uptime®

the magazine for maintenance reliability professionals

dec10/jan11

Presenting the Elements

STo shutdowns, turnarounds & outages
HaM human asset managment
mR mechanical reliability

uS ultrasound
MrO mro-spares management
PaM physical asset management
pR process reliability
PmO pm optimization

Mt motor testing
Oa oil analysis
RL reliability leadership
Ps planning and scheduling
eR electrical reliability
Rca root cause analysis

gR green reliability
iR infrared thermal imaging
Ms maintenance supervision
maM mobile asset management
Re reliability engineering
Rcm reliability centered maintenance
Lu lubrication
sT skills training
Adi asset data integrity
AhM asset health management

ViB vibration
nDt non destructive testing
Mm maintenance management
Op operations performance
OdR operator driven reliability
Kpi reliability performance metrics
A/B alignment and balancing
Brg bearings
EaM enterprise asset management
cMms computerized maintenance management system

condition monitoring maintentance
management
reliability
precision maintenance
decision support

7 Years of Sustained Reliability & Culture Change

At Alcoa Warrick Smelter

Infrared Safari:

On the Hunt for Reliability Problems with Thermography

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Editorial

A SYSTEM For Reliability Transformation

One of my heroes, W. Edwards Deming, stated that what is required for success is a profound system of knowledge. Operating your organization as one system with one aim is at the core of Deming's Profound System of Knowledge.

The newly revised Reliability Elements, on the cover of this issue of Uptime Magazine, are also designed to encourage you to understand and operate maintenance reliability as **one system**. Although there are many separate activities and elements that make up the system called "maintenance reliability," you must perform most of them, most of the time, in a competent manner in order to achieve high levels of performance. None of it is rocket science (with the exception of Weibull Analysis), however much of it is hard work and perseverance without much glamour.

That is why we take such pleasure to acknowledge the 2010 Uptime Magazine Predictive Maintenance Program of the Year Award winners in this current issue as well as at the outdoor sunset ceremony at Solutions 2.0, which just took place in Bonita Springs, Florida this past November 8th through the 11th.

We all learned a great deal listening as each winning program presented the details surrounding their journey to high performance maintenance.

Over a dozen winning programs presented and several common trends stood out for me from each program:

- Each program developed maintenance and condition monitoring tasks on criticality ranking and failure modes and effects analysis. In other words they directed maintenance activity to detect or prevent potential failures.
- Each program had earned a high level of active corporate support and respect by starting small, assessing, improving, then expanding.
- Each program excelled in communicating up the chain, down the chain and across the chain. All stakeholders and interested parties had a high awareness about the benefits of the program.
- Each program included short and long-term training and certification for team members that was far higher than what we typically find.
- Each program included passionate and energetic people who were highly motivated to perform at high levels.
- These programs reported gains in safety, productivity and reliability on a regular basis to justify and sustain the program.
- Each program subjected itself to annual assessment in order to identify current gaps, and then created follow-up plans to close those gaps. They expect to continually improve with no end in sight.

The award was a source of pride for each team member, and that pride was also communicated from the highest executive level at almost all winning companies. Several winning organizations issued press releases to the general business press heralding the awards which included quotes from the CEOs.

You can read about the Uptime PdM Award Winners starting on page 12. Watch for video presentations from several winners on the Reliabilityweb.com Web site if you missed attending Solutions 2.0. The winning organizations share their knowledge and experience so your time will be well spent.

You will be seeing a lot more of the Reliability Elements in Uptime Magazine, at Reliabilityweb.com and at the new Reliability Performance Institute in Fort Myers as we begin to operate as a **system**, communicate as a **system** and include you, our readers as part of our **system,** and we encourage you to do the same. We want you to take the **system** back to your organization. We also encourage you to share your own story with the maintenance reliability community by writing an article, presenting a paper, posting a blog or discussion post at AMP (www.maintenance.org).

We hope you find the new Uptime Magazine format as interesting, engaging and valuable as it has been in the past. This issue is filled with excellent information to help you and your team do their jobs better, easier and safer.

Please send us your comments and complaints about the changes you notice in Uptime and the Reliabilityweb.com network of Web sites so we can continue to evolve and improve as our mission is to **serve you**. That's right - it is all about **YOU**!

Best regards,

Terrence O'Hanlon, CMRP
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MaintenanceTips

"Plan for Unplanned Maintenance – Minimize MRO Risk"

A reliable availability of parts is required for good preventive maintenance procedures. For planned, scheduled maintenance, providing the necessary parts availability is routine. But unplanned maintenance happens and parts availability is equally (or even more) important to reduce the impact on operations resulting from unexpected breakdowns. Plan the MRO inventory quantities in advance to reduce risk. How severe would the impact be if maintenance had to wait for a vendor to supply a missing part? High criticality items with long lead times deserve higher stock levels.

Tip provided by Management Resources Group, Inc. (MRG) • www.mrgsolutions.com 203-264-0500

Contamination Control: One Size Does Not Fit All

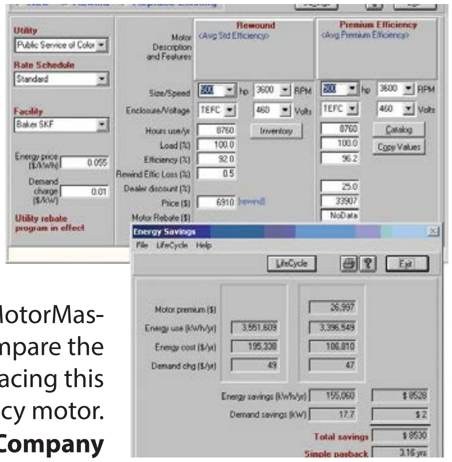
"One-size-fits-all" does not apply when selecting contamination control solutions. For low-flow applications, especially in high-humidity environments, a standard disposable desiccant breather may not be the best option. Hybrid breathers combine desiccant breather technology with an expansion chamber in a single, compact footprint. The expansion chamber and internal check valves allow the system to remain virtually closed in low-flow applications, while the desiccant media conditions the air from the headspace as the equipment breathes.

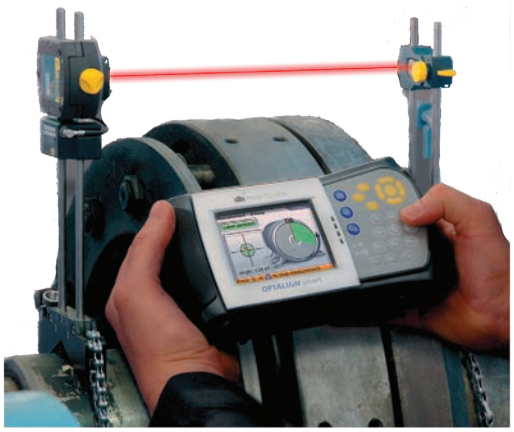
Tip provided by Des-Case Corporation www.descase.com 615-672-8800

EXP4000 Payback Period Tool

Baker SKF's EXP4000 includes the MotorMaster+ database of 20,000 electric motors and a Payback Period calculator. The EXP4000 provides a good estimate of the efficiency of an electric motor running under load. The efficiency estimate is usually within 1% of dynamometer efficiency measurements. This efficiency estimate can be used in the MotorMaster+ Payback Period calculator to calculate and compare the payback period of rewinding this motor versus replacing this motor with a new standard or high efficiency motor.

Tip provided by Baker Instrument Company www.bakerinst.com • 970-282-1200





LASER ALIGNMENT and REPEATABILITY

All laser shaft alignment systems should be able to take two sets of readings on well-built machines and find agreement at the coupling within 0.5 mils offset and 0.1 mils/inch angularity. It is important to always take two sets of readings immediately after setting up the brackets and compare the coupling results for repeatability. A good laser shaft alignment system should have the capability of automatically recording the misalignment information for the user to compare for repeatability. If the readings do not repeat, the problem may lie within the machines rather than in the bracketing or the alignment tool itself.

Tip provided by LUDECA, INC. • www.ludeca.com • 305-591-8935

Fort Myers, Florida
2011 Conference Schedule

Reliabilityweb.com** is pleased to announce its 2011 Conference Schedule and invite you to the new state-of-the-art **Reliability Performance Institute.

RPI™ **RELIABILITY® PERFORMANCE INSTITUTE**

Reliability Leadership Zero2One™ Series I
February 7–11, 2011
A unique learning event featuring Ron Moore, Jack Nicholas Jr., Terry Wireman and Ricky Smith, designed for anyone who is responsible for managing maintenance and ensuring reliability.

RCM-2011 Reliability Centered Maintenance Managers Forum
March 21–25, 2011
This event is designed for people who are beginning RCM; however, we are sure everyone will benefit regardless of experience.

CMMS-2011 Computerized Maintenance Management Summit
April 11–13, 2011
This learning and networking event is designed for those seeking to implement a new CMMS/EAM or reimplement an existing CMMS/EAM for more effective maintenance management and decision support.

CBM-2011 Condition Monitoring Forum
May 3–6, 2011
This learning event is designed for anyone who is responsible for establishing, creating or managing a condition based maintenance program.

Reliability Forum for Water / Wastewater Utilities
June 13–17, 2011
Attend this learning and networking event to discover new ideas to improve the performance of your utility. You will learn how utilities are using Reliability Centered Maintenance and other analysis techniques to drive more condition monitoring to replace ineffective time based maintenance strategies.

PAS 55-2011 International Benchmark for Optimal Management of Assets
July 12–15, 2011
A four-day educational session designed to enlighten you on PAS 55 and its move to an ISO standard, explain the opportunities and challenges, discover different PAS 55 road maps and explore certification options and business advantages.

Reliability Leadership Zero2One™ Series II
August 15–19, 2011
A unique learning event featuring 4 leading subject matter experts designed for anyone who is responsible for managing maintenance and ensuring reliability.

Reliability Centered Maintenance for SAP Plant Maintenance
October 4–7, 2011
Learn about the strategies and tools available for the SAP Plant Maintenance/EAM platform that support using Reliability Centered Maintenance, PM Optimization and FMEA to create an effective maintenance program. This event is designed for SAP users who are new to the concept of RCM; however, we are sure everyone will benefit regardless of experience level.

Lube-2011: Machinery Lubrication Conference
November 1–4, 2011
This event offers opportunities to deliver more business value through machinery lubrication best practices. Find out how some companies are increasing reliability performance and reducing downtime using proven lubrication strategies and techniques.

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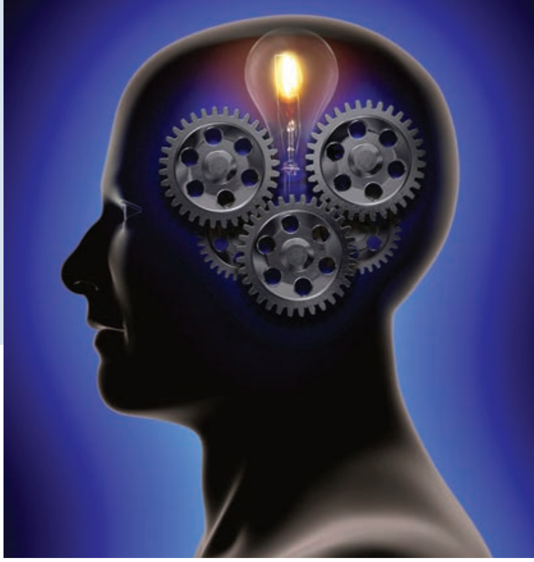

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The 2010 PdM Award Winners at Solutions 2.0, Bonita Springs, FL November 8th, 2010

UPTIME'S 2010 PdM PROGRAM OF THE YEAR

The 2010 Awards go to...

Uptime Magazine congratulates these outstanding programs for their commitment to and execution of high-quality Predictive Maintenance and Condition Monitoring Programs

Team members (L to R). First row: Gail Clayborne, Kaleigh Hatfield, Billy Terrell, Sarah Newberry, Adam Webb, Ramesh Gulati. **Second Row:** Teresa Wilhite, Brian Bennett, Dan Henley, Don Brandt, Vijay Narain, Charity Vandergriff. **Third Row:** Casey Schewe, Charles Starnes, Christopher Mears, Bob Walker, Bill Hane, Gary Jarrell, Dennis Weaver. **Last Row:** David Hurst, Roger Miller, Rod Stewart, Brad McClure, Chuck Bryant and David Riddle.

Arnold Engineering Development Center (AEDC) Aerospace Testing Alliance (ATA)

Best Overall PdM Program

In order to accomplish the mission of delivering best value war fighter support and asset stewardship, we have maintained over 15,000 assets using a reliability based program focused on Preventive Maintenance and Predictive Maintenance best practices. Through classical and streamlined FMEA/RCM analyses, asset class level Asset Management Strategies and an ISO9001 certified Asset Management Process, a right-sized maintenance program continues to be developed and refined for these assets. We utilize a strong advocacy program to ensure continued support to our CBM/PdM program by documenting and briefing success stories and overall cost savings to our client, the USAF. Their support as well as our upper management support has been the foundation needed to sustain our PdM program.

Arch Coal, Inc.

Best Overall PdM Mobile Fleet

St. Louis based Arch Coal is the second largest U.S. coal producer. Our backbone for maintenance and reliability activities is our Arch Initiative in Maintenance. **A.I.M. Goal:** A.I.M. is a strategic business solution that will create shareholder value by enhancing our planning efforts, resulting in a better understanding of today's business versus how we have managed in the past. **A.I.M. Vision:** Maximize asset availability and reliability based on production needs, and at the same time, reduce equipment costs through Reliability and Condition Based Asset Management.

From Left: Terry Taylor, Joe Swan, Bob McCreary, Arne Rajala, Randy Fizer

Back Row From Left: Michael Gaston, Billy Duncan, Jason Daniels, Ken Terry, Michael Rose, Kirk Parish
Front Row From Left: Glenn Parker, Abdon Davila, Michael Cook, Michael Muiter

Best Emerging PdM Program

Talecris Biotherapeutics

Talecris Biotherapeutics is a global biotherapeutic and biotechnology company that discovers, develops and produces critical care treatments for people with life-threatening disorders in a variety of therapeutic areas. The initiating event for creating an in-house PdM and Reliability program at Talecris was based on the results of a TPM program launch and assessment in 2007 that identified the need to increase the reliability of plant equipment beyond what our vendors were providing. In 2010 we have a staff of six PdM technicians and have increased the number of vibration monitored items tenfold. We've doubled the scope of the infrared program over the vendor supplied monitoring and have fully developed our dynamic motor testing, oil analysis and ultrasonic inspection programs as well. In the future, we are looking forward to a large plant expansion at our current location, having broken ground in March 2010. Our group has been involved in the early equipment management of the new assets, allowing for the integration of PdM and reliability.

Best Ultrasound Program

Talecris Biotherapeutics

An Ultrasound Inspection program was piloted in mid-2008. Two technicians that were most familiar with the equipment to be monitored were trained and certified. A process guide was developed by the technicians and engineering for the leak detection program. As a result, in 2009 an estimated $150K opportunity was diagnosed on steam traps and another $150K opportunity in condensate recovery issues was diagnosed as a result of failed and misapplied steam traps. Routes definition and a cost-avoidance tracking tool were developed as an Excel application. Later, the PM routes were moved into the CMMS. Plant P&ID's were updated with the individually assigned trap numbers and floor plans were updated to aid the technician monitoring the route. Path forward is to improve the cost-avoidance tracking on repaired traps in order to develop a system that will ensure modified or newly installed traps are documented and entered into the CMMS PM routes, and to improve efficiencies by incorporating infrared technology.

Back Row From Left: Jon Kvamme, Ken Brustad, Gary Mayen
Front Row From Left: Dave Knox, Doug Beavens

Best Infrared Plant Maintenance

Medtronic Facility Operations Thermography

From it's beginnings as a basic annual infrared (IR) route of the main distribution our Thermography Program has evolved, performing electrical IR routes for summer loads and winter loads as well as annual routes on secondary panels, main switchgear, production equipment and data center activities. We also utilize thermography for energy savings by performing building envelope and steam trap routes. Recently, Medtronic began using thermal scans in their process for new construction to help commission and baseline new installations. This process has already identified issues with new equipment under warranty. We uch as tightening lugs, cleaning electrical equipment, and taking amperage readings. Our Thermography Program strives for continuous improvement. Having a Level III Infrared Thermographer on staff has greatly helped the team to institute many best practice policies and procedures. Since 2003, the Reliability team has expanded the IR Program to twelve Medtronic facilities, partnering with them to standardize a global thermography process.

From Left: Kevin Stewart, Wes Horne, Tom Leslie, Dave Thornton, Bob Christenson, Carlton Boop, Ian Hatfield and Scott Alford.
Not Pictured: Danny Maksim and Rachel Brooks.

Best Infrared Transmission and Distribution

APS PDM Group

Arizona Public Service Co. PDM group has evolved over the last ten years from one tech, a laptop and an IR camera to a full-service predictive maintenance department including nine PdM technicians and an administrative technician. We have a training budget that allows every employee three opportunities per year. Additionally, we combine efforts with twelve statewide visual inspectors with a detailed and comprehensive RCM program; the PDM department is strategic in managing to inspect their facilities according to its maintenance basis. APS employs a condition status program that allows all information to be input and gives management and maintenance a "dashboard" view of all equipment and locations in our system. In the last nine years, four of which were exclusively infrared, APS has a total cost benefit of over 12 million dollars. In 2010 alone the cost benefit is 1.4 million dollars.

Back Row From Left:
Greg Osenga, Jeremy Holiness, Gary Latham, Vince Bellik, Robert Monthie,
Front Row From Left:
Brian Brzinski, Ron Biskup, Ed Lazzaro
Not Pictured:
Marie Getsug, Teri Tippett

Best Green Reliability Program

FutureMark Paper

FutureMark has applied Reliability Centered Maintenance (RCM) methodologies to new equipment installations, which have reduced energy usage and maintenance costs. Airborne ultrasound is performed by our technicians for a comprehensive air leak detection and repair program. To date, FutureMark Paper has realized more than $2,000,000 in cost avoidance and savings: 10% from RCM II, 10% from ultrasound, 5% from IR, 50% from vibration analysis, 10% from precision maintenance practices, and the balance from increased workforce utilization, reducing overtime and increasing FTE as a result of increased inspections.

Front Row From Left:
Larry Hoing, Dennis Pedersen, Matt Krommenhoek, Doyle Goss, Don Palmer, Allan Klink
Back Row From Left:
Arlan Britt, Lynn Moir, Mark Crowley, Chad Norris

Best Lubrication Program

Wells Lubrication

Wells is a family owned and operated company that was started in 1913 by Fred H. Wells, and headquartered in Le Mars, Iowa which coincidentally is the Ice Cream Capital of the World and the home of Blue Bunny Ice Cream. The lubrication and oil analysis program at Wells has been undergoing transformation since early 2007. Education, knowledge transfer, and corporate backing have all played an integral part of the lubrication and oil analysis program's success. The expectation of continuously improving the program and the clear identification of gaps, regular team meetings, and the increased knowledge of basic lubrication principles has created a competitive, yet nurturing environment that aids us in moving forward as a unified team. We began this project with 100+ lubricants and ended up with 1/5th of those lubricants. We have dedicated lubrication rooms in each facility for the bulk storage of both oils and greases, and the lubrication equipment. All oils are sampled and tested prior to being filtered and transferred to bulk storage containers. Oil changes are driven by oil analysis, which is done in-house utilizing a mini oil lab. We are constantly evaluating our lube practices and finding additional ways to increase effectiveness and reduce the potential for failures on equipment.

Peabody Powder River Services North Antelope Rochelle Mine

Front Row From Left:
Ted Lazarus, Layton Villalobos, Keith Haulkereid, Jim Hance
Back Row From Left:
Craig Brasfield, Glen Huseth, Dave Natchke, Troy Stuart, Brian Martinson

Best Lubrication Oil Analysis Mobile Fleet

North Antelope Rochelle Mine (NARM) is the largest production coal mine in the world. Our parent company, Peabody Energy, is the largest coal producer in the world. Knowledge and training play a key role in the program. Oil analysts have an average of over 24 years of mechanic experience as well as holding Level I and II certifications in Machinery Lubrication Analysis (MLA). Each has also had advanced training in failure analysis from Caterpillar. This experience and training pays off where the rubber meets the road; understanding and identifying the actual machine failure. Since March 2008, the NARM oil analysis program has included filter debris analysis which almost immediately increased the average life of monitored components. In fact, there are cases in which the average life has doubled through an in-depth understanding of equipment combined with forensics from filter debris analysis.

Domtar Espanola

Front Row From Left:
Rob Alexander, Mike Bond, Kim Hunt
Back Row From Left: Gord Bulloch, George Commission, Al McKechnie
Not Pictured: Al Schwartz, Keith St. Onge, Gary Martin, Charlie Lacasse

Best Oil Analysis Program

Many companies are good at oil sampling but what sets Domtar Espanola apart is the action that is taken when an anomaly is found. The lube techs work with the vibration analysts, PM millwrights and supervision to identify the defect, determine severity and recommend corrective action to be taken. In the case of a hydraulic or lube unit having a high particle count, a filter cart is immediately installed to bring the oil back to the target cleanliness level. The source of the contaminant is investigated and eliminated. Filtration is reviewed to ensure that it is adequately maintaining target cleanliness and that the specified filter has not been inadvertently substituted by a well-intentioned buyer looking to reduce costs. Domtar recognizes the value of training and education. Lube Techs are trained to Machine Lube Tech Level 1 and are certified Oil Monitoring Analysts (OMA).

From Left: Dean Weiberg, Jake McILwain, Jack Croswell, Jeff Cowling, Nick Maki, Tim Dickson, Jim Devyak, Dave Eddy, Bruce Bjelland, Jim Fetzik, Mike Yonkovich
Not Pictured: Jen Nelson

Best Vibration Program Mobile Fleet

Hibbing Taconite Company

Historically at Hibbing Taconite, major component replacements have been planned and scheduled based on the OEM estimated component life. With the ever-increasing costs of these components and the ability of new tools to better determine the actual condition of components, Hibbing Taconite Company has transitioned away from this practice to condition-based component replacement. Hibbing Taconite has been aggressively implementing the predictive maintenance tools such as Vibration Analysis, Oil Analysis, and Infrared technologies to provide us with a level of information that was not previously available. Utilization of these technologies provides an accurate picture of the health of our assets and components. Armed with these technologies, we have been able to substantially extend the life of our critical components well past the OEM recommendations. This has had a direct impact on our bottom line.

