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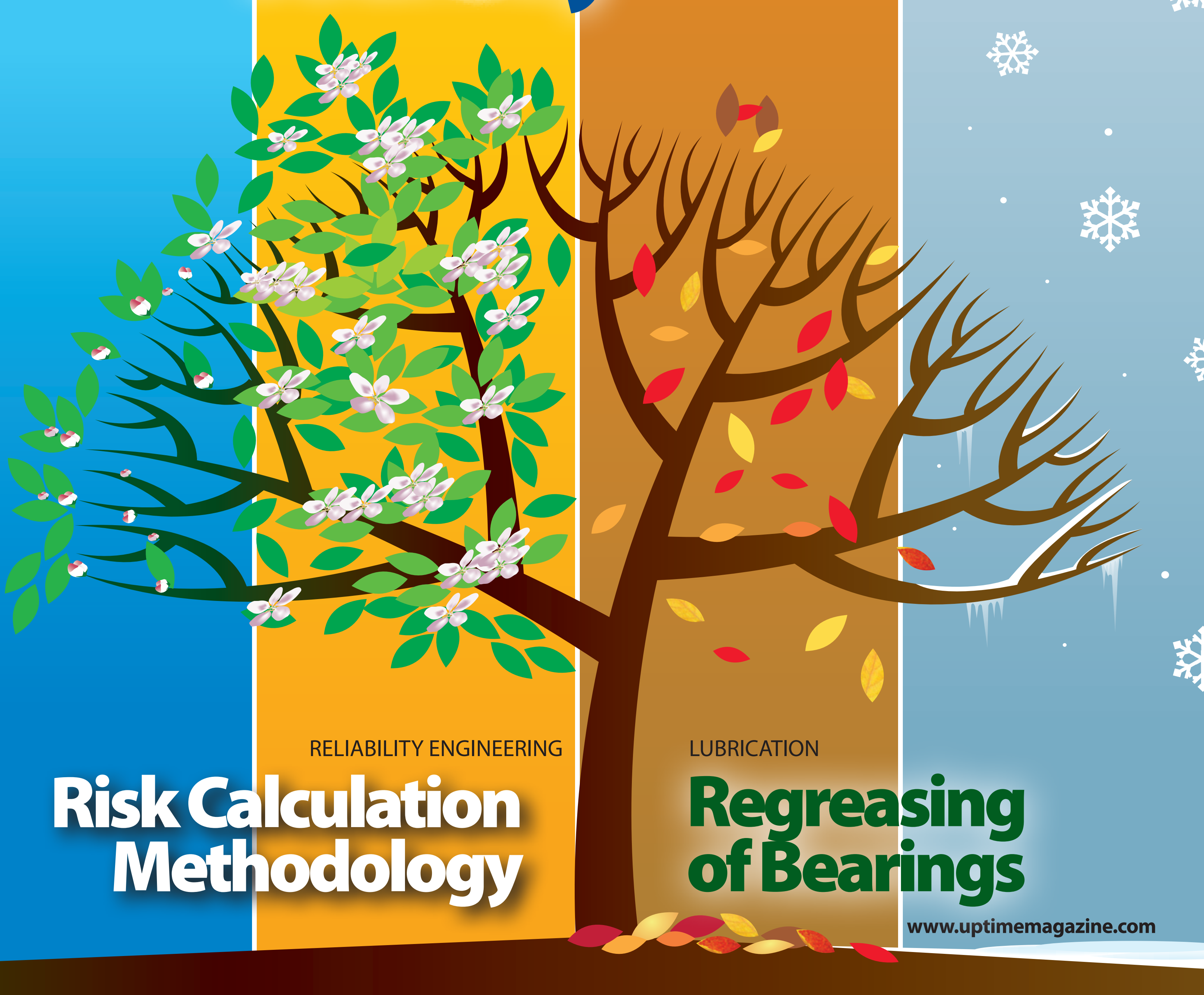
feb/march12

Continuous Journey

The seasons of Hibbing Taconite's journey to high-performance reliability



RELIABILITY ENGINEERING

Risk Calculation Methodology

LUBRICATION

Regreasing of Bearings

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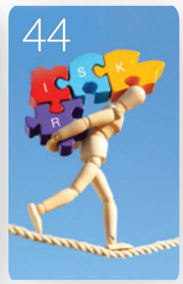

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Editorial

The Four Seasons of Reliability

This issue of *Uptime* features the story of Hibbing Taconite Company, managed by Cliffs Natural Resources, and its journey to *Uptime* magazine's Best Maintenance Reliability Program of the Year Award.

The more we worked with this special team of people, the more we recognized the distinct phases they went through as they changed ideas, strategies and practices that eventually changed the work culture.

Hibbing is in Minnesota, which is similar to where I grew up in Nebraska. The only change you could count on in Nebraska was the weather and the seasons, which got me thinking about the four seasons of reliability.

Spring – Working with your team and management to ensure the ground is ready for when it is the right time to plant seeds. You have planned your course and explained the vision, and everyone knows the part they play and the tasks they must complete. There is a lot of preparation, including training, gathering and cleaning information so it is accurate, and recommunicating a vision of the harvest that will be coming if everyone stays focused on the vision and does the jobs assigned.

Summer – Letting the sunshine and rain work their magic, there was not much to do in Nebraska as the crops grew, except to cultivate the crops and eliminate the weeds. A good plan, coupled with supportive and enlightened management, will cultivate a motivated team that will grow a new crop of reliability. Weeds are the equivalent of defects, and by now you should have empowered your team to spot and eliminate defects on an ongoing basis without requiring management direction.

Fall – Harvest the rewards of all the work you did in the spring and summer. Take a moment to reflect and celebrate, but not too long as next year is looming and the cycle starts over soon. Diligence and planning are required to be a high performance producer.

Winter – This is the time for renewal and, if possible, some rest. You could use planned shutdowns as a metaphor for taking advantage of non-growing time to renew equipment function and ensure that everything is ready to go as soon as spring (start up) rolls around again. It is also a good time to renew people through training, conferences, networking and other team development activities.

In today's hustle-bustle, high-pressure expectations of getting more done with less, we often fail to appreciate the cyclic nature of our activities and our progress. Cyclic recognition has been in our DNA since we lived in caves and hunted woolly mammoths. Working nose to the grindstone day in and day out without stopping to appreciate the progress of the journey could easily turn an adventure into drudgery.

Reliability is a hard enough journey without us making it even worse by creating drudgery. Going forward, think about developing some appreciation for the journey and worrying less about the destination because in high performance companies, the destination will always move. Lead your people and teach the joys of recognizing and appreciating the journey and the seasons. They will take to it easily, as humans have done for thousands of years.

Enjoy this issue of *Uptime* magazine and the new year. I hope you have already pledged to grow a high performance reliability program of your own.

Warmest regards,

Terrence O'Hanlon, CMRP
CEO/Publisher
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Uptime Awards

Best Maintenance Reliability Programs

2011

The Award goes to...

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

To read more about each company, download the Uptime Award Winners' stories at http://uptime4.me/award-boards.

L to R: Hardus Labuschagne, Allan Robertson, Jonny Kruger, Leon Truter, Lawrence Hibbert, Cobus Pretorius, Martin Dreyer, Wihan Marx, Ananias Ramaele, Joel van Rooyen, Stefan Breytenbach, Collen Williams, Johan Pretorius, Leon Muller, Chris van der Berg, Achard Mouton, Pieter Grobbelaar, Matt van der Westhuizen, Nick Roux, Antoinette Herbst, Mike Fitzpatrick, Schalk van Wyk, Patrick Nyandeni, Joseph Mosia, Abel Gulube

Best Condition Monitoring & Predictive Program

Sasol Mining

Toolbox Includes:

- AMS Suite: Machinery Health Manager (vs 5.3) – Emerson Process Management software
- CSI Vibration Data Loggers (2120, 2130) – Emerson Process Management standard
- CSI Laser Alignment – Emerson Process Management hardware
- CSI Oil Analysis equipment (5100, 5200) – Emerson Process Management hardware
- Auto Analysis oil software – Wirsam Scientific
- Fluke TI55 thermacam equipment & software – Microtech
- AVM UltraAnalysis (SDT 170, 270) – SDT
- 8. ALL TEST Pro 2000 - ALL TEST Pro LCC (USA)
- BeltView – Westplex
- OneProd XPR300 MetraVib 01dB – Areva

The 2011 Uptime Award Winners at IMC-2011, Bonita Springs, FL, December, 2011

Hibbing Taconite Company Managed by Cliffs

Toolbox Includes:

- Vibration Analysis: CSI 2130 w/ AMS Machinery Health Manager Software and CTC Accessories
- Online Monitoring: Emerson DeltaV
- Thermography: Mikron M7800 Cameras with Spyglass Ports and Lenses
- Fluid Analysis: The Fluid Life Corporation
- Ultrasound: UE 10000 Ultra Sound Gun

Team Members: John Tamminen, Larry Lokken, Dean Weiberg, Nick Maki, Dave Eddy, Tom Kemp, Joe Marturano, Tom Marturano

Best Maintenance Reliability Program

Left to right: Terry Kryczka, Nick Frenks, Terrence O'Hanlon, CEO/Publisher Uptime Magazine, Mark Bernadet, Dave Williams Van, Jeff Smith, Lindsey Wolf, Alan Beran, Barry Deluca, Ryan Ramage

Best Emerging Maintenance Reliability Program

Teck Coal Ltd.

Toolbox Includes:

EAM system:
- Dynamics' AX with MRO work management module; we have also developed an in house tradesman interface.

Reliability engineering Tools:
- Availability Workbench (Arms) - we utilize all modules which are RCM Cost, Lifecycle Cost, Availability Simulation and Weibull Analysis
- CMORE for Reliability statistics and spares modeling

Condition Based Monitoring Software:
- MAINTelligence is used for Oil Analysis, Vibration Analysis (also have CSI as backup), Thermography, Ultrasound, Hand-held Inspections- Maintenance, Operations, Safety and Environmental. We also utilize MAINTelligence for diagnostic Risk Evaluations for major components
- TRAKA is used for condition intelligence on our Oil Analysis information

Real time monitoring is conducted with:
- Mobile Equipment Monitoring (Matrikon-MEM) for Operational Loading, CBM, Haul Road Management, Trouble shooting Aid (MTTR reductions) and PM time reduction (if we have it in real time, we don't need to inspect for FM)
- Wonderware is utilized for our plant data historian

PDM Instruments are:
- UE UP15000 Ultrasound Guns
- Fluke Ti 32 Themographic Cameras
- CSI 2300 Vibration Data Collectors
- Comtest VB8-4CH Vibration Data Collectors
- Intermec CN3 Handheld Computers
- Rayteck MX 4 Infrared Thermometers

*Left to right:
Tammy McIntosh-Smith,
Dwight Richardson,
Jodie Allen, John Klink,
Steve James,
Deborah Hays,
Kami White*

Best Infrared Thermography Program

DMAX, Ltd. & IR

Toolbox Includes:

- Infrared-Flir P65
- Vibration Analysis-Emerson/CSI 2130
- Motor Circuit Analysis-ALL TEST Pro On and Off Line Testers
- Ultrasonic-UE Systems Ultraprobe 10,000
- CMM-MAXIMO 7.5

Best Vibration Analysis Program

*Left to right:
Mark Kumar,
Dale Rowswell,
Gilles Martin,
Kirby Engelking*

TransAlta Corporation Alberta Thermal Power Plants

Toolbox Includes:

- CSI 2130 Vibration Monitors
- CSI Machinery Health Manager (software)
- CSI Balancing Equipment
- Optalign Laser Alignment Tool
- Alignment Explorer software
- Monarch hand-held Strobe Light
- SDT Ultrasound Equipment

Luminant Mining

Toolbox Includes:

Software

- MAC is on our Windows-based CMMS (Computerized Maintenance Management System) and built on a dot. net platform. Fossil Division Root Cause Failure Analysis is also on our RCA Program.

NDT/PdM Instruments

- 2 ea. USN 50 Krautkramer Flaw Detection
- 1 ea. 52 Krautkramer Flaw Detection
- 2 ea. 58LT Krautkramer Flaw Detection
- 3 ea. USK 7 S Krautkramer
- 1 ea. USL 48 Krautkramer Branson
- 1 ea. USD 10 Krautkramer Branson
- 1 ea. Epoc 1 & 2 Panametrics Flaw Detection
- 1 ea. 5228 Ultrasonic Gage Panametrics
- 1 ea. Olympus IV8635L2 IPLEX LT Industrial Video scope/Borescope
- 1 ea. Flir 695 Infrared Camera & one more older unit
- 1 ea. Flir Hand Infrared Gun
- 5 ea. Equotip Piccolo Hardness Tester
- 5 ea. Parker 300 Mag Guns
- 3 ea. Black light
- 4 ea. Handheld Temp Guns
- 1 ea. UE UP 10,000 LRM Ultrasound Gun
- 4 ea. UE 9000 Ultrasound Gun
- 1 ea. Strobe Light
- 1 ea. SKF Micro Log GX70

Left to right: Michael Brinkman, Keith Lawson, Robbie Cross, Tony Jumper and Jackie Merket

Best Nondestructive Testing Program

Best Asset Health Management Program

Front left to right: Al McKechnie, Guy Desormeaux, Luigi Delvecchio, John Courtemanche, Keith St. Onge. Back row left to right: Tim Faulkner, Holly Gagnon, Mike Brown,Gabe Castonguay, Al Schwartz, Marc Lefebvre, Garry Piche, Adam Twigg, Paul Nadeau

Domtar Espanola

Toolbox Includes:

- Ivara EXP and EAM 5.3 (CMMS and asset condition monitoring software)
- UE Systems Ultrasound - (1) Model 10,000 and (3) Model 9,000
- UE Systems Ultrasound (3) Lube Units
- CSI 5200 on-site Oil Analysis
- SKF Micrlog Vibration Data Collectors and SKF Software
- SKF Baker Tester
- Fluke IR (1) Flexcam and (1) Fluke Ti32 Camera

Left to right: Dave Stabler - Facility Dynamics Engineering, Mike Ferrell - Gettle, Paul Shirk - Kinsley Construction, Craig Long - WellSpan Health, Mike Furlow - Walton & Co., Joel Altland - Barton Assoc. , Joe Deamer - Walton & Co., Shilpa Seroha - Wilmot Sanz, Wayne Wright - WellSpan Health, Bill DeFelice - WellSpan Health, Craig Moskowitz - Wilmot Sanz, Pattie Herbert - WellSpan Health

Best Design for Reliability Award

WellSpan Health Facility Management Department

Toolbox Includes:

- TMS (Total Maintenance System)
- WebView 2000
- FLIR
- UE9000

Top row left to right: Frank Carvajal, Don Kaczmarek, Rash Amin, Rich Padgitt, Frantz Bernadeau, Greg Emburgia, Joe Malak, Ralph Green. Second Row left to right: Dennis Lalk, Lyle Phelps, Margaret Kilburg. Third Row left to right: Tom Jennings, Jessica Karelas, George Mahone. Front: Ken Snyder

Best Green Reliability (Sustainability) Program

Merck & Co.

Toolbox Includes:

- CMMS Software: SAP
- Steam Trap Software: TLV TrapManager 2000
- IR: FLIR Therma CAM Reporter 8
- Ultrasonic Leak Detection: Ultra Probe 2000

Best Maintenance Reliability Programs

Uptime Awards Program of the Year Nominations will open May 1st, 2012 for the 2012 Awards

Best Lubrication Program

From front to back and left to right 1st row: Paula DiFonzo, Jason Escobedo. 2nd row: James Seeger, Brian Cooper, Cruz Gomez, Jason Theurer, Chris Gerchman, Ian Taylor, Trino Pedraza Not pictured: Terry Wiley, Hector Rubio

New Braunfels Utilities

Toolbox Includes:

Equipment

- Sheave Master Belt Alignment
- Dotline Laser Belt Alignment
- VB-7
- Ti32 I.R. Camera
- Easy-Laser E710
- Examiner 1000 w/Electronic Stethescope
- Spectrum Oil Storage Systems
- TIH 030m Induction Heater
- OTC 127 Bearing Pullers
- 1520 Megohmmeter
- All-Test IV Pro
- Hybrid-Breathers
- Oil Sight Glass (BSW) separators
- 3-D Bullsey

Software

- Ascent
- Smartview 3.1
- Emcat
- Infowater
- InfoSWMM
- CapPlan Water
- CapPlan Sewer
- ArcGIS
- Cityworks CMMS


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The Continuous Journey

Just as there is always a change in seasons, the journey to reliability excellence will continuously be changing and adapting

Nicholas E. Maki, Jack T. Croswell and Dean A. Weiberg

Maintaining a facility the size of Hibbing Taconite, a mining and natural resource company, is and always will be challenging. It is an endless cycle of preparing and repairing; continuously moving from one project to the next. It can be rewarding one minute and frustrating the next. As anyone involved with the process can attest, it is harder than it may appear to maintain equipment at its original designed capacity and efficiency. From the moment a piece of equipment is put into service, the clock starts and wear begins. It never seems to end and there appears to be no light at the end of the tunnel. You move from one project to the next, over and over again, seldom taking time to reflect and appreciate the work you have accomplished because the next project is waiting. This is how it is in the maintenance process. We execute repair after repair, continuously planning for the next shift, day, week, month and year, seldom taking time to look back and appreciate the work that has been accomplished.

Successful capital-intensive industries have realized a highly effective maintenance organization will increase shareholder and stakeholder value. Studies have shown dedication to maintenance excellence will positively impact safety, environmental stewardship, customer satisfaction, cost, productivity and return on invested capital. The most effective operations are those that have established excellence in maintenance. Hibbing Taconite Company in Minnesota is committed to being one of those companies.

Hibbing Taconite's journey to maintenance excellence has been a long road covering the past couple of decades. The 1980s were difficult years for Hibbing Taconite Company. A large percentage of the American steel industry and the iron ore industry that supported it had been shuttered. Along the way, many maintenance professionals had retired, been laid off, or simply walked away to other more profitable industries. Hibbing Taconite survived the 1980s, but employment levels had been reduced and critical maintenance had been reduced or delayed to

Aerial photo of the Hibbing Taconite Company located in Hibbing, Minnesota and managed by Cliffs Natural Resources

36'x15' Autogenous Grinding Mills

save money. There were still many thoughtful and dedicated maintenance professionals remaining at Hibbing Taconite, but at that time, survival was the preeminent measure of its success.

In the 1990s, the markets improved, but it was recognized that the iron ore industry was changing and the mines needed to get better in all phases to compete. Our safety performance needed to improve, our employee relations needed to improve, our product quality needed to improve and we needed to be more efficient in our processes to reduce costs for the future. Considerable efforts were made to improve the key drivers of Hibbing Taconite's success. Maintenance of the large mobile equipment fleets and plant equipment was one of several areas selected to be improved because of its obvious impact on the entire operation.

In 1994, a consultant was brought in to audit our maintenance practices and determine our first steps of improvement. The result of that audit indicated our best first step would be to develop a maintenance planning process. Based on the consultant's definition of maintenance planning, an organized effort in this area was lacking and would pay the biggest rewards. Over the next year, an effort was made to redirect the efforts of the existing maintenance planners. Their work at the time consisted of more scheduling and little of planning the work, which included organizing parts, tools, procedures and labor requirements. There was a work culture battle underway, one that was to go on for years.

