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Crossrail UK
Enabling Quality Asset Information

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UPTIME MAGAZINE
OCTOBER/NOVEMBER 2014

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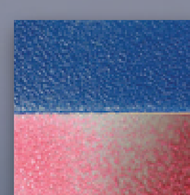

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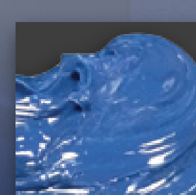

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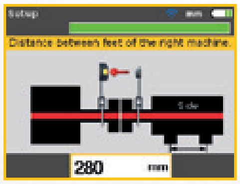

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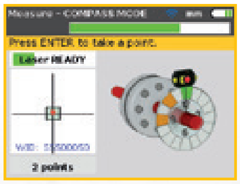

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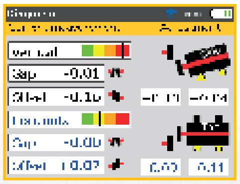

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ISO 55000 for Managers: Developing the Strategic Asset Management Plan	Leaders who are implementing an ISO 55000 initiative, including middle managers from across the organization	Identify the benefits and clauses of the ISO 55000 standard, develop the strategic asset management plan, and create a project plan for individual asset management plans.	Contact us to schedule a private onsite class.	2 consecutive days 1.4 CEUs	Contact us for pricing
ISO 55000: Creating an ISO 55000 Implementation Plan	Operations leaders who are implementing an ISO 55000 initiative, including middle managers from across the organization	Develop and draft an asset management policy for your organization, develop the strategic asset management plan, and create a project plan for individual asset management plans.	Oct 15-16, 2014 (CHS) Jan 27-28, 2015 (CHS) Apr 21-22, 2015 (CHS) Jul 14-15, 2015 (CHS) Oct 20-21, 2015 (CHS)	2 consecutive days 1.4 CEUs	$1,495
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Management Skills for Maintenance Supervisors DEVELOPED BY JOEL LEVITT	Maintenance Managers and Supervisors, as well as Supervisors from Operations, Warehouse or Housekeeping areas	Lead a world-class maintenance department using planning and scheduling best practices to drive work execution, improve productivity, motivate staff, increase output and reduce waste.	Mar 17-19, 2015 (CHS) Aug 11-13, 2015 (CHS)	3 consecutive days 2.1 CEUs	$1,495
Materials Management	Materials Managers, Storeroom Managers, Planner/Schedulers, Maintenance Managers and Operations Managers	Apply sound storeroom operations principles. Manage inventory to optimize investment. Understand the role of purchasing. Implement effective work control processes.	Jun 9-11 2015 (CHS)	3 consecutive days 2.1 CEUs	$1,495
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Reliability Excellence for Managers	General Managers, Plant Managers, Design Managers, Operations Managers and Maintenance Managers	Build a business case for Reliability Excellence, learn how leadership and culture impact a change initiative and build a plan to strengthen and stabilize the change for reliability.	SESSION 1 DATES: Mar 10-12, 2015 (CHS) Aug 25-27, 2015 (CHS) (Sessions 2-4 dates are available on the website)	12 days total (4, 3-day sessions) 8.4 CEUs	$5,995
Risk-Based Asset Management	Project Engineers, Reliability Engineers, Maintenance Managers, Operations Managers, and Engineering Technicians.	Learn to create a strategy for implementing a successful asset management program. Discover how to reduce risk and achieve the greatest asset utilization at the lowest total cost of ownership.	Nov 4-6, 2014 (CHS) Apr 14-16, 2015 (CL) Sep 15-17, 2015 (CHS)	3 consecutive days 2.1 CEUs	$1,495
Root Cause Analysis	Anyone responsible for problem solving and process improvement	Establish a culture of continuous improvement and create a proactive environment. Manage and be able to effectively use eight RCA tools to eliminate latent roots and stop recurring failures.	Feb 24-26, 2015 (CHS) Aug 18-20, 2015 (CL)	3 consecutive days 2.1 CEUs	$1,495

***LOCATION CODES:** (CHS) = Charleston, SC | (CL) = Clemson University in Greenville, SC | (UA) = University of Alabama

Contents

oct/nov 2014

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ON THE COVER
Crossrail's Architects' Impression: Canary Wharf Station.
See page 6 for complete story.

Features

Elements

Editorial

YOU ARE INVITED

We have been creating some remarkable breakthroughs with our work with Uptime Elements and the Certified Reliability Leader. I recognize as I go through this work and have periods of great creativity that I owe a lot to a great many people.

The opportunity for this work, I mean really being able to do it all, is the product from an enormous amount of support from a lot of people. This work is only possible out of those relationships and interactions and actions that people take with their lives and work.

So while it may look like we write about recipes and clever options in Uptime Magazine, one result I hope to generate is to get you to expand your thinking beyond a simple recipe for reliability. There are dangers with using a simple set of recipes for improvements. Have you experienced any of your reliability improvements as completed projects however you were unable to quantify useful data captured, changes in behavior or ROI?

According to research conducted by Reliabilityweb.com and confirmed by numerous other sources – over 70% of change efforts and new strategies used in reliability fail to create a sustained business result. This is a paradox because the most effective strategies and techniques about maintenance reliability are well known and well documented.

The solutions are an exploration that forms my life's work for the past 30 years. Early in my career I was in search of the recipe – that secret combination of options that would yield the highest reliability. Although there are some options or recipes that are better than others, I am inviting you into an even more powerful conversation where we can operate from a basic question – an exploration – where we can create a clearing – an opening where reliability is generated. By working from the space and not trying to rush to an answer or a solution or a recipe, we may be able to create a new possibility of reliability for you and your organization.

If you want to have a closer experience of the enquiry in a more direct way please make plans to attend one of our public conference like IMC, RELIABILITY 2.0 or Solutions 2.0, or an AMP Reliability Leader Tour or one of our in depth 2015 Reliability Leadership Institute training conferences – all based on Uptime Elements – A Reliability Framework for Asset Performance Management. We are still working toward our goal of 1000 Certified Reliability Leaders who use the reliability framework to enable the triple bottom of economic benefit, environmental sustainability and social responsibility.

I hope I get to welcome you to the Uptime Elements in person.

Warmest regards,

Terre O'Hanlon

Terrence O'Hanlon, CMRP
CEO and Publisher
Uptime Magazine
www.uptimemagazine.com

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PUBLISHER/EDITOR
Terrence O'Hanlon
terrence@reliabilityweb.com

FOUNDER
Kelly Rigg O'Hanlon

EDITOR
Jenny Brunson

CONTRIBUTING WRITERS
Robert Baird, Mark Barnes, Noah Bethel, Thomas Brown, Mary Jo Cherney, Ross Dentten, Jim Fitch, Thomas Godby, Jim Hall, Russell Harley, Wyhan Jooste, Joel Levitt, Ron Moore, Brian Oxenham, Doug Plucknette, John Reeve, Thomas Van Hardeveld, PJ Volk

VP OF SALES AND PUBLISHING
Bill Partipilo
bill@reliabilityweb.com

DESIGNERS
Andrea Brito and Jocelyn Brown

PRODUCTION COORDINATORS
Kaitie Sweet and Rebecca Winterburn

EDITORIAL INFORMATION
Please address submissions of case studies, procedures, practical tips and other correspondence to Terrence O'Hanlon
terrence@reliabilityweb.com

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Uptime Magazine
PO Box 60075, Ft. Myers, FL 33906
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ReliabilityTours: LUBRICATION ENGINEERS

August 6-7, 2014

ReliabilityTours stopped by Wichita, Kansas, to visit Lubrication Engineers (LE) and its state-of-the-art manufacturing facility. This two-day program included a full day Certified Reliability Leader (CRL) course, with the option to sit for the CRL exam and certification. Day two featured a reliability tour and overview from the team at Lubrication Engineers, with contributions from the CEO, Director and the operations, engineering and capital improvement teams. LE manufactures and distributes high-performance lubricants, which are made of highly refined or synthetic base oils and proprietary additives. Many thanks to all who attended and LE for hosting this great event!

Next ReliabilityTours:
Nissan North America
Smyrna, TN
October 1-2, 2014
Visit **www.reliabilitytours.com**
to learn more.

Reliability Leader Leads Young Athletes to Their Personal Best

When George Mahoney isn't in his role of Reliability Excellence Lead for Merck for North and Latin America, he is running Advanced Training, an athletic program in New York City dedicated to helping high school, college and professional athletes reach their optimal sports performance level.

Watch this short documentary to learn more about Advanced Training. http://www.youtube.com/watch?v=PRAPgx0oEAk&feature=youtube

University of Tennessee Takes Course to Munich, Germany

The University of Tennessee recently took its course, Global Perspectives in Lean Reliability and Maintainability, to Munich, Germany. The goal of the course was to provide a practicable overview regarding implementation of lean, reliability and maintainability processes. In addition to coursework, students spent time in locations such as the Technical University of Munich (TUM) for hands-on lean learning, performing plant assessments, observing communications satellite testing in a clean room environment and visiting the Zeppelin airship facilities.

WESTAR ENERGY and TOPEKA PUBLIC SCHOOLS Celebrate Unique Education Partnership

Westar and Topeka Public Schools' (TPS) Kanza Education and Science Park celebrated the completion of the Westar Energy's Education Station substation that supports STEM (science, technology, engineering and math) curriculum. Paint colors help identify key parts of the substation, including transformers and switches. The Education Station is also a working substation to strengthen Topeka's electric system for decades to come, while allowing Westar to retire five World War II-era substations. Additionally, Westar donated a wind turbine located near the substation so that students will be able to closely study renewable energy.

Congratulations to the newest CERTIFIED RELIABILITY LEADERS!

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Saudi Iron and Steele Co-Hadeed

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Scot Anderson
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Don't Miss This Highly Anticipated Event!

Asset Performance Management Summit

December 12, 2014
Co-located with IMC-2014

Asset performance management has rapidly become a recognized business process and best practice in sustaining assets and maximizing their return on investment. Properly and proactively maintaining assets minimizes costs, and reduces spare part inventories, the use of contractors, and overtime. By reducing the variability of capacity and throughput, organizations ensure customer deliveries, achieve revenue targets, and improve customer satisfaction.

The Asset Performance Summit will keep asset managers, reliability and maintenance leaders ahead of the pack to manage risk and ensure process safety and future proof the operation. Discuss today's urgent process and organizational issues and share ideas with reliability and maintenance leaders from Purac, ArcelorMittal, Therma Tru and more.

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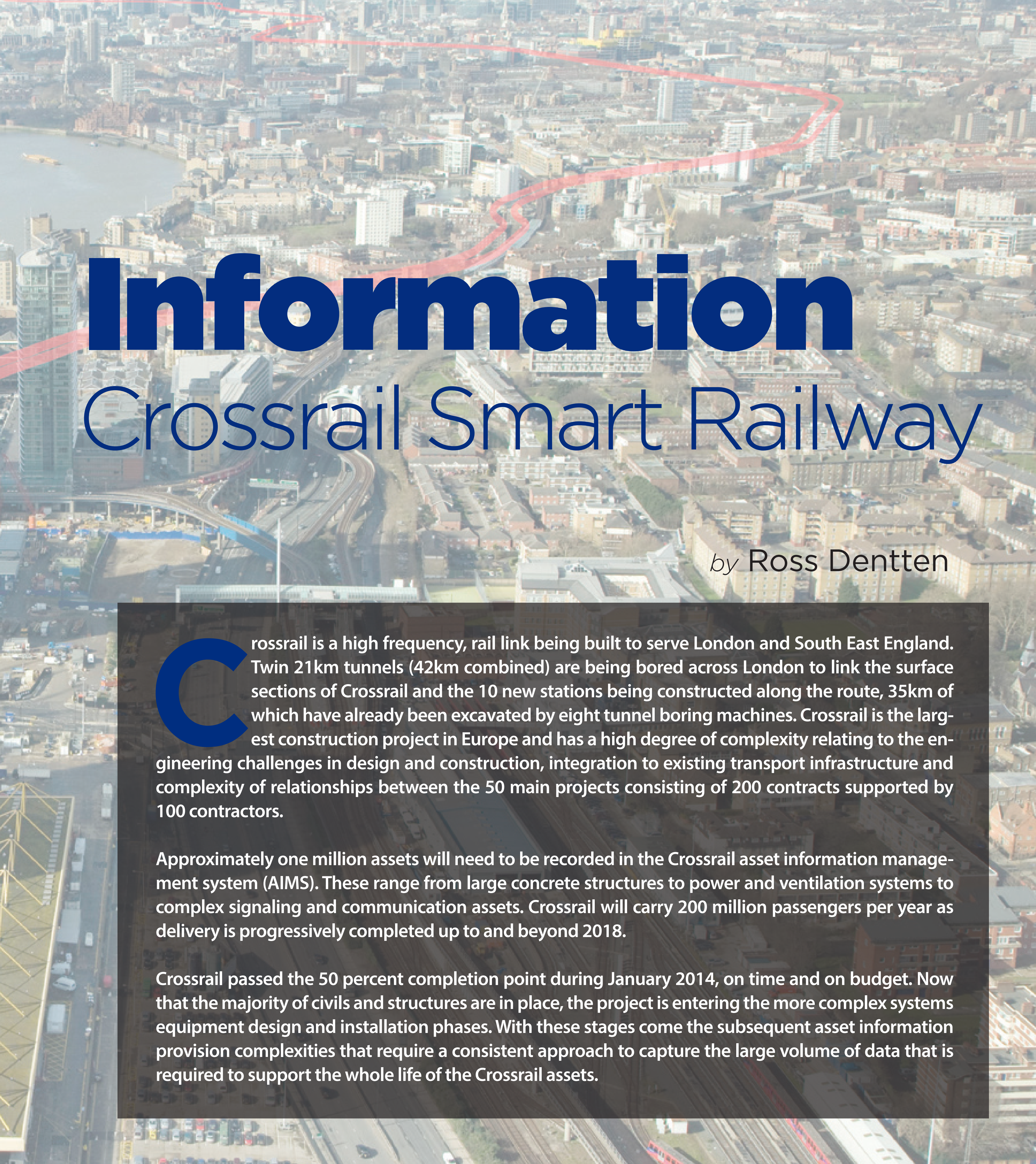


Information

Crossrail Smart Railway

by Ross Dentten

Crossrail is a high frequency, rail link being built to serve London and South East England. Twin 21km tunnels (42km combined) are being bored across London to link the surface sections of Crossrail and the 10 new stations being constructed along the route, 35km of which have already been excavated by eight tunnel boring machines. Crossrail is the largest construction project in Europe and has a high degree of complexity relating to the engineering challenges in design and construction, integration to existing transport infrastructure and complexity of relationships between the 50 main projects consisting of 200 contracts supported by 100 contractors.

Approximately one million assets will need to be recorded in the Crossrail asset information management system (AIMS). These range from large concrete structures to power and ventilation systems to complex signaling and communication assets. Crossrail will carry 200 million passengers per year as delivery is progressively completed up to and beyond 2018.

Crossrail passed the 50 percent completion point during January 2014, on time and on budget. Now that the majority of civils and structures are in place, the project is entering the more complex systems equipment design and installation phases. With these stages come the subsequent asset information provision complexities that require a consistent approach to capture the large volume of data that is required to support the whole life of the Crossrail assets.

Asset Information Fundamentals

Good Practice Asset Management

Besides delivering a functional and efficient railway, Crossrail needs to ensure the railway can be operated and maintained efficiently and effectively through its whole life in accordance with good practice approaches to asset management.

The Institute of Asset Management's asset management landscape tool demonstrates the main areas essential to good practices of asset management. Asset knowledge, which encompasses asset information, is a key underpinning area.

The availability of good, quality asset information is essential for achieving these long-term strategic goals. Crossrail is building two railways, one physical and one virtual, that involve utilizing a geographic information system (GIS) to pull together and present asset information holistically, including data, documents, assets, models and visualizations.

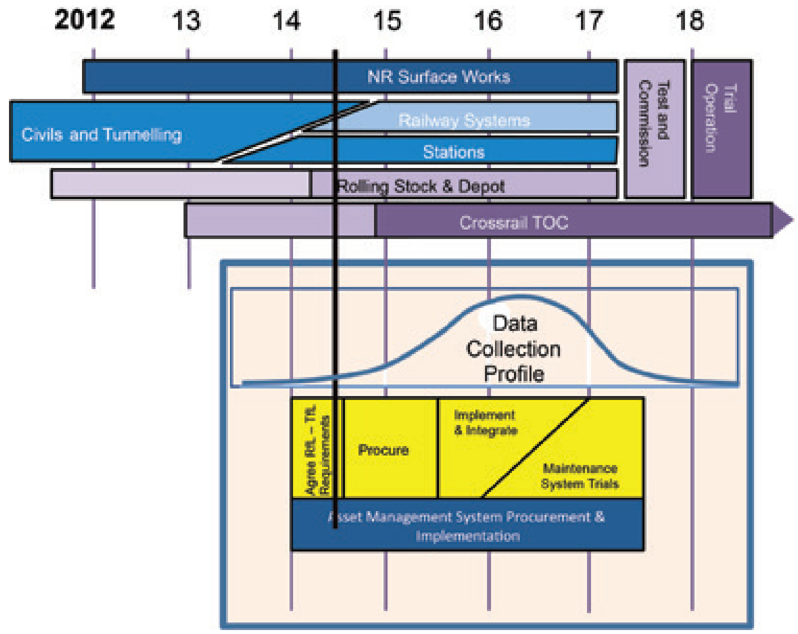


Figure 1: *Crossrail progress overview*

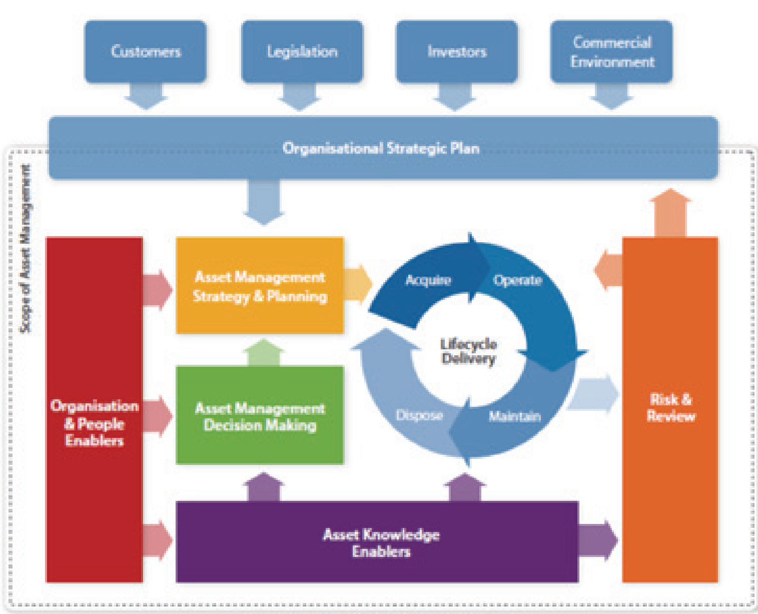


Figure 2: *Asset management landscape diagram*

Crossrail's approaches are informed by configuration management (CM) and asset management (AM) related standards. Some of the key standards include ISO10007 for CM and AM, PAS55 and the newly released ISO55000 series (replacement for PAS55), plus a key suite of British standards, most notably the BS1192 suite, Part 2 of which looks at the creation of a common data environment (e.g., the Crossrail central data hub) and the design phase of an asset's life. The recently released Part 3 looks at the remaining phase of the asset's life through operations, maintenance and renewal/replace.

Crossrail also has been involved in an advisory capacity with Part 4, due for release this year, which deals with the exchange of information between parties throughout the whole life of an asset and is supported by COBie.

Frequently on engineering projects, the acquisition of asset information is undertaken shortly before handover, leading to poorer quality asset information and more expensive data gathering activities post-handover. Crossrail is collecting asset information progressively throughout the project.

Crossrail identified Bentley Systems' Enterprise Bridge (eB) as very closely matching the project's 80 configuration management and 300 asset information management related requirements. The asset information management system is a proactive project to ensure that timely, good quality asset information is delivered through assured business processes.

The Crossrail business case for an information management tool deliberately took into consideration the need for a solution that allowed for documents and assets to reside in one system, subsequently reducing the need for integration between other applications to a practical level and reducing the likelihood of duplication of efforts. This initial strategy enabled Crossrail to bring other areas of the business, such as contract administration, into its central data hub.

Quality Asset Information Enablers

Crossrail has implemented a number of enablers to support the establishment and ongoing maintenance of good quality asset information. These include the:

- ✓ **Asset Information Management Plan** that details the framework being used by Crossrail to specify, acquire, manage and govern asset information.
- ✓ **Asset Identification Standard** that details Crossrail's requirements for the identification of assets. It includes details of asset naming conventions, the style and format of asset identification labels, label fixing requirements and requirements for machine readable identification.
- ✓ **eB/Asset Information Management System** (eB/AIMS) that is part of the central data hub for storing all asset information and related virtual structures and workflow.
- ✓ **Asset Data Dictionary** that specifies the functions, classes and related attributes agreed as relevant to Crossrail's assets.
- ✓ **Asset Data Dictionary Definition Documents (AD4s)** that describe just the relevant detail relating to a specific asset class and function within the asset data dictionary.

- ✓ **Asset Data Collection Spreadsheet** that holds each individual asset class being represented separately in its own worksheet with its own attributes. Contractors then populate these attribute fields while referencing the AD4 definition documents.

- ✓ **Asset Data Dictionary Master Configuration**, which is a baseline document/data model that brings together key reference information into one place for client and contractors use.

- ✓ **Asset Information Provision Procedure**, which is the overall process defined by Crossrail for the creation of assets in the eB/AIMS and the provision of relevant asset information by Crossrail staff, contractors and third parties.

- ✓ **Asset Painter** software being developed as part of an application software to support the application of Crossrail's asset tags to design elements and subsequently link the design elements to related asset information.

- ✓ **Asset Information & Configuration Management Team**, which is a client side Crossrail team that leads the establishment of quality, control and management of asset information and collaborates with site contractors to ensure the large volumes of asset information is provisioned to appropriate standards and requirements.

- ✓ **Contract Clauses**, which are adequate clauses within the contractors' contractual information to ensure compliance to the aforementioned enablers are achieved.

Asset Representation

Asset owning organizations typically like to record their assets in a hierarchy to assist finding and navigating to assets. Often, such hierarchies are based

Crossrail's approaches are informed by configuration management (CM) and asset management (AM) related standards

on the location of assets, or their duty or type, however, recording assets in a single hierarchy based on one of these approaches is usually too simplistic. The eB/AIMS provides Crossrail with the capability of recording assets in multiple hierarchies, consequently, each asset tag is included in three hierarchies representing location, function (or duty) and class (or type).

In addition to these relationships, assets in complex environments will be related to other assets. For example, electrical switchgear will provide power to multiple assets, however, such relationships are frequently difficult to represent correctly in many asset management systems. The eB/AIMS allows explicit relationships to be established between assets to ensure assets can be unambiguously linked to each other.

Collecting & Utilizing Asset Information

Quality Asset Information Provision

A Crossrail-specific asset data dictionary defining the classification of assets, their required attributes and relationship to each other is hosted in the eB/AIMS to provide wide visibility of asset requirements.

Attributes held against the asset data dictionary are intelligently exported into asset data collection spreadsheets (ADCS), with each individual asset class being represented separately in its own worksheet with its own attributes. Con-

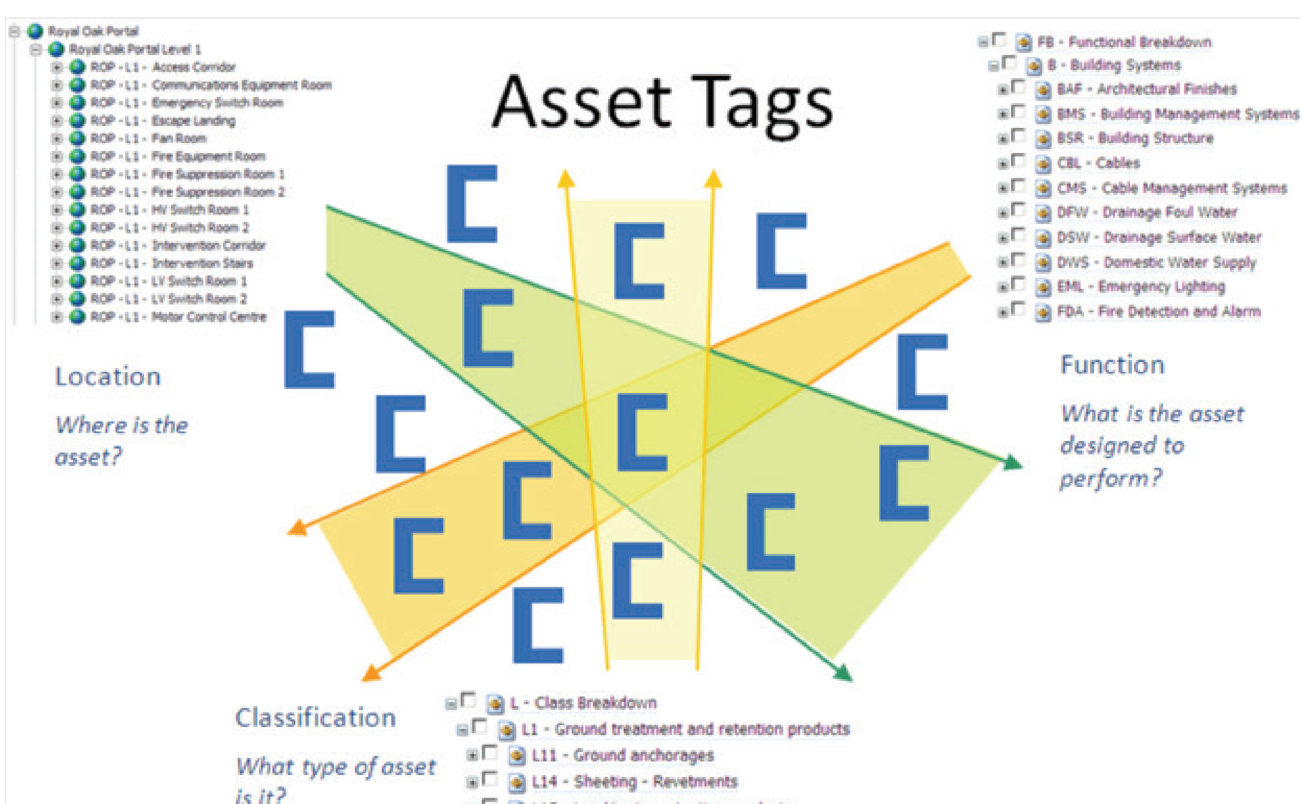


Figure 3: *Flexible assets*

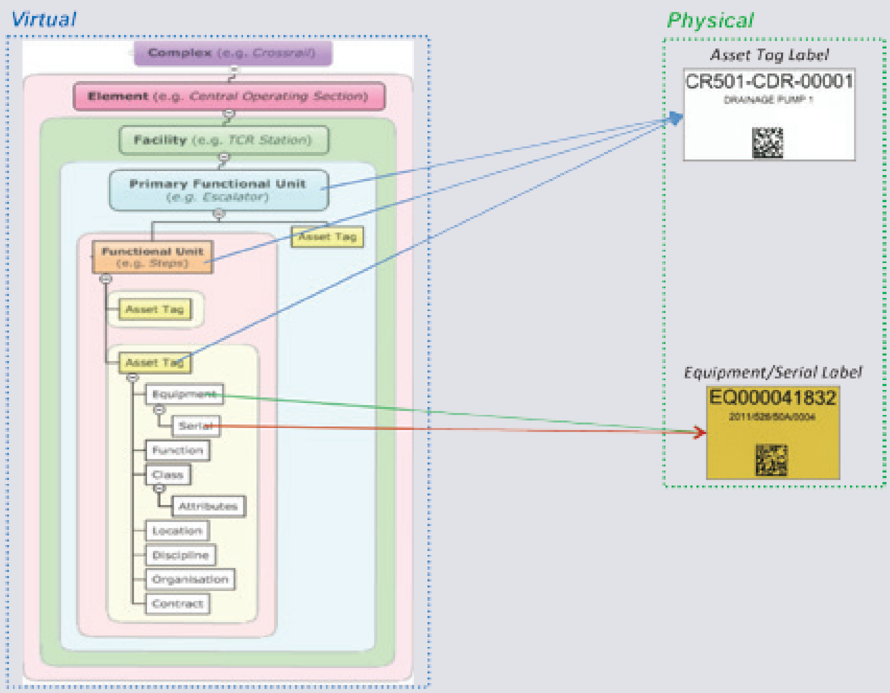


Figure 4: Crossrail's virtual and physical asset representations

The following terms help to represent a Crossrail asset.

