at:
uptimeawards.com

Bristol-Myers Squibb

Uptime Awards
Best Maintenance Reliability Program

Bristol-Myers Squibb is a global biopharmaceutical company firmly focused on its mission to discover, develop and deliver innovative medicines to patients with serious diseases. Around the world, our medicines help millions of people in their fight against such diseases as cancer, cardiovascular disease, hepatitis B and C, HIV/AIDS and rheumatoid arthritis.

Our biopharma strategy uniquely combines the reach and resources of a major pharmaceutical company with the entrepreneurial spirit and agility of a successful biotechnology company. With this strategy, we focus on our customers' needs, giving maximum priority to accelerating pipeline development, delivering sales growth and continuing to manage costs.

Bristol-Myers Squibb created a true global community, with a culture and passion for reliability focused on adding value to the business, sharing best practices, continuous improvement and also:

- Empowering employees and partners to deliver excellence in asset management;
- Reducing equipment-related production impacts;
- Increasing work order compliance globally;
- Reducing preventive maintenance tasks through preventive maintenance optimization;
- Development/deployment of standardized criticality analysis tool globally;
- Additional positions created and filled dedicated to reliable point of use vending machines;
- Significant availability improvements on key equipment;
- Paperless work execution on a globally standardized computer maintenance management system.

Central directives are in place for:

- Lubrication Management
- Storeroom Management
- Root Cause Failure Analysis
- Alignment and Balancing

Central Arizona Project

The Central Arizona Project (CAP) is Arizona's single largest supplier of renewable water. CAP is a 336-mile long system of aqueducts, tunnels, siphons, motors, pumps and pipelines that annually pumps more than 1.5 million acre-feet of water from the Colorado River to central Arizona, including the Phoenix and Tucson metropolitan areas. CAP's 15 pumping plants lift water nearly 3,000 feet in elevation and consume about three million megawatt-hours of electricity each year.

CAP provides water for five million people, more than 80 percent of the state's population, as well as 350,000 acres of irrigated agriculture and 11 Native American tribes.

Highlights of CAP's Maintenance Excellence Program

- Sustained maintenance excellence program for 13 years
- Company-wide asset management philosophy
- Dedicated reliability and maintenance engineering functions
- Centralized planning and scheduling
- Ongoing reliability-centered maintenance analysis and implementation
- Cross-functional/cross-departmental partnerships
- Centralized technical and leadership development
- Defined reliability processes, roles and responsibilities
- Arizona Division of Occupational Safety and Health certified voluntary protection program to promote worksite safety and health

University of Central Florida

UCF is the second largest university in the United States. The public, multi-campus, metropolitan research university provides opportunities to over 61,000 students.

UCF anchors the Central Florida city-state in meeting its economic, cultural, intellectual, environmental and societal needs by providing high quality, broad-based education and experience-based learning; pioneering scholarship and impactful research; enriched student development and leadership growth; and highly relevant continuing education and public service initiatives that address pressing local, state, national and international issues in support of the global community.

UCF has embarked on a bold venture to become a new kind of university that provides leadership and service to the Central Florida city-state. While sustaining bedrock capabilities in the future, the university will purposely pursue new strengths by leveraging innovative partnerships, effective interdisciplinarity and a culture of sustainability highlighted by a steadfast commitment to inclusiveness, excellence and opportunity for all.

The services we provide are research, education and public service.

Our goals are to:

1. Offer the best undergraduate education available in Florida.
2. Achieve international prominence in key programs of graduate study and research.
3. Provide international focus to our curricula and research programs.
4. Become more inclusive and diverse.
5. Be America's leading partnership university.

Facilities Operations supports the university's goals by cleaning, maintaining and repairing buildings and equipment to minimize interruptions and create a safe, comfortable and clean environment for our faculty, staff and students.

To support the university's mission and vision, Facilities Operations has implemented a reliability-based culture founded in reliability-based maintenance (RCM), reliability engineering and efficiency principles. As these concepts are new to UCF, this is a far-reaching goal. We have a plan that begins with growing our staff's tools, knowledge and abilities. This will enable us to take the next steps in fostering a reliability-based culture.

The plan for the next five to eight years of RCM implementation at UCF has been laid out and a blueprint developed.

Southern Gardens Citrus

Southern Gardens Citrus (SGC) Processing is the world's largest supplier of 100 percent pure Florida not-from-concentrate orange juice to private label industry and major brands. Opening in 1994, SGC is the newest orange juice processing plant in the United States. Our mission is to: "Continuously improve and become the low-cost supplier of high quality citrus products to our customers, while maximizing returns to our shareholders."

In 1995, we initiated a maintenance excellence effort with the vision of excelling our maintenance program from reactionary to proactive. The lowering of maintenance costs and improvement of the uptime of our equipment/assets for operations were the main goals of this vision. This effort was driven by a new general manager who brought in maintenance consultants to develop strategies and objectives. Asset criticality was established, planners were added and mechanics were placed on area teams. Key performance indicators were established and monitored to determine our results and future course of action. Laser alignment was added to the program to eliminate repetitive failures.

In 2004, our reliability excellence effort was launched with benchmarking and training and additional maintenance consultants. A lingering silo effect was eliminated by centralizing maintenance. A reliability engineer position was created, as well as an upper management steering team named the Reliability Excellence and Leadership (REAL) Team to monitor and support maintenance reliability efforts. A total productive maintenance inspection style approach to rebuilds was introduced to eliminate unnecessary maintenance costs. SAP as our computer maintenance management system went live in 2008.

Predictive maintenance programs were introduced: Infrared thermography; ultrasound analysis; oil analysis; vibration analysis; and off-line motor testing. Our lubrication program was reinforced with the use of ultrasonics. Fans began to be dynamically balanced with the assistance of vibration analysis. Resources were reallocated to expand these programs and ensure their success, such as training mechanics to become predictive maintenance technicians and redefining our utilities department's responsibilities for our air and steam systems. These processes have assisted SGC in becoming proactive by allowing us to focus on what needs attention. We are constantly looking to expand the use of our predictive maintenance tools to increase their usefulness. This, along with a plant culture of continuous improvement, has allowed our asset condition management to improve year after year and financially justify itself.

The results have been gratifying with year after year reductions in emergencies and maintenance costs, and maximized use of internal labor through the elimination of electrical contractors and the use of other contractors when skills or time is an issue. We have found that we could reduce the maintenance workforce through attrition: 12 mechanics to nine; 12 mechanic helpers to five; two instrument techs to one; and a 50 percent reduction in maintenance management.

Nova Scotia Power

Nova Scotia Power, Inc. (NSPI), a privately owned, vertically integrated electric utility, provides electricity to 500,000 residential, commercial and industrial customers in Nova Scotia, Canada.

In 2011, NSPI began the design and deployment of its asset management program. An asset management office and a common work management system, complete with identical work management practices throughout the fleet, were established at that time.

Key program design features include:

- Incorporation of all operation activities;
- Fleet-wide standards, practices, programs and tools;
- Highly measured activities;
- Technology as an enabler.

The asset management model employs reliability teams composed of representatives from plants, engineering and asset management. Maintenance strategies are deployed on an asset class basis across the fleet and all equipment and maintenance process information is integrated to produce metrics and key performance indicators rolled into layered dashboards and scorecards. Condition assessments are conducted on a fleet basis to produce risk profiles for each major asset class and drive outage planning and investment planning.

Continuous improvement is built into the asset management process.

Portland General Electric

Operating in 52 Oregon cities, Portland General Electric (PGE) serves approximately 829,000 customers, including more than 100,000 commercial customers. PGE receives oversight from state and federal regulatory agencies, including the Oregon Public Utility Commission and the Federal Energy Regulatory Commission.

As Oregon's largest utility, PGE's service territory attracts major employers in diverse industries, such as high technology and health care. Economic growth in northwest Oregon continues to fuel the customer growth rate.

PGE has a diverse mix of stable generating resources that include hydropower, coal and gas combustion, wind and solar, and key transmission resources. These 15 power plants have a total combined generating capacity of 3,357 MW.

By managing PGE's own power plants in conjunction with the available power supplies on the wholesale market, management believes that fully integrated power supply operations provide the flexibility and efficiency necessary to effectively balance the power supply resources to achieve the lowest possible cost for customers.

PGE is focused on providing reliable, responsibly-generated power at a reasonable cost. To accomplish this requires a broad mix of generation resources. While some utilities obtain their power from one or two sources, PGE relies on seven different sources. This greater diversity of power supply contributes to higher reliability and more stable prices.

Uptime Awards

Best Reliability Engineering for Maintenance Program

PGE regards equipment reliability as an indispensable component of our generation excellence business practices. Increased equipment reliability results in valuable improvements to business performance regarding safety, health, environment, sustainability, regulatory compliance and generation availability. Employees are responsible for reliability and strive for excellence in this area every day.

The generation reliability team mission is to integrate leading reliability engineering and maintenance practices into a continuous improvement process designed to reach PGE's maximum potential in a safe working environment. Through the implementation of these practices, PGE sustains improvements in safety, availability, workforce efficiency, risk reduction and increased reliability of our generation assets.

The 11-person corporate team supports a 29-person field team representing each of the power plants. Three recent notable achievements are the development of reliability block diagram models of each of the nine power plants, maintenance strategy development completed at a new wind farm before commissioning and boiler tube inspections using phased array ultrasonic testing.

Additionally, PGE's NDT lab contains various materials testing equipment for validation material composition and properties in the lab and field environment. Most recently, PGE has begun field use of a mobile optical emission spark spectrometer, testing for validation of materials installed in the plant prior to repair or replacement.

Special Recognition Awards

Merck

Best Defect Elimination Program

Merck, which delivers innovative health solutions globally, adopted a culture of defect elimination at its Rahway, NJ, facility. The program empowered the entire organization to eliminate defects at their source. The program resulted in a 25 percent reduction in corrective maintenance, $1.6 million in cost avoidance and $1.4 million in cost savings.

Malaysia Airports Holdings Berhad

Best Culture of Reliability

Malaysia Airports became the first airport operator in Asia in 1999 and is in a league of its own with its diverse airport portfolio and business model. Its "Runway to Success: 2015-2020" features sustainability-related plans, initiatives and targets in four focus areas of resource management: energy, water, waste and carbon. Results to date include a significant reduction in GHG emissions, implementation of green initiatives and improved service levels to ensure safety compliance at airports.

Lawrence Livermore National Laboratory

Best Maintenance Reliability Not-for-Profit

Company: Facility Infrastructure Systems of the National Ignition Facility at the Lawrence Livermore National Laboratory.
Hardware: Building, conventional utilities, process utilities, HVAC, vacuum, beam transport structures, large aperture optical components, automated diagnostic equipment, and transport / handling equipment.

Iluka Resources Inc.

Best Decommissioning Program

Iluka's United States mining, concentrating and processing operations are located in Virginia. Heavy mineral concentrate is processed into final products of chloride ilmenite and zircon at a mineral separation plant. Iluka implemented "The Path Forward" strategy, which included the development of a professional maintenance reliability team and focused on teamwork. In planning for the future, Iluka strives to move farther left on the I-I-P-F curve.

70% of reliability improvement efforts will FAIL

What is happening in the 30% of reliability initiatives that succeed?

The answer can be summed up in a single word:

Leadership

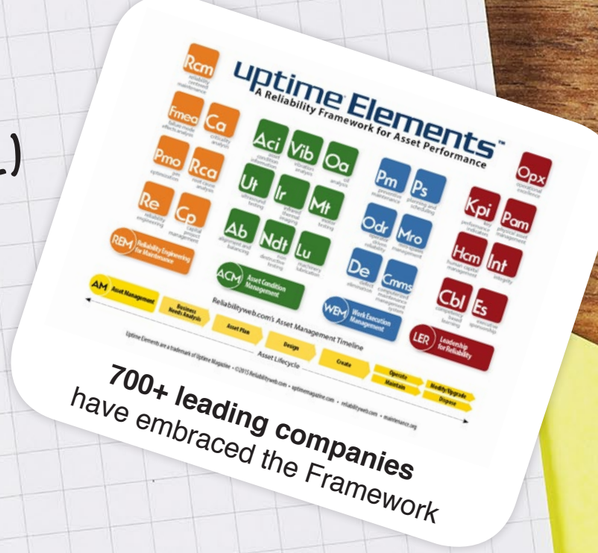
World-Class organizations recognize that success is achieved through **leadership**; however, they also realize that results are only delivered through **engagement** and **empowerment** of everyone in the workforce. Leadership does not come from one person, it comes from everyone.

This is especially true for reliability.

Uptime Elements Certified Reliability Leader (CRL)

WHAT: Provide assessment and certify individuals who demonstrate an awareness of integrated and interrelated reliabilty system, Uptime Elements.

OUTCOME: Promote **confidence** and **knowledge** around reliability leadership to align, engage, empower and energize asset performance.



Your Options to Get STARTED

1. Request private onsite team **Certified Reliability Leader Training**
2. Study online at the **Uptime.Academy Learning Management System**
3. Buy the **Body of Knowledge** at MRO-Zone.com or Amazon.com
4. Attend **THE Reliability Conference** in Las Vegas
5. Attend a **Certified Reliability Leader Workshop**

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www.reliabilityleadership.com

How to Develop an Industrial Internet of Things Solution

by Tomasz Puk

At the CeBIT and CED Tech Venture conferences last year, the Internet of Things (IoT) was surely one of the hottest topics discussed. Wearable gadgets are monitoring our fitness activities, home doors are recognizing our touch to let us in, and consumer shopping patterns are monitored and processed using beacon technologies. These are just a few examples of those dreams we once had coming true today.

Are you ready to develop an industrial IoT for your organization? This article uses a hypothetical organization to demonstrate what's involved in developing an industrial IoT solution and convince you to catch the IoT wave, as it seems to perfectly match the requirements of reliability management functions.

DEFINITION

What is the Internet of Things? Here's a look at two definitions:

"The Internet of Things (IoT) is the network of physical objects or 'things' embedded with electronics, software, sensors, and network connectivity, which enables these objects to collect and exchange data." www.wikipedia.org

"The Internet of Things is the network of physical objects that contain embedded technology to communicate and sense or interact with their internal states or the external environment." www.gartner.com

Those of you responsible for reliability management and condition monitoring will certainly find many similarities in these definitions and your current systems.

The biggest difference is the shift of the intelligence down to "things"/sensors operating in the immediate proximity of the monitored object. IoT sensors do not transmit data anymore; they process it locally, filter it and send only valuable information instead. Another major difference is the connectivity. In the modern world, developing a sensor that can communicate using global broadband service providers, Wi-Fi networks, Bluetooth connections, or any other means of communication is not a challenge any more.

Market Potential

Is this market worth fighting for? Gartner estimates the number of IoT devices to near 26 billion by 2020. IoT products are planned to generate $300 billion incremental revenue mostly in services. Gartner further predicts expansions in such industries as medical devices, factory sensors, agriculture, automotive and infrastructure integrity monitoring.[1]

Another important aspect worth adding to the IoT equation is the shift from a product to a service economy. Manufacturers are not only selling their products, but are starting to offer them together with accompanying services, like an extended operational warranty or replacement, and are even turning their former products into services.

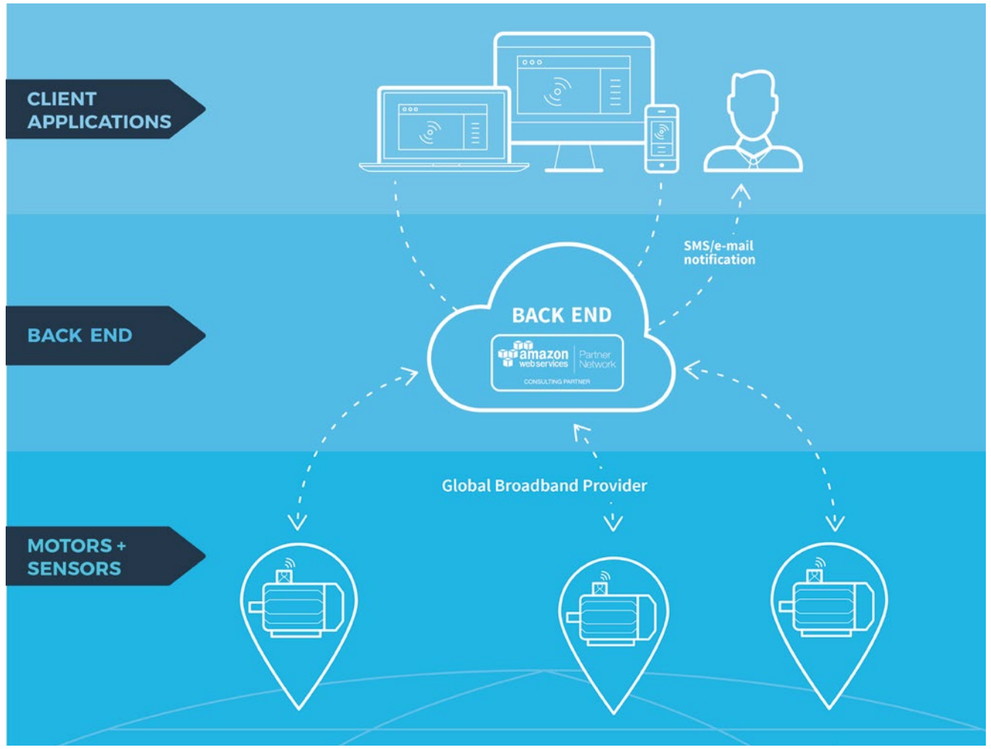
One cost implication in the business-to-customer (B2C) market seems questionable. For example, the price difference between the intelligent lightbulb and the conventional one can peak to 100:1. On the other hand, the price impact of a compute module at around $40 added, for example, to an electric motor, can be negligible, especially for more sophisticated equipment. This is perhaps the major difference between IoT solutions in B2C and business-to-business (B2B) markets, where the latter can offer added value with only a slightly higher end product cost increase.

ACME Organization Case

OK, are you ready for a short journey to IoT product development? Let's take an imaginary ACME organization, an original equipment manufacturer (OEM) of electric motors. A new head of business strategy required the company to broaden its standard product range with new services. Let us accompany ACME in developing its first IoT solution.

IoT products are planned to generate $300 billion incremental revenue mostly in services.