Initial successes, although limited, gave us a better understanding of where we wanted to go and they whet our appetites for further improvement. Cliffs Natural Resources, managing company and part owner of Hibbing Taconite, provided the additional impetus for maintenance improvement. In September 1995, a corporate-wide maintenance leadership team (MLT) was organized to champion maintenance excellence uniformly throughout Cliffs. The work of the MLT set the foundation for our current maintenance and reliability systems.

Considerable effort was made over several years to determine key maintenance processes, select the best practices and implement them. Cliffs' employees went anywhere they heard of maintenance success to find out what the company did and we told each other to "steal shamelessly" from them. If the practices were as good as advertised, they were put into our maintenance operating processes standards book, which became the bible for what would be expected from our maintenance departments.

The improvement process does not need to wait until the six-month time, as the craft/hourly and front-line supervisors or planners have the ability to elevate improvement suggestions to middle management as the deficiencies in the system are identified.

Through the late 1990s, progress was being made as we matured in our maintenance practices and changed our organizations to go with them. Upgraded information management systems came on line in 1999 that had been tailored to better support maintenance. Educating employees in the maintenance system became more widely embedded and their skills improved.

The severe economic downturn from 2000 to 2003 slowed us down, but did not sidetrack us. Cliffs Natural Resources' MLT and Hibbing Taconite continued to focus on maintenance system improvement. At Hibbing Taconite, the success seen to date provided all the impetus needed to continue on the path we had chosen.

In 2002, another huge step was taken by the addition of reliability engineers in each of the three major departments at Hibbing Taconite Company. Their direction was to develop, direct and support equipment reliability processes. The reliability engineers were charged with answering two fundamental questions: How is the equipment failing? and What are we doing about it? At the same time, a visit by the Cliffs MLT to a Canadian steel company that had a reputation for maintenance success opened our eyes to the front-end of our maintenance systems. The process of "Identification of Maintenance Work," the first step in the maintenance process cycle, was recognized for its power. The reliability engineers were directed to focus on this process and develop the use of the many new predictive maintenance tools and practices that were maturing around the world.

As the iron ore industry and Hibbing Taconite Company boomed from 2004 to 2008, many new employees were hired and matched to the maintenance systems. Their enthusiasm, computer literacy and education levels provided an additional boost to our maintenance and reliability systems. Continued tweaking of the maintenance organizations, a focus on predictive maintenance and emphasis on precision maintenance only added to the maturing of the maintenance processes.

In addition, our reliability department reviewed the preventive maintenance (PM) and predictive maintenance (PdM) work being generated in our computerized maintenance management system (CMMS). We found that through the years of open access to the system and system upgrades, the preventive maintenance system needed to be cleaned up and standardized before we could get a true measurement of how well our PM efforts were performing. The reliability engineers were charged with the task of cleaning up the system and rewriting the PMs for the proper content, sequence and timing. This effort provided Hibbing Taconite a clean and manageable PM structure to build our reliability systems.

By the middle of 2007, the systems work was completed and we began to track and analyze our system performance metrics. The four metrics tracked were PM, schedule compliance, schedule loading hours and break-in work. Analyzing these metrics on a weekly basis provided clarity as to where to focus our floor activities.

Improvements were embedded one work group at a time over the course of three years until all work groups were stabilized under our current best maintenance and reliability practices. Once stable, we turned our focus to improving process capability. Maintenance and reliability systems improvements have been our focus since late 2010 and continues to be our focus going forward. These improvements are defined in our maintenance and reliability process at Hibbing Taconite by the engineered maintenance tactic (EMT) program. This program is an operations, maintenance and reliability engineering approach to develop a maintenance strategy that produces improved and consistent operating and maintenance standard work.

The EMT process begins with the data collection of the following items:

1. Delay data from the delay accounting system (DAS), mobile equipment dispatch, CMMS, or a combination of the three where it is applicable.
2. Failure mode effects analysis (FMEA) of the piece of equipment being assessed. If a FMEA doesn't exist, one is built. We do not perform a FMEA as the FMEA process was originally designed to assist the airline industry. Unlike a traditional FMEA, we do not cover every failure mode of each nut and bolt on a piece of equipment. Our current standard is to try to assess what the main failures are for each major component on the piece of equipment and how it affects the system or process. From this assessment, a risk number is generated. This number focuses efforts on the right systems. We are able to associate what work needs to be performed to that component or system to either prevent or identify failures. As corrective measures or detection methods are identified and implemented, the risk number for that system drops and efforts are put forth on the next highest risk component. These FMEAs are the building blocks of our engineered maintenance tactic process.
3. Original equipment manufacturer (OEM) maintenance and operational input on the piece of equipment.
4. Site experience from mechanics, electricians, management and operators. This step often provides critical information gathered from the people who interact with the equipment on a day-to-day basis.
5. Current work review, which consists of reviewing the current state of the PMs, PdM work, daily inspections and standard jobs in our CMMS. The goal here is to analyze the content and estimate its value to the system.

These points do not represent all the data collected, but are generally the majority of the data. The above points typically are the most readily available and provide the most data to be analyzed.

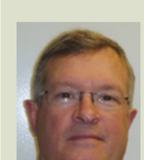
After the collection of data, the next step in the process is to review all the data and use it to establish a target condition of the maintenance system. This may require modifications to how all the above points are defined, performed and controlled. This consists of correlating the problems (e.g. delays) with the work that is or is not currently being performed. The target condition will find ways to prevent or identify some of the common delays.

Next, the various predictive maintenance technologies are evaluated. From this evaluation, we implement best practices in predictive technologies, such as oil analysis and lubrication, vibration analysis and thermography. These technologies are the foundation of our condition-based maintenance strategy. We also moved our maintenance philosophy for our most critical equipment to proactive maintenance and condition-based component change-out. Through early detection, we believe we have the ability to prevent failures in many critical areas.

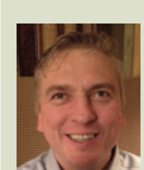
Finally, a review of the newly implemented system will take place about six months after the implementation date to reassess the program's affects and determine whether adjustments need to be made to the system. This is part of our continuous improvement process. If this process is skipped, the current process will become stagnant and improvements to the maintenance system, in most cases, won't be made. It is worthy to note that process improvements are communicated through the proper channels as they are identified. This allows the suggested improvements to be considered and acted upon in real time. The improvement process does not need to wait until the six-month time, as the craft/hourly and front-line supervisors or planners have the ability to elevate improvement suggestions to middle management as the deficiencies in the system are identified.

Hibbing Taconite Company firmly believes that through investment in our employees and their engagement in the improvement process, an effective maintenance and reliability team has been established; a team that uses a tried-and-true maintenance system to provide reliable equipment that ensures the safety of our employees, protects the environment and meets the production needs of Hibbing Taconite Company.

Nick Maki, Reliability Engineering Manager at Hibbing Taconite. He has worked in the mining industry for seven years. He has a Masters Degree in Manufacturing Engineering Technology. www. cliffsnaturalresources.com



Jack Croswell, has worked 32 years for Cliffs Natural Resources at Hibbing Taconite Company, currently as Area Manager - Mining. He has a Bachelor of Science degree in Mineral Engineering and a Masters degree in Infrastructure Systems Engineering.



Dean Weiberg is an Area Manager of Business Improvement for Cliffs. He has spent over 20 years in the mining industry. From 2007-2011, Dean was the maintenance and reliability manager for Hibbing Taconite Company. He has a Masters degree in Management.

Part 1 of a 2 part series

Stress: The Silent Killer

John Lambert

To properly install machinery, you must look at the whole process. Each component is necessary. Each technology has its place. Detecting faults plays a critical role in maintenance, but first you must install…and you must install properly.

The machinery installation process is a fundamental (basic) maintenance process. The goal is to create a stress-free environment in which the machine units can run. With this achieved, you will obtain the optimum life from the machines.

The installation process includes various items, such as soft foot correction, coupling run out measurement, thermal growth compensation, pipe strain, keyway length, etc. It also includes, or *should* include, base measurement. The installation process is a lot more than just shaft to shaft alignment, yet this is where many organizations place their focus.

Machinery installation is critical to all maintenance departments. Before you can begin to maintain your machine, you must first install it correctly. Yet many plants focus on technologies that detect faults after the fact, such as vibration, oil analysis, temperature, ultrasonic inspection, etc.

Yes, you should expect your equipment to vibrate more, create more heat and run louder when it has not been installed correctly. I'm not against these technologies; in fact I like and use them a lot. My point is before we use them, the focus should be on the installation. And the installation has to be done right the first time – guaranteed.

Again, the goal is to create a stress-free environment for your machines to run in. This statement says it all for me. Stress is applied force and the cause can be shaft misalignment, pipe strain, distorted bases, distorted machines feet (soft foot), etc. Your job is to find machine stress and correct it. In theory, you should be confident enough in your equipment installation (when it's not running) to loosen all the hold down bolts on a machine unit and not see the machine move.

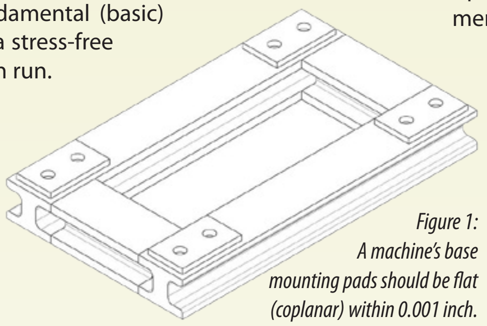


Figure 1: A machine's base mounting pads should be flat (coplanar) within 0.001 inch.

Figure 2: This motor is mounted on a piece of flat bar, which is flexing.

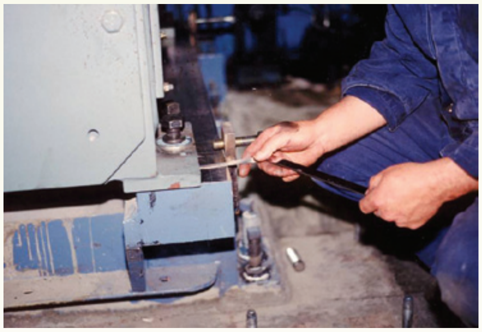


Figure 3: A large base is leveled and bolted to the floor.

Now would you do that –or would you expect your machines to move?

Let's look at one of the major causes of machine stress: the base. We all know that a base has to be strong enough to support the weight of the machine. It also has to be able to withstand the large amount of torque the machine produces. But what other requirements does a base need? For instance, does it have to be level? Does it have to be flat?

A machines base *has* to be flat, as shown in Figure 1. Level is desirable – not necessary – but flatness is a must. If a base is distorted or twisted and you bolt a machine to it, you will distort the machine's casing and deflect the shaft. In a sense, you are creating internal misalignment by offsetting the bearings.

The problem is the machine's feet and the base are not in the same plane. In other words, the machine's feet sit unevenly on the base. When the feet are tightened down, the machine's casing becomes distorted, thus creating stress.

In many cases, this is more detrimental to the life of the machine than the shaft-to-shaft alignment. With shaft-to-shaft alignment, you have two shafts and a coupling that allow for some flexibility – not much, but a little. In a machine's casing, you have a bearing on each end and one solid shaft, which is not flexible at all.

It's not just large machines that have base issues; it's also small ones as well. In most plants, there are a lot more small motors than large ones.

If you look at the base in Figure 2, you can see it's something that's been made in the welding shop or actually on the job site using an angle iron and flat bar. Who thinks that flat bar is actually flat?

Now look at the larger base in Figure 3 as an example. It is a fabricated steel frame that has been leveled and bolted to the floor. It also has been grouted in and the grout has been allowed to cure. The frame has two solid steel rails welded to each side that the new motor will sit on. These rails are six inches wide and four inches deep and the tops were machined at the fabrication shop. Looks like a nice job!

However, that is a 0.012 inch feeler that is sliding under the foot.

Out of all the feet, there is only a gap under this one foot. So if you tighten all the hold down bolts, you would be pulling this one foot down by 0.012 inches. Doing this would, in turn, drop the center of the motor down 0.006 inches, which would happen regardless of the distance between the feet. This means you have created a 0.006 inch of offset between the two bearings in the motor. In other words, you have created internal misalignment.

In the case of an electric motor, distortion could alter the air gap and create a vibration that, in time, would cause the motor to fail prematurely. If the distortion is severe, it could even deflect the shaft causing a greater vibration.

Please do not make the mistake of thinking that this is soft foot. Soft foot is a term used to describe a machine's distorted (twisted) mounting foot. This is a twisted base. To correct the problem, we need to measure the base to make sure we know where the error is.

The question we need to ask is: Where did the error occur? Was it in the fabrication of the frame? The machining of the frame? The installation of the machine? All of the above? In this case, the installation is where the problem occurred. However, another point to take is that many base frames are fabricated and machined incorrectly. Many more are installed incorrectly and there is an even larger amount that have distorted over time because after the base frames are fabricated, they are never stress relieved.

When base frames are welded and machined during fabrication, residual stress builds up and should be relieved (usually by heat). If this is not done, the base may distort or creep over the years.

Unfortunately, because many companies do not have an understanding of this issue, or in most cases, a way of measuring a base for flatness, it is ignored. We also tend to look at bases that look good and make the assumption they are flat. I admit that I have done it as well.

In Part 2 of this article, I will show you a case study of a base measurement and explain how you can use a laser shaft alignment system to measure twist in the base.

In the meantime, I leave you with this little tip: You can use vibration instruments to find this type of problem. No, I'm not talking about vibration analysis; I mean vibration monitoring. All you need is a simple vibration meter, then locate the highest reading (obviously with the machine running) in the vertical or horizontal plane, and watch the reading as you loosen and tighten each of the foot mounting bolts. You may be surprised at what you see. Sometimes, the vibration reading will go down. This is because you have taken the strain off the motor. In other words, the motor is distorted and you are easing the strain. Some call this a foot resonance check. I call it a stress test. Call it what you will, but I recommend you do it; it may save you some work later.

John Lambert served his apprenticeship in Mechanical Maintenance in Liverpool, England. After emigrating to Canada in 1973, he worked in the Aero Industry and Fiberglass manufacturing. In 1994, he started his own business, Benchmark Maintenance Services Inc., specializing in rotating machinery installation, training, service and equipment sales. He has conducted training on offshore oil rigs, paper mills, at chemical plants, cement plants and gold mines. www.benchmarkpdm.com

Preventing Mechanical Failures
An Introduction to Failure Mode Identification

Thomas Brown

Failure mode identification is often regarded as a specialized skill requiring years of study and training to master. However, it is much like vibration analysis. One does not have to be able to solve mathematics functions like Laplace transforms or Fourier series to be an excellent vibration analyst. Nor does the failure analyst have to solve linear elastic fracture mechanics problems to be effective.

The ability to recognize a characteristic spectrum pattern allows the vibration analyst to identify what is happening and the effect on a particular machine. The same may be said of failure mode identification. It is a process of comparing surface features of broken parts to characteristic surface features of known failure modes. This comparative analysis enables identification of the physical failure mode.

Whether or not a full blown root cause failure analysis or basic component analysis is done, correct identification of failure modes is essential.

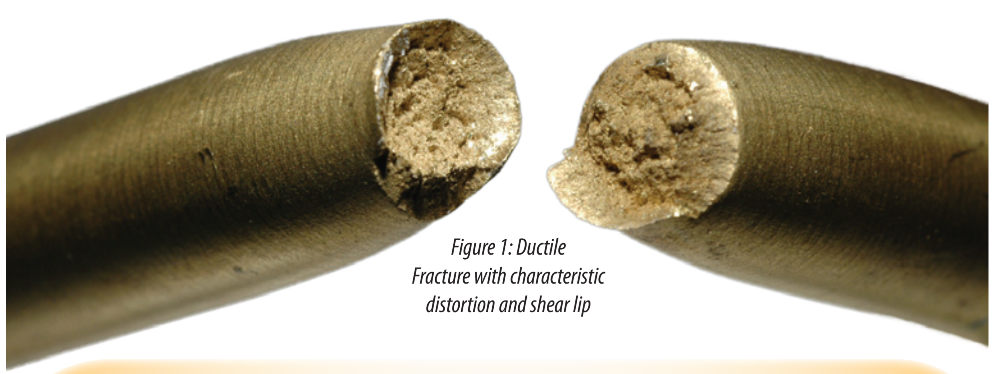


Figure 1: Ductile Fracture with characteristic distortion and shear lip

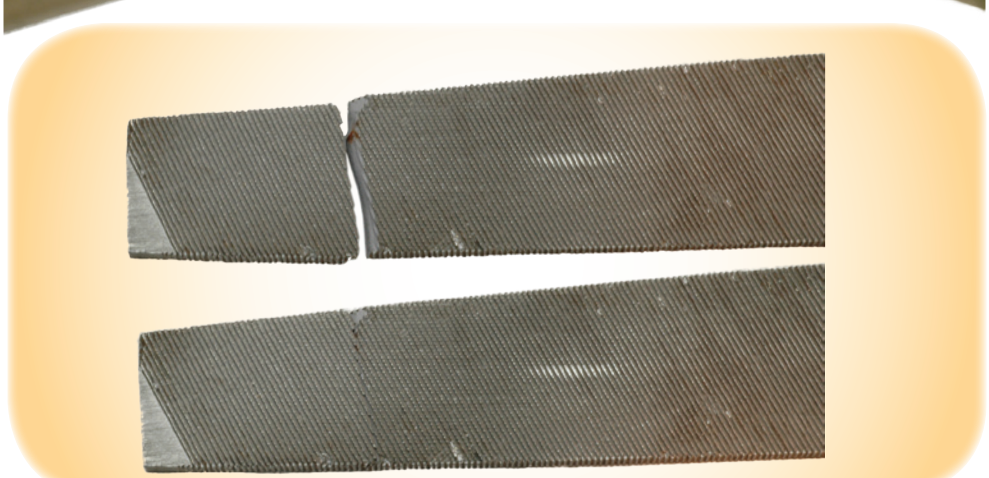


Figure 2: Brittle Fracture

Types of Fractures

Fractures are described in one of three ways: ductile overload, brittle overload and fatigue. Each type of fracture has distinct characteristics that allow identification.

Ductile Overload Fracture occurs as force is applied to a part causing permanent distortion and subsequent fracture. As excessive force is applied to the part, it bends or stretches. As more force is applied, it finally breaks.

Ductile fractures are easy to recognize because the parts are distorted. The fracture surface typically has a dull and fibrous surface. Figure 1 shows a classic example of a tensile ductile failure. The narrowing or "necking" indicates there has been extensive stretching of the metal. The part has a "cup and cone" surface; the sides have roughly a 45º angle.

