UPTIME MAGAZINE

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april/may 14

for maintenance reliability and asset management professionals

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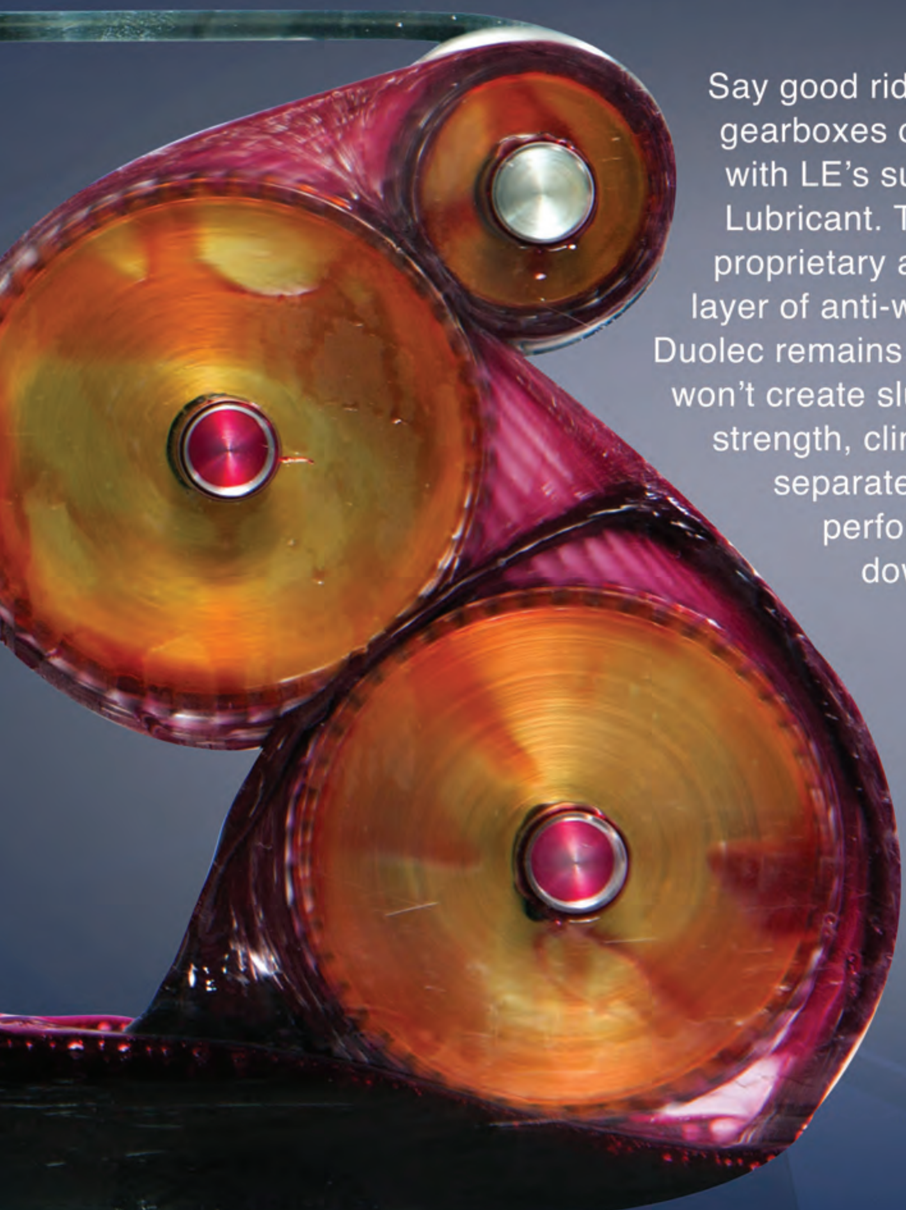

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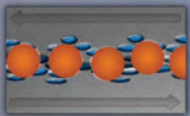

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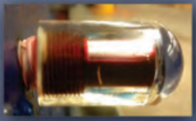

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ISO 55000 for Managers: Developing the Strategic Asset Management Plan	Leaders who are implementing an ISO 55000 initiative, including middle managers from across the organization	Identify the benefits and clauses of the ISO 55000 standard, develop 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.	Jun 10-11, 2014 (CHS)	2 consecutive days 1.4 CEUs	$1,495
Lean Maintenance (Delivered by Joel Levitt)	All levels of maintenance personnel, including Supervisors, Planners, Managers, Engineers and Maintenance Workers	Effectively eliminate waste in maintenance operations and projects, and use tools and processes to create a Lean organization.	Aug 5-7, 2014 (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.	Apr 8-10, 2014 (CHS) Sep 30-Oct 2, 2014 (CHS)	3 consecutive days 2.1 CEUs	$1,495
Maintenance Planning and Scheduling	Planner/Schedulers, Maintenance Supervisors, Maintenance Managers, Operations Coordinators, Storeroom Managers and Purchasing Managers	Apply preventive and predictive maintenance practices. Calculate work measurement. Schedule and coordinate work. Handle common maintenance problems, delays and inefficiencies.	May 12-16, 2014 (CHS) Jul 21-25, 2014 (CHS) Sep 15-19, 2014 (HOU) Nov 3-7, 2014 (CHS)	5 consecutive days 3.2 CEUs	$2,495
Operator Care (Delivered by Joel Levitt)	Production Supervisors, Operations Managers and Personnel, Maintenance Supervisors and Personnel, Team Leaders, Lean Implementers	Improve production performance and asset reliability with an Operator Care program. Make data-driven decisions to create effective Operator Care tasks and achieve operational stability.	Sept 9-11, 2014 (CHS)	3 consecutive days 2.1 CEUs	$1,495
Planning for Shutdowns, Turnarounds and Outages (Delivered by Joel Levitt)	Members of the shutdown or outage teams, planners, plant engineers, maintenance engineers	Save time and money on your next shutdown by learning how to effectively plan for and manage such large projects. Learn processes and strategies for optimal resource allocation.	May 20-22, 2014 (CHS) Oct 21-23, 2014 (CHS)	3 consecutive days 2.1 CEUs	$1,495
Predictive Maintenance Technologies (Delivered by Keith Mobley)	Plant engineers and managers, Maintenance, Industrial and Manufacturing Engineers, Maintenance Supervisors and Managers	Collect and analyze data to assess the actual operating condition. Use vibration monitoring, thermography and tribology to optimize plant operations.	Apr 22-24, 2014 (CHS) Jun 24-26, 2014 (CL) Sep 9-11, 2014 (CHS)	3 consecutive days 2.1 CEUs	$1,495
Problem Solving	Front-line Supervision, Quality Personnel, Team and Business Unit Leaders, Area Managers, Support Staff, Process Operators	Select and apply effective problem-solving methodologies and resolve problems that limit performance using five data analysis tools.	Aug 19-21, 2014 (CHS)	3 consecutive days 2.1 CEUs	$1,495
Prosci® Change Management Programs	Executives and Senior Leaders; Managers and Supervisors; Project Teams; HR and Training Groups; Employees	Build internal competency in change management. Deploy change management throughout your organization. Become licensed to use Prosci's change management tools.	Contact us to schedule a private onsite class.	Sponsor: ½-day Coaching: 1-day Orientation: 1-day Certification: 3-day	Contact us for pricing
Reliability Engineering Excellence	Reliability Engineers, Maintenance Managers, Reliability Technicians, Plant Managers and Reliability Personnel	Learn how to build and sustain a Reliability Engineering program, investigate reliability tools and problem-solving methods and ways to optimize your reliability program.	Aug 19-21, 2014 (CHS)	3 consecutive days 2.1 CEUs	$1,495
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: Jun 10-12, 2014 (CHS) Sep 16-18, 2014 (CHS) (Sessions 2-4 dates are available on the website)	12 days total (4, 3-day sessions) 8.4 CEUs	$5,995
Risk-Based Asset Management	Project Engineers, Reliability Engineers, Maintenance Managers, Operations Managers, and Engineering Technicians.	Learn to create a strategy for implementing a successful asset management program. Discover how to reduce risk and achieve the greatest asset utilization at the lowest total cost of ownership.	Apr 29-May 1, 2014 (HOU) Sep 23-25, 2014 (CL) Nov 4-6, 2014 (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.	Apr 29-May 1, 2014 (CHS) Jul 29-31, 2014 (CL) Oct 7-9, 2014 (HOU)	3 consecutive days 2.1 CEUs	$1,495

*LOCATION CODES: (CHS) = Charleston, SC | (CL) = Clemson University | (HOU) = Houston, TX | (UA) = University of Alabama

Contents

april/may 2014

54

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and asset management professionals

8

30

Features

Elements

Editorial

Asset Performance Management Takes Center Stage

IMAGINE THIS: Las Vegas - center stage – 8,000 global manufacturing, transportation, process and power industry leaders – and executive keynoters, one from Honda and one from the alternative energy power producer Infinis, mentioning mean time between failures (MTBF) and mean time to repair (MTTR) as primary metrics related to asset performance and reliability from an enterprise standpoint.

This was NOT a maintenance conference; it was IBM's Pulse 2014 The Premier Cloud Conference, an event that is focused on smarter infrastructures.

Of course, managing IT in the cloud, predictive analytics and mobile access to industrial strength apps were also huge topic themes at Pulse 2014, however, every presentation also dealt directly or indirectly with the challenges of getting people aligned for value delivery. The presenters spoke of changing the mindset of everyone in the enterprise, from equipment level to executives. Asset information management is one of the foundational elements of that effort.

This is similar to what I experienced at Bentley System's Year in Infrastructure 2013 Conference in London, where asset performance management is quickly becoming an embedded strategy for whole life value. I also experienced similar efforts at Oracle's Value Chain Summit in San Jose, where asset performance management across the entire enterprise was the focus of most of the presentations.

At Solutions 2.0 this July 28-31, 2014, in Bonita Springs, Florida, Crossrail UK and Southern Company will present on radical new approaches to effective value delivery through asset information management. At the same venue, MIMOSA will demonstrate an impressive oil and gas interoperability handover that supports asset value delivery from Capex to Opex through an expansive list of technology vendors. In just four days, you can capture a snapshot of best practices from around the world.

It is truly amazing to discover these new asset performance management technologies and practices. More impressive is to see asset reliability at the center of many of those value delivery strategies at all these major technology events.

The mission for the team at Uptime is to find and deliver information on solutions designed to make you safer and more successful as you drive more value from your assets. The rapid advance of asset performance management technology and practices evolves month to month and can be hard to keep up with. You want to change to improve value, not simply for the sake of changing.

To create and communicate a framework for asset performance and asset reliability in your own organization, we would like to suggest the use of Uptime Elements – A Reliability System For Asset Performance Management. The Association for Maintenance Professionals is now offering the Certified Reliability Leader (CRL) exam at www.maintenance.org to demonstrate your confidence and competency in this system.

By the time this issue is in your hands, you also should be able to purchase a copy of The (New) Asset Management Handbook, The Guide to ISO55000 (ISBN:978-1-939740-51-9), filled with guidance from many of the same brilliant minds who created the new ISO55000 asset management standards.

There is a perfect storm of asset performance management solutions emerging to meet the perfect storm of asset management challenges on the horizon. In addition to the technology leaders and resources mentioned above, there are dozens of others driving innovation at all levels of offerings for the enterprise.

The convergence of focus on asset performance management is simply too compelling and impactful for you to ignore. There are things you can do right now to improve asset performance at every level of the enterprise.

We hope you discover some of those solutions in the pages of Uptime or at Solutions 2.0.

If your organization is already creating results with asset performance management, please send me an email so we can begin to learn from you and your practices, as well.

Thank you for reading *Uptime* Magazine.

Warmest regards,

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

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THE (NEW) ASSET MANAGEMENT HANDBOOK THE GUIDE TO ISO55000

Reliabilityweb.com announced The (New) Asset Management Handbook, edited by Terrence O'Hanlon, CEO and Publisher, *Uptime* Magazine designed to provide early guidance on driving value from asset management and managing risk in your organization.

"The New ISO55001 Managing System for Asset Management standard is driving a great deal of interest from asset intensive organizations around the world," states O'Hanlon, "and the (New) Asset Management Handbook includes contributions from many of the same people who drafted the ISO standard including: John Woodhouse, Terry Wireman, Rhys Davies, David McKeown, and Thomas Smith.

Available at Amazon.com and at the MRO-Zone bookstore ***www.mro-zone.com***

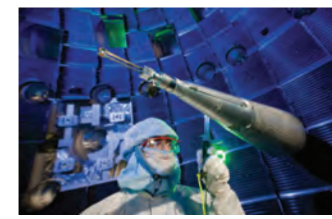
GLOBAL BENCHMARKING STUDY:

Asset Management Practices, Investments and Challenges

With the release of the ISO55000 series of standards shining a spotlight on asset management, this study is designed to reveal insights into current and future asset management practices, investment priorities and implementation challenges.

To participate in the online data collection phase of this project and to receive an advanced copy of the published study please visit: ***http://uptime4.me/1gN7ZH9***

EXPERIENCE RELIABILITY LEADERSHIP WITH PLANT TOURS



The Association for Maintenance Professionals offers a series of plant tours in order to highlight examples of reliability leadership found around the world. You read about reliability leaders in *Uptime* Magazine and online at Reliabilityweb.com but experience them first-hand in the field. Plant tours typically follow Certified Reliability Leader workshops and roundtables where attendees also have a chance to sit for the Certified Reliability Leader exam.

This two day program includes a full day Certified Reliability Leader Course, Certified Reliability Leader Exam (optional) and a reliability tour led by the team at the selected facility.

Attendees are invited to a special Reliability Leaders reception including food and drinks.

When: May 14-15, 2014

Where: Cincinnati Metropolitan Sewer District, Cincinnati, Ohio

When: June 18-19, 2014

Where: National Ignition Facility/ Lawrence Livermore National Laboratories, Livermore, California

For more details and to reserve your seat, please visit ***http://reliabilitytours.com***

Solutions 2.0 Conference

Making the best decisions possible supports maintenance reliability and asset management performance, and that requires new ways to manage asset information.

Uptime readers are invited to attend the Solutions 2.0 Conference held at the Hyatt Regency Coconut Point in Bonita Springs, Florida from July 28-31, 2014. Keynotes will be delivered from Crossrail UK, the largest engineering and construction project in Europe, and Southern Company featuring the new Kemper County energy project. This learning and networking event includes benchmarking activities, short courses, case studies, and Certified Reliability Leader exam.

SOLUTIONS 2.0 LEARNING TRACKS INCLUDE:

Asset Information Management – Making evidence-based asset management decisions to drive value.

Asset Condition Monitoring and Management - Vibration Analysis, Infrared Thermography, Electric Motor Testing, Ultrasound, Oil Analysis, Machinery Lubrication and Precision Alignment and Balancing.

Leadership – Learn the tools to bring everyone along on your reliability and asset management journey.

Early Bird registration and Team Discounts available at ***www.solutionsconference.info***

Two Best-selling Authors Keynoting at RELIABILITY 2.0 Las Vegas

Dan Roam

Dan Roam, Founder and President of Digital Roam Inc., a management-consulting firm that uses visual thinking to solve complex problems, and is the author of the international best seller, "The Back of the Napkin: Solving Problems and Selling Ideas with Pictures."

Wednesday, April 9 • 8:00am

RELIABILITY 2.0 Las Vegas

Garrison Wynn

Motivational speaker and best-selling author of "The Real Truth About Success," Garrison Wynn will help you make the jump from being really good at what you do to being consistently chosen to do it.

Thursday, April 10 • 8:00am

Reliability
Through Correlation and Collaboration
between Maintenance, Operations and Reliability Improvement Technologies

by Chad Broussard & Alan King

Reliability can cover a broad range of policies, guidelines, assets, strategies, systems and technologies. Energy manufacturing and logistics company, Phillips 66, has the upmost commitment to safety and operating excellence, which includes personal and process safety, environmental excellence and reliability. That commitment led us to develop a reliability program that not only manages equipment health at one site, but effectively and successfully operates assets across approximately 11,000 miles of pipeline. We included 144 pump stations and 22 product terminals of the total assets across the United States. Phillips 66's transportation business relies on a customized, integrated reliability approach, which uses a proactive maintenance model to identify defects in assets. This approach optimizes the return on asset reliability by maximizing utilization in a way that is cost effective – making good business sense.

Over the past two years, we have listened to our internal customers, including division managers, engineers, supervisors, rotating equipment leads, and technicians, through a careful national survey of each transportation operating division management, compiling a list of reliability needs weighted by cost and potential savings. From this analysis, we formed a reliability team consisting of division rotating equipment leads and subject matter experts to analyze data from our enterprise asset management (EAM) system, complete a high-level gap analysis, and implement a condition monitoring program using vibration analysis to build the foundation for what we consider to be a world-class maintenance reliability program consistent with our corporate focus on safety and operating excellence.

Gap Analysis and Benchmarking

We conducted a benchmark gap analysis comparing Phillips 66 to the overall oil and gas industry in 40 elements of the business, across each regional division. These elements were divided into four major areas - maintenance strategy, work identification, work control and work execution. The gap results helped to guide the design of the reliability centered maintenance (RCM) program, framework and structure, including the Reliability Policy and all necessary elements to enhance the program over the next five to seven years. To ensure we apply organizational expertise, leadership and division management continue to develop and review the reliability policy draft while the team continues to build out each area with guidelines, procedures and specifications.

All of this information, technology, programs and systems have evolved to form the foundation of the Phillips 66 Reliability Program. This initiative examples our

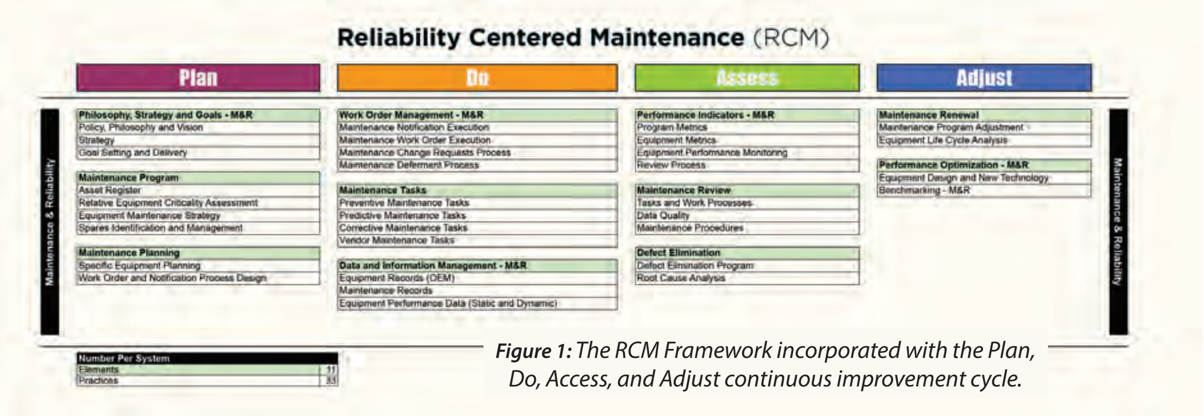


***Figure 1:** The RCM Framework incorporated with the Plan, Do, Access, and Adjust continuous improvement cycle.*

Figure 2: Oil Tanker Unloading

proactive culture around reliability which aligns with delivering profitable results.

Figure 1 is an overview of more than 30 elements the team is focusing on and incorporating into the Phillips 66 Transportation Reliability Program.

In an industrial environment that includes manufacturing facilities, pipelines, plants and refineries, Phillips 66 has an assortment of tools, technologies, processes, and most importantly, resources. Within this diverse environment, we are united by a central goal to run a safe and efficient business. As a result, we implement well-developed policies, strategies and business plans to enable improvements each day and improve our quality and reliability.

Development of Condition Based Monitoring and Maintenance (CBM)

In addition to specifications, training and technicians in place, in 2011, the company added a team consisting of a reliability engineer, rotating equipment subject matter expert (SME), and rotating equipment leads from each division to study alternatives in implementing a new vibration program.

The company used a three-phase approach. The first phase was to partner with an outside vendor that had the needed technology and support, including external manpower to collect vibration routes, analyze the data, and report back for corrections and improvements. A detailed and thorough business case helped to keep the team on track with parameters for the amount of equipment that could be monitored and a tight accounting for equipment justification and data collection frequency.

Currently, Phillips 66 Transportation has more than 700 drive trains in the rotating equipment vibration program. Across the pipelines and pump stations, the company has two mainline pumps at each pump station, which are about 50 to 75 miles apart. A "boots-on-the-ground," or manual, vibration data collection strategy would require driving 200 to 300 miles a day visiting three or four pump stations and collecting vibration readings on six mainline pumps. This demonstrates commitment of significant time and labor compared to most industrial plants where the average technician can cover approximately 100 pieces of equipment in an eight-hour period.

In the second phase of the program, the team set up external cloud servers where data is uploaded and made available from any computer in the country. The team also purchased vibration data collectors for each division to supplement the vendor's quarterly vibration routes, and provided training on the software, data collectors, and five remote online vibration suitcases for advanced data acquisition. For example, the vibration levels of rotating equipment are directly related to many factors, including the time the data is gathered. So the team created Class 1, Division 2-rated remote suitcases. These suitcases can be deployed over long periods of time to capture vibration data that may not be seen during a normal route.