Figure 1: Sample overview of the ACME solution architecture



New Business Model

Definitely, the first thing to start with is a business model design. ACME has to reinvent its existing business model and come up with a new, updated one that will provide justification for the effort and cost behind the new venture. Sounds odd? Well, think about Nespresso®, Uber, or even Microsoft® Office 365. All these examples present situations where old products, like coffee beans, taxi services and software licenses, were turned into new services with different value propositions. Likewise ACME has to modify or redefine its existing value proposition for customers. Is it extended operation time, the accompanying condition monitoring service, or a totally new market niche with the mission's critical equipment?

Within the business model design, in addition to the value proposition, ACME will need to specify markets and paths to reach them, distribution channels and revenue streams. It will have to think about key activities, such as the development of IoT solutions, key resources, cost structure and partners. If you are interested in more details, a good resource is the "Business Model Generation" book by Alexander Osterwalder[2].

Product Concept

As the outcome of its business model redesign, let's assume ACME came up with the idea to enrich its existing product value proposition with an extended warranty and reliability service. Clients would be informed about the condition of their registered equipment, vibration thresholds, or any pending maintenance actions recommended by the manufacturer. The service would be offered as a platform, where local service providing organizations can offer their services, such as shaft alignment or parts replacement, based on the registered machines' conditions.

ACME is planning to collect motor condition information automatically and anonymously using a global broadband service provider. The machines will not be identified without client permission. ACME plans to use information from all the motors for its new product quality improvements. The company also plans to analyze incoming data against new service types.

Where to Start?

ACME is now facing one of the key challenges of a new product development: How and where to develop such a program? Does ACME have such competencies internally or should it look for an external technology partner? Whichever option is chosen, ACME has to assure competencies in the following areas: project/program management, business analysis, electronic design and embedded software development, web application development, user interface/user experience (UI/X) design, quality assurance and cloud infrastructure IT management.

IoT Solution Architecture

Figure 1 presents an overview of the ACME solution architecture. First of all, there is a tier of ACME electric motors equipped with sensors collecting required information. The motors use global broadband subscriber identity module (SIM) cards to communicate with the back end component of the architecture. Only the processed daily reports are sent to the back end to avoid data overload and to minimize transmission costs.

The back end component is located on Amazon Web Services Cloud[3], enabling the whole IoT solution to operate on the global market from day one, independently to where the ACME motors will be shipped. It is responsible for collecting data from "things," processing and analyzing it, and sending any notifications to people in charge in case any action is required. That part of the architecture is also responsible for data storage on cloud storage services, like Amazon's Simple Storage Service (S3),[4] leaving the door open for future big data processing.

The next tier contains client applications, operating in web browsers on both desktop and mobile devices (responsive web design[5]). The applications are used primarily by clients and then by ACME service delivery teams responsible for providing new services.

Clients purchase ACME motors already equipped with sensors. If a client decides to use a new ACME service, the client has to register its organization and it assets using ACME's web portal. From that moment on, the client can use the new service.

Here are some advantages for the client:

- Communication is built into the ACME motors;
- No up-front investments;
- No additional infrastructure costs;
- No communication configuration required;
- Access to ACME's services in a software as a service[6] model with a monthly fee.

Program

In order to develop this IoT solution, ACME had to actually launch these projects:

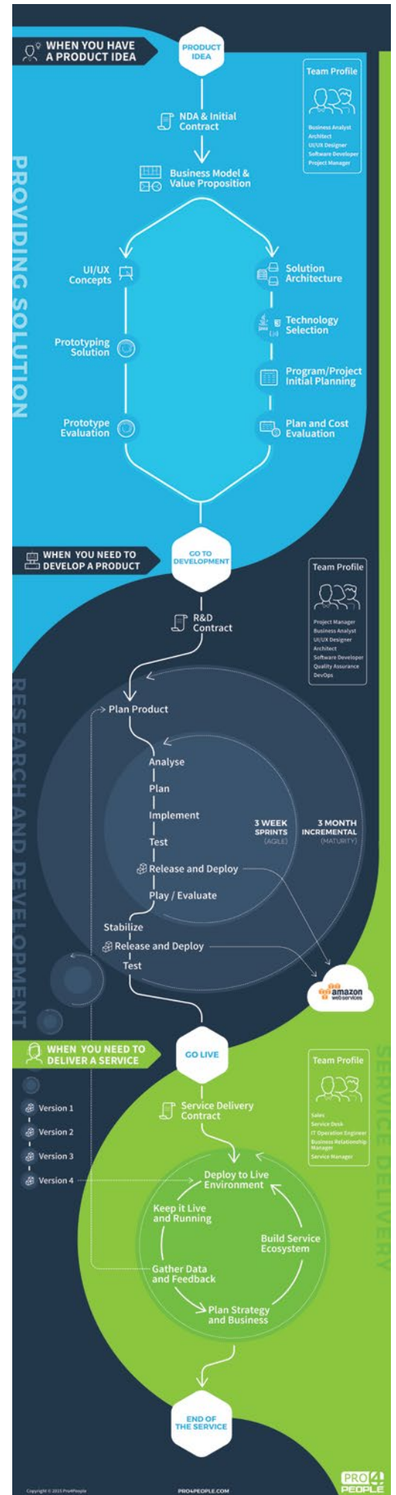
- Motor monitoring embedded device, with the goal to develop a measurement device for its motors;
- Cloud project, with the goal to develop back end system logic and client applications;
- IoT service delivery project, with the goal to build functions, processes and an organization structure to deliver new services to ACME clients.

There is also a need to set up a program umbrella above the three projects to assure all projects are synchronized, planned and tested together for the final outcomes. The program itself will go through different phases, such as:

- Solution providing, where the IoT solution concept is created, a prototype built and the program separated into a work breakdown structure;
- Research and development, when all the projects are started and developed together to deliver platform components;
- Service delivery, a phase when an IoT service is up and running after the first initial product release.

The different lifecycles of the IT service are presented in Figure 2.

Figure 2: IT Service Lifecycle



The first thing to start with is a business model design

Summary

Where is the hypothetical ACME organization now? After 12 months of research and development, it has launched its first version of the solution following the customer development process[7]. The company is collecting data from all newly shipped motors and using it to improve the quality of its products and to learn more about the usage patterns of its equipment. ACME continues to extend its new services portfolio.

Those customers who decide to register their equipment get a reliability report monthly or are informed automatically of a situation requiring direct action. By using its new IoT solution, ACME has managed to improve communication between machines and people responsible for reliability management.

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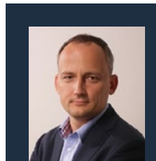

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10 Components of a Successful VIBRATION PROGRAM

by Alan Friedman

Right People and Right Leadership

Part 2 of this series on the components of a successful vibration program describes the skill sets and attitudes that are most appropriate for those who want to run successful vibration monitoring or condition monitoring (CM) programs.

Read Part 1: Right Goals

Figure 1: 10 components of a condition monitoring program

1. Right Goals	Having clearly defined and achievable goals that may evolve over time.
2. Right People	Having the right people in the right roles with the right training.
3. Right Leadership	Inspiring continuous improvement.
4. Right Tools	Having the right tools and technology to help reach the goal.
5. Right Understanding	Equipment audits, reliability and criticality audits, FMECA, maintenance strategies, etc.
6. Right Data Collection	Collecting the right data at the right time to detect anomalies, defects or impending failures.
7. Right Analysis	Turning data into defect or fault diagnoses.
8. Right Reporting	Turning data into actionable information and getting that information to those who need it at the right time and in the right format.
9. Right Follow-up and Review	Acting on reports, reviewing and verifying results, benchmarking, auditing and improving, etc.
10. Right Processes and Procedures	Tying together: people, technology, information, decision-making and review.

Right People

ISO18436-2, which covers training and certification of vibration analysts, recognizes four levels of certification that roughly translate into different roles in the program. Category I certified analysts are typically involved in data collection and simple alarm checking on pre-defined routes. Category II certified analysts are responsible for the day-to-day running of the program, including data analysis, reporting and general database management. Category III analysts are usually responsible for the initial program setup and overall management of the program. This includes everything from choosing which assets to test to defining test points, test setups, determining which monitoring technologies to use, developing baselines and alarms, etc. Category IV people are a rare breed and their focus is more on rotor dynamics and monitoring large process equipment. The different roles involve different skills and different pay scales, thereby making a division of labor a more cost-effective way to manage a program.

Certification from an accredited organization is important. It ensures that personnel have at least a minimum degree of understanding of the subject matter. Certification is also important for compliance and liability reasons. But does having certified personnel on staff ensure the program will be a success? Is certification enough?

There is a difference between a condition monitoring program and a guy with a tool. CM technologies are often used for troubleshooting known problems. This is considered reactive maintenance and it is the worst possible use of the technology. The whole point of having a CM program is to reduce emergency or reactive work. The difference here implies that the people running the program will need a program management mind-set and skill set, rather than a troubleshooting mind-set. The skills required to analyze data or troubleshoot a mechanical problem are often different than the skills required to run a program.

> The best person for any job is someone who loves the work

Some people suffer from the "hero complex," whereby a maintenance professional sees himself or herself as the person who gets called in an emergency situation to solve a difficult problem. He or she uses vast troubleshooting skills to save the day and keep the plant running. But after the celebration and parade in the person's honor subsides, one should stop to reflect that although it is much less exciting, the goal of having a CM program and other reliability measures in place is to avoid having this emergency situation arise in the first place!

To give an example, a great mechanic who loves fixing cars drives an old VW bus. When you go on a road trip with him, you are glad he is such a great mechanic and is able to keep the bus running. Compare this to someone who drives a new car, in particular a model that is a much more reliable vehicle. When you go on a road trip with this person, you don't worry about the car breaking down or requiring a mechanic. Likewise with the plant, the broader goal is to evolve it into a much more reliable state rather than just keep repairing things all the time.

Vibration analysis works best when data is trended over time. For trends to be meaningful, the data must be collected the same way every time. This means the same test conditions (e.g., speed and load), test points, test configurations, sensor, sensor mounting, etc. Data collection must be a well-defined, well-documented procedure that anyone can follow. Because trending is essentially looking for change, you can get your software to do most of the work if it is set up correctly. This involves creating good alarms or baselines and utilizing all the alarm and reporting features of the software. The trick here is to essentially tweak the software until it gives you the diagnosis that you want. As you get better at tweaking the software, assuming it has advanced alarm capabilities, and refining the alarms and baselines, you begin to trust the reports the software generates and spend less and less time doing manual analysis. This makes the program more efficient and the diagnoses more accurate. What this implies in terms of personnel is that they need to have good computer skills and enjoy spending a lot of time in the office tweaking the software.

A barrier to creating a program with well-defined processes and procedures and getting the software set up to do most of the analysis work is the "expert complex." The expert is the one who wants to make the plant reliant on him or her, or wants to hide or keep secret what he or she is really doing. The main cause of this is usually fear: Fear that if other people can do the job, this person might get fired, or fear that if anyone actually looked too closely at what he or she is doing, it may be discovered this expert is not much of an expert after all. Even if the expert does provide accurate results, the truth is that many programs fail when the so-called expert leaves. This isn't because the person is so great that he or she cannot be replaced, rather it's because there is no documentation of what the person did. Therefore, no one knows how to test the machines in the correct way to keep the baselines and trends meaningful. No one knows which machines in the database match the machines in the plant, or which alarms and baselines are set up correctly, that is, if there even are baselines and alarms configured in the system.

The expert complex is also common in consultants. When looking for an employee or a consultant, it should be clear that you are not hiring to become dependent on the person. You are hiring the individual to help you set up a program that can eventually be run in this person's absence. You are hiring the individual to be transparent, to teach and to share. An employee or consultant who does this will never lack work. There are always more problems to solve. In the case of a consultant, make it clear in the contract that you own the data and the database. It should be noted that a large part of the program is defining repeatable test conditions and creating alarms or baselines around them, in other words, defining procedures and setting up a database. This is what you are investing in, not just a monthly report.

Right Leadership

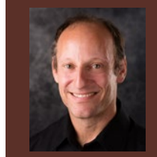
What is condition monitoring and proactive maintenance really about? It's about changing how you make decisions and solve problems. It is about getting out of a run to failure, reactive mind-set and ultimately, it is about organizational and cultural change. Nobody likes change, which is one reason so many programs fail. In terms of personnel, this means the program is going to need a champion; a leader. Someone who believes that change is possible and is willing to put up a fight, document both the financial and technical benefits, and make the case over and over again that these efforts are benefiting the company's bottom line.

When employees keep getting pulled away from their work setting up the condition monitoring program to react to machine failures and put out fires, it takes a strong leader to rein them in and keep them focused on the goal. Right leadership is all about keeping your eyes on the prize and keeping your team focused on the work that is the most beneficial, not the work that is screaming for the most attention.

> Right leadership is all about keeping your eyes on the prize and keeping your team focused on the work

The best person for any job is someone who loves the work. Vibration analysis is not an easy technology to master, nor is it something people can master in the little bit of free time they have between putting out fires and completing their other work. Running a vibration program requires a diverse set of skills (although they can be divided among the group), a large commitment of time, resources and expertise to get a program up and running, and consistency to keep it going over time.

But people and leadership are only part of the puzzle. To have a successful program, one needs to have all 10 components in place: Right goals, right people, right leadership, right tools, right understanding, right data collection, right analysis, right reporting, right follow-up and review and right processes and procedures.



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Leadership for Reliability

Bristol-Myers Squibb Journey

Part 1

Initial Implementation and Prioritizing of Uptime Elements

(Dec/Jan 2016 p. 30)

Part 2

Aligning a Framework Within Our Sites

Part 3

The Central Team's Effort Aligned to Our Strategy

Part 4

Journey to 200 CRLs

A Journey to Shape Reliability Excellence at Bristol-Myers Squibb

Aligning a Framework Within Our Sites

by George Williams and Robert Bishop

Uptime Awards — Best Maintenance Reliability Program

Part 1, published in Uptime Magazine's December/January 2016 issue, discussed the initial implementation of Uptime Elements at Bristol-Myers Squibb Company (BMS), including an exercise in which our sites prioritized the elements to determine our path going forward as a company. As we wrapped up our exercise, the sites were challenged with taking this framework back to perform similar exercises and integrate the framework into their local strategies. Part 2 demonstrates how the adoption of a common framework translates at the site level and how the unique use of this framework begins to drive the culture at BMS.

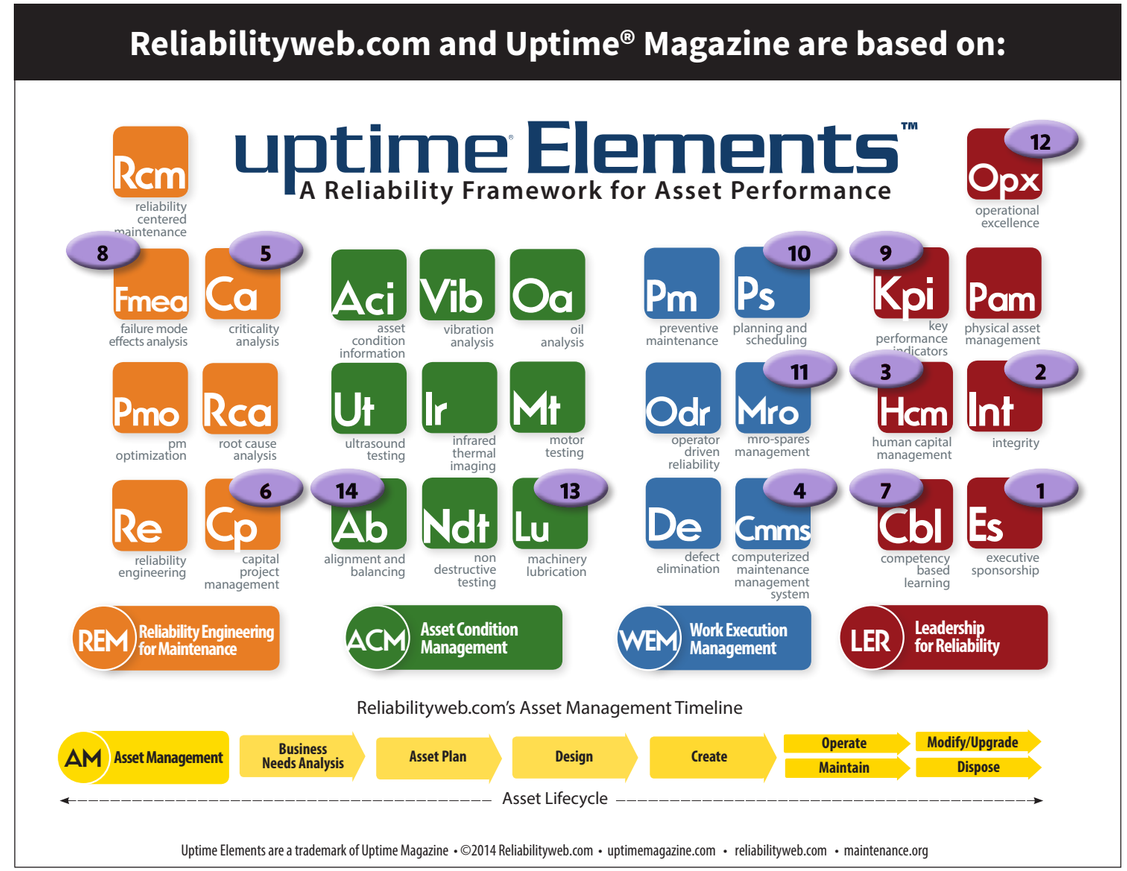

Figure 1: Uptime Elements prioritization developed at the Reliability Excellence Conference, October 2014

We left our conference with a sense of urgency and unity inspired by what our common path forward looked like and the opportunity ahead. Like any other amazingly inspirational and motivational moment within an organization, this one left us questioning afterward how to continue the momentum gained. How do we keep this going without losing steam and, more importantly, how do we take this new framework back to our sites and incorporate it? As a leader, your role is to set a vision, provide capability and, most importantly, get out of the way. The central team was to work on the elements prioritized by the team to develop the centrally governing base elements, but not to do so at a level that would impede progress and continuous improvement at the sites. Our approach was to wait. Wait for the sites to digest the framework and hopefully run with it.