Front Row From Left: Sergio DeSimone , Marc Comtois, George Sheppard, Kedrick Swain
Back Row From Left: Tom Alexander, Herb Payan
Not Pictured: Bob Carver, Mark Libby

Best Vibration Program

The Lightship Group, LLC, Azima DLI, COMMANDER NAVAL AIR FORCE (CNAF), Ship's Force Machinery Vibration Analysis Team (SFMVA)

Aboard the Navy's fleet of active aircraft carriers, members of the ship's force are providing timely, accurate, and detailed assessments of the mechanical condition of rotating machinery through a program of periodic vibration measurements and analysis. The Ship's Force Machinery Vibration Analysis, SFMVA, is a self-sufficient, shipboard condition monitoring program, using portable data collector/real-time analyzers and PC-based software to provide a local capability for detection and diagnosis of early stage machinery faults. The SFMVA program is managed by the Commander Naval Air Forces Maintenance Officer. Annual cost-benefit studies show that the SFMVA input to CBM produces significant savings in maintenance functions with an ROI greater than 15:1.

Southern Company

The condition based motor maintenance program was initialized at Plant Miller in 1995 by identifying motor failure modes and applying condition based maintenance technologies to address each mode. A formal reliability centered maintenance study was performed in 1995 identifying the criticality that each motor attributed to the production of electrical generation. The CBM team utilizes thermography, oil analysis, vibration analysis, ultrasonics and motor diagnostics to identify all types of motor performance issues. Peak season EFOR, equivalent forced outage rate, is a direct indicator of the success of the motor testing strategy. When large motors fail during peak season, detrimental effects occur to the peak season EFOR. Because of the condition based motor maintenance program, critical motors seldom fail at Plant Miller.

Best Motor Testing Program

Jeffrey Brasher

Kevin Starling

Gavin Love

Kim McAteer

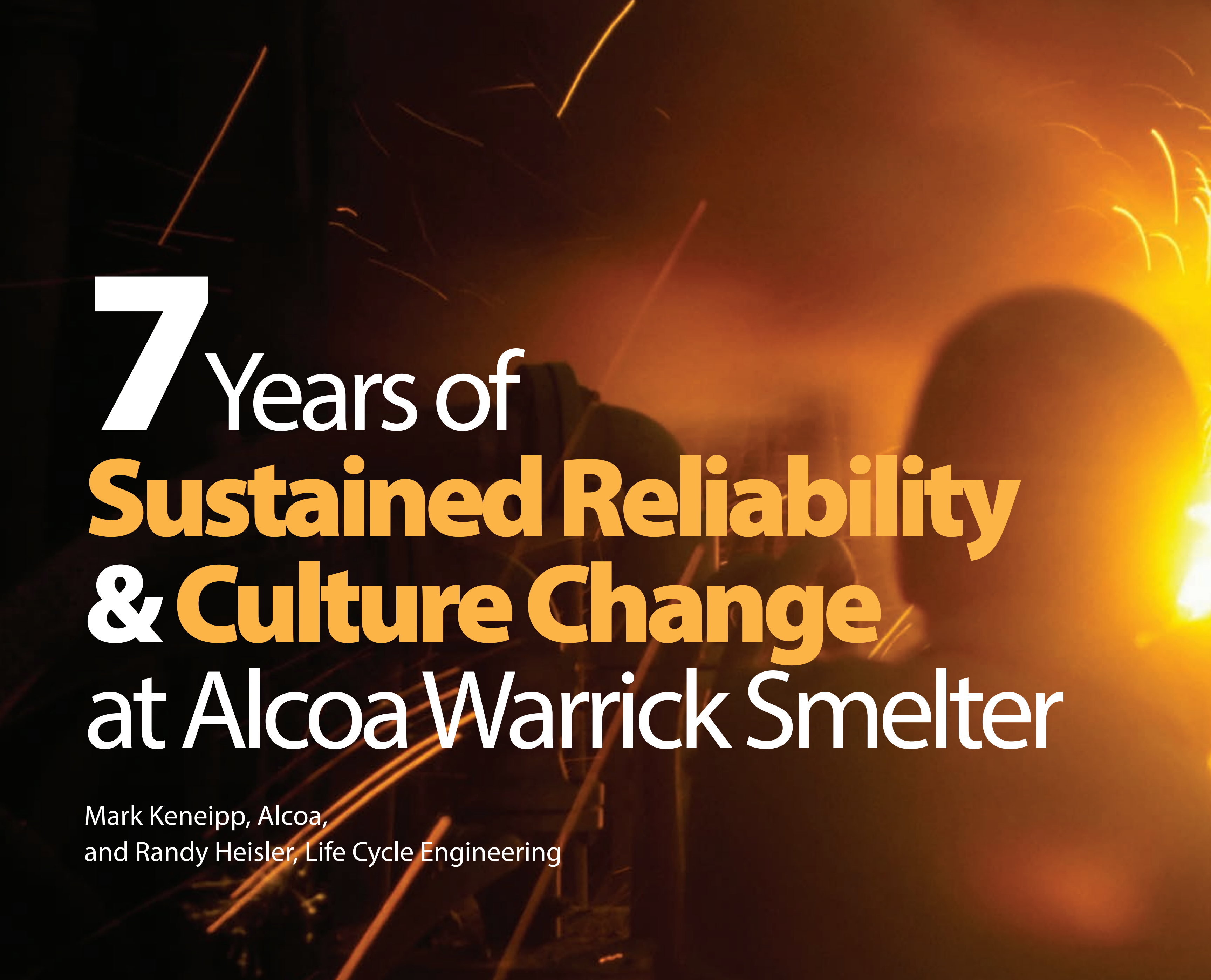
Uptime's PdM Program of the Year Nominations will open June 1st, 2011 for the 2011 Awards

Best Ultrasound Mobile Fleet

Iron Ore Company of Canada

Iron Ore Company of Canada has nine employees trained at Level I Airborne Ultrasonics and one employee trained at Level II Airborne Ultrasonics. The most impactful application for airborne ultrasound is the detection and elimination of haul truck engine dusting. Basically, dusting is when engine connections are loose and allow small dust/dirt particles into the crankcase, spiking oil contamination and creating abrasive engine wear and excessive oil changes. With a 24/7 operation, increasing the availability of haul trucks is a major contributor to increased revenue.

From Left: Michel Valcourt, Glen Oldford, Doug Thomas



7 Years of Sustained Reliability & Culture Change at Alcoa Warrick Smelter

Mark Keneipp, Alcoa,
and Randy Heisler, Life Cycle Engineering

Background

It is not often that one runs across an organization that is able to undertake a significant business transformation, implement the changes successfully, and then sustain the gains for seven years with no end in sight. Here is the compelling story of one organization that has succeeded—Alcoa Warrick Smelter.

The story began in 1997 when Alcoa decided to implement the Toyota Production System globally across all 250 locations. Significant progress was made, but the Alcoa Primary Metals division leaders were not seeing the results that they expected. A business unit level internal analysis showed that their assets and reliability processes were lacking stability and this was holding lean manufacturing gains hostage. Stability is a foundational element to the Toyota Production System. If one is familiar with the Toyota House, or any other house for that matter, having a solid foundation is the key to long-term sustainability. (See Figure 1)

In 2002 Vince Adorno, Vice President of Engineering for Alcoa Primary Metals, decided to form a corporate-led team to develop a business case and reliability implementation strategy. External consultants were included in this process to ensure that best practices and reasonable estimates of potential savings were incorporated into their strategy. They also looked at their own pockets of excellence and best practices that were in place in the plants.

During these sessions, Ron Moore, of the Ron Moore Group said, "You have way too much 'maintenance' in your reliability effort." The Alcoa team agreed that they were focused on improvements in the maintenance organization and were missing oppor-

tunities for improvement by not considering operation's impact on equipment reliability. Their efforts at that time were being driven by the maintenance and engineering managers at each plant site with little involvement from operations. In addition a high management turnover rate was hindering a long-term focus on reliability, and was making continual training and retraining of key leaders necessary.

Moore explained that the maintenance organization is responsible for many functions, but it has no direct control over the successful outcome of these functions. For this reason, reliability success can only be achieved via an active partnership between maintenance and operations. Moore called this concept "Reliability Based Operations" as illustrated in Figure 2.

"You have way too much 'maintenance' in your reliability effort."
- Ron Moore

The Strategy

Corporate leaders began to develop a strategy that included a model in which plant managers and operational leaders would drive and own the reliability effort. In addition, they wanted everyone to be responsible for reliability, just as they are for safety.

The ownership would be initiated through the development of a solid business case for the reliability improvement effort. This busi-

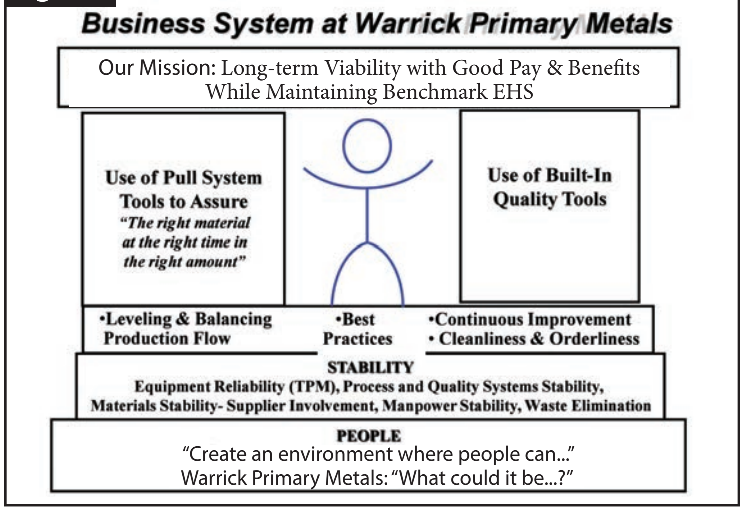


Figure 1

ness case would be reinforced with data from existing best practice plants in the Alcoa network as well as benchmark data from other external plants.

The ground rules for the return on investment was that it would not, and should not, come from deferring maintenance. Savings were to come from the Repair and Maintenance (R&M) budget of the facilities, with an understanding that the production gains, through improved stability, would increase throughput and eliminate waste. This was estimated to be much greater than the maintenance savings.

The group estimated that they could lower Repair and Maintenance (R&M) costs by 10% to 20% over a three-year period, and predicted that for every maintenance dollar saved by eliminating defects, they would realize 1.5 to 6 times that in Overall Equipment Effectiveness (OEE) gain. The production strategy was to implement OEE, calculate the value of a one percent increase in OEE, and use this knowledge to eliminate bad actors or defects that would subsequently drive plant improvement.

Having developed the business case for improvement, the group's next challenge was to craft a strategy to educate the organization, determine the existing gaps in reliability best practices, and implement the needed changes. A three-wave process was developed in order to create an orderly and sustainable phase-in of the program. (See Figure 3)

The first wave would focus on educating the site on what reliability excellence means, solidifying the sponsorship and creating the necessary alignment within the management team, union leadership and workforce. The second wave would assess a site's current performance using a 29-element Reliability Excellence Model, or what Alcoa eventually called "REX." (See Figure 4)

A master plan would then be created to close the gaps, and a business case developed to show the value of achieving reliability excellence at each site.

The third wave would entail forming a leadership team to manage the changes and focus teams to execute the tasks in the master plan that would close the gaps in best practices. Benefits were to be tracked, and audit processes were to be put in place to ensure sustainability. A pilot location was chosen to test the process. This is where Warrick came into the picture. . . .

Warrick Primary Metals

In the fall of 2003, Royce Haws, the Warrick Smelter Plant Manager was contacted by Vince Adorno, VP of Engineering and Maintenance. Adorno informed Haws that Warrick had been recommended as the pilot site for the three-wave process. Warrick's costs were among the highest across the Primary Metals business units. The plant being shut down before it's time was also a possibility. Although the challenges were great, the plant leaders agreed to go forward.

To lay a foundation of knowledge for what to expect, and how to manage it, Haws and his maintenance manager, Danny Reyes, began an educational journey to enhance knowledge and understanding of strategies and techniques to create excellence in manufacturing and maintenance reliability.

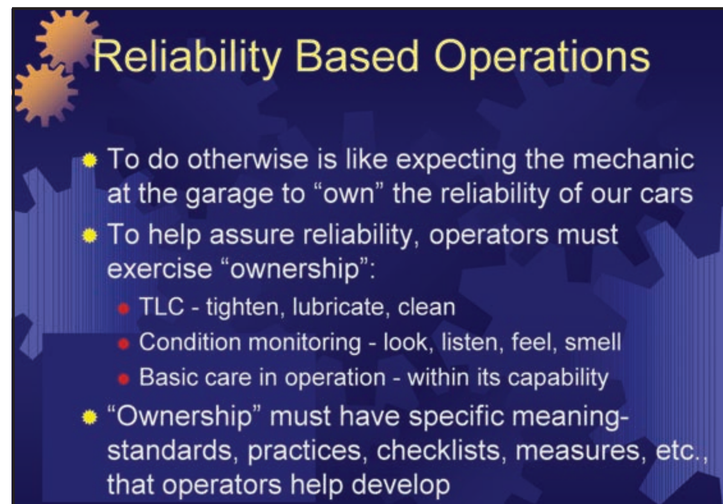


Figure 2

This introductory education was followed by a reliability best practices assessment that collected data and included interviews with managers, supervisors, crafts and operators. The plant's score was a 441 out of a possible 1000, indicating that Warrick was in a predominately reactive mode, with most of the focus on being really good at emergency maintenance response. The opportunities for improvement were considerable, but significant culture change would be needed if the site was to achieve the business case they had developed. The plant leadership paid specific attention to the Master Plan in terms of what had to be done to close the gaps in maintenance, operations and culture, in order to be successful.

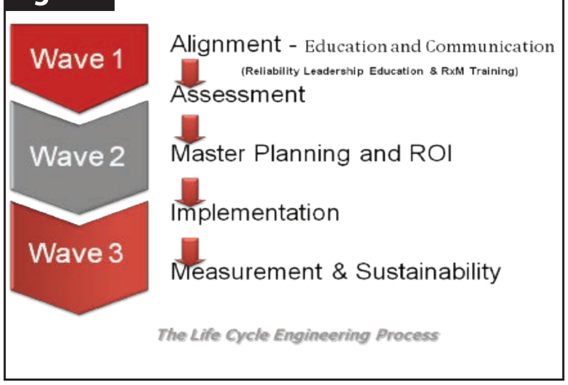
A leadership team was formed to steer what was now called the "REX" effort, including creating governing principles and measures needed to lead the organization into a proactive environment. The team developed and executed a communication plan that included "Town Hall" meetings. At these meetings site leaders communicated to the organization why they were implementing REX. They explained that everyone's help was needed if they expected to achieve the goals and enjoy long-term job security. Both salary and union personnel were chosen to participate on the focus teams that would design the future state of the business processes, how each part of the organization needed to function and what their roles would be in this new way of operating. The central premise of this new way of thinking was that the operations side of the organization would own the reliability of the assets.

Leading the Change

The plant manager's commitment was heard clearly at the Town Hall meetings. Haws shared that Warrick's R&M costs were almost the highest in the Alcoa smelting system and needed to be reduced 15%-20%. "I pointed out that we could do this the stupid way or the smart way," explains Haws. "The stupid way was to defer maintenance for a few years, avoid the consulting fee, and I could hope for a promotion before top management figured out the cost reductions were not sustainable."

Figure 3

Figure 4



Haws understood what he called the stupid approach, because that was the plant condition he inherited when he transferred to Warrick five years earlier. He knew the smart way was to approach this new opportunity as a potential transformation for a 43-year-old facility. Warrick did have a "burning platform" or business case to drive change. Less than 5% of the world's capacity for smelting aluminum is performed in plants that are 50+ years old and the Warrick Smelter was 43 years old. In the 1970s, there were 33 aluminum smelters operating in the USA; today there are only eight.

Due to the respect that the area managers had for Haws, their plant leader, they got on board, started asking what they could do to help, and started learning more about this new approach for maintaining plant assets. Admittedly, many were concerned this new initiative might become another program of the month.

The leadership team went to work and drafted a mission statement, plant floor communications plans, governing principles and partnership agreements. The team also developed a method and process for capturing production data that would later be used to calculate OEE and Pareto chart equipment bad actors.

Additional metrics were chosen, but most importantly, accountability for these additional metrics had to be determined. Haws decided that production managers would now be accountable for maintenance metrics like PM Compliance, Schedule Compliance and Maintenance Cost. It would now be the maintenance organization's responsibility to support operations in achieving best practice goals. The maintenance organization would now be accountable for more leading indicators like Percent Planned Work and Schedule Efficiency, Backlog, and PdM Diagnostic versus Corrective Work, to name a few.

"Assigning accountability in this way marked the beginning of a significant culture change," points out Mark Keneipp, who served as Warrick Smelting REX implementation facilitator. "We needed outside resources to teach us change management principles we needed to follow as we led the organization through this cultural change. As both Reliability Excellence and change management experts, Life Cycle Engineering (LCE) helped us navigate through the technical and cultural changes."

The leadership team asked another key question: "Where do we start?" In a lengthy discussion, the team considered factors like which area of the plant would bring the biggest financial gain and where success was most likely from a cultural and leadership standpoint. The group decided to focus on the aluminum services area. The success in this pilot area would later become the model for the rest of the plant.

Re-engineering Work Processes

The focus teams began re-engineering the work management processes, material management processes and reliability engineering processes. Roles and responsibilities were defined. Newly redesigned processes and roles were presented to the leadership team and approved for training and implementation in the pilot area.

Planning and scheduling meetings were re-engineered so that the planning and coordination of jobs was done prior to the meeting by smaller groups so that the focus in the "scheduling" meeting was just that, scheduling or "when" to do the work. Production managers now were in charge of prioritizing and scheduling the work with maintenance in an advisory role. A true partnership was beginning to form.

Each week a job from the upcoming week's schedule was chosen for review the following week in order to critique how well it went so that the group could learn from both successes and failures.

Operators were now paying close attention to how they were operating the assets and began entering requests for work into the Computerized Maintenance Management System. They also started collecting downtime data and working with Reliability Engineers to eliminate recurring failures. Changing the accountability for reliability was now creating a pull for help from Reliability Engineers so that OEE targets could be achieved.

Figure 5 Warrick Smelting Maintenance Kitting-Staging Area

Reliability Engineers corrected equipment hierarchies and assigned criticality codes to the assets. Simplified failure mode and effects analysis was performed on the pilot area assets by the engineers which set the stage for PM and PdM optimization.

Significant focus was put on parts and materials by both the Materials Management focus team and the planners. Obsolete parts were dispositioned and a parts kitting area was set up to kit and stage parts for planned work. A color-coded tagging system was put in place to provide a visual recognition of where parts and materials are in the process. (See Figures 5 and 6)

Active Leadership Yielded Significant Results

The REX implementation process also included a "REX Lead Team" responsible for driving the implementation of the Wave 3 Master Plan. The REX Master Plan included almost 140 action items; 20 of these were owned by the REX Lead Team. To this day, seven years later, the REX Lead Team continues to meet monthly to discuss opportunities.

Improvements in productivity and partnerships were quickly observed in the pilot area and subsequently roll-out plans were developed to implement the changes throughout the plant. Operation managers were responsible for implementation in their areas. This signaled to each area that this was not a "maintenance department initiative."

Progress was slow but the benefits were mounting. When this effort began, maintenance costs were excessive. In 2004, Warrick realized an 11% reduction in R&M costs/MT aluminum produced and another $2.4 million/year in improvements connected to OEE gains compared to our 2003 REX base. The benefits continued in 2005, with OEE gains coming in at $4.4 million/year and annual maintenance costs dropped by 15% from our 2003 REX base.

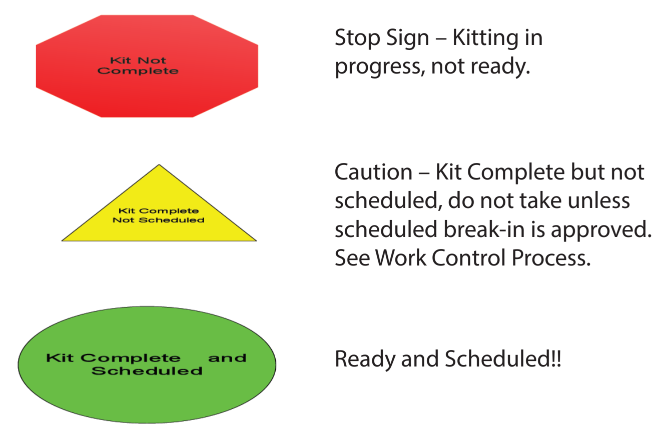
As significant as the results were, the journey to improve reliability was not over. The Warrick Primary Metals leadership believed they now needed to optimize the improvements they had made in order to continue their progress.

Optimizing Results to Continue Progress

The year was now 2007 and the journey was not over. Even though significant financial benefits had been achieved, the plant was still far from the initial goal that was set by the plant leadership. Achieving that goal was going to require more changes. Thousands of preventive tasks still needed to be optimized, organization structures needed modifying, and the span of control for planners had to be adjusted. Continued culture change was necessary for their success.

Joe Kuhn, Smelter Maintenance Manager explains, "We had to go all in. In other words, each of the twenty-nine elements [of the Reliability Excellence Model] had to be focused on and optimized to achieve best practice." This would require everyone to play a part. There was some temptation to "cherry pick" from the 29 elements but leadership decided to embrace all the elements. The REX Wave 3 was seen as a holistic model with the elements connected in ways that could not be separated to achieve the desired results.

Figure 6 Kit Tagging System



Maintenance and operations personnel reviewed each PM during PM Kaizen events. Estimates were inaccurate and tasks were outdated. PMs implemented 20 plus years ago were anywhere from 4 to 16 hours long and included time to do an inspection and then fix what was found. This was mostly driven by maintenance not knowing if operations would give up the machine later to do maintenance, so it was thought best to do it all while the machine was down. Machines sat idle for hours while parts and special tools and equipment were found to do the work.