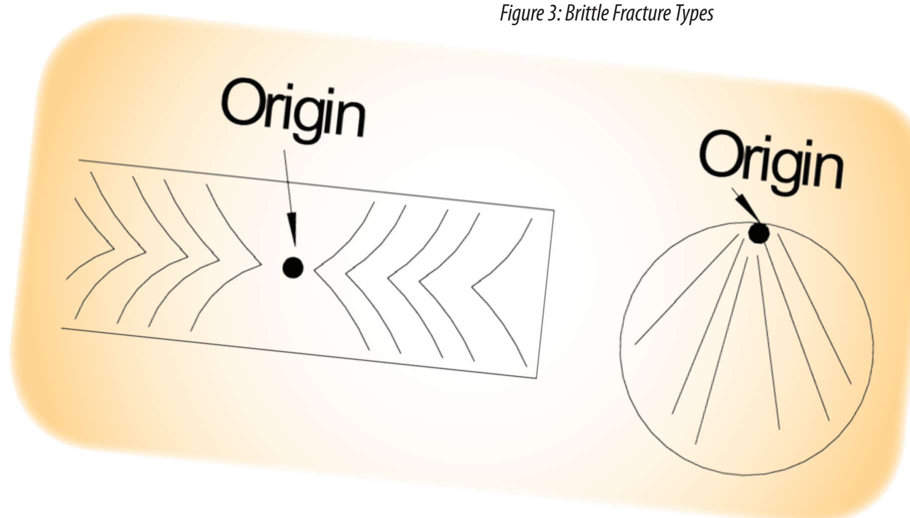


Figure 3: Brittle Fracture Types

Because ductile overload cracks start differently at the molecular level than brittle fractures, they frequently have a 45º shear lip. The presence of a shear lip is another clue the fracture was ductile.

Ductile failure is useful in many situations where bending or distortion absorbs energy. Steel highway guard rails are designed to distort and absorb energy before fracture, gradually slowing the vehicle. A part that bends gives the operator an unmistakable warning something is wrong.

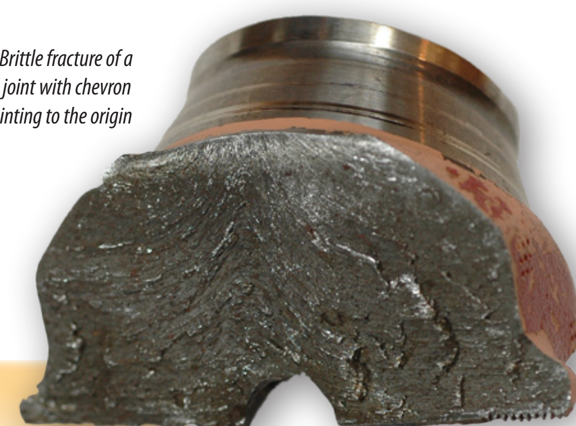
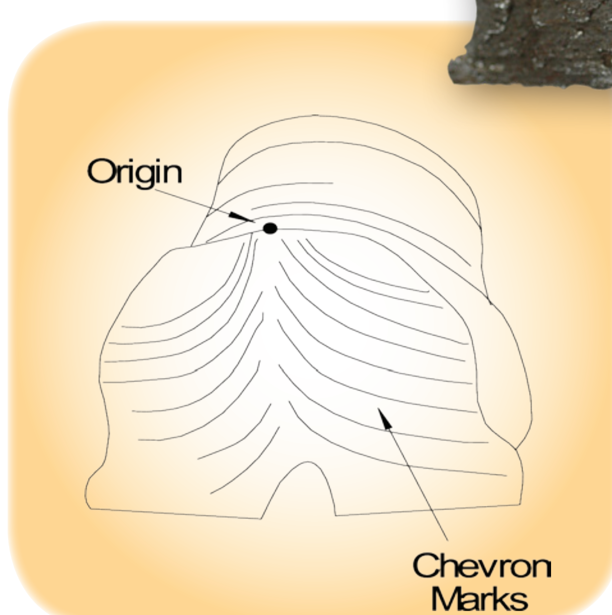


Figure 4: Brittle fracture of a universal joint with chevron marks pointing to the origin

Brittle Overload Fracture occurs when there is little or no distortion of the part before it breaks. The file pieces in Figure 2 could be put back together in perfect alignment.

Brittle fracture results from the application of excessive force to a part that does not have the ability to deform plastically before breaking. When a brittle fracture occurs, there is little warning. A high strength bolt breaks suddenly, a glass shatters when it hits the floor, or a cast iron bracket breaks without noticeable bending are examples of brittle fractures.



Brittle fractures frequently have chevron marks pointing to the origin of the fracture, shown in Figure 3. The one on the left is like the name implies, a series of chevrons. The chevron tips point to the origin of the fracture. The chevron marks on the right are fan shaped ridges radiating from the origin.

The brittle fracture in Figure 4 occurred when a drive shaft suddenly stopped. The universal joint fractured, creating the tell-tale chevron marks of a brittle fracture.

Fatigue Fractures are the most common type of fracture. About half of all fractures are fatigue fractures. They are usually the most serious type of failure because they can occur in service without overloads and under normal operating conditions. Fatigue fractures frequently occur without warning.

Fatigue fractures occur under repeated or fluctuating stresses. The maximum stress in a part is less than the yield strength of the material. Fatigue fractures begin as a microscopic crack or cracks that grow as force is applied repeatedly to a part.

Fatigue fractures have several distinct characteristics that make them easy to identify. Several distinctive features of a typical fatigue fracture are shown in Figure 5: an origin where a crack started, a fatigue zone and an instantaneous zone. This fatigue fracture started at the keyway and progressed across the shaft (the fatigue zone) until material remaining was no longer strong enough to support the load and it finally broke (the instantaneous zone).

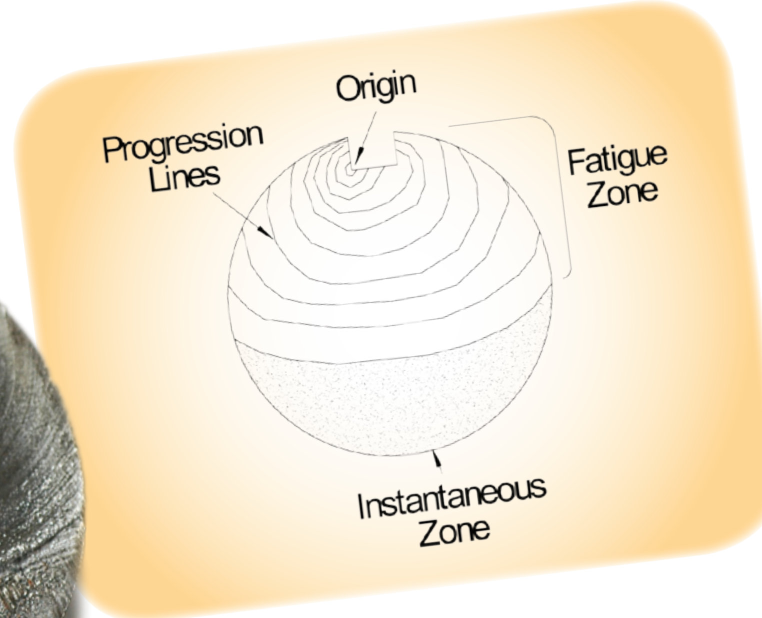


Figure 5: Features of a typical fatigue fracture: origin, fatigue zone, progression lines and instantaneous zone.

The fatigue zone is unique to fatigue fractures because it is the region where the crack has grown from the origin to the instantaneous zone. It may take millions or billions of cycles for the crack to travel across this zone. When the load is high, the number of required cycles for the part to finally break is low; but if the load is low, the number of cycles necessary for fracture is much higher.

The presence of progression lines in the fatigue zone is a positive way to identify fatigue fractures. Progression lines also have been called stop marks, arrest marks and beach marks, all in an effort to describe their appearance. Progression lines are visible ridges or lines that are typical of crack progression across a ductile material. Each mark or line is created when the crack stops. They can be formed by corrosion, changes in load magnitude, or loading frequency.

Sometimes progression lines are not visible. If the load doesn't change or the metal has very fine grains, they won't be visible. The fatigue zone will have a uniform fine grained texture like the tension failure of the cylinder rod in Figure 6. The instantaneous zone has a coarse grained or rock candy texture.

There may be some deformation of ductile materials as the final fracture occurs. The final fracture zone is essentially an overload fracture. If the material is ductile, deformation may occur. Brittle materials should not have any gross deformation. Frequently, there is little or no deformation from the fracture, but the surfaces rub against each other and are damaged after the final fracture occurs at the instantaneous zone.

Fatigue fractures don't require high stress, so there is usually very little deformation. It is often possible to fit the parts back together in good alignment like the journal in Figure 7. Remember that putting the parts back together damages the microscopic features of the fracture faces.

Stress Concentrations and Ratchet Marks

Every fatigue crack will have at least one and frequently more origins where the crack starts. Initiation of a crack occurs because there is a small region where the stress is higher. Higher stress regions may be caused by change in geometry of the part, such as a keyway, change in diameter, holes, corrosion pit, or metallurgical flaw.

Stress concentrations have two important characteristics. First is the severity. Sudden changes in shape, like a keyway, sharp corner, or corrosion pit, will cause a large stress increase in a very small area. Conversely, a smooth, large

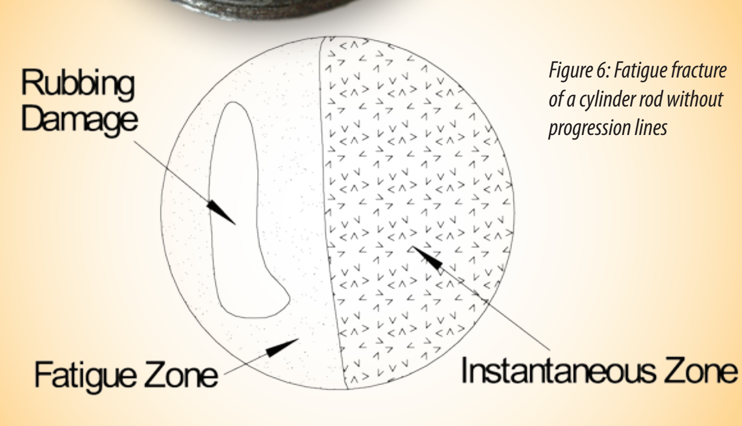


Figure 6: Fatigue fracture of a cylinder rod without progression lines

Figure 7: This journal fatigue fracture could be fit back together after it fractured.

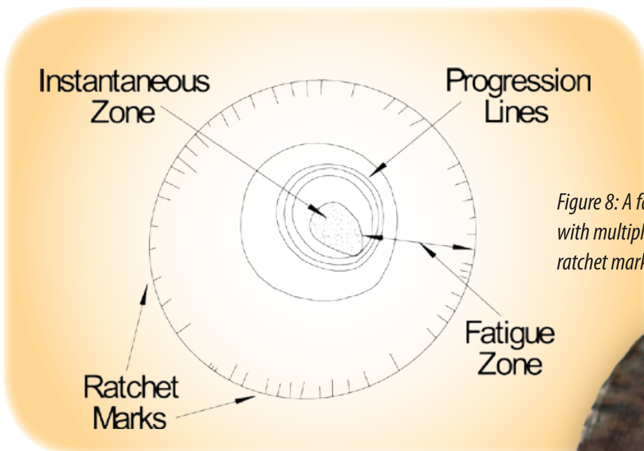


Figure 8: A fatigue fracture with multiple origins and ratchet marks

radius will cause a much smaller stress increase and the part does not fail.

Second, the number of stress concentrations provides multiple locations (origins) for fatigue cracks to start. Multiple stress concentrations are frequently caused by corrosion, rough finish, or welding.

Ratchet marks are formed when multiple fatigue origins are near each other. A crack starts at each origin. As cracks meet, a ridge or step is formed, creating the ratchet mark. Eventually, the cracks merge into one fracture and a single progression line continues across the part. Ratchet marks are not origins, but rather the location where cracks meet.

A large number of ratchet marks indicates an excessive number of stress concentrations on the surface and/or extremely high stress. When either or both of these conditions occur, the number of ratchet marks is greater than if there were fewer stress concentrations or lower force/stress.

The shaft in Figure 8 was welded around the circumference, creating multiple stress concentrations. Multiple fatigue cracks started around the circumference and progressed toward the center. The instantaneous zone is small, indicating the load on the shaft was small.

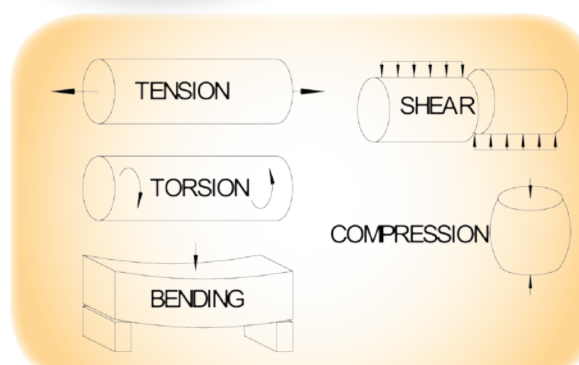


Figure 9: Five types of forces that may be applied to a part

Types of Force and Fracture

Figure 9 shows the five types of forces that may be applied to a part:

Tension occurs when a part is pulled at opposite ends. A bolt is a good example.

Torsion is caused by twisting the ends of a part. Torsion occurs in pump and motor shafts.

Bending occurs when one or both ends of a part are held and a force(s) is applied at a point(s) along its length. Belt tension or misalignment causes bending.

Shear occurs when two closely spaced opposing forces are applied across a part. It often occurs in bolts and pins.

Compression occurs when a part is pushed on both ends.

These forces may be combined in countless ways, but the direction of the fracture will tell which one or combination of these forces was present and what force was dominant.

Tension, bending and torsion are the most commonly encountered forces in failures. Pure shear, as shown in Figure 9, is less frequent and compression failures are rare.

We frequently discard broken parts before letting them tell us their history. An examination of broken and damaged parts will yield a wealth of information about their history. The parts will tell us if they were overloaded, exposed to corrosive materials, improperly designed, manufactured or assembled incorrectly, or installed improperly.

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Does Anyone Have One of Those **Phones** I Can Call Production With?

Dave Loesch

When was the last time you sat through a demo of your employer's phone system? Did you prepare lengthy specs describing your "telephone placement and receiving" processes that were diligently checked against vendor compliance? Did a cadre of project team members fly in to see others using the system? Did you endure weeks of training, temps and overtime while learning the new system? While a few telco pros may relate to this, probably no more than a handful of this publication's readers have endured such an ordeal for the purchase of a phone system.

Yet, if we replace "phone system" with Enterprise Resource Planning (ERP) or Enterprise Asset Management (EAM), the response likely would be quite different.

Someone around these parts must have remembered when I made my lonely prediction that stand-alone EAM would get largely supplanted by ERP-based maintenance modules because I've been asked for another "far out" prediction.

Let's start with a date: 2020. About a decade from now when companies buy enterprise software, it won't be through RFPs, demos, or site visits. A small group of specialists—probably like the telco engineer who actually had an opinion on *5 versus #5—will survey a couple of options and make a recommendation. Like phones, they won't spend a lot of time looking at the "plumbing" (middleware, database, or hardware for EAM; routers, switches and hubs for phones), rather they'll focus on cost and what others like them use. They'll look at the output (reports) and dive deep with the service specialists whom they'll spend more time with than the original equipment manufacturer (OEM).

"Over my dead body!" (or downed equipment) screams the maintenance department in hearty unison. "There ain't no way I'm letting IT pick my EAM system. If they wanna do that, they can take the heat for the [insert critical equipment description here] going down."

While that approach often worked as we were all getting used to software, the days of departments enforcing their will on the enterprise are just about over. Enterprises have learned—some the hard way—that they can't run the business when each department maintains their own IT fiefdom. Further, the cost of redundant IT systems waste precious margin points few can afford. While it was important that users owned the selection when technology was novel, an enterprise information management system needs to be acquired by, well, the enterprise, not departments or disciplines viewing the business through their own functional lens. The most successful companies in the global economy will be lean, seamless and agile. Not siloed, impenetrable and resistant to change.

Many of us have anxiously awaited the "next release" that would magically solve all our problems. The reality of enterprise software in 2010—whether it's financials, supply chain, EAM, or many others—is we've analyzed, built and delivered pretty much everything that can be accomplished with these products. We can always find the next (not so) new thing to get excited about—mobile, scheduling and hosting software have made multiple debuts in EAM over the years—but the basics are in place. And, it's not like we're dealing with national security secrets. Heck, you can buy books on Amazon that describe EAM products in excruciating detail. How much secret sauce can there possibly be?

What happens when functional innovation is no longer a differentiator? Issues like service and cost become a project's critical success factors. Imagine buying a

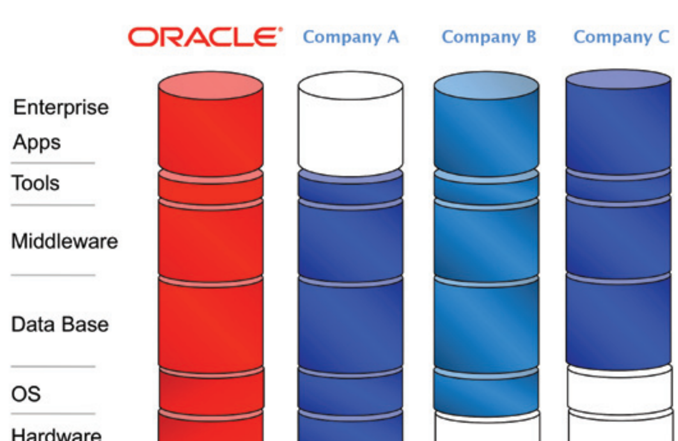


Figure 1
With enterprise applications—including EAM—at mature levels of functionality, the drive to lower IT costs, improve reliability, and enhance service has moved to delivering integrated technology solutions.

custom-built car. Because there's no other one like it, you have to fly in the mechanic for repairs instead of taking it to your local mechanic or dealer. Wait until you sign for that bill! But that exactly describes where enterprise software is headed—towards a rational number of platforms that a competitive body of service specialists can support. Without that ecosystem, reliability and cost limit both adoption and value.

And in that environment—perhaps not even 10 years from now—companies will no longer evaluate enterprise "platforms" through demos and evaluation teams, but will deploy proven components through a "black box" of hardware, software, database and middleware. Will there be "plug and play" components through which you can enhance the solution? Sure, but they won't be the major applications or business processes. (There's no such thing as application-level industry standards and besides, who needs 'em when the applications are 40 years old and interchangeable from a process perspective?) Making sure enterprise applications "talk" and deliver actionable business intelligence at an affordable cost are what matters. The only way to deliver that is through an integrated information platform that avoids the "finger pointing" of "best in class" software deployments.

It's always hard when the rules changes. Many of us embraced EAM because we loved maintenance and thought technology provided a vehicle for continuous improvement. While that held true for the first decade or so—and through a few dozen software releases!—enterprise software today is more like car manufacturing than gene research. Is it still a source of innovation? Sure. Do suppliers pour billions of dollars into R&D? You bet. But, do customers want their enterprise providers vacillating between the competing interests of departments or business units? No more than they want sales using a different phone system than finance. Enterprises need information platforms—like phone systems—that are affordable, reliable, functional and serviceable. That happens through the acquisition, integration and testing of all components before entering your first work order, which, if you take a look at Figure 1, is the solution strategy of virtually all major technology vendors. Customers are tired of "it's a database problem" or a "middleware problem," or whatever component is conveniently blamed. They just want affordable systems that work. While it made sense to let departments pick their software to get them used to software as part of their jobs, the break-in period is over and it's time to ensure technology benefits the entire enterprise.

As committed professionals, it can be hard to admit our interests aren't paramount. While maintenance efficiency may be our prime interest, it's not the enterprise's only concern. Every EAM user is part of an enterprise team that needs affordable, integrated and actionable software supporting the organization. Companies can't allow departments to buy their own phones, and enterprise software is no different. We all know the whole exceeds the sum of the parts. And it will take a single, integrated system of hardware and software to get the whole out of an enterprise in the 21st century.