And so we waited, not knowing if the sites had gone back and simply decided the framework had little value or if they were going to adopt it. Why did we wait? Simple, we were trying to create something bigger, something more than tasks, more than initiatives, something organic. We waited to ensure the sites would develop ownership of the framework, or not. Because only with a sense of ownership could we create a culture of empowerment. We planted a seed and were waiting for a grassroots, culturally aligned organization to sprout up and declare their independence as a unified community focused on reliability. And so we waited.

And listened. During our biweekly meetings where we discuss ongoing initiatives both at the sites and centrally, we hoped to hear progress. Sites are on a rotating schedule to deliver to the global community their current progress and any benefits realized, including details on implementation, struggles, lessons learned and next steps. Week after week went by, the anticipation turned into anxiety, and maybe even a bit of worry. Changing the direction of our strategy by implementing a new framework and doing so as described in Part 1 of this article presents some risk. It was time to see if the risk was going to pay off or cause confusion.

> Create something bigger, something more than tasks, more than initiatives, something organic

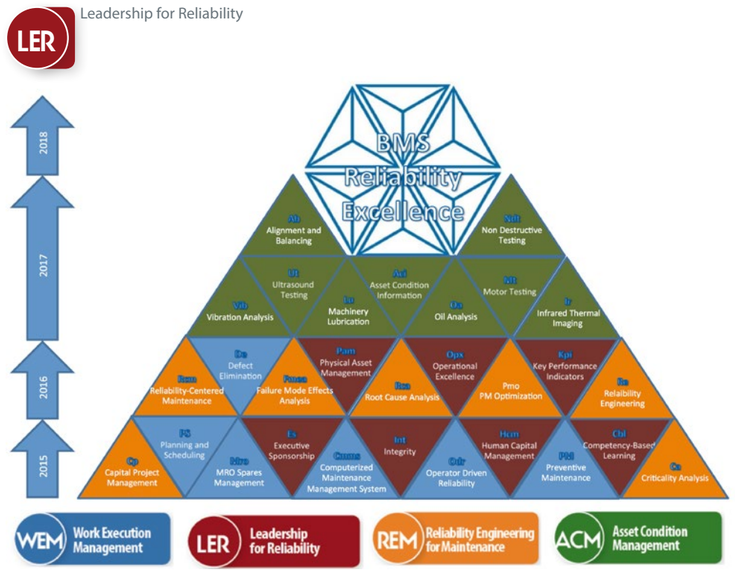

Figure 2: BMS Syracuse's strategy pyramid

Still waiting….waiting….then….spark, there it was. After four months of waiting, in March 2015, a site presented its initiatives and tied them to our community-developed prioritized elements. The site specifically detailed how its initiatives tied to the elements, demonstrating with communication boards throughout the site where the Uptime Elements were posted. A spark.

That's typically all it takes for a revolution. An adopter to an ideal, not the central driver, allowing others to see more clearly the potential that change can offer and providing the motivation to do so. The next month, we saw a breakthrough. Not only did this site provide its alignment with the global priorities, it did something we never even thought of – they showed creativity and ownership of the framework. There it was on the screen, an adaptation of the framework presented graphically. But more than that, it was an articulation of the site's path going forward from one element to the next covering more than three years. The plan was graphically represented as a pyramid and then detailed across a timeline with a plan for each element over the three-year period. The strategy, whole and complete, utilizes the framework, is owned locally and is easily communicated.

From the time we began, it seemed like forever for the central team to see adoption, ownership and commitment to the framework, but in reality, it was immediate. In speaking to our sites recently in preparation for this article, we found that all teams went back to their sites after our global conference and immediately began working on similar exercises. Most sites decided at the conference or on the way home that they were on a mission to align their efforts with the elements, discover opportunities and build a reliability infrastructure. As stated by one individual, "The first time I saw the Uptime Elements framework was an eye opener, like putting a face to a name. Immediately, we started working on a plan that would bridge what we were doing at the site and the Uptime Elements framework. It was simple, self-explanatory and easy to explain to others."

Each site went through its own journey, separate but independently similar. Some started from the ground up, others from senior management down, but in the end, the steps seemed to align in an organic way. All had the same steps in common: Reviewing the framework, site initiatives and areas of opportunity, and then, similar to the global team, prioritizing the elements and aligning them to their strategy. This took some time to coordinate, review, finalize, develop a working strategy around and create communications for the global team. All the while the central team was sweating it out.

Over the course of the next few months, much was the same from site to site. Each site approached the use of the Uptime Elements with a unique twist. We were all utilizing the same framework to come up with aligned, but unique, approaches to articulate our efforts. Each site leveraged the elements in similar, but very different ways. The organic nature of the elements (no pun intended) enabled the sites to link individual goals while aligning to corporate goals. This alignment was important to the overall reliability excellence direction of the company.

It is critical that the system you choose allows for everyone to leverage its structure while having individual creative freedom to develop solutions they can align behind. The Uptime Elements happen to provide a holistic approach to reliability that

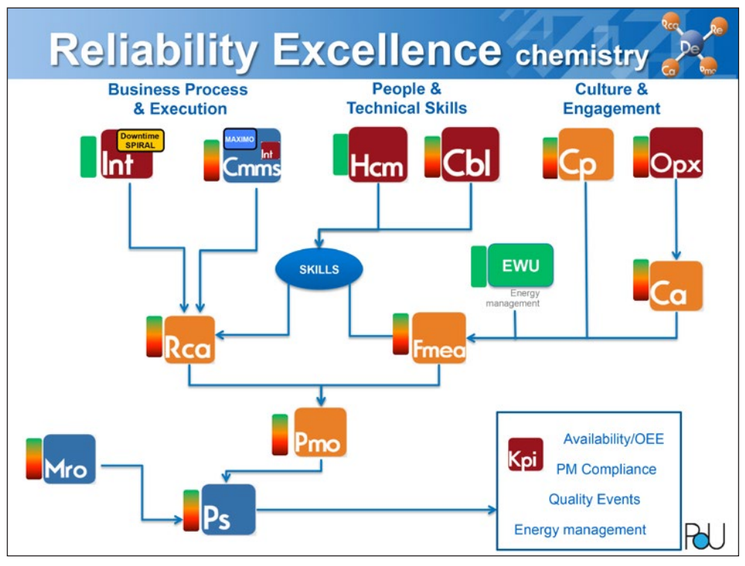

Figure 3: Example of site strategy using Uptime Elements

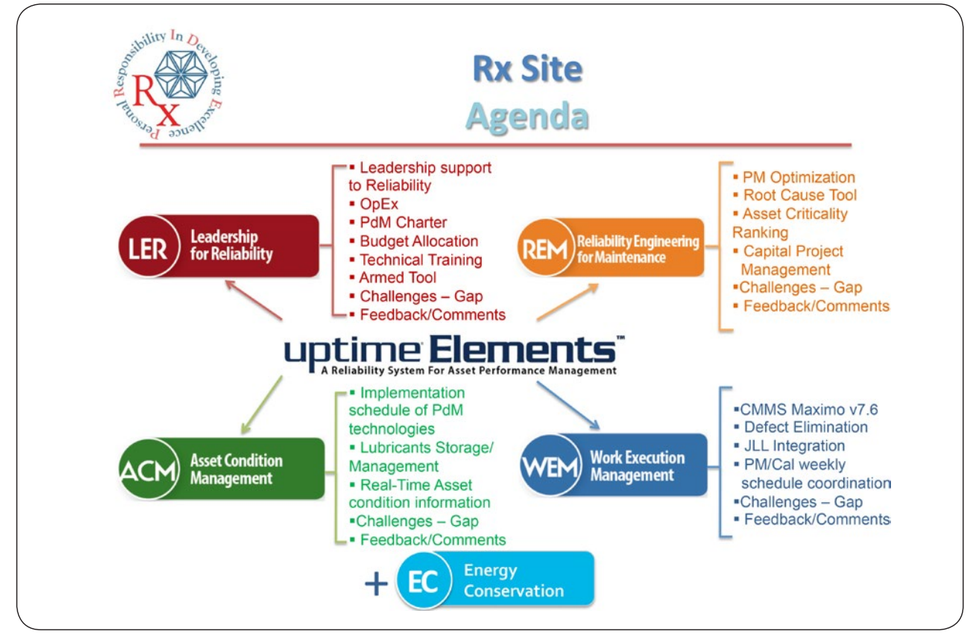

Figure 4: Example of site strategy using Uptime Elements

can be easily incorporated into your existing goals and facilitate further development and alignment of future goals. As you develop your strategy, it is important to have both structure and guided direction, but it is equally important when dealing with multiple groups to allow for the creative freedom necessary to instill a sense of ownership.

The ability to have complete creative freedom while being restrained to a defined approach is something this particular framework facilitates. One site started tagging all their projects with a correlating element. More than one site actually created new elements, such as Em (Energy Management), Ewu (Energy Work Unit) and Km (Knowledge Management). This demonstrated to us that the sites had grabbed ahold of the elements and taken steps beyond the core understanding. Only an excitement and true adoption of ideas would result in the expansion of this framework. Some groups even experimented with creating compounds from the elements, for example, if all conditions were not ideal or at minimal present, this element expansion would not occur. The framework provides an infrastructure, a foundation that enables success, but also can support both vertical and horizontal growth where an organization needs it. As the sites continue to spread this knowledge to more and more individuals the responses are best summarized as, "A powerful tool with great visual impact" and "An easy way to explain our way."

While we discuss this in terms of the framework's use, the key to this culture is a unified approach to communications, a common terminology and a clear vision for where we are going. The framework in and of itself does not drive this, but can facilitate it. What is driving this change is our people – a team dedicated to creating a culture of reliability, but using a framework to do so.

Creating a culture of reliability offers the ability to take full advantage of your team's potential. One site leader, when asked about the benefits seen, said: "The most significant benefit was the engagement of the entire maintenance team." Can you imagine the power of having the entire team engaged? Not only can you achieve results, but you begin to create something very special.

An organic culture has emerged within the company due to the sites utilizing a unified approach to articulate the strategy. It is a culture that is supportive, nurturing and spreads like wildfire as our team members feed off one another's creative input and successes. There is an environment of complete cooperation across boundaries and silos, one of knowledge sharing and not self-protection, and one where input from all over the world is welcomed, respected and discussed openly in an effort for the entire company to benefit.

So what are you waiting for? Anyone can plant this seed in their organization and it will grow with a little care and nutrition. Fortunately for you, there is an enormous network that can help you find that nutrition. Create connections inside this amazing industry full of professionals who genuinely look to help one another. Take that first step, be a leader, drive change, share the Uptime Elements framework within your organization and wait for a spark.

It's an exciting time at BMS in terms of reliability. To continue to foster this culture, we have set some goals for spreading the understanding of our framework. In the next installment, we will look at the role of the central team's effort to align with our strategy.

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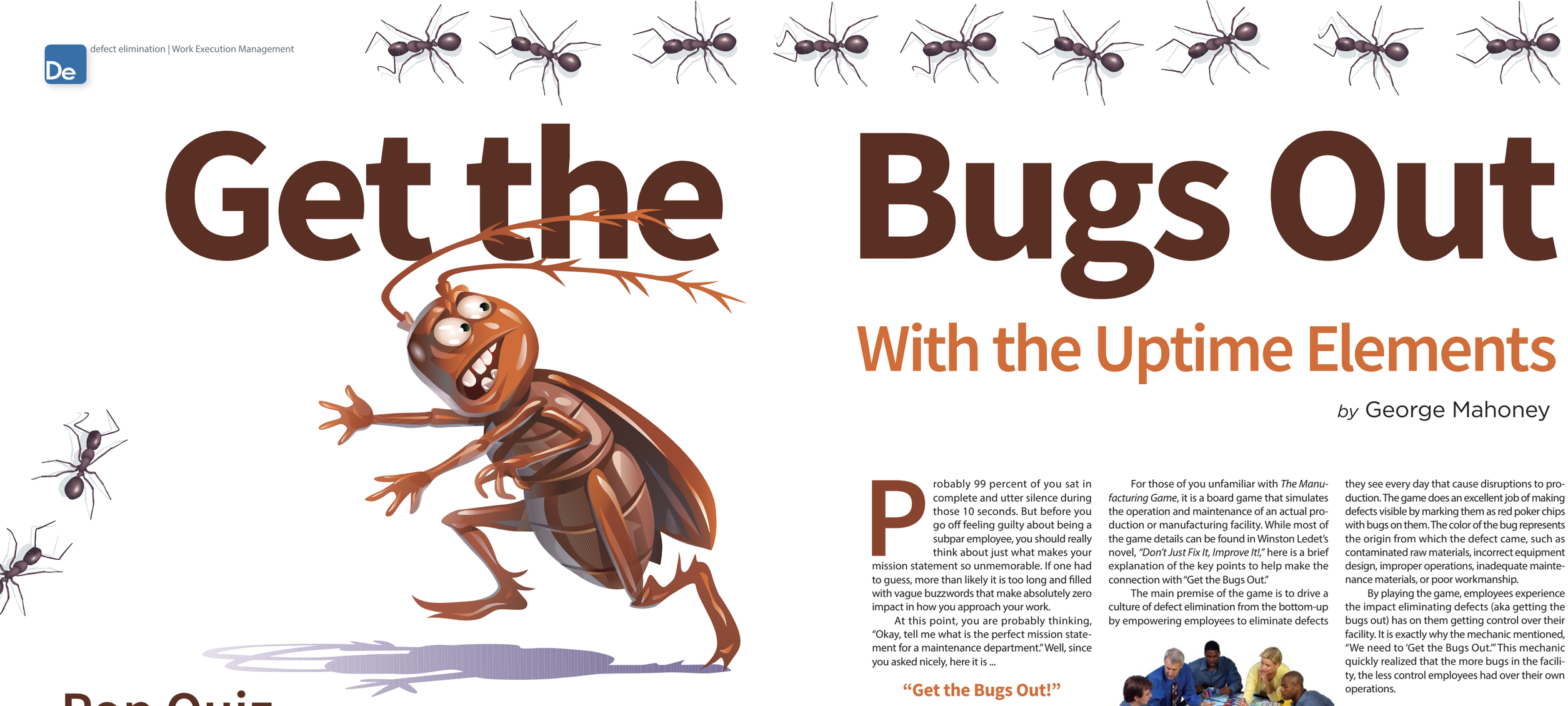
Get the Bugs Out

With the Uptime Elements

by George Mahoney



Pop Quiz ...

In the next 10 seconds, close your eyes and recite your maintenance department's mission statement. Ready ... 3-2-1 ... **Go!!!**

Probably 99 percent of you sat in complete and utter silence during those 10 seconds. But before you go off feeling guilty about being a subpar employee, you should really think about just what makes your mission statement so unmemorable. If one had to guess, more than likely it is too long and filled with vague buzzwords that make absolutely zero impact in how you approach your work.

At this point, you are probably thinking, "Okay, tell me what is the perfect mission statement for a maintenance department." Well, since you asked nicely, here it is ...

"Get the Bugs Out!"

It is simple (four words max).

It is concrete (everyone has seen thousands of bugs in their lifetime).

And most importantly, it creates a mind-set for how every person, from the maintenance lead to the mechanic, should approach every minute of their workday. Essentially, if you are doing something that is not going to help you "Get the Bugs Out," then you should not be doing it.

The Origin

"Get the Bugs Out" is a phrase a top mechanic said in 2012 while playing *The Manufacturing Game®*.

For those of you unfamiliar with *The Manufacturing Game*, it is a board game that simulates the operation and maintenance of an actual production or manufacturing facility. While most of the game details can be found in Winston Ledet's novel, *"Don't Just Fix It, Improve It!,"* here is a brief explanation of the key points to help make the connection with "Get the Bugs Out."

The main premise of the game is to drive a culture of defect elimination from the bottom-up by empowering employees to eliminate defects

Figure 1: A team playing The Manufacturing Game

they see every day that cause disruptions to production. The game does an excellent job of making defects visible by marking them as red poker chips with bugs on them. The color of the bug represents the origin from which the defect came, such as contaminated raw materials, incorrect equipment design, improper operations, inadequate maintenance materials, or poor workmanship.

By playing the game, employees experience the impact eliminating defects (aka getting the bugs out) has on them getting control over their facility. It is exactly why the mechanic mentioned, "We need to 'Get the Bugs Out.'" This mechanic quickly realized that the more bugs in the facility, the less control employees had over their own operations.

The Uptime Elements

One of the major benefits of *The Manufacturing Game* is that it introduces several of the Uptime Elements. Not only do game participants learn what some of the elements are, but they get to make a choice as to whether or not to apply the methodologies to their facility.

Having that choice is critical because it lets them experience for themselves the impact of using or not using one of the elements.

Here are some of the choices they have to make, with the corresponding Uptime Element in parentheses:

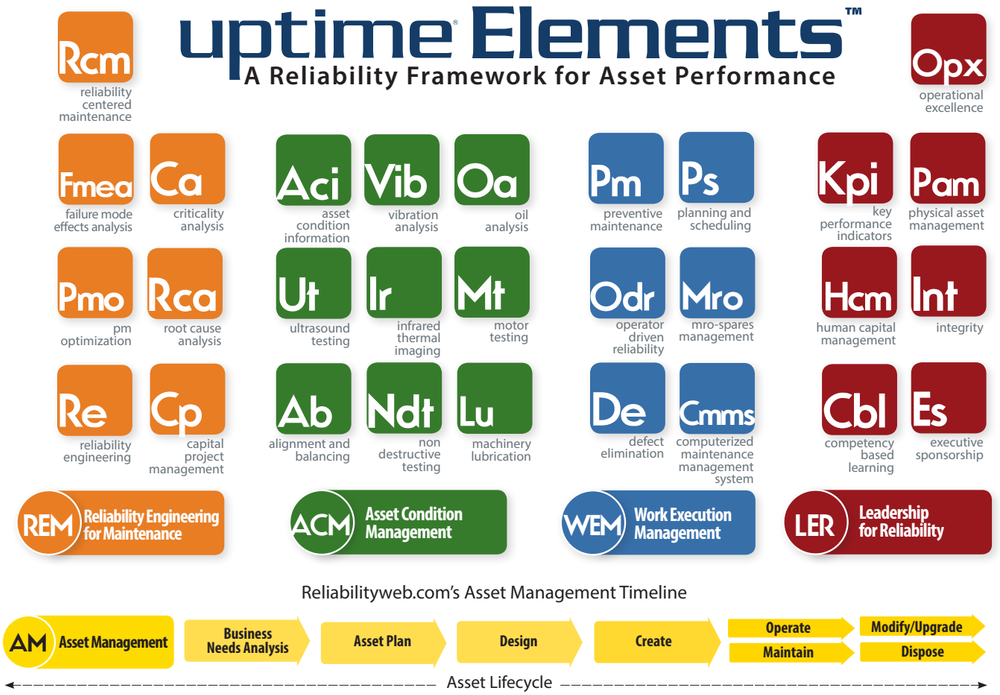


Figure 2: The Uptime Elements chart

- Do we use **asset condition management (ACM)** to prevent unexpected breakdowns?
- Do we use a **computerized maintenance management system (Cmms)** to **plan** and **schedule (Ps)** work orders to reduce the number of defects (bugs) added by rushed work and incorrect materials?
- Do we have our **maintenance, repair, operations (Mro) department** coordinate with maintenance and operations to ensure we have the right parts at the right time?
- Do we invest in **operator-driven reliability (Odr)** to help reduce operations-induced defects (bugs)?
- Do we utilize **key performance indicators (Kpi)** to help determine the main source of our defects (bugs)?
- Do we utilize **human capital management (Hcm)** as the driver to set up programs, like **preventive maintenance optimization (Pmo)** and **competency-based learning (Cbl)**, to help drive out even more defects (bugs)?