In Kuhn's words, "We took out stupid." Improvements were immediately visible. Repairs were no longer made during PMs. Findings were reported, then planned and scheduled. This was a huge eye-opener for the organization. Many tasks were replaced with condition-based tasks. Predictive Maintenance (PdM) was taken to the next level. In 2003, PdM work was only 1.5% of total maintenance hours. Today about 14% of the total hours is diagnostic and corrective follow-up work. Kuhn points out that there is still plenty of opportunity for improvement: "Ideal would be fifteen percent diagnostic, and thirty-five percent of corrective PdM follow-up work."

Previously the maintenance group would try to optimize a run-to-failure approach. Kuhn shares an example: "We would have oil analysis data indicating that functional failure had begun in a $15,000 gear box but we would attempt to operate it for another six months and hopefully replace it just before it got smoking hot." Today they have nine hourly technicians performing various PdM diagnostic duties around the smelter. The preventive and predictive maintenance program is now failure-mode based. Further, they act on the data the same day, then plan and schedule follow-up work. Some tasks were also shifted to operators. As a result of this massive effort, 55,000 man-hours were taken out of the PM program. Again, a significant number of these saved hours were

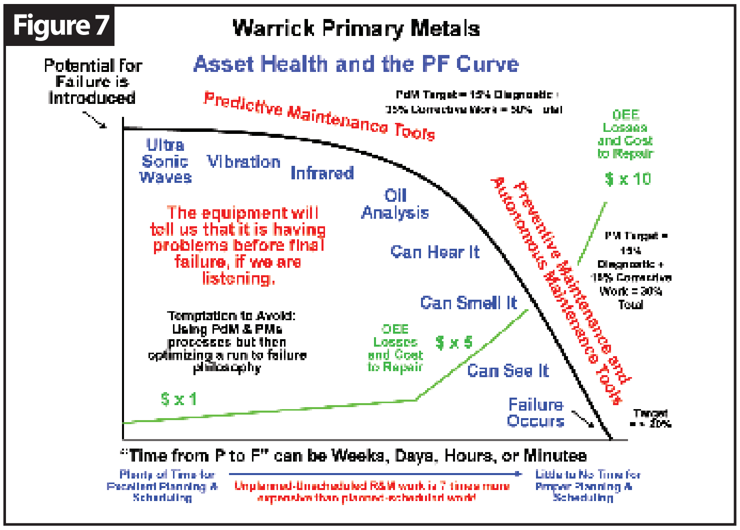


Figure 7

shifted into PdM diagnostic efforts and follow-up corrective maintenance.

The goal was to get higher on the Potential Failure curve (PF curve). (See Figure 7)

Since the beginning of the initiative, there had been an attempt to focus the maintenance organization on the three types of maintenance: preventive, emergency and backlog relief. Emergency work had remained high, which continued to divert resources away from PM and backlog reduction work. Leadership decided to centrally locate a crew that would handle emergencies across the plant for both mechanical and electrical work, while the remaining workforce focused on executing PMs and planned backlog. The message that emergency work is bad was communicated through signs throughout the plant.

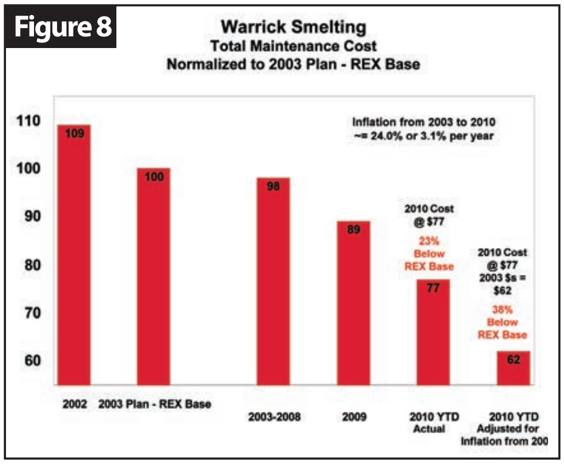


Figure 8

Kuhn addressed the span of control for Planners. They were now measured on the percentage of planned work that they were actually producing. Planner metrics were revisited because some former expectations were driving the wrong behavior. Previously, hitting the corporate expected numbers was more important than the quality or efficiency of the work that was put on the schedule. Leadership communicated to the organization that it was acceptable for the numbers to be lower, but accurate, so that the barriers to best practice could be removed. Keneipp, Warrick Smelting REX implementation facilitator, reflects, "Everyone's efforts were directed toward lowering costs and increasing OEE, which were the end results we were trying to achieve. The quality of maintenance work became more important than how fast something got fixed."

Standing work orders were driven out of the system. The more accurate asset repair data indicated that the average emergency call cost $500. Kuhn communicated this figure to operations leaders who were responsible for maintenance cost. The entire team now realized that prioritizing work properly would save significant money.

The storeroom was also a high cost area, due to inventory inaccuracy and high stock out percentages. Over the years, this condition contributed to "goody piles" around the smelter where craft folks kept spare parts to assure they would be on hand as needed. Another challenge was that 40% of the spare parts in the storeroom were "orphans," meaning they were not associated with a Bill of Material.

To improve efficiency, vendor stocking programs were put in place with parts being delivered for planned work. The storeroom was set up to house only parts needed for emergencies. Improved reliability on the plant floor was also lowering materials costs. Motor and gearbox failures no longer occurred weekly. Today, about 50% of spare parts come directly from the vendor and spend no time in the storeroom. This is a major benefit of planning and scheduling work four to six weeks in advance. "In reality," Kuhn points out, "a storeroom is mostly a huge countermeasure for emergency maintenance."

Management continued to reinforce the message that reliability was critically important. The communication plan included one-on-one conversations with employees and awarding of incentives. For example, the quality of feedback on PMs had suffered over the years. Due to the fact that follow-up corrective work was rarely scheduled, craft people often didn't fill out the PM reports. They saw it as a waste of time. To overcome the problem, crafts were recognized for detailed feedback on work orders. Operators were also recognized for accurate and detailed work requests. This type of behavior was rewarded with $25–$100 gift cards. Management put focus on getting work requests entered properly, the findings scheduled and executed, and the results communicated to employees.

Sustaining the Gains

Alcoa Warrick has encountered many bumps in the road on the long journey to reliability excellence, but significant results have been achieved in both, culturally and financially. The challenge

Continued on page 64

Publishers Note: We found this balancing tip written by Commtest's Dennis Shreve and thought Uptime readers would find value in the procedure. Please e-mail me if you would like to see more procedures like this one in the pages of Uptime.
–Terrence O'Hanlon, CMRP, Publisher, tohanlon@reliabilityweb.com

Balancing Without Phase

Dennis Shreve, CMRP

Sometimes it may be required to balance a rotating machine or part under conditions where a conventional phase measurement is either impossible or unavailable. In this situation, a four-run method can be used to arrive at an amount and position for a corrective weight.

To perform a four-run balancing procedure, one only needs a means to measure vibration amplitude and use polar plotting techniques. A 10-step process is outlined below.

1. With the machine in operation, locate and measure the point of highest vibration on a bearing. Either attach the pickup to this position or accurately mark its location so subsequent measurements may be taken from exactly the same place.
2. Measure and record the original vibration amplitude as value O.
3. Place a trial weight at some arbitrary location on the rotor, restart the machine, and record vibration as amplitude T1.
4. Stop the machine and rotate the selected trial weight 90 degrees to 120 degrees as most convenient at a constant radius, restart the machine, and record vibration as amplitude T2.
5. Stop the machine and rotate the trial weight another 90 degrees to 120 degrees in the same direction at the same radius, restart the machine, and record vibration as amplitude T3.
6. From the foregoing data, the location and the amount of a corrective weight may be determined as will be discussed and illustrated below.

   First, record all pertinent data:

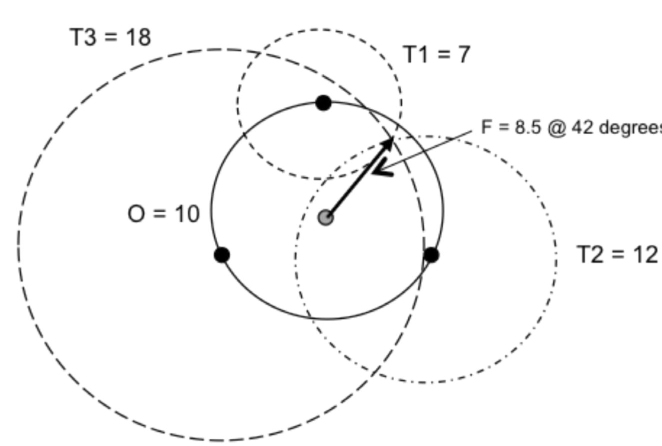
   - Original unbalance measurement, O = 10 mils. Selected trial weight, TW = 50 grams.
   - First trial reading, T1 = 7.0 mils with TW @ 0 degrees.
   - Second trial, T2 = 12.0 mils with TW @ 120 degrees.
   - Third trial, T3 = 18.0 mils with TW @ 240 degrees.

   Note: The angles refer to the trial weight positions on the rotor relative to an arbitrary zero point.
7. On the polar graph paper, draw a circle with a radius of 10 mils. On the circumference of the circle, mark the trial weight positions. (For this example, the angles of choice are 0, 120, and 240 degrees.)
8. Using the points marked on the circumference of the first circle as centers, draw arcs with radii equal to the respective vibration amplitudes measured with the trial weight at the three locations.
9. Draw a line from the origin of the original circle to the intersection of the three trial-weight circles. This is the angular position of the corrective weight relative to the trial weight positions (42 degrees in this example).
10. Measure the length of the line, F, drawn in Step 9. (It is 8.5 in this example.)

    The corrective weight addition may now be calculated from the formula:

    Corrective weight, C = TW * O/F = 50*10/8.5 = 59.0 grams

    This is the amount of weight to be placed at an angle of 42 degrees. See graphical illustration below.



Dennis is Channel Support Engineer for the Channel Partner Sales organization with Commtest Inc. He has 40 years of experience in designing and developing electronics and software systems and leading projects for real-time industrial process monitoring and control applications. Over the past 21 years, he has specialized in predictive maintenance (PdM) technologies and vibration detection, analysis, and correction methods for maintaining machinery health. www.commtest.com

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decision support

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Why Your Preventive Maintenance Program Isn't Working

Ricky Smith, CMRP

Does it annoy you that in spite of regularly performing Preventive Maintenance (PM) on your equipment it continues to breakdown? Some may call this insanity—continuing to do the same thing over and over, expecting a different result.

If you sat down and graphed out your company's PM labor hours versus emergency labor hours what would you find? In the chart below we find PM labor hours flat however emergency labor hours rising which indicates the PM program is not effective.

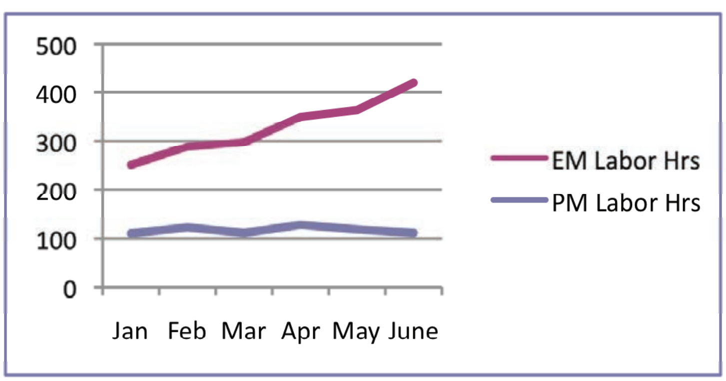


Figure 1: PM Labor Hours vs. Emergency Labor Hours

Have you ever heard of "killer PMs"? These are PMs which are intrusive and are known to quite commonly cause premature failure of an asset. One such example might be taking a pump out of service to inspect coupling shaft alignment. Consider carefully that this inspection could be easily performed using infrared thermography or vibration analysis without shutting down the pump. Have you ever seen someone lubricate an electric motor with sealed bearings? These PMs sound unnecessary. Yet these things happen every day.

Figure 2: Is this happening to you?

PMs can also absorb resources which could be used for work that would actually improve your reliability. Remember, the challenge of reliability is the detection of a defect early enough that a part or equipment change out or repair can be planned and scheduled in a proactive state.

The example below displays the P-F Curve where "P" is the point at which an abnormality begins (defect). The key is that we want to identify a defect (potential failure) as early as possible so we have the time to plan, schedule, replace or repair the item before it fails. Point "F" is the point of functional failure. This is where the item can no longer deliver its intended designed function. At this point there is typically a very small amount of time before total failure where catastrophic damage could occur, which is not good unless Run-To-Failure (RTF) is part of our maintenance strategy. If RTF is your maintenance strategy for specific equipment, contact me and let's talk about this issue.

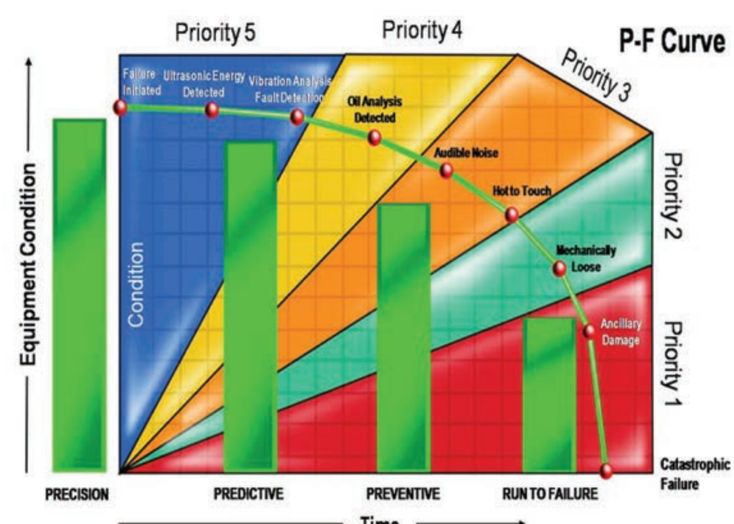


Figure 3: PF Curve

In the graphic above, it is important to notice that Predictive Maintenance allows one to detect a defect closer to "P" than Preventive Maintenance. We call this on-condition monitoring.

Do you realize that most Preventive Maintenance programs have not been engineered, they have just evolved? With every regulation or component failure, both the number of PM tasks and the frequency of the tasks being executed increases, until it consumes 30%–50% of your workforce and you are lulled into the false sense

"It isn't what you know that will kill you, it is what you don't know that will."

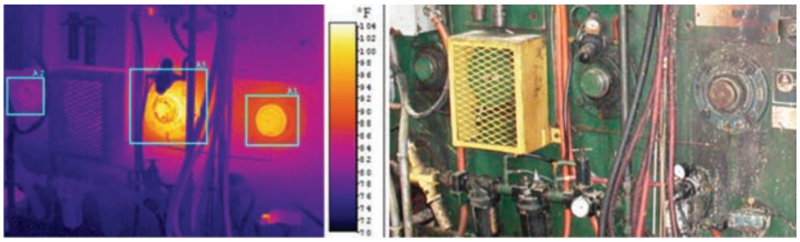


Figure 4: Have seen this problem before? How do you PM this equipment?

of security that you have evolved into a Best Practice or World Class organization." **Let's be clear, it is impossible to evolve into Best Practice; it must be carefully engineered.**

In fact, after numerous benchmarking studies, data states factually that most maintenance organizations are doing almost exactly the same type of maintenance they've always done. Now here's the scary part: a closer look at all Preventive Maintenance (PM) tasks reveals that on average:

- 30% don't add value and should be eliminated
- 30% should be replaced with Predictive Maintenance (PdM) tasks
- 30% could add value if re-engineered

What that means to you is that less than 10% of your PMs are truly adding value as written. Or in other words, *potentially 90% of your PM tasks should be eliminated or changed.* What's worse, when you conduct unnecessary, invasive maintenance, you actually introduce variability and potential defects into your asset and process reliability? That's right! You are actually causing some failures and you don't even know it!

What to do about the problem?

Striking the right balance of Preventive and Predictive Maintenance is absolutely necessary and it offers a rare opportunity to save millions of dollars through:

- Lower maintenance costs
- Lower spare parts inventories
- Lower energy consumption
- Better safety performance
- Increased throughput capacity

Achieving these results is not easy. For starters, you need to have a common vision, a basic implementation strategy, and a clear understanding of what's required for success. Let's look at the four most important steps you can take to begin achieving your reliability goals.

1. Receive training in PM/PdM Best Practices.
2. Update your functional hierarchy so that you have a clear understanding of the machines in your facility and their component configuration.
3. Conduct a criticality assessment on your assets. This assessment is used to help determine maintenance strategy, prioritize work orders, and make better overall risk management decisions. (Send me an e-mail if you would like more information on this topic.)

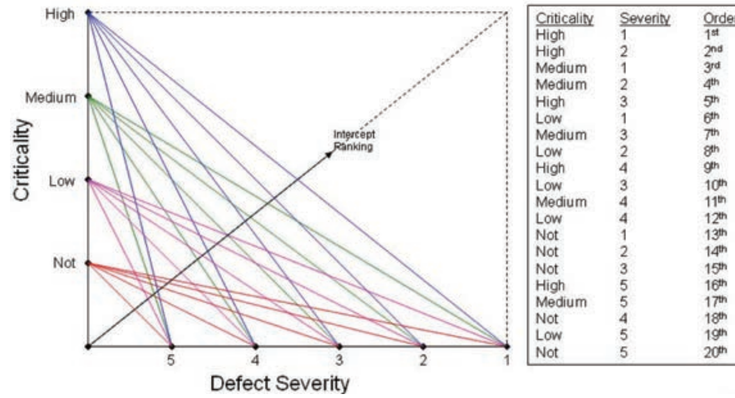


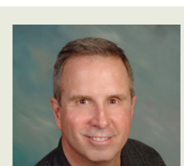
Figure 5: Prioritizing Work Using Asset Criticality and Defect Severity

4. Develop a complete understanding of the failure modes that are present or may be present in your components. These failure modes come from two places: 1) the inherent design of the machine; and 2) the operating context in which they are used on a daily basis.
5. Perform a Preventive Maintenance Evaluation (PME) where you identify each PM Task and any connection it may have to a failure mode you are experiencing. Are the PMs causing the failure or addressing it? If they aren't addressing and reducing failures, then they add no value.
6. Then, believe in the outcome of your PME. If it says a PM adds value, do it! If it shows it doesn't, then re-write/re-engineer it so it does, re-assign it to the appropriate PdM Technologies or get rid of it! See the chart below. This process frees up resources for use in proactive maintenance.

PM Task Action Recommendation	# of Tasks	% of Tasks	Man-Hours Represented
Non-Value Added (Delete)	1,640	8.2%	6,661
Reassign to Operator Care	1,380	6.9%	5,605
Reassign to Lube Route	2,856	14.3%	11,600
Replace with PdM	6,437	32.2%	28,222
Re-Engineer	5,200	26.0%	26,221
No Modifications Required	2,487	10.4%	8,987
Totals	20,000	100.0%	87,297

Figure 6: Example of a PM Evaluation Sorting Exercise

If a company is not seeing results from their current PM Program then it is time to change. Make it happen today. If you would like a one-hour webinar on the topic send me an e-mail at rsmith@gpallied.com. I also have a Tool Box Training Session on Failure Modes Driven Strategy you may enjoy. Just let me know if you are interested. ***Make something happen!***



Ricky Smith, CMRP, CPMM, is the Senior Technical Advisor for Allied Reliability. Ricky has over 30 years in maintenance as a maintenance manager, maintenance supervisor, maintenance engineer, maintenance training specialist, maintenance consultant and is a well known published author. www.gpallied.com

Editors note: The SAP EAM/PM study is available for download at www.cmmscity.com. It is an independent study performed by Reliabilityweb.com and is not associated, sponsored or connected to SAP AG in any way.

"Busted"

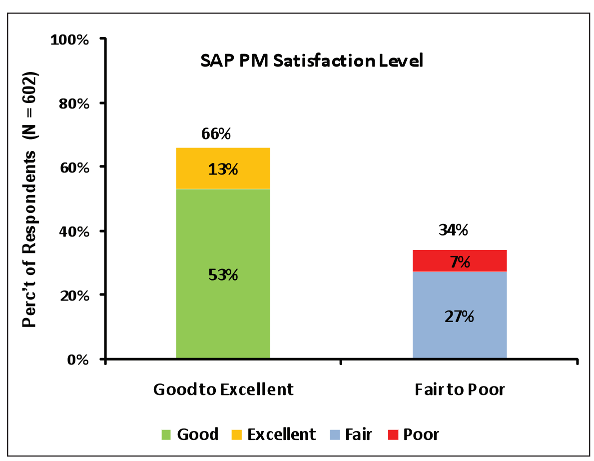
The SAP EAM/PM Maintenance Myth

Stephen J. Thomas

There are those that believe that SAP EAM/PM is a software application that does not provide satisfactory support for the maintenance and reliability work processes that exist within the plant environment. The recent survey of over 700 maintenance managers and reliability professionals conducted by Reliabilityweb.com dispels this belief entirely! In fact 66% of the respondents actually rated SAP EAM/PM as a good to excellent tool for the execution of maintenance activities.

The survey was conducted in a manner that permitted cross-linking of the satisfaction level with the software tool to specific components of the maintenance work process. What was learned was that software unto itself cannot deliver value. It needs to be coupled with maintenance work and support that process. To this end it was recognized that the companies that have successfully utilized SAP EAM/PM in the maintenance arena have included the following in their business strategy:

- Alignment of the software with the internal work processes. In many cases this required customization which was achieved with the use of outside consultants in order to utilize their extensive experience.
- All work orders and spare parts information were included in the system along with elimination of legacy tools that previously supported these processes.
- Extensive training both during implementation and after deployment to enhance understanding and gain acceptance.
- Increased understanding and utilization of reporting from within the SAP software vs. exporting data to third-party tools such as Excel.



It is far easier to blame the software than to institute a set of change management processes to support its implementation and optimum use.

- Inclusion within the SAP EAM/PM process of other tools and applications that support the overall maintenance effort but provide deeper and more robust functionality in key business areas.