Dave Loesch has been building and installing EAM systems for about as long as the space shuttle program. Fortunately, to this point, he avoided being de-funded. www.oracle.com

INNOVATION STUDY

How Newport Office Tower Adds Daily Temperature Monitoring to Electrical Maintenance Program

Aku Laine

For a majority of commercial office buildings, an annual infrared testing program is the sole measure of electrical system reliability. Infrared testing does a great job of detecting overheating anomalies caused by conditions such as loose connections, overloaded circuits and unbalanced loads. Also, the thermographer or electrician conducting the infrared testing can identify visual deficiencies, such as discolored components, wiring issues and mismatched fuses, within the electrical enclosures.

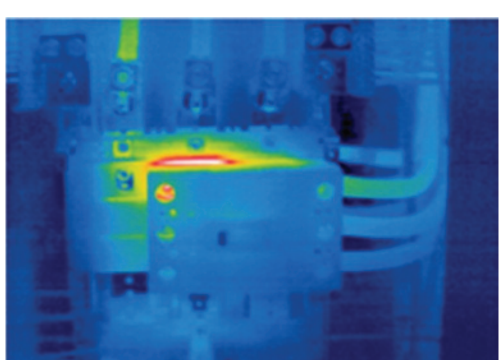
The technology is proven, dependable and a staple of electrical maintenance. But what happens in an electrical enclosure after the data is recorded and the enclosure is shut? Often, the enclosure's performance condition remains a mystery for an entire year until the next annual infrared test takes place.

As chief engineer of Brookfield Properties' Newport Office Tower in Jersey City, N.J., my job is to keep the building's hundreds of electrical enclosures operational.

Newport Office Tower is a 37-story commercial facility, measuring over a million square feet and housing a multitude of banks and financial brokers, often with their own on-site data centers and trading floors. A reliable supply of electricity is essential to their operations.

Although I have never faced a catastrophic electrical failure in my 20 plus years at the tower, like any experienced chief engineer, I know of incidents at facilities around the world where faulty electrical systems caused extended downtime, major repair and in the worst case, fire. For that reason, system reliability is foremost among my electrical maintenance priorities.

In 2009, a situation arose that led to our improving upon the facility's already high existing level of reliability, which consisted of annual infrared testing supplemented by periodic reliability examinations. It was during our infrared testing that we identified a hot spot in one of the main switchgear cabinets of our bus duct system. A root cause analysis showed that temperature fluctuations were causing parts of the bus duct joint to expand and contract. The resulting vibration loosened the bus duct joint bolts over time, allowing additional resistance, which caused the system to work harder. The bus joint was easily repaired after a utility shutdown that required hours of coordination among the utility company, the landlord and the building's tenants. If the loose bus duct joint had not been detected, the result would have been catastrophic failure. Although the bus duct joint was repaired, the incident indicated that my electrical system warranted more frequent attention. Since infrared tests incur a relatively high expense, I turned my attention to potential alternative solutions. What I wanted was a way to constantly monitor every critical electrical enclosure in the building in a way that would complement our existing electrical maintenance program.



Ecample 1: Infrared image of hot spot in a main switch cabinet of bus duct system (Photo courtesy of Delta T Engineering, LLC)

Wireless Temperature Monitoring

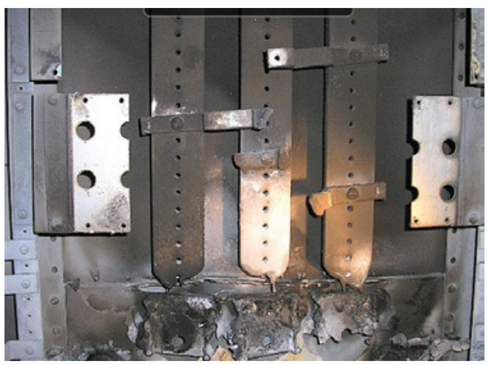
The answer arrived in the form of wireless temperature monitoring, a device created by Fred Baier, founder of Delta T Engineering, LLC. During his own career as a Level III certified infrared thermographer (Infraspection Institute), Baier had seen scores of incidents where consistent temperature monitoring would have vastly improved existing electrical maintenance programs. His experience led him to develop the Delta T Alert™ wireless temperature monitoring system, which consists of dual temperature sensors and dedicated software.

In addition to its primary function of identifying excessive heat rise conditions within electrical enclosures prior to failure, the system also offers energy savings by allowing for the timely repair of loose connections that create increased resistance, thus resulting in higher energy costs. The cost of cleaning and replacing electrical components is low compared to energy savings realized through this form of preventive maintenance.

Baier agreed to provide and install a sample wireless temperature monitoring system for our main switchgear application. The wireless dual sensor, which simultaneously monitors room ambient temperature and enclosure temperature, applies magnetically to an electrical enclosure cover. Installation requires only the drilling of a small NEMA IP20-approved hole, 15/32 inch. The device's enclosure temperature sensor is inserted in the hole and its magnet keeps it in place.

Once the sensor is installed, it is programmed via laptop with temperature thresholds determined by the enclosure's size and how much it pulls in amperage. The programming software can accommodate nearly any application. Installation was completed in about five minutes.

Next, my office PC was loaded with the system's software, which contained the preprogrammed information from the installed sensor. The sample system was now fully operational. It soon became apparent that the product worked well. From the convenience of my second-floor office, I could see at a glance the enclosure's temperature and whether it was in alarm mode. Temperature trending graphs, repair logs and a host of valuable reports were just a click or two away.



Example 2: Catastrophic failure of electrical components, such as the sample burned breakers (top) and bus duct disconnect (below) can cause extended downtime and incur major repair expenses. (Photo courtesy of Delta T Engineering, LLC)

I became convinced about the device's usefulness and ordered 80 for periodic installation over the next two years. Baier completed the installation work and provided software training. The system can record up to eight readings per day at specific time intervals every day of the year.

The devices are currently installed on 36 floors. I see the temperatures and operating status for any application I choose, including main switchgear cabinets, current transformers, transformers, bus duct disconnects, variable frequency drives (VFDs) and motor control centers. Forty more devices are currently on order for use on additional bus duct disconnects.

Wireless Monitoring in Operation

The wireless temperature monitoring system has performed as expected, issuing warnings of "Critical," which calls for immediate attention, and "Elevated," which mandates close watching.

One alert, for example, identified temperature fluctuations in our 30th-floor electrical closet – panel labeled RP-30A. The wireless device monitoring this panel showed that the operating status varied among "OK," "Elevated" and "Critical" on numerous occasions over a three-month period. Upon inspection, we discovered that the fluctuating temperatures were caused by different load conditions throughout the day. Although this three-pole, 200 amp breaker was not overloaded, infrared inspection showed a loose bus connection on phase "A" of the breaker as the cause of the alarm status. Once this breaker was repaired, temperatures reverted to within spec.

If the breaker temperature variations had gone unnoticed, phase "A" of this breaker would have burned up. In such a case, whatever's on the other end of that power grid would go down and businesses would lose their power until it is repaired.

In another instance, we placed wireless temperature monitors on transformers controlling a new $3 million elevator modernization. The monitors showed that the transformers were running hot. Closer inspection with a multimeter revealed that the transformers were running at 110% capacity, rather than the specified less than 80% capacity. Six new transformers were installed to correct the problem and eliminate potential elevator downtime due to transformer failure.

Return on Investment

It is difficult to put a dollar figure on savings associated with wireless temperature monitoring. One readily available statistic based on insurance studies of actual electrical-related past losses is expressed as *dollar savings per problem*. By this standard, Newport Office Tower has saved approximately $65,000 through various wireless temperature monitoring-inspired repairs.

However, the true cost savings far exceed that figure. *Dollar savings per problem* does not take into account the cost of lost downtime and labor, which are usually the largest monetary components of an electrical failure. Loose cables, poor bus bar connections, corroded terminal connections, corroded fuse clips on disconnect switches and countless other conditions that give rise to temperature increases are all potential system stoppers. Repairing them prior to failure is the highest form of electrical system maintenance.

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Visual Inspection: A Necessary Component of Infrared Inspections

Jeffrey L. Gadd

Visual inspections are a very valuable by-product of an infrared (IR) survey of electrical switchgear. Many electrical panel interiors have not seen the light of day since installation. Since one must remove the panel covers in order to do a proper survey, when they are opened during an IR inspection, two opportunities present themselves: The infrared inspection and the visual inspection.

1. **The infrared inspection:** The reason for performing this type of survey is to find electrical problems so maintenance personnel can repair them before failure and/or damage to the component and the resulting downtime. Many times, critical problems are obvious and other times they are not so obvious without some due diligence.
2. **The visual inspection:** Visual inspection can be just as important as infrared. There are many things visually that can't be detected with infrared as the examples in this article demonstrate.

It may seem that visual inspection goes beyond what thermographers are hired to do, but conscientious thermographers include notes and even images in their reports when they see code violations, broken equipment, incorrectly sized fuses, bad wiring, etc. A good thermographer will not ignore copper tubing used as a fuse (Figure 1), even if it looks fine in the infrared. Whether the inspection is insurance driven or a proactive stance, an infrared inspection and a visual inspection complement each other.

Figure 2 is an extreme case of high temperature, but not at all uncommon. In a case like this, when the cabinet is opened, the thermographer sees the problem using the IR camera, but also can often see the tell-tale signs of the problem visually by the damage from excessive heating.

Figure 1 – Copper tubing fuses installed in disconnect

Finding critical problems with large temperature differentials is easy for just about any thermographer as they show up visually on the IR camera's screen. But what about the smell of burned insulation on wiring or the sound of a squealing bearing, belt, or corona on high voltage lines? These are all indications of problems that are not necessarily hot at the time of the IR survey, but could all cause failures if left unreported with no follow up.

Faults need to be found in early stages of failure before damage has occurred and before total failure. This infrared technique is predicated on the fact that there is a locked relationship between temperature [rise] and an increased chance of failure. Electrical (and mechanical) problems in this stage often show very little temperature rise. It takes an experienced thermographer with a good piece of infrared equipment to find and document problems in early stages. In other words, anybody can see burning hot things with an IR camera, but low temperature anomalies and even ambient temperature objects can be critical problems as well.

For example, a small rise in temperature often indicates a low priority problem when scheduling for repair. But small rises in temperature can also indicate critical problems. As shown in Figure 3, the 200 amp panel had a small temperature rise on Phase B, which typically would not be that interesting; perhaps a slight load imbalance. But the load readings showed only 6 amps per phase, no imbalance and instead a faulty connection and probably a very bad one since this is a single digit percentage of rated load. If this panel is loaded to 100 amps or more, the temperature rise of this fault would increase exponentially and could result in a catastrophic failure.

It is smart to visually inspect the electrical switchgear while an infrared inspection is in progress. During inspections I have

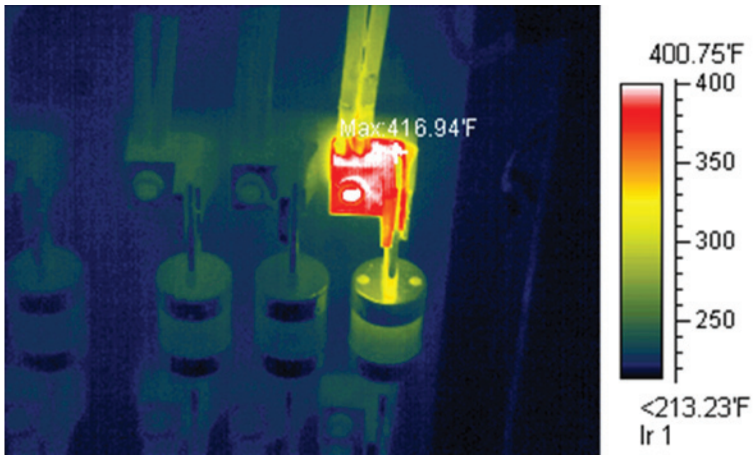


Figure 2 – High temperature connection

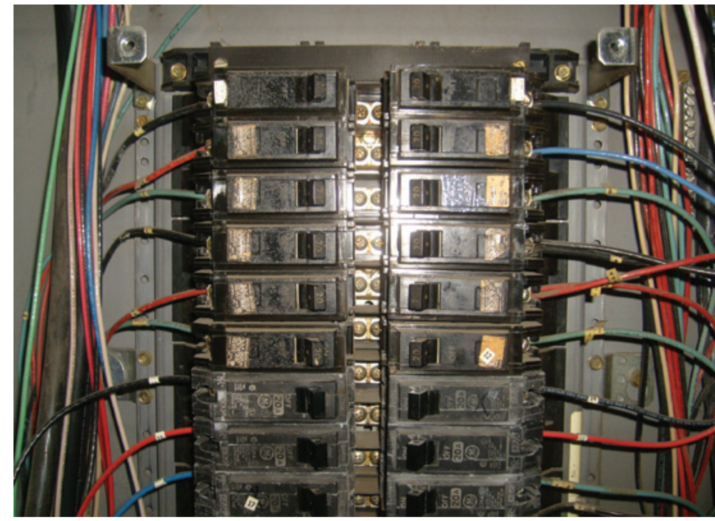


Figure 4 – Double tapped breakers on a distribution panel

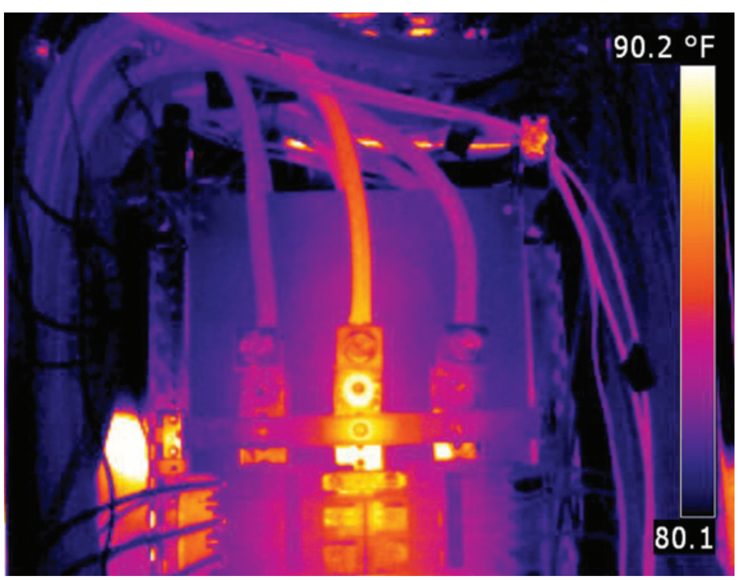


Figure 3 – A 200 amp panel lightly loaded with temperature rise on Phase B

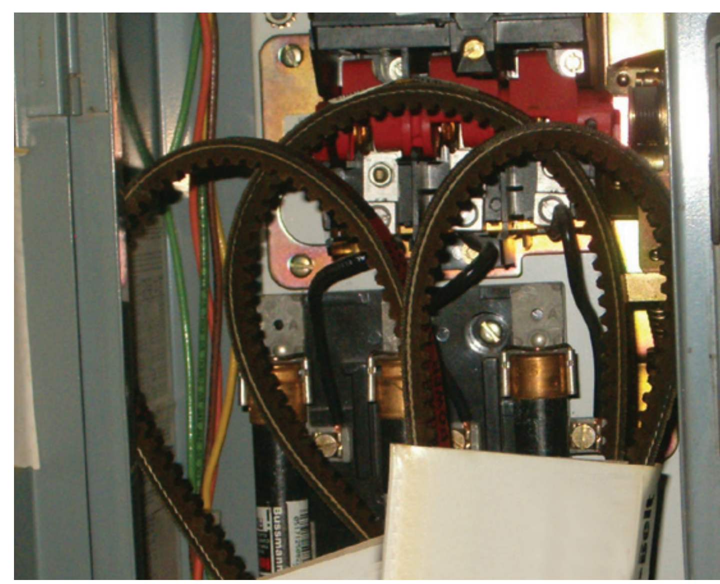


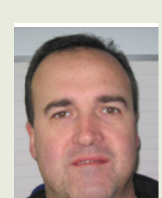
Figure 5 – Combination starter/disconnect being used as parts storage

conducted over the years, I was asked many times by corporate environmental health and safety officers, maintenance managers, facility engineers and plant managers to please note any electrical hazards or deficiencies that I was able to identify.

Examples found:

- Improperly fused disconnects (Figure 1)
- Panel breakers double tapped (Figure 4)
- Inoperable disconnects
- Disconnects and combination starters used as parts storage (Figure 5)
- Flexible conduit pulled out of box exposing conductors
- Exposed energized parts
- Fuses not installed or engaged properly
- Blown fuses

As thermographers, we find many problems through the use of thermal imaging. Large temperature differences are common and make beautiful images. Small temperature differences are typically low priority, but also can indicate critical problems under different load conditions. On the other hand, the value of visual inspection is often overlooked. Think outside the [thermal] box and take advantage of the visual inspection component of thermal surveys – it is in the best interest of all parties involved. In most instances, the thermographic report and visual inspection are documented separately. There may be several reasons for this, but ultimately, if you can identify and document a problem or potential problem with infrared or visual inspection, your proactive dollars have been well spent.



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Jeff is also President and Founder of Professional Infrared Network(PIN) www.professionalinfrared.com.

Precision Regreasing of Element Bearings:

Listen Carefully!

Mark Barnes

Regreasing of element bearings is one of the most common lubrication tasks any maintenance team needs to perform. Unfortunately, it's also one of the most poorly executed!

While the preferred method for simple plain bearings (bushing), in most circumstances, is pumping grease into the bearing until grease purges out, applying a similar approach to rolling element bearings - particularly in high-speed applications such as motors and fans – can result in a 70% to 90% reduction in bearing life. In fact, more high-speed bearings fail due to over lubrication than under lubrication. The old adage that if a little bit of grease is good for a bearing, a whole lot of grease must be better is certainly not true!

Figure 1: More bearings fail due to over greasing than under greasing

But it doesn't have to be that way. Precision grease lubrication of element bearings is actually fairly straightforward with a little care and attention.

To properly grease a rolling element bearing, there are three things we need to know:

- which grease to use;
- how much (how many shots) of grease should we apply;
- how often to apply the grease (regrease interval).

Let's examine these three factors individually.

Which grease should I use?

Like any other lubricant selection decision, the starting point for grease selection is viscosity. Viscosity selection is based on the applied load and speed of the bearing. Generally speaking, high unit loads require higher base oil viscosities, while higher speeds require lower viscosities. Perhaps the most common mistake with grease selection is to confuse grease consistency and base oil viscosity. Consistency refers to the stiffness or thickness of a grease and is related to how much grease thickener is used in the formulation process. Grease consistency is given by the grease's NLGI grade number (for example, EP 2 or AW 1) and is important in determining a grease's ability to flow and be pumped. The consistency of a grease has little effect on lubricant film thickness, which is almost entirely due to the viscosity of the base oil contained within the grease.

For high-speed applications, such as electric motors and fans, it's common to use greases with base oil viscosities in the 80 to 120 cSt range, while for slow-turning, heavily loaded bearings, base oil viscosities in the 600 to 1000 cSt range are not uncommon. Most multi-purpose greases have base oil viscosities in the 220 to 460 cSt range and should not be used in most high-speed applications.