Linking The Two Together

The more you become involved in defect elimination, the more you will realize that the Uptime Elements are what is needed to help "Get the Bugs Out." While defect elimination provides the platform for the bottom-up culture needed to save your facility, the Uptime Elements provide the means to make it happen.

In the spirit of making things more concrete (just like your terrific mission statement), let's take a look at exactly how the Uptime Elements can help "Get the Bugs Out."

Finding the Bugs

Asset condition management (ACM) and **Odr** can help you spot the bugs early enough on the P-F curve to avoid a catastrophic failure. If you catch the bug early enough, you may even have enough forensic evidence left to help you find the source of the bug. For example, caught early enough with vibration analysis, the wear patterns on a bearing could tell you the source of the bug was misalignment.

Finding the Source of the Bugs

Root cause analysis (Rca) and reliability engineering (Re) can help you determine the true source of the bug. Knowing the true source can help you stop it from coming back the next time.

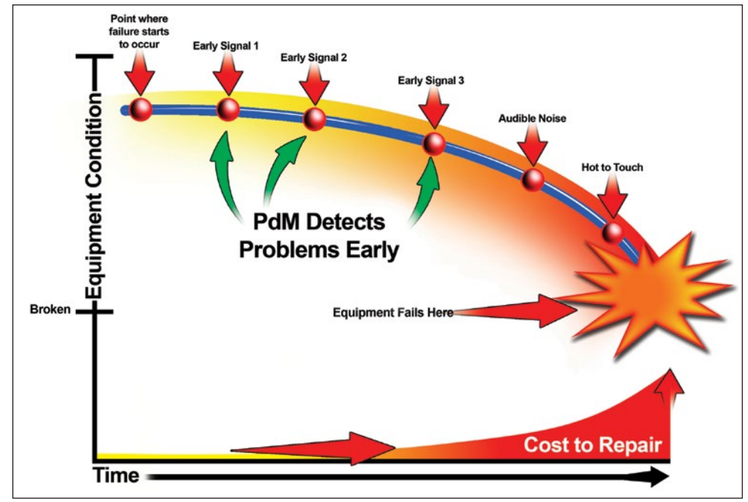


Figure 3: A P-F curve showing early identification of a defect

Efficiently Removing the Bugs

Planning and scheduling (Ps) and Mro can help you remove bugs as efficiently as possible. If your facility is riddled with bugs, you don't have time for mechanics to search the plant for three hours for an agitator seal, only to wait another two hours for operations to de-energize the vessel and get the permits ready.

Preventing Bugs From Coming Back

Competency-based learning (Cbl) and Odr can help correct the work habits that caused the bugs to enter your system in the first place. It does you no good to use RCA to tell you the bearing failed due to over lubrication if you do not provide your mechanics or operators with the right tools, time and training to lubricate things properly.

Criticality analysis (Ca) and **Pmo** can be used to ensure the right **preventive maintenance (Pm)** tasks are executed on the right equipment at the right time. While you cannot PM your way out of every problem, it will help you minimize the bugs that come in due to normal wear and tear. (Not coincidentally, you give yourself a good chance of letting equipment last long enough to see normal wear and tear if you utilize **Cbl** and **Odr**.)

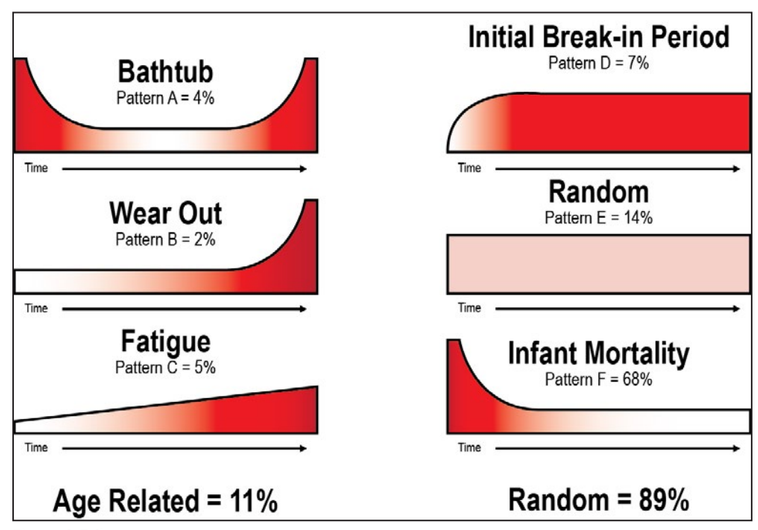


Figure 4: Failure patterns

Prevent Bugs From Ever Coming In

Reliability-centered maintenance (Rcm), failure mode and effects analysis (Fmea) and **capital project management (Cp)** are all very effective ways to get ahead of problems before they are ever introduced. If you identify how bugs can "infect" your process early enough, systems can be created so the equipment can be designed, operated and maintained with minimal introduction of defects.

Providing the Platform for Bug Removal

None of the previously mentioned actions are possible without **leadership for reliability (LER).**

- **Executive sponsorship (Es)** provides the resources (e.g., time, people, funding and tools) to eliminate the bugs.
- **Human capital management (Hcm)** ensures the people eliminating the bugs will be seen as more important assets than the "assets" themselves.
- **Integrity (Int)** ensures the bugs are being removed for the right reasons...to protect the well-being of the people in the company and the customers they serve.

Your Mission

After reading this article, go and make it your personal mission to help your site "Get the Bugs Out" with the help of the Uptime Elements. Trying to do one without the other is like trying to make a ham sandwich without the ham or the bread. It is just not possible.

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George Mahoney *currently acts as the Reliability Excellence Lead for Merck in North and Latin America. In addition, he serves as mentor, sponsor and instructor for Merck Six Sigma. He is an expert at making lean methodologies and continuous improvement a part of everyday life for an organization. From the shop floor to the executive board meeting, George will find a way to eliminate non-value added work so you can focus on what is important without distraction.*
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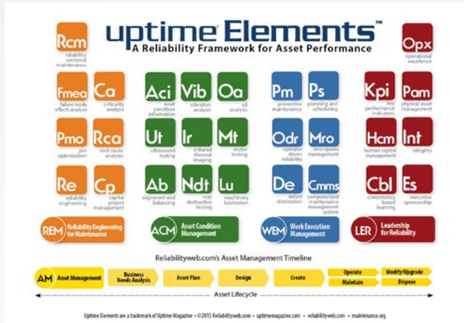

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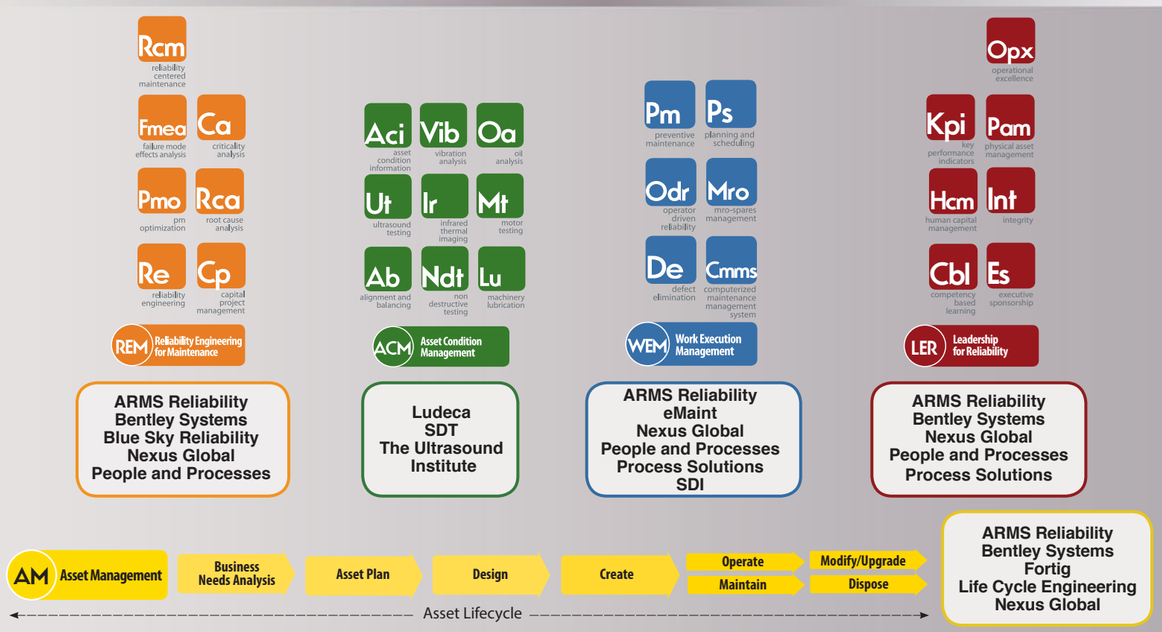

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Internet of Utilities Asset Management

by Praveen Kumar Agrawal and Sunder Rao Edulapally

With the advancement of new technologies, the world is moving toward intelligent devices and assets. Although sensors have been around for a long time, they have always been local to a machine and do a specific job, without much communication to the outside world. But if these sensors can communicate with other sensors, machines and human beings over the Internet, then this setup can form an Internet of intelligent devices.

This interconnected intelligent device setup can further be augmented by software, simulation techniques and algorithms to bridge the gap between information technology (IT) and operational technology (OT), and thus help machine operators and supervisors to quickly find a problem area, make quick decisions and act to reduce machine failure.

This point of view delves into this phenomena of smart connected devices and assets, their real-time interactions and overall impact on utilities.

The Asset Management Issue

Asset management is a critical function for asset-intensive industries, especially utilities. Over the decades, many asset management philosophies and frameworks have been introduced in the market and many software application vendors supported these thoughts in their asset management solutions. These asset management solutions helped organizations to understand their assets and accordingly, strategize investment and maintenance programs.

But these asset management software solutions alone are not able to provide useful information for decision-making in operating critical assets. These solutions require a significant amount of data for effective functioning and thereby, significant efforts in collecting this data. Still, the objective of having the right information on a real-time basis is not being achieved and is not sustained as information changes over time due to modifications in asset attributes. This problem is omnipresent in utilities with aging infrastructures and geographically distributed assets exposed to a wide variety of hostile environmental conditions.

Utilities have tried to gather real-time machine operating parameters by using supervisory control and data acquisition (SCADA) for utilities, but the SCADA systems are mostly used for network monitoring and operational purposes and don't provide real insight into asset functioning.

How IoT Can Help Asset Maintenance

Today, utilities struggle to find exact fault locations and related asset condition. Field crews and supervisors spend significant time trying to find the exact location and reason of faults, thus causing a delay in rectifying faults. Electrical utilities have some level of maturity if they are using an outage management system (OMS) for finding failure location, but that too provides only basic information and requires human intervention to complete the details. Generally, water and gas utilities have no such mechanism, as the assets and networks in these utilities are much more aged than electric assets and often are not connected with SCADA or OMS.

Internet of Things (IoT) enabled machines, with the help of sensors attached to them, can communicate their geographical information, operating parameters of all connected devices, environmental parameters and many more information elements over the Internet to machine operators and supervisors on a real-time basis.

Utilities invest a significant amount of time, money and effort to do repetitive inspections to avoid faults and outages. But the majority of these inspections can be avoided if utilities' assets are IoT enabled so they can communicate information about the asset condition before failure.

Imagine IoT enabled assets communicating information over the Internet so finally the exact location of the outage is determined and maintenance crews are informed about the outage in no time. Then, the outage information and location can be directly posted to social media without human intervention and communicated to utility customers. The whole process can be automated to the extent of automatic scheduling and dispatching of maintenance crews based on their real-time availability, location and skills. Request for permits can be automatically initiated based on the nature of fault.

Another example of automation could be the installation of smart and intelligent poles and streetlight holders. They can make streetlight inspection totally automatic, as the holders can directly communicate to the IT system that a bulb is non-operational. This way, maintenance and stores personnel are well-informed about the quantity required and where to replace.

Conclusion

The IoT is changing the world and utilities are no exception. Lots of maintenance money currently being spent on repetitive inspections based on old-school thoughts and aging infrastructures can be saved with IoT. Machines can speak about themselves before the failure and provide automatic alerts, thus kicking off the whole predictive maintenance engine.

However, because utilities have relatively old infrastructures compared to other industries – 50 to 100 years old in many cases – it will take some time before utilities start realizing the IoT benefits.

Praveen Kumar Agrawal *is a Consulting Partner in Energy and Utilities business unit at Wipro. He is a subject matter expert and recognized force in the industry in asset management and ERP, with knowledge levels spanning across industries. Praveen has global experience executing various EAM and ERP projects for energy and utility companies. He has been researching the asset management market for close to 20 years. Praveen's views on Asset Management can also be read at http://eaminsights.com/. www.wipro.com.*

Sunder Rao Edulapally *is a Senior Consultant in Energy and Utilities business unit at Wipro. He has 15 years of experience in asset management and has implemented Oracle EAM and IBM Maximo in the wastewater, alumina refining, power generation and electricity distribution industries. www.wipro.com*

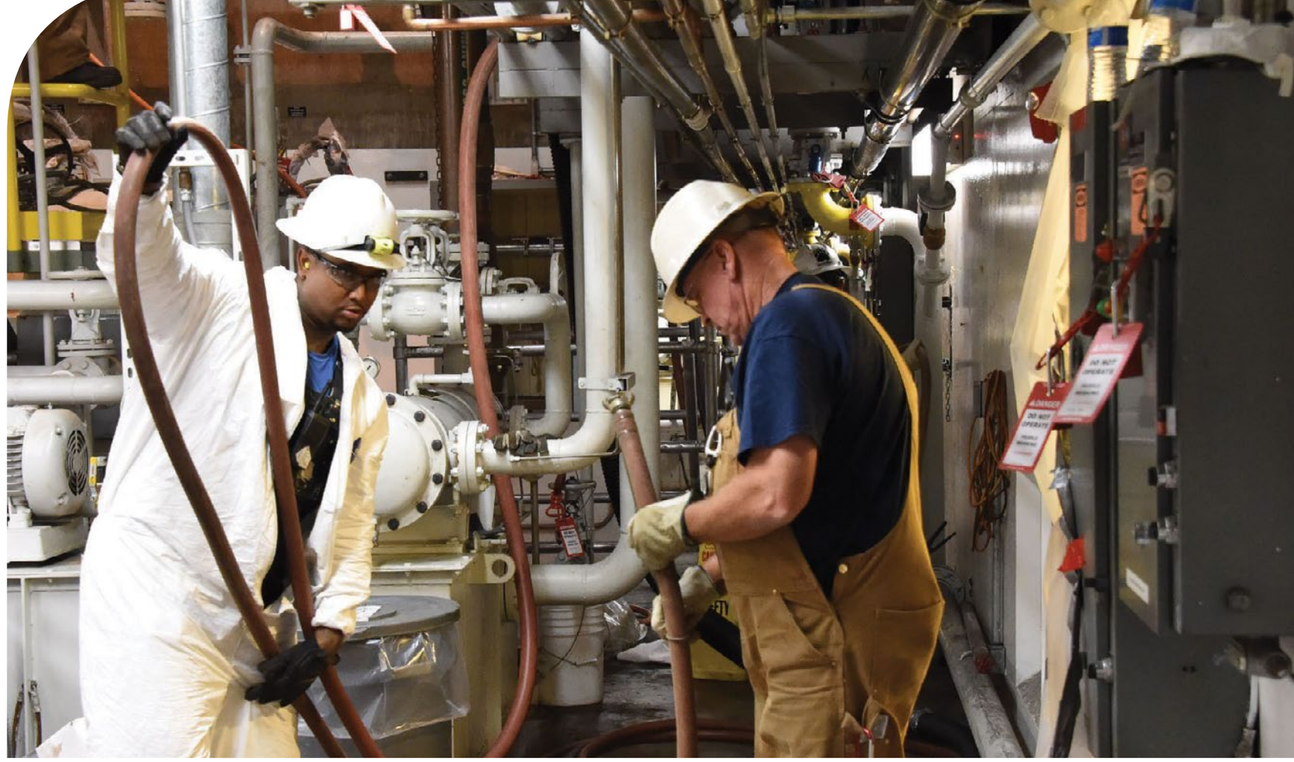
Leadership in Reliability

Central Arizona Project

by Tim Allen

Most people are aware that the State of Arizona has grown considerably over the past few decades. In fact, according to the U.S. Census Bureau, the state's population grew 40 percent from 1990 to 2000, second only to Nevada. Phoenix, the state's largest city, stands today as the nation's sixth largest city and is poised to be fifth soon. Interestingly, the five cities besting Phoenix in population all reside on great bodies of water along the East Coast, West Coast, Gulf Coast and Great Lakes, each with a river, port and shipping fleet. Contrast that to the metropolitan area of Phoenix with 4.4 million people living in a desert community with an annual average rainfall of less than eight inches. Ever wonder how that is even possible?