The data obtained from the survey was also able to explain some of the reasoning for the myth of SAP EAM/PM's inability to support maintenance. Some of these reasons include:

- The majority of the respondents indicated that the implementation of SAP EAM/PM was done to improve integration across business lines and did not include Maintenance as a decision maker in the process. Abandoning a system with which you are familiar for one in which you did not have input can cause problems.
- Failure of allow time for the system and the work process into which it was being embedded to mature. Of note is the fact that 58% of those who have been operating SAP EAM/PM for more than one year gave it a good to excellent rating.
- Failure to track all work orders and spare parts within the application. For those who did track 100% of the work orders and spares, the satisfaction rating was far higher than those who did not.
- Failure to acquire adequate training in the use of the software, not just at implementation but on a continuous basis. In fact where more than 50% of the staff received training in the past year, the level of satisfaction with SAP EAM/PM in the good to excellent range was three times higher than those who expressed dissatisfaction.
- Failure to abandon legacy reporting tools and only partially adopting those provided by the SAP EAM/PM software. Those surveyed who use SAP EAM/PM reporting ex-

pressed a much higher level of satisfaction than those who felt the reporting functionality fell short of their requirements.

- Failure to abandon legacy planning and scheduling tools. While over two-thirds of the respondents indicated that they use SAP EAM/PM, there still are approximately 30% of this group still using Microsoft Excel and Project as well. There can be many hidden reasons for this which tie back to other failures such as: lack of 100% work order tracking; low levels of initial and ongoing training; and others.

The point is that the myth surrounding SAP EAM/PM's lack of ability to support maintenance has contributing issues. It is far easier to blame the software than to institute a set of change management processes to support its implementation and optimum use. However, for software implementation to be successful, addressing the work process is critical.

Another area that was very revealing was the low number of respondents (17%) that indicated that they or their company was a part of the SAP EAM/PM user group. From the survey it appears that most organizations implement software and then move forward with the belief that the vendor is nothing more than a software salesman. The mature companies do not hold with this belief. Instead, they participate in the vendor sponsored user group to provide feedback about the tool, significantly impact future development, and overall, maintain a partnership relationship with the vendor. After all, applications such as SAP EAM/PM are not replaced often; why not have input into the product?

SAP EAM/PM can provide significant business value specifically due to its integration with departments such as Finance, Materials Management, and others within a company's business network. This can only be accomplished if action is taken to:

1. Address work process as the driver of software utilization. The process changes must go hand-in-hand with the software.
2. Make full use of SAP EAM/PM functionality in order to attain maximum value from the product, the employee user base, and the associated work processes.
3. Eliminate past practices that detract from the integration capability of the software.
4. Provide ongoing training to increase understanding of the tool and ultimately acceptance for its use.

In the end the myth that SAP EAM/PM cannot support maintenance appears from the survey to have far deeper root causes than provided by the software alone. The survey goes a long way to proving this fact. It is hoped that those who wish to improve their use of SAP EAM/PM, review the survey in detail, identify their gaps, and seize the opportunity for acceptance of the software and improvement of the work process.

Steve Thomas has 40 years of experience working in the petrochemical industry. He has published six books, the most recent being Asset Data Integrity is Serious Business *and* Measuring Maintenance Workforce Productivity Made Simple, *both of which will be published this year.*

Focusing RCM on Equipment Critical to Electrical Safety

H. Landis Floyd, PE, CSP, CMRP, Fellow IEEE

Business and commerce are totally dependent on electrical equipment and systems for energy, control and communications. These systems can be complex and the task to analyze failure consequences can be equally complex. Unrecognized consequence of failure, especially if the failure impacts personnel safety, can have unacceptable moral and legal implications as well as significant financial costs. Recent trends in workplace electrical safety shed new light on reliability needs for certain equipment in electric power and control systems. One trend is the increasing attention given to mitigating arc flash hazards in electric power systems. Historically, circuit protection devices served to protect the components in the electrical system from overcurrent or short circuit damage. Now there is an additional expectation from these devices. Selection of personal protective equipment (PPE) to protect people from the thermal hazards of an arc flash event, as illustrated in Figure 1, is based on the designed functionality of circuit protective devices. If these devices do not function as designed, the thermal and blast energy exposure may be orders of magnitude greater than expected. The photograph in Figure 2 illustrates an arc flash event in progress. The arc flash hazard analysis and the selection of PPE are dependent on the protective devices to function as designed. In other words, the maintenance of certain devices and systems are critical to the safety of personnel who interact with the electric power equipment. Circuit breakers must function as new. Overcurrent devices must operate at the designed and documented pick up and time settings. If circuit breakers or protective devices are dependent on an external power supply, the tripping power system (usually batteries and battery charger) must function as designed. If the protective device is a fuse, it must meet the design specifications and be the type, class and rating of the one documented in the arc flash analysis.

Figure 1

Figure 1: Arc rated personal protection equipment is selected based on design parameters of circuit protection devices.

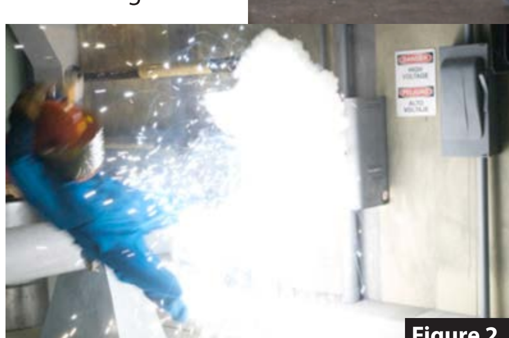


Figure 2

Figure 2: The thermal energy magnitude in an arc flash event is dependent on the reliability of the upstream protective device in the supply circuit.

(Photos courtesy of Coastal Training Technologies, now part of DuPont Sustainable Solutions)

Equipment and systems that serve to mitigate arc flash hazards are examples of engineering control measures described generically in occupational safety management systems standards, such as ISO 14001 Environmental Management Systems, OHSAS 18001 Occupational Safety and Health Management Standard, ILO Guidelines for Occupational Safety and Health Management Systems, ANSI Z10 Occupational Health and Safety Management Systems, and CSA Z1000 Occupational Health and Safety Management. These standards are well harmonized on the comprehensive hazard control measures in Figure 3. In addition, they are harmonized in how these equally important measures are ranked in descending order of relative effectiveness. The top three measures align with maintenance and reliability concepts of reengineering systems and equipment to eliminate defects and causes of failure. These control measures establish the inherent safety by design performance of the electrical system.

The third measure, engineering controls, includes hardware, equipment and systems whose designed intent is to prevent or limit exposure to a known hazard. In addition to the functional performance of circuit protective devices that protect people from arc flash and blast during fault conditions, other examples of engineering controls commonly applied to safeguard people from shock and/or arc flash include: equipment enclosure covers and access panels that serve to prevent contact with energized bare parts during normal operations; grounding and bonding equipment and hardware that prevent electrical shock, enable operation of protective devices during ground faults, prevent arcing in fault return paths (of particular concern in flammable and explosive environments) and prevent the presence of hazardous voltage on cabinets, enclosures, and structures during normal operation; and ground fault circuit interrupters that guard against fatal electric shock. Examples of engineering controls for electrical hazards are listed in Figure 4.

Engineering controls function automatically to perform their function. A major limitation of engineering controls is they can be rendered inoperative due to improper installation, shortcomings in commissioning or functional testing, or maintenance deficiencies. Unfortunately most engineering controls for electrical hazards fail unsafe, with no warning that functionality has been compromised. A hidden failure can go undetected until an injury occurs.

Applying RCM includes identifying critical equipment in its operating context (i.e., safety, uptime, etc.), understanding the consequences of failure, establishing goals, setting priorities, and allocating limited resources to achieve maintenance goals. Examples of proven reliability management tools include Failure Mode Effect Analysis, Pareto analysis, and other statistical tools; however, these methods by themselves may not identify electrical equipment critical to electrical safety. The first step in identifying the operating context is to identify the hardware, equipment, and systems comprising engineering control measures for electrical hazards. Some examples have been discussed in this article; however, there may be others unique to a specific installation or facility. Not all electrical equipment failure has a direct impact on personnel exposure to shock or arc flash injury. A motor or feeder cable failure may have significant impact on production and uptime, but little impact on safety. On the other hand a hidden failure integral to arc flash protection has a very significant impact on safety.

Three resources that address the application of RCM to electrical equipment include these documents available from the National Fire Protection Association (NFPA) and the Institute of Electrical and Electronics Engineers (IEEE):

- NFPA 70B-2010 Recommended Practice for Electrical Equipment Maintenance
- IEEE 902-1998 Guide for Maintenance Operation and Safety of Industrial and Commercial Power Systems
- IEEE 3007.2-2010 Recommended Practice for the Maintenance of Industrial and Commercial Power Systems (Note: IEEE 902 will be discontinued in the near future and replaced with this and two other new standards, IEEE 3007.1 Recommended Practice for Operation of Industrial and Commercial Power Systems, and IEEE 3007.3 Recommended Practice for Electrical Safety of Industrial and Commercial Power Systems.) This new standard significantly expands the treatment of RCM found in IEEE 902.

Reliability and maintenance management systems involve the application of tools to assess and prioritize the application of limited resources to maximize benefits to the business. Key metrics generally include operations uptime, meantime between failure of critical equipment, ratio of planned and scheduled maintenance vs. emergency breakdown maintenance, quality of predictive and preventive maintenance programs, and workforce skills and knowledge in critical maintenance competencies. A challenge to any organization pursuing excellence in electrical safety and in reliability and maintenance is the integration of the means to achieve these objectives. It will likely be helpful to engage a multidiscipline team, including electrical experts, safety professionals, and reliability experts. Each of these specialties brings a unique perspective when analyzing the reliability performance of electrical equipment and hardware that serve a critical safety function. Safety professionals are generally expert in safety management systems but not in the details of electrical safety. Electrical professionals may be knowledgeable in electrical technology and how things work, but not expert in safety management systems and maintenance and reliability systems. Maintenance and reliability experts are skilled in assessing functional criticality but may not be familiar with the details of safety management or electrical systems. Senior and middle managers may not be expert

Figure 3

A challenge to any organization pursuing excellence in electrical safety and in reliability and maintenance is the integration of the means to achieve these objectives.

Figure 4

Examples of Engineering Controls for Electrical Hazards

- Grounding and bonding systems
- Overcurrent protective devices
- Circuit breaker tripping power systems
- Ground fault circuit interrupters
- High resistance grounding for power systems
- Enclosures to guard energized parts
- Insulated power cords for tools and appliances

Figure 3: The hierarchy of hazard control measures. Engineering controls are highlighted as a focus of this article.

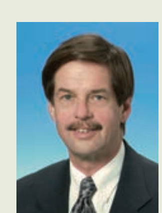
Figure 4: Examples of engineering controls commonly applied to mitigate electrical hazards

in either of these competencies, but hold the keys to financial and human resources to solve and manage issues of importance to the organization. Collectively, their skills, knowledge, and responsibilities can create an extraordinary collaboration and synergy to assess and improve both the electrical safety program and electrical systems uptime. This collaborative team could begin by addressing these questions:

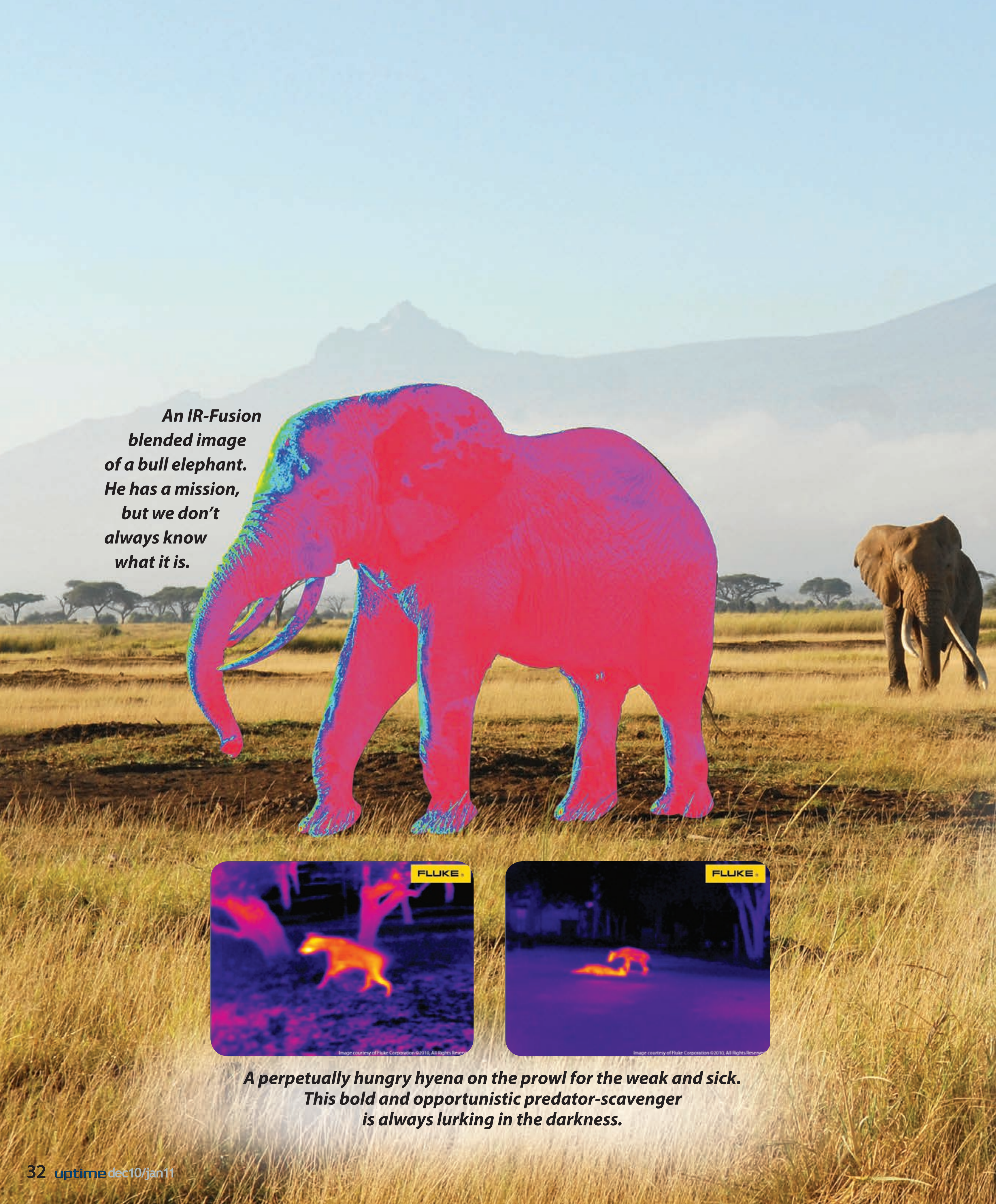
- Is the visibility of electrical systems in the reliability and maintenance program in alignment with the organization's dependence on uptime and reliability of critical electrical energy and control systems?
- Does the reliability and maintenance program involve participation of electrical experts familiar with critical electrical systems in proportion to the organization's dependency on the uptime and reliability of these electrical systems?
- How familiar are you with ANSI Z10 Occupational Health and Safety Management Systems, or CSA Z1000 Occupational Health and Safety Management, or other globally recognized safety management systems standards?
- How do these standards relate to the reliability and maintenance management systems for your organization?
- What role does your reliability and maintenance program currently play in your electrical safety program?
- What reliability do you expect for equipment critical to personnel safety? Is this different than reliability objectives for manufacturing or services uptime?
- How would you rate the collaboration and synergy among safety professionals, maintenance professionals, key members of management, and the electrical experts with respect to driving improvement in the electrical safety and the reliability and maintenance programs in your organization?

Discussion of these questions and tangential topics likely to ensue can help an organization optimize the application of RCM to equipment critical to electrical safety.

In conducting the critical analysis described in this article, an organization can develop a better understanding of how managing its electrical safety program closely coupled with its reliability and maintenance program will drive benefits across a broad set of business performance objectives. The benefits span improved energy utilization, improved on-time delivery, fewer environmental releases, optimum employee safety, improved raw material utilization, improved first pass yield, and increased operations uptime.

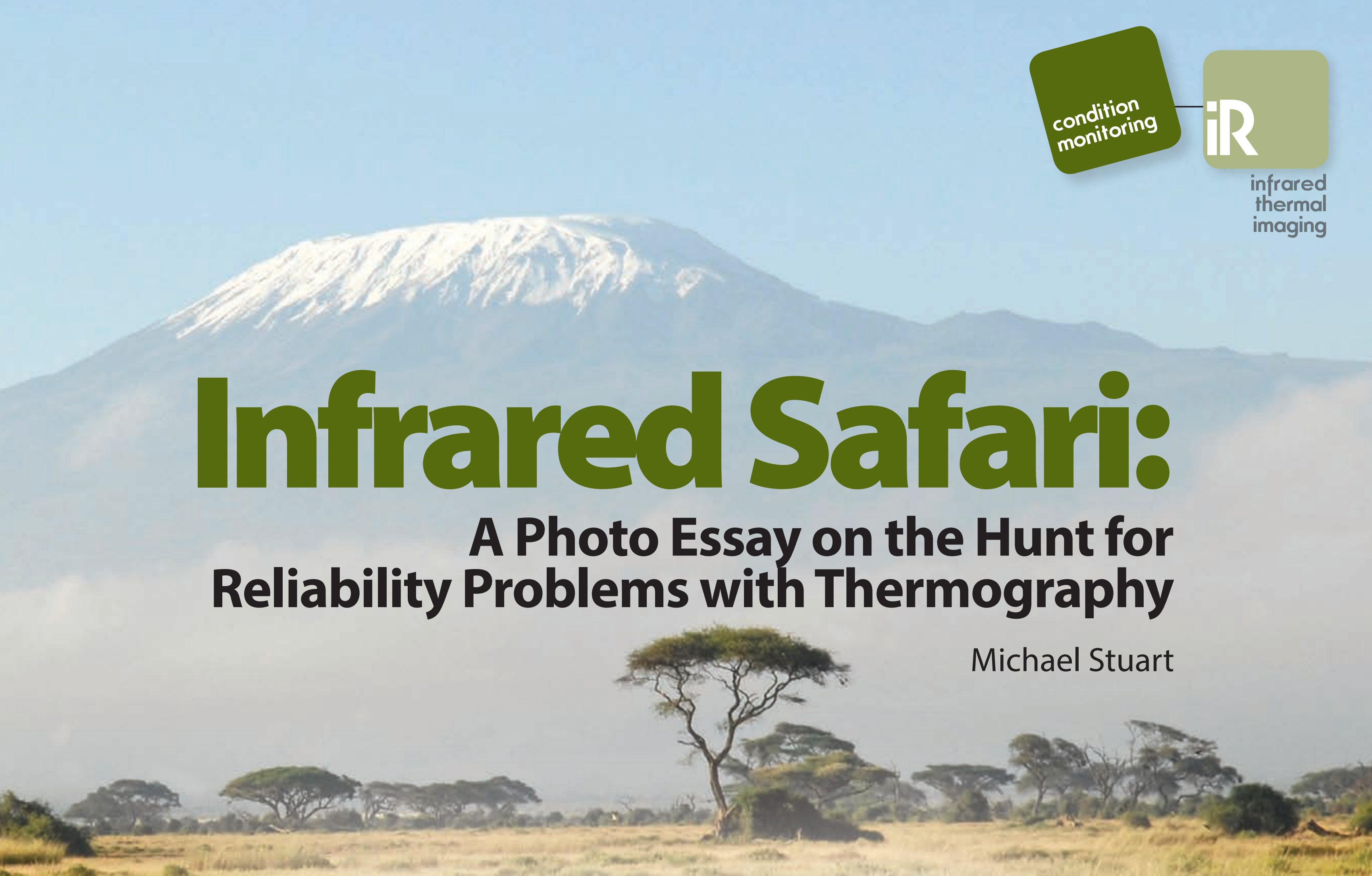


H. Landis "Lanny" Floyd has been with DuPont since 1973. For the past 25 years, his responsibilities have largely focused on electrical safety in the construction, operation and maintenance of DuPont facilities worldwide. He is currently Principal Consultant, Electrical Safety & Technology. He has authored or co-authored more than 50 published papers and articles on electrical safety. www.DuPont.com



An IR-Fusion blended image of a bull elephant. He has a mission, but we don't always know what it is.

A perpetually hungry hyena on the prowl for the weak and sick. This bold and opportunistic predator-scavenger is always lurking in the darkness.



Infrared Safari:

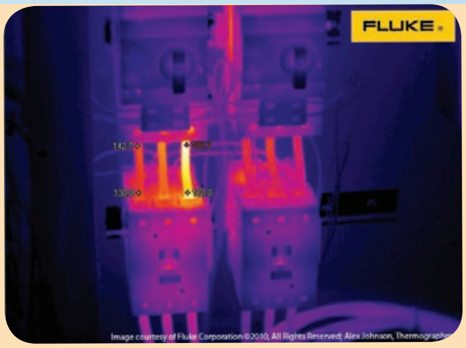
A Photo Essay on the Hunt for Reliability Problems with Thermography

Michael Stuart

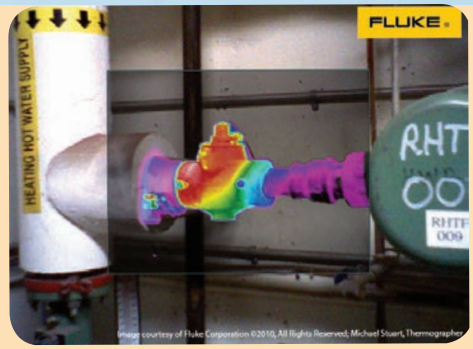
In the animal world, there is a natural law that is seen day in and day out all around the planet Earth. The strong survive the elements and endure hardships and move on to live another day and often prosper. The weak and the sick, however, succumb to the will of the environment or to those who are stronger, faster, or smarter. Such is the way that it has always been… and such is probably the way that it will always be!

Believe it or not, reliability maintenance can be the same way in many respects. We run into the "big elephants" that either stand in the way of progress or threaten to take down the operation in a wild and dramatic rampage. We also find ourselves battling the smaller, yet equally damaging issues ("hyenas") that creep up quietly and quickly and pick off the smaller things for which we have responsibility. Either way, if we do not have the proper tools to deal with these threats, we must live in continuing fear of potential loss… financial, time, productivity, energy, and sometimes even personnel.