Crossrail high-level asset representation:

- **Complex** (a group of elements, *e.g., Crossrail*).
- **Element** (a group of facilities, *e.g., Crossrail operating section*).
- **Facility** (a group of primary functional units, *e.g., a railway station consisting of discrete systems*).

Crossrail system/low-level asset representation:

- **Primary Functional Unit** (a system, *e.g., an escalator*).
- **Functional Unit** (a subsystem, *e.g., escalator steps*).
- **Asset Tags** (a functional requirement, *e.g., needing a pump*).
- **Equipment** (fulfills a need, *e.g., of the pump/asset tag*).
- **Serialized/Batch Items** (unique instances, *e.g., of pump/equipment or batch of cable*).

tractors then populate these attribute fields while referencing the AD4 definition documents. The eB/AIMS and the ADCS have already been utilized to issue 125,000 asset tags and collect the related attributes from the contractors.

Smart Initiatives

Crossrail made an early conscious decision to integrate the eventual operators and maintainers within the Crossrail project environment. This has made for a much improved relationship between the two parties and an excellent level of understanding of the operators' user requirements. Positive benefits of this relationship include the operator and maintainer working with the Crossrail team to introduce Crossrail good practice approaches to widely benefit other sectors of the operators' portfolio. The Crossrail asset information management plan has established reliable and safe foundations for ongoing operations. Even after handover, the Crossrail data hub will act as a reliable configuration to ensure consistent compliance to current standards and legal requirements, and provide the ability to draw on asset information, documentation, records and contractual administration.

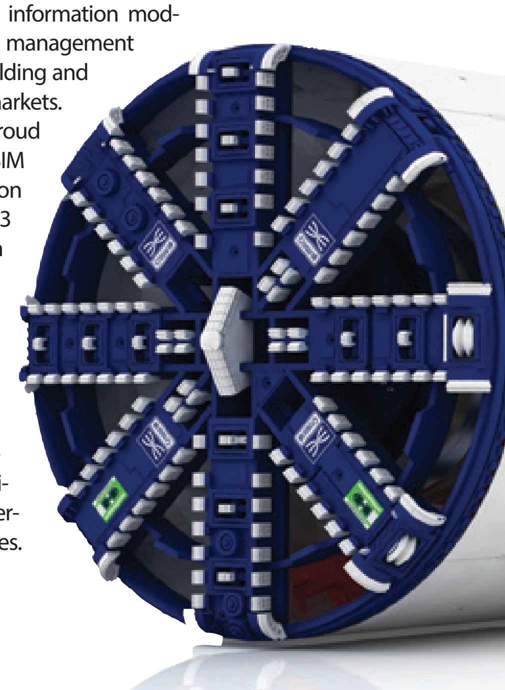
Stakeholder concerns that asset information may not support long-term asset management needs have been alleviated by defining appropriate governance arrangements through regular asset information governance group meetings with key internal and external stakeholders. Emerging issues are identified and resolved as early in the process as possible and provide assurance to key stakeholders that asset information will support handover of Crossrail to its future operators and maintainers.

Crossrail has formed a technical partnership with Bentley Systems and a Crossrail – Bentley Information Academy, which offers the many contractors and industry partners (600 to date) an opportunity to gain awareness of all the latest industry developments (e.g., the UK BIM government strategy) and learn the various Crossrail/Bentley informational and technological related processes through discrete information pods. The academy also acts as a focal point for general feedback, new ideas and information innovation.

Crossrail has a number of other initiatives in development that will help leverage the quality asset information that is being provisioned, including a field supervisor app, a document verification app, mobile GIS, and 4D modeling virtual planning and augmented reality.

Sharing Good Practices

Crossrail takes seriously its responsibility of sharing good practices with industry and realizes there are bi-directional benefits of pushing out and pulling in good information management practices. Crossrail has been involved with a number of initiatives, including the most notable UK government BIM strategy that sets objectives to look at construction and post-occupancy benefits of building information modeling (BIM) and management for use in UK building and infrastructure markets. Crossrail was proud to receive the BIM Project Application Award at the 2013 British Construction Industry Awards in recognition of its significant efforts in this area. Crossrail also works closely with a number of universities supporting a range of information management related initiatives, including configuration management, industry information management requirements, future proofing and virtual application development, plus industry supervision of students working on doctorates.



Crossrail chairs the Industry Partner Asset Information Forum, which brings together thought leaders from the rail sector to discuss initiatives through which all parties can gain mutual benefits.

Business Benefits

Crossrail asset information is pivotal to achieving Crossrail's vision of a smart railway that is safe for everyone, reliable for customers, efficient for business, predictable for operations and maintenance, and enables proud and motivated staff. Information is established and maintained through a central data hub for efficiency, effectiveness and consistency, reducing ambiguity and thereby reducing risk.

The development of eB/AIMS enables a number of key benefits to be utilized. For example, extending the usage of Crossrail's existing eB system to provide asset information management capability has avoided the need to purchase a separate and costly asset information system, thereby avoiding significant additional system implementation and integration costs.

> The Crossrail asset information management plan has established reliable and safe foundations for ongoing operations

eB/AIMS also reduces the risk that incomplete or poor quality asset information prevents handover of Crossrail to future operators and maintainers. Governance arrangements help ensure effective engagement with future infrastructure managers and reduce the risk of them not accepting the data at handover as a result of being otherwise unaware of its acquisition and provenance.

eB/AIMS provides a single, change controlled and widely available asset data dictionary to explicitly specify the classification of assets and their required attributes. This saves time when stakeholders need to understand information requirements and reduces the risk that out-of-date versions of a published asset data dictionary are inadvertently used.

The use of optimized managed processes to minimize the effort required to collect asset information and maximize the quality of this information is especially critical due to the large volume of assets (approximately one million) that will need to be recorded in eB/AIMS. Small improvements in the effort required to acquire information for an asset will have a significant benefit overall.

Site data acquisition is expensive and time consuming, and for users, it can be difficult to know what data is required. Crossrail's asset data collection spreadsheets present the data already in eB/AIMS and explicitly define the attributes to be populated. This supports standardization of information requirements and verification of existing data by site staff, and minimizes the volume of information site staff has to provide. Effective management of information from a very large number of information providers will be challenging, consequently, an optimized process has been developed for the provision of asset information.

By establishing and maintaining good quality asset information that is reliable, trusted and fully utilized by users, huge benefits can be realized, particularly during the operational and maintenance phases. Conservative independent studies have shown that good quality configured asset information can reduce an organization's whole life costs by at least five percent, or one to two years operating expenses (OPEX), based on a 20 to 40 average asset life.

Summary

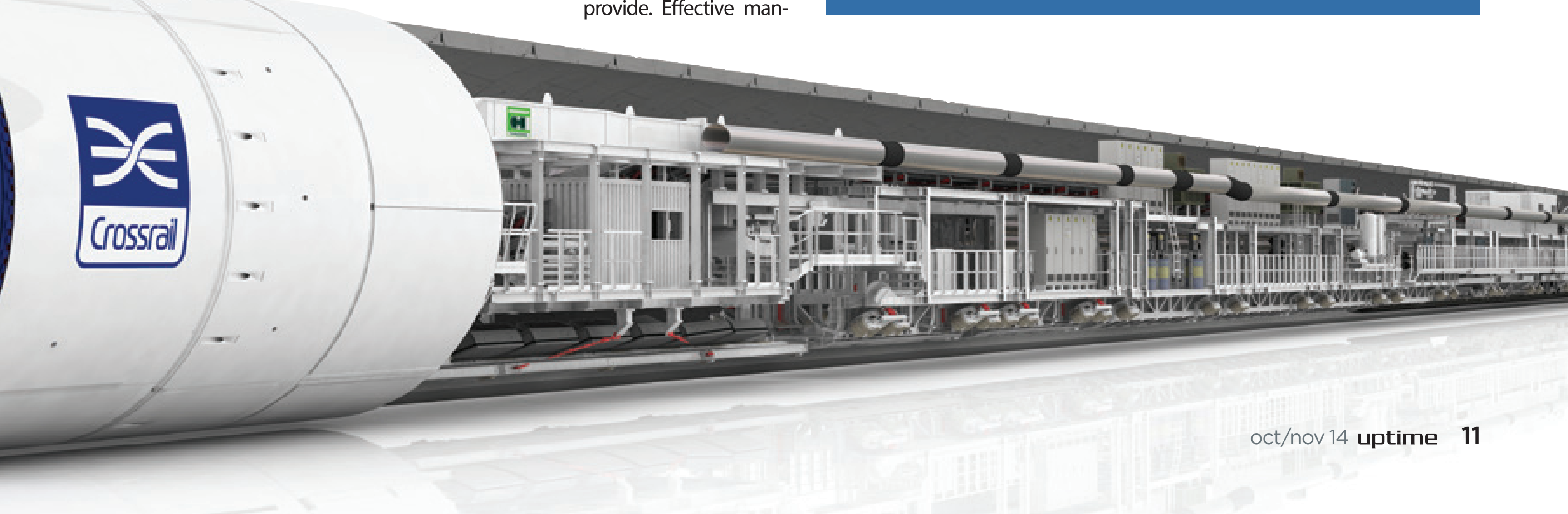
Being Europe's largest construction project, Crossrail takes seriously its responsibility to enable quality asset information to support the whole life of the asset. It has implemented a number of enablers to support the provision of quality asset information. Delivering this information needs to be conducted progressively and not at the last minute, which has typically been shown to provide asset information that is late, of poor quality and not fit for use by its owners, operators and maintainers.

Crossrail has, and continues to, work with industry to push and pull good practices in information management, recognizing that generic and more efficient approaches are required not only to support the physical assets, but also to control and manage the increasing volume of data that organizations and the general public use and demand.

Crossrail understands other external factors also need to be considered to fully realize and utilize the quality asset information it is provisioning. Control and management of people, processes, technology and information are key for organizations to fully optimize their potential.

Crossrail is taking its whole asset life responsibilities seriously and is well on track to enabling quality asset information to support the Crossrail smart railway.

***Ross Dentten,** Asset Information & Configuration Manager, is applying his 25 years of transport industry experience to take a lead on assets for the largest construction project in Europe, the £15 Billion Crossrail. He is enabling quality asset information to support one million physical assets while harnessing standards, information, technology, processes and people within the industry to optimize whole life value and to help with 'Moving London Forward'.*



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Averages Are Deceiving...

WHO Wants To Be 1. Excellent 2. Good 3. Average?

by Ron Moore

Averages are funny things. Someone once explained averages this way: Take one foot and put it in a bucket of scalding water; take the other foot and put it in a bucket of ice water. On average, you ought to be comfortable. With that caution in mind, let's consider three very different examples of the use, or perhaps misuse, of averages.

1

Example One. Mean time between failures (MTBF) is an often used term to characterize the average times between the failures in a given set of equipment. As demonstrated in the aforementioned example, it's also not particularly meaningful. For example, consider the data in Figure 1, in which 30 identical components were run to failure and then their life measured.

Looking at the data, the MTBF is calculated as 90. It is further evident that about half the equipment fails before getting to 90 and the other half fails after 90. So, how useful is knowing that the MTBF is 90? If the MTBF is increasing or decreasing, that might be useful since you would know whether things are getting better or worse. But it's not particularly useful, for example, in setting preventive maintenance (PM) intervals. If you were to set up a replacement PM for these components and used MTBF for the replacement interval, you would be sorely mistaken. About half the equipment would fail before being replaced and the other half would have life remaining, resulting in a premature replacement. Neither is a desirable outcome.

By reorganizing the data in order of shortest to longest life, the result is the Figure 2 graph.

Is this reorganization of the data useful? It's the same data, but now it shows that a failure occurs every five to 10 days, more or less. Would that be useful? Probably, since plans can be made for the parts needed and for when a certain percent of the equipment would be down and not available for production. How will you know which one of these components will fail next? After reflecting on this, you would likely conclude that you should do condition monitoring to detect which of the components has defects that would cause it to fail next. What sort of condition monitoring? That would depend on the failure modes associated with the equipment. How often? Well, something less than five to 10 days, so there is enough time to manage the consequence of the impending failure and to plan and schedule the work to mitigate the failure.

After a time, you would also try to be proactive and eliminate the defects that are causing the failure in the first place. At this point the MTBF would in-

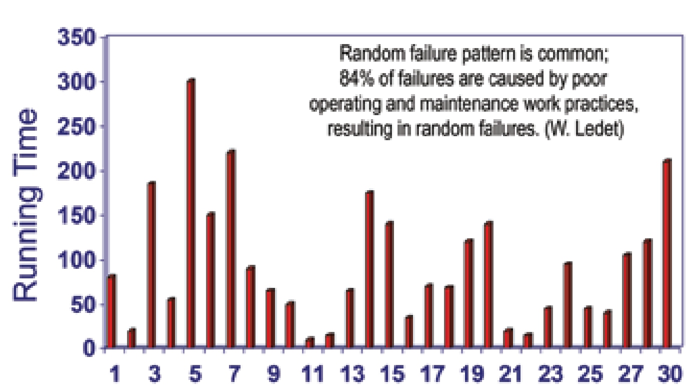


Figure 1: Component histogram

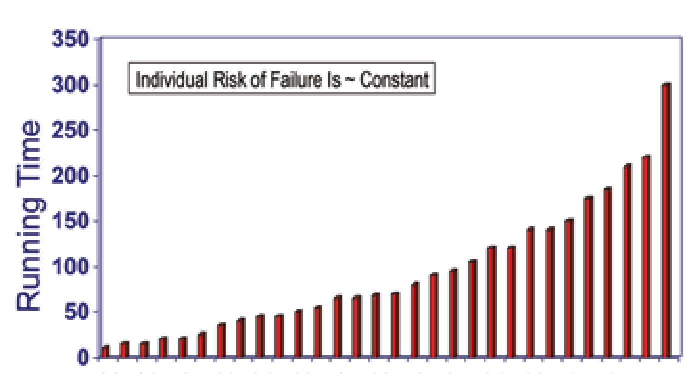


Figure 2: Component histogram redrawn

crease, but you would likely still have a random failure pattern. Some 80 to 90 percent of equipment failures are in a random pattern. Incidentally, according to Peter Todd, a Predictive Maintenance Expert with SIRF-Roundtables in Australia, Figures 1 and 2 represent an exponential failure rate and imply a constant conditional probability of failure. That is, the probability of survival, and of failure, of any given component is the same with a random failure pattern. According to reliability consultant Paul Barringer, this means there is a constant, instantaneous failure rate where the die-off rate is the same for any surviving or unfailing member of the population. That is, an old part is as good as a new part when you have a constant, conditional probability of failure. The way to manage a random failure pattern with a constant, conditional probability of failure is to use condition monitoring. MTBF, or average data, doesn't have much meaning in this situation, other than to let you know if things are getting better or worse.

Example Two. In operational excellence workshops, participants are asked to do self-assessments of their practices. These self-assessments are on relevant issues, like operating practices, maintenance practices, and organizational culture, leadership and alignment. Each assessment has 10 questions and each question has a scoring range of zero to 10. So, each self-assessment has a maximum score of 100. Participants use their individual experience and judgment to give a subjective score of their practices in each self-assessment. Over many years in conducting these self-assessments, average scores for a group of 20 people in a workshop have consistently been near 55, more or less. Is this useful? Not particularly. If your group scored in this range, you would tend to think you're average. However, the interesting part comes about when the score for a given group is lower, for example, 45. Are they slightly below average? Experience shows they are not. Indeed, they are typically well below average. On the other end of the spectrum, suppose a group scores 65. Are they above average, or about 50 percent above the group that scored below average? Experience shows they are, in fact, above average, but also far better than the group that scored a 45 and often more than twice as good when compared to a more comprehensive review of the details of their practices. That is, the group scoring 65 is more than twice as good in their practices as the group scoring 45. While about 75 percent of those surveyed score near 55, about 10 percent score near 65, another 10 percent score near 45 and a few percent score near 35 or 75. Incidentally, the difference between 35 and 25 is nil. These companies are just awful. In addition, the difference between a 75 and an 85 is also nil. These companies are really good, few though they are.

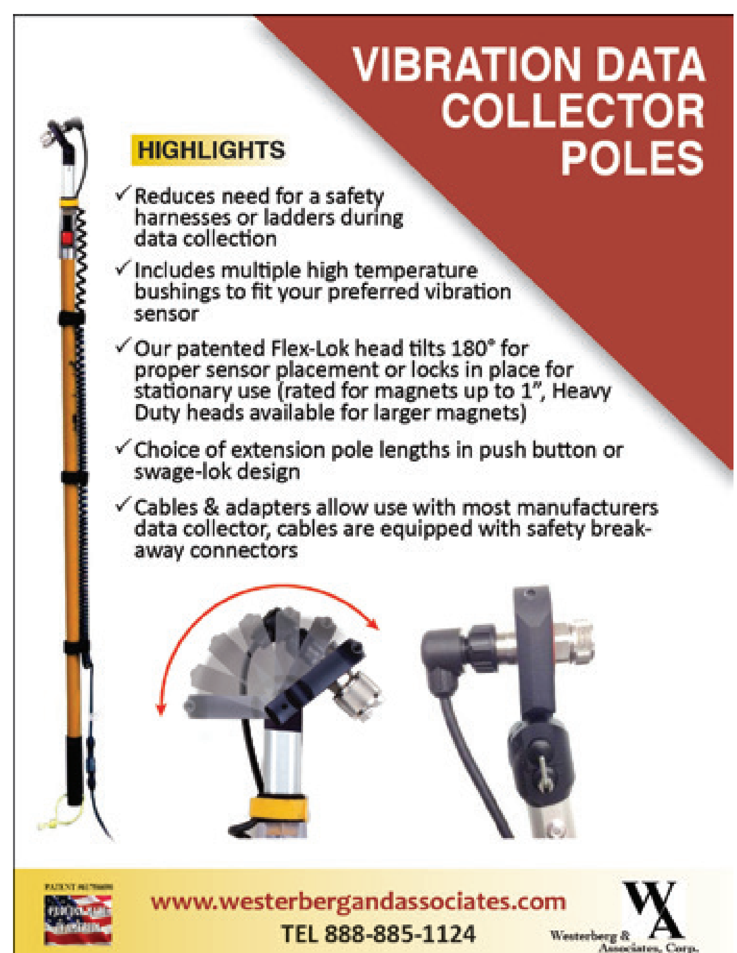
So, what's happening? First of all, it's a subjective assessment based on the experience and values of the individuals that is then averaged. The range of individual scores for a group average of 55 on a given assessment might be 35 to 75, or more, depending on the individual's experience and valuation. The net effect of this is that the average scores tend to compress toward the center of the assessment questions at 55. Interestingly, individuals in those operations that are really poor tend to say to themselves, "Well, we're doing a little bit of this practice, so I think I'll give it a four." They are measuring from zero and giving themselves credit for doing something, but they know they're not doing it well. On the other hand, individuals in those operations that are really quite good see all the things they are ***not*** doing and discount from a 10 to get their score. Individuals in the two operations have a different frame of reference. The better the operation, the more opportunity they see to get even better. The worse the operation, the more they want to demonstrate that they're doing something. Hence, the scores compress toward the center, or average, and mediocrity reigns. This is not a good thing. Averages are not useful in this situation if you expect to survive and prosper in your business. More importantly, measurements should be against ideal, or perfection, in order to *identify all the opportunities that are available to improve the business* and then make business decisions relative to the next opportunity.

Example Three. The executive level of two companies conducted employee surveys, dryly called the "Are You Happy?" surveys. The questions typically were related to employee satisfaction regarding a number of issues, such as pay, opportunities, benefits, etc. One common question was something to the effect of, "As an employee, would you rate yourself against your peers as being below average, average, or above average?" A large majority, about 80 percent, rated themselves as above average compared to their peers.

While this is a statistical impossibility, it is telling. A large majority of people do not consider themselves average in their work performance and yet, referring to Example Two, at the same time they consider their company to be average. If they're individually above average, why isn't the company above average?

The answer is simple. The systems in place within the companies are mediocre. Mediocrity has become their standard for excellence. It's the people who are excellent. If each person believes he or she is above average, then the systems should challenge them and facilitate excellence in their performance, thus fostering company excellence. As Hajime Ohba, a Toyota guru in manufacturing, said, "We get brilliant results from average people managing brilliant processes. Our competitors get average results from brilliant people managing broken processes." It's not the people that are mediocre, it's the company's processes. Change your processes to get better results. And measure your company against perfection, not averages.

__Ron Moore__ is the Managing Partner of The RM Group, Inc., and author of __Making Common Sense Common Practice - Models for Operational Excellence__, 4th edition; __What Tool? When? – A Management Guide for Selecting the Right Improvement Tools__, 2nd edition; __Business Fables & Foibles__; and __Our Transplant Journey: A Caregiver's Story__, as well as over 50 journal articles. Ron's latest book, __Where Do We Start Our Improvement Program,__ is scheduled to be released Fall 2014 from MRO-Zone. www.mro-zone.com



Why Systems Fail After Going Live

by John Reeve

The short reason is because complex systems can have more requirements which, in turn, increase the number of failure points. And each requirement can have multiple prerequisites. An asset management system has three main areas needing ongoing attention: software/data, process/procedure and roles/responsibility. Advanced processes have the most prerequisites. Weakness in any one area or supporting variable can cause system failure.

Were goals aligned?

System Failure Defined

From a maturity scale perspective, an asset management system failure could mean your system is simply below average. Symptoms within this category include poor data quality, lack of buy-in, inadequate user training, and/or minimal value-added reports. It could even mean your key performance indicators are poorly designed. In the case of absolute failure, a *tipping point* has been reached by the user community in that they no longer consider the system to be of any value. If a senior manager ever made comments like, "I don't see the value in this system. I can't get the reports I want. It costs too much," that should be a clue.

Let's Go Back in Time

With every implementation, there is an initial level of excitement. The leadership team has paid for the software and is now hoping to cash in on those benefits. Management is hoping to leverage data to make more informed decisions. The IT administration wants the newer technology to help them configure the system, load data and simplify integrations. Power users (e.g., planner/schedulers, maintenance supervisors) want to utilize the product to enhance workforce efficiency, generate ad hoc reports and automate key functions. And the working level simply wants to do their job and document failure history. They all want to do more with less effort. Bottom line: The system shouldn't make their job harder unless there is a benefit.

Was a long-range plan created after go live?

Decisions Are Needed

But will the decisions be the right ones? When setting up an asset management system, it is *easier to make a wrong decision than a right one*. Complex systems need expertise during the setup phase. You can ask the core team for requirements, goals and capabilities, but they might not always know what they want. They probably purchased a best of breed product because they sort of hoped it would give them flexibility once they determined what they really need to do. While it is true that you can easily configure the system, even after go live, some decisions are difficult to undo. Expertise is often needed to help a project team define the endgame, design analytical reports and develop a series of actions to get there.

Let's Talk About Failure History

As previously stated, the maintenance technician wants to record failure history on the work order. This is done for the benefit of the technician, so when the asset breaks again, he or she can quickly refer to prior events. It is good for the technician to record this text-based information (e.g., actions performed, problems discovered and failed component), but this is not <u>actionable data</u>. For those staff members who want to glean information from the asset management system in terms of recurring problems and worst offenders, they need to be able to execute structured query language (SQL) commands. Actionable data is validated data that enables analytical reports to quickly drill down and manage by exception. So depending on the person you talk to, there are two definitions of failure history, one that describes text-based information and one based on actionable data.

Was a core team involved?

You Have a Short Window

Some say the working level decides within the first five minutes of being trained whether the system will be of any value to them. And once the system is live, the grumbling may start. If these issues are not heard, discussed and resolved by the core team, frustration can set in. In addition, if procedures for updating are not adhered to, the database can quickly become invalid. Lastly, if management is told the analytical reports can't be produced, the software might be perceived as problematic or weak.

CMMS Expert and Business Analyst Roles

A computerized maintenance management system (CMMS) expert is extensively familiar with work order management (e.g., work prioritization, work type categorization, backlog management and planning/scheduling), asset reliability (e.g., failure coding, failure analysis; failure mode, effects, and criticality analysis; and setting up a preventive maintenance/predictive maintenance program) and supply chain management. A CMMS expert is able to discuss all the above, regardless of software brand, and can discuss the industry in detail.

A business analyst schedules regular visits with the working level to ascertain problems, issues, complaints, needs and suggestions. The analyst may observe them using the system and will ask about report needs. A business analyst also identifies training issues or system network speed issues and may also perform short topic training. During the visit, the analyst may look for data stored outside the enterprise asset management (EAM) system, such as reports on a wall, spreadsheet applications, or paper files in cabinets. In general, the business analyst looks for early warnings of problems and issues.

Either of the above roles might be tasked with designing the analytical reports and building training materials. Plus, they may become involved with periodic benchmarking activities. Often, these two positions are recognized as positions of value within mature organizations.