In 1968, thanks to the hard work of Arizona visionaries, the U.S. Congress approved the construction of the Central Arizona Project (CAP) to bring renewable Colorado River water to the arid metropolitan regions of Phoenix and Tucson, and the irrigated farmlands of central Arizona, areas that previously depended on nonrenewable groundwater. Operational in 1985 and substantially completed in 1993, this 336-mile aqueduct delivers over 1.5 million acre-feet of water annually with the contribution of 14 pumping plants. Daily, it has the capacity to push 2 billion gallons of water "uphill" from Lake Havasu toward Phoenix and terminating 2,900 feet higher in the City of Tucson. Built by the U.S. Department of the Interior's Bureau of Reclamation, CAP is maintained and operated by the Central Arizona Water Conservation District (CAWCD), a municipal corporation employing 475 people and governed by a board of directors elected by the residents of Arizona's Maricopa, Pinal and Pima counties.



As you can imagine, the reliability of CAP is paramount. CAP is a raw water wholesaler to municipal and private utilities, industry, agricultural lands and Native American tribal communities. Customer water reserves must be replenished daily. There is an expectation by all who live and work in Arizona that water will be available when they need it. CAP water deliveries directly and indirectly generate almost half of Arizona's gross state product, according to an Arizona State University study. As such, CAP has a responsibility to operate continuously 24 hours per day, each day of the year, for generations to come.

To ensure an uninterruptible water supply, CAP has had to adapt its approach to maintenance over the years. In 2003, CAP's maintenance leadership set out to transform a largely reactive maintenance culture to a proactive one, with an engineered, planned and scheduled maintenance program. This program, structured within an organized framework, originated with the outside assistance of Life Cycle Engineering and became known as the "Maintenance Excellence Program." It is based on a shared belief system to achieve reliability with worker safety as its foremost priority. In short, the objective is to set CAP on a pathway toward world-class maintenance organization status.

CAP adopted a framework of 21 building blocks to efficiently manage its critical assets and to base measurements of progress. The program, which continues today, is founded on teamwork and work processes too numerous to list, but major aspects include investments in training, tools and equipment, a computerized work order system, a digital technical library and a

A Available | R Running | S Scheduled Outage | F Forced Outage | G Generating

Description	Pump 01	Pump 02	Pump 03	Pump 04	Pump 05	Pump 06	Pump 07	Pump 08	Pump 09	Pump 10	% Available
MWP (MARY WILMER)	A	R	R	A	R	A					100%
BSH (BOUSE HILL B)	A	A	A	R	R	R	R	A	A	A	100%
LHQ (LITTLE HARQUAHALA)	A	A	R	R	S	R	R	R	R	R	90%
HSY (HASSAYAMPA)	A	A	A	R	R	R	R	A	A	A	100%
WAD (WADDELL)	A	S	S	R	R	A	A	R			75%
SGL (SALT GILA)	R	R	R	A	A	S	S	S	S	S	50%
BRD (BRADY)	R	A	A	A	F	A	A	R			88%
PIC (PIGEON)	A	A	R	R	A	A					100%
RED (RED ROCK)	R	R	A	A	A						100%
TWP (TWIN PEAKS)	S	S	R	R	R	S					50%
SAN (SANDARIO)	A	R	A	R	S	R					83%
BRW (BRAWLEY)	S	R	A	A	R						80%
SXV (SAN XAVIER)	R	A	A	A	F						80%
SND (SNYDER HILL)	A	A	A	S	S	A	S	A	R		67%
BLK (BLACK MOUNTAIN)	A	A	R	A	A						100%

Figure 1: CAP's maintenance management dashboard.

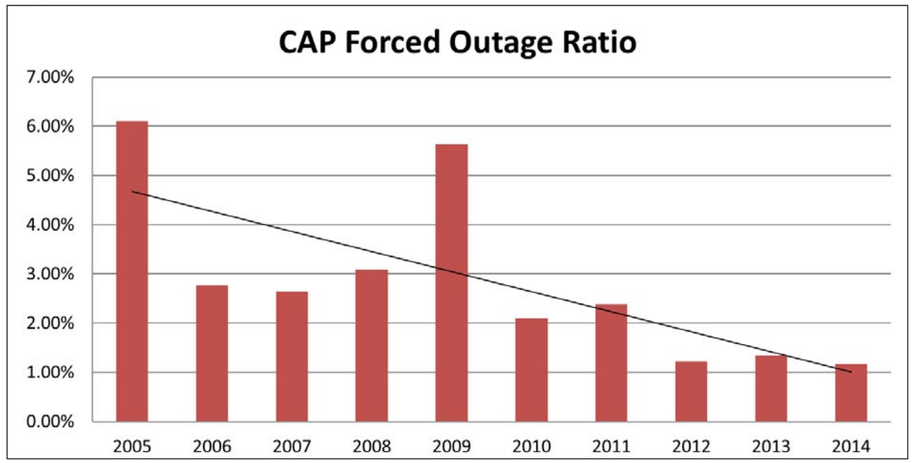


Figure 2: Reliability metric measures CAP's main unit pumps' forced outage rate, which has declined 80 percent since 2005

data repository network. CAP formed a centralized planning and scheduling department and organized into maintenance responsibility centers for the budgeting and execution of maintenance work. As the program progressed, continuous improvement activities were driven by asset management teams that hold bimonthly "town hall" meetings to assess reliability results and devise new strategies. Equipment maintenance plans were engineered and detailed preventive maintenance (PM) procedures were developed for all major systems and assets. Other notable activities include the design of an interactive maintenance management dashboard system which displays live availability status for all 109 of CAP's pumping units.

These changes did not come easy and required the prolonged dedication by many over the years. But the strategies paid off, as reliability and safety records improved. In 2010, CAP employed the services of CH2M Hill to assess and benchmark CAP's practices against other leading water utilities. The assessment scored CAP high against 41 international water sector agencies and concluded the maintenance program ranked in the category of "Excellence." CAP was well on its way to world-class status, but there was more to do.

A missing element on the road to excellence was the establishment of a reliability-centered maintenance (RCM) program. In 2013, CAP enlisted People and Processes to train the staff in the RCM process. The next year, CAP created a reliability engineering department to work hand in hand with the maintenance engineers. CAP also adopted Anthony "Mac" Smith's Classical RCM process and Mac, along with condition-based maintenance (CBM) expert Jack Nicholas, visited and advised CAP on its approach.

CAP has been an epicenter of RCM activity the last two years as reliability teams organize, execute and implement RCM initiatives. Facilitated system analysis workshops are a team effort involving reliability and maintenance engineering, maintenance crafts and trades, plant supervisors, maintenance management and operations. So far, nine complete systems have been analyzed, covering over 300 unique assets and 1,700 failure modes. Implementation has progressed well with five systems complete with new procedures written and tasks activated in CAP's computerized maintenance management system (CMMS). Many new and innovative condition-based strategies have been devised to replace traditional, time-based tasks. Moreover, numerous asset modifications were initiated to enhance reliability performance. These RCM workshops have been well received by the process participants and work to establish buy-in with CAP's asset maintenance professionals. RCM is becoming core to the maintenance culture, the basis for engineering and for improving planned maintenance requirements to preserve critical system operations. Future plans include RCM as a means of design review for CAP's capital projects.

There is much left to do, including the prioritization of future RCM efforts, coding CMMS corrective work orders to the failure mode level, and following up and auditing RCM results. CAP also must develop an enterprise system to consolidate and manage more than 30 predictive and asset condition processes for better trending, notification and preemption of system failures and forced outages. Additionally, maintenance managers are working on incorporating Reliabilityweb.com's Uptime Elements reliability framework into all processes.

Still, the efforts of the past 12 years have realized significant results. Following the 2011 development of CAP's strategic plan, the senior management team developed five major corporate goals for all employees to strive for. Among these "Big 5 Goals" were measurements for safety, budget and reliability. Related metrics in these areas are shown in Figures 2 through 4 and demonstrate that improvements have been occurring for some time.

CAP will continue to face maintenance challenges as its assets age. Also, it will need to combat the elements and fight biological invasive species, such as quagga mussels, throughout its aqueduct. But the CAP team is up for the task.

We are extremely proud and honored to have been selected for Reliabilityweb.com's Uptime Award for Best Reliability Leadership. Truth be told, champions of maintenance excellence, RCM, PM optimization, planning and scheduling, CBM, precision work execution and so on, have emerged in all pockets and all levels of the organization. Pride in our work and mission is the CAP way!

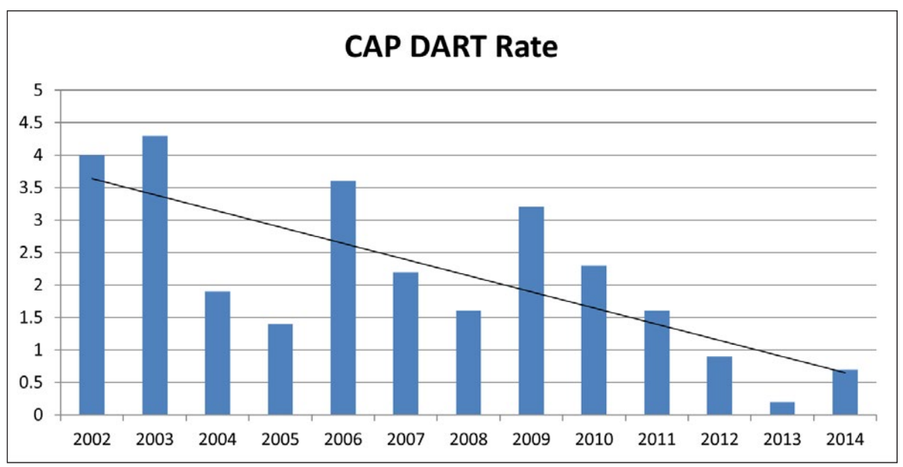


Figure 3: Lost time injury rate has declined substantially since establishing maintenance excellence and other initiatives, including the Voluntary Protection Program partnership with OSHA

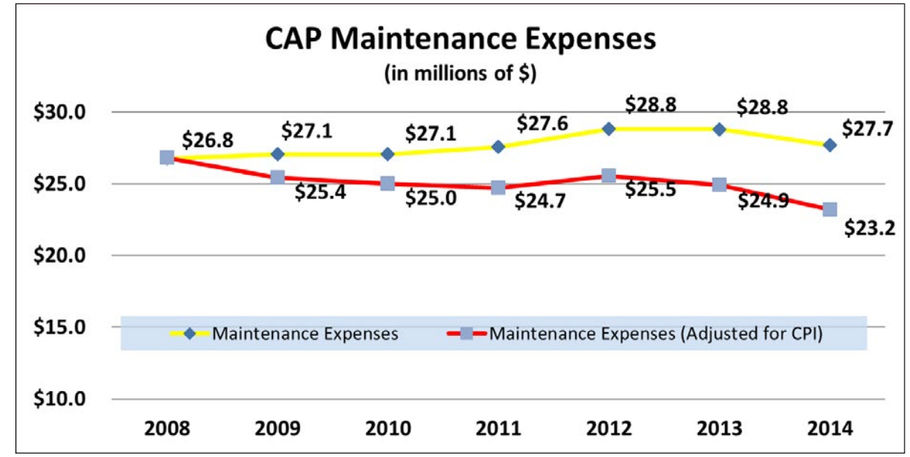
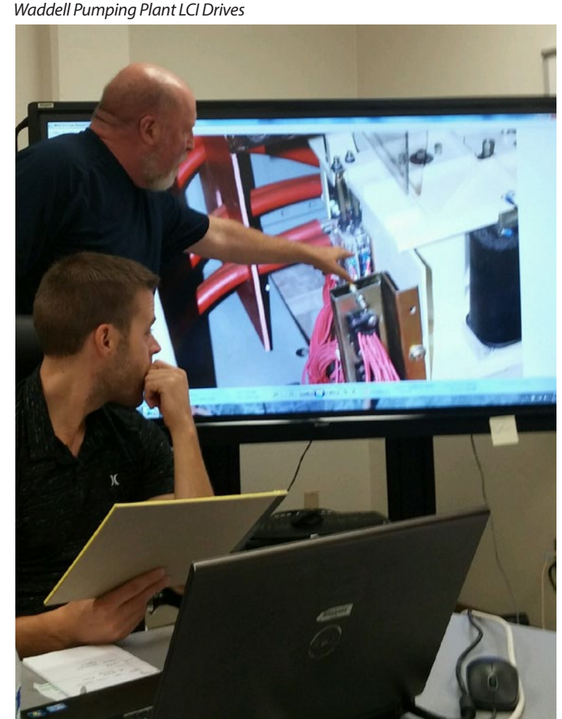


Figure 4: Reliability improves asset affordability as total maintenance expenses, adjusted for inflation (consumer price index), declined by $3.6 million per year from 2008 to 2014; improved outage planning and scheduling also was a contributing factor in this 13.4 percent reduction

Reliability Engineers, Jon Reisner and Bob Wagley, during a RCM Workshop for Waddell Pumping Plant LCI Drives



Tim Allen, CRL, CMRP, *is the Reliability Engineering Supervisor for the Central Arizona Project. Prior to working for CAP, Tim enjoyed a 20-year civil service career with the US Navy and served as RCM Program Manager for the submarine group. Tim spent 8 years as a reliability consultant with AMS Associates.*
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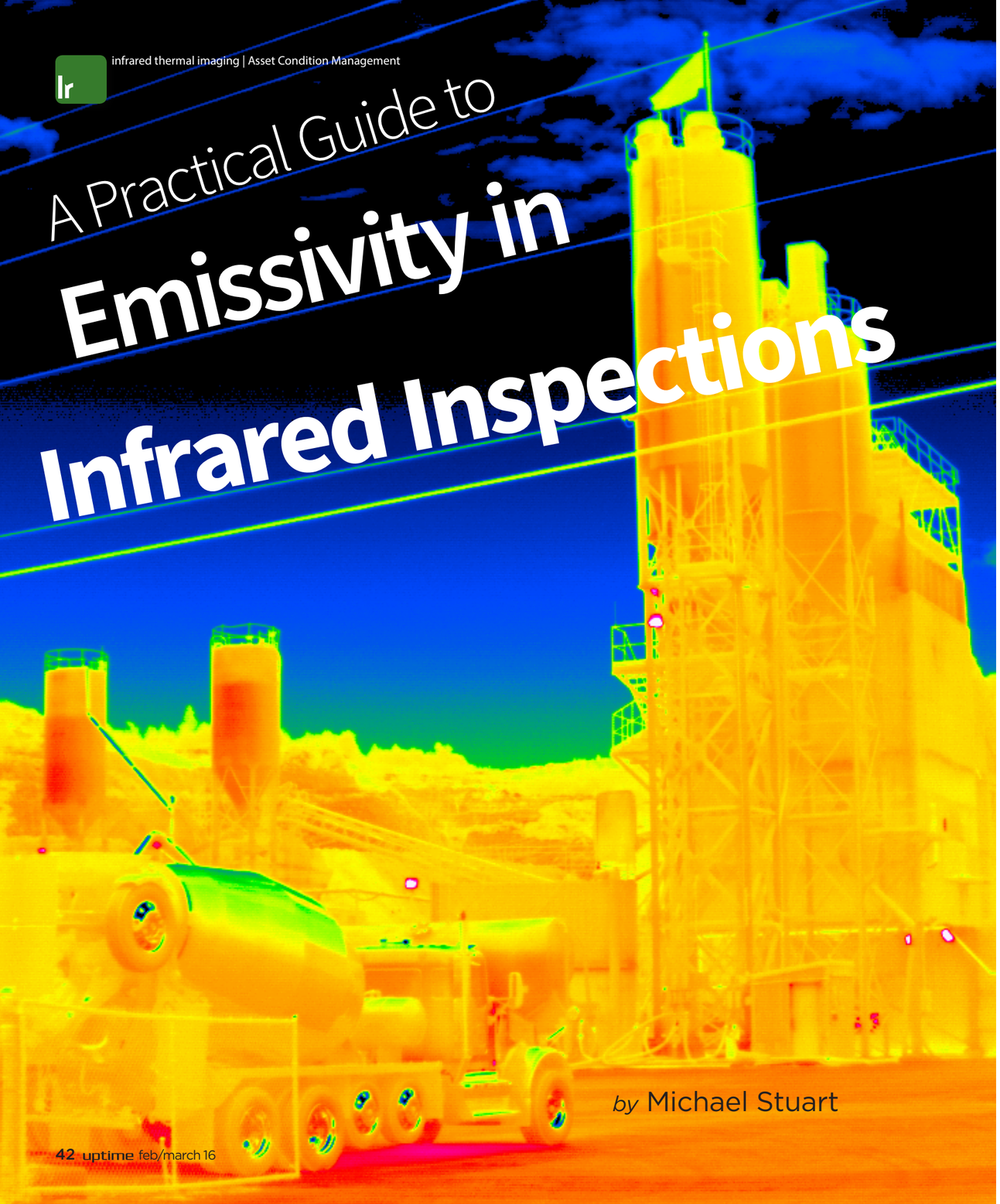
A Practical Guide to Emissivity in Infrared Inspections



by Michael Stuart

Many of you are probably familiar with spot temperature guns, those infrared (IR) test tools where you point a laser beam at an object (e.g., motor, pump, fluorescent light ballast, air conditioning or heating duct, or your barbecued steak). Point, shoot and voila! You have a temperature on the LCD display.

Nowadays, it is likely that you have done the same thing with an infrared camera, also known as a thermal imager. Not only does the infrared camera give you a temperature number, it also gives you an often fascinating image of what appears to be happening with your object of interest. Technology is great, huh? It's certainly easier, and safer, than putting your hand on something or using a contact temperature thermocouple.

But have you ever looked at the screen of a spot IR tool or an infrared camera and scratched your head saying:

"That just cannot be; no way is it that hot or that cold! I know everything is running fine here."

Maybe you thought: "This thing just isn't working right. Maybe the batteries are low."

What IR Cameras Measure

Spot IR guns and infrared cameras don't actually "measure" temperature. (You might be raising your eyebrows right about now, thinking: "The number is right there on the screen.") But guess what? Those infrared tools don't really "measure" temperature!