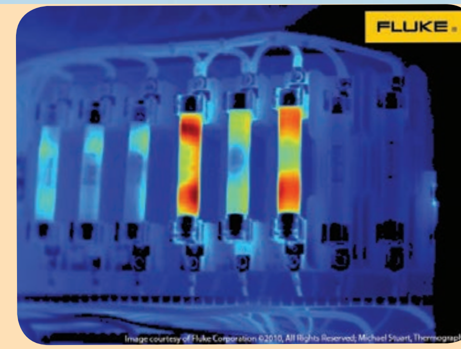
If a picture is worth a thousand words, then an "infrared picture" should surely be worth ten thousand! The images and captions that follow represent an "infrared photo safari" of our world and the beasts that we see every day.



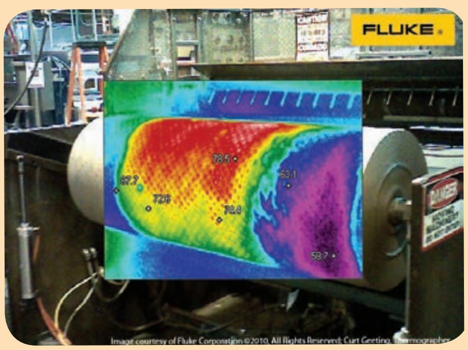
This high-resistance electrical connection cannot hide with the thermal imager!



A properly operating steam strap showing a hot steam side and a cooler condensate side. ***I've seen malfunctioning steam traps that cost up to $2000 per year in lost steam!***



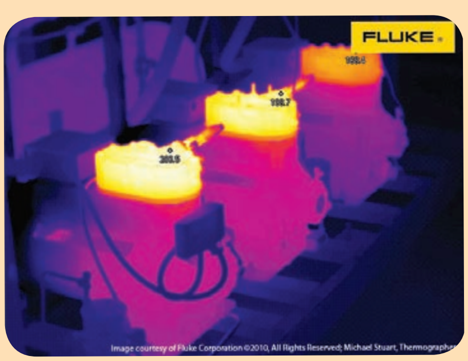
Some equipment fuse problems stand out ***like a zebra on the open plain.***



Improperly operating heating coils caused this uneven thermal image in a paper mill. Gonna have to scrap this roll.

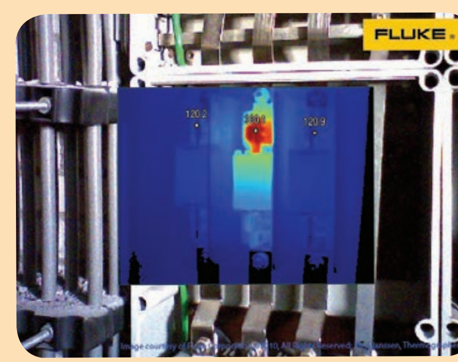
A coupling alignment issue causes abnormal heating on both the motor side and the load side. If you look really close, the infrared image even picks up the wobble.

Sometimes your problems lurk up high, where they are hard to detect. Here, a sticky roller bearing heats up and also creates drag on the conveyor belt, and added load on the conveyor motors.



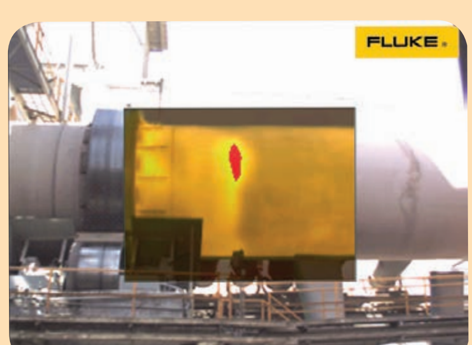
The third compressor (in the back) does not appear to be operating properly. All three are on and are supposed to be doing the same job. ***Must be sick.***

Use of a high-temperature color alarm shows a probable blockage in this process line in a fruit-packing plant.

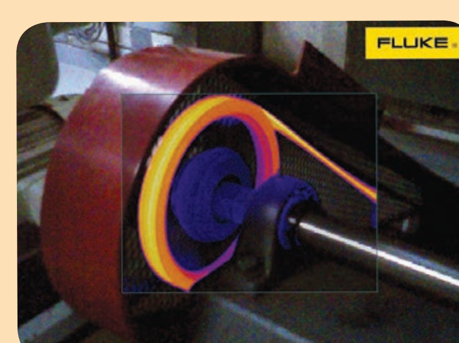


Whoa! This is a hot one!
A 380°F blade connection problem on the center phase fuse.

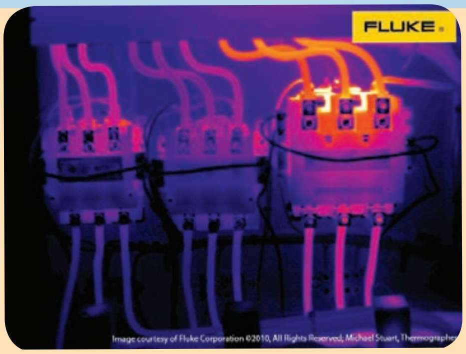
Here, a plant engineer has confirmed that the tank level gauges are, in fact, ***not*** *working properly. He was expecting a full tank.*



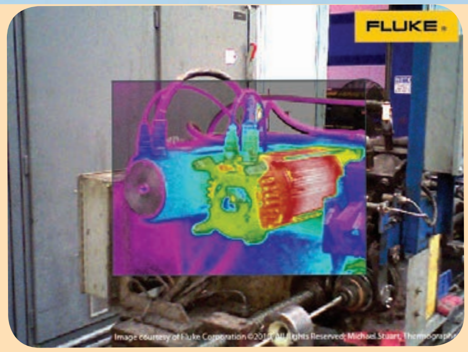
This image shows signs of refractory breakdown in a cement kiln (furnace). ***An elephant-sized problem here*** *could be catastrophic for this plant.*



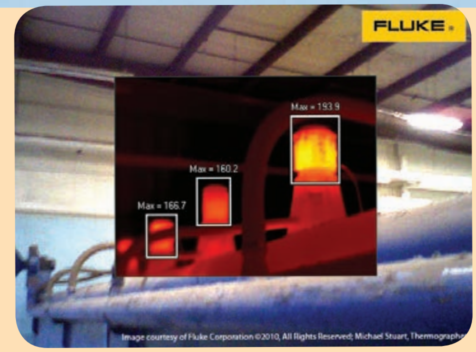
Belts that are out of alignment, too tight, or too loose can cause slow and steady damage to both the motors and the loads if not dealt with in a timely manner.



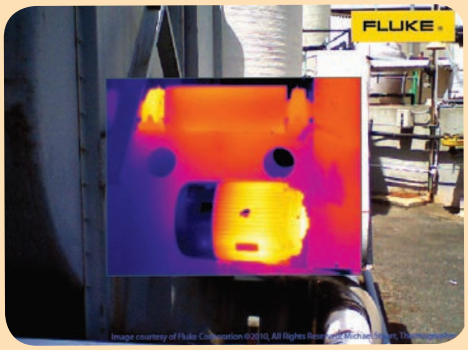
Looks like there is a potential current overload issue here.



Specialized equipment is more difficult to diagnose, but the line maintenance technician saw enough from this image to know that something was amiss.

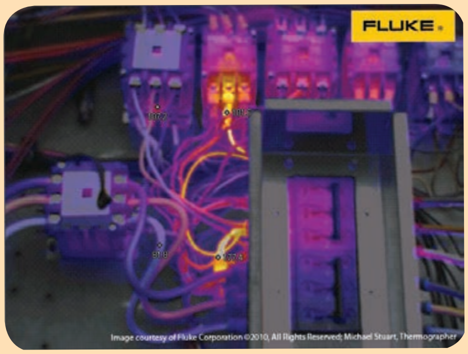


The air circulation fan motor in the front of this annealing furnace appears to be overheating. If it were to go out unexpectedly, the whole operation would go down, and probably stay down for two weeks.

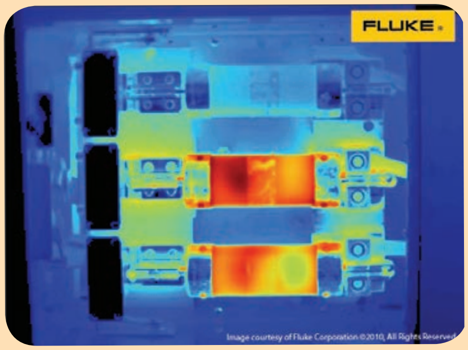


Sometimes, you catch multiple problems in one shot. This image shows an apparent problem with the pillow-block bearing on the left, and a possible bearing issue on the drive motor.

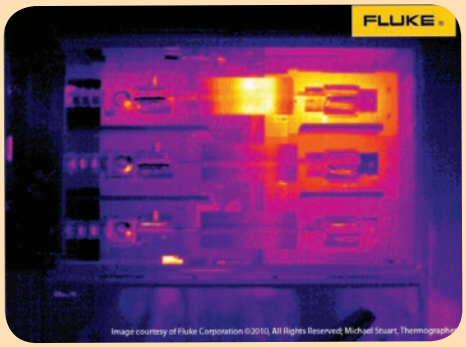
A close-up of the bearing area on the motor confirms suspicions.



Quite often, the use of an IR-Fusion infrared-visible blend really makes all of the ***"hyenas"*** *apparent… even in the* ***"tall grass"*** *of this crowded control cabinet.*

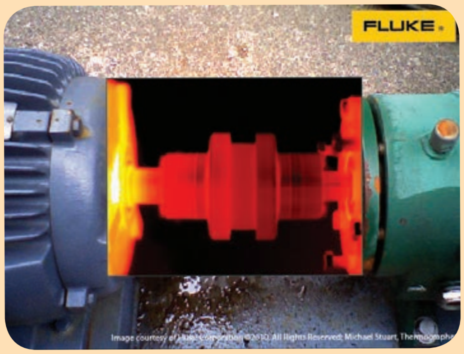


The hot spot is not always the root problem. There appears to be a possible blown fuse or single-phasing here (top leg).

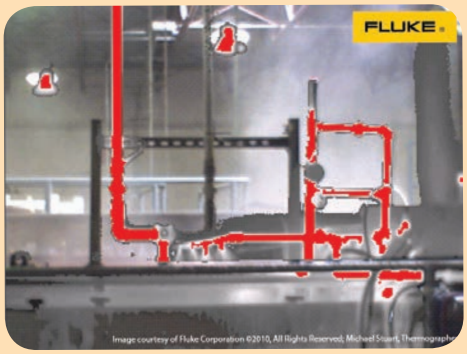


Simple high-resistance blade connection (top fuse) in some older switchgear. Over time, the fit sometimes become loose. This can cause issues when you least expect it.

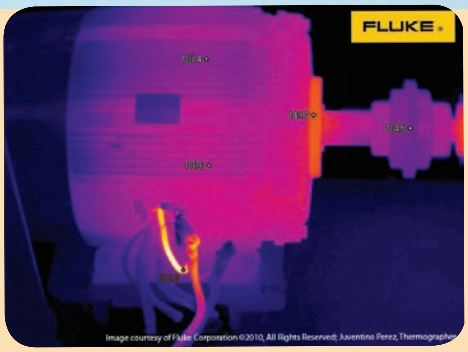
The issues are not always clear at first... but you know something is wrong. Here, the fuses in this disconnect look fine, but there is significant, unexpected heat coming from somewhere in back. The problem was with the main buss connection. Even though we could only see a surface temperature of approximately 165°F from our vantage point, there was evidence of melting and re-welding when everything was disassembled and inspected.



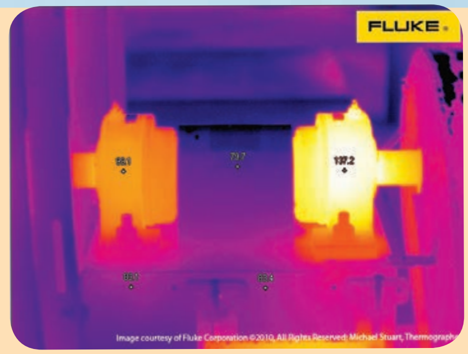
There was an alignment issue with the coupling on this motor-pump pair, which caused the motor's bearing to give off an abnormal heat signature. Luckily, it was found in time.



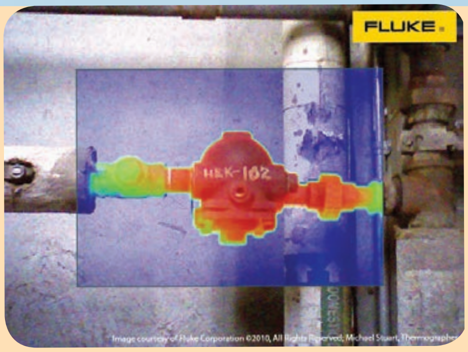
Oops! Guess that we have a faulty valve.
There is supposed to be hot water going up the center pipe. ***Line down!***



Once again, two problems for the price of one! A 212°F high-resistance electrical feed connection and a possible lurking bearing issue. (Adjusting the level and span would help to see the bearing issue better.) The bearing area was nearly 40°F warmer than the rest of the motor.

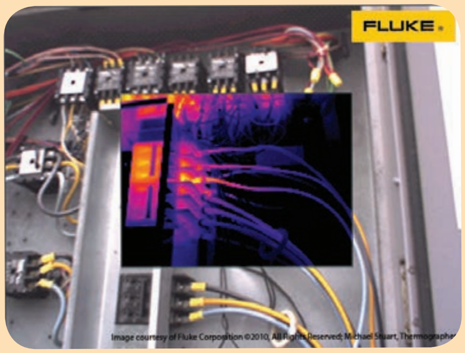


*The pillow-block bearing on the right stands out in plain, **infrared** sight.*



*In order to evaluate the operation of a steam trap, you often have to be patient… and wait for it to cycle. Most successful infrared **"hunters"** have learned this patience over time.*

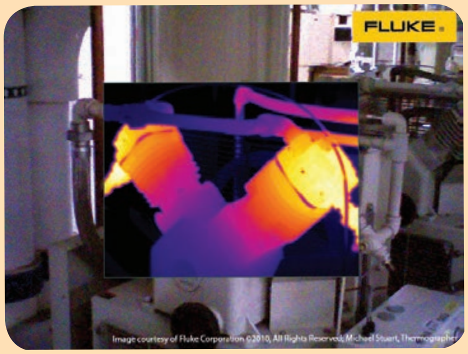
If you had not regularly monitored this motor on a regular basis, you may not realize that anything was wrong. However, comparison to previous images indicated a new hot spot that appeared on the bottom. It turns out that the motor was overheating and a winding issue was developing.



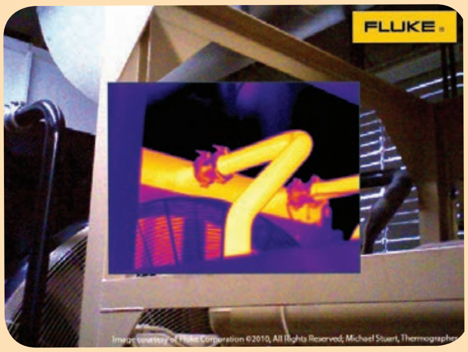
*Even though a typical high-resistance connection may only cost $2-$5 a year in added energy costs, think about how many connections there are in a typical facility. How many could be wasting energy? **Hyenas can be very irritating and expensive in the long run.***

A leak becomes apparent in this insulated cold water feed.

***Sorry, Mr. Hyena… you can't hide behind that barrel!** Here we see the motor bearing issue brewing. We will need to take the cover guard off the coupling and inspect the bearing on the pump too in order to determine where the root problem lies.*



***What do you know… something in this place that is actually working the way it is supposed to!** A healthy, properly-operating compressor.*



Regular inspection of back-up generating plants is as important as taking care of the main systems. You never know when you will need them. Pictured is an image of a cooling line going into the radiator of a diesel-powered back-up power plant.

Michael Stuart is a practicing T/IRT Level III Thermographer, certified in compliance with ASNT standards for Electrical, Mechanical, and Building inspection and analysis. He is also the Sr. Product Manager for Thermal Imaging Products with Fluke Corporation. www.fluke.com

Who says

INFRARED WINDOWS

have to be ROUND?

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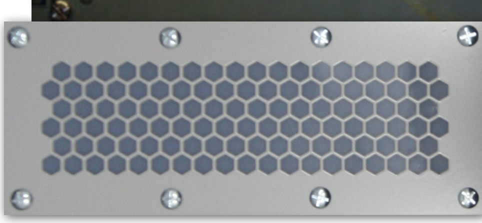

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precision maintenance

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lubrication

Not Just Good, But Great

In the past decade I have played a role in implementing dozens of lubrication programs all across North America. Though the facilities themselves differ, the fundamental elements of what makes a good lubrication program great remain the same. It's not enough to simply say that we want to apply lubrication best practice; the goal needs to be adopting best practice and making it the company's preferred practice based on the unique conditions in which the plant operates. Some of these conditions may be environmental extremes, production extremes, labor issues, skill issues, financial limitations . . . the list goes on. A good machinery lubrication program tries to apply lubrication best practice. A great machinery lubrication program takes best practice and creates a change in corporate culture through training, proper storage and handling, discrete procedures, and minor modifications. These fundamental elements will take you from good to great.

Jason Kopschinsky, CMRP

Training has always been a hot topic of conversation in the lubrication world. When apprenticing to be a mechanic or millwright, not nearly enough time is spent on lubrication. What typically happens is a maintenance or reliability decision maker appreciates the need for training within a great machinery lubrication program and decides to get his team trained. However, little attention is given to who exactly needs to be trained and what training those people require. For example, if electricians in your plant are responsible for electric motor lubrication, they don't need to attend a 3-day certification level class to learn about advanced lubrication or oil analysis, but they do need at least a 4-hour class on how to effectively grease an electric motor bearing. A great approach to training is to assign a "lubrication champion" on your lubrication team and have him trained and certified in all the areas of lubrication. Others should be trained based on their level of involvement in the lubrication program. Those responsible for oil analysis should be trained on it. Those greasing bearings should have task-based training for that task. Further enhance the credibility of the training with certifications.

To ensure the success of a great machinery lubrication program over the long haul, it is mandatory that the current culture adapts to the new business as usual.

Storage and handling continues to be an area I always shake my head at. It would seem to me that this is one of the more tangible elements of a great lubrication program, yet most have a hard time understanding its value. Some of the dirtiest areas of the plants I have been to have been the "lube room." They are typically dark and dingy, subjected to temperature extremes and moisture contamination and are always accessible to whoever wants access. I often ask my clients if they would store oil meant for their car or truck in the same way that they store oil for the machines in the plant. No one has ever said yes.

There are many turn-key systems that exist that will take a sorry-state-of-a-lube-room to near best in class. But it's not enough to just buy your way to best in class; you have to understand why it's important to handle lubricants in this manner. If you've had your team trained on methods and theory of proper storage and handling, you're halfway there. The next step is to reinforce your preferred practice with standard operating procedures.

Procedures are a key element to doing anything with consistency and accuracy. We have all read the articles highlighting the need for knowledge transfer before the retirement boom hits and our companies suffer corporate amnesia at a nationwide cost of billions or even trillions. Procedures should be clear and concise and represent how something gets done each and every time. To support this, procedures should be dynamic enough that we can change some of the elements if we need to. For example, duty cycles change, operating conditions change and production demands change. These changes all require a change in lubrication frequency, amount, type or method of application. A great machinery lubrication program understands the need for change and allows for modifications to procedures to support these changes.

We have all heard the saying, "You don't know what you don't know." Through training and procedures the unknown becomes known. We become conscious that there is a better, more efficient way to do something. These revelations, however, don't go very far unless we're given the right tools to do the job. It is one thing to implement best practice and it's quite another to execute preferred practice. Much of what makes a good machinery lubrication program great are the tools and accessories we use to get the job done. Sample valves installed on machine components, filter carts for periodic decontamination, grease meters on our grease guns, and sealable and refillable transfer containers are all great examples of the tools we need to execute a great machinery lubrication program.

To ensure the success of a great machinery lubrication program over the long haul it is mandatory that the current culture adapts to the new business as usual. The daily grind sometimes keeps us from seeing the obvious. Whenever I ask a client why they are doing something in one way or another, the most common answer is, "That's the way we've always done it." Right or wrong, we continue to form habits in our work, often to the detriment of the machines we are committed to making more reliable. This current business as usual can change as we adopt preferred practice and provide the right tools for the job. The new business as usual has us using our knowledge from training, storing and handling our lubricants they way they need to be handled, following procedures when executing tasks, and using the right tool for the job. Over time, this will become business as usual. Perhaps at the next plant I walk into, I'll see the proper implementation and execution of a great machinery lubrication program and ask why they are doing things that way, and they might say, "That's the way we've always done it." That would be great.

Jason Kopschinsky joined Trico July 2010 as Reliability Services Manager. Prior to joining Trico, he spent 7 years in asset reliability and lubrication management services with Noria Corporation. He has published more than 50 technical articles. www.tricocorp.com

The Importance of Organizing MRO Inventory & Purchasing

Terry Wireman, CPMM, CMRP

MRO inventory and purchasing organizations are the single biggest maintenance support functions that contribute to low maintenance productivity. MRO inventory and purchasing, in this article, stands for maintenance, repair, and overhaul inventory and purchasing. Many maintenance labor delays are related to issues concerning materials and spare parts. Because the purchasing function typically procures the materials for the MRO storerooms, it also has a big impact on maintenance productivity. Additional material problems that impact labor productivity include late deliveries from vendors, wrong parts delivered, and parts that are damaged and cannot be used when they arrive.

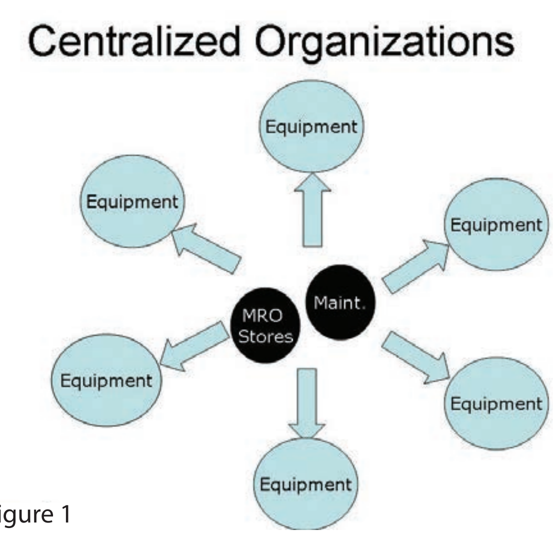


Figure 1

The conflict between maintenance and the MRO organizations arises when neither sees the big picture. If they can focus on their shared impact on equipment capacity, they can be successful. The MRO organization supplies the spare parts; the maintenance organization then uses the spare parts to ensure that the company's assets perform properly. Without focusing on a partnership to accomplish this, there will always be conflicts between the two organizations.