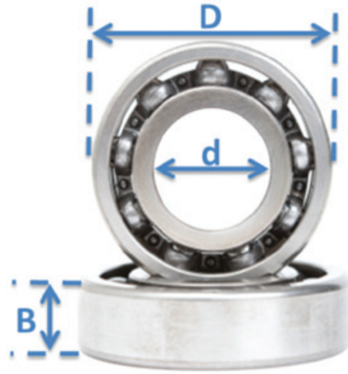
How much grease should I apply?

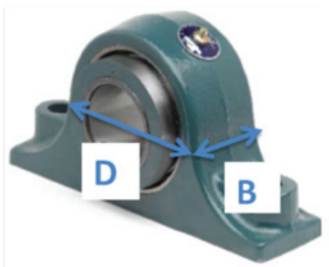
Determining the correct volume of grease for a bearing is largely a matter of bearing dimensions. Put simply, the bigger the bearing, the more grease we need to apply! Figure 2 shows a simple way of estimating how much grease should be reapplied during each re-grease interval. It uses two basic dimensions, the outside diameter (OD) of the bearing (desig-

$$G\ (grams) = 0.005 \times D \times B$$
(note: D & B in mm)

$$Gp\ (ounces) = 0.114 \times D \times B$$
(note: D & B in inches)

G = grease replenishment amount
D = bearing outside diameter
B = bearing width





When actual bearing dimensions are unknown, use the diameter and width of the bearing housing and divide the product by 3: $Gp = \frac{.114 \times D \times B}{3}$

(note: D & B in inches)

Figure 2: Regrease volume calculations (Reference - Des-Case Corporation Practical Machinery Lubrication Training Course Manual)

nated as D in Figure 2) and bearing width (shown as B in Figure 2), to estimate the replenishment volume in either ounces or grams. Where bearing dimensions are not readily available, housing dimensions can be used with a correction factor of 1/3 to account for the difference in D and B of the housing versus the bearing. These calculations should not be considered exact engineering calculations; they are simply designed to give an order of magnitude estimate that is adequate in even the most demanding and critical applications.

How often should I apply grease?

Once the correct grease volume has been established, the final step is to determine how often to reapply grease. Again, this is relatively straight forward, with the right information. Bearing regrease intervals are dependent on four basic factors: bearing size, bearing type, load and speed. There are several methodologies used to estimate regrease intervals, though perhaps the most reliable is given by the SKF Group as shown in Figure 3. In this method, we first calculate the so-called bearing speed factor (A), which is the product of the mean bearing diameter (D_m) and the rotational speed RPM. D_m is simply the arithmetic average of the bearing OD and inside diameter (ID) or bore diameter. This is then used in conjunction with a bearing type factor to read off the correct regrease interval in operating hours based on light and average or high unit loads relative to the rated load capacity of the bearing. Calculated regrease intervals should be adjusted up or down based on operating temperature, vibrations, degree of contamination and shaft orientation.

Adding Precision to Regreasing: Listen Up!

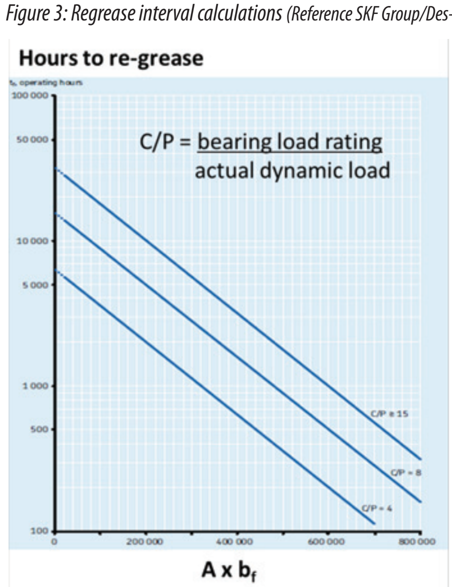
Increasingly, companies are starting to explore the use of ultrasonics to add precision to regreasing. Traditionally used for other predictive maintenance activities, such as checking for air leaks, steam trap integrity, or stray electrical discharges, ultrasonic monitoring has proven to be a very valuable tool for adding precision to regreasing activities. There are numerous articles on ultrasonic assisted regreasing, but on a basic level, ultrasonic bearing diagnostics work by measuring high frequency sound emissions caused by friction.

This applies to both under and over lubricated bearings. While under lubrication can result in high friction and ultrasonic emissions due to metal-to-metal contact, so too can over lubrication. Particularly in high-speed bearings, over lubrication causes churning and internal friction within the grease, resulting in higher ultrasonic emissions. So by measuring high frequency emissions and plotting time-based energy emissions, the exact quantity of grease required by the bearings can be determined empirically simply by looking for the “sweet spot” or the amount of grease that results in the lowest ultrasonic energy emission over time. Figures 4a and 4b show the time-based energy plot for an under lubricated bearing versus a properly lubricated bearing.

Over the past five to 10 years, I've been asked many times for my opinion on using ultrasonics in this manner and my answer is always the same. I believe with a few simple precautions, an ultrasonic gun is a very valuable addition to any lube tech's toolbox. So what are those precautions?

First, ultrasonic monitoring is only really useful for regreasing higher speed bearings. From a practical standpoint, that means 200 to 300 RPM and greater. That's not to say that ultrasonics cannot pick up incipient bearing problems at lower speeds – it most certainly can - but to evaluate and regulate regrease volumes, 200 RPM is a pragmatic limit that most practitioners agree on. Secondly, don't over-rely on ultrasonics. I have seen several instances where blindly looking at a decibel meter hoping to see a drop in overall ultrasonic emissions has led to significant and serious over greasing due to well-intentioned but misguided technicians who continue to add grease to try to make a high dB reading drop, when in reality, they are picking up ultrasonic energy from another source.

Figure 3: Regrease interval calculations (Reference SKF Group/Des-Case Corporation Practical Machinery Lubrication Training Course Manual)



The speed factor (A) multiplied by the relevant bearing factor (bf) where:

$$A = N \times D_m$$

N = rotational speed (rpm)
$D_m = 0.5 \times [d(mm) + D(mm)]$
b_f = bearing factor depending on bearing type and load condition

	b_f
Ball bearings	1.0
Cylindrical roller bearings (light/no axial load)	1.5
Spherical/tapper roller bearings	2.0
Spherical roller thrust bearings	4.0
Cylindrical roller thrust bearings	10.0

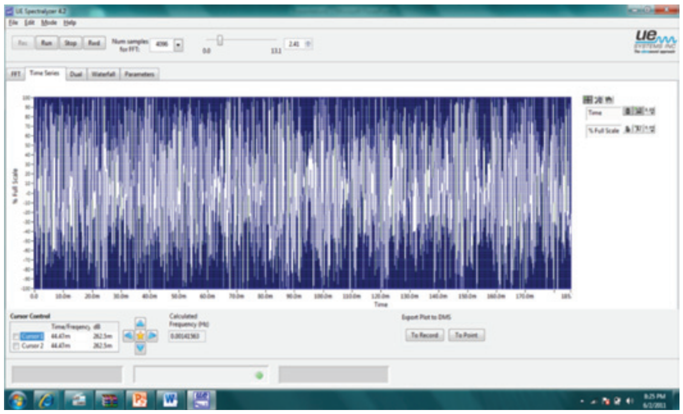


Figure 4a: Energy-based time plot for an under lubricated bearing (Image courtesy of UE Systems, Inc.)

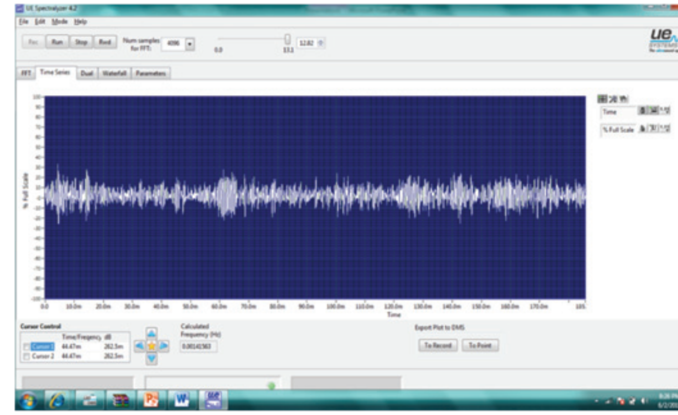


Figure 4b: Energy-based time plot for a properly lubricated bearing (Image courtesy of UE Systems, Inc.)

Conversely, I've also seen technicians who elect to add no grease at all since they have not seen any increase in the dB level since the last reading, when in actuality, attenuation effects are diluting the true ultrasonic emissions from the load zone of the bearing below the level to which it can be detected.

So how can we be sure we're doing it right? Figure 5 shows a simple procedure for adding precision to the act of regreasing using an ultrasonic gun. This procedure, which has been referred to as a "hybrid" approach, uses a combination of engineering calculations, such as those shown in Figures 2 and 3, coupled with an ultrasonic gun to add a level of precision to the process. In essence, the hybrid approach uses the ultrasonic device to ensure the calculations – which are, after all, just estimates – have not seriously under- or over-estimated the correct regrease interval or volume.

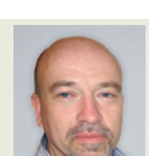
Hybrid procedure for high-speed bearing regreasing

1. Attach the ultrasonic detector to the grease fitting and record the baseline dB reading
2. Remove the drain port plug (if fitted) and ensure vent port is free from contamination and spent grease
3. Wipe grease fitting and grease gun nozzle with a clean (lint free) cloth
4. Slowly apply grease, ½ stroke at a time while monitoring the dB reading
5. If dB reading increases and fails to drop after 30 seconds, discontinue lubricating – the bearing is likely over lubricated
6. If the dB readings remains unchanged or drops, continue to apply grease ½ stroke at a time, while monitoring the dB levels
7. Discontinue greasing when either:
   a. an additional ½ shot of grease causes the dB reading to increase and remain high
   b. the maximum calculated quantity of grease has been added. This bearing has been calculated to require 1.2 oz (equivalent to 10 shots from a model ABC grease gun)

   Do not add more than the maximum calculated quantity of grease
8. Record the final dB reading
9. Allow 10-15 mins for new grease to become distributed throughout the bearing and housing, then replace drain port plug

Figure 5: Hybrid procedure for high-speed bearing regreasing

So if you're interested in doing a better job of lubricating motors, fans and other high-speed bearings, I strongly encourage you to look at ultrasonic monitoring as a very effective tool and a great investment. But don't just proceed on blind faith without applying common sense. Use a combination of tried and tested engineering calculations with state-of-the-art instrumentation to transform your regrease practices to best-in-class.



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

Goal Achievement made simple

Author: Stephen J. Thomas • Reviewed by: John Mitchell

In Goal Achievement Made Simple, the author has packed a great deal of valuable information into a small volume and presents it in a very friendly, first-person narrative.

If you are looking to rebuild a maintenance department and wondering how to gain support for objectives that may seem conflicting and even threatening to some or perhaps most of the people involved, this book will tell you how to do it. Logically, the narrative begins with problems you might encounter and challenges that could be faced moving an entrenched work culture into areas employees might find uncomfortable. Very specifically, people who have thrived in a highly reactive environment where their prowess in quickly restoring failures has been highly complemented and likely rewarded will find a proposed shift to a planned atmosphere where failures are minimized to be quite threatening to their sense of self worth.

Eight strategic elements of change are introduced and explained in Chapter 3. The accompanying Goal Achievement Model illustrates how all the elements work together to maximize success and how neglecting any one may cause the effort to suffer.

The last half of the book explains each element of the Goal Achievement Model in detail, including how it creates a broad understanding of vision, goals and objectives, links them to improvement initiatives and activities, and finally, provides a method for follow-up, feedback and reporting.

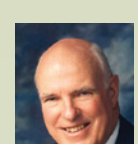
Mr. Thomas provides two examples of how a vision and goal, essentially established by management, are translated into an initiative and one or more activities within the Goal Achievement Model. This is followed by an explanation of how the eight elements of change apply to an activity.

The final chapter addresses a highly important area where many otherwise successful initiatives flounder: sustainability. The author offers eight suggestions to attain sustainability; not surprisingly keyed to the eight strategic elements of change.

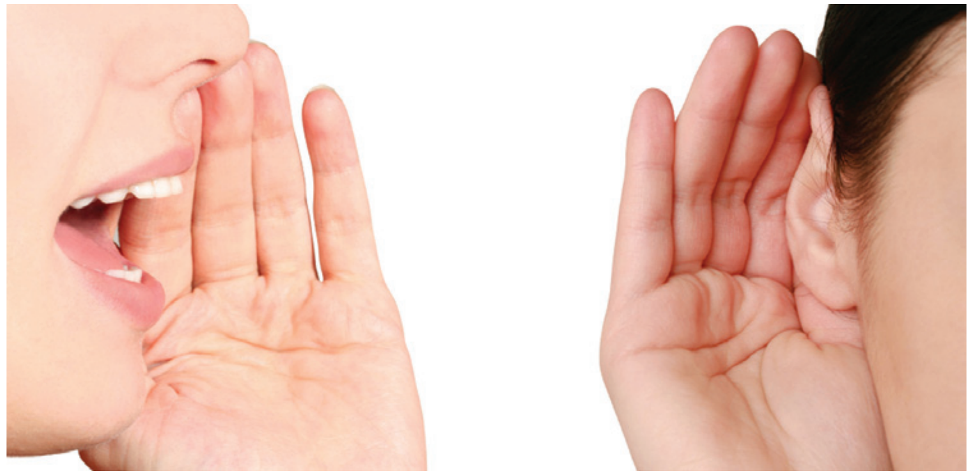
Each chapter ends with specific questions categorized under "Things to Think About & Things to Do." This is especially valuable for a reader who is either contemplating a change initiative or has one in progress. Translating lessons and ideas presented in the chapter into the reader's own environment adds great value to the thought process and assures success.

Copies are available at: MRO-Zone.com bookstore (www.mro-zone.com) and at Amazon.com (www.amazon.com).

Stephen Thomas has 40 years of experience working in the petrochemical industry. In addition to Goal Achievement, he is the author of several books including Measuring Maintenance Workforce Productivity Made Simple also published by Reliabilityweb.com



John Mitchell, CMRP has held leadership positions in the reliability and maintenance field during a professional career of more than 40 years. He is the author of two textbooks.



I Heard It Through the Grapevine: Communicating Effectively During Major Change

Dave Berube

I have never been known to be musically inclined, but I can recognize a great song when I hear one. One of these great songs is *"I Heard It Through the Grapevine."* **This particular song has been recorded and re-recorded numerous times over the years by many different artists and although it may bring thoughts of animated raisins to people in my generation, it is more closely associated with Marvin Gaye.**

Oh I heard it through the grapevine
Oh I'm just about to lose my mind
Honey, honey, yeah

Just as the grapevine in this song had a strong impact, the communication grapevine remains an extremely powerful medium for corporate communications. The effectiveness of grapevine communication and its use – both intentional and unintentional – should not be ignored. When coaching clients during major change initiatives, we continuously stress the importance of effective communication. Experience has shown that clients who struggle to communicate also struggle to successfully implement major change. Even post-project analysis of very successful projects often finds the company could have communicated more frequently and effectively at some point in the project.

One of the key success factors in effectively implementing a major change initiative is creating a comprehensive change management strategy and then integrating it into the project management plan. Creating a communication plan is one of the most critical elements contained within this change management strategy. In this plan, you identify target audiences, determine key messages, choose the preferred sender and select the appropriate communication channel for that message. The majority of communication channels typically chosen are formal communication channels. The communication channel that is often forgotten is the informal communication channel and this brings us to the topic of the infamous grapevine.

So what is the grapevine, how does the grapevine work and how can we use the grapevine to effectively communicate during major change? I am sure that the grapevine is as old as time itself, but I will discuss its context within modern organizations.

Grapevine Decoded

Every organization has both an informal and formal organizational structure, as well as formal and informal communications. Simply stated, the grapevine is a type of informal communication channel. It's all about people communicating directly with other people outside official channels of communication.

Our background and experience influence how we view concepts. For example, my background in electronics and submarine nuclear power often leads me to relate concepts to equations to enhance understanding. Personal experiences over the years related to the grapevine also can be translated and simplified into an equation to help us understand how the grapevine works. The amount of communication or "chatter" on the grapevine can be explained by the following equation:

Grapevine chatter =
information void + WIIFM + recent news + insecurity

Information Void

The laws of supply and demand apply equally to grapevine chatter and economics. An information void exists when the information demanded exceeds the information supplied. The supply and demand of the information are not defined by the organization, but by the individual person who desires the information. An information void will be filled with something – either rumors or valid information. The larger the information void is, the greater the amount of chatter in the grapevine.

WIIFM

What's in it for me (WIIFM) seems to show up in many places when we are talking about organizational change. Regardless of the situation, when change occurs, our natural tendency is to translate this into a WIIFM context. This is what we are listening for. How does this change affect me, my pay, my family, my free time, etc.? Whether that WIIFM is good or bad, it creates a vested interest. When people have a vested interest, they will want information. The greater the impact on WIIFM, the greater the amount of chatter on the grapevine.

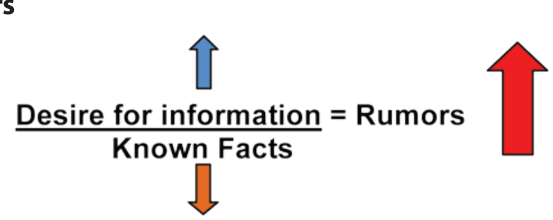
Recent News

Many organizations are stunned at how breaking news hits the grapevine at breakneck speed. Even something as simple as an office remodeling (occurring in our offices right now) can generate significant grapevine chatter. The fresher the story, the greater the chatter on the grapevine.

Insecurity

The impact of the WIIFM factor is exponentially compounded by the level of insecurity that exists. The greater the amount of insecurity that exists within the organization, the greater the amount of chatter that will exist on the grapevine. For example, with the current fragile state of the economy, one can easily see how this factor can become extremely high.

Rumors



As stated earlier, an information void will be filled. When the desire for information is high and the number of facts that are known is low, the number of rumors flying is huge. Most of us have experienced this firsthand and sometimes it is not a pretty sight. Regaining control of information in the midst of flying rumors is extremely difficult. The longer a rumor is allowed to fly, the more difficult it is to replace it with valid information. While some people try to fight rumor with rumor, the only effective way to combat a rumor is with facts. When a large

number of rumors exist, an even larger number of facts must be communicated to combat the rumors.

Leveraging the Grapevine

Knowing the factors that make up grapevine chatter – information voids, WIIFM, recent news and insecurity – we can proactively intervene with frequent and effective communications. Fill information voids with accurate information before rumors materialize. Proactively communicate when breaking news is expected. When information (such as impending mergers and acquisitions) is about to be communicated, be prepared and react quickly after the message is released. When communicating change initiatives, ensure that you communicate the impact of the change on the individual.

Addressing the factors associated with grapevine chatter can minimize, but never totally eliminate the amount of informal communication occurring. However, by better understanding the grapevine, we can successfully leverage it as part of our overall communication strategy. One of the tenets of a good communication strategy is evaluating the effectiveness of your communication. This is accomplished by obtaining feedback. What better way to gather feedback than to take advantage of an existing channel of communication?

Over the course of my career, I have been able to tap into the grapevine at your typical places: the water cooler (scuttlebutt in Navy terminology), the coffee pot and the smoke break area.