The third phase was a two-step process. The first step involved utilizing our data historian and process control system known as SCADA (supervisory control and data acquisition) to acquire analog data from transmitters and programmable logic controllers, which is transmitted via satellite to the control center. The data is then pushed from SCADA to ProcessBook (aka PI). Once the data is in PI, it is available to all SMEs to correlate seven key parameters, like vibration, suction, discharge, case pressures, con-

> We are united by a central goal to run a safe and efficient business. As a result, we implement well-developed policies, strategies and business plans.

Figure 3: *Large vertical pumps are often used at our Terminal Tank Farms to handle the net positive suction head (NPSH).*

trol valve percentage, run status and temperature. Using this data, Phillips 66 Transportation can correlate how a piece of equipment is being operated and how the operation is affecting the monitored asset's physical and mechanical state. All of this information is imparted through the overall vibration velocity (0-.8 in/sec.).

We can then utilize the remote vibration suitcases to accurately help diagnose the vibration data. The suitcase has eight channels to take readings from eight different measurement locations. This allows us to capture spectral and waveform data through cellular technology, and transfer that data to the cloud server for analysis and reporting. It also allows us to understand whether an operational technique is causing the vibration or performance anomaly. In that case, the Operations Control Center can help the pipeline controllers develop the awareness needed to operate the pipelines at the best efficiency point (BEP) on the pump curve, delivering optimum reliability.

In the second step of Phase Three, the team is beginning to populate equipment characteristics into a rule-based decision support software. This will help accurately diagnose equipment faults and correlate the severity. Alarms are designed to alert if a vibration level breaches its set points. In effect, this software speeds up the learning curve for internal technicians.

Figure 5: #1 Mainline Pump Before/Analysis Phase (illustration) and After Modifications.

Staying up-to-date is challenging; this complex asset reliability program will be ever-evolving. The company is using new technology and a qualified partner to ensure the program is a success. For example, web-based vibration programs show green, red and yellow status indicating the alarm statuses along pipeline segments that make up our pipeline and terminal divisons. These alarm set points are measuring the several key parameters.

Return on Investment
(KPI Metrics)

The financial results from the condition based monitoring (CBM) program produced a powerful success story. The contract cost of the program resulted in a $2 million maintenance cost reduction in 2013, yielding a ROI of 250 percent.

> The proactive approach has also realized savings through "cost avoidances" by catching rotating equipment anomalies before they failed.

The proactive approach has also realized savings through "cost avoidances" by catching rotating equipment anomalies before they failed. This avoids the tremendous burden of expediting necessary parts and labor to get the repairs completed, not to mention any lost profit opportunity (LPO) occurrences that could apply in certain situations.

Evaluating the Results

The results show a conservative estimated savings of $1 million in cost avoidances, including $500,000 at one refinery that avoided an LPO. The cost avoidances are defined as early fault detection that helps prevent costs associated with failing equipment. All of the divisions experienced savings. Highlights include:

- **Pump Station 1:** Spectral data on an electric motor showed looseness and imbalance in rotor assembly, and misalignment across the coupling. The rotor cage had actually shifted in the core and the rotor was loose on the shaft. Because CBM - vibration analysis detected the problem, the repair cost was only $21,000 instead of the typical $120,000.
- **Pump Station 2:** Spectral data and temperatures indicated a problem with the outboard bearing. Operators shut down the pump, repaired flat spots in bearings and polished the shaft at the site. Temperatures dropped 15 degrees and the vibration returned to normal, yielding a repair savings of $60,000.
- **Lubrication Program:** In performing our analysis, the team found cases of "wrong oil for the application" issues. The discovery and resulting decisions resulted in a one-time savings of more than $100,000.
- **Operational Deflection Shape:** In addition to savings, the program has driven innovation. Over the past couple of months, Phillips 66 Transportation has utilized a technology known as operational deflection shape, which offers visibility on how equipment or structures move based on vibration amplitudes and phase angles.

A mainline pump was experiencing higher than desired levels of vibration after installing a new foundation and motor, as shown in the data. The divisions worked together to identify a structural resonance on the pump frame support legs. These modifications were applied as reinforcement endplates to add stiffness to the pump, as shown in Figure 5. This single analysis lowered the vibration levels from .27 in/sec. velocity to about .05 to .08 in/sec. This was a reduction in vibration levels of more than 80 percent, which eliminated the nuisance of alarm trips at the pump station. The reduction in vibration also improves reliability and eliminates equipment component wear on seals, bearings and couplings.

Figure 6 shows a temporary engine installed at a Pump Station. The discharge piping was experiencing vibrations between six inches per second and 10 inches per second, depending on the pump's operation. Steel normally starts to break with vibration levels that exceed one inch per second. The rotating equipment lead and local team quickly utilized a vibration suitcase device, Figure 7, that monitors the vibrations every five to 60 minutes. The data was tracked from a wireless device and the team got vibration updates from a cloud server. Today, the vibration has been reduced to .3 inches per second and the team has decided to bury the piping underground to re-

***Figure 6:** Skid mounted engine and positive displacement pump.*

Figure 7: Mobile vibration suitcase

move the resonant vibration frequency from the associated discharge piping, see Figure 8.

We continue enhancing our condition monitoring program with web-based reporting and vibration reports, mainline pump vibration alerts and key performance indicators to keep us abreast of any vibration anomalies the equipment experiences along approximately 11,000 miles of pipeline.

Conclusion

Phillips 66's investment in asset reliability is yielding significant savings. Asset reliability is helping the company avoid costly repairs and reap financial savings through utilization of a system that is integrated in operational excellence. In addition, utilization and production is driving revenue through increased capacity.

Operational asset reliability improves asset availability, performance, and quality. These improvements create more capacity for the organization, while supporting the company's commitment to safety and operating excellence. Moreover, as we see it, the efforts in optimizing the return on asset reliability have helped position Phillips 66 Transportation as a leader in pipeline and terminal operations.

Figure 8: *The picture shows the completed modifications with the buried piping and a discharge dampener (orange) installed on the end of the piping. You can also see the accelerometers with yellow cables mounted on the piping linking it to the mobile suitcase.*

Chad Broussard, *CMRP and Sr. Staff Engineer, Reliability for Phillips 66, is known for his work in the areas of Maintenance & Reliability Engineering, Culture/Change Management, and Program Implementation abilities across several different industry sectors. Chad has worked in the chemical, paper, air/gas, and oil/gas industries. An Industrial Engineer by education, he also sits on the board as Vice Chairman of the Houston Chapter of the Society for Maintenance and Reliability Professionals and is an active member of SMRP.*

Alan D. King, *SME, has worked for Phillips 66 Pipe Line Co. for 25 years. Since 2008, Alan has had the role as Rotating Equipment SME. In this role, his focus is on rotating equipment standards, maintenance, reliability, vibration analysis and project support for the pipeline assets. Prior to this assignment, Alan has worked as a Reliability Specialist, Rotating Equipment Lead and Senior Technician.*

Amazing Risk Management

by Sam R. Harkreader

Managing risk is like working a maze, the kind you find in puzzle books.

Each maze has a beginning and an end, and often rules are applied. It would be unwise to begin a maze without first learning the end point and the rules of the game. If the rules allowed you to simply pick up your pencil and jump to the end, the game would be simple, albeit not very fun. If, on the other hand, the rules required you to start at the beginning, not lift your pencil and not backtrack, the game would be more difficult and challenging. Clearly, the strategy for winning differs based on the rules.

Similarly, everything you do in the workplace is for a reason: achieve the objective better than your competition. Avoiding penalties is helpful too.

Typically, people seek the path of least resistance within the rules until they reach their objective. As they work their way through the maze, they are sometimes met by walls that halt their progress. Just as there are consequences when choosing the wrong path in a puzzle maze, there are consequences in the workplace for making the wrong choices. Consequences are often predefined by the rules of the game. If the rules allow us to continue playing after a misstep, we get up, brush off and continue on.

Working many mazes throughout their lives, people have learned lessons

and developed strategies that work best for them given their circumstances. Implementing improved strategies improves their chances of success the next time. There are some basic strategies that tend to work for everyone. For example, when the maze is small, we may look ahead and see the entire solution. In this case, we just trace the path and we're done.

In some cases, you misstep and find yourself at a dead end, just as you do in the workplace. If the rules allow backtracking, you can do that, but it often comes with a penalty. If the rules do not allow backtracking, a misstep can make the difference between success and failure.

As the maze becomes more complex, your strategy must adapt. One option is to work forward from the start and backwards from the finish in hopes of finding an intersection. Combining the two paths, you can see the entire route, greatly improving your odds of success.

When the maze is even more complex, your mind becomes saturated before you see the entire route and your odds of success decline. With a more complex maze, your strategic options narrow and you must take on more risk as you start moving towards the goal point. If the rules allow, you may find it helpful to take extra time for a look ahead and conduct an analysis to minimize having to backtrack to correct errors.

It is common to look ahead as far as you can and then take cautious steps towards your objective, maintaining a clear focus to avoid errors. Everyone makes calculated decisions and inch towards the objective as they scout for traps. Unlike the previously stated strategy, factors may prevent us from connecting the start path to the finish path in one stroke, forcing us to progress with less certainty of the entire route. As we approach the end point, we may choose to add another strategy. For example, we may shift our eyes to the end and then work backwards until we see a clear path to our current position. In this case, we've combined strategies, something we also do in the workplace.

Since your risks are relative to your objectives, you must first clearly identify your objectives. In order to do so, ask yourself,

When the maze is even more complex, your MIND becomes saturated before you see the entire route and your odds of success decline.

"What am I trying to accomplish?" When risks are associated with a project, you may find it helpful to create an objective-based work breakdown structure. For each objective, ask yourself these two questions: "What event might prevent me from achieving this objective?" and "How will I know when this event occurs?" Log your answers to these questions; they will serve as an initial comprehensive list of risks, each of which deserves a response.

For each risk, you can conduct a qualitative analysis, followed by a quantitative evaluation. A qualitative analysis provides an initial screening of the risks so you know where to focus your resources. Starting with the more critical risks, you can continue with a quantitative evaluation of each risk to determine the impact each may have on your stated objectives.

You can analyze your risks by reviewing history and other special data. History in incident reports, vendor service records, production records and maintenance records can identify trends or correlations. In addition, data from project plans, production plans, economic forecasts, workforce availability, etc., can provide additional clues that can help you predict the outcomes of your plans. Analysis may compel you to develop risk response plans and integrate them into your overall implementation plans.

The impact of each risk can be measured according to one or more acceptance criteria. In other words, if you order a red car with four wheels to be delivered in one month, you have specified three criteria, each of which can be used to evaluate risk. For example, you could receive a blue car instead of a red car, or five wheels instead of four wheels. The implication of receiving a blue car with four wheels is quite different from the implication of receiving a red car with five wheels. For this reason, each attribute also needs to be weighed relative to one another. Again, the objective must be clear.

The acceptance criteria become risk factors. If you make risk response plans that improve the net impact to these factors, your risk management efforts are value-added, otherwise they are not.

A look ahead in the workplace can help you make more reliable decisions and take action that counts, just as looking ahead while working a maze can help you reach the end without backtracking.

All your objectives have risk factors, so a risk management system that evaluates risks relative to those risk factors will provide the best risk response plan. Current risk management systems are not ready, but technology advances on the horizon indicate that risk management systems will provide breakthrough opportunity in the years ahead.

The risk management paradigm will change. Someone will lead.

__Sam Harkreader__, founder of Paradigm Piliot, works in the petrochemical industry and is dedicated to exploring new concepts and changing paradigms for improvement. Sam's roadmap in the petrochemical industry starts at the ground level. He earned a B.S. in Industrial Technology from Lamar University.

7 questions to ask when analyzing your assets

1. What are the functions and performance associated with the asset's standards in its current operating context?
2. In what ways does it not perform its functions?
3. What is the cause stopping it from performing its function?
4. What happens when each failure occurs?
5. What is the impact of each failure?
6. What can be done to predict or prevent every failure?
7. What should be done if adequate work could not be performed before the failure?

Myths of RCM Implementation

PART 1 of 2

Reliability centered maintenance (RCM) focuses on identifying what should be done to assure the functions of a system or asset in a safe, cost-effective and reliable way. RCM analysis is carried out by a group of experts, called the analysis team, for the equipment, asset, or object of the study. It is their responsibility to answer seven questions (above) about the asset being analyzed.

by Carlos Mario Perez Jaramillo

RCM is the most effective, quick and cost-effective methodology for defining maintenance plans for assets, but today, many organizations are dedicated to creating excuses on why not to implement this method and have instead blamed RCM, creating a series of myths. The time spent in making excuses could instead be invested in successfully executing RCM.

The aim of this article is to refute the most common myths about RCM, with the assumption that any organization that has successfully applied this methodology has not identified any negative aspects and has received only the benefits of proper implementation.

MYTH 1: RCM means reliability centered maintenance because it helps to improve mean time between failures (MTBF).

The word reliability in RCM refers to a series of concepts, attributes and demands that together allow an organization to feel satisfied with its performance.

The most known concept to define reliability is: "The probability that an equipment or system operates without failure for a certain period of time under operation conditions previously established."

However, the concept is sometimes used in the wrong way because of the interpretation given to the word "failure." For many, failure means it just stops, so they build complex mathematical models to calculate the probability of stops without taking into account that there are also fails when it is unsafe, inefficient, expensive, or has high levels of rejections and contributions to a bad image.

For others, "reliability" is a set of theories and mathematical methods, operational practices and organizational procedures that, applying the study of the laws of occurrence of failures, can be directed towards the resolution of the problems of forecast, estimation and optimization of the probability of survival, improvement, average and percentage of time of functioning a system.

A very common argument is whether or not reliability is a statistical problem. The answer to this argument is that data management has an undeniable usefulness in the management of companies. It is necessary to distinguish whether the statistic is used to handle real data, view behavior, or support predictions and estimates that sometimes border on daring and irresponsible speculation.

MYTH 2: RCM solves all reliability problems of a company.

Going back to the concept of reliability as the average time between occurrences of failures, it must be remembered that it is an average number. There is a big difference between probability and reality, which creates a lot of confusion. A probable failure is a possible failure; when a failure took place, it is a real failure and not necessarily a calculation algorithm that guarantees its occurrence at a particular time.

The objective of RCM is very clear: define the most proper maintenance to ensure that assets meet functions required by its users. However, its rigorous and appropriate installation is useless if it is not conjugated to engage with other initiatives, activities, functions, methods, tools and methodologies that, when timely and correctly applied, provide the levels of reliability required.

These are some points that must be met in implementing RCM methodology, which will lead to great benefits. However, this does not mean that it will solve all reliability problems of the company.

Currently, there are tons of concepts and maintenance techniques, and more approaches emerge often in a permanent dynamic.

MYTH 3: There will be no more failures after applying RCM.

If having no failures is an ideal and desired state, and for many, reliability equals zero failures, then there is no method or methodology that avoids and/or reduces all failures or risks.

The RCM objective is to achieve more reliable assets and this is accomplished if they fail less, if failures last for less time, if there are fewer shutdowns lasting for less time, if risks are diminished, if they look better, if the nonconforming product is reduced and if the cost of operation is decreased.

A correctly elaborated and rigorously applied RCM analysis greatly reduces failure probabilities, the number of failures, risks and duration of non-desired events, in addition to providing best elements to be prepared if any component fails. Any combination of the above makes a more reliable asset.

Failure modes can be missed during the analysis and, therefore, periodic review of assets allows continuously improving quality. This explains why it is heard in some organizations that "equipment has failed, therefore RCM is wrong." This statement is totally groundless since if a defined failure management strategy for some modes has been leading to failure, therefore failures may occur.

RCM itself, as a concept, does not assure suitability of the analysis. It requires common sense, honesty and validity of those who make decisions.

MYTH 4: A probability curve defines if RCM is applicable.

RCM is defined as a process to determine the proper maintenance, the correct way to run it and the right opportunity to apply it. It is a process suitable for any type of asset, anytime and in any organization. Interpreting the famous "bathtub curve" for an entire asset according to a probability curve factor form and defining that a methodology applies only to a part of the curve or to a part of its operational life is a great mistake since this implies that RCM analysis considers only certain failures and characteristics.

If RCM analysis is well done, there will be failure causes due to human mistakes, influences of the environment, deterioration by normal use and wrong design practices. In addition, there will be appropriate failure management strategies for each of them through their operating life.

MYTH 5: Application of RCM should start from the current maintenance plan.

RCM is a zero-based analysis. This means the analysis is performed as if maintenance, which includes operational inspections, will not take place. As a result, the new maintenance plan is not biased by current practices that may not be technically appropriate.

In fact, the most popular method for "shortening" a RCM process begins with the current maintenance work. Users of this approach try to identify the failure mode that each task is meant to prevent and then work forward through the last three steps of the RCM decision process to reassess the impact of each failure mode and identify a more effective failure management strategy. This approach is also known as "reverse RCM."

This approach is disadvantageous because it is assumed that current maintenance plans cover all failure modes that reasonably require any maintenance. However, properly applied RCM generally shows that failure modes that really require a maintenance strategy are not covered by the current work in this area.

Retroactive approaches are especially weak when specifying proper maintenance for protection devices. This explains why most protective devices are kept in a deficient manner, or no maintenance is performed on them. So in most cases, a large number of protection devices will continue to receive no attention, since tasks were not specified for them in the past.

MYTH 6: A criticality analysis must be applied before RCM analysis.

An RCM analysis does not require a previous criticality analysis, which is recommended by some to choose assets to be analyzed. Criticality is the name given to the feature that allows establishment of a classification or hierarchy within a group of systems and assets according to a criterion. It aims at facilitating decision making by directing efforts and resources in areas where they are more important or necessary.

Criticality analyses normally can be made at asset level and the deepest ones at component level. But despite their goal, they are insufficient in defining the impact of a possible failure since components have many ways of failing and their structural analysis is insufficient, if lacking functional consideration. While some have factors intended to express concepts associated to affectations in the organization, sometimes they do not include human mistakes and environmental influences in the failure manner.

Frequently, seemingly superfluous assets are responsible for incorporating items that are very important in terms of safety and/or environmental integrity.

It is right to define priorities in order to run the analysis, but it should be looked at carefully whether to spend months of work and a lot of man-hours to make the classifications offer some benefit. Normally, those who lead organizations or operate and maintain them have sufficient criteria to know what dissatisfies them and that is reason enough to decide to run an analysis.

MYTH 7: It is hard to define systems and functions in RCM.

This is a groundless objection since an operator who knows an asset or those who have maintained it have no problem defining what they want it to perform. In fact, they understand it and know exactly what they expect from its operation.

Preparation of hierarchy diagrams, support from other maintenance tools and asset taxonomy, combined with proper application of the maintenance information system, allow for an understanding of what they are expected to do and selecting appropriate levels.

7

MYTH 8: RCA replaces RCM; failure analysis performed to find the root cause (RCA) replaces RCM analysis.

Failure is defined as the inability of a component, equipment, asset, or system to perform its function as specified, or an inability of a system or component to perform a function within specified limits.

Root cause analysis (RCA) is defined as a process to find the root causes and propose actions for each upon occurrence of a failure.

Under this assumption, there is a root cause to identify each time an event takes place and proposals are made when the failure occurs. This is the backbone of a reactive asset management strategy, which could be expressed in a concise manner like, "analyzing upon failing." It sounds good at the beginning, but under this point of view, the strategies all remain "waiting" for failures to occur.

Experience has shown that there is no single root cause for a failure; there may be several and all. But with different occurrence probabilities, orientation towards a possible fault is reactive and only serves to improve the performance of the work and not make the equipment more reliable.

RCM orientation is totally different. It seeks to anticipate the occurrence of failures, or failing that, have defined strategies if they occur. The real RCM proactive approach seeks to actually apply the plan, do, check, act (PDCA) cycle throughout the asset's lifecycle.

MYTH 9: RCM favors condition tasks at the expense of preventive maintenance.

RCM is a rigorous process to select the best type of asset maintenance. The correct application of the method ensures reaching appropriate conclusions without favoring any kind of maintenance. Rarely is there a relationship between equipment reliability and age, however, many failures give an indication or sign that a failure is occurring. When finding these faults in this state of "potential" failure, it is possible to avoid the consequences on the functional performance of the asset.

Condition-based tasks are inspections used to determine whether a potential failure is occurring since many failures show symptoms before reaching a point in which the functional failure occurs; it is recognized that sometimes the failure is occurring, but it has not progressed to the point of degrading the system's functionality.

Since most failures are random in nature, RCM first questions whether it is possible to detect them in time to prevent the loss of the function of the system. There is a big difference between realizing that a failure is beginning to occur and it is about to not fulfill its role. Therefore, elapsed time between when a fault is potential and can be detected, and when it really occurs with a loss of function must be sufficiently long to be useful in defining a condition-based task and its subsequent right action.

The frequency of condition-based tasks has nothing to do with the regularity in which a failure occurs, but rather how quickly it happens. Therefore, it has nothing to do with the frequency in which the system or equipment has failed in the past.

MYTH 10: RCM and TPM are incompatible.

Some people fall into error generating conflicts between various initiatives simply because they believe the use of multiple methods is not compatible with schemes that can be called totalitarian and border on fanaticism.

Total productive maintenance (TPM) and RCM are complementary processes and they have very well defined and clear guidelines. On pages 155 and 172 of the book "TPM in Process Industries," written by Tokutaro Suzuki and originally published by the Japan Institute of Plant Maintenance (JIPM), the author is clear and explicit when explaining the maintenance planned pillar at the stage of improvement maintenance effectiveness.