Stores Locations and Organization

A concern in most organizations is configuring the maintenance and MRO inventory and purchasing organizations. When considering MRO stores locations and organizations, one of the primary factors is how the maintenance department is organized. If the maintenance organization is centralized, then it is usually best to have the stores locations centralized as well.

Figure 1 shows the advantage of this configuration. This diagram shows that when maintenance and stores are together in the center of a plant or facility, it is easy to travel to the equipment. The distance that maintenance has to travel to obtain spare parts and then travel to the equipment is minimized. This arrangement maximizes labor productivity for the maintenance department. It also allows for more rapid response when equipment experiences problems. Therefore, for geographically compact plants or facilities, this is an ideal configuration.

The problem that is typically experienced when designing this type of an organization is trying to find the centralized space for both maintenance and the MRO storeroom. Most companies are reluctant to give up prime space for these two departments. How-

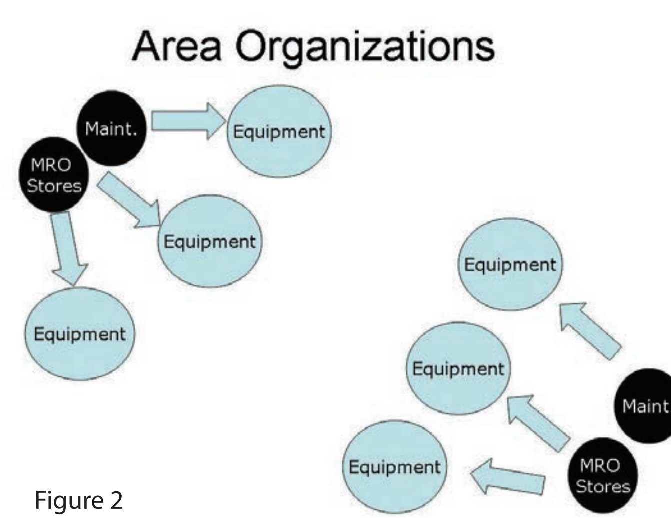


Figure 2

ever, once the total cost picture is clearly understood, it is a good business decision to centrally locate maintenance and MRO stores for smaller geographically compact plants.

If the maintenance organization has an area configuration, then it is usually best to have the stores locations in an area configuration as well. Figure 2 highlights this configuration. In this figure, there is a larger geographical footprint for the plant or facility. It may actually be several miles from one side of the diagram to the other.

Given this condition, it makes sense to have MRO stores and maintenance co-located on opposite sides of the plant. This minimizes the travel time for maintenance to get to the equipment. Increased maintenance labor productivity is the result, whether it is in a proactive or a reactive environment.

The common complaint with using this type of a structure is the increased stocking levels for the MRO storeroom. In this configuration, it is true that there will be an increase in the stocking levels. This must be balanced against the increased maintenance labor productivity and the reduced downtime (and increased equipment capacity) that will be achieved by using this configuration.

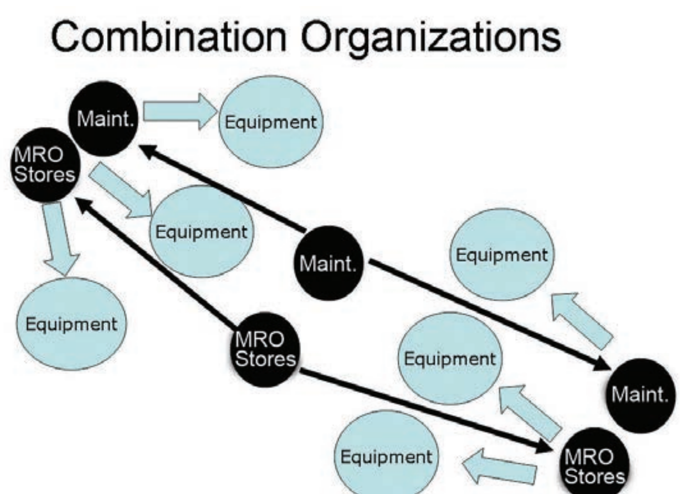


Figure 3

If the maintenance organization is in a combination configuration, then it is usually best to have the stores locations in a combination configuration. Figure 3 highlights a combination configuration. A combination organization is typically used on large plants. Although maintenance and MRO stores maintain an area presence, certain parts of the organization and types of spares are brought to a centralized location.

In a maintenance department utilizing a combination organization, the central trades group will be comprised of technicians that would not be fully utilized in a single area. The combination organization allows the sharing of central trade technicians among several areas to increase their overall utilization. The same reasoning applies to the MRO stores. There are certain common spare parts that can be kept centrally, while parts specific to a certain area should be kept in the area. This configuration works well for large organizations and optimizes both maintenance resources and MRO spare parts, and also increases equipment availability.

The reason for matching the configuration is the impact that travel time to and from the storeroom can have on maintenance labor productivity. If there is a mis-match between the stores and

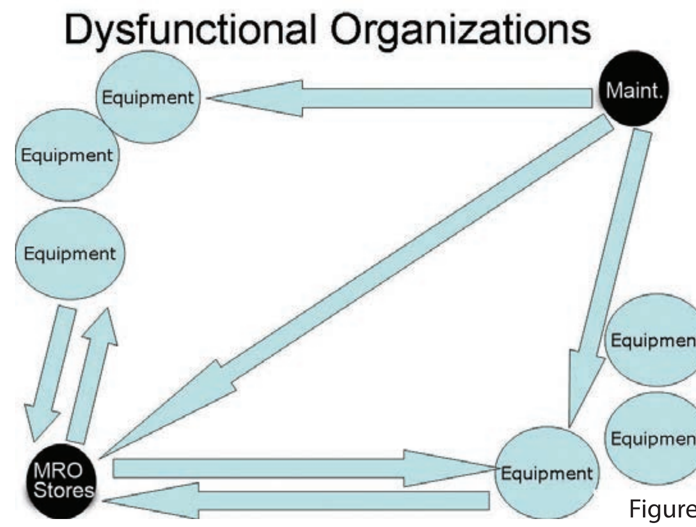


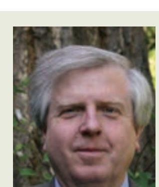
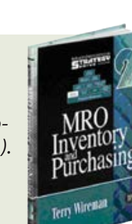
Figure 4

the maintenance organizations, then the travel time to and from the stores to procure spare parts can be considerable. Figure 4 highlights this issue.

As can be seen from this figure, the distance (and time to travel) can be considerable if maintenance needs to travel to the equipment. If the maintenance technicians need to go to the storeroom before going to the equipment, they would face even more travel time. If the equipment is down, waiting on maintenance, then the losses increase to include not just lost maintenance productivity, but also lost production. In geographically compact plants, this may not be an issue; however, in large plants, the losses incurred with dysfunctional organizations can have a dramatic impact on profitability.

This example of lost maintenance productivity and lost production is particularly true in the early stages of developing a maintenance organization because a reactive organization needs spare parts on short notice. As the maintenance organization matures and becomes better at planning and scheduling, material demands can be specified weeks in advance. With this level of forecasting, kitting and delivery systems can be implemented and the location of the storeroom becomes less of an issue.

The decision on the location of the storeroom and possibly the number of locations needs to be carefully balanced. The balance is between lost maintenance productivity and the cost of inflating the inventory to support multiple locations. Some organizations, in an attempt to increase maintenance productivity, will carry excessive numbers of spare parts to compensate for organizational mismatches. Delayed spare parts procurement does not impact only maintenance productivity; it also impacts equipment availability. When making the decision about spare parts locations and organizational structures, it is important to consider all of the factors, and then come up with a financially balanced decision.


Terry Wireman is a maintenance reliability expert who is a popular Keynote presenter at many industry events. He has authored dozens of books including the new Maintenance Strategy series published by Industrial Press (www.industrialpress.com). The second volume in that series, MRO Inventory and Purchasing, *is available at the MRO-Zone.com bookstore at http://books.mro-zone.com*


Level 5 Leadership What Is It *and* How Do I Achieve It?

Winston P. Ledet

Leadership is a subject that seems to be undergoing a dramatic change in recent times. The transformation seems to be from the "great man" point of view to the "great team" point of view. The reason for this shift may be that the level of complexity in today's world is much higher and therefore requires a more complex method of leadership.

Jim Collins coined the term "Level 5 leader" in his book, *Good to Great*, to characterize the type of leaders found in his team's study of companies that achieved the transformation from a good company to a great company by outperforming the stock market for at least fifteen years. Collins was careful to avoid attributing the greatness to a single person, but found that the companies he identified as great seemed to have common characteristics. He called people with those characteristics Level 5 leaders. David Marcum and Steven Smith have extended Collins' study of leadership from single individuals to teams, and Hazy, Goldstein, and Lichtenstein have proposed a new leadership theory in their book, *Complex Systems Leadership Theory,* based on Complexity Science. The common thread in these studies is that high performance leadership is a group process and not an individual leader taking the organization to higher performance.

The underlying principle in all of these studies seems to be fairly simple. Leadership is not a person but a relationship between people. With this principle in mind, the definition of a leader is simply: anyone who has followers. The other underlying concept change was discovered by Ilya Prigogine in the 1970s. The discovery was that a group of people can have traits that do not exist in any one of the individuals. Therefore, leadership traits can emerge from a group without any of the individuals conceiving them or even being aware of them. With these concepts in mind, leadership emerges as a result of the interactions among the members of a network of people and their environment. A simple way of envisioning this is a socio-technical network of people, tools, equipment, buildings, roads, etc., that have physical contact with each other in a particular space over a specific period of time. In this context, the equipment can be a leader if it commands the attention of people that follow the lead of the equipment. This is exactly what we find in production organizations that are in the reactive domain. The equipment decides to break and this determines what a number of people will do that day instead of what they wanted or planned to do.

A leadership process can have many leaders at the same time on different subjects, and who and how the leadership is enacted is determined by the followers. As people choose to follow a particular leader on a specific subject, they are creating the leadership process. When a financial crisis occurs, the people authorized to spend money then become the leaders. When the workers choose to strike, the contract negotiators become the leaders. When new technologies are developed, the technical experts become the leaders. All of these leadership activities could be occurring at the same time in the space of the organization.

Applying these ideas on leadership to the domains of operation, which we have experienced as reactive, planned, and precision, yields some interesting conclusions. In the reactive mode, the equipment is the main leader, and it exercises its leadership by breaking when it is not treated correctly. This act of leadership results from

In the planned domain, some of the leadership is transferred to caretakers in a reliability group. These people take on the role of discovering the abuse before the equipment has broken and create plans and schedules to remove the defects before the equipment breaks.

the consequences of many previous acts in people's treatment of the equipment. A useful metaphor for this case is to look at the equipment as an information system that keeps diligent track of how the organization treats its equipment. It remembers all of the acts of abuse as well as the acts of tender care it has received. From time to time it tallies up the score and decides it is time to break so that this information can be noticed by the caregivers. For an organization in the reactive mode, the response is to fix what broke. Sometimes in the process of repairing, someone may notice the root cause of the failure and change the method of caring for that piece of equipment, but usually that is not the case because there is often not enough time to address the root cause issue.

In the planned domain, some of the leadership is transferred to caretakers in a reliability group. These people take on the role of discovering the abuse before the equipment has broken and create plans and schedules to remove the defect before the equipment breaks. This avoids some of the collateral damage that often occurs in the act of breaking. This leadership process depends on the reliability groups to discover the defects, in a timely manner, that other people in the organization are inflicting on the equipment. This allows the existing resources to be used to remove the defects before failure. In cases where the acts of abuse are random, the number of people required to perform these acts of mercy is enormous. In spaces where the consequences of failure are catastrophic, such as a nuclear power plant, this amount of resource is warranted, and people are motivated to perform these duties. In many other facilities, the consequences are not as significant, and it is much harder for people to stay motivated to this approach. The planned domain is not very stable, and people tend to lack the will to maintain this operation when the consequences of not giving the care are only financial.

In the precision domain, people who pursue perfection in their treatment of the equipment provide leadership. People see themselves as maintainers and improvers of the functioning of the equipment in addition to users of the equipment. Everyone who touches the equipment is a leader in avoiding abuse of the machine during its operation as well as in the repair, restoration, or upgrading of the equipment. In the precision domain a leader is anyone who has expertise in the proper care of the equipment and the will to take that care.

The tricky part is what leadership looks like when an organization is trying to move from one domain to another. In order to move from the planned domain to the reactive domain, the answer is pretty simple. Stop the inspections, and wait for the equipment to break. While that sounds absurd, many organizations abandon their reliability initiatives and stop doing the surveillance of equipment needed to remain in the planned domain and then naturally fall back into the reactive domain.

Of course, most people would prefer to go from the reactive domain to the planned domain. In this case, the leadership needed is the maintenance best practices to detect potential failure modes and deal with them long before a failure occurs. People can then concentrate on finding root causes, or they can work on technology to detect defects early in their life so there is time to plan and schedule a repair before a failure occurs. Programs like RCM, TPM, etc., and technologies like vibration analysis, infrared thermography, etc., are the means of providing this leadership.

The best performance we have seen occurs in the precision domain. The transformation needed is for people to become the improvers of equipment instead of simply operators and maintainers. Since most organizations start from the reactive domain, it would be useful to look at the leadership needed to go from the reactive domain directly to the precision domain without going through the planned domain since it is inherently unstable. Leadership is best done as a combination of equipment and people. The thing that makes the reactive domain so stable is the fact that a broken piece of equipment is a clear message of the equipment's needs. In an attempt to get out of the reactive domain and move to a precision domain, Level 5 leadership would allow the individual with the best understanding of the situation to make the decisions. However, in most situations there is not one individual but several individuals who understand the situation from different points of view. A good leadership process would then be to have all of the leaders participate in the decision. This is best accomplished by using cross-functional teams of individuals who care about the equipment and have the desire to perfect it. A means of creating this situation is to let the equipment tell the team what needs to be improved, as well as what to fix. In the reactive domain, the equipment tells the people what needs to be fixed. If cross-functional teams are engaged around a particular piece of equipment, the team can also attend to the improvement of the equipment at the same time the equipment is being repaired. This is the "don't just fix it, improve it" strategy that we recommend. The work management system is also a good tool to use to target equipment for improvement work. The number of work orders for a specific piece of equipment can provide the information needed to know what equipment is breaking most frequently and consequently producing the random failures that keep an organization in the reactive domain.

Now that the equipment is doing the vast majority of the manual work in organizations, leadership is becoming a part of everyone's job. It is important that organizations create the freedom for all of their people to practice leadership.

The topic of Level 5 leadership is explored in great length in the next book of the Heroic Change series. *Level 5 Leadership at Work* will be released in 2011. To see teasers, and learn more about the Heroic Change series visit www.HeroicChange.com.

Winston Ledet, is a leading consultant and internationally known workshop instructor on proactive manufacturing and maintenance. He has 27 years of experience with E. I. DuPont de Nemours. Winston formed his own consulting firm, Ledet Enterprises, Inc., fourteen years ago.

GOOD Oil Analysis Starts With GOOD Sampling Practices

Jarrod Potteiger

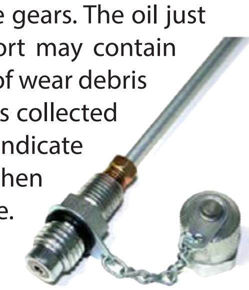
Proper sampling methods are an essential part of an effective oil analysis program. In many cases, the quality of oil analysis results and the subsequent decisions that are made are no better than the quality of sampling practices. Poor sampling methods can lead to incorrect diagnoses which can initiate unnecessary corrective actions, or, they may prevent abnormal conditions from being observed.

When it comes to taking samples for used oil analysis the primary objectives are data validity and data repeatability. To accomplish these objectives several things have to happen. To have repeatable data, the samples must come from the same location via the same pathway, and with a consistent procedure every time.

To have valid data that actually represents the condition in the machine, oil samples must be taken from the correct location for a given machine type, and the integrity of that sample must be protected from the ambient environment. It is quite possible to have suitably clean oil in a machine, yet have the oil analysis results indicate an abnormal condition due to poor sample handling or extraction practices. Likewise, it is not uncommon to get oil analysis results that look good while in fact, multiple problems exist with the oil or machine.

As previously stated, the primary objectives for oil sampling are validity and repeatability. In order for an oil sample to offer valid data it must come from a correct location. That location is typically one that provides information about the oil that is actually lubricating the lubricated components in the machine.

In a gearbox, the oil sitting at the bottom of the case is not really representative of the oil between the gears. The oil just above the drain port may contain many years' worth of wear debris making the samples collected from this location indicate excessive wear when that is not the case. When a sample is collected immediately after a high-performance filter in a hydraulic system, the resulting particle count will likely be quite good, but the oil lubricating the pump could be very dirty, so sampling downstream of oil filters is a poor practice for hydraulics.



To get repeatable data, we must simply follow the same sampling procedure each time. The best way to ensure consistent sampling is to rigorously document the procedures.

Which sampling method is best?

That really depends on the system being sampled. For gearboxes and other bath lubricated systems, a minimess-type sampling valve with a pitot tube is the usually the best option. This apparatus uses a fixed tube which can be cut to length and positioned in a desirable location in the sump. This is similar to the "drop tube" method but it eliminates the most common problems associated with drop tube sampling which are inconsistent placement of the sampling tubing, the excessive sampling pathway volume, and overall difficulty or time requirement to collect the sample. The use of a minimess and pitot tube minimizes the sampling pathway and ensures a consistent extraction point.

Using fixed hardware for sampling bath lubricated components ensures proper extraction location and minimizes the time required to complete the task.

Drop tube sampling refers to the use of a flexible tube which is inserted into the sump by hand. This method may produce valid results, but to do so you must be very careful and you must be aware of the potential problems. While the minimess is certainly the preferred method, drop tube sampling is an acceptable alternative. Most other sampling methods, such as drain port sampling, will not yield useful results and should be eliminated from your sampling program.

For hydraulic systems the primary sample point should be on a pressurized portion of the system upstream of system filters. All pressurized systems offer easy, consistent sampling if they are properly fitted with sampling hardware. The same type of minimess sampling port can be utilized although no pitot is required, and if the sample bottle cap is vented there is no need for a vacuum pump.

To address safety concerns, it is desirable to use a low pressure portion of the system such as the pump case drain or a bypass circuit. These locations offer easy sampling, safe pressures, and consistent data about the pumps and the fluid cleanliness.

For other circulating systems it is reasonable to sample from the pressurized portion of the system (after the pump and before the filter), but it may be better to sample from return lines. By sampling from the return line, you can get highly concentrated wear debris information making the oil analysis a very sensitive predictive condition monitoring tool.

What is the proper procedure for each method?

For drop tube sampling there are quite a few common mistakes, but a well thought out and documented procedure will ensure the best results. Always use a new piece of sample tubing. In any sampling procedure, always begin by flushing the sampling pathway with approximately 5 to 10 times the volume of the pathway.

Proper placement of the sample tubing is easier with a "one-handed" vacuum pump.

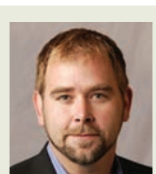
Technicians often choose to use a dedicated waste oil bottle for flushing that is larger than the sample collection containers so they can typically complete a sampling route without having to empty the waste bottle. The proper length of tubing should be predetermined so that you can effectively insert the tube end in the middle of the reservoir without touching anything. In general, the tube end should be at least two inches from the bottom of the sump, two inches from the sides, two inches below the oil level and at least two inches from any moving parts. This can be difficult to accomplish without three hands, but if you use a "one-handed" pump it is easier.

For sampling from pressurized systems, the extraction is simpler because a vacuum pump is not required, and if tubing is necessary, only a short length need be used. If the sample is to be obtained from a high pressure location in the system, additional steps such as the use of a pressure regulator may be required for safety.

As with the drop tube method, begin by flushing the sample valve and tubing with 5 to 10 times the pathway volume to a waste oil container before collecting the sample to be analyzed. Another hardware requirement for pressurized sampling is a vented sample bottle cap. If such a cap is not available, you can attach the sample bottle to a standard vacuum pump to allow the bottle to vent.

While there are several acceptable sampling methods for each machine, there is usually one best way. The best sampling methods will typically require some work up front in that you will usually have to install sampling hardware, but the end result will be well worth it. Using fixed hardware installed in the correct location, will provide consistent, valid data with which you can make good decisions about machine and lubricant condition. With the sample location selected and the proper hardware installed, all that is left is to document a detailed, stepwise procedure that will ensure the sample will be taken correctly no matter who takes it.

Vented bottle caps like the one shown here are necessary for collecting pressurized samples. Otherwise, a vacuum pump maybe used but with the risk of contaminating the pump.



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Using Cause & Effect Diagrams for Proactive Effect

Turn It Around with Maintenance Planning

Jeff Shiver, CMRP, CPMM

In Root Cause Analysis, one of the tools frequently utilized is the Cause and Effect Diagram to show how specific actions combine to define a particular result. Typically, the categories of ***Man, Materials, Methods,*** and ***Machine*** are illustrated in the diagram below. As opposed to using it as a reactive tool after the fact, we can turn it around for purposes such as diagramming effective maintenance planning in a proactive manner. To accomplish this approach, we can provide specific actions in each of the categories above to realize the desired outcome.

When you consider the similarities of equipment across the site, many of the activities that maintenance undertakes are repetitive in nature. With that in mind, we leverage the Maintenance Planner to create a library of job plans with the hope of creating them once and reusing the plans many times over. Realize that job plans are basically the same as Preventive Maintenance (PM) procedures, just not triggered at a specific interval. The primary uses for job plans are to accomplish corrective actions using a standardized work approach.