Tapping Into the Grapevine

Over the course of my career, I have been able to tap into the grapevine at your typical places: the water cooler (scuttlebutt in Navy terminology), the coffee pot and the smoke break area. Tapping into the grapevine is not normally achieved overnight. Grapevine communicators are a very selective bunch. They will not share all information with everyone. There must be some level of relationship and trust established, and building relationships and trust takes time. To accomplish this, you must get out of the office, talk with people and, most of all, listen.

But while the traditional grapevine is thought of as being a face-to-face or oral type of communication, this is no longer the case. Advances in technology and recent trends in social networking have significantly transformed the modern grapevine. Informal communication now occurs through email, texting, Twitter and on social networking sites, such as Facebook and Myspace.

Summary

Implementing major change in an organization is a complex and challenging task. In the end, creating organizational change is about cumulatively creating change in individuals. Successfully leading major change requires successfully leading individuals. To successfully lead individuals through change, we must be able to communicate effectively. We must find new ways to connect to our people and communicate in every imaginable way. That includes tapping into the grapevine. Without it, we might just about lose our mind. Honey, honey, yeah.

Dave Berube, a Senior Consultant for Life Cycle Engineering (LCE), has more than 30 years of experience in leadership and management. His expertise includes behavioral change management, project management and development, and process improvement within various types of organizations. www.LCE.com.


Accelerometers
High frequency mini-MIL Accelerometer
10mV/g
Multi-Purpose Accelerometer
50mV/g
Compact, Multi-Purpose Accelerometer
100mV/g
AC220-1D
AC224-1D
AC117-1A
AC118-1A
AC192-1A
AC194-1A
CTC
AC220-1D
SN: 1000
AC224-1D
SN:1000
AC117-1A
SN: 10001
AC118-1A
SN: 10001
AC192-1A
SN: 10001
AC194-1A
SN:10001
CTC
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100mV/g
Low Frequency Accelerometer
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Low Cost Biaxial Accelerometer
100mV/g/axis
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100mV/g/axis
AC102-1A
AC104-1A
AC135-1A
AC136-1A
AC119-1D
AC115-1D
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OEM or Non-OEM Parts?

Ron Moore

Background

The question posed in the title of this article is an age-old one and the short answer is "it depends." A longer, more useful answer is attempted below, but before we get to that, let's consider a few related issues.

When vendors bid on major equipment, they know their price is a major consideration. Because of this, I believe they tend to put forth the lowest possible price with the hope of making up the lack of profit in that price with the profit on future sales of spare parts. Various vendors likely have varying strategies and price/service points, but it seems that this is a key part of most strategies.

Because of this, and as most of you know, OEM parts are often perceived as "expensive" and that cost often drives users to seek alternative sources for those parts in non-OEM suppliers. When you combine this perception with the fact that procurement people are driven and rewarded to "save money" by procuring less expensive parts and maintenance managers are under continuing, and often intense, pressure to reduce their maintenance costs, it is very easy to see how a non-OEM supplier would look attractive.

However, a non-OEM supplier can be a long-term disappointment. Anecdotal evidence suggests that non-OEM part buyers may be disappointed more often than they are pleased, notwithstanding the initial feeling of saving money by getting a better price for the part. This disappointment is generally linked to overall performance of the non-OEM part and the consequential costs thereto. With this in mind, let's consider some of the issues that must be addressed when considering OEM vs. non-OEM parts.

Total Cost of Ownership

Rather than focus on price, it is likely more useful and accurate to use the concept of ***total cost of ownership***. Certainly price is part of the total cost of ownership, but there are so many other costs that occur downstream of the initial price. For example, the following might be examples of the elements used to analyze the total cost of ownership:

- Price
- Documents - drawings, bill of material, manuals, etc.
- Selection effort, including staff time, travel, etc.
- Procurement transaction, freight, duties
- Delivery, assembly, installation, startup
- Warranty coverage
- ***Performance capability, efficiency, operability***
- ***Energy use***
- ***Maintenance/PM requirements, maintainability***
- ***Parts stocking or inventory***
- ***Service levels (or lack thereof).***

Of course, there may be other costs of ownership not listed here that must be considered for any given business. These are offered as common ones and should get the thinking process started. The bullet points that are italicized are those that, in my experience, are not given sufficient consideration when making purchasing decisions. We'll come back to this later.

It's been reported by those who study this issue that, on average, the initial price of equipment in a large industrial operation is only about 25% of its total cost of ownership. While this percentage may vary dramatically depending on the equipment being considered, it appears to be a reasonable approximation. For example, one company reported the price for their pumps was only about 10% of the total cost of ownership, with another 10% for maintenance and the biggest component being energy at 80 percent. Another company reported the same 10% in price for their cost of ownership of their pumps, but had substantially different data for

energy (~33%), maintenance (20%), installation, operation and downtime (~10% each), and the balance being associated with environmental issues and disposal.

Others report even more different numbers. For tanks, piping and other stationary equipment, these percentages will likely vary dramatically as well, with price being a higher percentage. No matter which data is most characteristic of your operation, the point is that price may be only a small fraction of the total cost of ownership and should be part of a more comprehensive review when making these decisions.

Parts and Total Cost of Ownership

While the above discussion relates to buying major equipment, the same principles should be applied to the purchase of parts, particularly when considering OEM vs. non-OEM parts. What is your total cost of ownership in either case and what are some of the considerations in making this determination?

Since my background includes being a mechanical engineer, I tend to use mechanical equipment for examples. So not straying too far from that, I'll use pumps to illustrate these principles. If you're considering electrical equipment parts or other components, the same principles apply, but of course you'll have to use your specific knowledge of that equipment to apply them. Some questions you should ask, including requesting substantiating documents of tests or other evidence to support the responses, are:

1. Does the part provide for comparable performance relative to discharge pressures and flows, including suction head requirements? Issues here include energy consumption for a given pressure and flow, and avoiding cavitation under very low suction head or higher fluid temperature conditions. Cavitation destroys pumps, inducing greater costs and production losses. For example, some studies have shown that the use of non-OEM parts can result in a reduction of flow/head and efficiency by up to 15% when compared to OEM.
2. Are the part materials for the fluid being pumped and the operating conditions suited for the service? That is, do the materials have appropriate durability and reliability for the specific operating conditions? Materials that corrode or erode more quickly, of course, induce greater frequency of repair, lost production (and its related value), and can induce greater energy consumption as the parts wear more quickly.
3. Do the balancing standards for the parts assure long life and smooth operation? If a machine train is being supplied (pump and motor for example), similarly, do the alignment standards being used assure smooth operation and long equipment life (and lower energy consumption)? Likewise, poorer balancing and alignment standards assure shorter equipment life, more downtime and related repair costs and production losses. What are those worth?
4. Do the tolerances and precision of the parts or assembly assure a precision fit and optimal performance? Tiny deviations in clearances, e.g., a few thousands of an inch,

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in the part can make a huge difference in pump performance and life, and can induce substantially higher maintenance costs and production losses.

5. Do the surface finishes on parts for the interior of the pump assure efficient operation? As with precision of assembly, surface finish can have a substantial impact on flow hydrodynamics and must be considered.
6. Are the pump flange faces made of the proper material and do they meet strict tolerances and surface finishes to assure ease of assembly and proper operation? From my experience in helping design U.S. nuclear submarines, I understand how critical flange faces and finishes can be in minimizing the risk of leaks, and the criticality of having the proper gaskets installed in a precise manner. Does your supplier facilitate this?
7. Are the bearings for the pumps of proper quality? Have you specified the L10 (or life) of the bearing? The fit-up standards, e.g., C3 or C4? The ABEC number? Is the bearing the right design for the pump service? If seals are being used, are they the right ones for the intended service?
8. What other questions should you be asking? This list is just to get you started with thinking about how to make the right decisions to get the lowest total cost of ownership.

Of course, if you don't start up and shut down your pumps properly, or run your pumps at their best efficiency point (BEP), these issues may not matter. You're going to incur substantially higher energy costs, maintenance costs and related production losses because of poor operation, not because of parts selection. But, that's an issue for another day.

Your approach may also vary with the duty of the pump or other equipment. For example, if the equipment is non-critical and only operates infrequently, then buying a cheaper part that does not meet the criteria implied by these questions might actually be the lowest cost approach. Likewise, non-OEM vendors who can demonstrate that their parts and equipment meet the criteria implied in these questions should be selected since they can demonstrate the lowest total cost of ownership.

Parts in Inventory

What parts should be kept in your storeroom? This too, is an age-old question and lots of people have developed models for this. Such models take into consideration cost (working capital), failure modes (and parts needed thereto), failure frequencies (and risk/use rates), failure consequences and related equipment criticality (and loss of production), lead times (and ease of access), along with other factors. Some have used a vendor-stocking model for certain parts, or vendor guarantees for parts availability. Others in major industrial areas have used a "supplier park" concept wherein they have banded together to have one supplier keep and deliver the most common parts. All these are good things.

At the risk of oversimplifying, I'd like to respond to the question of what parts to keep in the storeroom with a two-part question – What fails most often that impacts production and what parts are needed when this failure occurs? Usually these are things like belts, bearings, seals, fuses, switches, hoses and hose connections, and the like. So, take each equipment and make a list of what fails most often. Make sure you have the parts for this, or have ready access to them.

A second question might be – What doesn't fail very often, but when it does it has a huge consequence to the business? Then we have to balance the capital cost of the part against the risk (probability x consequence) and make a business decision about keeping the part in stock. Also, we might put processes in place to make sure it doesn't fail, or if it does, we can detect the potential failure long before it becomes a functional failure.

Vendors' Strategy

We all understand that vendors must make money to stay in business and that we need good vendor support for the success of our business. I think we also understand that the best vendors supply the best value – not just the cheapest price, but rather the lowest cost of ownership for the equipment and parts provided. Vendors must also understand that if their prices for parts are perceived as high, then their customers will increasingly seek alternatives. The higher the perceived price, the more likely an alternative will be sought. My suggestion to vendors, both OEM and non-OEM, is to make sure their business case includes the concept of total cost of ownership and all relevant business costs for their customers.

Having been the president of a business, our strategy was **not** to sell instruments and software with certain features and prices. That was a consideration, but our focus was on making our customers' businesses successful. OEM and non-OEM vendors are likewise encouraged to do the same.

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management

Ps planning and scheduling

2 Planning and Scheduling Questions for Management to Ask

R.D. (Doc) Palmer

How did we do on the weekly schedule? What is the biggest issue we had where I can help? These two simple questions form the majority of the maintenance manager's direction and control of maintenance efficiency and effectiveness.

Management's jobs are to plan, organize, staff, direct and control. Maintenance management *plans* to create a maintenance effort that keeps assets functioning to produce production capacity. It *organizes* to have both an effective and efficient maintenance program. Proactive maintenance strategies, such as preventive maintenance (PM), predictive maintenance (PdM) and project work, perhaps with a reliability-centered maintenance (RCM) program, provide effectiveness. Planning and scheduling provide efficiency or productivity. The need for efficiency is simply embodied in the common problem of correctly identifying the proactive maintenance to execute, only to see that work sit in the work order backlog until it's too late to head off reactive maintenance. Planning and scheduling help ensure correct and timely completion of the proactive work. Furthermore, maintenance management *staffs* these elements of the organization. It hires and trains personnel for the various roles.

However, after somewhat easily planning, organizing and staffing the maintenance workforce, management typically has more difficulty with the concepts of *directing* and *controlling*. Instead of directing toward the goal of assets functioning to provide production capacity, many plants become bogged down with the reality of reactive maintenance. *Directing* tends to be how to handle the latest reactive maintenance and settle for good, but not great, maintenance results. Management has put into place a PM program, a PdM group and some project work, yet the busy maintenance force does not complete all the PM work, PdM results do not form a considerable portion of the executed work, and the plant still has a certain amount of failures that, while not overwhelming, is significant. Planners are in place, but frustrated. *Controlling* seems to be simply an exercise in making key performance indicators (KPIs)) look good. These results are common because typically management is better at specializing (planning, organizing and staffing) than at coordination (directing and controlling).

In light of these results, management instead can focus on persistently asking a couple of simple questions to greatly increase the effectiveness and efficiency of the entire maintenance program. The first question maintenance managers should ask themselves and others each week is, "How did we do on the weekly schedule?" This question deems schedule success as being "the ultimate measure of proactive maintenance" (as put forth by John Crossan of Clorox Company in 1997) and driving a lot of good maintenance behavior. The "abstract" idea of keeping assets functional by not letting them break quickly drowns in the heat of the reactive maintenance environment. When something does break, the maintenance workforce must become a service organization to restore service. Obviously, this continual effort to restore service as quickly as possible can creep into the mindset as the very objective of maintenance.

Directing tends to be how to handle the latest reactive maintenance and settle for good, but not great, maintenance results.

This false reasoning is common because there is a sense of busyness and mission when maintenance takes care of all the reactive work and most of the PM's. Other low priority work in the backlog is seen as "fill-in work" and enough does not get completed. Proper management attention to schedule success helps correct this reasoning. The proper reasoning should be that the backlog is "the work," and if completed in a timely manner, will reduce reactive work. Even so, the idea of the "whole backlog" as "the work" is daunting. Instead, management should focus the workforce only on the amount of work it can do in a single week. The scheduler picks the work in the best interest of the plant out of the backlog to match the labor hours available for the next week. With this reasonable and focused goal, productivity actually increases for the typical maintenance workforce and it completes more proactive work beyond the normal reactive and PM work, enough to make a difference. The concept of schedule success being the ultimate measure of proactive maintenance is this: the degree to which a maintenance workforce can complete a weekly schedule is the degree to which it is getting control of the plant. The question is really, "Did we get control of the plant last week or did the plant get control of us?" The question, "How did we do…?" refocuses the workforce on the real objective, doing the backlog work that increases production capacity. Management wants to get control of the plant by having at least a week's notice of any maintenance required.

The question also drives a lot of good planning and scheduling behavior. The only way to actually measure schedule success is from the prerequisite of having started the week with a schedule. The only way to have a weekly schedule is to have enough planned work orders. The only way to have enough planned work orders is to have planners in place to plan and also have the plant generating enough proactive or lower priority work orders. The only way planners can plan enough work orders is they must manage the time they can allot to placing time estimates and the level of detail in each plan. All of these good behaviors stem from having a clear and simple objective: the weekly schedule.

With this focus and good behavior directed by the first question, the second question maintenance managers should ask themselves and others is, "What is the biggest issue we had where I can help?" If there is low schedule success, something went wrong. There is a gap. Management's job is to control the gap between desired and actual performance. Did the schedule success suffer because of a high incidence of emergency and reactive work that could not wait a week? What is the most prevalent reason for the work that could not wait? Are there not the proper proactive work orders in the schedule? Why not? Did the schedule success suffer because of other work that could have waited? Why was that work done? Was there low schedule success without other interrupting work? Was this gap because of job plan problems or work execution issues? Having the right first question to help direct maintenance easily guides management to the right second question to properly control and help improve maintenance.

This consideration seems like a lot of semantics, but it helps focus the maintenance workforce and makes a difference. With two simple questions, management is *directing* maintenance toward its correct objective (functioning assets to produce operational capacity) and *controlling* to improve the effort. Seriously ask these two questions and get to work. How did we do on the weekly schedule? What is the biggest issue we had where I can help?

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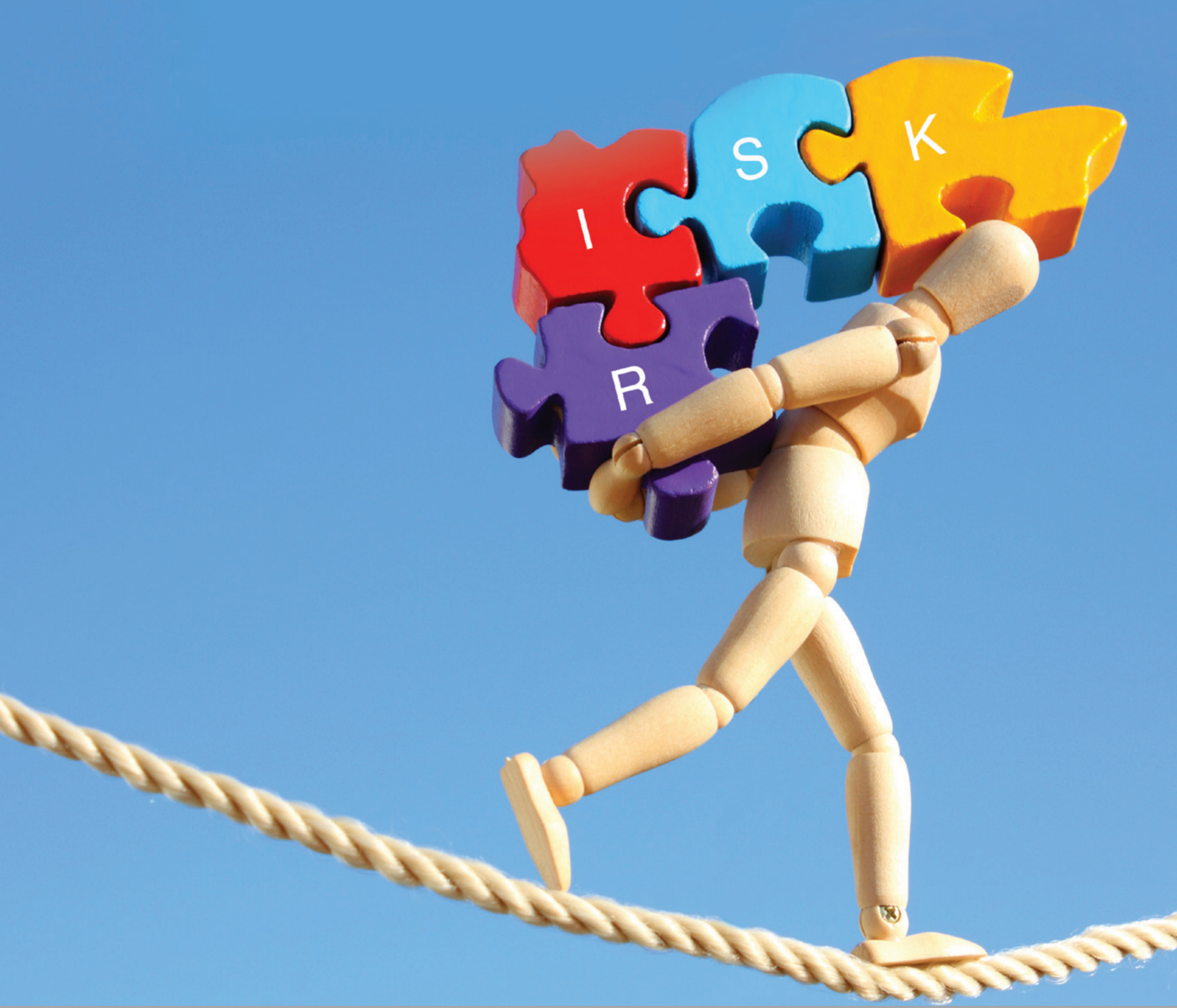

Understanding & Comparing Risk

Understanding Risk

In the Oct/Nov11 edition of *Uptime*, a concept of risk was introduced that utilized a Euclidean distance of probability and consequence, mathematically written as

$Risk^2 = Probability^2 + Consequence^2$

The author claimed that "this [method] provides for accurate comparison of relative risk." [1] *The purpose of this article is to explain the conflict between traditional risk calculation methods and distance methods, as well as the potential poor business decision that could result from using distance methods. For the purpose of this article, the Euclidean distance for assessing risk as described in the original article will be called the "positional risk."*

Brian Y. Webster

The method described in the original article basically assumes that adding a consequence and a probability together will yield a meaningful number. If we add the two numbers together, which do not have the same units of measure, the end result is meaningless. For example, would an electrician add the voltage and the amperage of an electrical motor to determine the wattage? (Hopefully not.) A strong caution about the use of distance methods for risk assessments is probably best stated by Edmund H. Conrow in his book, *Effective Risk Management: Some Keys to Success:*

> ***"There are innumerable representations of risk possible, but most do not appear to have a convincing mathematical and probabilistic basis. Computation of risk should generally be performed using a simple multiplicative representation (P * C), assuming the underlying data do not violate any mathematical or probabilistic principle."*** [2]

Understanding risk is important for making sound business decisions. If the basis for understanding risk is flawed, then businesses are making decisions on flawed information. Unfortunately, the distance method (Euclidean distance or "positional risk") described to calculate risk represents a potentially poor understanding of risk, which could lead to making poor decisions. Prior to looking at an example of how distance methods could lead to poor business decisions, we will first look at risk.