One Suzuki statement taken from the book reads:

"To improve maintenance effectiveness, start by reducing equipment failures, process problems, losses such as quality defects, high equipment wear, low production, safety risks and environmental problems....you may need exploring new approaches to assist you in this task, such as RCM."

Suzuki also quoted the definition of RCM from John Moubray, author of "Reliability Centered Maintenance."

"RCM is a process to determine what should be done to ensure that any physical asset continues fulfilling its required functions in its current operational context. It is a highly structured framework, initially developed in civil aviation, allowing users to determine the most appropriate maintenance strategy for different assets."

"A fundamental method to reduce processes failures is to select the most appropriate maintenance system for each of the functional components or major items of equipment. To do these, use the RCM methodology based on failure records and physical principles."

Suzuki recommends using both methodologies with an orientation towards complementarity, not competition. With this approach, the pillar of planned maintenance allows you to coordinate efforts to define the best maintenance strategy.

Throughout this article, we have discussed 10 myths about RCM methodology implementation that is widespread in organizations. This is intended to provide clarity about the true strengths and forms of RCM application. In Part 2, 10 more myths will be discussed, thus completing a more comprehensive and clear vision about this process.

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PROFiTABLE

Ethics in BUSINESS

And what do I get?

In a society where the scale of values emphasizes individual issues first, then the person's own family and ultimately society, I purposely begin this article with the provocation of the question above.

I believe we are all at a certain point on the scale, from one to 10, according to our moral development and the education we received. Frequently, we recognize the lack of ethics in others, but hardly recognize (sometimes even realize) our own lack of ethics. So, let's start this article by answering the question.

by Luiz Alberto Verri

The person who practices ethics has at least the following advantages:

- Sees the occidental society, formed mostly by individualists, as a crowd at a football field or the audience at a performance art event where there are places for everyone to be comfortably seated, but where no one sits because others are standing, blocking their views. But if most of them sit down (metaphor to practice ethics), everyone will watch comfortably. The game or spectacle of life is long, very long compared to a football game or an art show. Cooperation, therefore, leads to the well-being of everyone.

- Realizes the requirements of working in corporate environments with respect to the environment and safety have been increased greatly. The companies that do not adapt to these new requirements will not survive or have not survived. The reason is simple: Society no longer accepts companies that pollute or cause accidents. The methods of pressure are very wide -- stocks lose value on exchanges, authorities interdict activities, customers stop buying, the community takes actions against the company, etc. This will certainly happen to the ethical question. Incidentally, it is already beginning to happen. Pretty soon, the pressure on companies to issues ethics will be so large with regards to safety and environmental issues. And you, the reader, as a member of a company, will have to fit. You better start practicing now.

- Notes that, apart from the exceptions that prove the rule, the chief executives of companies are always in the top third of the ethics scale. The reason for this is because people hardly follow a leader who is not ethical. This is so true that I have observed some entrepreneurs hiring extremely ethical executives to lead their companies. So once again, your professional future soon will depend on how ethical you are.

Business Etiquette

Etiquette, according to Wikipedia, is a code that delineates expectations for social behavior according to contemporary conventional norms within a society, social class or group.

To a greater or lesser degree, we all received a basic education on the rules of coexistence with others. Among them, say good morning, respect the line, answer when asked and answer when someone rang the bell. By love or pain, we learned these rules, even in car traffic. We are able to live and deal with traffic, high speeds on highways and other various everyday situations with codes of conduct created for all of us to take the best in these activities.

I feel, however, that a basic set of rules on business etiquette is not clearly defined and, in many cases, not defined at all. In my opinion, few managers are willing to teach it. I, therefore, shall venture to suggest some rules of business etiquette to help the relationship in corporations.

- ***Answer e-mails:*** Of course, no one should respond to a direct sales pitch through an e-mail. I am referring to those e-mails that ask and ask for a clear answer. It seems to me something surreal in not replying to them. It's like someone asking something to another person in a public place and this person out-and-out not answering. Strange, is it not? We are always running about, not having enough time to complete tasks. But even so, you can evade answering with a simple, "I'm sorry, I do not have time to answer this right now." How many seconds would it take to send a reply like this?
- ***Do not send unnecessary e-mails:*** Given the ease in sending copies of e-mails, it is difficult to hold back on the urge to send copies "just in case" or "it is important that everyone has this news." But is it, really? Put yourself in another's shoes. How many unnecessary e-mails do you receive per day? The senders could decrease these numbers and probably you could, too.
- ***Meet schedules:*** To me, a very large amount of time and money is lost from people who are just expecting others to meet a schedule, thus generating unproductive hours. The lack of objectivity leads to endless activities, generating significant losses due to these non-productivity times.
- ***Pay attention to what people are telling you:*** Assume that when a person is speaking, the least you have to do is listen. After all, we all know that one of the supercritical manager's skills is listening to people. It's better to say, "look, I have no time to discuss this now," than have your body present, but your mind working on other things in total disregard to the other person.
- ***Answer the phone when no one is available to do so:*** Okay, answering a call directed to another person is almost always a "mess" since it will give us additional work. But think of it this way: It could be that customer you, yourself, are waiting to hear from, or the vendor telling something important, or even family information extremely important and urgent for that person. Put yourself in that person's shoes. Wouldn't you like that person to answer a call for you, especially, for example, it's a call from a loved one in urgent need of your help? Then, answer the phone for the others, as well. After all, a polite, "how can I help?," leverages the image of your company, your department and your image as a professional.
- ***Return a telephone call, including mobile:*** It's amazing the number of times that I, as a consultant, leave a message for someone to call me, with no return call. I know people are very busy and usually have more urgent and/or important things to do than talk to me since I'm currently a supplier. But it costs nothing for someone to return a call to solve the issue at hand, or at least give the person satisfaction in acknowledging their call. I did that when I held the position of general manager at a large refinery, so I know this is entirely possible.
- ***Ask if the person can talk on the phone at the moment you call:*** It is common to receive calls on a cell phone at any time and someone starting to speak incessantly without asking where we are or if we can talk on the phone at that time. The caller should ask the person if he or she can talk now. Besides demonstrating respect for each other, in the future, that person will most likely respond to your calls.
- ***Check how your stakeholders are being treated at your company's gate:*** I asked a friend of mine, a former president of a leading multinational in Brazil who is now a recognized consultant, how he deals with the profound disrespect we often receive from the "receptionists" and "guards" in the ordinances of the companies. He replied that none of his customers treat him in this manner because he would abandon them at the first occurrence of such treatment. I'm not as radical, but I use to work with more motivation in places where I am treated well. And I think this happens with all stakeholders, including customers and authorities.

Notice, readers, that at no time I have defined ethics. I believe it is not necessary. To me, ethics derives directly from a rule of thumb that we have been taught almost 2,000 years ago: "Love thy neighbor as thyself."

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Assume that when a person is speaking, the least you have to do is listen.

ETHiCAL

Equipping A FIELD SERVICE TEAM to Do Shaft Alignment

by Alan Luedeking

I am often asked, What tools and equipment does a millwright team need to do shaft alignment? Beyond the obvious safety equipment, such as hearing protection, steel-toe shoes, work gloves, hard hat, safety glasses and fire retardant clothing, some of the other essential equipment is not so obvious. So here's a little list, with commentary, based on nearly 30 years of field experience.

• **Laser Shaft Alignment System:** Buy the best you can afford. At a minimum, it should measure and record soft foot values (the best systems will even analyze soft foot conditions and suggest solutions); monitor horizontal moves live as you perform them; evaluate your measured alignment with respect to tolerances (including doing so in real time while in the move monitoring mode); let you configure short couplings, spool pieces and spacer shafts; let you configure vertical flange-mounted machines with any support flange shape and anchor bolt pattern (circular, square, rectangular, etc.); input target specifications for thermal growth, as well as anticipated thermal growth values at the machine supports; and finally, let you take accurate readings with less than a quarter turn of the shafts, rotating them in any direction, starting from any rotational position and stopping in any position, either coupled or uncoupled. Only the most capable systems can do all this, but the investment is well worth it and will save you a great deal of time in the field while ensuring the highest precision alignment.

• **Precut Stainless Steel Shims:** Buy in the appropriate sizes and thicknesses for the job. Good precut shims have a safety tab that lets you manipulate the shim without ever letting your fingers get under the machine's feet. There is much more to proper shimming than meets the eye. For a more in-depth look at this very interesting subject, I recommend the article, *Best Practices: Machinery Alignment Shimming*, in the April/May 2013 issue of *Uptime* Magazine (www.uptimemagazine.com). Precut stainless steel shims will save you money since they guarantee precision adjustments and you never need more than three of them to achieve any desired thickness up to 0.150 inches. Six standard sizes are available, traditionally called A, B, C, D, G, and H. These will cover footprints from two inches square to eight inches square and motors from a half horsepower up to 5,000 HP.

• **Shears, Flat File and Ball-Peen Hammer:** In the event your standard precut stainless steel shims don't fit your machine's feet, you may find yourself having to cut shims out of rolls of brass or stainless steel shim stock. It is imperative that you deburr your shims after cutting and ensure their flatness. Your ball-peen hammer is very handy for this, letting you roll out your burrs, rather than beating them out, thereby minimizing potential damage to the shims.

• **Pancake Jacks and Pry Bars:** If vertical jackscrews are not available, lift your machines with small hydraulic pancake jacks whenever possible, rather than with pry bars. This will ensure a safer environment for placing and removing shims. It will also prevent overlifting the machine with pry bars, with the associated risk of damaging the coupling, shafts, connected piping, or conduit. Lifting with pry bars also carries with it all the safety risks of the pry bar slipping out and the machine crashing down on your fingers or toes.

• **Inside and Outside Micrometers:** A good 0- to 1-inch **outside micrometer** is an essential tool since even the best quality precut stainless steel shims are only guaranteed accurate through 25 mils and are nominal in their thickness for thicknesses greater than .025 inches. Therefore, you should always mike (measure with a micrometer) every shim you use that is 50 mils or greater in thickness. An **inside micrometer** is important to mike the gap between shaft ends or coupling faces in order to measure and comply with the coupling manufacturer's installation gap requirements. Note that this value should not be confused with the coupling gap difference resulting from angular misalignment. When it comes to alignment tolerances, you should follow the standard industry norms, which are designed to ensure the overall health and longevity of the coupled machines and their internals (bearings, seals, etc.), and ignore the coupling manufacturer's specs for maximum permissible angularity gap differences *unless* these values are tighter than the standard industry norms for alignment. The coupling manufacturer's maximum angular gap difference values are only intended to convey what the flexible coupling is capable of withstanding. These values are typically much greater than what is good for the machines involved in terms of the vibration that would result from misalignment at these values.

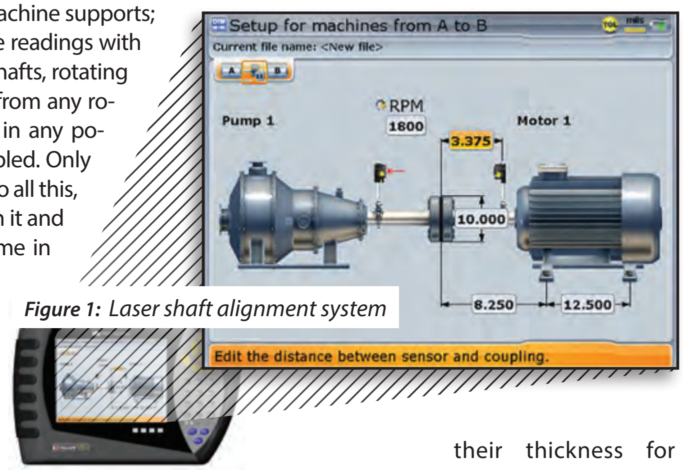

Figure 1: Laser shaft alignment system

The reasons why a good, quality flexible coupling is built to withstand so much more misalignment than what is good for the machines are two-fold: (1) to minimize the risk of catastrophic failure in the event excessive misalignment occurs while in operation; (2) to permit the machines to be deliberately misaligned to target specifications while in the cold or stopped condition; the coupling will then allow the machines to run at larger amounts of misalignment than what is recommended, while initially starting up and reaching their final operating state, at which point they should be running well aligned. In other words, a good coupling will let you run with large amounts of misalignment in order to accommodate thermal growth and positional changes arising out of dynamic load stresses, but this is no excuse to ever let your machines run this way continually. For a more in-depth understanding of the subject of alignment tolerances, I recommend the PowerPoint presentation entitled, *Understanding Spacer Shaft Alignment: Applying Tolerances the Right Way* (http://uptime4.me/1iRzSzs) and the article, *Shaft vs. Foot Alignment Tolerances: A Critique of Various Approaches*, in the October/November 2008 issue of *Uptime* Magazine (www.uptimemagazine.com).

• **Set of Feeler Gauges:** These are essential in gathering the data you need to properly diagnose soft foot conditions. Your laser system, in addition to checking for soft foot, should also diagnose the soft foot conditions for you. To this end, you need to measure the shape of the air gap under the machine's feet to determine what specific type of problem the measured soft foot condition represents in order to properly diagnose it and come up with the correct single-shot solution. For a more in-depth look at how to properly measure, diagnose and correct soft foot conditions, I recommend the PowerPoint presentation and related video entitled, *Soft Foot Diagnosis & The Soft Foot Wizard*, (http://uptime4.me/LQ5aLN)

• **Torque Wrench with Crow's Foot Adapter** (see Figure 2.)**:** Tightening and loosening anchor bolts on machinery should be done to the

Once the job is done, you or your customer needs to receive a comprehensive report from the technician in the field about the alignment job.

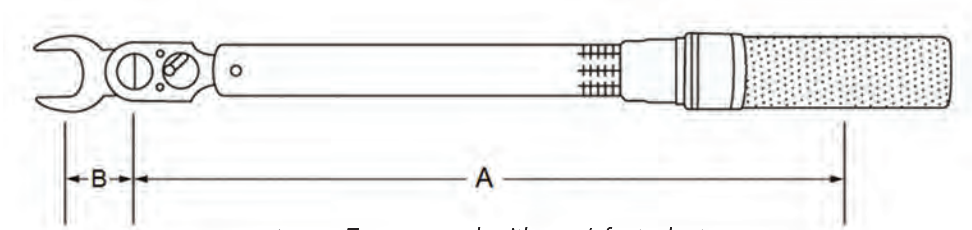

Figure 2: Torque wrench with crow's foot adapter (Image courtesy of www.motorcraftservice.com)

correct torque values for the grade, thread and size of the fastener involved. Also remember to lubricate the threads of your fastener with white lithium grease or other suitable lubricant for the environment at hand and use the appropriate torque values, adjusted according to any adapters used and their angles. The crow's foot adapter is extremely useful for situations where a socket cannot be directly fitted over the anchor bolt head.

• **Dead Blow Hammer:** Unfortunately, horizontal jackscrews are not very often installed on the machines you are aligning. In those cases, it may be necessary to move a machine by hitting it with a hammer. Avoid doing so with a steel sledgehammer as you will be sure to damage the bearings or seals! Instead, lighter blows from a good dead blow hammer will give you far greater control over your moves and reduce the risk of damaging the machine.

Figure 3: Hard hat light

• **Flashlight:** A good pocket penlight or hard hat light is essential when working in poorly lit environments and for looking under machines for dirt or debris that can obstruct you when lowering the machine or making soft foot corrections.

• **Pi Tape:** In addition to your standard tape measure, which you need to measure the standard dimensions to input into your laser alignment system, pi tape is useful for quickly determining coupling, shaft and flange diameters that may also need to be entered, and to mark rotational positions around the circumference of a shaft or bearing housing on vertical flange-mounted machines.

• **White Correction Fluid and Scribe:** Correction fluid (such as that used to correct typing errors on a printed document) is useful for marking positions on a shaft when having to remove and replace brackets on multiple machine trains when you move from coupling to coupling, and for marking rotational measurement positions at the bearing housing on vertically oriented machines.

• **Cotton Rags:** These almost go without saying. You never know if the job site will provide rags on site, but you will need them constantly for everything, from cleaning off the name plate on the machines (so you can retrieve essential data to record on your job report) to wiping down your equipment, your hands and sometimes just to provide a clean spot to sit on.

• **Dry Spray Solvent and a Can of Compressed Air:** The solvent and air are useful for cleaning the area under and around the machine's feet prior to shimming, and blowing out any debris that may be lodged there.

• **50-Foot Extension Cord with Triple Tap:** Useful for plugging in anything that might need recharging or power during the job, such as a fan or a heater.

• **Sturdy Folding Work Table and Chair:** You will need a handy place to set your equipment down on, takes notes and otherwise organize your workspace.

There are, of course, many more things required to properly equip your team, from training and liability insurance to having the right socket for the anchor bolts, but in the interest of brevity, this should at least get you well on the road to doing good alignments efficiently. I would add one more thing, though: reporting. Once the job is done, you or your customer needs to receive a comprehensive report from

The crow's foot adapter is extremely useful for situations where a socket cannot be directly fitted over the anchor bolt head.

the technician in the field about the alignment job. Your laser alignment system should be capable of generating this report directly as a PDF file to a memory stick, or as a hard copy to any connected printer. The report, at a minimum, must contain not only all dimensions and results, but also soft foot values, target specs, the measure mode utilized, moves made and, particularly, a graph to scale of the alignment condition.

Finally, also consider alignment software for your PC. The best alignment software will let you download and save the job to your PC from your laser system as a fully editable file. The software should let you customize the report with more than one set of alignment result values and graphs so you can document your "as found" and "as left" conditions; add digital photographs of your machines; insert commentary; insert a logo, either yours or your customer's; and view a measurement table that documents all significant events that transpired during the alignment job.

References

Thank you to Marty Krueger of Tern Technologies, Inc. in Alaska and Marvin Williams of Baton Rouge in Louisiana for their invaluable experience and insights in preparing this article.

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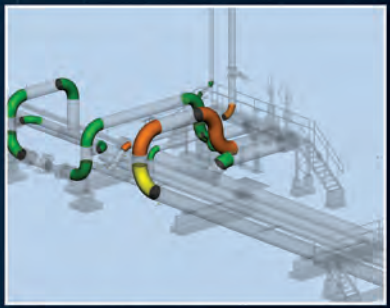

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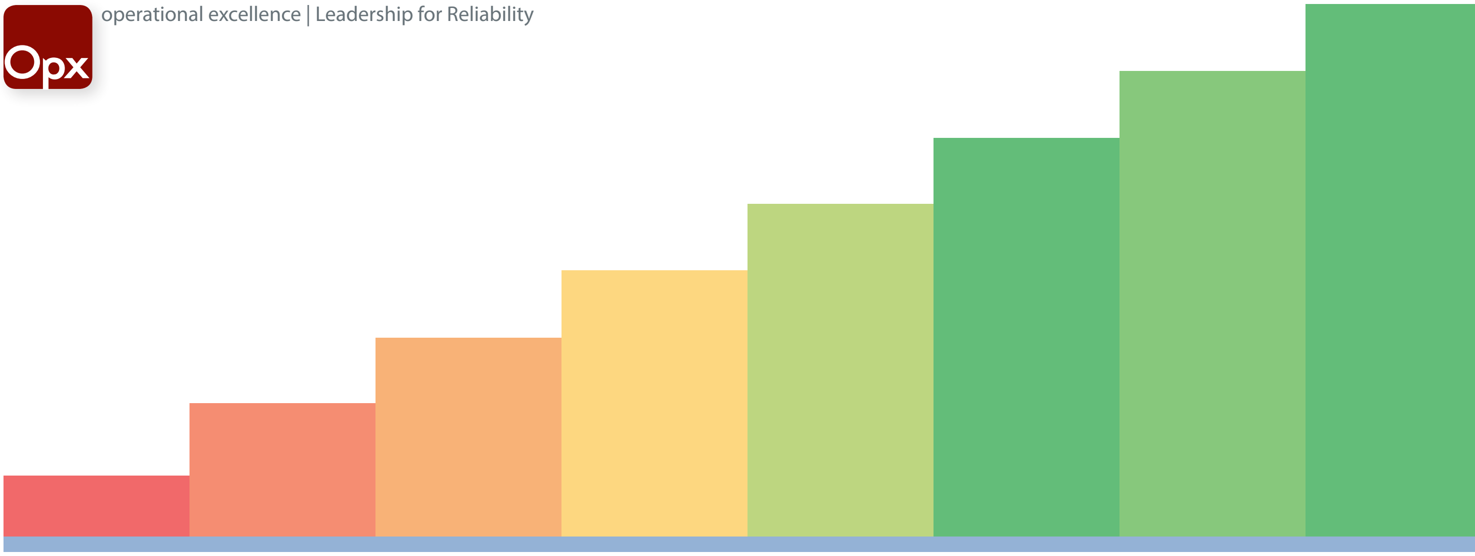


VENDOR SELECTION and PERFORMANCE EVALUATION

Building Successful Reliability Partnerships

by Ward Bond

In the mind of an average layperson, reliability is most likely a concept comprised of the predictable, continuous function of a system or repeatable action. When I joined my company's reliability team, I learned that the reliability of an asset can impact our company's overall operations. Our Greenfield, Indiana, site is made up of multiple business units, occupying approximately one million square feet. Each business unit has a group of functions and a unique list of support requirements that are critical to its continuous operation. Our reliability team supports the function of these critical systems by working with our shops and craftspeople to facilitate those needs. As a layperson myself, it is because I am part of that group that I have really begun to understand what reliability truly is. I have also learned that the reliability of critical systems can be very different in scope, yet have the same expectation of reliable performance. It is with this concept in mind that we developed a process for managing the reliability of contracted services.