In the creation of the job plan with the Cause and Effect Diagram as shown in

Figure 1: A Typical Cause and Effect Diagram

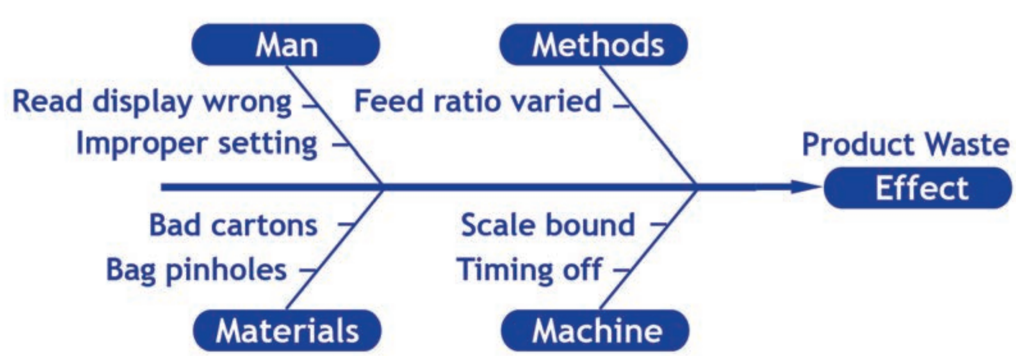


Figure 2, one of the first categories for consideration by a Maintenance Planner is that of ***Man.*** In this case, we are referring to the human assets or resources that are required for the tasks. This includes the identification of the crafts required along with an estimate of the time required to complete the job. Using a gearbox repair as an example, you may require an electrician to disconnect and reconnect the motor with a mechanic completing the bulk of the work in the middle.

Ideally, we will write child work orders for the individual crafts linking back to the overall parent work order. While some groups subscribe to a process of precise analytical estimating techniques for time estimates, I believe in good faith estimates based on the Maintenance Planner's experience. We can always improve the estimates over time. Guard against always assigning two resources when one person can do the job. Work down by using a mechanic plus a helper over assigning two mechanics.

With the ***Materials*** category, the Maintenance Planner can truly impact the efficiency of the maintenance workforce. The planner should identify the parts and consumable materials required to execute the job. These items can either come from the storeroom or be requisitioned for purchase. Ideally, the materials management group should be staging and kitting the items for delivery once the work is scheduled.

To flag the maintenance scheduling function of parts availability, we use the "Schedule Ready" status in the work order system. While we prefer great maintenance job plans, recognize that the three items above (crafts required, estimated hours, and materials) constitute a basic, yet effective job plan. From a craft efficiency standpoint, it's better to complete twenty basic job plans with those three items over spending all week to do two great job plans with everything defined.

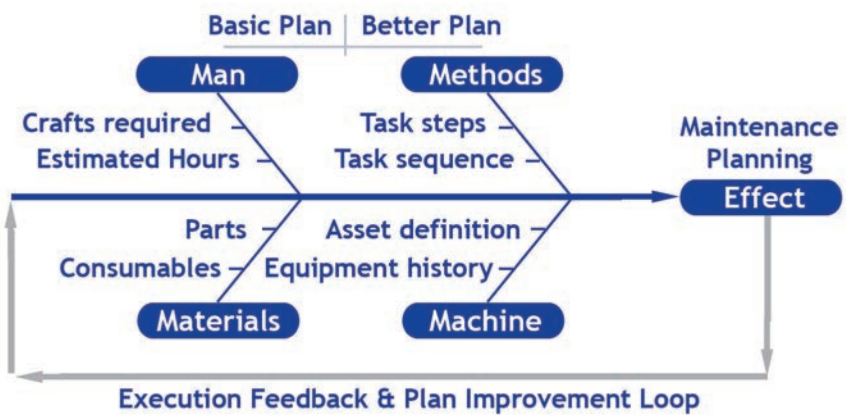
Ideally, the Maintenance Planner should spend roughly one-third of his day in the field, which brings us to the ***Methods*** category on the diagram. When visiting the job site, the planner should document the steps or procedures required to execute the job. During this phase, they can develop their analytical techniques to improve their estimating ability. Simply put, this means breaking down the job into individual task steps or procedures and estimating those individually. Using the old cliché, the technique allows for eating the elephant one bite at a time.

While at the site of the work, it is an ideal time for the Maintenance Planner to take pictures, create sketches, and collect nameplate data and other items that will enable the development of a more complete job plan. Once back at the desk, the planner can assemble cut sheets from the manufacturer, material pick lists, safety information, permit forms, and the job procedures into the job plan package.

A ***Machine*** is identified by the equipment or asset number within the CMMS or EAM and must be identified on the work order. It's important that we ensure the right equipment or asset number(s) are identified so that we can track work done to the individual asset. Realize this is much more than just an equipment or asset number; it is the enabler for searchable historical data. Since the Maintenance Planner lives in the CMMS or EAM, he should understand and share the equipment history with others doing the work.

Typical thoughts or questions that should be asked or explored follow: When was the last time we worked on the asset? What work was done? Are we doing the same work too frequently indicating a higher rate of potential failure? In the case of Preventive Maintenance, are we doing the right work at the right frequency?

Figure 2: Maintenance Planning Cause and Effect Diagram



When you consider the similarities of equipment across the site, many of the of the activities that maintenance undertakes are repetitive in nature. With that in mind, we leverage the Planner to create a library of Job Plans.

These are just some of the questions that we should be mining from the work order system data as it is the historian of maintenance data. Furthermore, the Maintenance Planner is also a guardian of the system data, working to ensure the completeness and accuracy.

It would be a serious omission if we did not loop back around with a continuous improvement process. We need to require and use feedback from the craft workers and others as an example to improve the work done or the materials required. We need to educate the craft workers to help them understand the value and benefit of providing feedback to the Maintenance Planner. Before they climb a 20ft. ladder or extend a man lift, do you think they would prefer that the planner told them to take a 2" wrench and other specific tools into the job plan so they didn't have to go down and then, back up again?

The continuous improvement loop is another way to capture knowledge from those workers that are retiring to share with less experienced craft workers. It can also be used to drive standardized work and precision Maintenance practices.

For the purposes of the article, the focus was on the typical four categories listed. However, don't allow those categories to limit your application of the concept. If you were going to customize the Cause and Effect Diagram for your organization's Maintenance Planning, what other categories might you add? How about measurement as an example, i.e., job plan quality and estimate accuracy? Money might be another as related to an approval process.

Using the Cause and Effect Diagram, you can define a proactive outcome from maintenance planning processes. Borrowing from Lean Six Sigma concepts, the end product regardless of what that product is, results from the processes that created it. Turn your processes around now. What are you waiting for?

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reliability

Re

reliability engineering

Deriving Task Periodicities Within Reliability Centered Maintenance (RCM)

Bill Berneski, CRE, CMRP

This article does not present original theorems in mathematics or RCM, but is an attempt to consolidate some existing but distinct concepts relating to maintenance periodicity selection, and to provide some guidance on the best way to apply them. An RCM analysis should result in the optimum failure-management strategy for a piece of equipment or a system. A failure-management strategy means that the analyst will choose whether to prevent a failure mode (preventive maintenance), modify the equipment to preclude a failure mode (alterative maintenance), or simply allow it to occur and accept the consequences (fix when fail). When the choice is made to prevent the failure mode, a preventive (PM) task is chosen. But the tough question after a task is chosen is how often should it be done? We will attempt to answer that question.

There are a three fundamental types of PM tasks within RCM; tasks performed based solely on time (not condition), tasks based upon condition, and tasks designed to detect a hidden functional failure. Going back to the original DoD RCM manual by Nowlan & Heap, time-based tasks were called Scheduled Discard or Scheduled Rework. These tasks replace or overhaul a component regardless of condition at a specified interval, and are often today called Hard-Time tasks.

In this study we will group these tasks and call them Time-Directed (TD). The TD task can be the most economically punishing, as it doesn't take into account the condition of the component. By replacing an item on a hard-time schedule, we may be giving up useful service life, or we run the risk of the item failing before it is replaced.

When we choose to perform maintenance based upon the as-found condition of the component, we are performing an On-Condition type task, or CD task. CD tasks are typically more economical, if a cost-effective trigger to perform them can be identified.

Finally, when we perform a task to identify whether a functional failure of a component has occurred which is hidden to the operators under normal operations, we are performing what we call a Failure Finding (FF) task. FF tasks are in place to prevent the occurrence of secondary damage resulting from the loss of the hidden function, e.g. testing of a fire alarm, or test starting an emergency generator.

As a result of the RCM logic-tree analysis, when we choose to prevent a failure mode, we will choose to use the TD, CD, or FF (or combination) tasks. Once we have defined our PM tasks, and how they will be performed, we must then decide upon initial PM periodicities or frequencies. This can be a challenging endeavor, because up to this point we have been following a rigorous RCM logic flow. When the RCM analysis is complete, we are not told how to logically derive an initial task periodicity.

One way is to use best engineering judgment or past experience. However, for each type of RCM task, there are mathematical models, based upon statistical distributions that can be used to "engineer" the initial periodicity. It is important to state that there are data requirements and assumptions that must be made in the models. It also takes more time and research to derive a periodicity for each task, so the analyst must balance the importance or risk associated with the PM task and determine whether the effort to derive a periodicity mathematically is worth the effort.

It seems most prudent to use such methods for higher risk or higher cost failure modes and PM tasks. What follows is a description of mathematical models for deriving initial periodicities for each type (TD, CD, FF) of RCM task.

TD Tasks:

Typically the most costly choice for any PM is the Time-Directed task. Because we are replacing or rebuilding a component based not on its condition, but on a calendar, hourly, or usage basis, we are often giving up useful life for the component. The most practical reason for choosing a TD task is that a CD task is just not applicable or cost-effective. However, RCM tells us that at a minimum there must be a point in the items life where the conditional probability of failure shows a marked increase, i.e. the object has a "wear-out" age.

Typically simple items wear out at a certain age and complex items and systems break down randomly. If the analyst has good data for the failure mode in question, then the data can be analyzed to determine whether the item has a wear-out age. It is important to note that the wear-out age should correspond to a specific failure mode.

One method that some use to pick a TD maintenance periodicity is Mean Time Between Failures (MTBF). The simple method is to divide the total operating time for an item by the number of failures and thus arrive at the MTBF. The MTBF can then be used to set a maintenance interval. This is an approach that, though simple, invites error. Consider Figure 1.

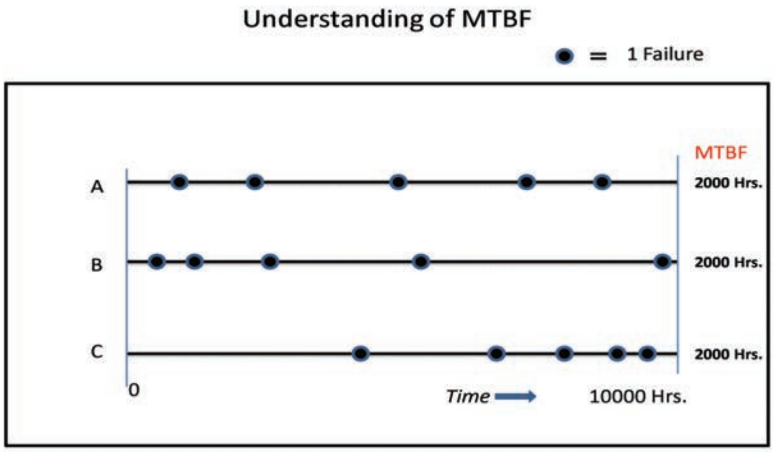

Figure 1

Three different items (A, B, and C) are placed in service and each is operated for 10,000 hours. Coincidentally, each item fails a total of five times over the 10,000 hours. Thus the MTBF for each item is 10,000 hrs / 5 failures = 2000 hrs. If we treat each item equally because they all have the same MTBF, we are missing out on the failure trends that the data show us.

It can be seen by inspection that each item has a different failure pattern. Item A appears to have a random or non-time-dependent failure rate, certainly not a good candidate for a TD task. The non-time-dependent failure rate is best represented by the exponential failure distribution. Item B appears to have a decreasing failure rate indicative of "wear-in." This makes it an even worse candidate for a TD task because we actually increase the probability of failure for the item after each renewal. The only item that displays the failure pattern conducive to a TD task is item C which shows a significantly higher failure rate near the 10,000 hour point.

The following illustration shows graphically how these failure rates appear when plotted as continuous functions.

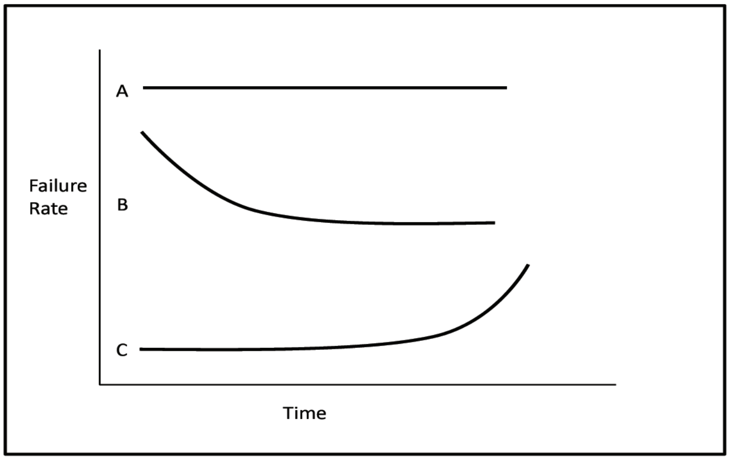

Figure 2: Failure Rate Curves

If the maintainer is thinking about using a time-directed approach to a PM task, he really should be sure the failure pattern supports this decision. To accomplish this, the failure data should be analyzed to determine if there is a trend or pattern in the rate of failure. One way to analyze the failure data for an item is the Weibull method. Weibull analysis has been in use since the 1950s and there are many software packages (some are free or very inexpensive) available that can be used to develop the Weibull plot.

There are also many books and articles written about Weibull that provide a great deal of in-depth information. Weibull is applicable to systems where the component is replaced after failure, rather than repaired in-service. Weibull assumes that the system is as good as new after replacement. If this is not the case other methodologies such as the Power Law Method (developed by AMSAA in the 1970s) are more appropriate.

Weibull is a continuous failure distribution, one of many that can be used to model reliability. Others include Gaussian (normal) distribution, log-normal, exponential etc. What makes Weibull popular is that it has multiple variables that can change the shape of the distribution to resemble these other distributions. It is important to note, however, that Weibull is intended to model specific failure modes. The input parameters to the distribution are, for the specific failure mode, the time-to-failure, and whether the data timeframe ended before all units failed, i.e. the analysis is suspended at a specific time.

So one must know the size of the population of components under analysis, the length of the analysis timeframe, how many and at what time failures occurred. After input of these values into the Weibull software (or on the old-fashioned Weibull graph paper), two distribution parameters will be generated: the shape parameter (η) and the scale parameter (β).

The value of β will tell if you what type of failure pattern you have. If β is much less than 1.0, then you have a decreasing failure rate (burn-in) similar to line B in Figure 2. When β is greater than 1.0, there is an increasing rate of failure, for the failure mode in question. This corresponds to line C of Figure 2. When β is equal, or nearly equal to 1.0, then there is no trend.

The scale parameter (η), in a Weibull distribution is also known as the "characteristic life" of the distribution. It provides a frame of reference of the point at which 62% of failures should have occurred. In this fashion, it could be used as a point for when to perform a TD maintenance task. The higher the value of η, the higher the rate of age degradation is. However, the best way to determine a TD periodicity is to plot the Weibull reliability vs. time (or usage wear) for the failure mode with η > 1.0. Then choose a Pf point, where reliability becomes lower than what is desired to trigger the maintenance.

The PLM process, is similar to Weibull, but is designed for systems that break down, are repaired, and then placed back in service. This continues until the system is either replaced or overhauled. Like Weibull, a β parameter is computed from failure data and the slope of β determines the trend in failures. β values less than 1.0 indicate a wear-in period, values equal or nearly equal to 1.0 indicate no trend, and values greater than 1.0 indicate the item is experiencing wear-out. The PLM methodology can be used to calculate the most economically feasible overhaul frequency for items that wear out. The TD task periodicity is given by:

$$T_0 = \left[\frac{Cv}{\lambda(\beta - 1)Cr} \right]^{1/\beta}$$

Where: T_0 = TD task periodicity
Cv = Overhaul or TD task cost
C_r = Typical repair cost

λ and β are computed values based on failure data and times to fail for the equipment. Calculating these values is beyond the scope of this text, but may be found in the literature. The important point is to use Weibull analysis for failure modes where the component is replaced with a new component upon failure and PLM where the component is repaired and returned to service after repair. Both the Weibull and Power Law methodology are described in detail in literature, some of which are included in the references section at the end of this article.

Failure Finding Tasks:

FF tasks cannot prevent functional failures. They are intended to discover hidden failures that may result in the loss of a protective function, e.g. testing of a fire alarm. Nowlan & Heap described a method to compute the interval for a FF task that relies upon some basic assumptions. First, is that the failure mode must be time independent and thus follow an exponential failure distribution (like item A in Figure 1). Second, the analyst must know the MTBF for the failure mode. Last, the analyst must input a desired Reliability level (in terms of percentage) for the equipment. For example, we could use a 95% or 0.95 confidence in the equipment operating when needed. The equation to use is a variation of the familiar exponential reliability function:

$$R(t) = e^{-\lambda t}$$

where λ is equal to 1/MTBF and t is time. For a FF task interval we solve the equation for t (the FF task interval) and thus have:

$$t = -\ln(R) * MTBF$$

As an example, if we have a switch with an MTBF of 15,000 hours, and a required reliability of 0.95, then solving for t we get a task interval to test the switch of 769 hours, or approximately 32 days of continuous operation. So a monthly periodicity FF task to test the switch will give us a 95% confidence it will work when needed.

Condition Directed Tasks:

Condition Directed (CD) tasks are periodic tests or inspections to compare the existing conditions or performance of an item with established standards to determine the need for a follow-on renewal, restoration or repair to prevent the loss of function. There are two factors that are relevant with respect to choosing a CD inspection interval: the characteristics of the failure mode in question, and the accuracy and consistency of the inspection method.

A CD task only works if a characteristic related to the failure mode is detectable, and it can be measured with accuracy and consistency, and there is a sufficient and relatively consistent interval from detection of potential failure until actual functional failure. This concept is illustrated in Figure 3.

As can be seen in Figure 3, there is an "as-new" resistance to failure (point A). Notice we show this as less than 100% as nothing is considered 100% reliable. Over time or operating usage, resistance to failure decreases. There is a point P, where we say that onset of failure has occurred. The time between P and F (functional fail-

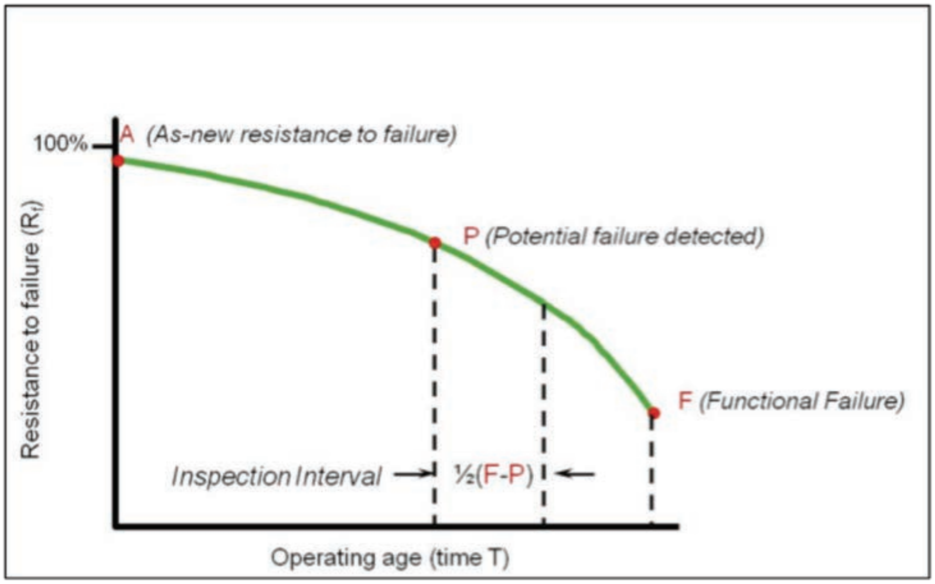

Figure 3: Condition-Directed Tasks

ure) is F – P. A rule-of-thumb inspection interval is one-half of F – P. This assumes that each inspection is 100% reliable. If some level of confidence is required in the ideal inspection interval, then the formula will become:

$$I = \frac{(F - P)}{n}$$

Where n is the number of inspections performed within the P-F interval. If there is a confidence or probability the inspection will identify a potential failure when it exists, we define the probability of success for the inspection as θ. Consequently, the probability of not detecting the potential failure is (1 – θ). If each inspection has a 1 – θ probability of not detecting the P point, then for n inspections, the total probability of not detecting P is (1-θ)n. If the acceptable probability of detecting P is given as Pa, then the minimal acceptable Pa occurs when Pa = (1-θ)n. Solving this equation for n yields Equation 2:

$$n = \frac{\ln(Pa)}{\ln(1-\theta)}$$

Obviously the equation will not work when θ = 1. Therefore we cannot calculate a 100% confidence in our inspection detecting P, which is in agreement with practical experience. In this way, n is calculated and can be used to determine the required inspection interval (I).

The greater the value of n, the smaller the inspection interval and thus greater confidence in early detection of potential failure. CBM technologies such as online real-time monitoring effectively decrease the inspection interval to seconds or less, and fully satisfy this equation.

Conclusion:

The RCM process is the optimum means to establish a scheduled maintenance program. Initial task periodicities often present a challenge to the analyst. For significant failure modes, or failures where we have good data established, initial maintenance periodicities can be calculated reasonably well. However, these periodicities should not remain static. RCM is a living, continuous improvement process and task intervals should be revisited and adjusted based on as-found condition, failure data, and operator feedback. Such feedback is an integral part of an age-exploration program to optimize the cost-effectiveness of maintenance intervals.

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DANGER
DANGER
HIGH VOLTAGE

Left Page Top: Inspecting Pump Bearing
Left Page Bottom: Scanning Switchgear
This Page Bottom: Checking Bearing Grease Levels

Ultrasound Assisted Lubrication

Alan Bandes

"As many as 60 to 80 percent of all bearing failures (catastrophic, functional and premature) are lubrication related, whether it's poor lubricant selection, poor application, lubricant contamination or lubricant degradation."
- Mark Barnes, Des-Case Corporation

In today's manufacturing aenvironment, cost control is important . . . in fact, it is essential to survival. Profit margins are shrinking; often the difference between profit and loss can be as simple as improving efficiencies. Locating sources of waste and identifying failure conditions can contribute to helping improve the bottom line.