Management Versus the Core Team

It's too easy to blame upper management for everything. In this regard, the core team should accept full responsibility of the asset management system. Management should authorize the software selection, provide budget dollars and approve decisions to integrate systems. But, the core team should be heavily involved in implementation and operation, including the CMMS's five-year plan. Periodic involvement by a steering team advocate may be needed to occasionally break through roadblocks. The core team needs a system to track enhancement requests, document CMMS changes, monitor change management issues via the business analyst and track training needs.

Based on the assessment of your system, the data you've diligently entered for the last 15 years is of no value

Good News: The next upgrade will only cost us the consulting time to load the new version, configure the screens and perform the training.

Bad News: We won't have any historical data.

Typical Chronology

Figure 1 shows a series of events and problems that pop up after the implementation team disbands. Inside the dotted line are positions and roles that are often overlooked. Not every organization is able to pursue these roles, but remember, the subject of this article is, "Why Systems Fail After Going Live."

Staff Turnover and Tribal Knowledge

Every organization has employee turnover. This turnover could be within the maintenance trades, supervisors, or even the asset management stakeholders. Either way, this is a never-ending battle. In order to sustain excellence and optimize CMMS utilization, emphasis needs to be placed on creating a true knowledge base to store repair procedures (job plans), spare part lists, vendor contacts and failure history. Other more advanced techniques include repair/replace criteria, work order feedback, asset condition grading (as-left) and failed component identification, in addition to problem codes.

Analyzing Past Mistakes

Are you implementing software or an asset management system? Implementation teams frequently gravitate to software because the workshops may be weak when it comes to defining asset management concepts, purpose and definitions. Project teams may spend days discussing problem code hierarchies, *but fail to identify the analytical report or who this report will be given to.* Additionally, opportunities for improvement could be missed during the requirements phase.

One Should Not Assume Continuous Improvement Will Happen

Once the implementation team disbands and the consultants leave, there can be an enormous weight placed on the remaining staff. Perhaps foundation data is still missing (i.e., a job plan library). Or worse yet, maybe the reliability team is still studying the failure modes to determine ideal maintenance strategy (e.g., preventive maintenance, predictive maintenance, etc.). Maybe the procedures, such as completing a work order, are not finalized.

It is in these early months post go live that it is often discovered that the trades need more training. Perhaps they weren't quite clear after the four-hour training class. For some, it takes longer to catch on, but once they do, they become more involved, including asking for changes.

It should be noted that it may take a full year before an organization has settled into a comfortable routine.

How Do You Stop Bad Data

The core team should anticipate bad data at go live. It can and will happen. Therein, a prevention plan might be crafted to say:

1. Utilize validated fields. Activate mandatory features where applicable.
2. Identify a gatekeeper role to facilitate standardized reviews of incoming work.
3. Be sure the business rules are clear. Ask who is responsible for the accuracy of the work order record at job completion. Create a responsibility-accountability chart linking roles to asset management updates.
4. Identify pain points by the working level. Is it a training issue, data, or a system design change? Work closely with the maintenance organization. Understand its needs and concerns in terms of asset management interaction.
5. Conduct blended training that shows software and explains why this data is needed. This may be in the form of refresher training.

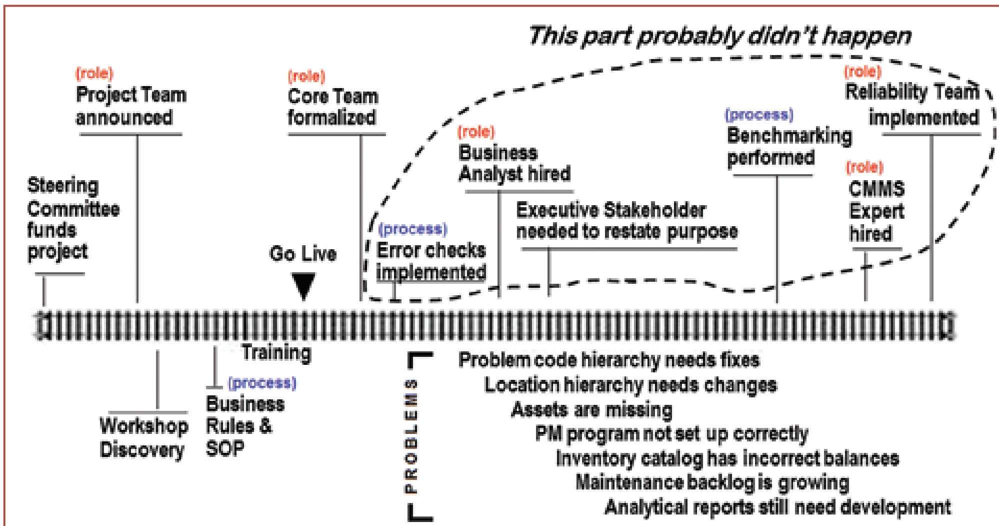


Figure 1: Example of train tracks events after go live

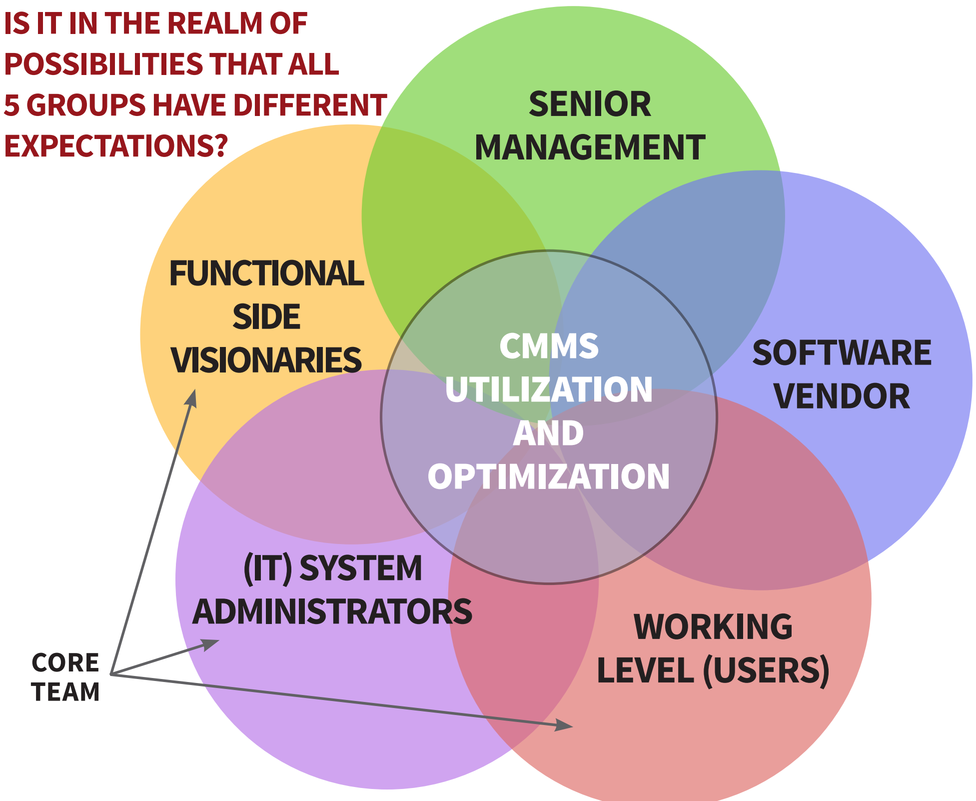


Figure 2: Asset management system's core team

6. Set up error checks to proactively look for bad data. Even validated fields can have bad data.
7. Perform periodic process audits using a business analyst.
8. Conduct regular reviews of the maintenance backlog. Look for stale or duplicate work.
9. The core team should process change requests and issue tracking numbers to the requester in the form of a punch list.
10. Bad data could also mean missing data. Failure data as entry fields may be missing on the screen.

Different Groups Have Different Needs

Asset management systems do not run by themselves. The core team should be responsible for optimizing system value and meeting the needs of each stakeholder. The IT organization manages all software applications and integration therein. IT, however, should not be responsible for the data content or the surrounding processes.

Senior management should be extracting data using analytical reports to make better decisions. In support of continuous improvement, they should also develop and maintain a five-year plan. Without a road map in place, poor decisions could be made.

Stakeholders on the functional side, including the business analyst and CMMS expert, are responsible for understanding the current process and developing advanced processes. Without advanced processes in place, it is difficult to achieve a real return on investment (ROI).

Importance of a Core Team

The lack of a core team is usually the Number 1 indicator of a system in trouble. If an organization does not have a formal core team, then who will ensure fair representation of all the user groups? Who will fairly prioritize change requests? Who will document these changes? If you don't have a core team and are relying only on one person to manage the system, then you are putting the database at risk. Very seldom does a core team have a fully implemented vision at go live, but it is still the team's responsibility to keep that vision in view. The core team provides the glue that brings all the functions together.

You Don't Know What You Don't Know

The best advice for any organization implementing an asset management system is to closely monitor the data as it comes in for the first 12 months post go live. This strategy can help improve your knowledge of the system and users' needs. The second tip is to perform aggressive benchmarking. For example: What are other organizations doing for work scheduling? What techniques do they use to reduce reactive maintenance? How do they generate analytical reports? How do they track maintenance costs? How do you acquire best practice knowledge? Benchmarking can be done in several ways:

1. Self-study, using books, magazines and online forums;
2. Visiting other sites;
3. Talking to other users, such as at user group conventions;
4. Consultant services.

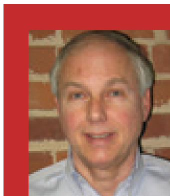
Don't Let This Happen to You

If senior leadership continually asks about meaningful reports, there could be a problem. If maintenance trades only see the asset management system as a time entry tool, there is a problem. If the backlog is mostly unplanned, poorly prioritized, or contains inaccurate statuses, there is a problem. Once the database becomes inaccurate, it becomes overwhelmingly impossible to recover. Thus, do you fix the data or the processes first? This is obviously a bad predicament to be in and most assuredly will reduce confidence in the system. And when the data goes bad, one of two things will happen:

1. Leadership will say the product is not working and may suggest switching software.
2. Leadership will request upgrade services and then tell the upgrade team not to bother migrating data.

Summary

So now that you know why systems fail, don't let it happen to you. Ten to 15 years of entering work orders shouldn't be for naught. Similar to managing assets, anticipate problems and analyze what happened. Discover the real fault. A failure point could happen at any level in the organization, or any step in the process. And, there could be multiple points of failure. But with a strong asset management system, you can prevent, or at least be prepared, for when "stuff happens."



***John Reeve** has over 25 years of diverse industry experience with expertise in work, asset and reliability management system design. John demonstrates knowledge in business process reviews, influencing culture, 5-year plan creation and maintenance playbook development. He is a frequent speaker at user forums and author for industry trade magazines. John has a United States Patent 7421372 for maintenance scheduling involving unique "order of fire" routine in support of resource-leveling.*

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Torsional Fatigue Failures

Identification, Diagnosis and Prevention

Figure 1: Torsional fatigue fracture of a pump shaft with fracture face 45 degrees to the shaft

by Thomas Brown

Torsion fatigue failures occur more frequently than we realize. As a teacher of failure mode identification, it is common to have one or more individuals in every class bring an unusual failure to class that, upon examination, is torsional fatigue. Depending on the particular industry, torsional fatigue is involved in 10 to 25 percent of rotating equipment failures.

Identifying Torsional Failures

Identification of torsion fatigue failures is straightforward. Just look for the fracture oriented 45 degrees to the shaft centerline, like the example in Figure 1. The fracture face typically has one or more origins, a fatigue zone with progression lines and an instantaneous zone.

A large fatigue zone and small instantaneous zone mean the fatigue load was small. A small fatigue zone and large instantaneous zone mean the fatigue load was high. More information about fatigue failure characteristics can be found in the "Preventing Mechanical Failures – An Introduction to Failure Mode Identification" article in the February / March 2012 issue of *Uptime*.

Torsional fatigue fractures frequently occur in a shaft that is inside a hub or coupling. These fractures usually start at the bottom of a keyway and progress around the shaft's circumference. In Figure 2, the fracture travels around the shaft, climbing toward the surface so the outer part of the shaft looks like it was peeled away. The fracture surface has characteristics of a fatigue fracture: one or more origins, ratchet marks and a fatigue zone with progression lines. The shaft fragment is usually held in place by the coupling or hub, so there is typically a very small or no instantaneous zone.

A less common torsional fatigue failure is caused by reversing loads. When the load changes direction, two fractures occur at 45 degrees to the shaft centerline. Figure 3 shows a shaft with a reversed torsional fatigue fracture starting at the keyway.

Reversed torsional fatigue fractures may have a starburst pattern. Each of the splines in Figure 4 has two cracks, each at a 45 degree angle. These usually occur on splined shafts that rotate in both directions.

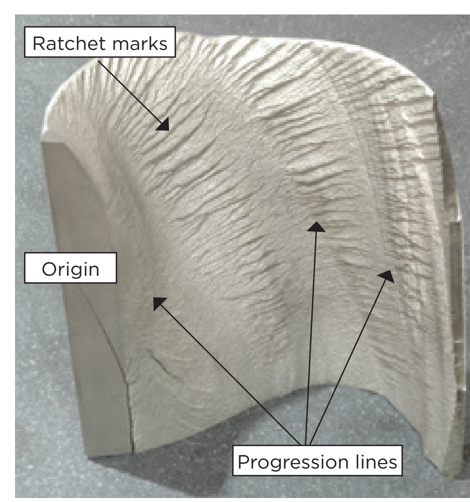

Figure 2: Torsional fatigue fracture of a shaft inside a hub that started at the keyway on the left-hand side and progressed around the shaft

If there are two 45 degree fracture planes in a shaft whose load does not change direction, it is an indicator of torsional vibration.

A shaft fracture may have both torsion and bending fatigue forces applied to it. When this occurs, the orientation of the fracture face may vary from 45 degrees to 90 degrees with respect to the shaft centerline. The shaft shown in Figure 5 combines dominant bending with torsion, so the fracture is closer to 90 degrees.

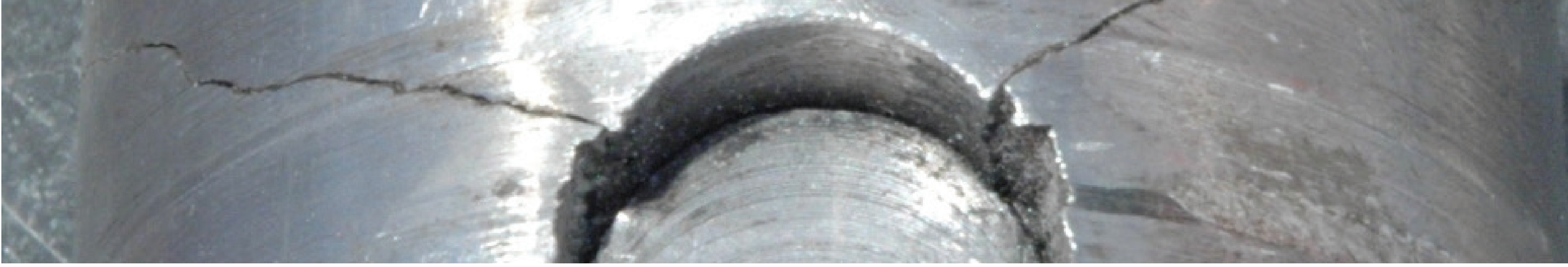

Figure 3: Reversed torsional fatigue, where two 45 degree cracks started at the keyway

Figure 4: Reversed torsional fatigue failure of a splined shaft; each spline has two cracks, each at 45 degrees to the shaft

The fracture angle offers key evidence. If the angle of a fatigue failure is:

- Closer to 90 degrees, it is a dominant bending force.
- Midway between 45 degrees and 90 degrees, it is a combination of torsion and bending forces.
- Closer to 45 degrees, it is a dominant torsion force.

Evidence of torsional fatigue also may be found on gear and coupling teeth. Most equipment runs in one direction, so wear is expected on one side of a gear or coupling teeth. Wear on both sides of a gear or coupling teeth that rotate in one direction is an indication of varying torsional force. When coupling alignment is good and wear occurs uniformly on both sides of all coupling teeth, it usually indicates torsional vibration. Alignment quality can be verified from vibration spectra and phase readings. An absence of 2X running speed spectral peaks and uniform phase across the coupling occurs when the alignment is good.

Torsional Measurement and Analysis

When torque applied to a machine by an electric motor is constant, a torsional fatigue failure that requires a varying torque can occur. Changes in torque may happen in one of three ways:

- **Machine characteristics** – Repetitive events, such as gear mesh, vane pass, cutting tools, electric motor faults, fluid pulsation, lateral and torsional interaction, or any repetitive event that momentarily changes the shaft torque.
- **Reversing loads** – Occur when the direction of rotation changes.
- **Torsional resonance** – Occurs when the frequency of an exciting torque and a polar natural frequency are the same; the response is twisting of the shaft around its longitudinal axis (further explanation can be found in Chapter 38 of Reference 1).

To eliminate a torsional fatigue failure, one must be able to measure the shaft torque variation and torsional vibration. Several types of wireless systems are available for measuring torque variation and torsional vibration. Two common measurement transducers are a strain gage and wireless transmitter, and a ring containing accelerometers and a wireless transmitter. Strain gage systems can be used to measure bending, applied torque and torsional vibration. However, strain gages are small and must be carefully adhered to the shaft for good results. Rings containing accelerometers are easier to attach, but may require a bushing for different shaft sizes. They measure torsional vibration, but not shaft torque, and have a higher frequency range.

The output of a strain gage torsional vibration system can be coupled to a data collector or signal analyzer capable of accepting a 0-10 volt signal. There are two components in the output signal, absolute torque and torsional vibration.

Absolute torque is measured using DC coupling at the signal analyzer or data collector. The time waveform in Figure 6 shows the absolute torque variation using DC coupling. Torque in this shaft varied from zero to just over 7,000 ft-lbs.

The second component of the signal is torsional vibration. AC coupling allows the torsional vibration portion of the signal to be analyzed. When the output of the torsional vibration system is AC coupled, the signal analyzer or data collector can calculate a frequency spectrum.

The spectrum in Figure 7 shows torsional vibration peaks occurring at 8 Hz and 105 Hz from an AC coupled signal. The source of these spectral peaks can be determined from machine characteristics or a torsional model.

Evidence of torsional fatigue failures or measurements indicating torsional natural frequencies warrant further analysis using a torsional model. A Holzer or an eigenvector/eigenvalue matrix model will calculate the undamped natural frequencies and torsional mode shapes.

Figure 5: Fatigue failure caused by bending and fatigue that started at a keyway; the fracture angle is between 45 and 90 degrees and progression lines are visible

Preventing Torsional Fatigue Failures

Torsional fatigue failure prevention can be grouped into three categories:

1. Correct machining, assembly and installation to eliminate:

- Incorrect fit/finish of a shaft and bore.
- Small radius in a keyseat.
- Excess clearance between the key and keyseat.
- Misalignment.

These are the easiest to fix. Frequently, the effort stops here and the failures continue. However, with more investigation, torsional fatigue failures can be eliminated.

2. Identify torque characteristics of the system:

- **Machine characteristics**–Repetitive events, such as gear mesh, vane pass, cutting tools, electric motor faults, fluid pulsation, lateral and torsional interaction, or any repetitive event that momentarily changes the absolute torque.
- **Reversing loads** – Direction of rotation changes.

Torque measurements, both absolute and vibration, can be used to identify these sources of torsional vibration. Torsional failures can be stopped once machining and assembly are correct; the variations are identified; stress analysis is done to verify components have sufficient fatigue strength; and, if required, components are strengthened.

3. Identifying and correcting torsional resonance by requiring:

- Construction of a torsional model using Holzer or matrix methods.
- Validating the model with torsional measurements.
- Changing the mass or stiffness of the system to shift one or more natural frequencies, or changing the forcing frequency of a component.

Everyone in equipment reliability knows that things interact. When this happens, changes must be made in all three categories to eliminate future torsional fatigue failures.

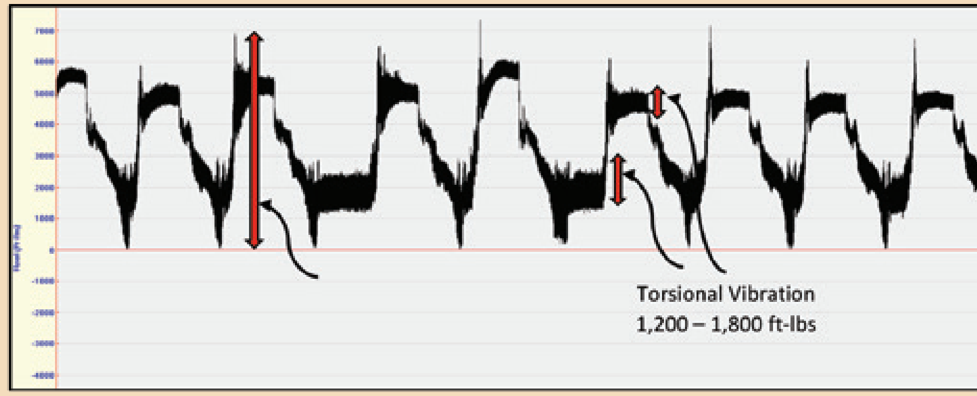

Figure 6: Time waveform of shaft torque from 0 to over 7,000 ft-lbs during 7 hours

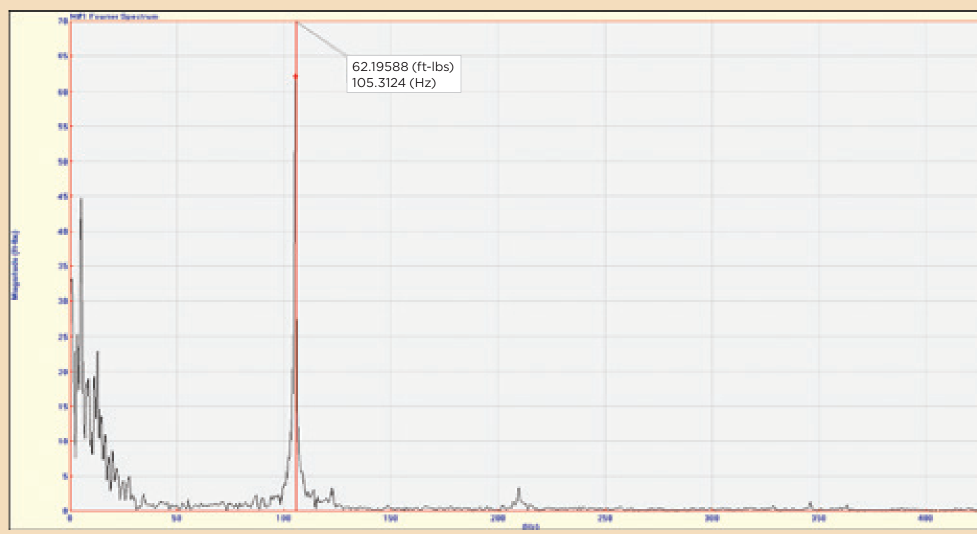

Figure 7: Spectrum of torsional vibration

The Holzer method was developed in the early 1900s and is readily adaptable to a spreadsheet. Matrix methods are more versatile, but require specialized proprietary or matrix software to solve the matrices. Both will produce good results that can be verified with AC coupled spectrum analysis.

Modeling a torsional system requires care to ensure accuracy. A consistent set of units must be used throughout the analysis, especially where several sets of vendor prints or data are used. Details and procedures for the Holzer and matrix modeling methods can be found in the references listed at the end of this article.

Fits and Finishes

When a torsional failure occurs in a shaft inside a coupling or hub, the fit between the shaft and bore should be verified. The clearance between the side of the key and keyway is sufficient for microscopic movement if there is not enough interference fit. Even then, low levels of torsional vibration will cause movement. The shaft and bore wear and fret, causing premature repair or failure.

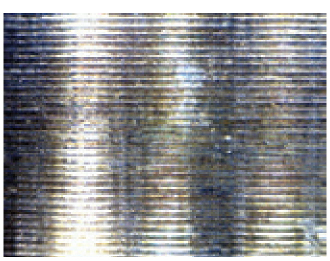

Figure 8: Rough finish of a shaft at 60X

The shaft and bore finish also has significant influence on the ability of the shaft and hub or coupling to tolerate torsional vibration. If the finish is rough or ridged like the surface of the shaft in Figure 8, the frictional area is reduced, leaving the shaft and bore susceptible to premature wear and fretting.

One frequent contributor to torsional fatigue failure is a small radius in the keyseat. If the radius does not meet the ANSI B17.1-1967 (R2013) standard for keys and keyseats, it should be corrected by remachining the keyseat using a cutter with the correct radius. When this is done, an oversized key is typically required, especially when the original keyseat and key had a slide or interference fit.

The ANSI standard also defines several classes of keys and keyseat fits. When torsional vibration is occurring and an ANSI Class 1 fit is used for the key and keyseat, it may help to increase the fit to a Class 2 or 3. However, more care will be required during assembly.

The interference fit between the shaft and bore should be sufficient to transmit the torsional vibration forces in a shaft using keyseats and keys. Even if dimensions and resultant fits are within a particular standard, never assume friction is sufficient to prevent micromotion between the bore and shaft.

If torsional vibration data is available, the minimum required amount of fit may be calculated using equations that can be found in most machine design books.

Conclusion

Torsional resonance and failures are more common than recognized. They can be eliminated by:

- Careful machining and assembly.
- Measurement and correction of torsional variations.
- Changing the natural frequency(ies) of the system.

Analysis of a torsional failure may seem daunting at first, but it is always easier and less expensive than fixing repeat failures.

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***Thomas Brown**, P.E., is the principal engineer of Reliability Solutions, headquartered in Duluth, Minnesota. Tom is an educator and practitioner of failure analysis, FMEA and equipment reliability skills across a broad spectrum of industries. www.reliabilitysolutions.us*

CASE STUDY

The input gear in a gearbox had experienced repeated torsional fatigue failures. The failures became worse when the input shaft coupling was replaced with a different type coupling. Torsional vibration measurements with a strain gauge and a Holzer analysis identified a torsional natural frequency at the motor speed. The change in angular deflection was greatest near the input gear.

Several coupling designs were evaluated using Holzer modeling to determine which one would move the natural frequency away from the motor speed and reduce the angular deflection at the input gear. A coupling was selected that shifted the natural frequency and reduced the angular deflection at the input gear. Results of the torsional mode shape at motor running speed before and after the change are shown in Figure 9. The natural frequency changed about 10 percent and the angular deflection at the input gear was reduced 60 percent. Note that both plots vary from 0–1 (normalized), but maximum value of angular deflection after the coupling change was reduced 80 percent.