However, all is not lost. These tools are still unbelievably useful and often critical for individuals involved in maintenance reliability in facilities and plants.

This article will be a refresher for some, but for others, (those with raised eyebrows, perhaps) it will be a deeper, practical understanding about how IR cameras work. This knowledge should help you make better diagnoses and decisions, and ultimately get the job done with greater confidence and less frustration. While this article will not go into the detailed mathematics and hundreds of years of science behind how it is known what is really going on, it will cover the truth of the situation and tell you what you need to do to deal with it and move on with your work as usual. The only difference is that

Figure 1: An infrared camera can provide useful information about apparent hot and cold spots in electrical cabinets, but results can be misread unless you understand how different materials emit heat

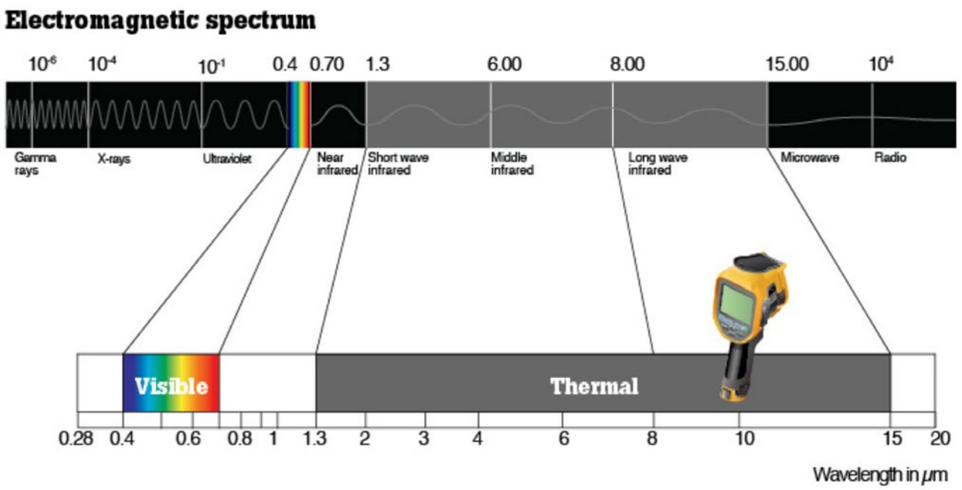


Figure 2: The electromagnetic spectrum covers many types of energy, including radio waves, X-rays, high energy gamma rays and even visible light; infrared cameras detect wavelengths that are outside the visible spectra and most commonly associated with heat

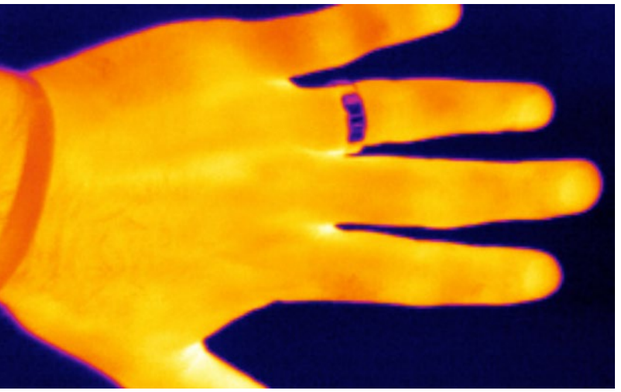


Figure 3: An example of how emissivity can affect an infrared image, as the ring is the same temperature as the hand, but due to a lower emissivity value, the ring does not emit as much infrared towards the camera; it also reflects infrared from cooler areas, so low emissivity and high reflectivity make the ring appear significantly cooler

you will now be armed with practical knowledge. This knowledge will make things go faster and help you get better results.

Think about this: Did you ever notice a pattern relative to the times you thought the temperature value was off for the type of material or surface you were inspecting? Did you notice that shiny objects made of metals or highly polished surfaces seem to have a role in whether your spot IR gun shows strange readings or your infrared camera shows peculiar hot or cold spots that you know could not be correct? Don't worry, this is completely normal and should be expected with some types of equipment and component surfaces.

Now, back to what IR cameras measure and how that can help answer why those temperatures are likely off.

All About the Heat

Thermal imagers (infrared cameras) and spot temperature tools don't actually see "temperature." They see infrared energy, otherwise known to most of us as "heat" energy. This infrared energy is all around us in the universe, in varying amounts. Some things produce heat. Some things absorb heat. Some things reflect heat. Heat is always flowing from where it is in high amounts to areas where there is less heat. This energy is moving.

Infrared cameras, like what most of you have in your plants today, can see heat coming off the surfaces of objects that you are inspecting. Most have passive detectors that work like the human eye, except they see infrared heat energy, whereas the eyes detect visible light energy. Just like human eyes are able to detect different colors of visible light, an infrared camera can detect different amounts and levels of infrared energy, and where it is moving. Are you following so far?

Why Material and Type of Surface Matters

A thermal imaging camera sees infrared energy coming from all over, such as the piece of equipment you are inspecting, the ceiling, the floor, other equipment, etc. Different surfaces can absorb, give off, and reflect infrared energy in different ways. Some materials can even have some infrared heat energy traveling through them. This is not unlike the energy that makes up visible light. With visible light, some objects reflect all of it or only certain colors. Some objects absorb all visible light. For example, black is actually a lack of color. Other objects, like common glass, allow much of the visible light to pass through.

Let's apply this same concept to infrared energy, or heat. It is an easy way to think about it and the parallels are very close. Just keep in mind that the same object may treat visible energy and infrared energy differently. You might have to forget what your own eyes are telling you and instead think about what the infrared camera eyes or spot IR eye is telling you.

So what does this all mean? It means that not everything may be as it seems on the infrared camera or spot temperature gun. What these tools are actually doing is taking in the infrared energy, processing the signals created by the sensors and using that information to calculate an apparent temperature, which is then displayed on the LCD screen. With infrared cameras, the brain of the tool also creates a picture of the different amounts of heat and where they are apparently located. Pretty cool, huh?

Table 1 – Emissivity Values for Common Surfaces

Material	Emissivity
Water	0.98
Ice	0.97
Electrical tape, black plastic	0.95
Paint, oil, average	0.94
Paper, black, dull	0.94
Rubber	0.93
Concrete	0.92
Porcelain, glazed	0.92
Tar paper	0.92
Paper, white	0.90
Lacquer, black, shiny	0.87
Shellac, black, shiny	0.82
Cast iron, rough casting	0.81
Iron, oxidized	0.74
Steel, rusty red	0.69
Iron, sheet galvanized, burnished	0.23
Brass, dull, tarnished	0.22
Cast iron, polished	0.21
Steel, sheet, nickel plated	0.11
Aluminum, rough surface	0.07
Copper, commercial burnished	0.07

Remember the Three Variables

Part of the calculation involves variables. The three primary variables, which often have the greatest effect on the math, are known in the infrared world as emissivity, reflected background and transmissivity. From a practical standpoint, emissivity is how reflective or "infrared shiny" a surface is. Reflected background is the infrared energy that is coming from somewhere else, but reflecting off of that infrared shiny surface. Transmissivity is how much of the infrared energy can pass through the material. (This article is not going to discuss much about transmissivity because most of the things inspected in maintenance reliability settings are opaque, so there is little concern about the infrared heat passing straight through a motor or the components of the switchgear. One big exception, however, is the infrared transparent window or IR window, but that is a topic for another time.) Most of the time, the only heat energy that maintenance reliability thermographers really care about is the heat coming from the actual piece of equipment. That is, the heat being given off from that equipment, not the stuff that is reflected from somewhere else or some other piece of equipment.

How the Emissivity Number Works

The emissivity number is measured on a scale of zero to one. A value of zero means the surface is so shiny to infrared that all you will likely ever see is just infrared reflection from somewhere else. (Reflected infrared background is high in this case.) To the contrary, an emissivity of one means an infrared detection tool can see a really great picture of the target's actual heat and an excellent apparent temperature calculation. In the real world, however, the values are always somewhere in between. Determining what that number actually is for any surface can be a real challenge the lower the number goes. However, most maintenance inspection work is qualitative and comparative in nature, so knowing an exact, precise and truly accurate temperature of an object is not really needed. That's not to say it cannot be done, but it might end up being a lot of work. As a general rule, try not to knowingly use any temperature calculation on an object with a 0.6 emissivity value or less because the variables become so unmanageable and inconsistent that it is just not worth the added effort for only an incremental increase in confidence. It's much better to rely on practical tips and tricks to know that you have a reflection and work around it to still get an analysis of what is going on and make a reasonable decision on what is really happening. In general, shiny metallic surfaces have an emissivity value too low to provide accurate or meaningful images.

> From a practical standpoint, emissivity is how reflective or "infrared shiny" a surface is.

From a purely practical standpoint, as long as you realize that something you are looking at with your infrared tool (e.g., camera or spot IR) might be giving off more infrared reflection than what is really coming from the inside, you are a step ahead of the game. Then, knowing whether it really matters for what you need to do or knowing what you can do about it is really what pushes you across the finish line.

Hopefully, your infrared eyes have been opened wide for the first time, or at least seeing a little more clearly than before, and you are able to go out and tackle your inspection work with more confidence. The topic of emissivity, along with many others that surround infrared cameras and spot temperature

How to Recognize a Questionable or Low Emissivity/ Reflectivity Problem?

1. Are you looking at something that is shiny or reflective in any way?
2. Is the material surface made of a bare metal? (Polished metals are usually low emissivity. Rusted or heavily corroded metals can have a higher emissivity and not have infrared reflections.)
3. Are you looking at your object from a really steep angle?
4. Is the surface being inspected extremely smooth or mirror-like? (The surface can often produce very distinct reflections in both visible light and infrared.)
5. Do you see an unexpected, but apparent hot or cold spot in one of the above situations that does not make sense based on your understanding of how that component or equipment works?
6. Have you tried the "thermographer two step?" Move a little to the left and then a little to the right, or a little higher and then a little lower to see if the apparent hot or cold spot moves position as you move.

If you answered "yes" to any of these questions, you may need to be concerned about low emissivity and infrared reflections from other places confusing your infrared image and/or apparent temperature value.

How to Get the Job Done
When Low Emissivity Stands in the Way?

1 Change the material surface when possible and safe to do so. This can be done by adding a surface with a high emissivity that conducts heat well from whatever you put it on. Examples are electrical tape, paint, a high emissivity decal or sticker, or you can scuff up the material surface. Important Safety Note: Do NOT do this on live electrical systems, live rotating equipment, or things dangerously hot or chemically reactive.

2 Inspect instead parts of the object that may be in very close contact with the reflective parts. They will likely be at about the same actual temperature even though the apparent temperature and/or infrared image may be very different. For example, inspect the cable insulation instead of the terminal block or bus bar.

3 Don't inspect at steep angles greater than 30 degrees when possible. Even though a surface might be high emissivity at a normal angle of view, it may become very reflective at steep angles. Think about how the asphalt pavement is not reflective when you look straight down at it, but can reflect the sky and look like a mirage when you view it steeply on the horizon.

4 Don't inspect a low emissivity surface when you are 90 degrees perpendicular to it because you will most likely see a reflection of your own body heat. Inspect at perhaps 60 to 85 degrees to target. Move up and down, left and right when measuring to find out.

5 Look for cavity radiators on infrared reflective objects. Lug holes in terminal blocks, cracks and crevices act like little heat projectors and collect and project more of the infrared energy toward your tool.

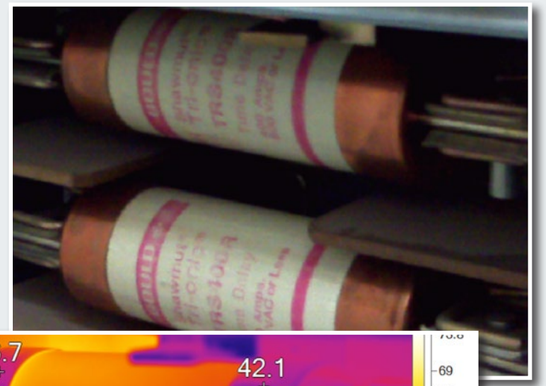


Figure 4: The top image shows two fuses in a three-phase fused disconnect panel; the visible light shows the fuses have white paper bodies, but polished copper end caps. In the bottom image, the fuse bodies emit infrared energy at a level showing 50°C to 56°C, but the fuses end caps have both low emissivity and high reflectivity, as portions of the end caps indicate temperature in the 40°C range, while other portions are reflecting infrared from in front of the panel, indicating temperatures in the 30°C range. The left end cap of the lower fuse show one spot reflecting infrared from the upper fuse, indicating 52.3°C. In reality, the entire length of both fuses is likely in the 50°C to 56°C range.

tools, can go wide and deep. A significant amount of information can be found when, and if, you desire. Don't be afraid of asking why and questioning what your eyes or your test tools are telling you.

You are the brain behind the tools. Make sure you understand how they work and what limitations they have before and while using them. This is the only way to ensure your expectations for tool performance are level set so you can get the job done day in and day out.

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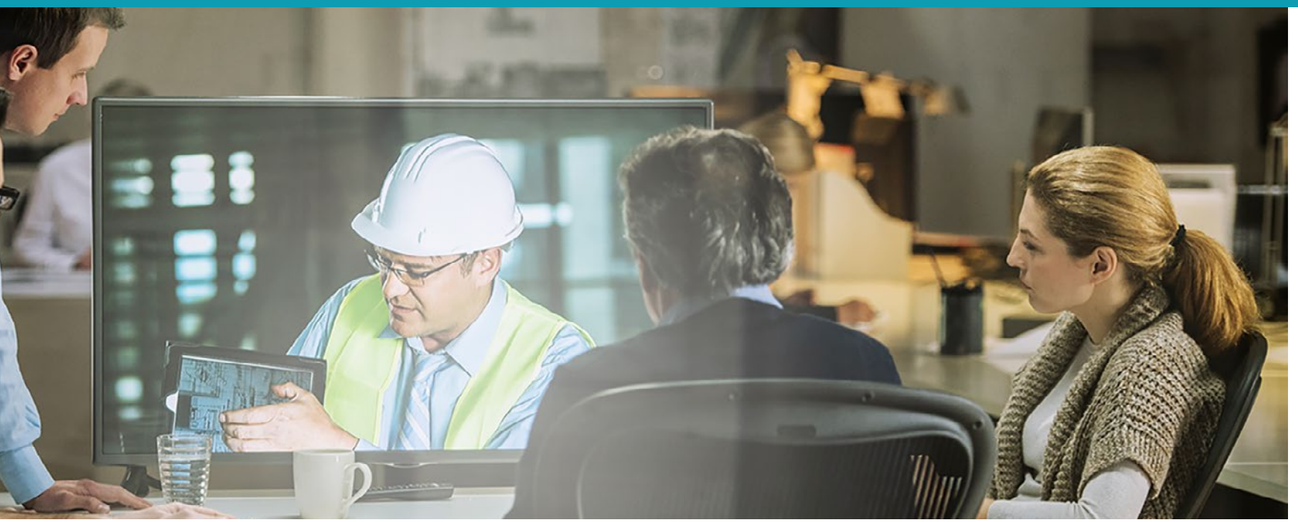

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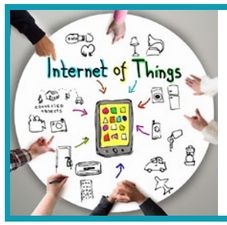

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Practical Plant Analysis: Understanding Viscosity's Effects on Centrifugal Pump Performance

by Umeet Bhachu

The current low oil market environment has forced many producers to look into efficient and cost-effective ways to do business. Therefore, it becomes the responsibility of every engineer involved in the oil and gas sector, or any industry for that matter, to come up with innovative ways to analyze, understand and resolve problems plaguing their respective disciplines without incurring excessive costs.

The Hydraulic Institute published the ANSI/HI9.6.7 standard in 2010 detailing the effects of liquid viscosity on rotodynamic pump performance. The new standard built on and improved some of the concepts covered in the previous procedure. While there are many references available on the differences, it is worth noting that the new procedure provides a mathematical framework to analyze and correct pump performance due to fluid viscosity variation in contrast to the previous procedure, which only provided a graphical means to perform such corrections. These equations enable a rotating equipment engineer or process engineer to use spreadsheet software and/or various other tools to evaluate, rerate and troubleshoot centrifugal pump issues. An exercise that can prove fruitful in both the operational and project selection stages of engineering would be to evaluate the effects of higher viscosity fluids on pump performance, temperature and its potential impact on the reliability of the machine using basic tools prior to going out for a pump bid or providing feedback during a root cause analysis session.

Consider the case of an API 610 between bearings two-stage centrifugal pump that has been performance tested on water and the performance curves subsequently provided by the vendor. These curves can be recreated in a spreadsheet at various flow points, however for this article, the curve is analyzed at 60, 80, 100 and 120 percent of the rated best efficiency flow. Assuming the test conditions to be at 20 degrees C, with the viscosity of distilled water 1.005 cSt and the revolutions per minute (rpm) set at 3,585 for the original curve (see Figures 1 and 2, page 52, and Table 1), the spreadsheet can be then customized to correct the pump performance if the pump were to pump castor oil with a viscosity of 300 cSt and a specific gravity of 0.95.

The Hydraulic Institute recommends calculating the parameter (B) based on the water performance best efficiency flow ($Q_{BEP\text{-}W}$) as follows:

$$B = 16.5 \times \frac{(Vvis)^{0.50} \times (HBEP-W)^{0.0625}}{(QBEP-w)^{0.375} \times N^{0.25}} \qquad \text{(Eq.1, Metric Units)}$$

$$B = 26.6 \times \frac{(Vvis)^{0.50} \times (HBEP-W)^{0.0625}}{(QBEP-w)^{0.375} \times N^{0.25}} \qquad \text{(Eq.2, Imperial Units)}$$

(Where Vvis is viscosity of the new liquid, HBEP-W is water head at BEP, QBEP is water flow at BEP and N is the rpm of the pump)

If the parameter B falls within one to 40, then the Hydraulic Institute recommends calculating the correction factors for flow (C_Q), head (C_H) and efficiency ($C\eta$). You can refer to ANSI/HI9.6.7 – 2010 to understand how these correction factors are calculated and applied to the original water curve.