What is Risk?

ISO 31000 and ISO 73 both define risk as the "effect of uncertainty on objectives."[3] This broad definition encompasses: 1) Either a positive or negative effect, 2) Objectives that can reflect one or many different categories, such as safety, environmental, or financial goals, and 3) The uncertainty reflecting the likelihood (probability) of events actually occurring. This broad definition allows for qualitative, semi-quantitative, and quantitative risk analysis of the consequences and associated probabilities.[4]

Correspondingly, risk has been traditionally defined as the likelihood and the consequence of an event where the expected value of the risk is expressed mathematically as:

Risk = Consequence * Probability.[5]

I refer to this as traditional risk. This basic mathematical and probabilistic concept of risk is used for common industry tools, such as event tree analysis, fault tree analysis, Monte Carlo simulations and other tools. In addition, this definition of risk has been used in many industries (insurance, refining, medical research, statistics, banking, etc.) for many years. Furthermore, the mathematics supporting this method also allows cumulative risk to be calculated.[6] Thus, we have strong reasons for using the traditional quantitative risk analysis.

Visual Representation of Risk

Since the positional risk in the original article was applied on a risk matrix, we should discuss risk matrices and how they illustrate risk. There are numerous methods and approaches for risk matrices.[7] A risk matrix can often be developed where the probability and consequence axes have quantitative scales in conjunction with qualitative descriptors.[8] The quantitative scales allow for the calculation of risk using the traditional C * P method, while visually representing the increasing levels of risk by color. An example of a risk matrix is shown in Figure 1. This example risk matrix utilizes qualitative descriptors, associated quantitative scales that have a log-log scale and a color scheme that reflects relative risk that is consistent with the calculated expected value of the risk.

Often, the quantitative scales will use a log-log scale to allow the risk matrix to represent a very wide spectrum of risk. Within some industries, risk matrices that have a range of four to five orders of magnitude are used on a daily basis. For consequences, the matrix could show the progression from a slight injury to a minor injury to a major injury to fatalities to multiple fatalities. For the probability, the matrix could show

a 0.1% to a 1% to a 10% to a 100% probability that an event could occur within a year. It is important to keep in mind that risk matrices are typically not linear and represent exponential increases in magnitude along the axes. In general, risk matrices may vary by design, application and color coding, meaning we should be mindful of applying any generalizations.

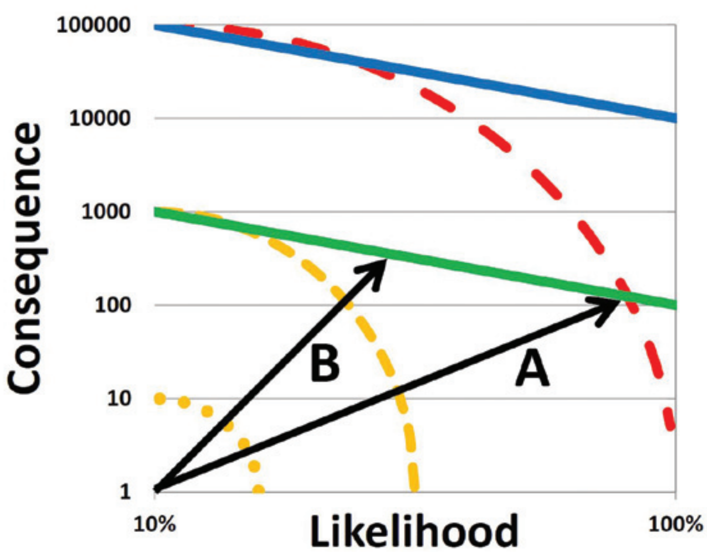

Figure 1: Example of a 5x5 risk matrix using log-log quantitative scales

Comparing Positional Risk to Traditional Risk Methods

To illustrate the difference between positional risk and traditional risk, we will compare constant risk as defined by each method. The visual representation of constant risk is similar to isolines (lines of constant elevation) on a contour map. Both conflicting definitions (traditional vs. positional) of risk can be represented by lines of constant risk, much like lines of constant elevation on a map. In a contour map, the elevation is set to a constant level and the lines represent the constant elevation using longitude and latitude as the axes. With risk, we can set the risk to be a constant level and chart the constant risk with consequence and probability axes.

In the traditional risk definition, constant risk appears as straight lines on log-log scale charts (similar to many quantitative risk matrices). An example of constant risk lines using the traditional risk definition are illustrated on a risk matrix with a log-log quantitative scale shown in Figure 2. Also visible in Figure 2, the lines of constant risk run parallel, with the color changes representing increasing risk levels.

In the distance method proposed (positional risk), the constant risk is a fixed distance from the origin point of the graph, which looks like concentric quarter circles. An example of constant risk lines using the positional risk method is shown in Figure 3.

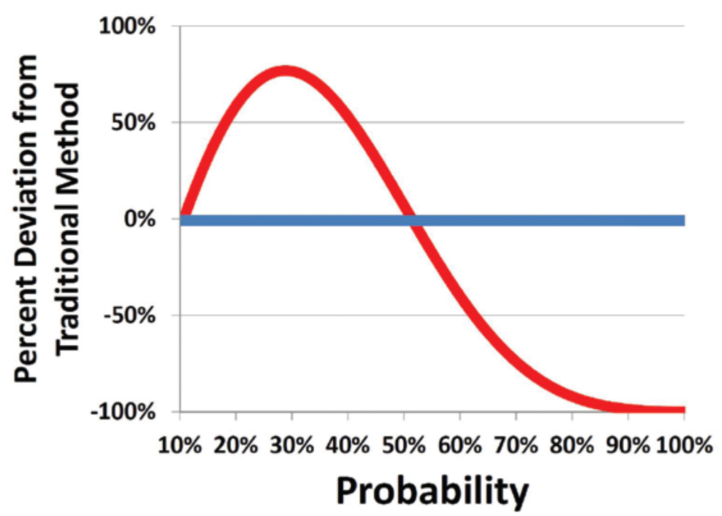

Figure 3: Example risk matrix with superimposed constant risk contour lines as described by a distance method (positional risk) definition

A problem becomes immediately clear with the positional risk in Figure 3, whereas the constant risk lines wander through several levels of differing risk. In Figure 3, the constant risk line starting in the upper left moves from yellow to orange to red and back again, which indicates that the risk is not nearly as constant as proposed.

To further illustrate the difference between traditional risk and positional risk, we can compare the two methods, as shown in Figure 4. In the figure, we have superimposed two constant traditional risk lines with

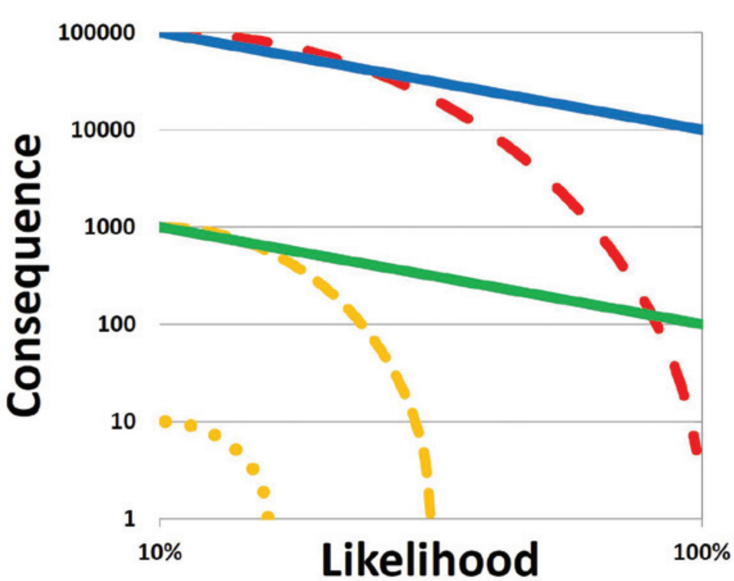

Figure 2: Example risk matrix with superimposed constant risk contour lines

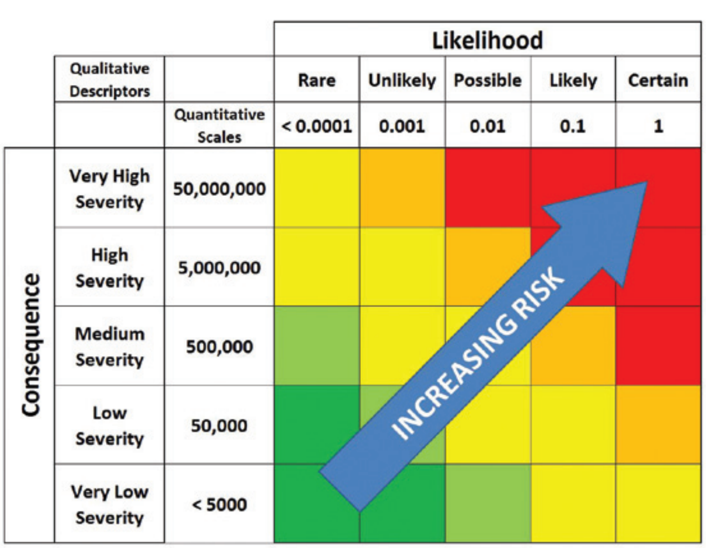

Figure 4: Quantitative comparison of traditional and positional risks with a 10% to 100% likelihood scale

three constant distance lines. The traditional risk is represented by two constant risk lines shown by the blue and green straight lines, while the positional risk is represented by the dashed lines. For the purpose of the example, we are using probabilities from 10% to 100% likelihood and consequences of $1 to $100,000, much like the risk matrix in Figure 1 but with reduced scales on the x-axis. In Figure 4, the perceived slope of the traditional constant risk lines, as compared to Figure 2, has changed due to the x-axis scale, but the underlying mathematics and actual values of the risk have not been affected by the change in scale.

Difference Between Risk Definitions

We can calculate the difference between the traditional risk calculation method and the positional risk method. First, we need a starting point where the two methods agree on the risk. This is a single point where the probability and consequence are the same for both methods, i.e. where lines intersect. In Figure 4, the solid blue line and the dashed red line intersect at a probability of 10% and a consequence of $100,000. By calculating the risk along the paths of the red and blue lines, the differences in risk level can be shown as a percent difference between the two. Figure 5 shows the calculated deviation between the traditional risk calculation method and the positional risk calculation method, which varies from +80% to -100% of the traditional method of evaluating the level of risk.

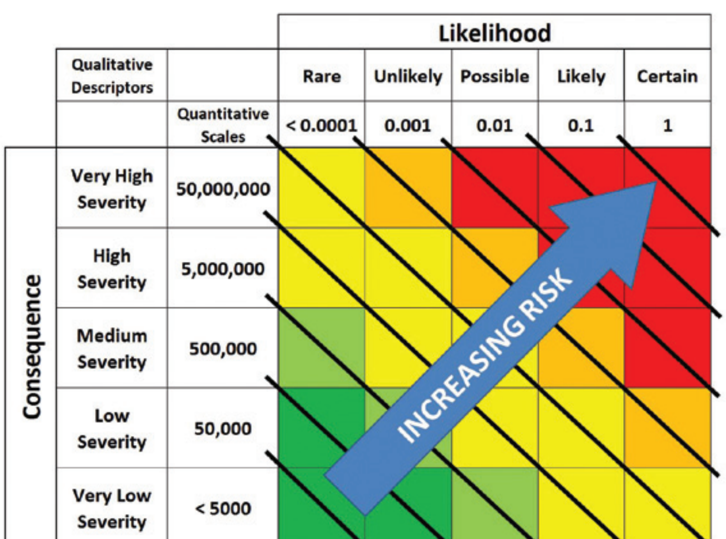

Figure 5: Percent deviation of the positional risk method (red line) from the traditional method (blue line) constant risk lines in the Figure 4 example

Impact from Misunderstanding Risk Example

Given the magnitude of the deviation between the traditional risk and positional risk, we should look at how the difference of risk measurement could impact business decisions. Suppose we have a problem, Option A, within our hypothetical plant that has a 95% probability of occurring with a consequence of roughly $100. We can graphically represent this as arrow "A" in Figure 6. The length of arrow "A" shows the positional risk method for calculating risk. We also see the traditional definition of risk associated with the problem being shown as the green line.

To eliminate this problem, our hypothetical plant underwent an improvement effort to develop a solution. The proposed solution, Option B, resulted in changing the risk, as shown by arrow "B." Using the positional risk method, the risk of Option B was less than arrow "A" because the length of arrow "B" was shorter than arrow "A." If we had used the traditional risk method, we would have understood that both Option A (the original problem) and Option B (the proposed solution) have the same risk level as represented by the green line.

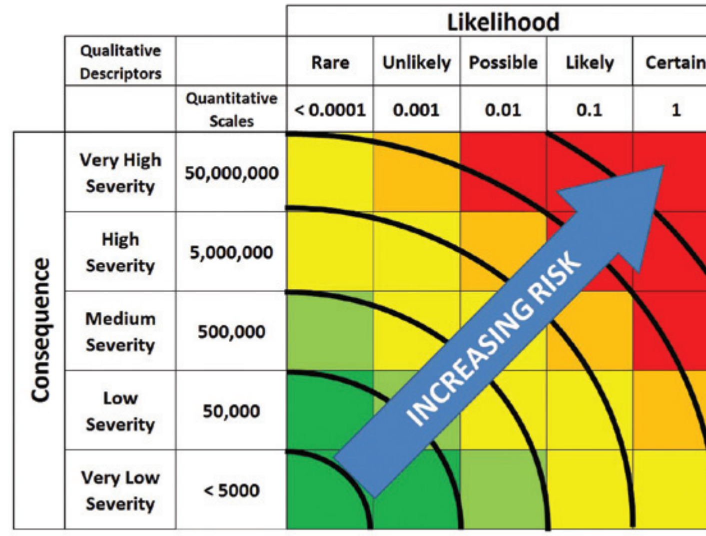

Figure 6: Positional risk incorrectly shows improvement from A to B, whereas actual risk has remained constant.

Thus, if we had used the positional risk in our risk assessment for our project screening and approval process, we would have approved and implemented a project that would not have reduced the overall risk of our hypothetical plant. With respect to the project, we would have had a negative return on our investment even though the positional risk clearly (and incorrectly) showed an improvement.

Conclusion

The use of Euclidean distance for comparing and assessing risk is not consistent with the mathematics used in other industry-accepted reliability and risk analysis methods. Without a solid understanding of the risk, we have incomplete information to make sound business decisions. ISO 73 and 31000 may allow for a broad range of risk analysis methods, but the practitioner should be mindful of the limitations of the methods, tools, underlying assumptions, limitations and objectives when using various methods to assess risk. Thus, caution should be used when using Euclidean distance or other distance methods when comparing risk as described in the original article.

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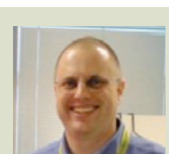

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In response to Brian Webster's article, Terry Nelson requested the opportunity to supply additional information relating to his article in the Oct/Nov 2011 issue of Uptime.

Risk Calculation Methodology

Terry Nelson

I appreciate Mr. Webster bringing risk calculation methodology to the forefront for discussion. The focus of my article was limited to the overall processes of analysis rather than specifics. The very character of risk is an excellent topic in further exploration of these important concepts and principles.

Mr. Webster contrasts positional risk - determined using distance in space as I suggested in my article on traditional risk - calculated using a simple product of consequence and probability (which I will refer to as actuarial risk because it merely expresses risk as cost-over-time).

I first emphasize that both risk calculation methods have value and place. In fact, my intent is to supplement rather than supplant actuarial risk. It is important to understand the value and how each method should be used. There is no correct or incorrect method, rather better and poorer applications for each.

Mr. Webster suggests that using positional risk is synonymous to simply adding voltage and current to get power (wattage) for a motor. In fact, Euclidean distance is more closely related to the product of the components than to the sum and most importantly incorporates the fact that consequence and probability are two very different characterized contributors to risk. Positional risk is a "planer" calculation rather than a linear one. Think of consequence as a north-south value, while probability is an east-west value, with positional risk being distance over the landscape. Figure 1 shows a simplified comparison of constant risk lines using positional risk and actuarial risk calculation methods along with points for many risk events one might encounter within a real system represented as dots.

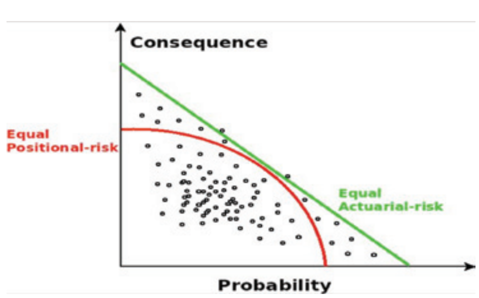


Figure 1: A simplified comparison of positional risk (red) and actuarial risk (green) calculation methods with the dots representing risk events

For an electrical motor, wattage is certainly a limit for the motor in many ways. However, it is not the ONLY limitation. Voltage limits exist that are based on insulation capabilities. On the other hand, amperage limitations are based on heat dissipation capabilities – quite different characteristics and also different from those associated with wattage limits, such as shaft torque, etc. Hypothetically, even with extremely low voltage applied to a motor, high current could damage the motor even though the total wattage is far below acceptable levels. Similarly, extremely high voltage could damage the motor even if far below wattage limits. In a motor (any electrical circuit), we need to be concerned about outliers in respect to ANY of the three aspects: voltage, current, or wattage. Likewise, we need to identify outliers in any of the three aspects of risk: consequence, probability, or actuarial. It is easy to see in Figure 1 that positional risk identifies outliers, while actuarial risk limits outlier identification to only those based on actuarial risk.

This is further demonstrated in chart form. Figure 2 is produced using positional risk calculations. It shows that outliers along each axis (rows one and four) calculate risk values comparable with outliers in actuarial risk (row three) and greater than values for non-outliers, such as row two.

Consequence	Probability	Positional-risk
1	9	9
3	3	4.2
6	6	8.5
9	1	9

Figure 2: Positional risk calculation

Consequence	Probability	Actuarial
1	9	9
3	3	9
6	6	36
9	1	9

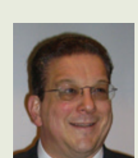
Figure 3: Actuarial risk calculation

Figure 3, with the same four points as Figure 2, shows that actuarial risk calculates very low values for even extreme outliers along the axes (rows one and three) similar in value to non-outlying points such as Row 2. Only the single actuarial risk outlier is identified.