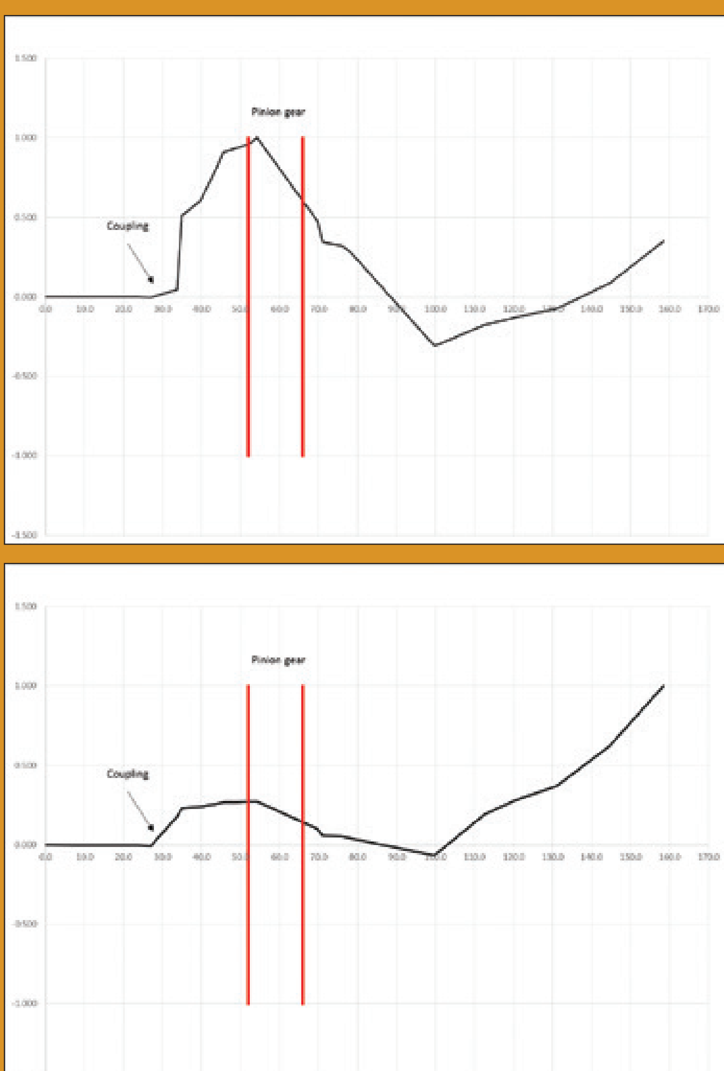

Figure 9: Before and after results of coupling change

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Why Total Effective Equipment Performance

by Doug Plucknette

Understanding where to apply reliability measures is a foundational element of reliability engineering. If you want to improve a process, you need to understand the present level of reliability, where the losses or deficiencies are located and what you can do to reduce or eliminate these losses. One of the biggest problems regarding reliability measures is there are so many of them, so much so that they have begun to overlap, adding further confusion to those who are in the process of learning and applying the measures.

As an example, when the term MTTR is used, does it refer to mean time to restore, replace, repair, or respond? Each of the four Rs means something completely different, so if you are asking someone to measure MTTR, you should specify which R you are interested in.

While organizations should be performing a failure modes driven reliability strategy on critical assets, they also should be measuring overall equipment effectiveness (OEE) and total effective equipment performance (TEEP) as part of their upfront tasks prior to starting an analysis to get a baseline for the reliability of the asset prior to reliability centered maintenance (RCM) task implementation. But as soon as the term OEE is mentioned, there is often pushback, with comments ranging from, "We started measuring that, but were never happy with the number" to "We argued so much over what belonged in OEE that we could never settle on a good measure." Perhaps the most common excuse is, "I don't think we are ready for OEE/TEEP; our organization is just starting out with our reliability journey."

Really now, you believe you are ready to perform and implement an RCM analysis, but you are not ready to measure the reliability of your critical assets? Interesting, really. Many reliability engineers find the measures to be extremely helpful in understanding where equipment losses are located and which reliability tool might work best to reduce or eliminate the losses. But it turns out the problem most people have with OEE is that they don't measure TEEP as well.

Confused?

Think about it this way: How many ways have you seen people measure OEE? Let's start with total productive maintenance (TPM) founder Seiichi Nakajima's definition: Availability x Performance x Quality = OEE. The three factors making up the calculation seem quite clear, but the problem people begin having is understanding what the following parts of the equation mean?

- Is the equipment available?
- How did it perform?
- Did we maintain product quality?

Availability is quite simple. The equipment is available to run 168 hours each week. In that same time frame, how many hours was it actually capable of running? This is where the confusion begins. What is the difference between available and capable?

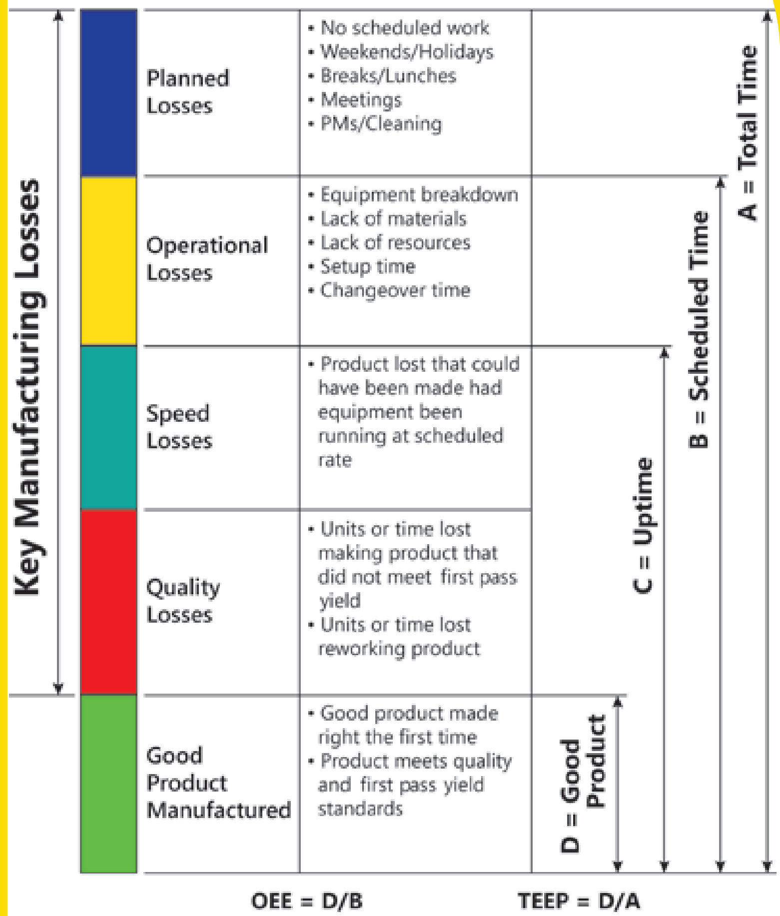
Here's a clarification: In your schedule to make product each week, how often did you need the machine to run and did it, in fact, run when you needed it to? Now that you have the equipment running, how did it perform and did it make good quality product while it was running?

Confused? You should be. The problem with measuring OEE on its own is that too much critical information is often lost because people play with the definitions of availability, performance and quality. The reality is they want their OEE number to look good and if it's not world-class, or what they think it should be, the next thing you know, off-spec quality is the only measure for finished products, which doesn't include all the products that had to be reworked to meet the quality standard.

Well, it's time to relax and put away the excuses because there is a much easier way to measure both OEE and TEEP. This method will bring clarity to both measures and to the reliability of all your organization's critical assets. The greatest value in measuring TEEP is that it captures everything, so the game playing and excuses are gone when it comes to the asset because it captures every single minute of time on the calendar. So, regardless of whether you want to include the downtime for your preventive maintenance (PM) tasks, or the time it takes to perform a product change in your schedule as part of OEE or TEEP, it does not matter. When you account for every minute of time (TEEP), it has to be recorded; when you only account for scheduled time (OEE), it allows one to manipulate.

The importance of understanding OEE and TEEP is essential so you can accurately forecast, plan and schedule production. Regardless of what the numbers are, if they have been consistent, you can now, with a high degree of accuracy, schedule what you can manufacture for your customers. Once you understand these measures, you can then begin to look at each of the loss categories, speed, quality, operational and planned, and use the appropriate reliability tool to reduce the losses.

Figure 1
OEE/TEEP
In Terms of Good Product Manufactured and Key Manufacturing Losses



Looking at the bar chart in Figure 1, one can clearly see the similarities and differences of OEE and TEEP. If your present weekly schedule is designed to run the equipment 24 hours a day, seven days a week, then the OEE and TEEP numbers would be identical. If you decide to shut down the equipment for 20 minutes at the beginning of each shift to perform some TPM cleaning and lubrication tasks, then the one hour of lost time would be captured in the planned losses category. The key in measuring OEE and TEEP is to understand the true reliability of your assets.

Prior to beginning your effort to measure OEE and TEEP on your critical assets, you should first meet as a team with operations, maintenance and quality managers. Each organization should get an equal say regarding the composition of the loss categories.

These basic definitions of the terms used in Figure 1 can be enhanced with details based on your business:

Planned Losses – Part of TEEP, planned losses represent the time or units lost because the equipment was not scheduled to run. Planned losses might include weekends, holidays, breaks, lunches, or lack of demand for the product. Time for PMs and capital improvement projects should be considered a planned loss.

Operational Losses – These represent product losses associated with unscheduled equipment downtime due to equipment failure, lack of resources, lack of materials, product change, or cleaning.

Speed Losses – This loss category includes all product lost due to being unable to run the equipment at the desired or scheduled operating speed.

Quality Losses – This category represents product lost from being unable to meet first pass yield quality standards. It should be noted that even if the product is reworked in any way and sold, it still should be counted as a quality loss.

Good Product Manufactured – This represents good product made right the first time within the schedule. This product must meet all first pass yield quality standards and the number cannot exceed the scheduled rate.

With these generic statements, your business can now add language to make each category more specific to your business. Once you have agreed upon what belongs in each category, the trick here is to never change it for any reason.

The importance of understanding OEE and TEEP is essential so you can accurately forecast, plan and schedule production

Setting Goals Around OEE and TEEP

As stated earlier, the objective of measuring OEE and TEEP is to be able to understand the reliability of your critical assets and determine where your losses are located so one can use the correct reliability tool to reduce those losses and improve reliability.

While continuous improvement always should be your goal, be cautious regarding some of the traps of OEE and TEEP. Back to the late 1980s, one can find examples where someone made the statement that if your equipment had an OEE of 85 percent or better, you had world-class equipment reliability. However, there are two solid examples as to why this statement is nonsense:

- If Company A is a utility that provides electric power to hundreds of thousands of people some place in the world and the OEE of its power supply equipment was 85 percent, the company would no longer be in business.
- Company B is a food company that manufactures a batch product that requires cleaning between batches. If it did everything correctly every day for 30 days, the best OEE it can achieve is 78 percent. This is well above world-class for its industry.

Again, the key to setting goals around OEE and TEEP comes down to continuous improvement and understanding what tool/tools to use to reduce or eliminate the losses. Once you have reduced or eliminated your losses, your goal should be to sustain the improved number. Remember, one of the greatest benefits of reliable equipment is the ability to accurately plan and schedule production. If you can accurately plan and schedule production, you then should be able to easily plan and schedule your PM and predictive maintenance (PdM) tasks as well.

Who Should Collect and Post OEE/TEEP Numbers?

Nothing is more shocking than seeing a reliability engineer collecting OEE and TEEP information and reporting the numbers to plant managers, all the while failing to include the operators and maintenance technicians who collectively have the greatest ability to impact the numbers.

OEE and TEEP data collection and reporting should be performed by your operations team leaders and reported at the end of each shift. Doing so will result in the best shift exchange your company has ever experienced because your lead operators now have some data and information to discuss. As an example, if the average OEE for a given asset is between 81 and 83 percent and the next shift comes in and notices that the prior shift ran at 76 percent, don't you believe these lead operators will have something to talk about?

Collecting this information at the correct level is a key part of engagement at all levels of the company. Collecting the data at the correct level engages the equipment operators and maintenance technicians. You then need to understand the data and this is where your reliability engineer comes in. Upon analyzing the data and understanding the losses, he or she can now engage people and managers from all aspects of the business to reduce losses.

OEE and TEEP Losses = What Tool, When

What's most beneficial about measuring OEE and TEEP in this format is they can very easily lead reliability engineers to the correct tool for reducing or eliminating the loss. The following list features various reliability and quality tools and the types of losses they will eliminate.

Reliability Centered Maintenance (RCM) – Reduces or eliminates equipment, process, or human-based speed, quality and operational losses experienced across a wide variety of machine components.

Root Cause Analysis (RCA) – Reduces or eliminates equipment, process, or human-based speed, quality and operational losses that can be attributed to a specific part, component, or incident.

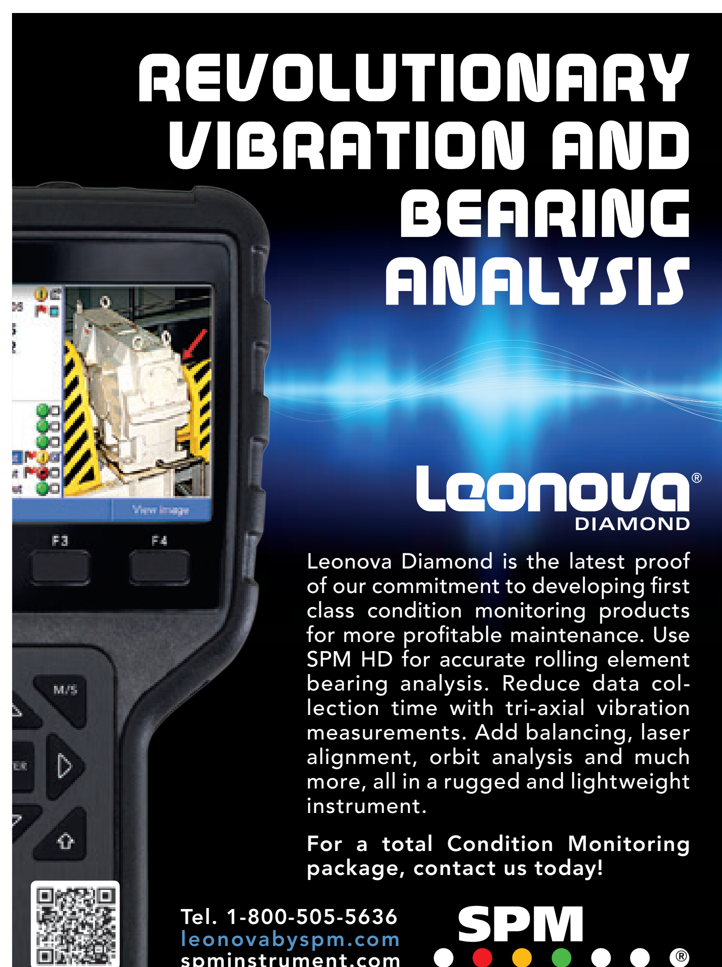
Statistical Process Control (SPC) – Should be used along with OEE data to reduce quality losses that are human, process, or equipment based.

Total Productive Maintenance/Manufacturing (TPM) – Used to develop operator care tasks, TPM can drastically improve reliability and reduce planned losses.

Lean Manufacturing – This warrants caution as far too many companies try to implement lean manufacturing techniques before they have achieved equipment reliability, resulting in a failed lean manufacturing effort. One should only begin to implement lean manufacturing once there has been a sustained OEE and TEEP for three to six months. With that being said, lean manufacturing techniques can further eliminate process-based operational and planned losses.

There you have it! The first key to a successful reliability initiative should always start with measures. Understanding where you are today is an important part in charting the course for your journey.

Doug Plucknette *is the worldwide RCM Discipline leader for GPAllied, creator of the RCM Blitz Methodology, author of the book, "Reliability Centered Maintenance using the RCM Blitz Method," and Co-Author of the book , "Clean, Green & Reliable." Purchase at www.mro-zone.com www.rcmblitz.com*



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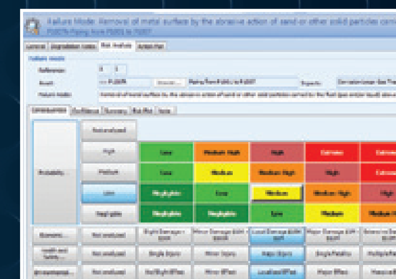

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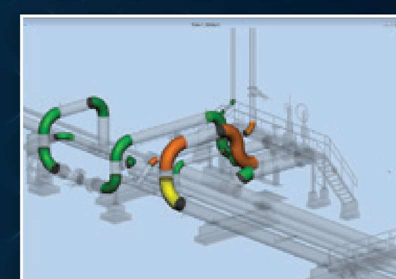

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International Perspectives on RELIABILITY

by Thomas Van Hardeveld

Reliability has become such an integral expectation in our society that it is difficult to imagine a world where things do not work as expected. The first use of the word reliability was by poet Samuel Taylor Coleridge, who bestowed the word on his friend, the poet Robert Southey, to praise his steadfastness.[1] From this seemingly insignificant usage of the term, reliability has grown enormously to a broadly accepted, if not entirely understood, property that everyone expects for a wide range of situations. Online searches for reliability and related terms result in thousands of references in papers and manuscripts and literally millions of hits on the Internet.

The Origins of Reliability

The main pillars of reliability are the concepts of probability and statistics, which emerged earlier from the works of two Frenchmen, Blaise Pascal and Pierre de Fermat. The emergence of the need for quality became apparent with mass production and this evolved into statistical quality control and later statistical process control in the 1920s.

Reliability principles and practices became active as an engineering discipline around the 1950s, with a catalyst being the vacuum tube and the many failures that were being incurred. A key moment was the initiation of the Advisory Group on Reliability of Electronic Equipment (AGREE), jointly established in 1952 between the U.S. Department of Defense and the American electronics industry. The AGREE report of June 4, 1957, provided all the armed services with the assurance that reliability could be specified, allocated and demonstrated. The reliability engineering discipline has since come into existence. The first conference on quality control and reliability (of electronics) was held in 1954 and its proceedings evolved into a journal that is still being published by the Institute of Electrical and Electronics Engineers (IEEE) as the *IEEE Transactions on Reliability*. Another important development was the work of Wallodi Weibull, who pioneered the flexible statistical distribution that now carries his name.

Reliability has become such an integral expectation in our society that it is difficult to imagine a world where things do not work as expected

Reliability came into further prominence in the 1960s when many military standards (MIL-STD) and specifications were developed to meet the needs of design and implementation of defense production in the United States. Worldwide industry acceptance of the MIL-STD was noted as the leading source of reliability knowledge and practices. The most well-known reference is the MIL-HDBK-217 Reliability Prediction of Electronic Equipment, which has been adopted in many countries and used by industry organizations as the framework methodology and basis for failure rate estimation. Other methods for testing, reliability growth and reliability analysis have originated from military standards.

Reliability engineering now encompasses statistical methods, techniques, such as failure mode and effects analysis (FMEA) and fault tree analysis, physics of failure, hardware, software and human reliability, probabilistic or quantitative risk assessment, and reliability growth and prediction, to name only a few. Databases of information have been widely established and their use has increased dramatically. Practically every engineering discipline has a focus on these aspects as a key component of business success.

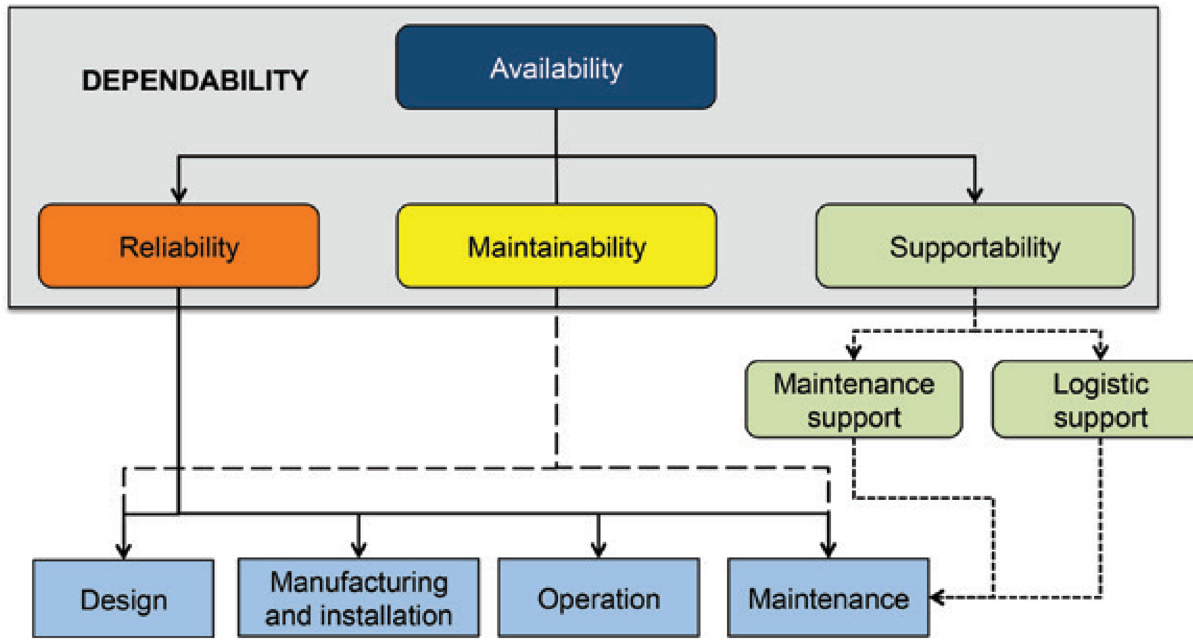
The term reliability now has a much broader meaning and includes not only the specific meaning of reliability as the probability that something may fail, but also related concepts of availability, maintainability, supportability, safety, integrity and a host of other terms. This has led to a proliferation of aggregate terms, such as reliability and maintainability (R&M), reliability, availability and maintainability (RAM), RAMS, where the additional "S" is safety or sometimes supportability, and dependability, which is used by international standards.

International Standardization

In 1965, the International Electrotechnical Commission (IEC) established a technical committee (TC56) to address reliability. The initial title of IEC/TC56 was "Reliability of Electronic Components and Equipment." In 1980, the title was amended to "Reliability and Maintainability" to address reliability and associated characteristics applicable to products. In 1989, the title was further changed to "Dependability" to better reflect the technological evolution and business needs on a broader scope of applications based on the concept of dependability as an umbrella term. In 1990, following consultations with the International Organization for Standardization (ISO), it was agreed that the scope of TC56's work should be no longer limited to the electrotechnical field, but address generic dependability issues across all disciplines, thus making IEC/TC56 what is referred to as a horizontal committee.

The scope of IEC/TC56,[2] according to its strategic business plan, covers the generic aspects of dependability management, testing and analytical techniques, software and system dependability, lifecycle costing and technical risk assessment. This includes standards and application guides related to topics, such as system and component reliability, maintainability and supportability, dependability of systems, technical risk assessment, integrated logistics support, dependability management and management of obsolescence.

Figure 1: Main attributes of dependability and the lifecycle



The Concept of Dependability

Dependability is the "ability to perform as and when required."[3] It applies to any physical item, such as a system, product, process, or service, and may involve hardware, software and human actions or inactions. Dependability is a collective set of time-related performance characteristics that coexist with other requirements of a system, such as output, efficiency, quality, safety and integrity, and, in fact, enhances them.[4]

Dependability does not have a single measure that can be attributed to it, but is instead a combination of relevant measures that vary with application. In a broad sense, dependability is trusting an item to provide its required functionality and expected value and benefits.

The main dependability attributes of an item are:

- Reliability for continuity of operation;
- Maintainability for ease of preventive and corrective maintenance actions;
- Supportability for provision of maintenance support and logistics needed to perform maintenance;
- Availability for readiness to operate.

Dependability is the term that has been adopted internationally to cover the main attributes of availability, reliability, maintainability and supportability (see Figure 1). Quite often, the term reliability is used as a blanket term to include all these attributes. This proliferation of terms leads to considerable misunderstanding of this important engineering discipline, thus adding to the need for standardization.

Reliability is an inherent result of the design and is sustained by proper operation within prescribed conditions of use and appropriate maintenance. Maintainability is dependent on the system design architecture and technology implementation and is guided by maintenance strategies. It is primarily a function of an item's design and installation. Supportability is the ability of an item to be supported from a maintenance perspective and consists of two components, maintenance support and the logistics required to deliver that maintenance support. The starting point for supportability is the maintainability of the item, which is then enabled with specific resources and logistics necessary for the use of the item. Availability is the result of a combination of reliability, maintainability and supportability appropriate for the application.

Thus, dependability is a general term that provides a framework for these attributes, as well as others, such as recoverability, durability, operability and serviceability. Safety is not considered a direct attribute of dependability, although the two are closely related. Safety is enhanced when dependability is integrated into the design and operation of an item.

Dependability and Risk and Asset Management

With the recent publication of the ISO55000 suite of standards, an increasing amount of emphasis is being placed on the concept and practice of asset management. Lifecycle management is the basis of asset management, including lifecycle costing and financial aspects. Risk management is also considered a major focus of asset management. Dependability shares most of the aspects of asset management, including risk management, the lifecycle, information management and quality. Without proper consideration of dependability, asset management objectives could not be achieved.

International standards are now leading the way in continuing to improve the very high levels of dependability that have already been achieved.

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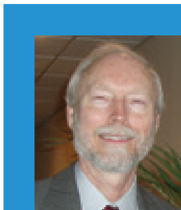


***Thomas Van Hardeveld** has 40 years experience in all aspects of the operation and maintenance of gas turbines, compressors and other gas transmission and process equipment. He is a specialist in maintenance management of all types of equipment, as well as reliability techniques and risk and integrity management. He conducts training courses on a variety of rotating equipment and asset management topics. Tom is actively involved in standardization activities with the IEC/TC56 Committee on Dependability.*

Rationalized and Unified Machine CONDITION MONITORING

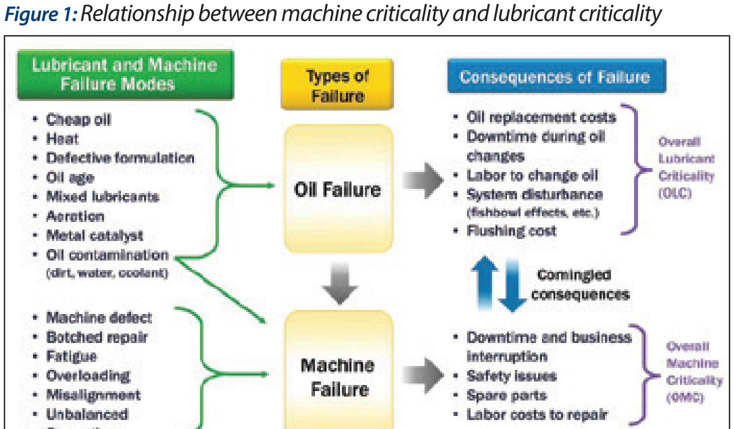
by Jim Fitch

Machine condition monitoring requires a proper foundation from understanding and aligning criticality and failure mode analysis. Sadly, for most plants, condition monitoring consists of multiple technologies that are cobbled together in an attempt to enhance machine reliability.