Furthermore, the increase in power as a result of the fluid viscosity increase can be calculated by:

$$Pvis = \frac{Qvis \times Hvis\text{-}tot \times s}{367 \times \eta vis} \qquad \text{(Eq.3, Metric Units)}$$

$$Pvis = \frac{Qvis \times Hvis\text{-}tot \times s}{3960 \times \eta vis} \qquad \text{(Eq.4, Metric Units)}$$

(Where Qvis is corrected flow at the new viscosity, Hvis-tot is the total head corrected at the new viscosity and ηvis is the new efficiency at the corrected viscosity*)*

The resulting temperature rise in degree F can be determined from the following equation (see Table 2):

$$°F = \frac{Total\ Head\ in\ Feet}{778 \times Cw} \cdot \left(\frac{1}{e} - 1\right) \qquad \text{(Eq.5, Imperial Units)}$$

A more practical scenario that you can assess is the effect of an increase in viscosity (see Figure 3, page 53) of bitumen (heavy oil) or other process fluids with decreasing temperatures. These cases often arise in operating plants that are situated in northern regions. The failure of electrical heat tracing, loss of process heating and other factors resulting from lower temperatures on pumps located outside the ambient temperature all lead to an increase in the viscosity of the substance being pumped. This, in turn, leads to machinery performance degradation and subsequent failure.

Corrected Curve (Head Per Stage)				
Fluid Data				
S.G of viscous liquid	0.950			
Viscosity of viscous liquid (cSt)	300.000			
Pump shaft speed (rpm)	3585.000			
Ratio of water BEP flow (Qw/Qbep-w)	**0.600**	**0.800**	**1.000**	**1.200**
Water head per stage (Hw or Hbep-w)(m)	242.500	231.000	212.500	190.000
Water rate of flow (Qw or Qbep-w) (m3/hr)	193.200	257.600	322.000	386.400
Water pump efficiency	0.620	0.670	0.690	0.680
Parameter B	5.922			
Correction factor for flow (Cq)	0.930			
Correction factor for head (Ch or Cbep-H)	0.952	0.941	0.930	0.919
Correction factor for efficiency	0.718			
Correct flow (Qvis) (m3/hr)	**179.611**	**239.481**	**299.352**	**359.222**
Correct head per stage (Hvis or Hbep-vis) (m)	**230.872**	**217.256**	**197.553**	**174.678**
Corrected efficiency	**0.445**	**0.481**	**0.495**	**0.488**
Viscous shaft input power (Pvis) - kw	**241.282**	**280.144**	**309.193**	**332.893**
Original Curve Data (Head Per Stage)				
Flow (m3/hr)	Head (m)	Efficiency	Power (kW)	Ratio of Water BEP to flow (%)
193.2	242.500	0.620	200.0	60
257.6	231.000	0.670	235.0	80
322	212.500	0.690	262.0	100
386.4	190.000	0.680	287.0	120

Table 1: Calculations developed on pump performance in spreadsheet software

Temperature Rise in the Pump (Total Head)				
Ratio of BEP to flow	60	80	100	120
Total pump head (ft)	485.000	462.000	425.000	380.000
Specific heat of fluid	1.800	1.800	1.800	1.800
Pump Efficiency	0.445	0.481	0.495	0.488
Temprature rise (F)	**1.400**	**1.154**	**1.003**	**0.923**

Table 2: Temperature rise in pump

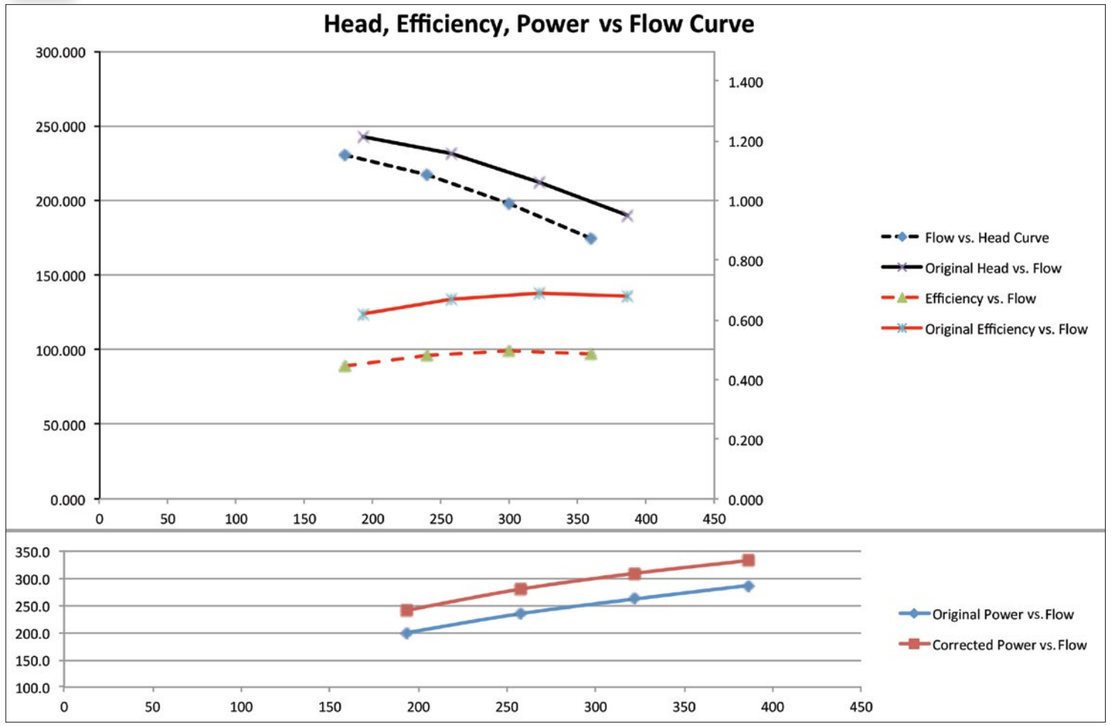


Figure 1: Head, efficiency, power original and corrected curves vs. flow

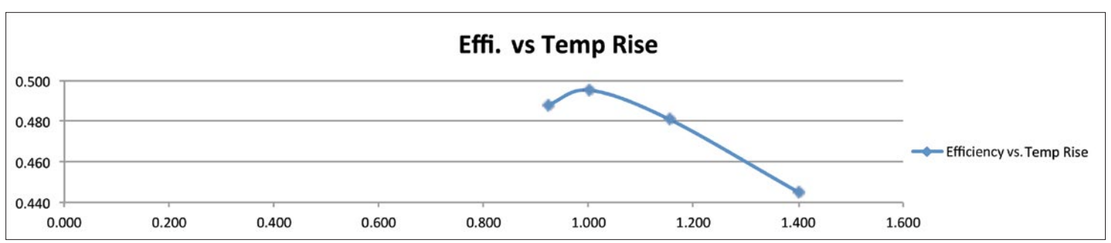


Figure 2: Temperature rise as a result of drop in pump efficiency

Observations

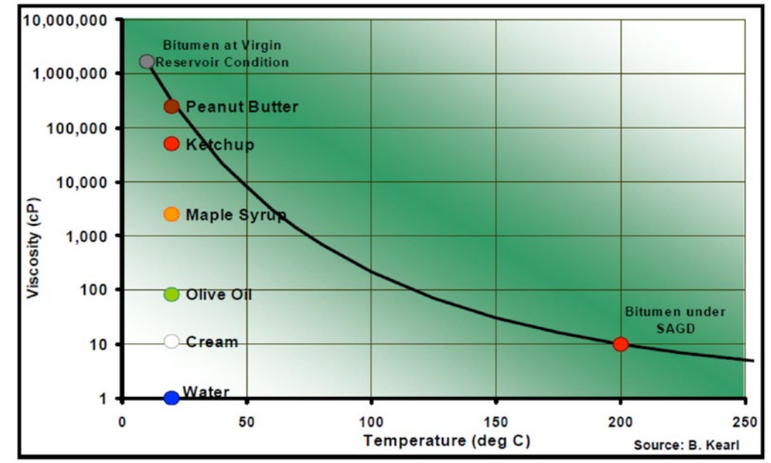
It can be well appreciated that a rise in the fluid's viscosity leads to a degradation in pump performance.

- The head produced by the pump decreases
- The brake horsepower requirement increases
- Pump efficiency decreases, which also affects the heat generated (losses) within the pump (Figure 2)
- Changes (reduction) in flow can be observed as a result of change in the H-Q curve.

The heat generated in the pump is worth further consideration because it has a direct, detrimental effect on both the operation of the pump and the mechanical seal. It should be noted that the previously calculated Equation 5 (Eq.5, Imperial Units) should not be used to calculate the temperature rise during the shutoff condition. The temperature rise at shutoff is calculated differently from other pump operating points since the temperature at other operating points stabilizes as a result of continuous flow; this is not the case at shutoff. From the aforementioned analysis, it should be noted that the temperature increases with a drop in the efficiency, especially more so as the pump operates toward the left of the BEP point in the low flow region. This can be attributed to a lower volume of liquid carrying away the heat generated as a result of losses within the pump. This is one reason why pumps are equipped with minimum flow lines to avoid excessive heat generation by recirculating flow in the low flow regions.

One key advantage of using equation-based approximate methods to assess equipment performance is the ability to develop simple spreadsheets to simulate performance effects from process changes without spending excessive money on sophisticated and complex modeling software. Basic spreadsheets also have the additional ability to integrate easily with the plant data historian or process simulation software to provide real time data analysis.

These tools provide value to process, project and machinery engineers during equipment selection, rerate and design, in addition to helping the bottom line of an operating plant by helping to troubleshoot operating problems and build on plant reliability.



Courtesy of Canadian Heavy Oil Association

Figure 3: Graph showing increase in viscosity (cP) as a result of a temperature drop

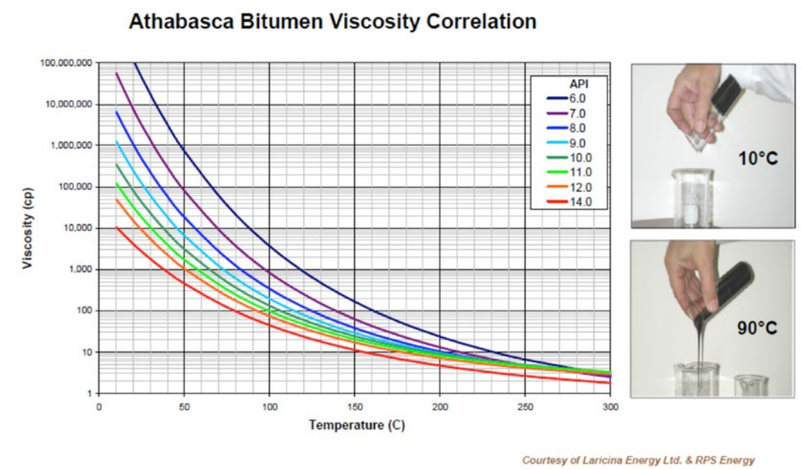


Figure 4: Viscosity variation on various API grades with temperature

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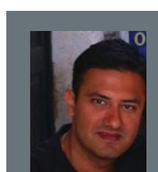

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Do You Fit the Bill?

8 Crucial Skills Maintenance Managers Must Have

by Jeff O'Brien

As a maintenance reliability professional, you have technical training of some kind, basic knowledge of asset management principles, technical knowledge of the equipment you manage and practical experience from years working in the field. These are the hard skills needed to perform your job. However, technical education, training and knowledge will not give you the skills you need to effectively manage a team of maintenance professionals. Along with hard skills, you need a very particular set of soft skills to excel in your role. These skills will lead to greater productivity and efficiency across the maintenance team. More importantly, they will lead to less stress, greater job satisfaction and ongoing career achievement for you.

These soft skills are:

1 Excellent Interpersonal Skills

One of the most important life skills is the ability to communicate clearly and concisely with those around you. Employers tend to promote employees with good interpersonal skills as they can communicate effectively and maintain good relations with internal and external customers. Having excellent interpersonal skills will help you maximize the value of each interaction you have to everyone's benefit. Maintenance managers negotiate daily with subordinates, management, suppliers, contractors, machine operators and project managers, so effective and excellent interpersonal skills are crucial to their day-to-day jobs. Others perceive people with good interpersonal skills as calm and assertive. Moreover, listening is not the same as hearing. When you communicate, 45 percent of the time is spent listening, so take time to hear other people's point of view. Good interpersonal skills can be the foundation on which other life skills are built so they must be continually improved and refined.

2 Leadership Skills

To be a successful maintenance manager, you need to demonstrate leadership ability. You must be self-motivated, organized, trustworthy, empathetic and optimistic. It is necessary to have a clear vision of where you want the maintenance team to get to and set a positive example that encourages others to follow. Your motivation and confidence will rub off on the team and create a healthy and productive work environment.

In addition, leadership is about getting the job done properly through others. Delegating work to subordinates is an important function of management, otherwise nothing gets done. It frees up precious time so the manager can focus on high-level, high value activities. Great leaders get things done by inspiring and empowering others to do great work for them. They foster motivation by giving subordinates autonomy to do the job by creating a supportive environment around them and giving recognition when the job is done well. Follow this simple process to ensure the job gets done correctly:

- Set the policies and ground rules, such as the level of quality expected.
- Select the best person for the task, not necessarily the superstar on the team, but the person with the right skills for the job.
- Agree on what needs to get done.
- Agree on timelines to get the job done.
- Provide the resources needed to ensure the team is successful and remove any roadblocks along the way.
- Follow up at regular intervals to ensure everyone is on schedule.
- Recognize employees when the work is done well.

3 Problem-Solving Skills / Critical Thinking

In his 1995 book, *Critical Thinking*, author Barry K. Beyer defines critical thinking as making clear, reasoned judgments. Good critical thinkers can think clearly and rationally, solve problems systematically and make the right decisions quickly. Today's asset managers need to be adept critical thinkers and problem solvers. They have to deal with a multitude of responsibilities, including managing the maintenance budget, supervising a team of technicians, prioritizing work based on need, managing maintenance metrics and staying abreast of the latest technologies. Accordingly, they need to be able to process information quickly and make fast and effective decisions. The most skilled critical thinkers will look at all the evidence, interpret the data, evaluate all the alternatives, prioritize and form a judgment that delivers the most effective solution in the quickest time possible.

4 Ability to Develop People

In any business, one of the biggest challenges is finding, developing and deploying the right talent to achieve business goals. Many organizations are great at hiring and deploying people, but they forget the developing part. Change is inevitable, so your team members need ongoing training and development so they can learn new skills and take on bigger and more complex challenges. Work with subordinates to identify their areas for improvement and provide the training and development they need. Some people may want to further their skills through training and education, while others may simply want more responsibility. Hold regular knowledge transfers so the team can share knowledge, ideas and experiences. Plan your work orders so experienced team members can mentor the less experienced. In addition, if you have well trained, capable people, you will be able to quickly promote from within when more senior positions open up. Identify potential leaders in the group and reward them with promotion opportunities when you can.

Having the ability to develop people is an important skill for a maintenance manager to master because it creates a culture of continuous learning and incessant betterment. Make the long-term career development of your staff one of your top priorities as it leads to a high performing, productive and motivated maintenance team.

5 Time Management Skills

Time management is the process of organizing and planning how much of your time you spend on each activity to provide the greatest value for the organization. As maintenance managers, you are constantly interrupted and pulled in different directions by conflicting demands, so it can be difficult to plan your time. However, you need to avoid running around trying to get everything done in the order they come in. This is inefficient and leads to more stress, missed deadlines and poor quality of work. Don't confuse activity with achievement. Good time management requires a shift in thinking from getting stuff done to achieving results. It's about working smarter, not harder. Spend 15 minutes each morning planning your day, stick to meeting schedules and ensure all meetings end on time. You can use your computerized maintenance management system (CMMS) to help plan your and your maintenance teams' day by prioritizing and scheduling the work. Insist that all work requests are submitted through the guest request portal so your phone is not constantly ringing and you can get things done. You can schedule time in your day to review the work request queue. Reserve the phone for issues that could be critical to the business. The most effective maintenance managers have excellent time management skills and get more done in the same time. It's a valuable skill that can be learned easily and then honed over time.

6 Promote Teamwork and Collaboration

Teamwork is viewed as the most efficient way to get things done in an organization. The results achieved by the entire team are greater than the sum of the results achieved by the individuals. When individuals work together as teams, they can bounce ideas off each other and arrive at the best solution quicker. Teamwork can lead to better decisions, products, or services.[1] In your role as a maintenance supervisor, you need to promote behaviors that lead to effective teamwork. You need to recognize the different strengths in the team and combine them in a way to gain the maximum amount of value and meet or exceed the department's goals. Having the ability to get the most out of the team through teamwork and collaboration is a crucial skill to have and will take you a long way in your career.

7 Adaptability

In today's fast-paced world, you cannot be set in your ways or you will get left behind. As mentioned earlier, change is inevitable. Equipment and systems are getting more complex, health and safety are now the highest priorities, carbon dioxide (CO^2) emissions are influencing how goods are manufactured and mobile apps are used for everything. The modern maintenance manager must have the ability to adapt quickly in response to changing circumstances and environments. The most adaptable individuals respond positively when their routine changes. You must be willing to embrace new ideas, new ways of working and new technologies. You must thrive on change and uncertainty.

8 Ability to Handle Stress

Stress can affect your productivity, emotions, quality of work and mental health. If stress is allowed to build up over time, it can consume you. As a maintenance manager, having the ability to handle stress may not be a skill in the strictest sense, but it can mean the difference between success and failure. Managing stress doesn't mean taking a deep breath and just getting on with it. Rather, it means controlling the things around you that can lead to stress. When you control the controllable, you reduce your chances of suffering from stress. If you possess the aforementioned soft skills, you probably handle very little stress on a day-to-day basis. Having the skill to control stress will keep you in good spirits and positively affect those around you.

If your goal is to lead a team of maintenance engineers, then master these skills and you are sure to succeed. If you are already in a position of management, developing and refining these skills will help you get the most out of your team, help you gain greater respect from company executives and give you more opportunities for career advancement.

Many of these skills intersect, so improving one will have a big impact on others. Some of these skills will come naturally to you, but they all require additional effort to perfect. They will help you create a healthy work environment where employees look forward to coming to work and taking on more responsibility and exciting new challenges.