What determines the criticality of a system can vary widely and may be based on a number of factors. In the case of our site, it is often the business unit the system supports and to what degree that system's function may affect many factors, including scientific data. When one seeks to employ the expertise of a vendor to meet a need for reliability, it is necessary to first evaluate the need based on system criticality. Once a thorough review and ranking is completed, it is possible to determine the reliability services required. When considering available vendor options, a selection matrix can be a valuable tool for evaluating potential vendors and improving the fit of the vendor to the service desired.

The Foundation of a Successful Partnership

All partnerships take effort to establish and maintain, but in the case of a reliability partnership, this is especially true. It may be necessary to dedicate a substantial number of hours to determine the needs of a single system. At the very least, it will require the acknowledgement of the level of expertise required and its availability. In the examples I will give here, I had the advantage of the availability of a staff reliability engineer, mechanical engineer and sev-

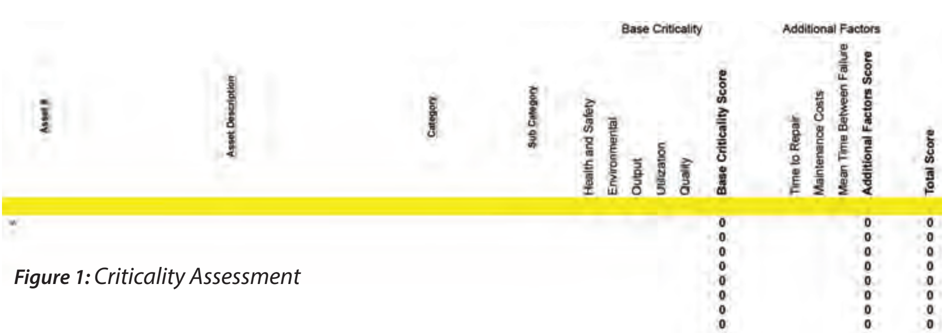


Figure 1: *Criticality Assessment*

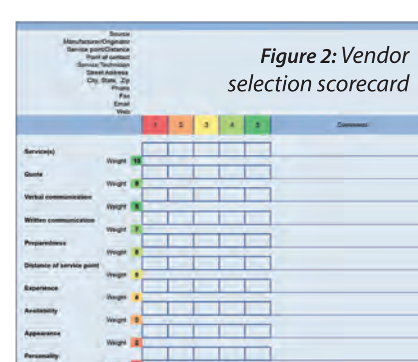


Figure 2: *Vendor selection scorecard*

Our reliability program consists of several teams, each with a leader, craftsperson(s) and/or a subject matter expert (SME).

eral excellent craftspeople with many years of dedication to their chosen fields, all of whom I am proud to be a colleague of and support through my work as a CMMS administrator. I joined this group as part of an effort by the reliability engineer to reestablish a reliability program.

When our site transferred to new ownership, we lost some capabilities. Our reliability program consists of several teams, each with a leader, craftsperson(s) and/or a subject matter expert (SME). The team leaders of each group are also members of a larger advisory reliability group and act there as representatives for their team. The first order of business of the reliability group was to perform a criticality assessment of all assets currently tracked in our computerized maintenance management system (CMMS). Each asset was scored based on a predefined set of criticality criteria and any corresponding weighting (multiplier) was then applied, resulting in a numerical representation of the asset's criticality (see Figure 1).

Once we identified the needs of our critical assets, we began the process of evaluating our capabilities. Many of the reliability program functions were implemented quickly when our site was transferred to new ownership. It was during that assessment when we identified a need for program improvements in certain areas. Since we had lost the capability to perform vibration analysis ourselves, we were collecting the data and sending it out to be analyzed by a vendor. This disconnect between the analyst and the equipment was identified as the probable cause for the poor performance of our vibration program. We essentially needed to hire a vendor who could bridge the gap between our identified need for reliability data and reliable systems. It was this process of ranking critical assets and evaluating needs that gave me the idea of ranking potential vendors via a similar method.

Figure 2 offers an example of a scorecard that can be used for this purpose. Once each vendor had been evaluated, team members reported their scores and the average of each criterion from all evaluators was recorded in a comparative matrix (see Figure 3).

This tool then became what is now utilized as our selection matrix. Once all averaged criteria scores were recorded for each vendor, we were able to view the score totals side by side for final ranking. As soon as the leading potential vendor was identified, contract negotiations proceeded and were finalized shortly thereafter.

Figure 3: *Vendor selection matrix*

		Vendor A	Vendor B	Vendor C	Vendor D	Vendor E
Source Manufacturer/Originator Service point/Distance Point of contact Service Technician Street Address City, State, Zip Phone Fax Email Web						
		Vendor A	Vendor B	Vendor C	Vendor D	Vendor E
Service(s)		1	1	5	3	4
	Weight 10	10	10	50	30	40
Comment						
Quote		4	3	5	2	1
	Weight 9	36	27	45	18	9
Comment						
Verbal communication		3	2	1	5	4
	Weight 8	24	16	8	40	32
Comment						
Written communication		2	1	5	3	4
	Weight 7	14	7	35	21	28
Comment						
Preparedness		5	5	5	5	5
	Weight 6	30	30	30	30	30
Comment						
Distance of service point		3	3	5	4	4
	Weight 5	15	15	25	20	20
Comment						
Experience		3	5	2	3	4
	Weight 4	12	20	8	12	16
Comment						
Availability		3	5	5	3	4
	Weight 3	9	15	15	9	12
Comment						
Appearance		4	4	5	5	4
	Weight 2	8	8	10	10	8
Comment						
Personality		5	5	4	3	5
	Weight 1	5	5	4	3	5
Comment						
Weighted Total		163	153	230	193	200
Key All vendors scored 1 - 5 on each criteria. For best result calculate mean of multiple scores.		1 = Very Poor	2 = Poor	3 = Average	4 = Good	

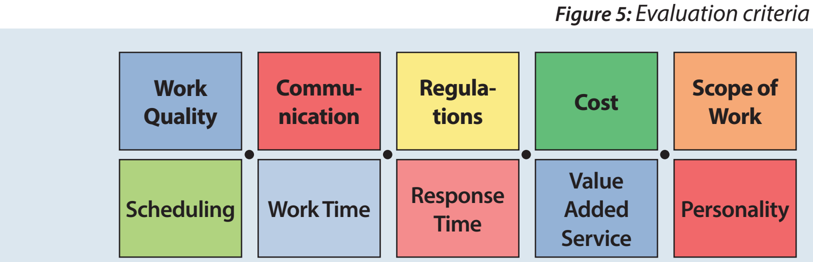
If we are willing to subject ourselves or our employees to rigorous performance management and evaluation standards, why are we willing to potentially accept less from our service providers?

Figure 4: Vendor Performance Matrix

Vendor Name	Score	Vendor Contacts	Phone	Contract Manager / Point of Contact	General Scope	Acc. Code	PO#	PO Value	PO Value Remaining This Term	Average Bill Per Service Interval	Contract Term	Remaining Term	Renewal Date
Average Joe's Reliability Services	219.16667	Tom Tomlinson	800-555-555	Ward Bond	Vibration Data collection and analysis	12345	61542	$00,000	$00,000	$0,000	24	23	15-Jan-14
Vendor 2													
Vendor 3													
Vendor 4													
Vendor 5													

Figure 6: Vendor Performance Matrix

Figure 5: Evaluation criteria



Work Quality – Report quality, Verified quality, Function of a finished product, Fitness of design.

Scheduling – Impacts other schedules, Rework, Met due date, Met project timeline.

If we are willing to subject ourselves or our employees to rigorous performance management and evaluation standards, why are we willing to potentially accept less from our service providers? Certainly, the information we gather on vendor performance is not as granular as a performance management document used to track personal growth. But at what point would we want to reevaluate a vendor's status as a service provider? I say anything less than average is unacceptable performance. With this in mind, I set the midpoint of all possible scores to be that action point. In a matrix as I have described with 10 weighted criteria and scoring from one to five, that number is 165. This score is also reflected in the contracted services list where we track vendor information and contract expenses (see Figure 6). If the value falls too low, the conditional formatting reminds us of the vendor's performance score.

The use of selection/evaluation matrixes forces us to objectively examine potentials based on real needs, rather than subjective personal preferences. I believe the inherent process also supports competition among potential vendors and likely reduces the choice of a vendor based solely upon a past relationship. After all, if we require our operations to be reliable, shouldn't we also expect reliable performance from our service providers?

Building and Maintaining a Successful Reliability Partnership

We liked the comparative analysis approach so well that we agreed to perform further analysis of the vendor's performance during the initial setup phase and after each service interval. In this way, we are able to trend changes in the vendor's performance over time. Through the use of a performance matrix (see Figure 4), we identified a few service issues and worked with our vendor to address them. An additional advantage to using this or a similar method is the added value of facilitating feedback to the vendor. Essentially, this tool is used for tracking and trending service performance.

The criteria we used for evaluation are based on our specific needs, as identified by polling our team members. Even though all service types are not the same, similar qualities may be objectively evaluated and trended over time. Accordingly, we based our specific criteria on these 10 basic categories (see Figure 5).

Using work quality and scheduling as examples, here is how these categories can be used as a base for criteria creation:

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If Reducing Unplanned Downtime Is Your Goal, What Is Your Game Plan?

by Dragan Trivanovic & John Yolton

IS BETTER THAN 50 PERCENT accuracy an objective or goal for a condition monitoring program? Do you measure accuracy of recommendations as an output of your program? It is not unusual for paper mills with mature condition monitoring programs staffed by competent, skilled and experienced technicians to achieve over 95 percent accuracy in the prediction of a failure, and somewhat less accuracy, due to lack of knowledge and data, of the recommended corrective action, which for some, is still a whole lot better than flipping a coin. But how about a goal of zero unpredicted failures?

A Case Study

Zellstoff Celgar is a market pulp mill located in southeastern British Columbia and sister mill to two other similar sites in Germany, owned by Canadian-based Mercer International. The mill, by North American standards, is a modern producer of pulp, having been upgraded in 1993 following a C$850 million rebuild project.

The mill produces 520,000 air-dried metric tons (ADMT) per year of northern bleached softwood kraft (NBSK) pulp, a versatile raw material used to make many finished grades of paper, including printing, writing and tissue. The mill consists of three fundamental parts: the fiber line, including wood fiber, cleaning and screening, cooking and washing, bleaching and chemical recovery, including causticizing; the pulp drying, baling and shipping; and the utilities area, including combined heat and power (CHP) and water and effluent treatment.

Converting wood fiber to market pulp is a chemical process involving several interconnecting processes, each with hundreds of assets, many of which rotate. A significant part of the process is CHP generation. Excess power, in the form of electricity, is sold to the local utility at competitive rates, generating a separate, but very important revenue source for the mill.

Of 8,657 rotating pieces of equipment in the mill, the predictive maintenance (PdM) team monitors 856 assets based upon criticality. Criticality is based on the asset's contribution to the site's business goals and changes with business conditions. An ongoing, periodic maintenance strategy review (MSR) using reliability centered maintenance (RCM) provides updated priorities and strategies.

Condition Monitoring Program

The current condition monitoring program consists of over 50 wireless units, several fixed online data collection stations and eight mobile data collection units configured for use by operators and vibration technicians.

The turbine generator #2 (TG2) and turbine generator #3 (TG3) have protection systems. Both are also equipped with a condition monitoring system. The TG2 protection system is dated and is planned to be replaced in 2014. There are also plans during 2014 to further expand the mill's condition monitoring program with four online data collection stations.

Program Expectations

The reliability effort at Zellstoff Celgar is tasked with these expectations of the PdM program:

• Targeted 92 percent uptime. This is a moving target depending on product mix, market conditions and business goals. For example, in 2006, production was 1283 T/day, while in 2011 that increased to 1520 T/day.
• Maintenance cost versus replacement asset value (RAV) goal of three percent.
• Safety total incident rate (TIR) of 1.76.
• Zero failures on criticality "1" equipment.

Changing Priorities

The second steam turbine (54 MW) installed in 2010 changed the mill's production strategy, balancing priorities between production of pulp and sale of electricity. This change required an adjustment to the existing asset criticality and corresponding maintenance strategies.

Staffing

The original program consists of two certified vibration analysts. In addition to the vibration technicians, there are seven certified lubrication technicians, supervised by the PdM group supervisor, who has a bachelor's degree in mechanical engineering and is a certified vibration analyst. Included in the reliability effort are a motor condition analysis technician and two reliability engineers.

The program's effectiveness is directly related to the efforts of this group of skilled, knowledgeable, dedicated and focused specialists to constantly try to improve the mill's reliability.

Program Effectiveness Issues

An evaluation of the traditional PdM program's effectiveness reveals several issues:

• Dynamic production processes with continuous changes and updated automation requires new knowledge and skills.
• Skilled people's retention and increasing average age of operations and maintenance professionals, plus the expectation to do more with less.
• The technicians can collect data, but there is no process for using the data effectively and efficiently.
• Inconsistent data analysis efforts caused by different personnel analyzing data with different levels of knowledge and experience.
• No continuity of the maintenance effort, therefore, history is lost with no effective means to improve.

This classic approach to a PdM program has problems:

• Route-based, taking readings every two or four weeks instead of as required depending on condition.
• Collecting data before and upon start-up after shutdowns and for all new asset installations strains the routine data collection.
• Insufficient troubleshooting expertise to determine how bad is bad and how long before intervention is required.
• Data analysis is time demanding, largely subjective and relies upon single technology (e.g., no interaction with process data or different operating parameters).
• The analysis is highly dependent on the analyst's skills, the quality of the database, the point setups, alarm adjustments, the process for tracking changes and the instrument type.

Assets Monitored

The list of assets monitored includes:

:: 2 steam turbines, (48 MW and 54 MW);
:: 652 pumps;
:: 8,675 electric motors and 6 hydraulic motors;
:: 456 gearboxes;
:: 4 compressors;
:: Lots of process rolls, in both slow and variable speed applications.

The frequency of monitoring varies depending on the equipment and its criticality.

:: Route-based data, four to six weeks frequency.
:: 51 wireless units at different frequencies, from five minutes to two hours.
:: 5 permanent vibration monitoring units at 15 minute frequency.
:: Transient mode on both turbine generators at a speed change of more than 10 percent.
:: Process data (e.g., amperage, flows, pressure, temps, speed rates, etc.) every 30 minutes.

• Even after a problem is found, providing a solution based on someone's knowledge and experience, entering work requests, executing the corrective action and following up has no effective means to improve.

Solution

An @ptitude Decision Support system (@DS from SKF) was installed as part of the technology upgrades. The system does all the diagnostics, providing recommendations, supported with references, through e-mail notifications.

A certified vibration analyst evaluates all system recommendations and makes the call whether to adjust alarms for that specific asset, do more troubleshooting, or initiate a work request.

The support system is the main asset health diagnostic center, continually providing diagnostics for 1,472 assets at 30 minute intervals, providing not only alarm notifications, but also recommended actions. This system processes huge amounts of data, some 200,000 different readings a day, while not requiring database growth. The system closely monitors critical equipment by analyzing vibration data, process parameters, oil analysis results and operator driven reliability (ODR) program inspection data. Critical equipment is monitored before shutdown and during start-up, reducing resource constraints.

The mill's root cause analysis (RCA) program is supported by the system providing faults statistics. This same support is critical for those so called "big calls" that impact production, safety and the environment.

Configuration of the system uses existing models provided by the vendor, plus development of the mill's models based on the function of the assets in their operating environment. Additionally, adjustment of existing models to reflect existing circumstances is a continuing process.

This development and configuration took place over a six year period as assets were added to the program and technology was purchased and installed to collect data. It is estimated that 400 to 500 assets can be modeled into the application in three to four months and will require up to one year of adjusting or tweaking, providing near 100 percent accuracy.

Implementation

First, the database is optimized (e.g., proper point setup, alarming and faults identification). Optimally, this optimization should take place periodically, as assets and priorities change regularly.

Turbine Generator 2

In September 2010, a disturbance is noted on the #2 turbine generator. An alert is sent to the appropriate list of mill personnel via the decision support system.

The system's alarm status indicates the problem is with the rotor blades.

The alarm status indicates trouble with the rotor stage wheel.

Additional details present themselves when drilling down into the rules.

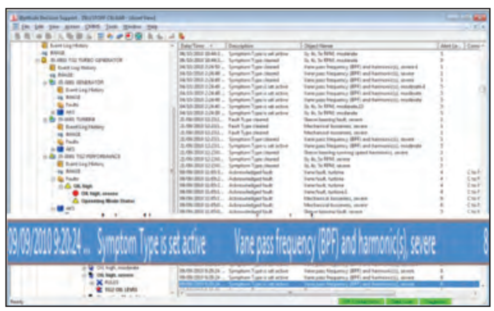


***Figure 1:** First alert*

Following the setup of the decision support system, monitoring continues, showing the fault as severe vane pass frequency and harmonics.

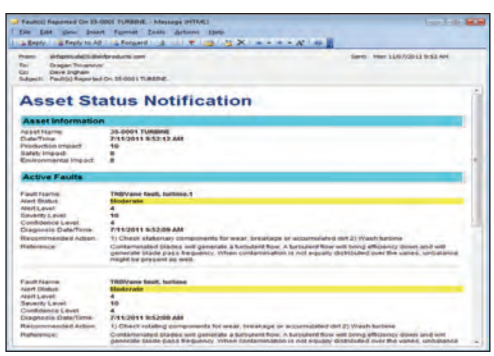


***Figure 2:** Access directly to CMMS*

Access to data in CMMS is direct with the decision support system (Figure 2).

The system recommends checking turbine rotor wheels 8, 9 and 10 for damage. The turbine is due for an overhaul in June 2011. The alarm is first made in September 2010 and final acknowledgement is made in October.

The turbine overhaul is rescheduled for a fall 2010 shutdown.

Several dents are identified in Wheel 8 caused by the damaged retracting seal between stages (see Figure 3).

Severe damage was avoided by taking action based on the alert, acknowledgement and recommendations.

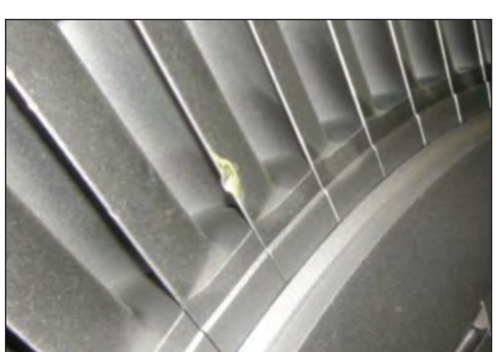


***Figure 3:** Defect during overhaul*

Next, designed standard models for motors, pumps, gearboxes, process rolls, mixers, fans, etc., are incorporated into the application. Examples include electric motors, roller bearings, sleeve bearings, AC variable frequency drives and DC variable frequency drives in 900, 1200, 1800 and 3600 RPM.

Each potential fault must be connected to the specific data providers, for example, route-based data, wireless, ODR and process data from the distributed control system (DCS) through OPC. Then, each asset's profile is tested, making sure alarms are properly set and data providers connected correctly.

Notification

E-mail notifications, via desktop, smartphone and/or tablet, is the primary communication. The notification includes a recommended corrective action and the degree of severity. An interface between @DS and the new computerized maintenance management system (CMMS) is being developed to create work requests and work completion notifications.

Implementation Challenges

Some of the challenges during implementation were due to the fact that most decision support models were generic and required customization to site and process-specific circumstances. In addition, 90 percent of the models had to be rebuilt and fine-tuned in-house, a very slow and time-consuming process.

A duplicate e-mail notification problem has recently been resolved. Currently, managing alarms requires at least a Level 2 analyst, but this is a good training exercise leading to analysts becoming experts and learning about rules and models.

Currently no interface exists between this system and the CMMS, although development is in progress. The work request has to be entered manually, requiring time from a resource. Checking the CMMS for duplicate requests or work orders is also required.

Valves are a critical asset in pulp and paper mills and currently there are no developed models for monitoring valves, so the mill is in the process of reviewing an interface.

Zellstoff Celgar's Expectations

The goal is zero unpredicted failures on all 854 critical monitored assets under the PdM program. Additionally, continuous improvement is to be measured by mean time between failures (MTBF), especially on pumps and electric motors.

The establishment of key performance indicators (KPIs) benchmarks resulting from a site assessment led to a development plan to close the identified gaps. This ensures that the continuous improvement process is in place.

Saves/Benefits

Several issues have been resolved as a direct result of the program.

- TG2, 48 MW Steam Turbine Shutdown Call:
  - The mill was able to add this overhaul to the planned 2010 shutdown due to predicted failure issues, thus mitigating a potential catastrophic event. Originally, the planned overhaul was scheduled for 2011.
- Pump Cavitation:
  - Effluent pumps performance can limit production; one pump down a 20 percent production rate reduction in order to meet regulations is experienced. This rate reduction averages 1,500 tons of pulp until corrected.