Alignment greatly helps to optimize deployment of activities and spending to minimize waste and redundancy. Alignment also keeps maintenance reliability professionals on the same page by providing a clear understanding of what's being done and why.

It is intuitively obvious that smart maintenance decisions require a heightened sense of both the probability and consequences of machine failure. For instance, there are real consequences when lubricants fail that are, at least initially, independent of machine failure. These include lubricant replacement costs (e.g., material, labor, flushing, etc.) and associated downtime. These costs can exist in the presence of a perfectly healthy and operating machine. Of course, lack of timely replacement of a defective lubricant will invariably lead to dire machine failure consequences. For some machines, these cascading events can produce enormous collateral damage and financial hardship to an organization.

Figure 1: Relationship between machine criticality and lubricant criticality



Alignment greatly helps to optimize deployment of activities and spending to minimize waste and redundancy

The method presented in this article is believed to be the first, truly rationalized and unified approach to condition monitoring based on both machine and lubricant failure mode ranking and criticality analysis. The condition monitoring methods and technologies being integrated include oil analysis (real time, portable and laboratory), field inspections (advanced methods providing frequent and comprehensive assessments) and other portable and real-time condition monitoring technologies (e.g., thermography, vibration, etc.).

This approach is important enough that it deserves a name: unified condition monitoring (UCM). What makes UCM different from other strategies is:

1. Periodic condition monitoring technologies and methods for each machine are integrated and optimized.
2. Periodicity for each technology and method is optimized.
3. The method of optimization is based on criticality analysis and failure mode ranking.

The optimum reference state (ORS) concept is a central theme in condition monitoring and defines the specific machine and lubricant conditions sought to monitor and control. The ORS is a state of preparedness and condition readiness that enables lubrication excellence and machine reliability. It gives the machine and its work environment reliability DNA as it relates to lubrication. Of course, the ORS can be easily applied to other reliability objectives, too. For lubrication, the enabling attributes of the ORS are:

- **People Preparedness**. People are trained to modern lubrication skill standards and have certified competencies.
- **Machine Preparedness.** Machines have the necessary design and accouterments for quality inspection, lubrication, contamination control, oil sampling, etc.
- **Precision Lubricants.** Lubricants are correctly selected across key physical, chemical and performance properties, including base oil, viscosity, additives, film strength, oxidation stability, etc.
- **Precision Lubrication**. Lubrication procedures, frequencies, amounts, locations, etc., are precisely designed to achieve reliability objectives.
- **Oil Analysis.** This includes optimal selection of the oil analysis lab, test slate, sampling frequency, alarm limits, troubleshooting rationale, etc.

These ORS attributes are simple, fundamental changes that are within a plant's ability to modify and manage. They are definable, measurable, verifiable and controllable.

Failure Mode Ranking

Ranking failure modes helps customize and optimize the condition monitoring strategy. This is another way to say gaining the greatest benefit for the least possible cost and risk. According to the Pareto principle, the top 20 percent of failure causes are responsible for roughly 80 percent of the failure occurrences. It only makes sense, then, to focus resources and condition monitoring on the top 20 percent.

Failure modes and failure root causes are closely associated and often the same. For instance, abrasive wear may be the failure mode, but particle contamination is the root cause. Ignorance, culture, insufficient maintenance and poor machine design are all possible preexisting conditions that individually or collectively lead to contamination. Because you can always search for deeper levels of cause, for simplicity, the terms failure mode and root cause are used interchangeably.

Figure 1 shows the relationship between machine and lubricant failure. On the left are common causes (failure modes) of lubricant failure and machine failure. For example, heat, aeration and contaminants are known to be highly destructive to lubricants. In a similar sense, overloading, misalignment and contamination can abruptly cause a machine to fail. Note how contamination not only can fail a lubricant, but also a machine directly without the need to harm the lubricant first.

It is best to not only list failure causes, but also to rank them in terms of probability and severity. This helps allocate resources by priority. From lubricant and machine failures come specific consequences, which are listed on the right in Figure 1. Again, these consequences are mutually exclusive. Lubricant failure consequences include oil replacement costs, downtime during the oil change, labor to change the oil and flushing costs. Machine failure consequences relate to safety, spare parts, labor to repair and downtime (e.g., production losses).

***Figure 2:** Surveillance planning table for the machine*

MACHINE FAILURE MODE (MFM) RANKING (Example below)	Overall Machine Criticality (OMC) Score									
	100	90	80	70	60	50	40	30	20	10
1. Particle Contamination	CM1	CM1	CM1	CM2	CM3	CM3	CM3	CM4	CM4	CM5
2. Water Contamination	CM1	CM1	CM2	CM3	CM3	CM3	CM4	CM4	CM5	CM5
3. Varnish & sludge	CM1	CM2	CM3	CM3	CM3	CM4	CM4	CM4	CM5	CM5
4. Low oil level	CM2	CM2	CM3	CM3	CM4	CM4	CM4	CM5	CM5	CM6
5. Wrong oil	CM2	CM3	CM3	CM4	CM4	CM4	CM5	CM5	CM6	CM6
6. Misalignment	CM3	CM3	CM3	CM4	CM4	CM5	CM5	CM6	CM6	CM6
7. Aeration & foam	CM3	CM3	CM4	CM4	CM4	CM5	CM5	CM6	CM6	CM6

The overall lubricant criticality (OLC) defines the importance of lubricant health and longevity as influenced by the probability of premature lubricant failure and the likely consequences for both the lubricant and the machine. The overall machine criticality (OMC) defines the likelihood and consequences of machine failure alone. Like many methods, the approach for calculating OLC and OMC is not an exact science, but, nevertheless, is grounded in solid principles in applied tribology and machine reliability.

Building the Surveillance Planning Table

Figure 2 shows an example of a surveillance planning table (SPT) for a given machine, in this case a reciprocating compressor. The SPT is used to define the degree of surveillance, for instance an oil analysis and inspection, for each of the ranked failure modes. These failure modes are ranked from one to seven on the left of the SPT. Tribology analysts and reliability professionals are best suited to assign this ranking for individual machines. The list shown in Figure 2 is hypothetical for the compressor example to illustrate how to build an SPT.

Across the top is the OMC range from 10 to 100. A score of 100 represents high criticality from the standpoint of probability of failure and consequences of failure. In this example, the arrow shows the compressor to have an OMC score of 80. There are seven color-coded condition monitoring zones corresponding to time-based surveillance levels that range from CM1 (real time) to

***Figure 3:** Surveillance planning table for the lubricant*

LUBRICANT FAILURE MODE (LFM) RANKING (Example below)	Overall Lubricant Criticality (OLC) Score									
	100	90	80	70	60	50	40	30	20	10
1. Heat	CM1	CM1	CM1	CM2	CM3	CM3	CM3	CM4	CM4	CM5
2. Water Contamination	CM1	CM1	CM2	CM3	CM3	CM3	CM4	CM4	CM5	CM5
3. Cross Contamination	CM1	CM2	CM3	CM3	CM3	CM4	CM4	CM4	CM5	CM5
4. Aeration	CM2	CM2	CM3	CM3	CM4	CM4	CM4	CM5	CM5	CM6
5. Metal Particles	CM2	CM3	CM3	CM4	CM4	CM4	CM5	CM5	CM6	CM6
6. Wrong or Defective Lubricant	CM3	CM3	CM3	CM4	CM4	CM5	CM5	CM6	CM6	CM6
7. Microdieseling	CM3	CM3	CM4	CM4	CM4	CM5	CM5	CM6	CM6	CM6

TEST AND INSPECTION CATEGORIES

A = Real-time Sensors
B = Daily Field Tests or Inspections
C = Weekly Field Tests or Inspections
D = Monthly Lab Analysis
E = Bi-monthly Lab Analysis
F = Quarterly Lab Analysis

CONDITION MONITORING ZONES	SURVEILLANCE LEVEL
CM1 = A plus D	Real-time Surveillance
CM2 = A or B plus D	Daily Surveillance
CM3 = A, B or C plus E	Weekly Surveillance
CM4 = D	Monthly Surveillance
CM5 = E	Bi-monthly Surveillance
CM6 = F	Quarterly Surveillance
CM7	Never Surveillance

Figure 4: Surveillance planning table for machine and lubricant

Oil Analysis Tests and Inspections	OMC OR OLC SCORE	PARTICLE CONTAMINATION	WATER CONTAMINATION	VARNISH AND SLUDGE	LOW OIL LEVEL	WRONG/ DEFECTIVE OIL	MISALIGNMENT	AERATION AND FOAM	HEAT	CROSS-CONTAMINATION	METAL PARTICLES	MICRODIESELING
MFM	80	CM1	CM2	CM3	CM3	CM3	CM3	CM4				
LFM	70		CM3			CM4		CM3	CM2	CM3	CM4	CM4
Viscosity						L4				L4		
Acid Number				L4		L4						
FTIR-Ox				L4								
FTIR-Nitr				L4								L4
FTIR-Phenolic Inhibitor				L4		L4				L4	L4	
Linear Sweep Voltam.				L4		L4						
RPVOT				E		E						
MPC				L6								L4
Particle Count		R & L4									L4	
Water - KF			L4									
Elemental Spectroscopy						L4	L4			L4	L4	
Ferrous Density							L3				L4	
Wear Particle I.D.							E					
Inspection/Field Test: - Oil Color/Clarity - Oil Level - Oil Aeration & Foam - Magnetic Plug			F2	F3	F2	F2	F3	F3		F2		F2
Real-time Sensors									R			
Vibration Analysis							F3					

LEGEND
E = Exception lab test (e.g., analytical ferrography)
R = Real-time monitoring (e.g., an online particle counter)
L = Routine lab testing (either onsite lab or offsite commercial lab)
F = Field inspection (e.g., oil level inspection) or field instrument (e.g., portable patch test kit, portable vibration tools)
2 = Daily monitoring
3 = Weekly monitoring
4 = Monthly monitoring
5 = Bi-monthly monitoring
6 = Quarterly monitoring

CM4 (monthly) to CM7 (never). For an OMC of 80, the condition monitoring zones range from CM1 to CM4.

The only things that change from machine to machine using the SPT are the failure mode rankings and the placement of the arrow corresponding to the OMC score. Otherwise, all SPTs look exactly the same. For instance, the compressor has particle contamination assigned to the highest ranked failure mode. With an OMC of 80, the intersecting box shows a CM1 condition monitoring zone. This relates to real-time surveillance. You can see in Figure 2 that real time refers to the use of real-time sensors (A) and monthly oil analysis (D) from the test and inspection categories list. There are numerous online particle counters on the market that could be conveniently used for CM1 surveillance. On the other hand, water contamination merits a CM2 surveillance level. This can be done using daily inspections and monthly oil analysis.

Figure 3 presents a similar SPT, but specifically for the lubricant. The lubricant failure mode ranking is on the left and the overall lubricant criticality is across the top. In this case, the OLC score is 70, which has condition monitoring zones ranging from CM2 to CM4.

Combining Machine and Lubricant SPTs

Figure 4 shows the SPTs for both the machine and lubricant in a single unified table. The failures for both the machine failure mode (MFM) and lubricant failure mode (LFM) are listed across the top, with the corresponding condition monitoring surveillance zones just below. Down the left are various oil analysis tests and inspections that satisfy the condition monitoring requirements for each failure mode. This list was developed based on the available and required technologies and methods. The legend lists specific surveillance types (e.g., lab testing or inspection) and periodicity (e.g., frequency of use).

By referring to the condition monitoring zones under each failure mode, the surveillance type(s) and periodicity can be properly selected and optimized. For instance, under particle contamination is the R designation for real time and L4 for monthly laboratory analysis. Under aeration and foam is the F3 designation for weekly field inspections of the compressor's sight glass. Misalignment is monitored using multiple methods, including elemental analysis of wear metals (monthly laboratory analysis), ferrous density analysis (monthly), wear particle identification (on exception based on elemental analysis and ferrous

Figure 5: Condition monitoring work plan

	ORS FINAL TESTING AND INSPECTION PLAN			
	REAL-TIME MONITORING	FIELD INSPECTION TEST	ONSITE LAB TESTING	FULL-SERVICE LAB TESTING
Viscosity				L4
Acid Number				L4
FTIR-Ox				L4
FTIR-Nitr				L4
FTIR-Phenolic Inhibitor				L4
Linear Sweep Voltam.				L4
RPVOT				E
MPC				L6
Particle Count	R			L4
Water - KF				L4
Elemental Spectroscopy				L4
Ferrous Density			L3	L4
Wear Particle I.D.				E
Inspection/Field Test: - Oil Color/Clarity - Oil Level - Oil Aeration & Foam - Magnetic Plug		 F2 F2 F3 F3		
Real-time Sensors	R			
Vibration Analysis		F3		

density), magnetic plug inspections (weekly) and vibration analysis (weekly). These tests and inspections can be easily rationalized and streamlined to improve efficiency and reduce costs.

All tests and inspections can be condensed into a single condition monitoring work plan for the compressor, as seen in Figure 5. The tests and methods needed are clearly shown, as well as the frequency for the four main monitoring categories: real-time sensors, field inspections/tests, on-site lab testing and full-service lab testing. This work plan is the final product of the UCM strategy.

Using the Unified Condition Monitoring Model

From the preceding information, you can see how nearly all decisions related to periodic condition monitoring depend on four factors: overall machine criticality, overall lubricant criticality, machine failure modes and lubricant failure modes. These factors influence what to test, when to test and how to test. In relation to oil analysis, these factors affect where to sample, how often to sample, which tests to conduct, which alarms to set and the general data interpretation strategy.

UCM is an overarching principle that can be adapted for many applications and uses in the reliability field. The more you know about machine-specific failure modes and criticality, the better you can plan and optimize condition maintenance across multiple technologies within both predictive and proactive schemes. On the surface, these foundation pieces can seem time-consuming and arduous, but in the long run, you gain by reducing costs and optimizing the benefits. These are solid and wise reliability investments indeed.

Jim Fitch is the CEO and a co-founder of Noria Corporation. He has a wealth of "in the trenches" experience in lubrication, oil analysis, tribology and machinery failure investigations. Over the past two decades, he has presented hundreds of courses on these subjects. Jim has published more than 200 technical articles, papers and publications. He serves as a U.S. delegate to the ISO tribology and oil analysis working group, and since 2002 has been director and board member of the International Council for Machinery Lubrication. www.noria.com

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Design for Overall Equipment Effectiveness

by Robert Baird

If your organization is like most using automation for productivity, then overall equipment effectiveness (OEE) is most likely being used as a key metric in determining where improvement efforts should be focused. If most of your production steps utilize production machines, then all the OEE factors, availability, performance and quality, apply. On the journey to be world-class, there also must be considerations about the complete production system.

Most organizations use an OEE of 85 percent as a world-class benchmark. But after tracking organizations and implementing some improvement efforts, the results of the OEE factors of availability, performance and quality have averaged 90 percent, 86 percent and 98.7 percent, respectively. This equates to an OEE of 76.4 percent, significantly short of the 85 percent benchmark. Even this world-class benchmark can be exceeded with a shift in focus of when and where improvements are made.

Improving production equipment while in situ incurs significant hidden costs over the lifetime of the equipment. These hidden costs can be defined as expenses not normally included in the purchase price of the production machine, such as for maintenance, supplies, device add-ons, poor quality, inefficient energy use and training time. There also can be unnecessary design costs, for example, needlessly increasing the speed without consideration of production system requirements (e.g., increasing the speed of a machine that will be feeding a bottleneck). The financial term for this is sunk cost.

Design for overall equipment effectiveness (DFOEE) is a new concept that shifts the equipment improvement focus to the design stage. The methodology accomplishes this by incorporating local knowledge, six big losses of total productive maintenance, seven wastes of lean manufacturing, energy conservation, theory of constraints (TOC) and Six Sigma into the design stage of production equipment.

The DFOEE methodology makes losses more transparent, highlighting areas for improvement during the design stage of new production equipment. With the losses known, there obviously can be improvements made when the equipment is in situ, but improvements at the design stage provide a significant reduction in hidden and sunk costs.

The basic steps of the improvement methodology DFOEE are:

1. **Define the Purpose** – This is primarily the responsibility of the organization's leaders. This must include a review of the complete value stream. How will the equipment effectiveness improvements align with the overall strategy? How will this new equipment benefit the system? What are the direct and/or indirect improvements and how will they benefit your customers?

2. **Establish a DFOEE Team** – It starts with the structuring of a diverse team and stakeholder involvement. Most operational departments are involved, including the original equipment manufacturer (OEM) supplier and its key component suppliers, engineering, value added workers who will be running the machine, a Lean Sigma practitioner, maintenance, purchasing and sales. They all bring both local and technical knowledge about what is required to make this new equipment the most effective within the value stream.

With this diverse knowledge, you will be able to answer these critical for design questions:

- ☐ Can we improve energy efficiency (servomotors versus pneumatics)?
- ☐ What is the most effective throughput for the system?
- ☐ How can we improve the six big losses?
- ☐ Which components must improve to reduce scrap?
- ☐ How can we minimize transportation within the machine?
- ☐ How can we minimize changeover time?
- ☐ How can we design for product flexibility?
- ☐ What are the safety and ergonomic concerns?
- ☐ How can we improve preventive maintenance (e.g., modular components)?
- ☐ How can we simplify autonomous maintenance tasks?
- ☐ Can the design combine the prior or next operation, or both?
- ☐ Can the operation be simplified, improving training time?
- ☐ How can we standardize the input and output for the prior and next operation?
- ☐ Why is the flow left to right and the next operation right to left?
- ☐ Can we optimize the footprint?

The DFOEE methodology makes losses more transparent, highlighting areas for improvement during the design stage of new production equipment

3. **Determine OEE Targets** – The team reviews the current state data from existing equipment OEE measures and value stream mapping analysis. Next, there are discussions about applicable new technologies, current best practices and what needs to be developed to improve the OEE factors and flow. From this discussion, targets can be formulated.

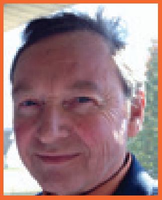
4. **Determine Cost Saving Targets** – Equipment effectiveness improvements must translate to the bottom or top line; it is why organizations are in business. From the OEE targets set in Step 3, financial ratio targets related to revenue gain, cost of goods sold and gross margin must be determined.

5. **Start the Design Stage** – With the completion of the previous DFOEE steps, the OEM supplier and its key component suppliers take the team leadership role. However, this does not mean the other members are not participating within this step. The diverse knowledge of this team will continue to provide critical direction in the design of the equipment. The blueprint, some component prototypes, drive systems, ergonomics, energy efficiency and specifications are established. A prototype machine is then put together. Part of this stage is reviewing the design milestones with the stakeholders, who include the leaders who set the purpose.

6. **Conduct the Testing Stage** – This involves operational replications of applicable products, with the DFOEE team members present. Capability (Cm and Cmk indices), quality (yield), downtime analysis, speed test, training time, changeover time (includes adjustments), energy use, operator motion (ergonomics) and noise studies are all part of the required measures. These studies must be conducted with the appropriate unit volume and with the range of products targeted for the equipment. Completing a test with small volumes will not capture all the variations required to determine the actual values of these indices and mentioned variables. A procedure to follow can be found at ISO.org. Finally, standard work documents are determined by the DFOEE team to include all operational important steps, task key points and reasons for the key points. All test procedures, documents and test results are stored and attached to the equipment in a format that can be efficiently used at the target destination. Any failures during this stage of variable tolerances must be corrected at this time.

7. **Perform the Acceptance Stage** – With the new equipment set up and in situ, all the variable tests are repeated for all products with live production. The same test procedures conducted during the testing stage are followed and results are recorded and compared to the testing stage's results. If there are any unacceptable results related to specifications or variable deviations, it is the responsibility of the DFOEE team to correct them. These unacceptable differences have been outlined already within the equipment contract by the DFOEE team.

OEE is a key lean metric. To achieve world-class equipment effectiveness with system considerations, the new DFOEE methodology must be applied.



__Robert Baird__ is the Owner and President of Lean Teams USA, LLC, a Lean Six Sigma consulting firm. During 33 years of working for both service and manufacturing organizations, Robert has led successful Lean Six Sigma transformations globally. He is the author of __The Four Components of a Fast Paced Organization: Going Beyond Lean Sigma Tools__. Robert is a certified and practicing Six Sigma Black Belt. www.leanteamsusa.com

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THE TRIFECTA OF Motor Maintenance

by Noah Bethel

The odds of picking the first place winner in a horse race are slim. The odds of picking the first, second and third place winners are even less favorable, but when it happens, the trifecta payday is big! In the world of horse racing, guessing the winners is pretty much a gamble. But imagine if gamblers knew in advance the trifecta of the race. It would be a no-brainer to put everything they had on the race knowing they would see huge returns on their investment.

Using the same concept of a trifecta, or three factors for success, this article provides companies with the winning strategies of motor maintenance, focusing on the three reliability tasks for electric motor testing and the order in which they should be applied. Following these steps will drastically improve their odds in motor reliability and put a big payday at the end of their production goals.

Talmadge Ward, a senior engineering technologist with Duke Energy, believes the trifecta of motor maintenance saved his company both time and money. "Motor reliability is paramount in the electrical generating business," says Ward. "Duke Energy has performed motor testing for more than 50 years."

Electric Motors

A basic understanding of the construction of electric motors is essential before discussing the trifecta of motor maintenance. Usually, an alternating current (AC) electric motor is a component of a fan, pump, or larger piece of equipment, such as a mixer, conveyor, or winder. Electric motors have three main parts: the rotor, the stator and the enclosure. The rotor and stator are the working parts of the motor. The enclosure serves to protect these working parts.

The stator is the part of the motor that doesn't move. The core of the stator is made of thin laminations of metal. These laminations are arranged in a hollow cylinder, into which coils of insulated wire are placed. The rotor, as the name suggests, is the rotating piece in the motor. It is also made of thin, metal laminations to form a cylinder and a shaft is inserted into its center. The rotor is inserted inside the stator, but a small air gap ensures they do not physically touch. The enclosure holds the stator and rotor assembly. A yoke supports the stator and rotor assembly, while bearings mounted on the rotor shaft allow the rotor to spin. A cooling fan also may be attached.

Electric motors work on the basic principle of electromagnetism. When an electric current is passed through the insulated wire windings in the stator, it creates a rotating magnetic field. The magnetic rotor, working on the principle that opposite electric charges attract, spins as the electric field moves and pulls the south pole of the rotor toward the north pole of the field and the north pole of the rotor toward the south pole of the field. This, in turn, spins the shaft, which allows work to be done, whether the shaft is connected to a pump, conveyor, or other piece of equipment.

TRIFECTA PART ONE: Quality Control

The first piece of the motor maintenance trifecta is *quality control* (QC). QC is a general term that impacts a wide variety of people, assets, times and locations. It's both the asset being maintained and the environment in which it's stored. Companies should ask several questions regarding their motors from delivery to installation. First, is the motor tested when it's delivered, or do employees in charge of receiving the equipment assume all is well? Assuming the motor works as specified, a second consideration is how the motor is stored. Is the environment suitable in terms of temperature, humidity, protection from the elements and easy accessibility? Third, the motor should be tested intermittently during storage. Just because the motor worked when delivered does not guarantee that problems won't develop as the motor sits idle over time.

Additionally, motors should be installed in an overall system that is quality controlled. The electrical distribution system is a vital component. For example, a voltage imbalance of five to 10 percent can cut the life of a motor in half. In this situation, replacing a motor isn't solving a problem, rather it's starting the failure cycle again. This leads to the old adage cited by veteran employees in work environments without adequate QC: "Let the new guy start it."

Duke Energy's Ward says all its motors are checked before storage or installation. "In the case of our most critical large motors, we review the vendor test reports for both new and repaired motors as a quality check based on our purchase or repair specifications for motors." Adds Ward, "For these motors, we also perform our own motor testing once they arrive at the generating station. All the large stations have staff and they are qualified to perform these tests and evaluate the data. These tests are also done once the motor is installed and ready for service."

TRIFECTA PART TWO: Trending

Once a motor is in place and operating, it's not a good practice to leave well enough alone and assume there are no problems if everything seems to be running smoothly. While many motor failures are mechanical, nearly half are electrical in nature. A 1985 Electric Power Research Institute/General Electric study showed that 41 percent of motor failures were caused by bearings and 12 percent by "other" problems, while a whopping 47 percent of failures were caused by rotors (10 percent) and stators (37 percent).

Data collection is the key to preventing these failures. Machine operators often call a repair company with just one data point. *Trending* is a term that refers to taking data points on a regular basis so potential problems can be identified well in advance and a detailed history of the problems can be assembled.

For example, it's smart to monitor one's health over time rather than wait until a problem develops that requires a visit to the doctor. Just like machines, as people age, certain problems are common. With regular visits, physicians can monitor indicators, such as cholesterol levels or blood pressure over time. If the doctor sees a trend developing, for example, cholesterol levels steadily rising at each yearly checkup, the physician can advise the patient to take preventive actions, such as modifying diet, increasing exercise, or taking cholesterol-lowering medications. Without these frequent data snapshots and preventive measures, the doctor may end up working with a heart attack victim, or worse.

What types of trending data should be gathered for motor maintenance and how often? When it comes to data collecting, "trend is your friend." Using software and testing equipment that can analyze both dynamic and static data, a detailed history can be obtained for a motor that shows potential problems before a catastrophic failure occurs. There are six fault zones that should be analyzed regularly to obtain trending data:

1. **Power Quality:** This relates to the quality of the voltage, which is determined by the power system, and the quality of the current, which is determined by the load. Factors that can be analyzed include low or high voltage, harmonic voltage factor, crest factor and total harmonic distortion for both the voltage and current.
2. **Power Circuit:** This fault zone contains everything from the test point down to the motor, including circuit breakers, fuses and disconnects. Measurements of voltage imbalance and resistive imbalance can be taken to analyze the power circuit fault zone.
3. **Insulation:** This can be affected by old age, moisture, temperature, vibration and other factors. In the insulation fault zone, appropriate hardware and software can measure resistance to ground, capacitance to ground, the polarization index and step voltage.
4. **Stator:** In the stator fault zone, inductive and impedance imbalances are measured to indicate the health of the insulation between the turns of wire in the stator coils.
5. **Rotor:** In the rotor fault zone, current signature analysis (CSA), inrush current, inductive imbalance and a rotor influence check (RIC) test are performed.
6. **Air Gap:** In the air gap fault zone, CSA and RIC tests determine levels of static eccentricity and dynamic eccentricity in the shaft.

How often these tests are performed depends on the type of motor being used, the frequency, intensity and duration of use, and the company's seasonal production patterns. Other factors may include the environment in which the motor is run. Whatever the interval, consistency is key. Quarterly or semiannual trends may be much more valuable than tests performed at random intervals, or whenever the staff remembers to have the data collected.