Related to bearing failure, the most influential cause of failure is lubrication related. This includes using the wrong lubricant along with improper lubrication practices such as not enough or too much lubricant. Using improper lubricant can damage a bearing to the point of irreversible failure, causing machine and production shutdown, lost hours and significant downtime. Bearings running with too little lubricant can cause friction requiring more energy to overcome the resistance, which can lead to bearing failure and eventual seizure. Using too much lubricant can also produce heat, break seals and decrease acceptable tolerances, which will lead to bearing failure.

Proper lubrication of bearings is essential as it helps dampen stress distribution. As stated, lack of lubrication will create friction while overlubrication creates grease build up, thickening the area around the bearing, making it difficult to rotate.

In order to eliminate the problems caused by over- or underlubrication as well as several other inspection requirements throughout the plant, many companies around the world have incorporated some form of a condition monitoring program. Condition monitoring is used to check the health or "condition" of operating equipment, as opposed to the other forms of maintenance, such as reactive, in which a failure condition has occurred and maintenance personnel must "react" to the problem, or preventive, where maintenance activities are performed on a set schedule. Any change in monitored fields can alert maintenance personnel of potential failure and allow the repair to be performed on a scheduled, controlled basis.

Traditional lubrication condition monitoring programs include preventive procedures such as time-based lubrication, where lubrication is performed at set, timed intervals with a specified amount of grease applied. However, the issue with time-based lubrication is that if the bearing being lubricated has a sufficient amount of grease already and therefore DOES NOT need lubricant, the inspector is at high risk of overlubrication. Another issue with time-based lubrication is that some bearings may require lubricant to be applied more frequently than assumed through this procedure.

These types of issues do not preclude the need for standard preventive procedures such as removing old, used-up grease and adding new grease. Among the most effective methods available to assist in lubrication inspection is the use of ultrasound technology.

Ultrasound technology

Airborne/structure borne ultrasound instruments receive high frequency emissions produced by operating equipment, electrical emissions, and by leaks. These frequencies typically range from 20 kHz to 100 kHz and are beyond the range of human hearing. The instruments electronically translate ultrasound frequencies through a process called heterodyning, down into the audible range where they are heard through headphones and observed as intensity and/or dB levels on a display panel.

Adding ultrasound monitoring to standard lubrication best practices can prevent potential overlubrication of bearings, which can also lead to fewer bearing failures, extend motor and bearing life, and lead to a decrease in the amount of lubricant used.

And, that affects your bottom line through:

- Savings in maintenance costs, lubricant and man-hours
- Improved asset availability and reliability

Lubrication: What is too much vs. too little?

While many bearings can fail due to lack of lubrication, overlubrication is considered one of the major causes of bearing failure. Standard preventive time-based procedures may be useful if this practice is followed without any feedback regarding the condition of a bearing. However, it may lead to an overlubricated condition that will eventually cause bearing failure. Many maintenance departments are therefore switching to a combination of preventive and condition-based lubrication.

A condition-based lubrication program requires a combination of trending bearing decibel levels and basic sound analysis. A baseline decibel level is set, along with (if possible) a baseline sound sample, and an inspection schedule is established for periodic testing. When a bearing sound level exceeds 8 dB with no change in the sound quality (usually a smooth, "rushing" sound), the bearing is considered in need of lubrication.

A lubrication technician, while listening to the bearing, will then apply lubricant, a little at a time, until the baseline level is reached. Stopping at that point prevents overlubrication.

Case in point

A maintenance manager for a food manufacturing plant reported at a recent ultrasound conference a savings of $220,000 in their bearing-monitoring program. The company also reported that since initiating ultrasound condition monitoring at another of their facilities more than three years ago, there have been no unannounced failures in the 340 bearings they monitor, and that their motor repair cost was reduced from $2400 to $600 per motor. In fact, all their criteria for rebuilding a motor are based on condition rather than preventive, time-based procedures.

This switch has resulted in a three-fold savings, which translates into $90,000 per year. The benefits of an ultrasonic condition-monitoring program also go beyond bearings. Ultrasound instruments are used to reduce energy costs by locating steam and compressed air leaks and improving equipment availability by locating arcing and tracking problems before flashover in electrical apparatus such as transformers, switchgear, and motor control centers.

How can ultrasound technology provide such accurate results?

During inspection using airborne/structure borne ultrasound, the inspector will sense friction in mechanical instruments. Trending associated amplitude levels and changes in sound quality of a bearing also provide early indication of conditions such as lack of lubrication and overlubrication.

Beyond its ability to detect premature or existing bearing failure or over/underlubrication conditions during a route, the newer digital ultrasonic instruments (such as the Ultraprobe® 10000 and 15000) utilize data management and sound analysis software to predict potential failure conditions.

These digital instruments will enable the plant technician to set baselines, log data, record sound samples for spectral analysis, and analyze sounds. Some of the newer portable digital instruments have onboard spectral analysis and data software to allow for on-the-spot analysis.

Beyond accuracy, what are the advantages of ultrasound related to lubrication analysis?

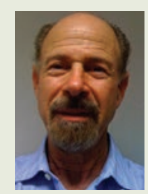
The basic advantages of ultrasound and ultrasonic instruments are:

1. Provide early warning of impending mechanical failure.
2. Isolate signals to a specific test point.
3. Can determine the quality of a bearing.
4. Can detect exact lubrication needs (i.e. add or stop adding lubricant).
5. Can be used in loud, noisy environments.
6. Can be used on slow-speed bearings.
7. Support and enhance other PdM technologies or can stand on their own in a maintenance program.

So what are you waiting for?

The benefits of ultrasonic condition monitoring are quite substantial. From identification of bearings in need of lubrication to prevention of overlubrication, ultrasound instruments can reduce the amount of grease you need in inventory, improve your asset availability and most importantly, your bottom line.

The initial investment is relatively inexpensive and the return on it could be immense. To help push an ultrasound program along, it is a good idea to attend a training course. There are certification courses available that cover all the major applications and provide all the information necessary to implement a successful program.



Mr. Bandes has been involved with airborne/structure borne ultrasound since 1973. He has lectured and published articles in many highly regarded technical journals.
www.uesystems.com

Detecting Bearing Faults

Jason Tranter

This article is the first in a series of four. In this article we will provide an overview of how vibration analysis can be used to detect bearing faults. We will only consider the typical failure mode where a spall develops in the bearing and the fault slowly worsens until the bearing ultimately fails. In the next article we will explore how techniques such as enveloping, PeakVue, Shock Pulse, time waveform, and spectrum analysis can be used to detect bearing wear. In future articles we will explore additional fault conditions (cocked bearing, EDM, skidding and other conditions), and in the final article we will examine what the vibration analyst can do to extend the life of the bearing through acceptance testing, correction of unbalance and other conditions, and root cause failure analysis.

Your job relies on accurate fault detection

There is no doubt that the primary focus for most vibration analysts is the detection of rolling element bearing fault conditions. When a bearing fails unexpectedly it costs a great deal of money (downtime, secondary damage, etc.) and it is a black mark on your name and your department. For all the successes you may have achieved, missing just one bearing failure can set your reputation back months.

Dryer Fan

Then again, the opposite is also true. If you report that a bearing has a defect and must be replaced, yet it is found to be in good condition, you also don't look good. People lose confidence in your skills and in the technology.

So what is the solution? I guess that's obvious; don't make mistakes! If only it were that easy . . .

It's actually not that hard to detect faults . . .

Detecting rolling element bearing defects is not as difficult as it may seem—I bet you did not expect me to say that! With a good screw driver and frequent trips around the machines, most people would be able to detect that a bearing needs to be replaced. There are, of course, a few issues with this approach. First, it is hardly a safe practice. Second, the greatest benefits are achieved when the maintenance and production group have more than a few days warning that a machine needs to be stopped to replace a bearing.

The earlier the better

The challenge is to correctly assess the nature and severity of the defect and the life of the bearing. If you could confidently detect a bearing fault weeks or months before the bearing needs to be replaced, then the work can be planned to minimize the impact of the bearing change. You may even be able to extend the life of the bearing by correcting the root cause of the fault condition (unbalance, misalignment, poor lubrication, etc.).

There is some good news

The good news is that the design of rolling element bearings makes it much easier to detect fault conditions at an early stage. Thanks to the geometry of the bearing (and their unique "defect frequencies") it is easy to distinguish bearing vibration from other vibration generated by the machine. And thanks to the high frequencies generated in the early stage of wear, again it is easy to distinguish from other fault conditions. Armed with this information we just need to measure the vibration correctly and analyze the data correctly, and we can be very successful.

OK, I may have made it sound too easy. In truth there are a number of challenges to overcome. But understanding the challenges and their solutions is the key to success.

Key #1: Measure the vibration correctly

Assuming the goal is to detect the bearing fault as early as possible, the first thing you have to do is recognize that the way you measure the vibration is absolutely key to success. In the earliest stage of bearing wear, the frequency of the vibration is very high

Poor mounting

Two-pole magnet – not ideal mounting

Flat magnet or stud – ideal mounting

and the amplitude is very low. I don't care who you are; you just can't hear it. And if you use "conventional" sensor mounting techniques, you cannot capture these high frequencies.

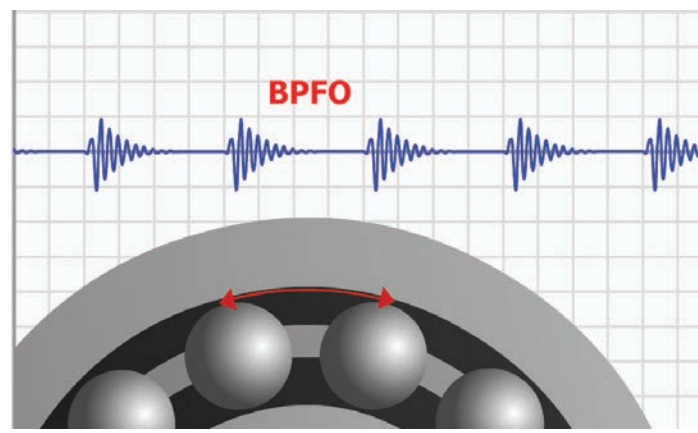
Techniques such as ultrasound, Shock Pulse, enveloping (demodulation), Spike Energy and PeakVue are designed to detect high frequency, low amplitude vibration. Without getting into the details, these techniques work by first removing the high amplitude, low frequency vibration, then listening carefully to the high frequency vibration for the telltale signs of bearing wear, then transforming that vibration into a form that is easy to analyze. We'll examine these techniques more closely in the next article.

A little bit of background . . .

When a defect is first initiated, the surface of the bearing may not actually be damaged; the damage may be ***subsurface***. Even when the damage does extend to the surface, the vibration generated is still weak. As the balls or rollers move around the bearing and there is contact at the point where the damage exists, two things will happen: there will be a shock wave (also called a stress wave); and the bearing may vibrate (or resonate). The shock wave ripples out from the point of contact ***very*** quickly. The vibration that results will be very weak, and thus difficult to detect.

Bearing Series

We can calculate, or search bearing databases for the telltale frequencies: the ball-pass inner race frequency, ball-pass outer race frequency, ball (or roller) spin frequency, and cage (or fundamental train) frequency. If you can visualize the shaft turning inside the bearing, and the balls rolling around, there will be a fixed time between each impact. The time will be different depending upon where the bearing is damaged; on the inner race, the outer race, or on the rolling elements themselves.



Slice from Flash Simulation

Good news!

The good news is that this frequency will always be ***non-synchronous***; it will never be exactly 2.0, 3.0, 4.0 (or any other integer) times the turning speed of the shaft. It will be a non-integer number such as 3.09, 6.71, or 11.43 times the speed of the shaft. That's the good news. It makes it easier to distinguish these sources of vibration from the numerous sources of vibration that occur at exact integer multiples of the running speed—from rotating elements such as pump vanes, fan blades, gear teeth, and so on.

More good news!

Another piece of good news is that when these impacts occur, the vibration that results is not smooth; the vibration will suddenly spike in amplitude before it settles again. That causes ***harmonics*** to appear in the spectrum. And even more good news is that under certain conditions the amplitude of those spikes will rise and fall (as a spall on the inner race of the bearing, or the damaged rolling elements, move in and out of the load zone). That causes sidebands to appear in the spectrum.

All of these telltale signs, which we can look for even if we do not know which bearing is installed in the machine, provide an early warning that the bearing is damaged. We can look for these signs

well before we would ever hear a change in vibration, even with the best screwdriver.

Some bad news . . .

The bad news is that in the earliest stage of bearing wear, we will not be able to see peaks at these telltale frequencies in the standard velocity spectrum when it is displayed in the linear format that most people use. (In truth, we might see them in a logarithmic spectrum or in an acceleration spectrum.) So we have to look elsewhere. And that's where enveloping (and the other techniques listed previously) can be put to good use.

So, what is the solution?

There are a few ways to tackle this challenge.

1. There are simple meters that focus on higher frequencies can be used to get an indication that a fault exists. However, other fault conditions can be confused with bearing faults.
2. Shock Pulse meters are specifically designed to detect bearing faults. When used properly they provide an affordable way to get started.
3. Ultrasound meters allow you to listen for the presence of high frequencies. It is possible to detect lubrication problems and bearing defects. Again, they offer an affordable way to get started.
4. If you rely on "standard" velocity spectra (in linear format) then you will find it difficult to detect the fault until the fault has become more severe. Switching to log can help, and using units of acceleration and setting a higher Fmax will help.
5. The best solution is to use more sophisticated techniques such as enveloping (also known as demodulation), Shock Pulse (with access to the spectra and time waveforms), Spike Energy, and PeakVue. We'll discuss these techniques in the next article.

In the next article we will explore the techniques described in item 5 above. I hope this article has given you a better understanding of how the vibration changes as a defect grows, and the challenges involved with detecting the fault at the earliest stage.

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management

RL reliability leadership

Q&A

Terrence O'Hanlon, Publisher at *Uptime* magazine recently caught up with entrepreneur and innovator Tim Rohrer of Exiscan for a discussion on a new line of Infrared Viewing Windows.

Q *Tim, you started a new company in the midst of one of the worst economic downturns in recent history. Are you crazy?*

A It sure sounds like it when you put it like that! But, I'm just really passionate about electrical safety, and I'm passionate about the concept of predictive maintenance. And actually, in a tough economy like this one, every company is looking for ways to save money, increase workforce efficiency, improve electrical efficiency, protect their process uptime and avoid OSHA fines. IR windows help companies accomplish all of these things while creating a work process that reduces inspection costs by 75% to 95%.

Q *Infrared Viewing Windows have become more popular as more companies become aware of and follow the NFPA 70E and 70B guidelines. Do you agree that Infrared Viewing Windows make Infrared Thermographic inspections much safer?*

A Absolutely. My experience in the industry and with the standards tells me that more and more emphasis will be placed on infrared inspections as a cost-effective and accurate way to identify electrical faults. You can see that in the way insurers have adopted the NFPA 70B recommendations for periodic infrared electrical inspections.

But every electrical safety standard in the world—including NFPA 70E, OSHA 1910 and CSA Z462—agree that personnel are safest when electrical equipment remains closed or de-energized. IR windows are the perfect solution, allowing thermographers to gather the insurer mandated images and data in the safest and most efficient manner; because the gear remains closed, there is no user-initiated electrical hazard. Therefore, the risk of electrocution or arc flash is not elevated above standard administrative tasks, such as reading a panel meter. It goes back to what I said earlier—I have a passion for electrical safety—and I believe that IR windows will ultimately save lives.

People have a choice: they can spend an inordinate amount of time with multiple personnel removing panels and creating hazard conditions, ultimately placing personnel at risk; or they can use one engineer spending a couple of minutes without elevating risks, while gathering data that is arguably *more* accurate due to reflection issues.

Q *We have seen several other companies offering Infrared Viewing Windows. What makes the Exiscan products different?*

A Due to my experience in the IR window industry, I understand the strengths and liabilities of the other manufacturers. There are some good solutions out there right now that help to make thermography easier and safer. We simply looked at the strengths of the two predominant solutions to come up with the best of both worlds, and then we upped the ante on the ruggedness.

Users expressed the need for an optic that was truly impact resistant, not just covered over, and they wanted an optic that would maintain a consistent transmission rate for accuracy. A polymer optic was the best way accomplish those demands. But thermographers wanted a ghost-free image and we wanted to be able to give clients a single transmission rate that worked with all cameras, again for accuracy. So we have a patent-pending design for an impact-resistant optic that requires no grills.

Then, for the housing, everyone wants a rugged metal body and cover, and they want to make sure that once installed, the window will not be the weak point of the system, even in non-arc-resistant gear. So when you pick up our window you will notice that it is *substantial*. I kept telling my partner, "It has to be bomb proof!"

Q *One thing we noticed is that the Exiscan Infrared Viewing Windows are square and most of the others we have seen are round. What is up with that?*

A Well, thermographers always want the biggest IR window that they can get their hands on. So it's simple math; a square window increases the area of the window by roughly 27% to 55%. Besides, even though the IR camera lens might be round, the image is rectangular or square—so why cut corners?

Q *What has the initial customer reaction been?*

A When we started sharing the product with customers and other industry leaders, they expressed that the product's ruggedness and transmission characteristics really stood out. I think we are really filling a void.

Q *What are the issues about transmissivity for Infrared Thermographers?*

A Too often, thermographers disregard the effect that transmission rates play in temperature measurement and therefore Delta Ts (or differences in temperature), and even the images they view. If the thermographer properly calibrates their camera for transmission and emmissivity, they can get meaningful data, and meaningful images. But if their IR window experiences transmission degradation, or if its grill causes variable transmissions across the optic, then it makes proper calibration impossible, and therefore, accurate data and images impossible.

Q *What is ghosting and how does the Exiscan Infrared Viewing Window prevent it?*

A Well it has nothing to do with the Ghost Hunter, or finding spirits using thermography. Spread your fingers out and put your hand up a few inches from your face and look off in the distance. I am guessing that you can see the objects in the distance, but you can also see the "ghosted image" of your fingers. That's because one eye is receiving the light from the distant objects while the other eye is receiving light from your fingers. The result is a "ghosted image" of your fingers.

Thermography works the same way. When you take an image through a grill, the grill allows variable amounts of radiation through to the camera's sensors. Since the camera has a bunch of sensors behind that lens, some sensors are receiving full radiation from a target point, while others receive none. It's not a huge problem for the expensive cameras with a large lens, again as long as the thermographer presses the lens to the grill. But like everything else, the technology is making the cameras and the lenses smaller and smaller. Those cameras with a small lens are far more affected by ghosted images and inconsistent temperature readings. So Exiscan designed its windows to yield clean, "ghost-free" images, with higher transmission rates that are the same for every camera, and uniform across the surface of the optic—it all results in better accuracy.

Q *Tim, we wish you great success in this new venture. Can you share with us what your vision is for 5 to 10 years into the future?*

A I see predictive maintenance and condition-based monitoring becoming more and more common across industries as the technology becomes easier and less technical for companies to implement and utilize. This will only increase the need for, and the value of highly trained and experienced technicians, as there will be a larger base of companies that will need good people with a broad vision.

With regard to my part of the industry, there is no doubt that we are already seeing IR windows becoming a standard across the industry. I sit on various industry standards dealing with arc flash and electrical safety; the people driving those standards appear to universally support the use of windows and similar tools or design methods that limit or eliminate the need for personnel to open equipment. In fact, even as some of the market moves toward online temperature monitoring, the need for windows becomes even more critical since engineers will always want to double-check a sensor's readings prior to ordering a facility to shut down, but no one will want to open gear that is likely experiencing near-catastrophic faults.

As for Exiscan, we will continue to listen to our clients and distribution channels. Ultimately, they will drive us to invent new ways to limit risks, save money and save lives. We've already got a few products in the pipeline—so stay tuned, Terry.

Readers interested in more details should visit Exiscan LLC online at www.exiscan.com.

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over the last few years has been to sustain those gains. Several focus areas have helped them ensure sustainability:

Harnessing the power of Reliability Engineers: When REX was first implemented it was discovered that existing Reliability Engineers were in fact doing mostly project engineering work. Two Reliability Engineers are now assigned to focus solely on "Top Ten Bad Actors" and root cause failure analysis. Their job is to prevent recurring failures and track the benefit in dollars plant-wide. Operations managers call on them to help make problems go away.

Solid, long-term leadership: This was a key success factor. Haws, the plant manager, remained at the helm and continued to ask his managers how he could help. This kind of support allowed members of the management team to take risks like reorganizing and changing metrics expectations. Active leadership was crucial for building the partnership between maintenance and operations that continues today. As evidence, the Warrick Smelter has a direct salary work force of about 85 people and 20 of these are CMRPs or Certified Maintenance Reliability Professionals. Many of these CMRPs are in operations.

Regularly assessing progress: Frequent re-assessments were another key driver for sustainability. LCE was asked to re-assess the Warrick Smelter on an 18-month frequency. Warrick started with a score of 444. Within 18 months the score had improved to 555. Within another 18 months it improved to 603. Eighteen months later the score rose to 719, placing Warrick in the proactive range.

Conclusion

So where does Warrick stand now, seven years into its REX journey?

The asset health of the 50-year-old smelter is greatly improved from 2003 when REX was started. Mark Keneipp points out, "Remember all those $10,000 to $25,000 major components like motors, gear boxes, and pumps that use to fail unexpectedly at odd hours? It rarely happens now, and when it does we perform root cause analysis to reduce the chances of it happening again." The financial results are impressive. Maintenance costs per ton have been reduced by 38% (see Figure 8), and 2010's current OEE gain is $5.8 million over the 2003 REX base. Progress reports are generated quarterly so that comparisons can be made with other Alcoa plants and best practices are shared globally.

The journey has been difficult, but the rewards have been many. Alcoa Warrick has eluded the threat of shutdown and become a model for other plants to follow on the path to excellence.

Mark Keneipp is the Alcoa Business Systems Manager for Warrick Primary Metals. A registered Professional Engineer and CMRP, Mark has over 32 years of experience in the aluminum industry.

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