Results of a Global Survey

An evaluation of over 1,100 surveys of industrial and utility sites globally reveals the following information (Figure 1) in response to the question, "How accurate are your predictive maintenance (PdM) program recommendations?"

Consider this: Flipping a coin will provide you with a 50/50 chance of being correct in your decision. Here 60 percent indicate better than 60 percent accuracy. One questions what the other 40 percent are accepting as a PdM program output.

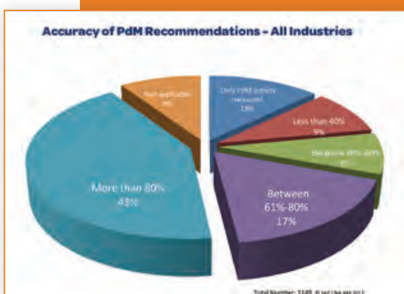


Figure 1: Global CNA AM response to Question 12

Removing one key industry indicates the issue is worsening (Figure 2). Only 50 percent of global industries surveyed, other than pulp and paper (P&P), indicate their PdM program recommendations are more than 60 percent accurate. Sixteen percent do not have a PdM program, 14 percent do not measure recommendations accuracy and the 20 percent that do measure accuracy are below 50 percent.

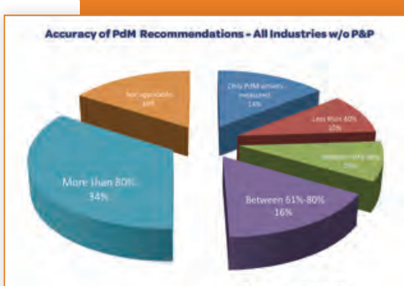


Figure 2: Global CNA AM response, All industries except pulp and paper

Pulp & Paper

In the pulp and paper industry, a majority, 61 percent, of those responding claim their program's recommendations are more than 80 percent accurate, while another 17 percent claim better than 60 percent accuracy. The remaining 22 percent are almost evenly divided with not having a PdM program, not measuring accuracy of recommendations, or less than 50 percent accuracy (flip a coin).

Figure 3: Global PdM program responses, P&P

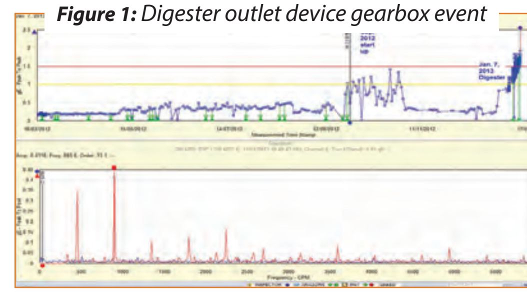
Why the Discrepancy among Industries?

The maturity of the PdM condition monitoring programs in the paper industry is not surprising. As far back as the 1970s, electronic vibration monitoring of bearings was common in the paper industry, especially in the United States.

First and foremost, the papermaking process is continuous, meaning if one part of the process fails, the whole process is down. Second, the equipment is large, using lots of variable frequency drives (VFD) and typically slower rotating than some other industries. In addition, the asset base includes lots of rotating equipment, such as pumps, motors, gearboxes, mixers, agitators and rolls. The technology providers targeted the paper industry because of these factors.

Like any adoption of a new technology, skills and knowledge are required, followed by experience. These combined produce credible analysis and timely corrective action recommendations. Credibility is the most difficult to achieve because of many factors, many of which are subjective due to the so-called human factor.

Figure 1: Digester outlet device gearbox event



- A bottom circulating pump on the digester was damaged during a planned shutdown, however, the damage was discovered during start-up. Repairs delayed start-up by eight hours, but a catastrophic failure that could have resulted in potential loss of production for 24 hours was avoided.

- Shutdown and Start-up Problems:
  - A bleach plant do stage feed pump electric motor fault was noted on start-up. A simple addition of grease avoided a possible 400HP motor failure and start-up delay. Without the support system and the wireless network as a data provider, there would have been another failure and RCA process candidate.
- Processing Huge Amounts of Data:
  - The resource level, for instance three condition monitoring technicians, could not possibly analyze the huge amount of data being processed continuously. To date, the recommended corrective actions produced by the system have been 100 percent correct.
- A traditional PdM program without continuous monitoring and automated analysis would have missed the failure shown in Figure 1, a gearbox jamming on the digester outlet device, which allowed a controlled shutdown and correction versus an unplanned, uncontrolled outage.
- Zero unpredicted downtime on 854 critical assets.

Conclusion

The decision support system enabled the mill to do better by providing instantaneous, reliable diagnostics with useful recommended actions, thus avoiding catastrophic production failure events, lengthy production start-up delays and costly repairs. As a result, the mill is able to devote more resources to RCA and the elimination of repetitive failures.

Mercer International and Zellstoff Celgar's management are pleased with the results from the decision support system and are in the process of reviewing additional implementation at its two German mills.

The next steps include incorporating valve monitoring analysis in the @DS; interfacing with the CMMS or enterprise asset management system; and expanding the ODR program from the current four designated areas. Also coming up are the installation of new continuous monitoring systems and a change in the scope of work for vibration analysts to more follow-up analysis from ODR and continuous monitoring systems instead of route-based data collection.

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www.skf.com/us/index.html

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PROUDLY MADE IN THE USA

Priority Vs.

pri·or·i·ty,
something that is more important than other things and needs to be done or dealt with first

by Bill Keeter

One of the most misused terms in the maintenance reliability world is criticality. Organizations often use the word criticality when what they are really talking about is criticalness. The fact that an item of equipment is critical to an organization's success doesn't define its criticality. This article will clarify the difference between critical items and criticality of items.

Why It Matters

Maintenance reliability efforts consist of two different types of work. There is the daily work of keeping equipment running by managing work orders and responding to emergencies, and the long-range work of activities designed to improve overall performance. The daily work requires a set of priorities to ensure the most important work is done first. The long-range work also requires a set of priorities that ensure improvement efforts are focused on where the most benefit can be gained for the least cost and effort.

Criticality is a function of probability and consequence of failure. It, therefore, can change based on efforts that either reduce probability, consequence, or both. Criticalness is a singular property and does not change unless another, more essential, item of equipment is installed in the system. It is possible for an extremely critical item to have a low criticality. In other words, criticality is useful for setting strategic priorities so long-term reliability efforts are focused on the right things; criticalness is useful for setting daily work priorities so the most important daily work is accomplished on the most essential items.

An Example

Everyone would agree that a turbine compressor in a primary gas compression train is essential to successfully compress and export natural gas. If it fails and there is no backup, the system will be unable to produce output. Its criticalness is high and the priority of daily work scheduled for it should be high as well. However, it may be well maintained by an effective combination of preventive maintenance (PM) and condition monitoring activities that reduce its probability of failure to an extremely low number, which means its criticality can be low compared to other items of equipment. Focusing reliability improvement efforts on the unit would likely be a waste of valuable resources that could better be used to improve reliability in other items of equipment.

Using Criticalness to Set Daily Priorities

Criticalness and work type are often used to create a ranking index for maintenance expenditures (RIME). The first step is to understand how essential certain types of equipment are in order to determine their criticalness. A starting point might be rankings, such as those in Table 1. These are only suggestions. An organization will want to set their own definitions for their system.

The next step is to determine work order type priorities, such as those in Table 2.

These rankings are multiplied together to produce a priority number that can be managed based on local policy. This should be determined by a cross-functional team consisting of operations, maintenance and appropriate health, safety and environment (HSE) personnel.

Daily work now can be prioritized so the critical few work orders are accomplished first. It is important to not let work languish at the bottom of the index. This work can be managed be either designating a certain percentage of planned jobs to be done on work that has a priority number below a certain value, or by adding some specified number to a work order's priority ranking each week so it floats upward (Figure 1).

Using Criticality to Set Strategic Priorities

Determining criticality is a more complex process because it involves the interaction of probability of failure and consequence of failure. Criticality requires a level of granularity that allows the organization to recognize the few high criticality items that can lead to major improvements in performance. Applying the power law to the Pareto principle shows that it is possible for as little as five percent of the equipment in a facility to cause more than 50 percent of its losses. Criticality ranking systems with a granularity that only allows the identification of the top 25 percent of criticality are not strong enough to accomplish the goal.

Criticality is added from layer to layer in the hierarchy, so a good method is to do criticality at a high level with just a few questions (Figure 2). For instance, it is possible to divide a large facility into areas and determine area criticality first. The team can then drill down into the most critical areas by identifying system level criticality. The most critical systems or items can be then focused on using tools, such as reliability centered maintenance (RCM), to determine the best improvement strategy.

The starting point for criticality analysis is to produce severity rankings for various impacts. A table similar to Table 3 would be a good starting point.

		WO Priority									
		10	9	8	7	6	5	4	3	2	1
Equipment Criticalness	10	100	90	80	70	60	50	40	30	20	10
	9	90	81	72	63	54	45	36	27	18	9
	8	80	72	64	56	48	40	32	24	16	8
	7	70	63	56	49	42	35	28	21	14	7
	6	60	54	48	42	36	30	24	18	12	6
	5	50	45	40	35	30	25	20	15	10	5
	4	40	36	32	28	24	20	16	12	8	4
	3	30	27	24	21	18	15	12	9	6	3
	2	20	18	16	14	12	10	8	6	4	2
	1	10	9	8	7	6	5	4	3	2	1

Figure 1: Sample RIME chart

Criticality

•crit·i·cal: indispensable, essential
•crit·i·cal·ness: the state or quality of being critical

crit·i·cal·i·ty,
a relative ranking of equipment based on the probability of its failure and the consequences of the failure

Table 1: Equipment Criticalness Ranking

*Standby unit in place and operationally ready

Item Type	Criticalness (Process Importance)
Safety/Environmental Protection	10
Utilities – Not Spared*	9
Utilities – Spared	8
Essential Production – Not Spared	7
Essential Production – Spared	6
Essential Production Support – Not Spared	5
Essential Production Support – Spared	4
Non-Essential Production Support	3
Personnel Comfort	2
Buildings and Grounds	1

Table 2: Work Order Type Priorities

WO Type	Priority
Immediate Threat to Health, Safety, or Environment	10
Potential Threat to Health, Safety, or Environment	9
Immediate Production Loss	8
Potential Production Loss	7
Preventive Maintenance/Condition Monitoring	6
Corrective Maintenance	5
Modification	4
Painting	3
Relocation	2
Appearance (Grass mowing, etc.)	1

Severity	Safety	Environment	Production	Down Time	Maintenance Schedule	Maintenance Cost	MTBF
5	Loss of Life or Limb	Significant Environmental Impact	Prolonged Interruption or Loss of Facility	> 1 week	> 1 week	>$25000	< 6 months
4	Lost Time	Reportable Release	100% Loss	< 1 week	> 24 hr Interruption	< $25000	> 6 months
3	Recordable	Non-Contained Non-Reportable	50% Loss	< 48 hr	< 24 hr Interruption	<$10000	> 1 Year
2	First Aid	Contained, Non-Reportable	10% Loss	< 24 hr	< 4 hr Interruption	< $2000	> 2 Years
1	Near Miss	Near Miss	5% Loss	< 1hr	< 2 hr Interruption	< $1000	> 5 Years
0	No Impact	No Impact	No Impact	0	No Impact	No Impact	> 25 Years

Table 3: Sample Severity Ranking Table

The severity rankings used should be in alignment with corporate guidelines for safety and environmental performance. Again, a cross-functional team of appropriate personnel is required to achieve consensus on rankings.

It is a simple process to rank each failure by maximum severity in each area and add them together to get an overall severity. The organization can then sort from highest to lowest to help prioritize performance improvement initiatives.

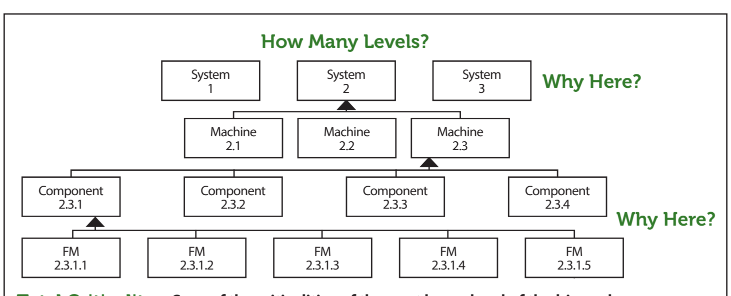
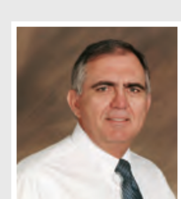


Figure 2: The additive property of criticality

Conclusion

Prioritizing daily and strategic work efforts ensures that the limited resources in the organization are used as efficiently and effectively as possible. Using separate systems to perform prioritization ensures that a constant property is used to manage daily work and that long-range efforts are adjusted based on the reduction in criticality that comes from those efforts.



Bill Keeter *is the owner of BK Reliability in Titusville, Florida. Bill is an experienced maintenance professional who provides reliability training and consulting services around the world. He is passionate about helping organizations understand and eliminate system failures so they can achieve better safety, environmental, operational, and financial performance. www.bkreliability.com*

RELIABILITY 2.0 Las Vegas

Bill will be presenting at RELIABILITY 2.0 in Las Vegas. He will present Tuesday, April 8, at 9:00am Workshop, Failure Reporting and Corrective Action System (FRACAS) and Wednesday, April 9, at 2:00pm, Introduction to Weibull Analysis.

Do you have an extraordinary

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***Uptime*® Magazine** is devoted to asset management, reliability and machine condition monitoring. Part of our mission is to promote and acknowledge best practices.

We have created the Uptime Magazine Best Maintenance Reliability Awards to provide positive exposure and acknowledgment for maintenance reliability professionals from around the world.

MONITORING PLAIN BEARINGS WITH Ultrasound

Friction: friend or foe? The answer all depends on your particular situation. When driving your car aggressively over wet or icy roads, friction, as well as a good set of tires, is your friend and will save you from some stressful moments. If you're in the reliability game and are tasked with extending the life of your bearings, then friction is the enemy. While zero friction is neither practical nor even possible, you search for the best ways to minimize these forces between the elements of your bearings.

by Gus Velasquez

For rotating machines, it is necessary to reduce friction most of the time to increase efficiency, decrease power losses and support loads. The element of choice is the well-known team of bearing and lubricant. Bearings, in their different configurations, are one of the most efficient ways to reduce friction between a stationary and a rotational part of a mechanism.

Two broad classes of bearings exist: plain bearings and rolling contact bearings. Which type of bearing is used depends on several factors related to the design of the machine and its process. Sometimes both types are used in the same machine doing different jobs. For this article, the focus is on plain bearings.

Choosing the best technology to monitor friction and condition in plain bearings is a challenge. Due to the physical characteristics of plain bearings, using vibration analysis (VA) is more effective for rolling contact bearings and less so for plain bearings. Ultrasound (US) is trending more frequently for condition monitoring of rolling contact bearings and it also shows promise for plain bearings. Understanding the physical differences between the two bearing categories is critical for developing condition monitoring strategies for plain bearings using ultrasound.

Rolling contact bearings consist of several elements (e.g., cage, inner and outer race, and roller elements among the important ones). This category of bearings relies on rolling instead of sliding to decrease friction. Plain bearings have a more simple design. In their most basic form, plain bearings consist of two surfaces, one stationary and one rotating. The rotating part slides over a lubricant film to reduce friction.

Plain bearings have some advantages, the most relevant being the following:

- As long as the lubricant film is maintained, there is separation between the stationary and moving part, thereby keeping the friction low.
- A very high load carrying capability.
- A better capacity than rolling contact bearings to withstand shocks and vibration.
- The lubricant film dampens vibration and noise, making plain bearings quieter than rolling contact bearings.
- Less sensitive than rolling contact bearings to contaminants in the lubricant.

TYPES OF PLAIN BEARINGS

There are four types of plain bearings:

1. **Journal** (sleeve bearings) - They are cylindrical and the inner surface can be lined with Babbitt metal, bronze, or other material softer than the rotating journal.
2. **Segment Journal** - Similar to journal bearings, with the difference being the stationary bearing consists of segments or bearing shoes.
3. **Thrust** - These bearings are used to support axial loading.
4. **Self-Lubricated** - These are journal bearings with a solid lubricant deposited over the internal bearing surface. The lubricant is activated by friction.

PLAIN BEARING LUBRICATION

Plain bearings rely on a fluid film lubrication to keep the stationary and rotational parts separated with very low friction between them. When an external high pressure lubricant supply is used, the journal is lifted and the lubricant film keeps the surfaces separated. This is known as hydrostatic lubrication and special care is needed to maintain a steady lubricant flow. This type of lubrication is used mainly for big machines, such as turbines, where heavy journals need to be floating in oil at start-up to avoid rubbing and wear.

For medium and small size plain bearings, the film is achieved by a rotating action of the shaft, which forces an oil wedge

Figure 1: *Using ultrasound to measure plain bearings*

between the shaft and the bearing, thus developing hydrostatic pressure that lifts the shaft. This type of lubrication is known as hydrodynamic and the oil wedge is maintained as long as the shaft rotates.

Oil or grease is suitable for lubricating plain bearings. But using one or the other depends on the shaft speed, load and temperature. In general, it is better to use grease for low speed and oil for high speed.

PLAIN BEARINGS FAILURE MODES

Plain bearings have some advantages over rolling contact bearings, but also some disadvantages. One of them is a sudden loss of fluid film will cause an almost instantaneous metal-to-metal contact with serious consequences, like wear and temperature increase. Loss of lubricant isn't the only error that can cause problems. Contaminants in the lubricant, incorrect assembly, poor workmanship, corrosion, oil whip and oil whirl between the elements all can damage the bearing.

Problems related to the absorption of hard contaminants range from a light wear of the inner liner surface to scoring of the journal. Good housekeeping practices and filters in the breathers help to avoid contamination.

Mistakes in the assembly cause excessive fretting damage and flexing in the outer diameter (OD) of the shell and housing. Other problems related to the assembly are excessive interference and misalignment. Corrosion is caused by a chemical attack to the inner liner from chemical components in the oil. These

Ultrasound (US) is trending more frequently for condition monitoring of rolling contact bearings and it also shows promise for plain bearings.

Table 1

Condition	Rolling contact bearing	Plain bearing
Ultrasonic signal intensity	Strong	weak
Materials impedance effect	Negligible	Low (Depends on the inner metal layer)
Measurement points	One	More than one (One point for every two square inches of project journal area)
Type of sensor preferred	Needle	Magnetic foot
Sampling time	Short	Short to medium (according to journal speed, 1 minute, 3-5 rotations)
Problems detected	Starving lubrication Contaminants	Lost lubrication Hard contaminants Misalignment (Larger plain bearings need several measurement points due to low energy generated by faults. Draw a profile of the static values along the projected journal area.)
Window to action	Medium to long	Short

originate from certain additives or oil degradation itself. Oil whirl and whip happens when the oil can't form a stable oil wedge.

USING ULTRASOUND FOR MONITORING PLAIN BEARINGS

In recent years, improvements to instrumentation and software have challenged the concept of ultrasound applications as ONLY a simple inspection tool for leak detection. Many successful reliability teams have adopted ultrasound as an important tool for condition monitoring and predictive maintenance. Monitoring rolling contact bearings and acoustic assisted lubrication are performed daily using ultrasound. This has freed up valuable time for vibration analysts to focus on assessing critical assets first identified by ultrasound as being in a problematic state.

Plain bearings are widely used in turbo machinery and many other types of machines in the plant. Different to rolling contact bearings that enter a starved lubrication condition slowly and, therefore, are easier to trend, plain bearing lubrication requires a steady fluid film to work. Any situation that alters this oil flow leads to almost instantaneous contact-to-contact metal. Therefore, the window to failure for plain bearings is much smaller than it is for rolling contact bearings.

The data gleaned from monitoring plain bearings with ultrasound has some differences compared to rolling contact bearings. These differences are shown in Table 1.

HEALTH ASSESSMENT BASED ON STATIC ULTRASONIC DATA

There are three primary failure modes that are identifiable by trending static ultrasound data and analyzing dynamic ultrasound data. In order to easily visualize the different positions of the journal inside the bearing, imagine the bearing as a clock with a clockwise rotation (see Figure 2).

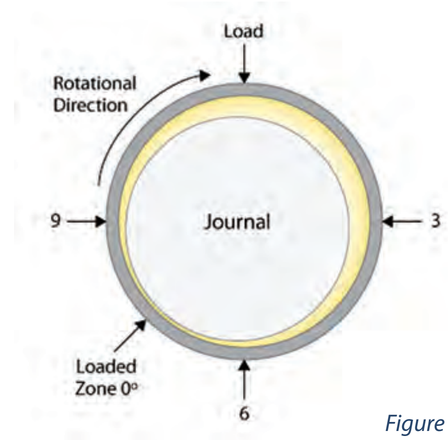


Figure 2

Normal

With a well lubricated, normal plain bearing, as the journal rotates, the pressure effect of the oil wedge moves the journal towards 7 o'clock. The highest static ultrasound data should be expected at this point. Inspectors have to think in two dimensions now. Following a line at the 7 o'clock point position, several static readings are taken across the face of the bearing. All should be similar. An ultrasonic data collector with very good sensitivity is required because friction levels are low. The acoustic impedance of the shell and inner liner affect the acoustic energy reaching the contact sensor. The ultrasonic crest factor (CF) should be low. Crest factor is a numerical value that describes the ratio between the root mean square (RMS) value and peak decibel micro volt (dBuV). This is a condition indicator that provides insight for inspectors. CF allows them to differentiate between friction and impacting as the cause for high static values. Readings taken at 12 o'clock and 3 o'clock positions should be lower than seven. The time wave trace should be uniform without many spikes of energy.