Duke Energy's Ward has found that an annual interval works best for his company. "Testing motors for trending is done as frequently as every year for the most critical population of motors, but for less critical motors, we use a scalable approach based on the probability and consequences of a motor failure. Our goal is to plan motor service rather than be forced to limit generation for motor repairs because they have reached end of life."

Duke Energy's trending data collection has paid off. "Recently, we found a large difference in resistance in the circuit of a critical 125 HP AC induction motor during a routine off-line test," says Ward. "The cause was loose field cable connections. After the connections were properly torqued, the follow-up test showed only a 0.1 percent resistive imbalance verses the nine percent imbalance first observed."

TRIFECTA PART THREE: Troubleshooting

All motors have a limited life span. Eventually, a motor will fail. What happens at this point is heavily dependent on whether the company has been diligent with quality control and trending, parts one and two of the trifecta. If so, the third part of the trifecta, *troubleshooting*, will be much easier. Troubleshooting refers to what happens when a motor fails or performs poorly enough that it causes a problem.

A good example is the case of a local coal mine that experienced trouble with a wound rotor motor on a Saturday. The local electrical company was dispatched to the mine, where production had ground to a halt and dollars began to bleed from the operation. This motor type generally can't be fixed in the field, but the mining company had the foresight to have a spare motor on hand. By Monday afternoon, a crane was in place to swap the motors and by midnight, the new motor was installed and ready to start.

The miners waited with baited breath under the stars as the start button was pressed. A growl and a blown $1,000 fuse resulted, adjustments were made and another $1,000 fuse blew. By 4:30 in the morning on Tuesday, the third $1,000 fuse blew. At 7 p.m. Tuesday, more than four days after the initial failure, the electrical company prepared to remove the spare motor and take it to the shop for inspection. However, someone had the idea to use electric motor testing equipment and software to identify the problem. On Wednesday morning, testing revealed that two leads were reversed. The problem was quickly fixed and the spare motor started.

Needless to say, this scenario could have been avoided had the three parts of the trifecta been in place. QC would have detected faulty wiring in the spare motor at delivery or while in storage, trending would have identified problems in the original motor before it failed and troubleshooting—what to do when a problem arises—would have saved the miners five days of downtime.

When it comes to troubleshooting, the first key is having written instructions in a manual that spell out the company's policies on motor failures. This includes employee training. Second, the policy should require the availability of technology at the job site to assist in diagnosing the problem. If the miners and the electric company had used the electric motor testing equipment on Monday morning, downtime on Tuesday and Wednesday would have been avoided. The plan should also stipulate calling in outside experts when the scope of a problem exceeds the training or knowledge of the employees.

"Critical motor failures are very rare in our generating stations," says Ward. "What is more common is to find a degraded motor and determine the cause and contribution factors. Then we develop an increased testing plan. Degraded motors require more frequent testing to understand the cause and understand the rate of degradation. With an understanding of both the cause and the rate of degradation, we can have a high degree of confidence that we will avoid an in-service motor failure."

Management, Predictive Maintenance and the Bottom Line

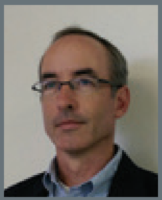
Management also plays a key role in successful troubleshooting. Creating manuals takes time, which costs money. Training employees may result in reduced labor available, which may cause scheduling conflicts. Calling in experts is expensive. However, it's much more costly to lose extra time due to fumbles and false starts than it is to do things correctly in the first place. For example, studies show that industrial rotating machinery failures cost $17 per horsepower of the motor per year for companies practicing only reactive maintenance. In other words, if it breaks, fix it. Compare that with $12 per horsepower for companies practicing preventive maintenance (regular maintenance without the benefit of data) and $8 per horsepower for companies using predictive maintenance. The maintenance trifecta is the very essence of predictive maintenance by using QC and regularly collected data to fend off and forecast problems before catastrophic failures occur. And the impact on the bottom line? Repair costs reduced by more than 50 percent over companies with a "close our eyes and hope it turns out okay" approach.

Predictive maintenance saves money in other ways, too. With predictive maintenance, there are fewer unexpected motor failures and less need to keep extra motors and parts on hand, resulting in less costly inventory and need for storage space. And repairs and maintenance can be scheduled during the company's slow periods, not at peak production on a Saturday.

"In the last 20 years, we have secured the support of senior management. With this support, we have developed specification, procedures, motor alliances with repair shops, budgets for purchase of motor test equipment and what we consider to be a solid motor maintenance program," Ward reports.

Winning the Trifecta

All business involves risk. Some risk, such as entrepreneurial risk, is beyond anyone's control. But other types of risk can be alleviated and mitigated with best practices. By putting their money on the trifecta of motor maintenance—quality control, trending and troubleshooting—companies can "hedge their bets" and increase their chances of a big payday.



Noah Bethel, *CMRP, is vice president of product development for PdMA Corporation in Tampa, Florida, a leader in the field of predictive maintenance, condition monitoring applications and development of electronic motor test equipment for motor circuit analysis. www.pdma.com*

Inspect for Success with Visual Oil Analysis

by Mark Barnes

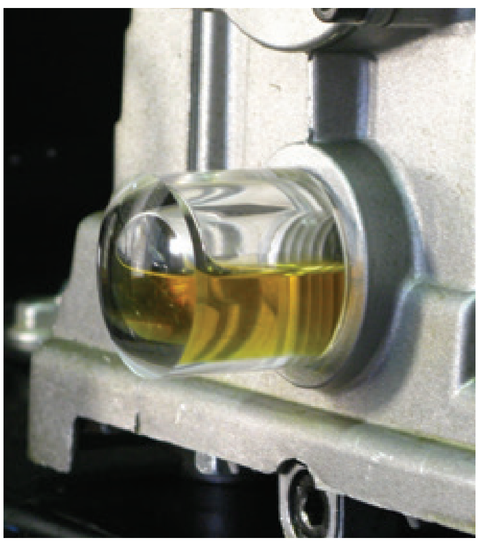


Figure 1: A 3D sight glass is much easier to read than conventional flat sight gauges

As a scientist by training and an engineer at heart, reliability engineering is a fascinating subject, replete with neat technologies, like vibration analysis, ultrasound, ferrography and oil analysis. To the geeks among us, there's nothing more magical than trending bearing defect frequencies, recording decibel readings, observing severe sliding wear particles on a microscope slide, or interpreting acid numbers.

But while the value of these technologies cannot be overstated, there's something to be said for the powers of human observation. You see, many lubrication-related problems are not deep-seated in the intricacies of elastohydrodynamic film thickness or boundary lubrication, but are basic errors of human judgment, or simple issues related to how a machine is operating within its environment. As such, there are some very basic–but insightful–visual inspection tools that, when executed properly, can become a powerful complement to the more sophisticated predictive maintenance technologies we all know and love.

What Is Visual Oil Analysis?

To most people, oil analysis means taking a four ounce sample bottle of oil and sending it to a commercial oil analysis lab for physical and chemical analysis. However, many basic lubrication problems can be found just by simple visual inspections, referred to as visual oil analysis (VOA). Here are just a few of the things that can be found using VOA.

Correct Oil Level

Having the right amount of oil in the machine–particularly in wet sump applications like pumps and gearboxes–is critical. Take, for example, the element bearings in a small API or ANSI pump. The correct oil level is halfway up the rolling element at the bottom of the bearing. Any higher and you run the risk of fluid friction and excess heat and/or leakage, and any lower and the bearing may become starved of lubricant. This is particularly relevant when you consider that the physical size of a rolling element in a small ANSI pump may be only one-half to three-fourth inches, meaning the oil level must be maintained around one-fourth inch to ensure optimized lubricant level.

Of course, many small pumps are fitted with constant level oilers to maintain oil level for this very reason**. But these never should be used as a way of checking oil level.** While the glass bulb may appear full, any small restriction in the narrow bore tube that connects the oiler to the bottom of the oil sump can prevent oil from flowing into the bearing housing. There have been many instances where the bottle oiler is full, but the oil sump has very little oil left!

Of course, most pumps also have a standard sight glass, which is designed to allow mechanics and operators to inspect for the correct oil level within the pump. However, over time, these become stained and discolored, making it difficult to check the oil level in a dark process plant. A much better option is to use a 3D sight glass, such as the one shown in Figure 1, which permits the oil level to be viewed from any angle. Used with a strong flashlight or laser pointer, a 3D sight gauge is a far more reliable option for ensuring the proper oil level in pumps and small gearboxes.

In some instances, wet sumps do not have sight glasses, but rather an oil dipstick or a thread plug at the correct oil level. While in theory both work, in reality neither are very effective. With dipsticks, the only real way to check the oil level is to shut down the machine and wait for the oil to drain to the bottom of the oil pan. But in most plants, shutting down equipment simply to check the oil level is simply not an option and, even if this is feasible, the dipstick port becomes a source for contaminants to enter the machine.

Oil level plugs also tend to be less than effective. In most plants, operators and mechanics simply do not have the time or motivation to remove a plug and check for oil on every piece of equipment. Furthermore, having the machine in operation impacts the accuracy of the level check.

Figure 2: Column level gauges are a great way to quickly and simply check oil level, but any level gauge should be marked with the oil level when the machine is running (red) and shut down (green)

Figure 3: Installed at the lowest point on a wet sump, a BS&W bowl is an excellent way to observe free or emulsified water in oil

A much better option for when the housing does not have a sight glass port at oil level is to use an external level gauge. With a properly installed level gauge, checking the oil level takes a matter of seconds and is much more likely to actually be done regularly. Any liquid level gauge should be marked with level markers, as shown in Figure 2, showing the correct level when the machine is running and when it's down.

Free and Emulsified Water

With 60 to 70 percent of all lubrication-related problems caused by contamination, visual oil analysis is also a great tool for determining the presence of contaminants, particularly water. Even with the use of desiccant breathers, water still sometimes enters a machine through poor sump management, dirty new oil, shaft seal ingression, or packing leaks. Because of this, inspecting for water in any lube oil system is important. Water in oil can either be free (separated on the bottom of the sump) or emulsified (mixed with oil in a cloudy suspension).

If one waits until the oil in the sight glass turns cloudy, it's often too late. A better option is to install a small, clear inspection tool on the bearing drain, something often referred to as a bottom sediment and water (BS&W) bowl. Installed correctly at the lowest point of the system, see Figure 3, a BS&W bowl can be used to find the presence of water before it impacts the bearing.

Figure 4: Using a color comparison chart in conjunction with a column level gauge is an excellent tool for determining changes in oil chemistry over time

Oil Color

Surprisingly, oil color also can be a good indicator of a problem. A number of issues can cause an oil to change color, including oxidation, thermal stress, external contamination, or the presence of wear metals or other debris. Whenever oil is observed to have changed color, it's usually a good idea to extract a bottle sample and perform additional diagnostic tests. It should be noted that not all color changes necessarily mean something is wrong.

Many lubricants will change color in sunlight or other strong light sources due to an innocuous photocatalytic process. Having a liquid level gauge or 3D oil sight glass is great for determining changes in oil color over time, particularly if used with a color rating chart, see Figure 4, analogous to other chemical testing kits, such as soil testers or pH paper.

Oil Clarity

In addition to the color of the oil, its clarity also can be measured. To do this, a 3D sight glass or level gauge in conjunction with a laser pointer is an ideal tool. Just like shining a laser pointer through a glass of water versus a glass of milk is markedly different, a change in the oil's turbidity or opaqueness can be an indicator of a problem. These include water, solvents, detergents, the wrong lubricant and aeration.

Whenever a change in oil clarity is observed, a bottle sample should be taken for a static sit test. Simply sit the bottle on a desk or window ledge out of direct sunlight and observe how the clarity of the oil changes over the next few minutes, hours and days. This also can be combined with a simple field demulsibility test, see Figure 5. Simply add five to 10 percent by volume of water to the oil and shake vigorously by hand for two minutes. Just like the static sit test, leave the oil to sit for a few hours and observe how the oil and water interact. If the oil is in reasonably good shape without major chemical contaminant impurities, the oil and water will separate. Note any change in the clarity of the oil layer. If it's clearer than before you added water, you probably have some kind of aqueous or other polar contaminant present.

Putting It All Together: Developing Inspection Check Sheets

In watching NFL football, fans often celebrate the quarterback, running back or wide receiver, believing these stars of the game are the keys to winning. Just as important–and some may say even more important–are the offensive and defensive lines because without basic blocking and tackling, the stars can't do their jobs.

Figure 5: Simple field demulsibility tests can be very insightful in diagnosing the source of clarity problems within an oil sample

In maintenance, many of the "star" technologies, like vibration or ultrasound, provide limited value without the basic "blocking and tackling" of good alignment and balancing, along with the right lubricant in the right quantity that's clean, dry and cool. As such, visual oil analysis plays an important role in ensuring the "rights" of lubrication are done correctly.

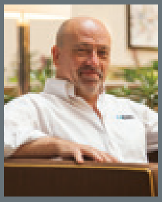
Visual oil analysis tasks should be included as part of daily or weekly rounds. Ideally, these should be done by operators as part of their daily work, but, at a minimum, weekly mechanic rounds should be introduced. Inspections should be set up in a check sheet fashion. Rather than simply state, "check pump," the check sheet should have a series of questions with binary answers. For example:

- Oil level: Low or High;
- Free water present in BS&W bowl: Yes or No;
- Desiccant breather color: Blue or Pink.

Making questions binary takes away any subjectivity and permits task-specific training so the operator understands what he or she is looking for. Even better, include a picture of what "good" and "bad" looks like as part of the inspection check sheet. These inspections should also include other basic mechanical integrity checks so mechanics are not constantly visiting the same pump for different reasons.

Conclusion

As much as professionals in the lubrication community would like to believe, lubrication will never have the same sizzle as technologies that require gadgets, gizmos and data analysis. But unless the basics of lubrication are done correctly and inspected routinely through visual oil analysis, the only thing all those "star" technologies will tell you is that you should have done a better job at lubrication "blocking and tackling." So don't just take lubrication for granted; inspect for success!



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

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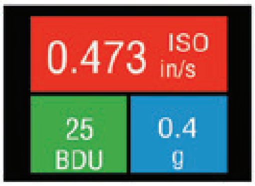

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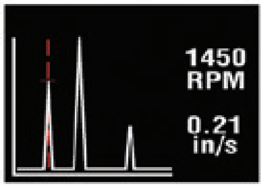

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The Critical Success Factors for Asset Management Services

by Wyhan Jooste and PJ Vlok

Management periodicals are unanimous in advocating the integration of services into core product offerings. Servitization is the term for these integrated packages of client-focused combinations of products, services, support, self-service and knowledge.[1] Historically, most of a product's value was added during the production process, which transformed raw material to a useful product. Today, value comes from technological improvement, styling, branding and other attributes that only services can create.[2,3,4]

Asset management (AM) services form part of what management publications refer to as industrial services or business-to-business services. In general, a service is a process that consists of a series of activities taking place between a client and service provider in response to the client's problem(s).[5] Applying this definition to AM, **an AM service refers to activities targeted at optimizing the use of physical assets to increase their value for the client.**

The AM standard, ISO55000,[6] refers to *outsourcing*, which implicitly includes AM services. According to the standard, outsourcing forms part of the operations requirements of the asset management system, which refers to the contracting of external service providers to perform certain activities impacting asset management objectives. This *exchange of activities*, a result of the outsourcing decision, can be described as an AM service.

AM services can be classified according to the value proposition for the client and the revenue model of the service provider. Figure 1 illustrates four service classifications.

The most basic AM service is transactional and oriented at the asset itself. Such installed base services include installation, training in the use of the asset and the selling of spare parts.

The next type of AM service is also transactional, but oriented at the asset owner's AM processes. Client support, training and consulting form part of this service type.

Outsourcing services are relationship-based and oriented at the asset. The outsourcing of certain maintenance activities is an example of this type of service. The last type of service is integrated solutions. With these services, there is substantial value co-creation between asset owner and service provider. An example is an organization contracting out its entire maintenance function. Integrated solutions often involve performance contracting and gain sharing agreements.

Why Are AM Services Important?

The increased focus that standards like PAS55 and ISO55000 are bringing to the asset management industry, as well as industry and technological pressures, are leading to an increased need for AM services. Some of these pressures are the technological advancement and complexity of assets; the shift to whole life-cycle asset management; the requirement for industry best practices and processes in support of AM standards; and the shift to software as a service (SaaS) in the enterprise asset management system industry. In the midst of this increased need for AM services, **it is important for AM practitioners to be cognizant of the underlying factors that will increase the likelihood of successful service partnerships within the AM services arena.**

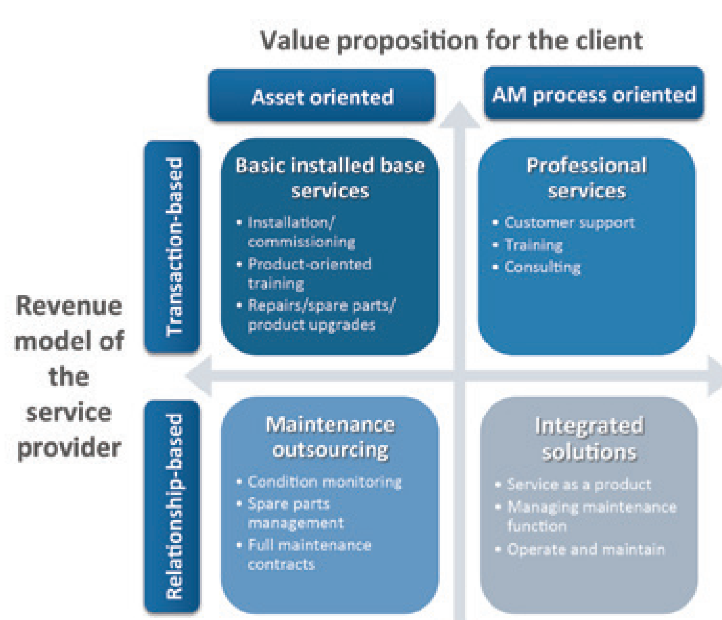


***Figure 1:** Types of AM services*[7]

Critical Success Factors

The critical success factor (CSF) approach is appropriate for supporting the synergy between asset management and services. **CSFs are those characteristics, conditions, or variables that, when properly sustained, maintained, or managed, can have a significant impact on the success of an organization competing in a particular industry.**[8]

Both CSFs and goals are required to fulfill the organization's mission (see Figure 2). They are interdependent and neither can be disregarded without affecting the other. When managers define their goals, they intuitively consider the factors that are required to successfully accomplish them. The influence CSFs have on goal attainment, therefore, is made explicit, even if the actual CSFs are not.

For example, a person might set a goal to lose three pounds in a year. To achieve the goal, the person needs to be mindful of two things: improving his or her diet and exercising regularly. Close attention to these two CSFs will help the person realize the goal of losing three pounds. Conversely, failing to manage these factors will, in all probability, lead to the goal not being achieved.

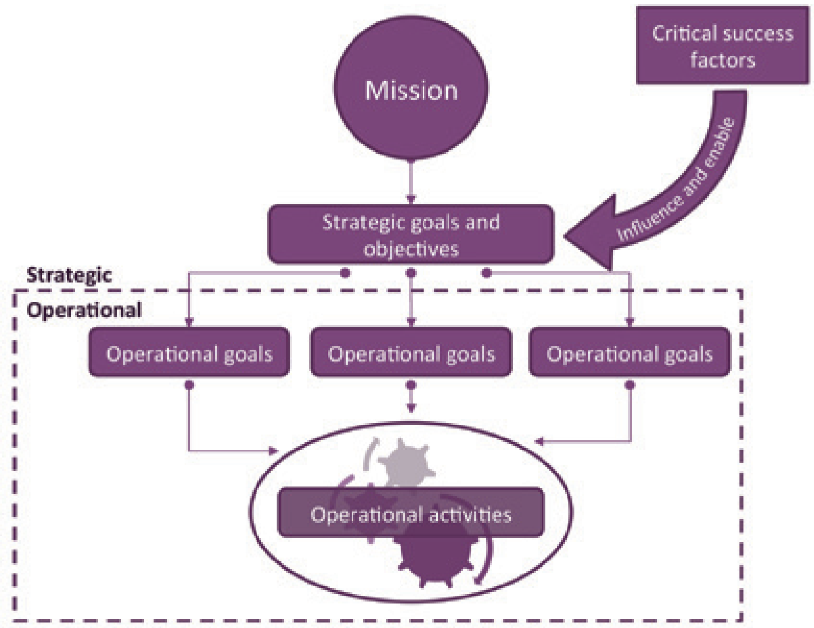


Figure 2: The role of critical success factors in strategic planning

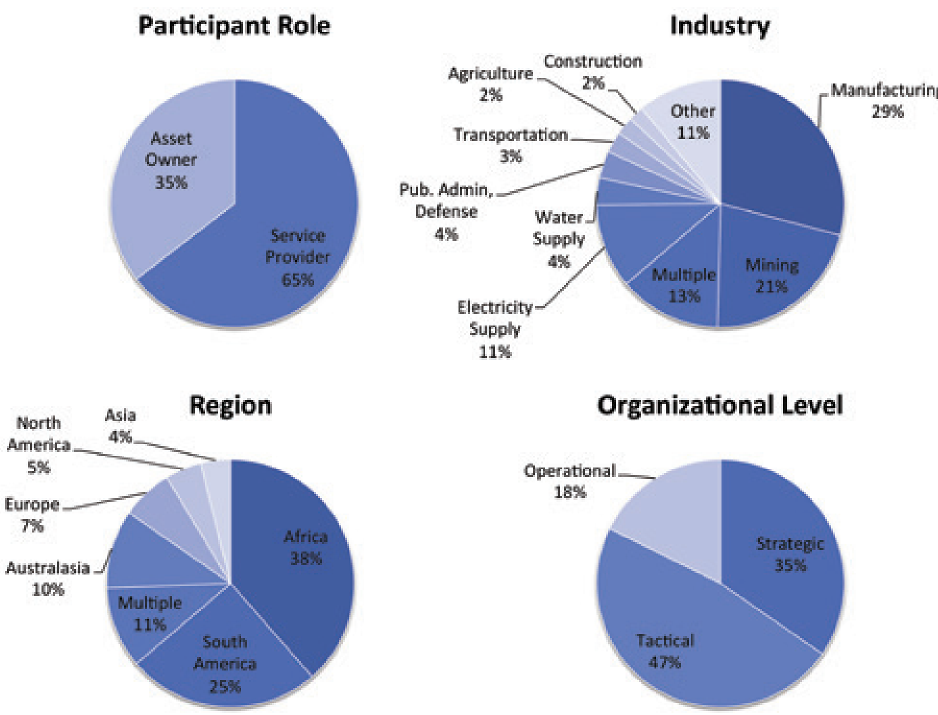
A Global Study of the CSF for AM Services

A global research study was conducted by Stellenbosch University to identify the CSFs that are required for collaborating in a successful AM service environment. A mixed method research approach was used. The content of existing literature was analyzed and developed into a Delphi study to identify the success factors relevant to the field of AM services. (A Delphi study is a technique that allows consensus to be reached among a panel of experts on a certain issue or topic by using multistaged questionnaires.)

The outcomes from the Delphi study were developed into a survey questionnaire that was used to identify the critical success factors for AM services. For the questionnaire, data was collected from a sample of AM service providers and asset owners. The questionnaire's outcomes were used to construct a prioritized list of the CSFs for AM services. English and Portuguese versions of the questionnaire were created for data collection. A total of 392 responses were received, of which 254 were valid and statistically usable. Figure 3 shows the four response distributions of the sample.

The ratio between asset owner and service provider responses is 1:2. Of the respondents, 82 percent work in a strategic or tactical capacity. The majority of the responses originate from Africa (38 percent) and South America (25 percent). A further 11 percent of the respondents indicated they work globally and 10 percent in Australasia. The remaining 16 percent originate from Europe, North America and Asia. Respondents operating in the manufacturing industry represent 29 percent of the responses, while 21 percent of the responses come from the mining industry. Respondents working in multiple industries

Figure 3: Distributions for the survey results



represent 13 percent and a further 11 percent is attributed to responses from the electricity supply industry.

Key Findings

All respondents unanimously agreed on the CSFs. Statistically, there is no evidence that the responses from any one of the response groups within the role, industry, region, or organizational level distributions in Figure 3 differ from another.

The CSFs are shown in Figure 4 with the corresponding phase of the service's lifecycle. **The top ranked CSF is the continued and sustained commitment and support for the service from the asset owner's senior management.** This support forms part of the organizational environment and capabilities, and is continuous throughout the lifecycle of the AM service.

The second, third and fourth ranked CSFs are all related to the operational services phase. Effective communication (ranked second) and mutual trust and respect between asset owner and service provider (ranked fourth) are critical as part of the day-to-day service operations. In support, a focused improvement process for improving the service relationship is equally important (ranked third).

Ranked fifth is the alignment of AM service requirements with overall business strategies during the initial needs and value proposition activities. During the service implementation phases, the active involvement of the asset

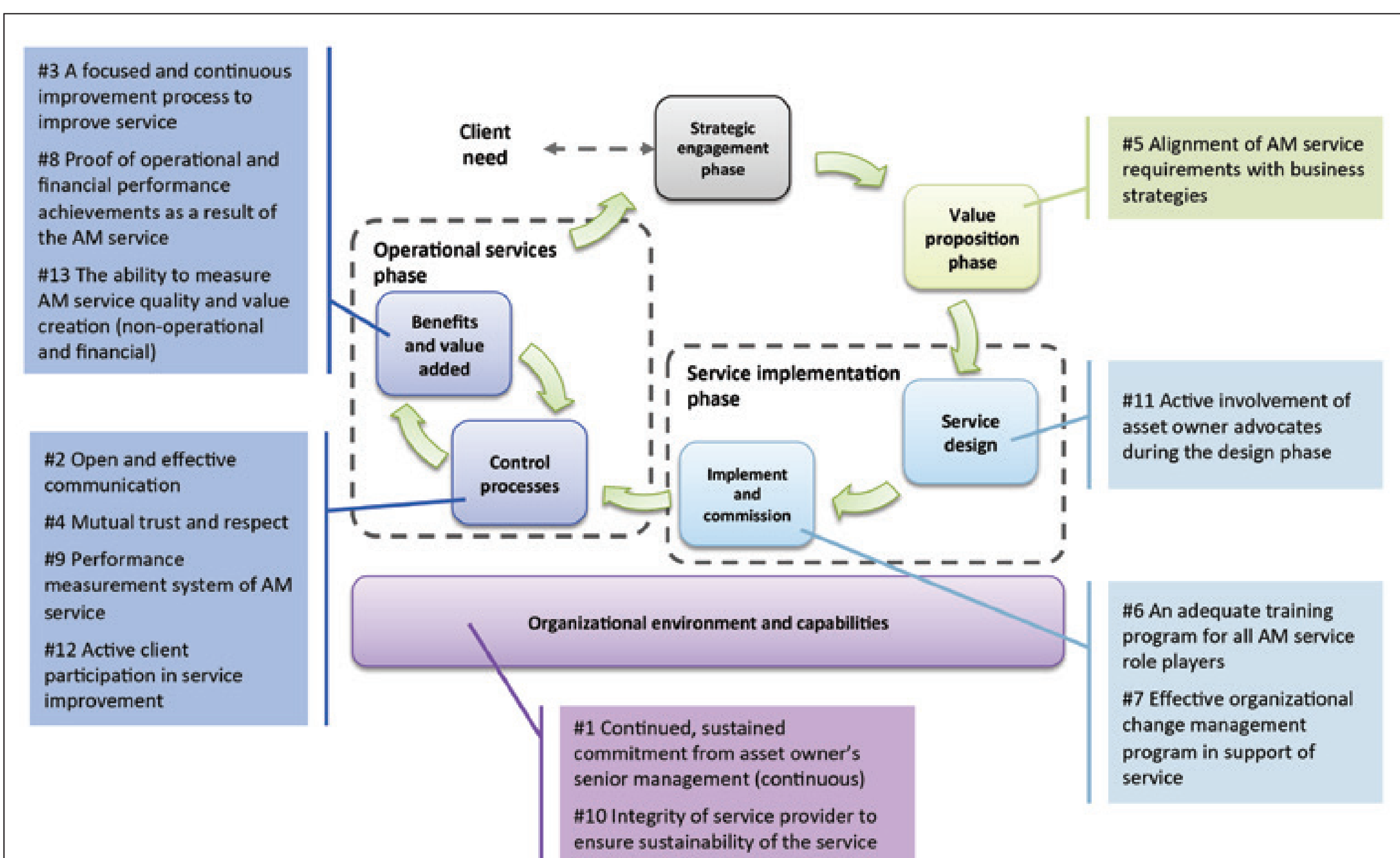


Figure 4: CSFs for AM services categorized according to the AM service lifecycle phases

owner in the solution design is critical (ranked eleventh). An adequate training program (ranked sixth), combined with a formal change management process (ranked seventh), should support the service implementation.