Jeff O'Brien *is a product specialist, CMMS evangelist and industry blogger at Maintenance Assistant™, which develops and delivers maintenance software solutions that are used by thousands of asset-intensive businesses around the world to transform their maintenance operations, eliminate waste and costly downtime, and manage risk.* *www.maintenanceassistant.com/cmms/*

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How High Performance Oils and Greases Extend the Application Range for Sealed Bearings

by Heinz P. Bloch

The development of high performance perfluoropolyether (PFPE) lubricants dates back a few decades. These developments were both necessitated and accelerated by aerospace and aviation markets where lubrication at the extremes of low and high temperatures was far more important than it would be in the average industrial environment. Even beyond aviation and aerospace, PFPEs have served admirably whenever the higher initial cost was easily overcome by the far more important need to consistently meet and even exceed performance expectations.

To what extent the traditionally lower initial cost of mineral oil-based lubricants has influenced procurement decisions in process industries is of peripheral interest at best. However, solid cost justification for PFPEs has recently become available. Such cost justifications were derived from a large Canadian paper mill[1] that struggled with grease-lubricated electric motor bearings. When the mill opted to dispense with re-lubrication of electric motor bearings by purchasing and converting to PFPE grease-filled (i.e., sealed, lifetime lubricated) bearings, its electric motor bearing life improved drastically.

> It simply ***pays*** to reconsider "old" regreasing strategies

The purpose of this article is to examine PFPE greases and highlight their applicability in many process lubrication services. A cost justification calculation is also provided.

Composition of Standard PFPE Lubricants

Standard premium fuel efficient (PFE) oils and polytetrafluoroethylene (PTFE) or Teflon® thickeners contain only three elements: Carbon, oxygen and fluorine. The molecular structure provides thermal and chemical stability to lubricants, which are produced in ISO viscosity grades ranging from two to 1,000. One prominent manufacturer of high performance chemicals engineered a PFPE molecule with its otherwise degradation-susceptible oxygen atoms fully "encased" by fluorine. The manufacturer's PFPE product bulletins show the degradation temperature or onset of decomposition in air for this grease to be above that of competing products.

A straightforward comparison of PFPE oils to alternatives[2] is reproduced in Table 1.

From a practical point of view, PFPE lubricants excel and surpass in their capability to form an elastohydrodynamic film, an important oil strength in service property that explains effectiveness at all temperatures of interest. The film stays in place under many operating conditions imposed on, for instance, the rolling element bearings in electric motors. Staying in place is a desirable property; it implies both resistance to water washout and the necessity to use special procedures to remove PFPE lubricant from bearings, if necessary. Compatibility concerns require PFPE lubricants to be applied to clean bearings only. In this regard, one may take cues from the Canadian paper mill, which purchased its electric motor bearings from a competent manufacturer. This manufacturer then prefilled the bearings with the specified grease and applied the bearing seals.

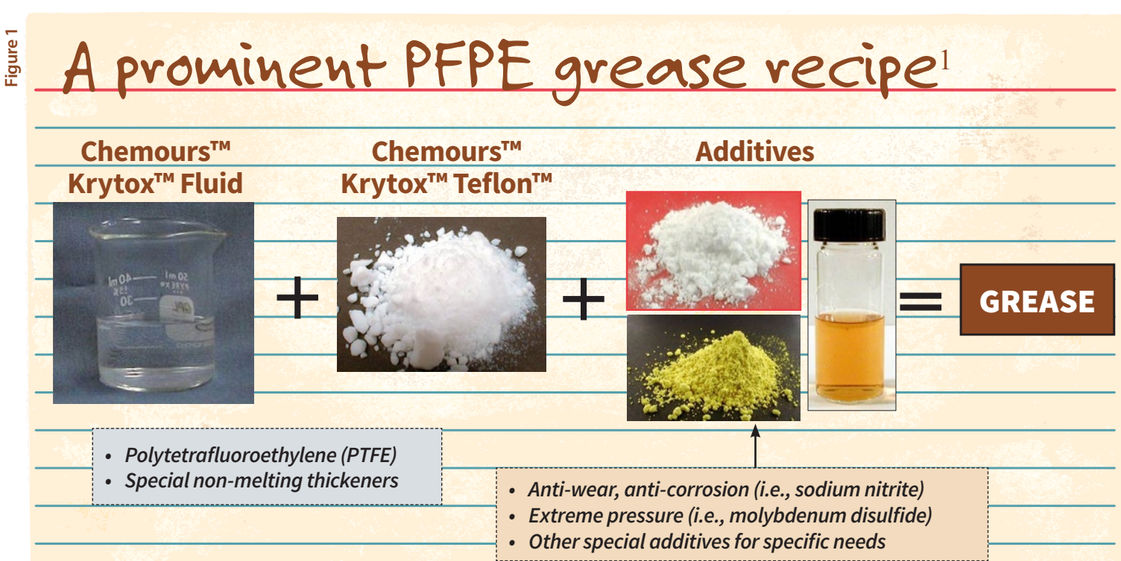
Table 1 – PFPE Oil Comparison to Alternatives

Property	Mineral	PAO	Diester	Silicones	Chemours™ Krytox™
Thermal Stability	Moderate	Moderate	Good	Very Good	Excellent
Oxidation Stability	Moderate	Very Good	Very Good	Very Good	Excellent
Hydrolytic Stability	Excellent	Excellent	Moderate	Good	Excellent
Volatility	Moderate	Very Good	Good	Very Good	Excellent
Viscosity Index (VI)	Moderate	Very Good	Good	Excellent	Good to Very Good
Fire Resistance	Poor	Poor	Moderate	Good	Excellent
Seal Material Compatibility	Good	Very Good	Poor	Good	Excellent
Lubricating Ability	Good	Good	Good	Poor	Excellent
Toxicity	Good	Excellent	Good	Excellent	Excelent
Cost Compared To Mineral Oil	1	3-5	3-7	30-100	60-120

Examining Cost Versus Benefit

Based on experience, polyalphaolefin (PAO) premium grade greases are a baseline competitor of the PFPEs; PAOs are certainly among the leading products presently used in electric motor bearings. The question is: What would be the cost justification for the more expensive PFPEs? Assuming the PAO grease costs $1.00 and a certain size bearing sells for $200, the cost of grease equals 0.5 percent of the total. Based on cost ratio information derived from typical commercial suppliers, the PFPE grease would cost $24 per bearing, although it might be assumed the bearing manufacturer will charge

Figure 1



$250. Purchasing the bearing with PFPE sounds reasonable at this relatively small incremental cost. But, you need to make a more detailed comparison. The projected incremental cost (perhaps $50 per bearing) should convince you to dig a bit further. In a more careful examination, you may want to know what it really costs to periodically reapply traditional PAO-based greases to electric motor bearings.

The frequency of grease replenishment is determined by the rotational speed, bearing diameter and the environment in which the bearing operates. You have to look at a number of plausible scenarios and compare these with simply purchasing and installing lifetime, PFPE prefilled (sealed) motor bearings. Here are three different scenarios, but others are entirely possible. The purpose is to show the ease in which such cost justifications can be explored and how the results are easily expressed as payback or benefit-cost ratio.

Scenario 1
Using Bearings with PFPE Sealed In (no regreasing possible)

This is the base case scenario. All comparisons will take into account that a set of sealed in (no regreasing possible) electric motor bearings will cost $100 more than customarily supplied (regreasable) bearings.

Scenario 2
Periodic Regreasing

A reasonable assumption would be a bearing is being regreased 16 times during its assumed average 8-year life. A rather optimistic expectation further assumes the person doing this type of work is doing everything just right. This individual ascertains that the grease fitting is clean, will not over grease, will diligently remove the drain plug while adding grease and carefully reinsert the drain plug after greasing is done. This person can do 16 electric motors per day. Counting straight salary, overhead, vacations, training time, administrative costs, etc., a trained craftsperson costs the employer $800 per day. Therefore, regreasing the bearings routinely found in a conventional electric motor will costs its owners $800 over the bearing's 8-year anticipated life. However, the incremental cost of two sealed bearings per motor would be only $100.

Subtracting an incremental $100 from $800 = $700; the motor with sealed bearings leads with a payback ratio of 7:1. That simply means that the owner of the electric motor saves $700/8, or about $87 every year. An installation with 1,200 motors would save approximately $100,000 in labor costs per year. Assume further that 10 motors require bearing replacement each year. Therefore, bearings would be replaced after eight years of operation, regardless of bearing style (regreasable and being regreased versus lifetime sealed with no need to regrease).

Scenario 3
Standard Grease with No Periodic Regreasing

A facility with 1,200 electric motors and not doing any regreasing might expect, on average, 200 motors requiring bearing replacement each year. This is to be contrasted against lifetime (PFPE sealed in) bearings. No labor cost is incurred if standard motor bearings are never getting regreased. However, an incremental number of 190 sets of motor bearings would have to be replaced each year. Replacement bearings and associated labor would cost $2000; 190 x 2,000 = 380,000 per year. It might be prudent to assume there would be a process unit outage event – the cost is anybody's guess. In that case, however, the entire Scenario 3 makes even less economic sense than Scenario 2.

In the end, it simply pays to reconsider "old" regreasing strategies in light of the recent experience at the Canadian paper mill. High performance oils and greases extend the application range for sealed bearings and call for a rethinking of the way things were done before.

References

1. Aronen, Robert. "Krytox™ Blog." *Boulden Company*. Coshohocken, PA, November 30, 2014. http://www.bouldencompany.com/blog/dupont-krytox-solves-costly-problem-for-pulp-paper-plant-2/
2. Rudnick, Leslie R. "Synthetics, Mineral Oils, and Bio-Based Lubricants." Boca Raton: CRC Press, 2013.

***Heinz P. Bloch** began his professional career in 1962, which included long-term assignments as Exxon Chemical's regional machinery specialist for the U.S. He has authored over 600 publications, among them 19 comprehensive books on practical machinery management, failure analysis, failure avoidance, compressors, steam turbines, pumps, oil mist lubrication and practical lubrication for industry. Mr. Bloch holds BS and MS degrees in mechanical engineering.*

Q&A with Industry Leaders


Susan Lubell


Ricky Smith

***Uptime* Magazine caught up with Susan Lubell and Ricky Smith, authors of the recently published book, "Root Cause Analysis Made Simple." They shared some of the most frequently asked questions regarding root cause analysis (RCA) that are asked by not only maintenance practitioners, but also their production operations teams and management, who they need to support them in their work.**

Q: Why investigate failures? In other words, why bother with RCA?

The goal for any RCA is to prevent the recurrence of failures and/or to minimize the consequences (effects) of a failure. Unexpected equipment failures are not normal and should not be tolerated.

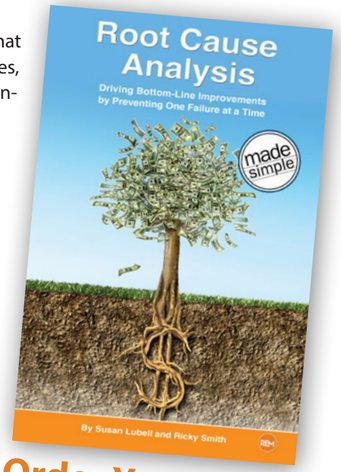
There are three main reasons or consequence categories to guide our investigation of failures: health and safety consequences; environmental consequences; and financial and production consequences. Some companies choose to add a fourth category focused on reputational risk. All failures that pose a risk to safety or the environment must be investigated. Addressing chronic or repeat failures that have a financial or production consequence can result in bottom-line savings for all types of facilities, such as manufacturing, oil and gas, mining, hospitals, food production, etc.

Q: Will RCA really make a difference?

Maintenance technicians and professionals are frequently too busy fixing repetitive problems and not spending enough time preventing failures. We need to break out of this reactive approach to maintenance to improve not only the safety and reliability of our facilities, but also to reduce our production costs.

To put things into perspective with a simplified business case, if a company produces 100,000 items per day (e.g., liters of soda, barrels of oil, tonnes of coal or fertilizer, boxes of cereal, etc.) with a profit margin of $1/item, then a 0.1 percent improvement in the volume produced per year translates into an additional $365,000 per year of profit. From an operating perspective in a continuous processing facility, 0.1 percent equals approximately nine hours of additional production time per year, based on 8,760 hours in a year.

Is it possible to achieve an extra nine hours of production per year from your facility? What benefits would you see from refocusing your maintenance staff on preventing failures, completing predictive maintenance routines and analyzing asset health instead of constantly executing repairs on a rush basis.



Q: How do I perform an RCA?

There are four fundamental steps to performing an RCA:

1. **Quantify the magnitude** of the problem;
2. **Perform the analysis** using the appropriate technique;
3. **Develop a list of options** for solving the problem;
4. **Document the results** and **implement recommended actions**.

The payback from performing an RCA comes from implementing the recommended actions and ensuring they have stopped the cycle of a repeat failure.

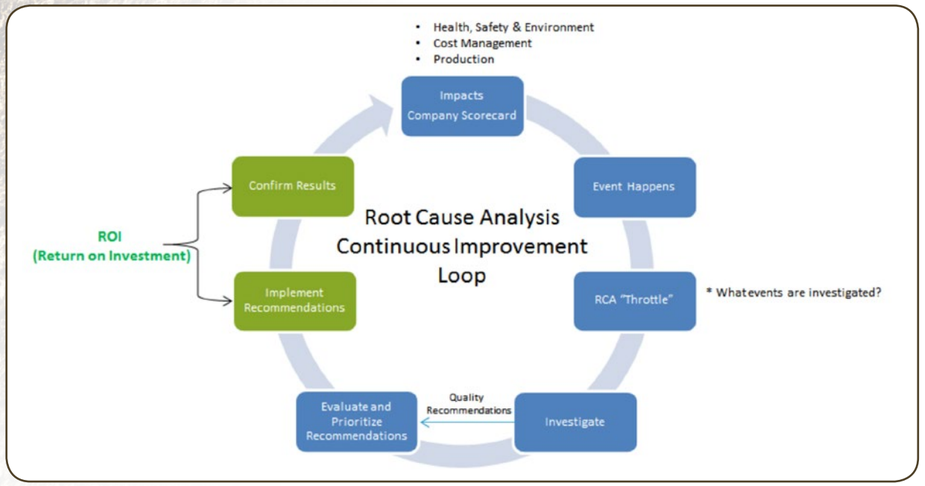
Q: Who needs to be involved?

Once the decision has been made to conduct an RCA, the next question is typically who should participate. The RCA typically brings five to six knowledgeable people together as a core team to investigate the failure using evidence left behind from the failure event. The composition of this team should stress complementary skills with an understood common purpose of identifying the root cause of the failure.

Q: What is the most important step in performing an RCA?

Preserving the broken parts and evidence!! Information, including operating parameters, broken parts and components, and documenting what people heard, smelled, saw and felt, is absolutely critical to conducting an RCA. In the haste to get the facility back up and running, valuable evidence is quickly lost. Take pictures and preserve the broken parts as you're dismantling and repairing the equipment. Even if you later decide that an equipment failure isn't worth investigating, you'll have the luxury of making this decision in the future and not regret a hasty decision made while dealing with the failure's aftermath.

Here's a diagram that demonstrates when you achieve return on investment (ROI) on your RCA efforts. Many people think that it's when you *investigate*, but it's actually when you *prevent recurrence* that your efforts pay off.



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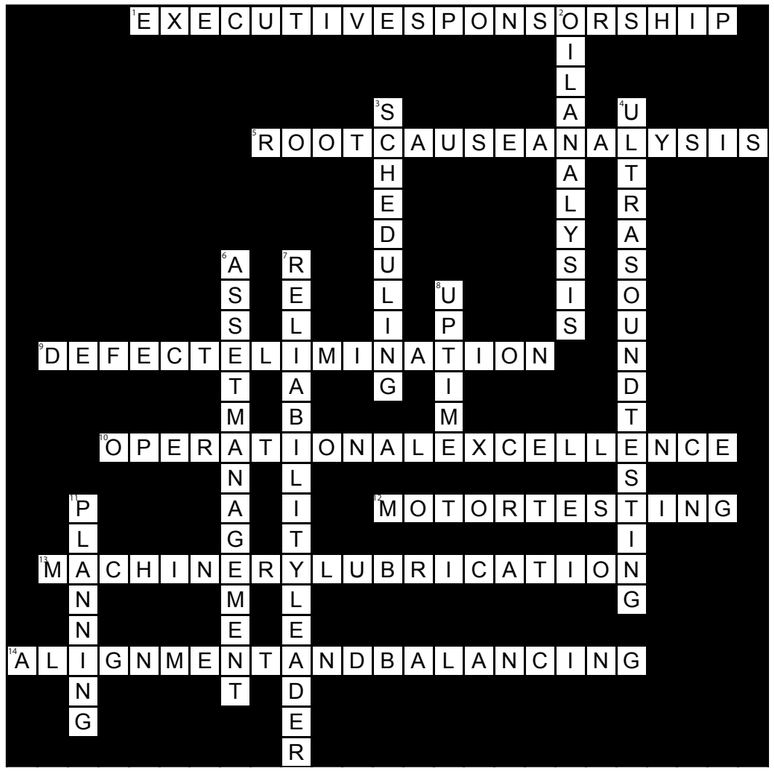
ANSWERS

Crossword Puzzle

Created by Ramesh Gulati



ACROSS

1 Support required from the management to implement a sustainable change

5 A methodology that leads to the discovery of the cause of a problem

9 The identification of a nonconformance and its removal

10 A philosophy of leadership, teamwork and problem-solving resulting in continuous improvement throughout the organization

12 Encompasses several predictive maintenance technologies to monitor and assess motor health

13 Performed to reduce friction and heat

14 Key techniques to minimize effects of vibration in rotating equipment

DOWN

2 A predictive maintenance technology used to determine the quality of the lubricant oil and/or condition of equipment being lubricated

3 A process of determining which jobs get worked on, when and by whom based on priority, resources and asset availability

4 A predictive maintenance technology used to detect leaks and other defects in assets

6 An organizational process to maximize value from an asset during its life

7 Anyone who helps another person, a machine or a gadget to do a better job

8 The time during which an asset or system is either fully operational or is ready to perform its intended function

11 A process of determining the resources and method needed, including safety precautions, tools, skills and time necessary to perform maintenance work efficiently and effectively