Hard Contamination

A steady supply of lubricant keeps friction levels low. Soft contaminants are embedded in the soft metal liner, but hard contaminants scratch the journal surfaces and are revealed by random, high static peaks (RMS peaks) and increasing crest factor values.

The time waveform shows random peaks if the contaminants are floating. If the hard contaminants remain in the same position, the time trace will show sinusoidal peaks.

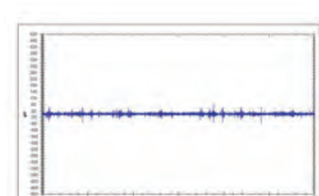


Figure 3

Plain bearing
Static reading: 14.2 dBµV

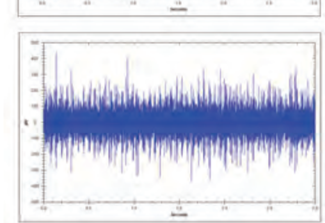


Figure 4

Rolling contact bearing
Static reading: 36.4 dBµV

The presence of contaminants will be predominantly seen at 6 o'clock and 7 o'clock positions because clearance between the shell liner and the journal are smallest there.

Oil Starvation

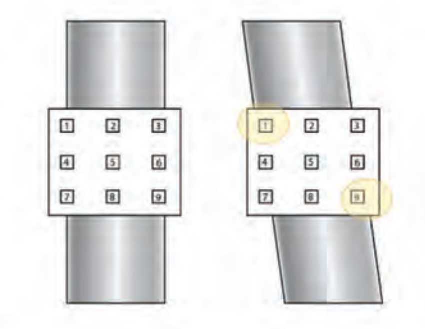
A low supply of oil causes problems in lifting the journal and consequently, metal-to-metal contact is possible. Static signals at the 5 o'clock, 6 o'clock and 7 o'clock positions increase against the normal values and readings at the 9 o'clock, 12 o'clock and 3 o'clock positions likely remain the same or decrease a little bit. Temperature also increases, so it is necessary for the ultrasonic data collector to capture a non-contact temperature value in the trend. The time waveform shows a general increase. The CF should remain low without the presence of impulses.

Misalignment

In mid- and large-size plain bearings, when comparing static ultrasound readings across several points, it is possible to uncover a misalignment situation. To illustrate this, Figure 5 shows an analysis of a hypothetical bearing that has nine measurement points over the journal's projected area.

Points 1, 4 and 7 are located axially on the left side of the bearing, at the 9 o'clock position. Points 2, 5 and 8 are at the 12 o'clock position, while points 3, 6 and 9 are at the 3 o'clock position. Under normal operation, the maximum load (friction) should be at the 7 o'clock position (points 1, 4 and 7) and lower friction at the 12 o'clock position (points 2, 5 and 8). If the journal is aligned, these values should remain stable over time.

Figure 5



For points 1, 4 and 7, the readings should be similar (highest in the bearing) and points 3, 6 and 9 also should have similar readings between them, but be a little higher than points 2, 5 and 8.

If points 1 and 9 increase and 7 and 3 decrease, or 7 and 3 increase and 1 and 9 decrease, it is a clear indication of an uneven journal rotation. By capturing dynamic signals with sample time sets that are long enough to reflect three to five shaft rotations, you will see a clear variation in signal along the time axis.

Testing plain bearings has proven challenging using traditional condition monitoring techniques. Oil analysis remains an important technology here. Advancements in ultrasound technology made by manufacturers are providing additional tools for assessing conditions in plain bearings. Follow the techniques here and use both static and dynamic data to observe changes. Always remember that the window to failure is a little bit smaller with plain bearings than it is with roller bearings and plan your uptime with the precision of ultrasound.

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Figure 1: The drum interior at Garpenberg during a service stop clearly shows the rubber lifters. The rubber lifters are clearly visible.

Figure 2: The autogenous mill at the Boliden Garpenberg Mine

The Perfect Pair

Shock Pulse and Vibration Monitoring Combo Pays Off at Boliden Mine

by Tim Sundström

IN THE MINING INDUSTRY – one of the most capital-intensive industries in the world – preventive maintenance makes good business sense. In a process involving high costs and specialized equipment, the grinding mill is not only the most energy-consuming processing unit, it is also a highly critical application. It stands to reason that optimizing this bottleneck is of pivotal interest to the industry. Swedish mining company Boliden successfully combines a shock pulse measurement technique and vibration analysis to do just that.

This technology has become a game changer when it comes to reliable condition measurement on low speed and other hard-to-monitor applications. Having performed extensive testing and evaluation of this installation on the autogenous mill in its Garpenberg mine in central Sweden, Boliden is an early adopter of this technique in the mining industry.

If the grinding mill malfunctions, the entire production process at Garpenberg can be severely limited or completely halted. Therefore, close observation of mill equipment condition is essential. A potential breakdown of this plant stopper directly affects total mine output and cost per ton. The consequences may range from extensive process limitations to a complete production stop with significant financial implications.

But monitoring the condition of a grinding mill is not a trivial task. Variable process characteristics and a noisy environment creating interference with desired signals all contribute to making successful condition monitoring difficult. To further complicate things, grinding mills run at fairly low, and in some cases variable, revolutions per minute (RPMs). Under these conditions, traditional vibration measurement techniques alone do not yield clear answers. When combined with shock pulse measurement, on the other hand, these problems can be overcome in a solid technical solution.

Grinding Mills

Part of the concentration plant, the grinding or tumbling mill is a large-scale grinding device (see Figure 2) used in mineral processing to grind large chunks of ore into a suitable size for the next step in the concentration process. A similar setup is used in the cement industry for crushing clinker.

There are several different types of grinding mills: ball, rod, autogenous and semi-autogenous grinding (SAG). In a ball mill, steel or stone balls are mixed with the ore and during rotation of the drum, the ore is ground by friction and compression into a suitable fineness. A rod mill uses a similar principle, but the steel or stone balls are replaced by rods to create the grinding action. In an autogenous mill, the ore itself is used in the grinding process. A SAG mill is a combination of a ball mill and an autogenous mill.

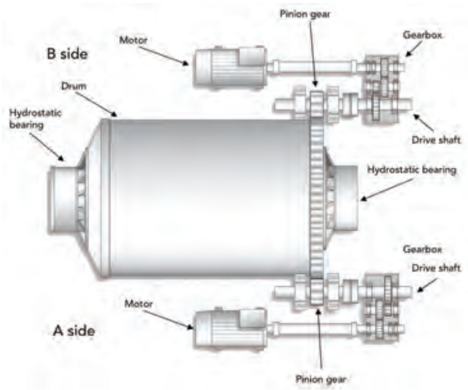


***Figure 3:** The autogenous mill seen from above*

The main component of all mills is a horizontal rotating drum, typically with a rubber liner and regularly spaced lifter bars (see Figure 1). Generally, the ore is continuously fed into the drum in one end, then crushed and transported out in the other.

In autogenous mills, a sufficient amount of bigger parts of ore inside the drum is critical to an effective grinding process. Maintaining particle size while minimizing equipment wear, downtime and power consumption is a challenge to production and maintenance engineers.

The Garpenberg Autogenous Mill Case

The online system Intellinova Compact with SPM HD with shock pulse measurement technique was installed for trial measurements on the autogenous mill in Garpenberg in January 2012. Between then and October 2013, two serious problems were detected well before any serious consequences: a bearing damage in one of the two gearboxes and a loose (wobbling) gear in the same gearbox. Had they gone undetected, both problems might have caused serious malfunctions with severe economic consequences.

The combination of vibration and shock pulse measurement is ideal for this type of application. The shock pulse technology is very suitable for detection of bearing damages in noisy environments, such as in these gearboxes, while vibration technology is optimal for low frequency related fault conditions, like unbalance, loose gears and misalignment.

The Technical Solution

The main part of the autogenous mill is the drum, rotating at approximately 15 RPM and driven by two frequency controlled motors on opposite sides of the drum. Via a two-stage gearbox, a pinion gear drives the drum itself.

A total of 28 installed transducers cover the motors, gearboxes and drive shafts, with 10 shock pulse transducers and four vibration transducers on either side. In addition, two RPM probes are mounted on the drive shafts. The shock pulse transducers are mounted as closely as possible to the load zone to pick up bearing related signals. Since they do not detect low frequency signals, the purpose of the vibration transducers is to cover such low frequency movements.

Using shock pulse transducers with SPM HD for bearing condition assessment in gearboxes yields superior capability to detect bearing condition. The multiple gear mesh frequencies in a gearbox significantly affect normal vibration transducers, making the spectrum and overall values very hard to interpret. The shock pulse transducer, however, is not affected by the gear mesh (if there are no gear damages), hence the readings are very clear and crisp, showing bearing condition only. This is because normal mesh frequencies are too low to be detected by the shock pulse transducer. If a crack or surface imperfection were to occur in one or several gear teeth, the shock pulse transducer would react due to the shocks.

Measurement Setup

Since the mill is running continuously, no triggers or measuring conditions are applied. The parameters followed and trended are high energy shocks (HDm) and vibration velocity RMS. A moving average filter with 10 readings applied to both parameters has proven useful in avoiding false alarms caused by random high readings.

For gear mesh trending, band values from acceleration spectrums are useful, again, with a moving average filter of 10 readings.

The measurement interval is set to one reading every two hours; however, since the damage development process is relatively slow, twice a day would be more than enough.

The standard spectrum setup for the shock pulse readings is 1600 lines, symptom enhancement factor equals 10 and an upper frequency of 100 orders.

The two vibration transducers mounted on the gearbox input shaft are used to detect all gear mesh frequencies in the gearbox. A 6400 line spectrum is used and order tracked with an upper frequency of 100 orders. Because this shaft has this application's highest speed, the 100 order upper frequency setting enables all gear mesh frequencies to be detected in the vibration spectrum. Alternatively, pseudo tach may be used.

By applying bands around the gear mesh frequencies in the spectrum, its amplitude can be trended, revealing gear problems in the gearbox.

Very Good Results

From the very first reading in January 2012, the drive side on one of the gearbox's middle shafts showed a very unstable trend, with the occasional clear outer race signal pattern mixed with a clear inner race pattern. On bearing replacement 10 months later, clear inner and outer race spalls were found in the bearing (see Figure 4).

Twenty-four months after installation, the system in Garpenberg continues to perform very well. System sensitivity and long forewarning times enable the planning of maintenance actions well in advance, giving full control of this process critical application. The technical solution at Garpenberg can be used for all types of grinding mills.

***Figure 4:** The inner race of the gearbox middle shaft bearing.*

Boliden Garpenberg

In operation since the early 13th century, Garpenberg is Sweden's oldest mine. After being acquired by Boliden in 1957, exploration work has resulted in a substantial increase in Garpenberg's reserves of complex ore containing zinc, copper, lead, gold and silver.

The Garpenberg mine is currently in the midst of a major expansion, where ore production will increase from 1.4 to 2.5 million metric tons of ore per year. In this process, condition monitoring plays a key role in maximizing availability and securing production. The expansion will be carried out between 2011 and 2014, with production being successively increased. Full production capacity will be reached by the end of 2015.

www.boliden.com/Operations/Mines/Garpenberg/

***Tim Sundström** has a Master of Science degree in Applied Physics and Electrical Engineering from Linköping University, Sweden. For over 20 years, he has been specializing in electronics development and has held managerial positions in the field since 1992. In 2001, he joined SPM Instrument as head of Research and Development, where he has been deeply involved in SPM HD development and field evaluations. Sundström is a certified Category III vibration analyst through Mobius Institute Board of Certification. www.spminstrument.com*

ROUTE-BASED OIL ANALYSIS ENABLES CONDITION-BASED OIL CHANGE

by Ken Caldwell & Ray Garvey

Portable instrumentation that evaluates a machine's condition at the asset is widely used to collect vibration data to quickly and accurately identify developing faults in rotating machinery. Machine oil condition monitoring yields other useful and critical information on machinery health, complementing the data provided by vibration analysis. Now, the same advantages obtained with route-based vibration collection and analysis and thermography are possible with route-based oil condition monitoring.

Changing oil on a calendar basis is rarely done at the correct time. Most of the time, the oil in a machine is changed far too often because without knowing the oil condition, there is no alternative but to change the oil according to an elapsed time interval.

Figure 1: FluidScan® Q1100 Route-based IR spectroscopy tool.

With the newly-developed maintenance approach described in this article, oil is tested before deciding to service or change the oil. The cost of testing oil is almost nothing compared to the cost of the oil itself, so following this approach will result in overall savings. If the oil is fit for continued service, it can remain in use, yielding savings in several areas. The cost of the oil, labor for frequent oil changes, oil disposal, and any tools and materials needed to complete the oil change are avoided. The costs incurred by the potential for damage due to the intrusive oil change process are also eliminated with route-based maintenance. Finally, skilled personnel may be employed in other areas rather than always servicing the oil. It just makes sense; change or service oil based on its condition, not on the basis of calendar time, operating hours, or distance traveled.

No one likes changing oil. It is time consuming, costs a lot of money and can introduce problems that did not previously exist. It takes people, time, effort and availability to get oil analysis results before executing an oil change. So why not just test the oil and keep using it when useful life remains?

A New Solution to an Old Problem

Things are changing with the introduction of a new walk-around, route-based infrared spectroscopy tool. This new tool (see Figure 1) allows a lubrication technician to follow a planned route from machine to machine, testing a few drops of oil from each sample point to obtain the total acid number (TAN) of the oil, water content and oxidation levels for machinery oils in just one minute. This allows a real-time decision as to whether or not to change the oil based on the actual oil condition and the alarm limits for that particular component for TAN or water content. Other parameters are measured for engine oils. Table 1 gives the parameters measured by the oil application category. A new ASTM method describes the use of this instrument in ASTM D7889 – 13 Standard Test Method for Field Determination of In-Service Fluid Properties Using IR Spectroscopy.

Table 1 - Measured Fluid Properties by Oil Category

Oil category and parameters

Oil Property	Properties measured by FluidScan
Transmission	Water (PPM), Oxidation (Abs/0.1mm)
Hydraulic - Fire resistant (Phosphate Ester)	Water (PPM), TAN (mg KOH/g)
Hydraulic - Aerospace (Synthetic Hydraulic Fluid)	Water (PPM), Oxidation (Abs/0.1mm), Alien Fluid mineral based (MIL-H-2304) (%), and Alien Fluid engine oil (MIL-H-23699) (%)
Heat Transfer (Quenching Oil)	Water (PPM), Oxidation (Abs/0.1mm)
Industrial (Steam and CCGT Turbine, Hydraulic, compressor, Chiller, Gear, etc.)	Water (PPM), Oxidation (Abs/0.1mm), TAN (mg KOH/g)
Turbine Aerospace (Synthetic Gas Turbine Oil)	Water (PPM), TAN (mg KOH/g), Antioxidant (% depletion)
Engines (Engine oil for different engine types, including Gasoline, Diesel, Heavy Duty Diesel, HFO, Natural Gas, etc)	Water (PPM), Oxidation (Abs/0.1mm), TBN (mg KOH/g), Sulfation (Abs/0.1mm), Nitration (Abs/cm), Soot (%), Glycol (%), Anti Wear (%)
Ethanol in Gasoline	Ethanol (%)
FAME in Diesel	FAME (%)
Biodiesel Feedstock	Water (PPM), FFA %
Biodiesel	Water (PPM), TAN (mg KOH/g), Total Glycerin (%)

In addition to supporting an immediate oil change decision, all data, observations and other findings from walk-around oil analysis can be recorded on the handheld device and uploaded to a related software for trending, analysis and integration with vibration and other condition monitoring information.

A key element of this new solution is the ability to create and follow machinery oil condition inspection routes. A route is created on a desktop PC and downloaded to the device. The route information contains the measurement point identification along with the fluid type and the alarm limits associated with that lubricant.

Is This Like Route-Based Vibration Analysis?

With a route file, the technician is never going to make a mistake regarding measurement points, fluid identity, or alarm limits. Route-based oil analysis using infrared spectroscopy parallels walk-around vibration analysis, which is an accepted, proven practice for proactive and predictive maintenance in industrial plants. Proactively, it is used to detect root causes of failure and deterioration. Predictively, it is used to detect and trend rates of change as component damage progresses from incipient to catastrophic. The data collected by a device delivers outstanding returns on investment and results in more reliable plant operation.

Route-based oil analysis promises to be a powerful tool for proactive maintenance. Testing oil, rather than frequently changing it, extends drain intervals, thereby reducing costs.

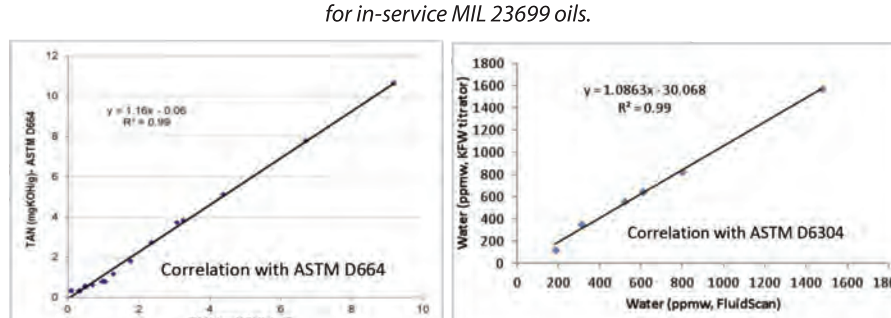
Route-based vibration analysis was made possible in the 1980s with the introduction of lightweight, handheld, battery-operated fast Fourier transform (FFT) vibration analyzers, along with computer software to acquire and store the data, and analyze, trend, report and manage machine condition based on information derived from vibration waveform and spectral analysis.

Previously, a plant maintenance engineer experiencing a machine reliability problem would call for a pair of vibration experts to travel to the plant, install their sensors and vibration analyzers with data recorders, collect data for a day to analyze results, perhaps on the next day, and then report the results before packing up and leaving. That process took several days and only yielded results for one troublesome machine. Now, a typical walk-around vibration data collection and analysis program can instantly yield valuable data from a thousand machines.

The combination of oil and vibration analysis will provide far greater insight into the health of rotating industrial machinery, such as pumps, motors, compressors, gearboxes, fans, turbines and hydraulic systems. Oil analysis adds particulate contamination, water, other corrosive fluid contamination and inadequate lubrication details to information detected by vibration analysis so these issues can be corrected before damage occurs.

Keep the oil clean (free of abrasive dust and wear particles); keep the oil dry (free of moisture contamination) and fit for use (correct oil with the right viscosity and additive pack, and the correct oil level). Oil analysis can further complement vibration analysis for rotating machinery by detecting and trending particulate and ferrous

Figure 2: *Correlation TAN and KF water by IR versus TAN by titration for in-service MIL 23699 oils.*



Most infrared spectrometers are benchtop instruments with graphical display outputs that must be read by a chemist to fully appreciate significance of subtle or obvious differences between baseline and reference spectra.

Table 2 - Measured Fluid Properties and ASTM Methods

Fluids properties and corresponding (compliance or correlation) methods

Oxidation	Nitration	Sulfation	AW Additive	Soot	TBN	TAN	Water	Glycol	Antioxidant
D7889[1]	D7889[1]	D7889[1]	D7889[1]	D7889[1] Gravimetric[2]	D4739[2]	D664[2]	D6304[2]	Gravimetric[2]	E2412[2] Gravimetric[2]

Notes:

1. FluidScan complies with ASTM D7889
2. FluidScan correlates to ASTM method for TBN, TAN, Water, and gravimetric method for Glycol, antioxidant

Comparison of FluidScan ASTM D7889 and corresponding FTIR ASTM methods

Oil Property	FluidScan Repeatability	FTIR Repeatability	FTIR ASTM
Oxidation (abs/0.1mm)	0.2	0.68	D7414
Nitration (abs/cm)	0.53	0.078	D7624
Sulfation (abs/0.1mm)	0.31	0.3	D7415
Antiwear Additive (abs/0.1mm)	0.38	0.53	D7412
Soot (abs/cm)	0.43	0.9	D7844

By testing oil in this manner, rather than automatically changing it, results in many benefits, including extended drain intervals and reduced costs.

wear debris, commonly resulting from abrasion, adhesion, fatigue and corrosion.

Laboratory Infrared Spectroscopy

Infrared spectroscopy has been used for decades to analyze in-service lubricants for detection of several troublesome issues. They include lubricant degradation from oxidation for any in-service lubricants and from nitration and sulfation for in-service engine oils, as well as lubricant contamination with either moisture or coolant. Most infrared spectrometers are benchtop instruments with graphical display outputs that must be read by a chemist to fully appreciate significance of subtle or obvious differences between baseline and reference spectra.

Recent technology developments[1] have enabled infrared spectroscopy to measure and report TAN for industrial in-service lubricants and total base number (TBN) for in-service engine oils. This new capability, added to the many other measurements available from infrared spectroscopy, makes it a perfect choice in deciding whether to service or change the oil now. Table 2 provides measurement parameters and corresponding ASTM test methods, as well as a comparison to Fourier transform infrared spectroscopy (FTIR) methods.