The remainder of the CSFs focus on the sustainability of the ongoing AM service activities. The eight ranked CSF states that proof of operational and financial performance achievements as a result of the AM service is fundamental towards the success of an AM service. These measures should form part of a formal performance measurement system (PMS) for measuring the service (ranked ninth). The PMS should further have the ability to measure the quality and value added through measures that are not only limited to operational and financial (ranked thirteenth). The active participation of the client in improving the service is equally important (ranked twelfth).

Conclusion

This is the first study that explores factors affecting the synergy between AM and services. It supports the outsourcing requirements, as stated in ISO55000, with the CSFs, which should be managed for a value adding AM service relationship. A prioritized list of CSFs is presented. These factors should be actively managed by all role players for the best probability of a successful AM service partnership.

- There needs to be continuous support from the asset owner's management for the AM service.
- The AM service needs to be built on sustainable cooperation between the asset owner and service provider.
- A performance management system needs to be in place. The system should include: a measurement system and process; measures for operational and financial benefits resulting from the service; and measures for the service's quality and value added, including, but not limited to, operational or financially oriented benefits.
- Active management for the improvement of both the service relationship and the value creation as a result of the service.

The findings presented in this article are part of ongoing doctoral research. Based on the reported data, a decision support model is being developed to further assist the AM industry in AM services decision-making.

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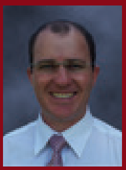


Wyhan Jooste, MScEng, *is a part-time doctoral student at Stellenbosch University and works for Pragma in new product and services development in the field of asset management.*

PJ Vlok*, PhD, is an associate professor at the University of Stellenbosch in South Africa consulting on, and doing research in, advanced topics in asset management.*

Risk-Based Inspection Method

for Flow Accelerated Corrosion Detection

by Thomas Godby

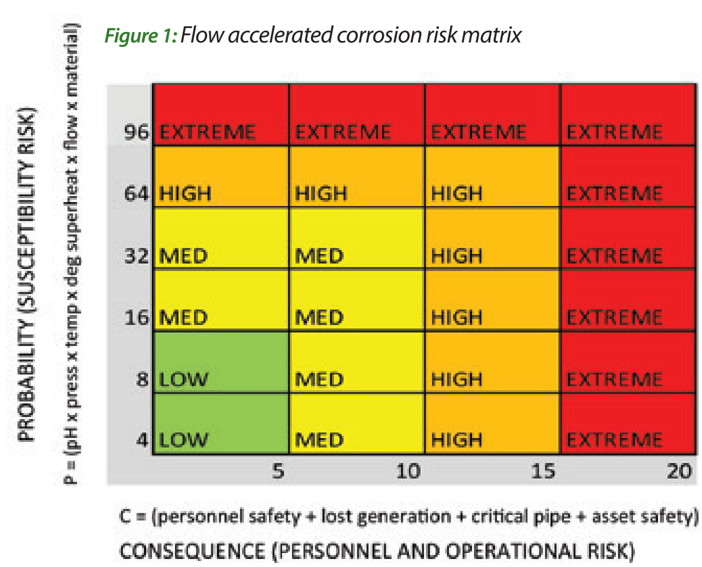
With limited resources and a mixed fleet of both legacy and new build power plants, it can be a challenge to keep up with the many inspection locations and data produced by a fleet flow accelerated corrosion (FAC) program. In addition, for those new to this realm of inspections, it can be intimidating to determine where to begin an inspection program, considering the thousands of possible locations from which to choose. To remedy this, a risk-based inspection approach that focuses on the highest impact areas first should be used. This approach leverages the risk grid, or risk matrix, where a composite score can be generated by using the formula: Risk = Probability x Consequence (R=PxC). This score subsequently can be used to determine where resources are to be focused on areas of highest probability of FAC and whose consequences could result in personnel injury, severe equipment damage and lost generation.

To begin, one must first understand the mechanisms that influence FAC in power plants. For the purpose of this article, the focus will be on lessons learned from elevating an internal FAC program for a lignite coal burning fleet on low energy piping. The piping systems included the boiler feedwater, condensate, heater drain, extraction steam, boiler water separator and boiler blowdown systems. As you can see, even with immediate elimination of other power plant piping systems, there are still many components to screen across an entire fleet of assets. To continue to drill down further, certain documentation can be useful in understanding where FAC is most likely present. Piping line lists that contain information on the line size, material composition, design and operating temperatures, pressures and flows are a valuable asset. This information can help you understand your plant's risk and susceptibility to FAC.

Industry experience has shown that FAC occurs predominately in water or water steam mixed media systems with carbon steel piping that operate in the range of 150 to 500 degrees Fahrenheit. If you obtain this temperature information, along with pressure information, you can better understand what degree of superheat exists and determine if you have single or two-phase flow in the piping. Industry information indicates that FAC wear rates accelerate in a certain range of temperatures. Using this information, you can assign a scoring system based on where you are on the curve. For example, you could divide the FAC temperature range into five distinct bands and assign a score to each based on an assessment of severity as it applies to wear rate. This same principle holds true for understanding where your plant operates in the pH band and which flows are present in the piping. These points of reference, along with their scores, will ultimately tally up to a probability score for susceptibility.

It is understandable that not everyone has great documentation. In this case, obtaining a heat balance is your next greatest ally. You can then look at the FAC susceptible systems and get a basic understanding of temperatures, pressures and flows to do your assessment. A visit to your control room can also help by taking a look at your control system and seeing what is displayed while your plant is operating. By taking the same probability approach, you can ask additional questions as they pertain to plant chemistry and operating context. For example, an older site may have been exposed to reducing chemistry, like all-volatile treatment reducing AVT(R) or the addition of hydrazine. In this case, plants running reducing chemistries are very susceptible to FAC, so a detailed search is in order. A meeting with the local chemistry team will allow you to understand where in the FAC pH band the plant has historically operated. If you are operating newer plants, it is likely running oxygenated chemistries, such as

Figure 1: Flow accelerated corrosion risk matrix



all-volatile treatment oxidizing AVT(O) or oxygenated treatment (OT) with a higher pH. This profile has been shown to almost completely eliminate single phase FAC. If this is the case, your search becomes even more focused since you essentially will be looking at two-phased flow in systems where you can have flashing, such as heater drains piping sections, after control valves. As you discover more information about your susceptible lines, add it to your probability scoring algorithm. The more information you have, the more robust your calculation will be. If you find you are limited in the information you can uncover, do not be discouraged; little information and taking a logical engineering approach to probability is better than none at all.

Figure 2: Risk ranking spreadsheet

line #	description	probability risk	consequence risk	composite risk score	
line hd-1	heater cascading drain	96	15	1440	
line hd-2	emergency drain to cond	32	10	320	
line bs-1	boiler separator to cond	16	5	80	
line fw-1	fw discharge line	8	5	40	inspection
line cd-1	cond booster inlet	4	2	8	cut line

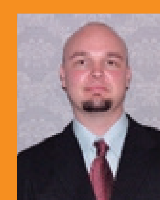
The next part of the equation is the consequence side of the calculation. The first consequence to think about is personnel safety. Once you have the lines selected based on susceptibility, walk them down and take pictures of each inspection location. Develop a communication package and schedule times to meet with the operators in the control room, the folks doing operator rounds and any seasoned veterans at your plant that have a good feel for what areas would be considered high traffic. Score these assessments accordingly using a numeric value. For example, you can assign a five for a high traffic area and a one for a low traffic area. Other locations to consider are those that are near workshops, restrooms, or any area where personnel may have a tendency to congregate. For those sites that are older and have asbestos insulation, an additional scoring category should be added to account for the increased risk to personnel.

The more information you have, the more robust your calculation will be

The consequences of equipment damage should be considered next. While performing your walk down, think about what would happen if there was a steam leak or rupture in the area. Is there switchgear or other electronic equipment in the area? Give consideration to any equipment that, if damaged, would result in a unit trip or require a major maintenance outage to repair. Lastly, while discussing locations with the operators, ask what would happen to unit operations if a pipe rupture or leak occurred. Score the responses accordingly, for example, a one would be no effect to plant operation, whereas a three could be a unit derate and a five would be a unit trip.

Now you are ready to begin developing your risk grid and inspection scope list. An example of the risk grid can be viewed in Figure 1. In this example, scoring has been applied to the various categories on the X and Y axis such that a composite risk score can be displayed. The grid is then broken down into areas based on low, medium, high and extreme risk. This information can be applied to the inspection scope list and risk ranking spreadsheet, an example of which can be viewed in Figure 2. As the scores are added to each proposed piping line, you can begin to see which lines pose the highest threat to safety and generation. This information is also great to have in the case of reductions in budget or outage scope. If either of these situations occurs, you will be armed with information to make a very good risk-based decision on where to draw your cut line. Be sure to add any inspection location that has been removed to your next year's plan.

In summary, this methodology can be used to focus resources and budgets while reducing risk to safety and generation for your generating fleet. It provides a framework by which piping lines can be evaluated using various sources of data and institutional knowledge. It also offers an organized approach to collating and displaying data for discussion meetings where budgets will be allocated towards future inspections. Lastly, it offers a visual method to display the information graphically so program managers and inspection leads can quickly show high risk and high impact areas to managers, facilitating data driven decision making and reducing risk exposure to flow accelerated corrosion related piping failures.



Thomas Godby is a Reliability Specialist at Luminant Power, servicing its lignite coal-fired generating fleet. He is a Certified Maintenance Reliability Professional with an MS in Engineering Management from Cal State Long Beach, an Executive MBA from the University of Phoenix and a BS in Nuclear Engineering Technology from Thomas Edison State College. Thomas is also a veteran of the U.S. Navy, serving as a Nuclear Reactor Operator and Electronics Technician in the U.S. Naval Nuclear Propulsion Program.

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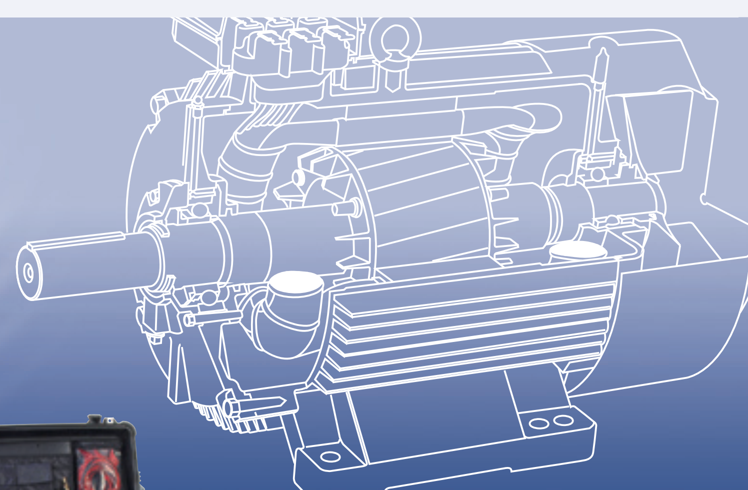

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MRO Data Analytics & Business Intelligence

by Brian Oxenham

Currently, there is considerable excitement and growth in the fields of data analytics and business intelligence (BI). This article serves as a primer, to inform and explain their relevance in the maintenance, repair and operations (MRO) domain and to illustrate some of the potential opportunities.

Background

Over the last 25 years, MRO activities have become almost entirely administered through the medium of computer systems. Initially, stand-alone computerized maintenance management systems (CMMSs) were deployed at single site level, some were developed in-house, while others were commercially available products. As software development became cheaper and personal computers appeared on every manager's desk, these management systems grew in complexity. A need for multi-site capability gave rise to a generation of enterprise asset management (EAM) systems. A requirement for integration with wider corporate financial and business management applications then brought about the growth of enterprise resource planning (ERP) systems, accelerated somewhat by the hyped fear of the possible Y2K bug. Many smaller system vendors were absorbed into larger businesses and, inevitably, some dominant ERP vendors emerged. The result has been global deployments of highly capable transactional systems. However, as the size of the system vendors supplying ERP systems grew alongside that of the industrial organizations adopting them, the rate of innovation within system product development started to fall away because of inevitable large organizational inertia.

Against this developmental backdrop, the pace of business change actually accelerated to address issues of globalization and rapidly fluctuating economic cycles. The business landscape is continually reforming. News of corporate acquisitions and mergers, often private equity backed, fill the financial pages. Investors are keen to identify and quickly realize the benefits possible through exploiting the economies of scale to maximize shareholder value.

Much of the business value in a modern organization, even an asset-intensive one, is locked in the data and processes that it uses in its day-to-day transactions. Inevitably, however, when two businesses come together, they are often found to be operating on different systems; they have different DNA. Yet, the basic transactional processes that go on in both, such as work orders, purchase orders, inventory management and so on, are the same. It is not uncommon to find two organizations separated by a common language. Standards are slowly evolving, which means key transactions are becoming more uniform in their structure and data more standardized. But this is a slow process not always embraced enthusiastically by system vendors who might not want to make it too easy for a business to migrate to a competitor's product.

Data Analytics: A New Technological Wave

The emerging field of data analytics, which at present is populated by smaller and nimbler vendors, has burgeoned in the last few years. This has been fueled by a number of exciting technological factors. Among them are the emergence and widespread acceptance of cloud-based technology for business, adoption of tablet computers in the workplace and the step improvements in the presentational capability of modern browsers. However, coupled with the fact that technology now makes more things possible is an underlying need, or perhaps even a thirst, for what can be done. Users now have far higher expectations than just a few years ago. Up until now, much of the battle in the workplace has been one of successfully implementing and gaining acceptance of essential transactional systems. That cultural battle is now all but won. Older workers are comfortable with the concept of information technology and have seen and acknowledged its benefit. The new generation struggles to imagine how it could have been any other way. Couple this with the everyday familiarity people now have with the Internet, social media, tablet computing and the common usage of information technology at home to create high quality content themselves for others to see as opposed to simply consuming it, and it is evident that the imagination of employees is increasingly oriented towards thinking about what might be possible. They are completely comfortable with information technology as a concept and are running with it ever more confidently by using it as just another tool.

Organizations are now seeing employees at all levels thinking creatively about how they can leverage corporate data for competitive advantage and demanding the ability to do this on an everyday basis. Data analytics and BI tools fill the gap to satisfy this demand.

There have been some well-documented examples of data analytics tools being used to identify and predict crime patterns. Marketing functions within businesses are aggressively exploiting customer data by using analytic tools to further sales by unearthing latent consumer needs. Financial businesses have often led with complex tools to analyze vast amounts of market data. But what about MRO?

MRO Data Analytics: The Process

Most industrial organizations now have huge amounts of MRO data in various forms, offering a potential gold mine. The challenge is in efficiently aggregating this diverse data, giving it some uniform meaning and then analyzing the big, and ever-changing, picture to identify opportunities. It is all about the skilled conversion of raw data into meaningful business intelligence.

A typical large industrial organization stores its MRO information in various ways. Some will be isolated in "silos" and some will be interconnected and accessible to all across the business. Much of it will be dynamic, reflecting its transactional nature. There also will be a historical dimension. Often, there are different systems broadly performing the same function in different geographical parts of the business. Data standards probably differ wildly.

The first step in the process is to aggregate all this information and ensure a mechanism is in place to update it at an appropriate frequency to reflect changes recorded in the day-to-day activities of the business. Methods vary and a number of different ones might be adopted to satisfy individual local requirements or limitations. Foremost of these is the synchronization of databases via secure, cloud-based tools, such as those offered in their Microsoft® Azure suite, which fortunately makes the process relatively simple compared to just a few years ago. Basically, the data has to be pulled back and replicated in one place, albeit a virtual one.

Figure 1: *Business process diagram*

Once a successful data aggregation process has been established, there is an important intermediate step of data normalization. Poorly managed, this can become a resource consuming black hole. This is where working with partners who have a detailed understanding of MRO systems and processes pays massive dividends. Knowing your way around a database of customers' names and addresses is one thing, understanding the detailed construction of work order processes and material master formats, for example, is a whole other league. The normalization processes need to be configured in accordance with agreed business rules, then automated for continuous updating. Some effort may be required to clean MRO data and then repopulate the local host databases with the revised data. A pragmatic view needs to be adopted here to decide how much data cleaning effort is justified to achieve expected benefits. The Pareto principle often applies.

With the MRO data now aggregated and normalized to a standard that provides a useful level of uniformity across the business, it is in a state suitable for analysis. As a broad differentiator, analytics processes focus simply on portraying data in innovative ways, while BI tools build upon this data and, with further user input operating discrete applications, carry out specific tasks, adding further value to the data. An example would be analytic reports of stockholding values enhanced with niche BI tools that use the normalized inventory data as their input to calculate optimal stock levels using specialized algorithms.

Usually, businesses can initially envision a series of stock reports they wish to see developed from their data, which can be built and effectively hardwired. However, it soon becomes apparent that the list of desired reports needed across the business is potentially vast. What isn't clearly known is what all the reporting needs are and how they will evolve. This is where inbuilt system flexibility is essential. Allowing users to mine MRO information and configure their own reports by building upon the normalized data is key. Furthermore, the easier and more widespread the access is to the required BI tools, the more organizations find that their employees help themselves in identifying and exploiting business intelligence in even more diverse ways. Internet/Intranet deployment meets this need.

MRO Data Analytics and BI Tools: The Possibilities

A top candidate area for finding opportunities is within MRO inventory data. When purchasing and stock data are viewed as a whole across an entire business, fascinating information frequently comes to light. A few examples include local variations in supplier pricing, component commonality and inventory duplication between sites, and finding corporate opportunities to rebalance stock holdings by moving excess stock to demand points. Understanding that a business has multiple small- or medium-sized local accounts with a global supplier, where the sum total expenditure should mean the business is a prime customer, can fundamentally change supplier/customer pricing negotiations conducted at a global level.

A comparison of metrics between operating sites for internal benchmarking can be extremely valuable. For example, seeing and understanding how different maintenance regimes and their resulting direct costs can impact reliability and availability of ostensibly similar assets in different locations.

It is not just about finding opportunities to drive down costs and improve efficiency. Increasingly for global corporations, there is shareholder ethical pressure to adopt unilateral standards for environmental and safety management. The first step towards this is to actually understand at board level what the aggregated corporate physical risk profile is and how it might vary on a site-by-site, day-by-day basis. A large portion of that physical risk is driven and managed by MRO activity. BI tools that help in reporting and analyzing the effectiveness of maintenance tasks at a global level are used to monitor this. Demonstrating effective global risk monitoring and control might be a regulatory compliance issue. Now that BI technology makes this possible, it increasingly puts pressure on all corporations to implement solutions that raise their standards in this field to meet the raised bar.

With large amounts of MRO data available, correlations between seemingly unrelated values sometimes become apparent. Of course, every competent engineer will understand that correlation does not necessarily imply causation, but it can illuminate potential areas for further evidence gathering. Patterns and cycles emerge that can be used to predict future events with greater certainty. For example, good mean time between failures (MTBF) data found on a large data set, combined with BI tools built to replicate probabilistic usage models, can be used to predict whether an asset has adequate logistic support to carry out a fixed mission profile with an acceptable level of certainty. Weather data, when cross-referenced with reliability data, might expose shortfalls in technical support that might be addressed to improve asset availability.

As organizations shift toward a policy of more openness with their corporate data, some businesses, in the spirit of gain sharing, are allowing consultants, suppliers and other stakeholders to independently analyze their aggregated corporate MRO data, frequently off site.

Conclusion

New data analytics techniques and innovative BI tools are now being used to "sweat" corporate data assets to bring about business improvement and fundamental change. MRO activities, with the associated huge amounts of transactional data they generate, represent an area of great opportunity. Domain specialists familiar with both underlying information technology and detailed business processes are emerging within this complex business area to work with global industrial organizations hungry for improvement. These projects may be trivial, but the rewards can be significant. The future has just started.

Brian Oxenham *is a Chartered Mechanical Engineer who has worked extensively worldwide in the fields of maintenance management, business consulting and IT. He is a Director at MRO@nalytics and has been building IT businesses in this niche sector for over 15 years.*
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Contact and Magnetic Sensors

for Ultrasonic Bearing Inspection and Acoustic Lubrication

Positioning and Pressure of Transducers Matter

by Jim Hall

Ever wonder why the readings and/or data collected are inconsistent when using either the magnetic contact sensor or handheld contact sensor during ultrasonic bearing or mechanical inspections? As Jason Tranter, managing director of the Mobius Institute, writes in an article published on Reliabilityweb.com entitled, *Using a Magnetic Mount Accelerometer for Vibration Data Collection,* "Portable sensors are ***sensitive*** to how they are mounted on the machine during data collection." Note the emphasis on the word "sensitive."

During the practical exam for a recent training class for Ultrasound Level I, technicians were receiving inconsistent readings when using the magnetic sensor while taking readings on a bearing trainer unit. Upon further inspection, it was determined that the approach the technicians were using was to simply come *near* the target mounting pad and let the sensor snap onto the pick-up point. In his article, Tranter warns vibration techs that this practice can damage an accelerometer. He recommends approaching the pad from 90 degrees and rolling the magnet onto the surface.

Another area of concern during the practical exam was the decibel response of the three individual bearings of the bearing trainer. When the technician turned the ultrasonic magnetic transducer either clockwise or counterclockwise, or simply nudged the sensor in any direction, a difference of five to 10 decibels could be seen. This difference could mean the difference of changing a bearing today rather than later, scheduling a replacement at the next earliest convenience, having a non-scheduled production stoppage for catastrophic motor or bearing replacement, or losing a weekend spent with the family because of unscheduled maintenance.

The readings in Figure 1 show differences that could be an alert to a potential problem, or simply the result of how technicians touch or contact the target for readings. Even in this particular graph, the readings in the white area of the grid are well within the good range, but if they were in the upper graph in the red, this could be a problem.

A target mounting pad, shown in Figure 2, is commonly referred to as the vibration pad that an accelerometer is placed on for data collecting. It also

"Portable sensors are ***sensitive*** to how they are mounted on the machine during data collection" *Jason Tranter* can be the point where an ultrasound technician comes back to from the previous data collecting reading to keep the readings consistent for comparison purposes.

The ultrasonic contact, or stethoscope probe as some may call it, went through a change in appearance awhile back. This change involved the waveguide, the five- to six-inch rod screwed into the ultrasonic contact sensor that is placed onto the surface of the motor, gearbox, or pump. Earlier versions had a rounded tip; the newer designs seen today are sharply pointed. Why? Mostly because of the movement at the end. A sharp pointed rod or waveguide allows the point to dig into paint and prevent "walking." This walking is friction. Friction equates to higher readings than normal. Yes, some technicians in those days did, and many may still do, position a washer as a reference point for the placement of the waveguide to achieve comparative information or data.

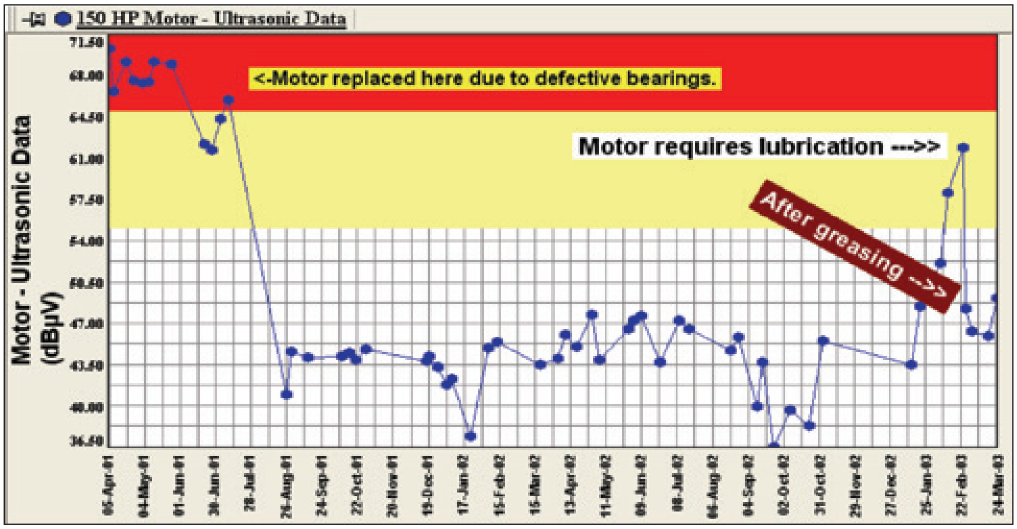

Figure 1: *Graph data taken from March 2001-March 2003 using a handheld contact pointed sensor (Used with permission from Ralph Kopp, July, 2005)*

Another problem when using a contact sensor is pressure. How much pressure is too much or too little? An exercise used in Level I and Level II classes is for a team leader, senior technician, or an experienced ultrasound technician to take a reading on a shop grinder. Most maintenance shops have an industrial grinder in the plant's maintenance space, usually one of those two-wheel grinders that is typically older than everyone in the shop or plant.

The exercise goes like this: First, take a marker and mark a spot on the motor for technicians to take their readings. Or, take a washer and adhere it to a preferred pick-up point on the grinder that will allow for a good reading on the bearing of either the left or right grinding wheel. Next, the experienced technician should place the contact probe or point on the mark or in the center of the washer. Then, the technician should apply force on the contact sensor until he or she feels there is a good read of the bearing in question. Lastly, anyone else tasked with using the ultrasound instruments should be encouraged to repeat the steps, with the exception of marking the spot.

Magnetic mount sensors can be a blessing in disguise for those maintenance teams wanting to reduce inconsistent reads or trending data. But, they also could be a problem. Data collection requires repeatable information for good assessment. For sensitivity and diagnosing, the standard handheld sensor (non-magnetic) is typically more responsive, particularly those sensors made by the manufacturer.

Some manufacturers of ultrasound equipment may purchase an ultrasound magnetic sensor from a third-party vendor and include it in their kits. However, those sensors designed and directly manufactured by the manufacturer are typically calibrated to their instruments for peak performance.

Magnetic sensors, such as a two-pole magnetic sensor, are preferred by many since the two-pole magnetic base may mount on flat or rounded surfaces. Standard pick-up points need to be flat and free of dust, dirt, grease and excessive buildup of paint or coatings.

Notice in Figure 4 that the 30 kHz frequency and the 40 sensitivity reads 51 decibels, with the sensor positioned in the opening between the

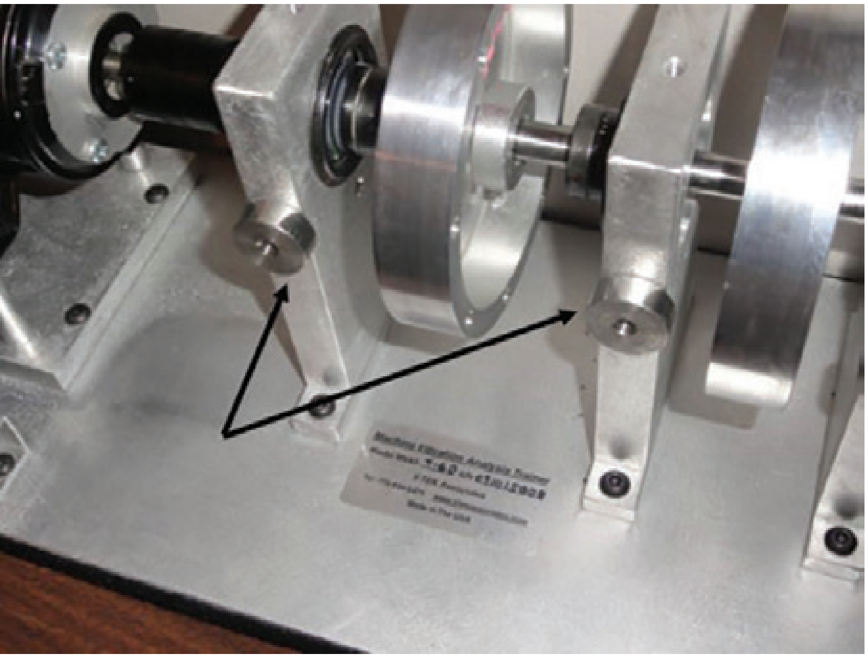

Figure 2: *Target mounting pad, shown with arrows, on a bearing trainer (Provided by V-TEK Associates, Cumming, Ga)*

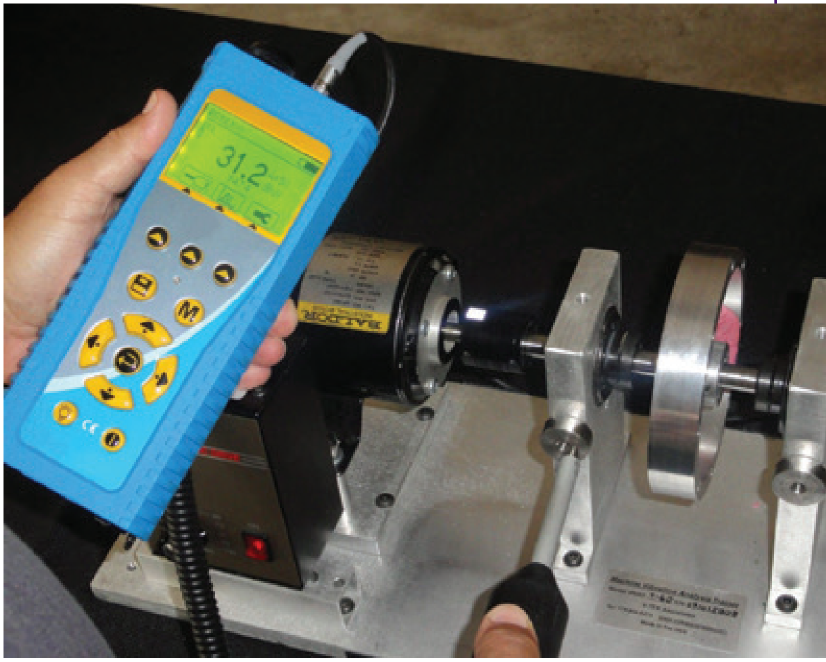

Figure 3: *Handheld sensor*

Figure 4: Bearing trainer (bearing #3) 51 decibels with magnetic sensor (red dot) at the 12 o'clock position

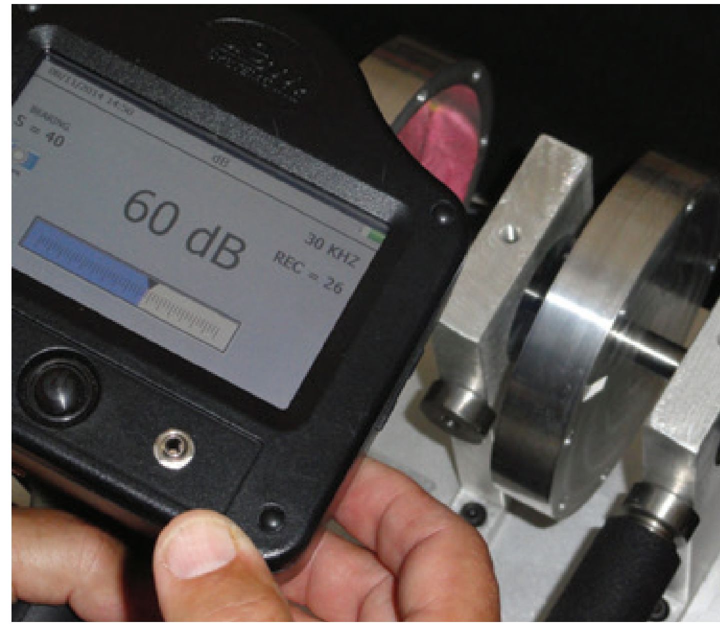

Figure 5: Bearing trainer (bearing #3) 60 decibels with magnetic sensor slightly nudged in another direction

magnetic poles facing up (red dot) on the target mounting pad of a bearing trainer (bearing #3). Figure 5 is the same instrument set at the same frequency and sensitivity, but the sensor is slightly nudged. Notice the difference in decibels.

Although the bearing training unit only shows a nine decibel difference, motors in a plant may vary much more. A nine decibel difference may not seem like much, but imagine preparing for a weekend off and you get a call that overtime has been approved for you to change a critical motor in production that just registered that bearing in the catastrophic range. Had the sensor been positioned for decibel reading and sound quality, there may not have been a difference. That being said, you should never try to manipulate your findings to the lowest possible decibel. However, you should place the magnet on the target and position it for a decibel number and sound quality before storing your readings.

When trending bearings, whenever decibels increasingly go up, no matter which sensor (contact probe or magnetic base sensor), there is a reason. Whether it's general wear or lubrication, it is an indicator of action to be taken. Unlike with vibration, ultrasound depends on the amount of decibels for condition. However, plants with vibration technology on hand should use the ultrasound decibel indication as a time to then use vibration as a final or complementary technology.

With regards to acoustic lubrication, most technicians that are engaged in acoustic lubrication use magnetic sensors. Many are not briefed on the importance of placement for consistent readings. As such, many take readings too far from the bearing's outer race. Others may place the magnet in a position closer to the bearing, resulting in a much greater decibel reading then the previous person who took the reading too far away. As the saying goes, always compare apples to apples and oranges to oranges.

Let's quickly review:

- Be sure the target mounting pad is free of dirt and grease.
- Be sure placement is near the bearing for consistent readings.
- Be sure the pressure placed on the contact probes is consistent among all ultrasound technicians by practicing on a shop grinder or motor.
- After placing the magnetic sensor on the target, position the magnet by rolling the sensor onto the surface.
- Keep readings consistent by watching the decibel and listening for sound quality.

To some, these suggestions may be just common sense, however, new employees may be using the equipment for the first time and are not aware that the placement of the sensor can make a big difference. Or, as what happened in a recent class, several seasoned mechanics were not aware of the importance of the positioning and/or pressure needed on either the contact probes or magnetic sensors.

***Jim Hall** is President/Owner of Ultra-Sound Technologies (UST). Jim has been in the ultrasonic market for over 25 years and has trained employees in many Fortune 500 companies in the use of airborne ultrasound. He has attended over 250 conferences, seminars and lectures on the use of airborne ultrasound and predictive maintenance. http://ultra-soundtech.com/*

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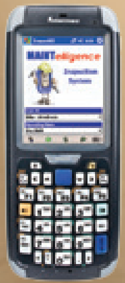

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How Efficient Communications are DAMAGING Projects

By Russell Harley

This may sound difficult to believe, but it can be true. In the definition of *efficient*, we find the following: "achieving maximum productivity with minimum wasted effort or expense." While this is great for busy executives and companies, it is terrible for projects, especially when it comes to communicating about the project with others.

How many meetings have been held where the participants arrive late, have another meeting so they need to leave early, or just want a 15-minute review of what is going on? While this can certainly meet the definition of efficient, it completely ignores the underlying need for the time to communicate the real issues/challenges for a project. If the project is of great importance for a business, then the leadership/sponsors involved should be willing to actually make time for an in-depth review on a regular basis. Don't believe this?

In the *International Journal of Computer Applications (0975 - 8887) Volume 86 - No 6, January 2014*, a research paper titled "Project Failure Case Studies and Suggestion" was published by Nilofur Abbasi, et el. (http://research.ijcaonline.org/volume86/number6/pxc3892696.pdf) In section 2.1, the authors state that, "Senior management must prioritize requirements and make decisions. If any person is not actively involved in a project, that project is doomed for failure." They go further in the same section saying that unclear project objectives, scope creep, gaps in communications, and lack of visibility of all projects are additional causes of project failure.

The sad thing is, none of this should be news to anyone. All of these causes can be traced, directly or indirectly, to people trying to communicate too rapidly and concisely. The fact that these reasons are still being highlighted in 2014 indicates that people are not willing to address them in order for projects to succeed. Basically, we know what we need to do, but choose not to.

Imagine this scenario. Your family is having a crisis of some kind. Maybe you and your spouse are not communicating as much. Or misunderstanding each other more and it is causing major issues. If you want things to get back on track, do you want to spend just 15 minutes of your day or week trying to fix things? If you are serious, you take the time, like hours, maybe even a weekend, to discuss what is wrong, best ways to fix it, and how to move forward better. Doesn't that sound very similar to what companies need to do to fix critical projects that are in trouble?

Yet project/program managers feel lucky if they get a full 30 minutes with leadership/sponsors on a regular basis. Much less the hours with the full team that is really needed. To cover all the decisions, risks and issues in depth is typically out of the question. This is because these items are needed to be reviewed as efficiently as possible so everything can at least be addressed. Otherwise, you get comments like, "Why was this not brought up in our last meeting?" While not helpful to long-term employment, maybe a response of, "You were too busy to listen," would underscore the real issue.

There also seems to be some misunderstanding between *efficient* and *effective*. They do not mean the same thing at all. You can have very effective communications that are also efficient, but being efficient does not necessarily mean communication will be effective. Very often it has the complete opposite effect.

> You can have very effective communications that are also efficient, but being efficient does not necessarily mean communication will be effective.

There have been meetings where everyone has agreed on a plan of action, even documented, and then a week or two later things are off track again because party A misunderstood a decision or plan. This is one reason that the Project Management Institute's project process requires so much documentation (which no one reads once approved, but that is a different communication issue). The talks involved in determining what goes into the Charter, Scope, etc., has to have lots of discussions. So having to cover similar topics over and over again about the project at least can get things better understood by repetition, if nothing else. Even if the repetition is only in 30-minute segments a week.

Then we have the challenge of adding additional communication steps into the mix. While you might be able to have efficient communications with person A, this does not mean A will have good communications with B. This is common when sponsors say, "I am too busy to handle this project so Joe/Sally/anyone else but me will handle everything from now on." While, hopefully, whomever they delegate to may have more time to communicate, this does not mean that they can have any more time with the sponsor than was already available to the project/program manager already. Yet we now have an additional person(s) to communicate with.

The other challenge with delegation is that the delegate may not have the full authority to make decisions for the project. While this official transfer of authority does not happen very often, when it does AND the delegate does have the time to spend with the team to have in-depth conversations, it can have an amazing impact on a project. Unfortunately, most of the time, the delegate is just there to take notes and have to check with the sponsor for any decisions. This just adds to the communication difficulties and the time involved versus being helpful, at least to the project, anyway.

So how did we get here and what can we do about it? Shortened communications started with trying to communicate over long distances using flags, smoke signals, etc. Today we have Instant Messaging, Twitter, etc. If people could figure out how to communicate well with just using a single letter, we would be doing it. It has become a source of pride to see how much can be said with just 140 characters.

This seems to have been extended into the work place as well. Even to emails with answers like, "Yes" to questions like, "Do you think we need to extend the due date or add more people to the task? "While one could make the assumption that the 'Yes' applies to the first part, 'extend the due date,' that assumption could lead to even more issues if that assumption turns out to be wrong. So to be sure, and project managers really like to be sure about dates and resources, additional back-and-forth emails are now needed to gain clarity. Not efficient by any means.

Is communicating quickly and with minimal content efficient? Yes. But it is not a way to communicate well by any means, not without a lot of effort. How many 140 characters are needed to cover a complex task or decision to the point where everyone has a clear understanding? And that is the bottom line. To communicate well, time needs to be spent so that the content is clear and understood by all. Without that, 10 years from now we will still be reading about why projects fail and have the exact same list of reasons as to why.

__Russell Harley,__ PMO, is a veteran project manager and PMO director, passionate about helping organizations embrace world-class project management practices and "climb out of the quicksand" in terms of gaining control over complex, ever-changing project portfolios. The best practices he advocates stem from key learnings acquired from his M.S Degree in Project Management, combined with over 20 years of hands-on PM experience in the high technology, telecommunications, and clean energy sectors. http://thepmoview.com

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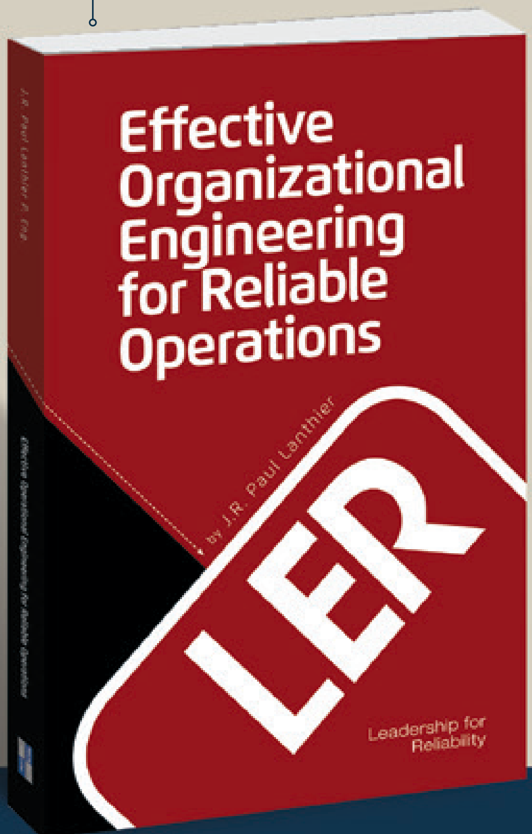
Kitting in Maintenance
Made Simple
by Daniel DeWald and Jeff Shiver

Kitting is a method to ensure that work orders are released for work execution with the necessary materials or parts to perform the work. This book discusses in detail the kitting model for maintenance that is the basis for a successful program.

Effective Organizational Engineering for Reliable Operations
by Paul Lanthier

This book describes how to define a best in class organization and develop the necessary skills within your team. We discuss how to develop meaningful meetings and KPIs and how to use these to engineer an efficient and effective organization that is sustainable and evolves with your needs and level of maturity.



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Q&A with two Industry Leaders

Nissan North America

"THE POWER COMES FROM INSIDE."

This simple phrase familiar to every Nissan employee conveys a powerful truth. Any company is only as strong as the people who bring it to life. Companies do not create products, deliver services or solve problems; people do.

Uptime Magazine recently caught up with Mary Jo Cherney, Manager - Total Productive Maintenance, and Matt Breedlove, Reliability Maintenance Supervisor - Predictive Maintenance Lab, from Nissan North America to discuss how they came to Nissan and how they are working towards Nissan's mission: To enrich people's lives, building trust with our employees, customers, dealers, partners, shareholders and the world at large.

Q: What is your career background – where did you start?

Mary Jo: I began my career as a high school business teacher. When I received my MBA, I shifted my focus to higher education and became a faculty member at Lorain County Community College in Elyria, OH. That led me to a long career as a consultant in process improvement, organizational development, six sigma and continuous improvement. I was hired as a Division Manager of a steel company in Cleveland, OH and that led me to Nissan.

Matt: I started at Nissan back in 1994 as a production technician working on the assembly line. I did that for 7 years and then put in for the maintenance apprenticeship program. I was accepted and worked in the trim & chassis maintenance department for a little over 10 years. I then transferred to the reliability group as a technologist in 2011 and received certification in infrared thermography, lubrication (MLT) and motor testing (MCE). This past January I was promoted to supervisor over the predictive maintenance lab.

Q: What are some of your personal career highlights to date?

Mary Jo: Helping the Maintenance, Engineering, and Utilities Department in the steel mill in Cleveland to win the "Bronze Award" for TPM. Additionally, passing my Certified Reliability Leader from the Association of Maintenance Professionals and my CMRP from the SMRP organization. Lastly, being a co-author on a book about Visual Management with the former head of Global TPM at ArcelorMittal Steel.

Matt: I believe just finding problems using the predictive tools we have to find problems before they happen or anyone else is even aware of the problem. The area responsible is able to be notified and the repair is planned instead of the downtime occurring during production. Avoiding downtime is an accomplishment for the PdM group. Also getting my CMRP certification was a highlight for me.

Q: How did you come to be in your current role at Nissan?

Mary Jo: I was hired as a manager in Nissan Production Way. My former boss moved me to the Manufacturing Engineering Department to work more closely with the Global Maintenance Reliability department. I added the management of the GMR department to my TPM responsibilities a year or so ago.

Matt: I was promoted from reliability technologist to supervisor over the predictive maintenance lab.

Q: You are hosting the Certified Reliability Leadership and a plant tour in October, so obviously you value continuing education. What advice could you give the Uptime readers regarding their educations?

Our reliability program is centered around continuous improvement in the manufacturing of our vehicles through thorough cleaning, inspection and the use of technologies to reduce and eliminate production losses.

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Mary Jo: Being a former teacher, I understand the value of life-long learning. Take advantage of all the training that your company offers. If you are the head of a company, training your employees is critical to the success of your company. The old philosophy "if we train our people, they will leave," needs to have a funeral and be buried in our world of extreme competition! Education is one of the major components of success!

Matt: Always look for new ways to prevent downtime of your asset and continuous education on the equipment you are looking at. The machinery is always changing, so should you.

Q: Your title is Manager – Total Productive Maintenance. There have been many differing views of TPM over the years. What is your vision of TPM?

Mary Jo: TPM is an operating system that drives improvement in all facets of a company. Only the very best of the best companies run their organization by TPM. My vision is to have TPM and its methodologies engrained in every employee at Nissan. We have a foundation in the Nissan Production Way philosophy and I will just continue to fortify that philosophy.

Q: Your title is Supervisor - Reliability Maintenance Supervisor - Predictive Maintenance Lab. There have been many differing views of Predictive Maintenance over the years. What is your vision of Predictive Maintenance?

Matt: I think predictive maintenance is key to keep the machinery running efficiently and productively. To be successful here it is vital to have the equipment available and running properly to produce a high quality vehicle. If we can detect problems and have them repaired before they start affecting the performance, that's our goal.

Q: Why do you think TPM has been successful at Nissan?

Mary Jo: We have seen the results in improved safety, lower downtime and increased productivity. Once you can show dollars, the program will take off. We have given a voice to all employees. We also improved communication and coordination between maintenance and operations—they now work well together. The employees love it because their equipment runs when it is supposed to run!

Q: Why do you think Predictive Maintenance has been successful at Nissan?

Matt: Our department is growing and we are continuously finding problems earlier and expanding to more equipment. We measure our success by downtime avoidance. Those numbers continue to grow.

Q: Any final advice you could provide for the Uptime readers related as to how to be successful with their maintenance and reliability strategies?

Mary Jo : As Jim Valvano stated in his acceptance speech for the Arthur Ashe Courage Award, "Don't give up, don't ever give up!" That is the attitude you have to have about Reliability and Maintenance strategies. Many of you will become change agents for your company! You must plan and implement with rigor and untiring enthusiasm. As a reliability professional, you must be the evangelist of improvement within your organization. Don't expect results overnight—realistically it can take 3 – 5 years to fully implement. The journey is worth it. When you embrace this philosophy, you will be successful!

Matt: Having support from upper management is key. Provide a business case to show the value. Continuous education and know your equipment and its failure modes.

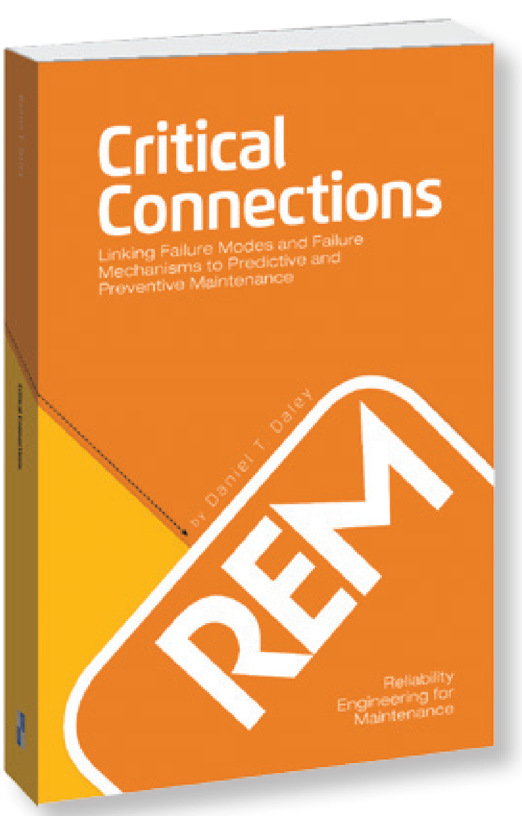
In 2012, Smyrna Assembly Plant received the John R. Battle Award for Excellence in Machinery Lubrication

Critical Connections

Linking Failure Modes and Failure Mechanisms to Predictive and Preventive Maintenance

Written by Daniel Daley • Reviewed by Joel Levitt

In this short book, Daniel Daley strikes again. With dozens of real-life examples, he makes a case for linking failure modes and failure mechanisms to predictive (PdM) and preventive maintenance (PM), which happens to be the subtitle of this book.



His model of four mechanical failure mechanisms – corrosion, erosion, fatigue and overload – appeals to me. Failure mechanisms are in the environment, therefore, the reliability of the equipment is directly linked to the effectiveness of the components and subcomponents to resist these mechanisms. These failure mechanisms cause the specific failure mode, which causes a specific loss of function of your asset.

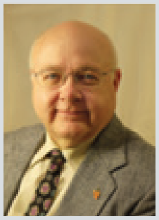
This is a useful book, especially for those people wrestling with how to populate a computerized maintenance management system (CMMS) or how to instruct people to fill out the work order. Daniel has simplified and clarified an area that has seen confusion and contradiction, even in the literature. In addition to a data collection model, he shows the advantages of using the data for troubleshooting, diagnosis and especially defect elimination leading to continuous improvement.

He values PdM in noting, "The value of predictive maintenance is that it prompts an action that will prevent a failure and restore the inherent reliability of the asset." He apparently, and correctly in my view, includes traditional human senses inspections in PdM.

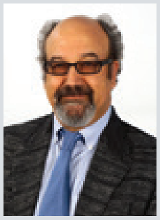
Daniel has laid the groundwork for a more consistent definition of the relationship between predictive maintenance and preventive maintenance. Up to this point, PdM has been appropriated by equipment vendors. However, Daniel's definition moves PdM back in alignment with common practice and the dictionary.

His definition and usage of preventive maintenance recognizes it as a fundamental and intrusive activity (that actively restores reliability and has hopefully avoided the failure) that has its own infant mortality associated with its usage.

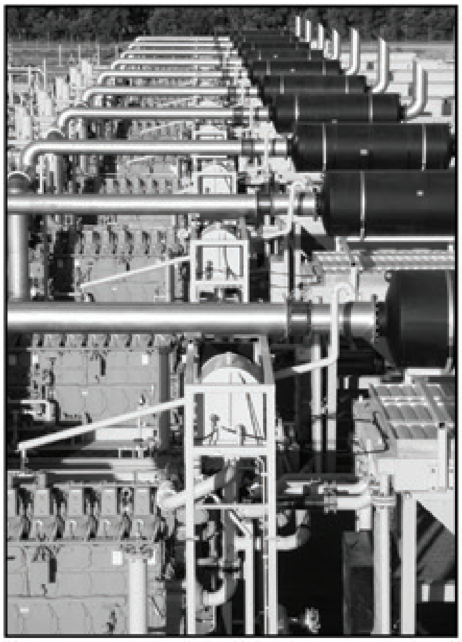
The book includes some useful appendixes, a short index and a complete table of contents.



***Daniel Daley** has been the owner and principal of My Reliability Team (MRT) since 2008. Mr. Daley has spent the majority of his nearly 42 year career working in a variety of roles in the refining and process industry. While the last fifteen years have been focused primarily on the areas of reliability engineering and maintenance excellence, he has had extensive experience in operations management, project management and maintenance management in roles at both the plant and corporate levels.*



***Joel Levitt** is the Director of International Projects with Life Cycle Engineering (LCE). He has over 30 years' experience in the maintenance field, including process control design, source equipment inspection, electrical expertise, field service technician, maritime operations and property management. A recognized expert at training maintenance professionals, Joel has trained more than 17,000 maintenance leaders from 3,000 organizations around the world.*



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