Conclusion

A portable, handheld infrared oil analyzer now can be used on machinery oil condition routes, providing an immediate analysis to determine if the oil needs to be serviced or if it has remaining useful life. By testing oil in this manner, rather than automatically changing it, results in many benefits, including extended drain intervals and reduced costs.

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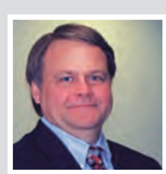

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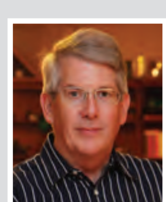

***Ray Garvey** is an engineer and inventor named on more than 20 U.S. patents associated with oil analyzers, infrared thermography, machine monitoring and composite structures. Ray has been an employee of Emerson Process Management for 22 years and is known for his participation in the development of Emerson's CSI 5100 and CSI 5200 Minilab analyzers. Ray received his bachelor of science degree from West Point and master of science degree from the University of Tennessee. www.emerson.com*

The Quest of the Two Questions

A Basic View of Industrial Reliability

and the

Things That Hold Programs Back

Part II - What Are We Doing to the Equipment?

This is Part 2 of a two-part article. In the February/March 2014 issue, the How Is the Equipment Failing? article answered the question with a discussion on the value and methods of understanding how our equipment is failing. In Part 2, What Are We Doing to the Equipment?, we address the value and methods for understanding the services that we may or may not be providing our equipment.

by Peter Chalich

What are we doing to a piece of equipment? Or put another way, can we really determine what services we are actually performing on a given piece of equipment? In a large, capital-intensive organization, this is not as straightforward as it seems. Determining what we do to equipment largely depends on how well our basic maintenance systems (e.g., preventive maintenance program, planning, scheduling, work execution, etc.) are designed and institutionalized. It also depends on how well we use the data associated with these systems. Data weaknesses typically come in two forms: the data was never generated in the first place or the data may be somewhere in the computerized maintenance management system (CMMS) or predictive maintenance (PdM) databases, but cannot be readily accessed. The value of the second question stems from the fact that it is very difficult to improve current maintenance practices if one does not know what the current practices actually entail.

WHEN DATA IS NOT GENERATED IN THE FIRST PLACE – LACK OF WORK ORDER DISCIPLINE

The first case arises when work is performed outside of work orders or against blanket work orders. This is a common shortcut that is seen as facilitating the execution of work in the present, but does so at the expense of the future. The loss of information that could be useful in preventing future failures is often not a consideration because the people performing the paperwork have never seen the benefits of such analysis.

An extension on the first case is where work orders are closed without proper coding or feedback. Here, the mechanism is slightly different, but the cause -- expediency in the present -- is the same as with working outside the system. The result is also the same, the loss of work history.

Both are work order discipline issues and can be addressed through management's setting of expectations, properly designed and displayed metrics that highlight work order discipline behavior, the visible use of work order history data and routine work process audits.

WHEN DATA CANNOT BE READILY ACCESSED – LACK OF DATA SYSTEMS STRUCTURE

Is there a consistent and well-known place in your CMMS where you can determine all the services actually performed to a piece of equipment? This does not mean those that are supposed to be performed, but those that are actually performed. In the case of specialized databases, such as those for fluid and vibration analysis data, this single point can be expanded to a short list of information sources. The point here is that equipment service information is readily accessible without special knowledge of any nooks and crannies that might have been built into the system for convenience or special purposes. This doesn't mean just work order history, it also means the data collected on routes, such as those for lubrication, condition monitoring, contractor services, etc.

Here are a couple of examples to better illustrate this point. In the first example, data proved to be difficult to extract because the equipment register within the CMMS had been set up to facilitate the segregation and execution of work, as opposed to housing of equipment history. "Dummy" pieces of equipment had been set up to group work performed by certain individuals or work by type of task. While this may have made some aspects of work execution easier, it made any analysis of work history very laborious, if not impossible.

Another example involves a situation where CMMS data showed that vibration routes had been consistently completed on time. However, the data in the vibration analysis database showed there were pieces of equipment on these routes that had never had a reading taken. Further study revealed that some of the routes were too long to be completed in the time allotted, so the tail ends of these routes were never read. The organization believed this equipment was being monitored, but in fact, it never had been. As a result, the organization was bearing more risk than it thought it was.

The ability to readily extract work history data depends largely on system setup, consistent execution to a preventive maintenance strategy, and work process discipline and feedback.

SYSTEM SETUP

Because of all the various CMMS systems in use, this topic is highly specific to individual organizations, however, there are some general guidelines that can be offered. The foremost guideline is to set up your CMMS with the mindset of future data extraction. As straightforward as this sounds, there are many exceptions to this. The people involved in system setup and configuration often don't have the background or the visionary agenda to keep eventual data extraction in the forefront. It is often the case that CMMS implementation supersedes the implementation of a reliability function. This results in reliability having to work with a system that was not set up for the reliability function. In extreme cases, it may be necessary to rewrite or reconfigure certain portions of the CMMS to facilitate data extraction.

CONSISTENT EXECUTION TO A PREVENTIVE MAINTENANCE STRATEGY

Organizations with the ability to make modifications to preventive maintenance (PM) content and frequency tend, over time, to end up with either low value PM, more PM than they can ever accomplish, or both. PMs that are set up in the absence of an overall asset management strategy tend to be driven by the emotional responses stemming from equipment failures. Emotional stimulus results in many "good ideas" as to what could or should be done. Unfortunately, these ideas may not be cost effective and build into the system more work than the available resources can accommodate. By applying a strategy that uses business goals and available data to balance risks with available resources, a PM program can be constructed that manages risk and actually can be executed. This is where tools, such as reliability centered maintenance (RCM), come into play. Just remember that the utility derived from RCM depends on how well the two questions can be answered for the equipment in question.

Another aspect of PM program design is load balancing. This is where the workload is matched to the available resources on a period-by-period basis. Proper PM content and frequency are of little value if the work bunches up into untenable piles. Ideally, PMs would be set up on a throughput or usage basis. However, most maintenance organizations have some constraint, such as available weekly man-hours, available truck shop bays, availability of overhead cranes, or some other specialized equipment. These constraints often make it advisable to set up PMs on a calendar basis so the work can be performed with the available resources.

The aspects of adhering to an asset management strategy and applying load balancing dictate that the ability to alter PM content and frequency be confined to a limited population equipped with the proper training and skills. This is what really defines the reliability function within the organization.

WORK PROCESS DISCIPLINE AND FEEDBACK

As indicated, work order discipline is necessary for the capture of equipment data. Let's expand on this concept to the entire work management process. Having well-designed PM content in place does not add much value unless it is consistently applied. In the case of PM, it is better to be consistently wrong than to be inconsistently right. This is because consistency allows performance verification, inconsistency does not. To give a simple example, if you believe changing the oil in your car's engine every 3,000 miles has a positive effect on engine life, you can only validate this if you indeed change your oil every 3,000 miles. It's this type of thinking that gives rise to metrics, such as PM compliance. There are different forms of this metric, but typically it is a ratio of how many PM work orders were due and actually completed within a period over the total that were due within the period. There are often penalties included for things, such as uncompleted PMs from prior periods, the lack of manpower, or resource charges to closed PMs. Given this, PM compliance is really a work process discipline metric. If an organization does not have good work process discipline, it is impossible to have legitimately good PM compliance. Without good work process discipline, it is very hard to answer the second question.

Another aspect of work process discipline is the utilization of feedback. In this context, feedback relates to the work order work steps. If the work process does not have enough discipline to utilize feedback from work execution, then the execution will drift from the documented work steps. People don't like to perform work if they feel it is poorly thought out, inefficient, or ineffective. Over time, they will do what they believe is right and not bother with what is written on the work order. The result is a loss of control over what is being done to the equipment. One of the primary drivers of this behavior is generic job plans that are so broadly applicable as to not be really applicable at all. While it is not possible to utilize all feedback, if for no other reason than some will counter the asset management strategy, it is possible to acknowledge all feedback with honest dialogue. This makes people feel included and also spreads knowledge as to why the asset management strategy is the way it is.

THE PATH FORWARD

A lot of information has been presented here so far, but what's of use to you? Well, that depends on where your organization is in its development. Any bells that went off during the reading of this article might be clues as to where to go next. If just a few bells went off, then maybe you have a higher performing organization and are ready for some of the higher end tools, such as RCM. If however, so many bells went off as to create a confusing racquet, then consider the following.

Any bells that went off during the reading of this article might be clues as to where to go next.

While addressing both questions is necessary for good asset management, from a value-added perspective, it may be beneficial to focus on one or the other. If your business is currently process constrained, meaning you can sell all you can make, then focus on the first question in the area that constrains the process. The *first question* is more throughput centric, while the second question is more cost centric. With process constrained, the cost of lost production typically dwarfs the cost of maintenance. However, if your business is market constrained, meaning you have excess capacity, focus on the *second question*. Just don't lose sight of the fact that both questions are important and neither question is 100 percent throughput or cost centric.

If your maintenance processes are either imma-

ture, weak in the basics, or you just don't know where to start, condition monitoring and delay analysis offer fertile ground. Both deal with how the equipment is failing and both add value in the near term. **The addition of value is critical because it builds political capital that can be traded for time or resources.**

Condition monitoring is a big topic that should be explored in earnest. However, here are some considerations.

Start with vibration analysis. It's okay to start with a contractor, but if at all possible, build in-house capabilities and work towards bringing the program in-house. This helps build understanding and thereby faith in the technology. When an issue is found, get it planned, scheduled and executed. Get the work order properly closed with the work history captured. This will help build the work management processes. Then estimate the cost savings or avoidance, taking into account both maintenance and production losses. Keep these figures conservative, but realistic, and then publicize heavily. This is where the political capital is created. Keep moving, but don't move faster than you can build competence because wrong or missed calls on equipment issues cause setbacks.

Next, take on fluid analysis. This includes lubricants, fuels and coolants. Find a qualified and competent lab that not only can handle the volume you are likely to generate, but also offers coaching and guidance on program development. Get some members of your team adequately trained in how to read test results and in understanding the underlying meaning of the values and the limits of the various tests. As with vibration analysis, broadcast the findings and value. Use every avenue and occasion to build and spread understanding of these technologies and their value.

The remaining major condition monitoring technologies include thermography, passive and active ultrasound, and motor current analysis. Where you go next depends on the nature of your equipment and a value evaluation.

Delay analysis is as big a topic as condition monitoring. While covered in Part 1 of this series, it's important to re-emphasize that there is always a story in the data and it's your job to find it. Don't let imperfect data hold you back, but rather strive to understand and work with the data's limitations. Blend data analysis with interviews. There is no substitute for face-to-face discussion with the people who operate and maintain the equipment. This communication serves two purposes: it validates or invalidates the results and it shows people that the data is being used. Used data breeds better data. Do not allow yourself to completely discount the value of the data. Doing nothing because the data is perceived as being inaccurate does not advance anything. As with condition monitoring, act on the findings and then broadcast the value.

Achieving good equipment reliability is a journey without end. However, no matter where your organization is along this path, the *two questions* should always be in play. If your efforts cannot be linked directly back to the *two questions*, then maybe you should question what you are doing. After all, it's all about the equipment.

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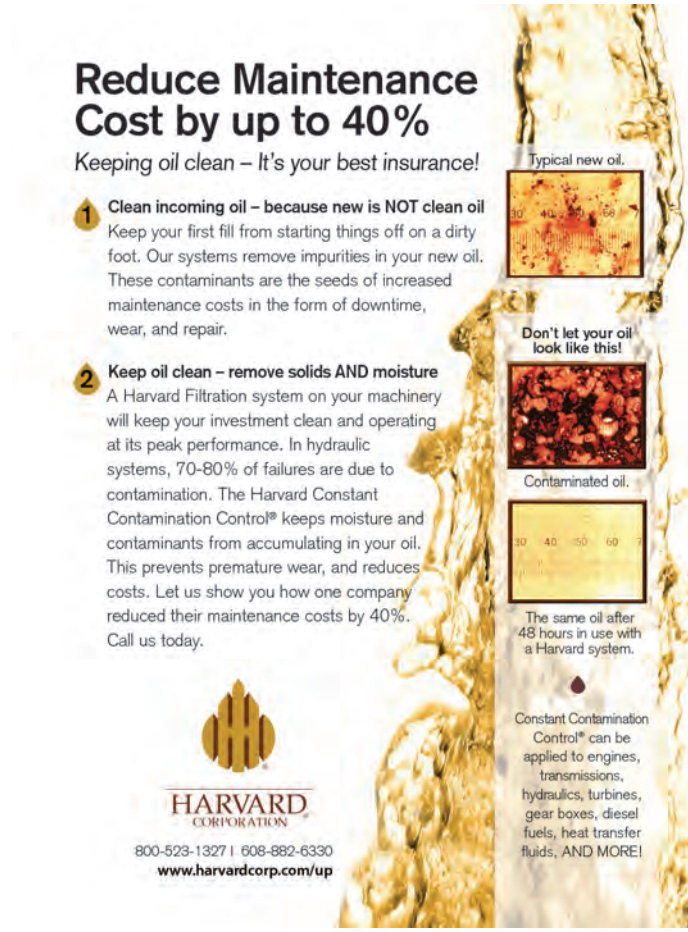


Figure 1: *Measuring rotating machinery vibration*

Machinery HEALTH MONITORING

Figure 2: *Study of rotating machinery vibration*

THIS IS PART 4 of a five-part series entitled, *Machinery Health Monitoring Depends on Accelerometers*. Part 1 addressed the mechanical aspects of selecting and using accelerometers, while Part 2 examined the electronic aspects of dealing with those small signals. Part 3 focused on calibrating accelerometers to determine their sensitivity. Parts 4 and 5 will conclude with views of accelerometers attached to various machines so they can report on machinery health.

by Wayne Tustin

Machinery Monitoring

Now let's get to the point of this series: machinery investigations and monitoring. Visualize being equipped with an accelerometer system that includes an oscilloscope readout. You can attach the accelerometer at any location and on any machine, vehicle, equipment, or structure.

Now, here's the question: Where would you find the vibration to be sinusoidal?

The answer is: Nowhere.

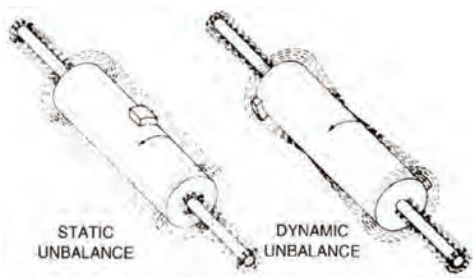
The only location where you *might* find clean, sine motion is in calibration laboratories, but even there, a tiny bit of distortion can be measured.

You certainly wouldn't find sine motion on the stationary rotating machine shown in Figure 1, to which "Young Charley" is listening. The vibration is complex, a summation of vibrations from several sources, such as unbalance of each shaft and bearing, shaft misalignment, each pair of gears, etc., occurring simultaneously. On a spectrum analyzer, these complex vibrations would give a multi-line spectrum, something like Figure 4 (top report), but with many more lines at various frequencies and having various heights.

Figure 1 shows "Young Charley" using a stethoscope to listen to one of many points on various machines. He's even better than "Old Charley," who diagnosed machinery ills with the aid of a long screwdriver held to his ear. Both are famed for their diagnoses being confirmed when machines were disassembled.

Instead of the stethoscope of Figure 1, let's get up-to-date as in Figure 2 and contact our machine with an accelerometer. Let's record a signature, a frequency domain spectrum of the machine's vibration. Then, let's compare today's spectrum with one taken a year ago, perhaps when the machine was new. Changes in the signature alert us to deterioration of gears, bearings, etc.

Figure 3: Static versus dynamic unbalance



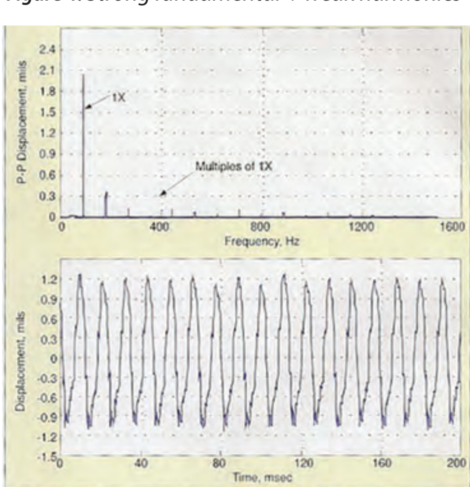
Static Unbalance

The principal contribution of rotating unbalanced components, such as shafts, to overall machine vibration is first order vibration. This means the vibration frequency is 1 x shaft speed. When a rotor spins at 1,800 revolutions per minute (RPM), ff= 1800 cycles per minute (cpm) or, dividing by 60, 30 cycles per second (cps) or 30 Hz.

People who correct unbalance problems often differentiate between static unbalance and dynamic unbalance. What do these terms mean? Take a look at Figure 3. On the left is a rotor that somewhere carries extra weight. If that rotor rested on knife-edge supports, it would rotate until the heavy side was down. Thus, without spinning the rotor, we could identify the problem and correct it by grinding off that extra weight or by adding another equal mass on the side opposite the original heavy spot. We quantify the original unbalance by the product of our correction, mass x radius, at which we implant our correction mass (ounce-inches, kg-mm, etc.).

We would achieve static balance. That was good enough for early, low RPM machinery, but not for today's automobile tires, disk drives, jet engine rotors, dental drills, precision grinders, etc.

Figure 4: Strong fundamental + weak harmonics



If some shaft unbalance was our only problem, our machine's spectrum and time history might resemble Figure 4.

Dynamic Unbalance

Suppose the original extra weight of Figure 3 (left) was at one end of the rotor. While it is true we could achieve static balance by adding a correction weight on the opposite side anywhere along the rotor, we still might have dynamic unbalance. Suppose we correctly attach the correction weight on the opposite side, but mistakenly attach it at the opposite end. On knife edges, we again demonstrate static balance. But if we place the rotor into bearings and spin it, we find severe vibration (dynamic) forces exerted on the bearings, as in Figure 3 (right).

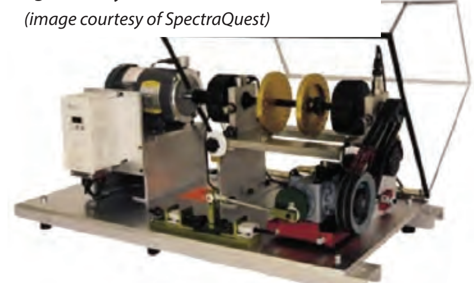
We must place the correction weight in the plane of the unbalance. Then we would have both static and dynamic balance. Zero force results from spinning the rotor.

If that plane is not available, then a greater, mathematically calculable, correction weight must be placed in some other plane that is available.

The operation of adding or subtracting mass at the proper location is done on a dynamic balancing machine, such as that shown in Figure 5. The machine spins the part. The machine senses the resulting bearing forces and an associated computer tells the machine or its operator how much mass to add or subtract and at what lengthwise location, radial distance and angular location.

When a large, immovable machine goes out of balance, the balancing technician carries portable balancing instruments to the job site. Dynamic balancing is both an art and a science. Learning to do dynamic balancing requires some training. The training unit, shown in Figure 6, allows the instructor to insert unbalance and misalignment problems for the student to solve.

Figure 6: Dynamic balance education
(image courtesy of SpectraQuest)



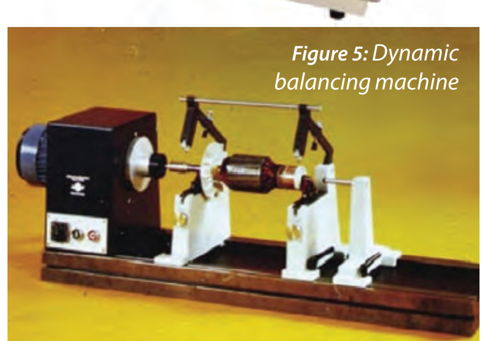


Figure 5: Dynamic balancing machine

As the student achieves proper balance and correct alignment, electrical indicators (not shown here) show the student and the instructor the progress of the student.

The next time you purchase new automobile tires, observe them being dynamically balanced on a rig.

The mechanic first removes all the lead balance weights that were clamped on the wheel rims. Then, the mechanic mounts the new tire on the wheel, fills the tire with air and places the assembled wheel on the balancing machine. With the wheel spinning, the computer recognizes forces due to unbalance, then computes and tells the mechanic what size weights to attach at certain locations on each rim. The mechanic stops the spinning wheel and follows those instructions. If you are watching, the mechanic will probably spin the wheel again, this time smoothly, stop it and proceed to the next wheel.

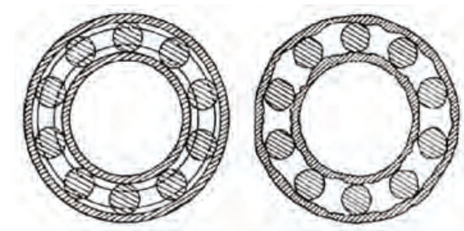


Figure 7: Smooth and rough bearings

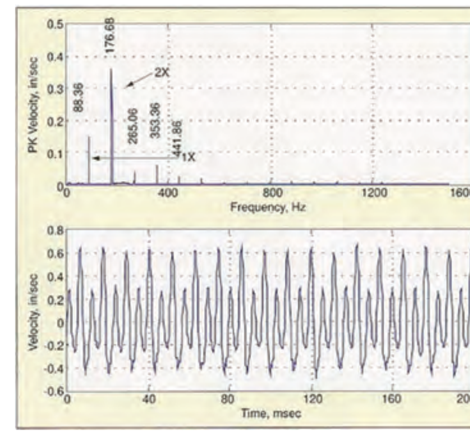


Figure 8: Weak fundamental + strong second

Bearings

Another source of rotating machinery vibration is in the bearings where shafts rotate. They are never perfectly smooth. Figure 7 exaggerates the roughness in the inner race, outer race and individual balls or rollers of the unit on the right side.

Figure 10: Properly aligning a shaft's bearings

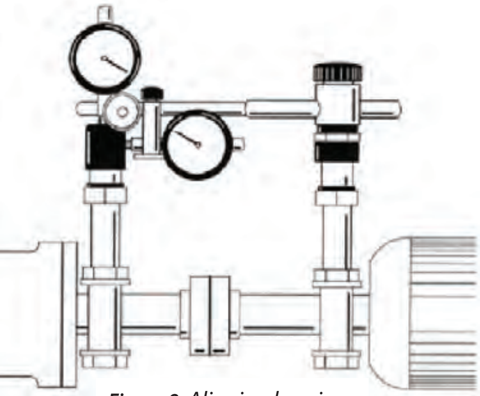


Figure 9: Aligning bearings

Misalignment

If the signature, as in Figure 8, shows a weak fundamental, but a strong second harmonic, one would immediately think misalignment.

Our geometry is fouled up. A bearing must be moved until the two shafts have the same axis of rotation. That is what is being done in Figures 9 and 10, using dial indicators. For additional information, you may wish to visit http://uptime4.me/1eSPEvo.

Gear mesh

Another source of machinery vibration is the imperfect meshing (a rolling plus a sliding motion) between teeth on pairs of mating gears. The major frequency here is: Shaft Speed (in RPM) x number of teeth / 60.

The same f_s should appear on either gear of a mating pair. Make a list of all possible gear mesh frequencies on a complex gearing system similar to Figure 11; repeat the calculation for each mating pair. Turbomachinery gears generate frequencies up to 30 kHz, thus demanding high-frequency, stud mounted accelerometers.

In Part 5, our final article of this series, we will finish our discussion on the use of accelerometers for machinery health monitoring.

Figure 11: Gears can generate vibration and noise

Wayne Tustin *has been involved with vibration and shock measurement and testing since about 1950, mainly as a teacher. He emphasizes the practical aspects of vibration and shock measurement and testing, and he favors simple explanations. www.equipment-reliability.com*

Partners, Not Competitors

The debate over which software platform is best suited to manage physical assets continues. There are two main contenders: enterprise resource planning (ERP) systems offering a consolidated approach to tracking the organization's activities and enterprise asset management (EAM) systems offering best-in-class functionality.

by Tracy Smith

At times, this debate has been contentious, pitting one department or function against another, with the winner being, in many cases, who can yell the loudest or who has the most sway with top executives. The key participants in the ERP vs. EAM debate are most often finance, IT and operations.

Historically, IT and finance prefer the ERP approach. With ERP, IT has fewer applications to support and finance has a one-stop shop for the organization's financials. Operations, on the other hand, likes the EAM approach, as it offers rich functionality, ease of use and better reporting tools.

So, who is right? Which software system should an organization use to manage its assets?

Organizations that rely on their assets to accomplish their business objectives should take this question seriously. Choosing the right software tool is critical to achieving and sustaining success. To better answer this question, it is always best to begin with the basics by defining exactly what each system is designed to do.

Defining ERP and EAM Systems

ERP is business management software that allows an organization to use a system of integrated applications or modules to manage its activities. ERP is designed to combine all of a company's activities into a single database, eliminating incompatible and duplicate technologies.

EAM is a broad term used to describe software specifically designed to manage an organization's physical assets (e.g., buildings and equipment). EAM systems are used by asset management functions, like engineering, maintenance, operations, MRO materials management, purchasing and accounting, to capture and track asset lifecycle activities.

Comparing ERP and EAM Systems

At first glance, particularly at the executive level, choosing an ERP system to manage physical assets looks pretty enticing. There is only one software system to support and the data is all in one place; a finance and IT heaven. In recent years, many organizations have bought into this approach.

This movement towards one system to "do it all" conjures images from the 1950s movie, *The Blob*, where a giant amoeba-like alien from outer space terrorizes a small community by assimilating and consuming everything in its path. In this case, the blob is ERP software modules, gobbling up all the critical business functions, including asset management.

This approach is unfortunate. ERP is a great fit for functions like IT and finance and can do an excellent job of managing an organization's finances. However, it places other critical operations, like asset management, at a disadvantage. ERP systems can be difficult to use and difficult to implement.

When it comes to asset management—a key driver of an organization's financials and the guts of the operation—an organization needs tools that are easy to configure and deploy, and have robust reporting capabilities; that is, everything that EAM systems offer.

In many cases, when asset management operations are forced into using an ERP system, they end up in the back of a slow-moving implementation line with the rest of the organization, waiting for their turn to go live. Then, once live, they are stuck with a tool that offers less functionality and is harder to use. Getting less and having to wait longer to implement place asset management operations at risk. For asset-dependent organizations, this risk is unacceptable.

However, the tide is turning. Organizations are now beginning to realize that the ERP one-stop shop approach might be shortsighted, that it is difficult, if not impossible, for one software system to optimally serve the needs of the entire organization. A more balanced approach is required where critical functions, like asset management, get the tools they require, while finance and IT get the consolidation and system simplicity they need.

Delek Refining, a division of Delek US Holdings, operates two oil refineries with a production capacity of more than 140,000 barrels per day. Delek was recently involved in a comprehensive asset management software evaluation and selection process. They compared best-in-breed EAM systems against comparable ERP system modules, focusing on functionality, ease and efficiency of use. Key areas evaluated included system navigation, asset management, work management, planning and scheduling, asset reliability, shutdown coordination, capital project tracking, inventory management, purchasing, vendor management, accounts payable and reporting.

On a scale of 200 possible points, the evaluation revealed the following scores:

Software	Functionality Rating	Ease of Use & Efficiency Rating	Totals
EAM	83	80	163
ERP	77	61	138

Delek chose to go with an EAM system over an ERP system to manage its assets. Frank Simmons, vice president, Refining Best Practices at Delek Refining, put it best:

"Asset management is a top priority for us. We rely on our assets to be successful. Therefore, we want the best when it comes to technology tools that can help us accomplish our goals. Tools that offer rich functionality, are easy to use, easy to integrate and don't break the bank in the process. The EAM system met this criteria and was the best choice for us."

There is one word that has spread fear and terror into the heart of IT and finance departments since the beginning of software time: *integration*.

So it's a no-brainer, right? The numbers clearly show that EAM systems are better than ERP system modules for managing an organization's assets. Why should anyone choose to manage their assets with anything but an EAM system? Well, not so fast.

Integrating ERP and EAM Systems

There is one word that has spread fear and terror into the heart of IT and finance departments since the beginning of software time: *integration*. Integration is the act of bringing two or more systems together to share data.

ERP systems normally manage the organization's financials. By using an EAM system, a portion of those financials—those related to asset management activities (e.g., MRO purchasing)—are initiated and tracked in the EAM system. To ensure costs are correctly allocated across the chart so accounts and vendors are paid, cost information must be passed to the ERP system. The two systems must be integrated.

This is where it gets sticky. EAM and ERP system integrations have been historically complex and expensive. Different types of databases, table structures, upgrade issues and system constraints have added costs and headaches to getting EAM and ERP systems in sync and communicating. The difficulty associated with system integration is the primary reason why some organizations have chosen ERP over EAM when it comes to asset management.

However, times are changing. Three recent developments have made system integration easier and even desirable:

1. Rapid advancements in technology;
2. Improved understanding of where certain business processes should reside;
3. Rationalizing the flow of information between systems.

Technology Advancements

Traditionally, middleware applications (i.e., software that connects two or more systems) have been extraordinarily complex. Often, these applications were custom developed by outside resources using somewhat disjointed estimations of how the interfaces will work once everything goes live. Then once the switch is thrown, necessary changes are subject to the bureaucracy of the support model, rather than the usually leaner iteration model.

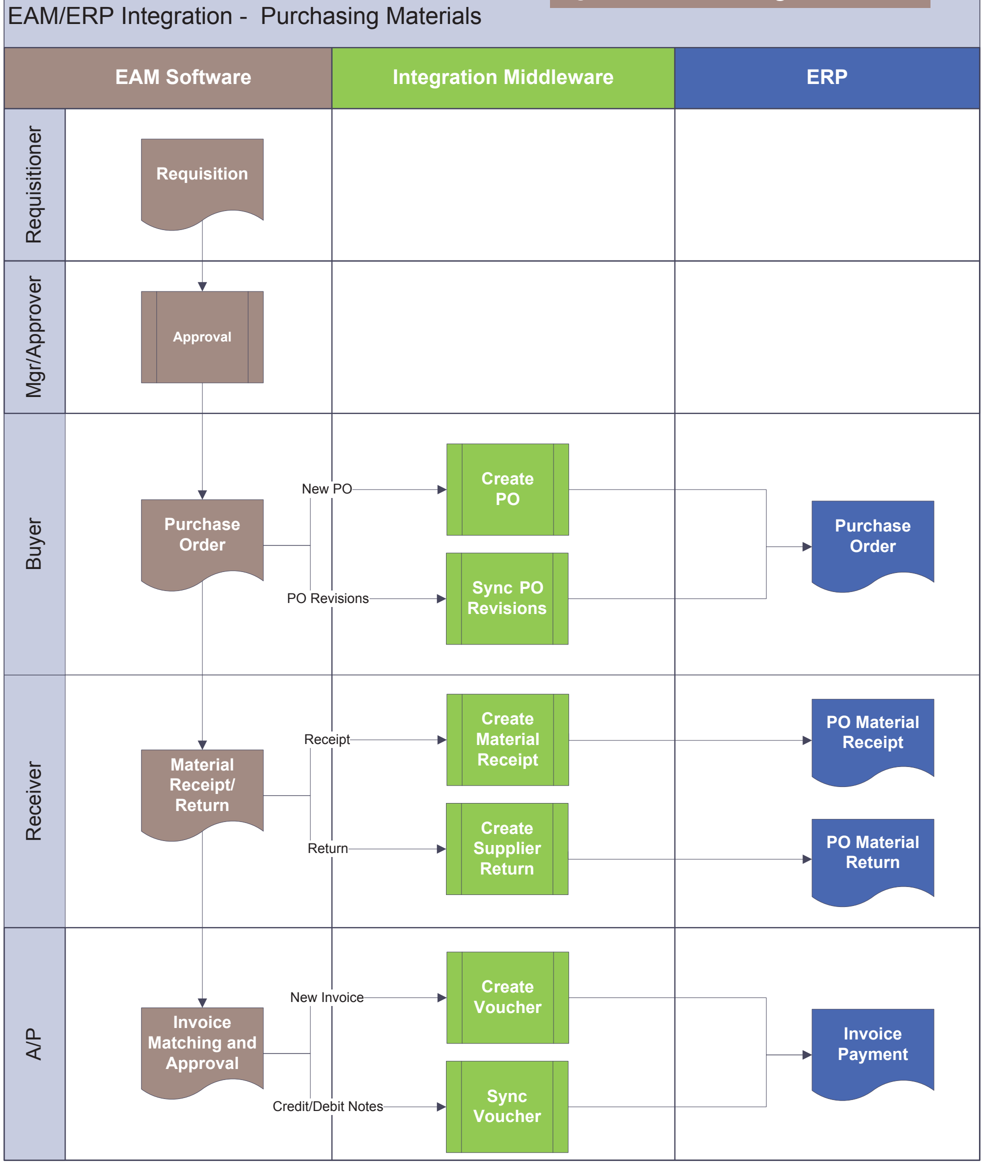
Now, middleware technology, like ERP and EAM, is evolving to enable non-technical resources to manage document flows. This means that more and more, middleware tools are embedding elements, like graphical tools for flows, mapping, exceptions handling and so forth. In other words, middleware is evolving into a platform, not just a point-to-point mechanism. This new platform approach enables multiple integration models to exist within the same application. For example, an organization might want a parallel flow for new employee records from ERP to EAM to customer relationship management (CRM), while maintaining a simple point-to-point flow for invoice documents from ERP to EAM, or vice versa.

Flexibility is king in the new integration world. No longer are organizations shying away from using an EAM system because integration with ERP seems too scary. Advancements in technology are making integration easier and less costly.

Business Process Development

Additionally, many of the past complexities of system integration were not only due to the technologies employed, but also where certain business processes reside. Defining where business process will be executed (i.e., EAM vs. ERP) is a key factor of integration success. If overlooked, it could result in a long, expensive and painful integration experience.

Figure 1: EAM/ERP integration model



Ultimately, organizations should strive to drive their costs to the asset level. Knowing what the organization spends to operate and maintain assets supports informed and educated business decisions. With that said, the most efficient and effective means of capturing asset lifecycle costs is to perform work management (e.g., maintenance and engineering), MRO materials management and purchasing all in one system. These are integrated functions and ideally should have one system home for their activities, preferably the EAM system. Let the EAM system do what it does best, which is to manage the organization's assets and asset support activities.

Rationalizing Information Flow

One of the goals of system integration is to minimize information flow between systems, while ensuring each function has the information it needs to do its job. This approach simplifies the integration project, lowers integration costs, and reduces ongoing support and risk, while meeting functional business requirements.

If an organization's current integration looks like a bowl of spaghetti (i.e., lots of bidirectional information flow) and is riddled with duplicate documents (e.g., purchase orders in both systems), then it may be time for it to rethink how best to get the EAM and ERP systems talking.

Figure 1 shows a high-level EAM/ERP integration model that minimizes application touch points (the source of many problems), keeps asset management costs and activities tied to the asset, maintains a consistent workflow and information flow, and gives the ERP system what it needs to associate costs to the general ledger to pay vendors.

In the Figure 1 example, MRO materials management, requisitioning, quoting, purchasing, receiving and invoice management are executed in the EAM system. Cost and vendor payment information are then passed to the ERP system. This is consistent with the belief that asset management activities are best performed inside the asset management system and financial reporting and vendor payments are best managed through the financial system.

The reality is that every organization is different. No one integration model, like no one software, is capable of optimally servicing the needs of everyone. There are certainly different ways to accomplish the same thing. But keep in mind, less can be more. Keeping integration simple and thorough keeps costs down, meets business requirements and allows the organization to fully realize the benefits that both ERP and EAM systems can provide.

Conclusion

Asset-intensive organizations need EAM and ERP systems to act as partners to help fully deliver their strategic plan. Both ERP and EAM systems serve distinct, specific and value-added purposes. Each system complements the other by doing what it does best in its respective field. Each system should occupy a prominent place in an organization's software portfolio.

EAM systems do a better job of managing physical assets. ERP systems are better at managing financial assets. Bring both systems together with an effective integration strategy and let them do what they do best. EAM and ERP systems are partners, not competitors, in the ongoing effort to help organizations accomplish their objectives.

__Tracy S. Smith__ is a sixteen-year veteran of helping organizations design, implement and improve Asset Management Systems. He is the President of Swain Smith & Company. As a certified and Endorsed Assessor of PAS 55, Tracy delivers PAS 55 auditing and accreditation services. He is a member of the Institute of Asset Management and an active participant in the US Technical Advisory Group aiding in the development of ISO 55000. Tracy's educational credentials are an MBA from Clemson University with a BS degree from the University of South Carolina / David Lipscomb University.

Q&A with an Industry Leader

Rey Marquez, CRL

While at IMC 2013, Uptime® Magazine had an opportunity to catch up with Rey Marquez, CRL, with Goldcorp, Inc. Rey is based in Toronto, Canada, while corporate headquarters is in Vancouver. Rey is the Manager of Maintenance and Mechanical Engineering Canada and USA. He is responsible for leading the development and implementation of maintenance reliability strategies for Goldcorp mine sites. He supports regional, site and project business plans. Additionally, he is responsible for the application of reliability strategies, root cause analysis and team based problem solving.

Uptime: It has to be quite a challenge steering multiple sites, is it not?

Rey: It is, since we are responsible for the maintenance of all mobile equipment and the fixed and rotating equipment. Also, Goldcorp has two types of mines, underground and open pit. This led us to develop a maintenance framework for Goldcorp. The document is 27 pages covering the various phases of maintenance, including planning and scheduling. The key performance indicators (KPIs) are also provided for the framework. Since it is a framework, each site is allowed to customize it to meet its needs, since there are significant differences between underground and open pit mines. Each site has maintenance strategy plans that can be customized to help the workforce on their journey from reactive to proactive. This maintenance framework is designed to help them move forward.

Uptime: How did the framework approach develop?

Rey: The maintenance strategy group developed the plans. The group took some of the existing plans and improved them. They added some new procedures and intiatives, then added some KPIs, particularly in planning and scheduling. We then took the framework to the mine sites. We helped the maintenance departments of each site understand what the new maintenance strategy plan entailed. We then solicited feedback from the maintenance teams and customized and adapted the framework as necessary. For example, an open pit mine may have 400-ton trucks, whereas underground will have 30 -ton trucks. Also, the operating conditions in the mines are different. For example, an underground mine is hot and humid, while an open pit mine can have variable operating conditions depending on the weather and time of year.

Uptime: Since your team developed the framework, certainly there are still some organizational issues that came up. Are there any of these that stood out to you?

Rey: One specific one was the use of planners. The planners needed to focus on how to transition from expediting parts for reactive work to planning proactive work. When a problem comes up, the planners want to help, but they really need to focus on planning. In the framework, we use both planners and schedulers. The planner plans the work and then the scheduler meets with operations. Together, they pick the planned jobs and set the schedules. After this meeting, any job must be a break-in to get on the schedule. However, the biggest challenge was getting our operations partners to buy-in to the maintenance framework. For example, when starting out, the maintenance planners and schedulers reached out to them two or three times per day, which provides constant communication. They especially work hard on communication before, during and after the scheduling meeting.

Uptime: What are some of the more advanced techniques in your maintenance framework?

Rey: Operator driven reliability is part of the

Underground Red Lake mine

framework. At the mines, it is in its infancy, but they are working in that direction. The mines have some pre-operating check sheets that call out tasks, such as greasing. The operators are being educated as to why this is important. This helps them realize it's really part of their job. The operators then get training to do it right. Even now, they wash their equipment before they bring it to the shop and this saves time from maintenance performing it.

Uptime: What do you see as some future hurdles?

Rey: It is probably what it will take to get to the next level, which is operator driven reliability. The operators will be looking at preventing equipment damage and assisting with timely preventive maintenance. The maintenance and operations teams need to stay on schedule with preventive maintenance and not work on it too early or too late.

Uptime: What are you doing as far as personnel development?

Rey: We are focusing on coaching and mentoring. Everyone from the superintendent to the wrench turners must ask questions that are designed to get people to think out of the box. We can't continue to do things the way we have always done them if we want to improve. Even now, people freely volunteer ideas when we are around. They know we really want their input. The more visible managers are to the people, the less threatening they appear to be, so people open up more readily.

At Goldcorp, there will be many retirements in the next three to five years. We're aware of that problem, particularly in the skilled trades, so we are looking into setting up apprentice processes. This will be comprised of on-the-job training and related courseware – our Human Resources is working on it right now.

The skilled trades shortage is important because it's hard to find people to step into these positions. There is a 20-year generation gap. Many younger workers did not follow in their father's footsteps. You can't just hire skilled people off the street. Temporarily, until we have our programs and processes in place, we are using some contractors to fill the void.

Uptime: If you could have one wish right now for the maintenance organizations at Goldcorp, what would it be?

Rey: I would like to see the mines move to a more solid predictive maintenance program. For example, we are working on oil analysis, vibration analysis and tire management, but we need to widen our use of these techniques. I also really want more operations involvement, even if it is just the basics, such as using their five senses to find problems early. For the operators to be able to do greasing, we need to make sure they are fully trained on the basics. Just something this basic will free up maintenance technicians to do more advanced predictive work.

Uptime: If you could give a piece of advice for future maintenance managers, what would it be?

Rey: They should strive to become a certified reliability leader (CRL). A CRL would fully understand all the asset performance management elements. This would enhance their career. This would make them a better manager. This will help them identify weaknesses in the organization and look for opportunities for improvement. Being a CRL would make them more credible with their maintenance people when they are out in the field with them.

Uptime: What would you like to see in the future for the mines at Goldcorp?

Rey: While I realize the opportunity to fully develop the maintenance framework will take time, I would like to see one of the mines qualify for the Uptime Award. We are working in that direction. We recently performed some RCM analysis and solved some problems that led to modifying and improving preventive maintenance, and identified some other action items. Because of the RCM analysis, the mines are running longer and producing more. We just need to take one of these examples, document it and apply for the Uptime Award.

Uptime: We look forward to the time when one of the mines wins the Uptime Award. Then you can write the case study for *Uptime* Magazine. Best wishes in your endeavor.

Everyone from the superintendent to the wrench turners must ask questions that are designed to get people to think out of the box.