The essential aspects of identifying outliers that are closer to the axes are many, but the two most important are to avoid becoming "bean counter" driven and to find real opportunities for improvement. Actuarial risk methods likely would not have identified significantly major, but rare events, like the Bhopal disaster, the Fukushima nuclear reactor disaster, or the BP oil spill, because their extremely low probability would relegate them to obscurity. Positional risk methodology might have made all three possibilities clear and difficult to downplay. On the other end of the spectrum, extremely frequent but relatively low consequence events would also be ignored by actuarial risk, resulting in "consequence leaks" that might add up to major overall significance and multiple lost opportunities for improvement, known as pound wise and penny foolish.

Once outliers are identified using positional risk, then responsive actions can be evaluated for potential outcomes and compared to as-is or alternative cases. This is where actuarial risk is rightly applied as suggested by Mr. Webster's comparison of his cases A and B. As he suggests, a real and actual improvement in risk profile is necessary to justify making the change. We don't want to just move the problem from one of consequence to one of probability, or the other way around.

Just as actuarial risk is less valid for discriminating and prioritizing opportunities and challenges, positional risk is less valid for evaluating effectiveness of various options to address those opportunities and challenges. In essence, positional risk is the horse and actuarial risk is the cart. We should not use a cart in place of a horse, or the other way around. As we all know, we shouldn't put the cart in front of the horse.



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New Paradigms

in Oil Analysis and Condition Monitoring

Jack Poley

It is simply coincidence, but the outset of the 21st century has witnessed numbers of very significant, even seminal events in condition monitoring (CM), particularly where oil analysis is concerned.

Here are some of the most salient developments that began to take hold at the end of the 1900s:

- Online/Inline sensors for ferrous and non-ferrous wear debris;
- Improved, compact onsite test kits and sophisticated handheld and portable instrumentation;
- Large particle and filter debris analysis;
- Intelligent Agents: Sophisticated collaborative software for assessing data severity and rendering in-depth, nuanced advisories in very specific applications and components.

Wear Debris Sensors

Having predicted this development decades earlier, I am genuinely surprised at how long it took for online sensors (beyond oil temperature and pressure, which have existed for a century) to become a viable solution and improvement in monitoring oil-wetted machinery. I suppose I should not be. It was as much a question of robustness as it was detection and measurement. Previous offerings were simply not rugged enough to stand up to immersion in hot, sometimes highly contaminated oil, nor did these devices demonstrate sufficient precision and repeatability under such conditions.

The technology, employing magnetometry, is now in a mature stage. Today, all the issues - detection and measurement, sufficient sensitivity and repeatability, and stability and ruggedness - have been met.

The metallic particle count sensor depicted in Figure 1 not only detects ferrous metal with size classification, but can also derive counts via signal analysis for non-ferrous particles at sizes as low as 135µ.

Figure 1: Metallic Particle Count Sensor
(Photo courtesy of Kittiwake Developments LTD)

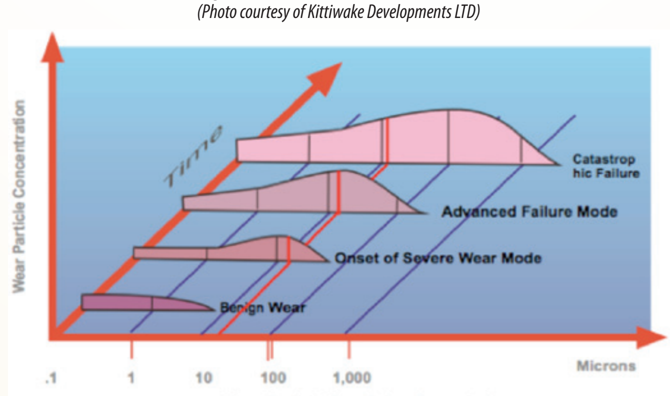

Figure 2: Importance of wear particle size in assessing trauma (Source Moubray et al)

Large Particle Investigation

The oil analysis industry has long shown an interest in small particulates, especially those that could wreak havoc in hydraulic systems where clearances are so critical to safe and effective performance. Thus, "particle counting" instrumentation is and has been routinely employed to monitor particles from 4µ to 70µ (current range as indicated by ASTM International standard D7647).

The advent of online sensor detection of wear debris, however, begins at ~40µ. It is well understood that larger particles are indicative of fatigue or severe wear. Detecting such particles at the earliest (real time) opportunity is clearly a major advantage toward minimizing damage when it develops, or possibly avoiding failure altogether (Figure 2).

Because 40µ and larger particles are readily filtered out, systems with filters remove a significant amount of particulate evidence at such sizes. Improved filtration technology, too, impedes the gathering of large particle evidence, all for the good goal of lubricant cleanliness. This led to greater interest in and emphasis on inspecting filter debris.

For decades, filters have been cut open and their particles inspected via microscope and other means. Often, important information was gleaned to assist in vetting routine oil analysis results.

Today, the process is being approached at a much more sophisticated level, such as performing semi-automated analysis and using a combination of techniques, including x-ray fluorescence. Filter debris analysis (FDA) is rightly emerging as a specific inspection discipline in CM routines.

Intelligent Agents (highly nuanced expert systems)

The "oil analysis business" is crowded with competent laboratories, providing adequate services to their customers. Most of these laboratories, whether commercial or private, provide commentary, but much of the time such commentary is rather limited in scope, or is simply not sufficiently informative for recipients to understand whether or not action should be taken and, if so, what that action should specifically be.

This situation exists for a number of reasons:

1. Commentary has always been subordinate to the creation and gathering of data. No standards or minimum expectations exist; the comments are often an afterthought.
2. In many cases, the evaluators at the testing site have limited knowledge about the equipment under surveillance, resulting in uninformed or minimal commentary.
3. Evaluation of an oil sample's test data requires solid knowledge of both the component and its lubricant. Many evaluators are not equally comfortable with these totally different aspects, yet there is considerable interplay and implication that can be overlooked if the evaluator is not aware of this interplay.
4. Subsequent samples from a given component may be commented by various evaluators, each with a different feel and understanding of the component, its application and its lube. The result can be a disjointed, discontinuous evaluation from sample to sample.
5. If the testing laboratory is remotely situated from the sample source, there is no opportunity for the evaluator to "see" the component. There may be some obvious indication of trauma that is key to the comment being rendered, but if the sampler doesn't see it or report it when submitting the sample, this information will not be the necessary part of the evaluation it could and should be.
6. Many recipients of oil analysis data and reports are only drawn to obvious problems, such as very high wear metals, or presence of water or abrasives. Additional nuances are not even considered, nor requested, because the recipient is simply not aware of such a possibility. Why should he be? He's not an evaluator. If the comment doesn't reflect a need to consider such nuances, they may never come to light.

Today's oil-wetted systems are more complex than ever, and oil chemistry and performance characteristics are at their highest level, simply owing to significant scientific advancement in lubricants chemistry. There isn't any one expert who can recall everything needed, know where to go to find specialized information, or simply find the time to make such an effort.

2-Phase Rules Set for Iron Wear and Abrasives (silica?)

	Si SEV 1	Si SEV 2	Si SEV 3	Si SEV 4
Fe SEV 4	• Severe Wear	• Severe Wear	• Severe Wear	• Severe Wear
	• Notable Silicon	• Abnormal Abrasives	• High Abrasives	• Severe Abrasives
Fe SEV 3	• High Wear	• High Wear	• High Wear	• High Wear
	• Notable Silicon	• Abnormal Abrasives	• High Abrasives	• Severe Abrasives
Fe SEV 2	• Abnormal Wear	• Abnormal Wear	• Abnormal Wear	• Abnormal Wear
	• Notable Silicon	• Abnormal Abrasives	• High Abrasives	• Severe Abrasives
Fe SEV 1	• Notable Wear	• Notable Wear	• Notable Wear	• Notable Wear
	• Notable Silicon	• Abnormal Abrasives?	• High Abrasives?	• Severe Abrasives?

Figure 3: A generic 2-phase rule for Fe/Si

The most interesting case is where Si is 'high' but Fe is only Notable.

It is not clear if the Si is in another (non-abrasive) form or if it is in abrasive form, but only recently introduced into the sump and is about to cause wear. The next sample in the sequence should help clarify.

Automated expert system evaluation and pattern recognition of oil analysis data (or other CM data) can overcome limitations, weaknesses and inconsistencies in the oil analysis evaluation process, relieving the pressure that is placed on human effort and maximizing the program's value while minimizing errors. It can be programmed and taught to respond to complex data patterns, no matter how subtle, in order to render commentary rich in content and depth with speed, accuracy, consistency and nuance. It is the next level in oil analysis competence - it is the "Intelligent Agent." Such software allows collaborative knowledge infusion so that multiple aspects of evaluation can be addressed by highly competent domain experts.

Let's take a look at what intelligent agents can do. Figure 3 shows a typical 2-phase table for iron (Fe) and (Si) that allows 16 different relationships based on data severity at four levels of interest: notable, abnormal, high and severe.

This particular rule set is generic, in that it could apply to virtually any component type. If, however, we apply it to a specific type of component, say a diesel engine, we will add terminology like rings or cylinders to describe likely sources of Fe.

We'll also consider the possibility of a compromised air cleaner element or housing and recurring issues with reciprocating engines. Additionally, we may want to inquire about oil handling and storage practices if we see multiple examples of components with issues involving these two elements since it is unlikely that several air intake systems are faulty at precisely the same time.

Perhaps the greatest key performance indicator (KPI) of a condition monitoring program is the return on investment (ROI). The only way to measure this vital number is to garner feedback, i.e., record findings and maintenance action based on report information, commentary and advisories (see Figure 4).

Here, too, some intelligent agents provide a convenient gathering mechanism that can be attached to the actual sample and the machine's found condition and subsequent repair, as applicable.

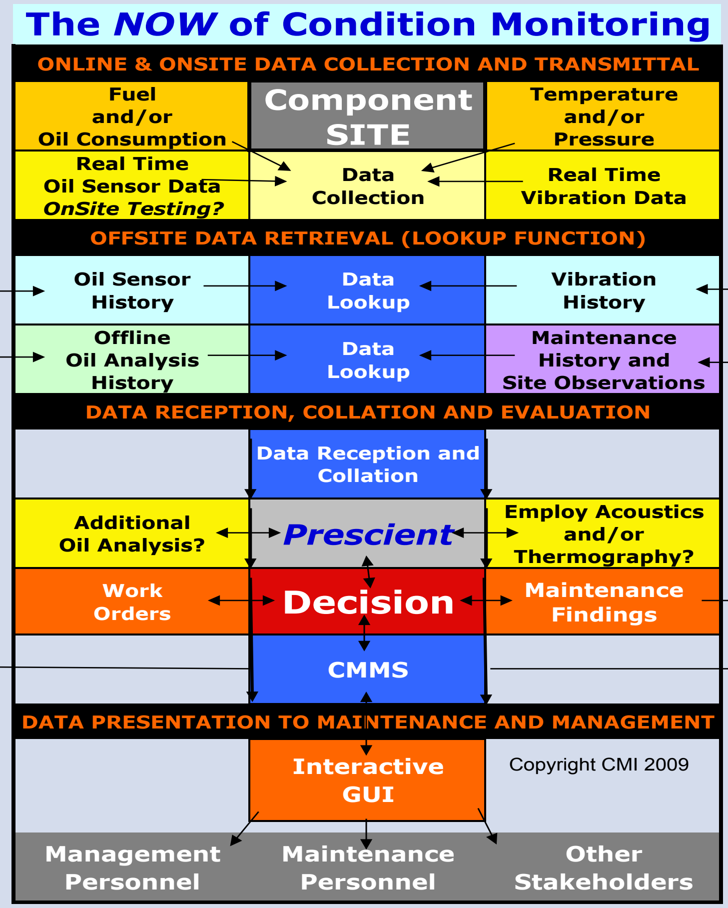

Figure 5: Holistic closed-loop CM schematic example

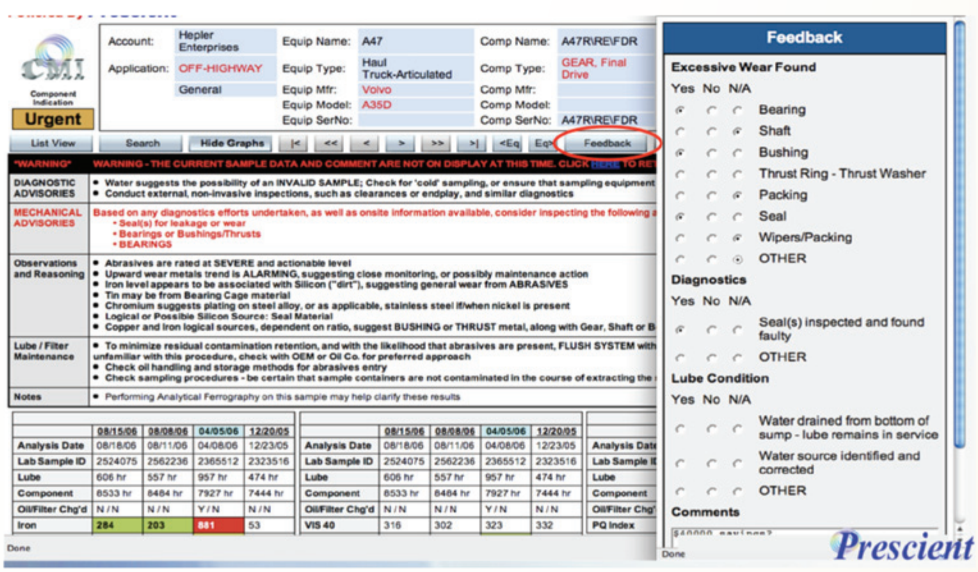

Figure 4: Feedback logging directly online to feed CMMS and vet intelligent agent performance

Once the maintenance has been logged accurately, the ROI can be calculated based on known costs, including machine parts and production losses in conjunction with a computerized maintenance management system (CMMS).

When all the pieces of modern CM are brought together, spearheaded by (now available and effective) real-time condition monitoring for both oil and vibration, and anchored by a purpose-built intelligent agent with a report delivery system tailored to users, one can envision a very holistic, synergistic amalgamation of essential tools to achieve a CMMS that exacts the maximum from the efforts and resources expended (see Figure 5). Ultimately this is the goal of a CM program: *Maximizing the Bottom Line*.

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management RL reliability leadership

Sunshine & Rainbows
The Journey Toward Cultural Change

John Scott

We have all heard the old saying that "a journey of a thousand miles begins with a single step," but never did this Confucius saying ring truer than when implementing manufacturing excellence.

When you consider the elements and tools available to us and the promise of good things for any company, it is no wonder more companies are starting reliability processes. There are many successful reliability models that we could try to emulate, yet in true blue American style, we select pieces of a multi-faceted process and provide half the resources required, yet somehow we make it work. We are amazed that progress takes as long as it does, but when we see results and improvements, we all get that "atta-boy" we want.

We live in an industrial age where resources are hard to come by, yet results must be achieved. If implementing a reliability process only involves the basics, we would certainly be in high clover. However, the reality is much of our time at the beginning of this process is more about culture change and less about protocols and procedures. Implementing a process is easy, having people follow it is another story.

The red bicycle syndrome

Consider the process of culture change and the level of complexity required if you are the driving force behind your reliability initiative. For example, you have a piece of equipment that requires a monthly preventive maintenance ((PM) that takes 45 minutes to complete. You ask production for the piece of equipment during a slow production day and receive a resounding "no." Your production counterpart knows the importance of a good PM, but wants the equipment to run all the time because shutting down during production hours just goes against the grain. Let's add to this scenario the fact that this piece of equipment is a very bad actor that provides daily stop and start action. Now we have a piece of equipment that reduces uptime several times a week, yet production will not shut down early on a slow day to let you and your team in to complete the PM. The downtime throughout the week clearly belongs to maintenance, which could not have possibly performed the PM properly last month, otherwise our equipment would run. I refer to this as the "red bicycle syndrome."

This phenomenon first came to my attention as a dairy farmer when I happened to notice all of my cows standing in an informal circle staring at something. When I walked closer, I realized that the cows were staring at my nephew's 20-inch red bicycle. This was culture change in a pure and raw form. I have often seen the same reaction anytime a cultural change suddenly appears on the horizon.

Cultural Change #1: How do you get production to shut down equipment for you during good processing time? Culture dictates that we need to run while it is functioning semi-normal. This can be a very frustrating time for both production and maintenance. Part of the answer to this challenge is to take a solid look at what you are doing. Look at the history of the machine and ask a few tough questions. Are the problems with this machine related to the PM? Are the machine problems associated with component failure or are there other causes? This is the time to perform a good analysis and review of all past work orders. Work orders, even if poorly documented, can give you good information. What type of issues are you seeing? How many work orders have "adjustment" in the description? What patterns are you seeing on the work orders? You may find that the same component is changed during a reactive work order on a regular basis.

This brings us to **Cultural Change #2**: Are we buying and using original equipment parts or something aftermarket? Generally, when looking at this factor, I have found that somewhere along the way someone found a cheaper part based on unit cost. While we all want to save money, we need to look beyond just the cost of each unit. On one such piece of equipment, I found the unit cost for a drive motor was actually about $200 less than the original equipment. That is a great cost savings; the problem is replacing 17 motors in five years, all during a breakdown situation. Our cost savings goes south when you consider production labor, loss of product, labor for reworking product and pulling a craftsman off a scheduled job to complete an emergency repair. Our $200 savings just cost us $2,000 or more depending on time.

The real cost savings is when we use the right component and change it out on a planned and scheduled job plan. Again, we face the frustration of a culture that sees a savings and jumps on that band wagon without a proper analysis. For our example, we will make the assumption that our components are of excellent quality. Looking at the patterns in the work orders, we also see a steady flow of those pesky adjustment work orders. When comparing the patterns, we may determine that even though our parts are first rate, we are significantly shortening the lifecycle of the component through over adjustment. However, we don't know why.

Time for **Cultural Change #3**: Are we looking at an alignment problem? We all know that equipment should be solidly mounted to the floor, properly squared and plumbed, but you know working on this thing is easier if you can slide it away from the line a bit for easier access. Anyway, we can tell it is properly aligned just by looking at it, right? So long as production does not speed up the cycles so the machine jerks, it can run smooth like that for years. Well, here we go again with that cultural thing; some people will just not see the plumbed forest for the trees. For these folks, it is obvious where the problem is, which brings us to the next cultural change.

Cultural Change #4: Operator error. Following the progression of adjustment work orders, it should be clear to anyone that some operators simply cannot stop making adjustments. The constant adjustment of the machine is contributing to the wear of the components; anyone can see that, can't they?

When you begin the reliability process, it is amazing how many companies out there have just the answer you are looking for. Technology, proactive tools, oil analysis, computerized work orders and statistical analysis are all pieces of the pie that we want to grab a hold of and bring to our plant. They are all good and they all have a slightly different slant on what you need, for a nominal fee of course. Now don't get me wrong; without question, there are incredible tools and services available out there that can add value to the bottom line. What I see as a concern is moving forward with a product or service without having done our homework before making the leap.

In our example, we meet frustration on both the maintenance and production side. This frustration comes from our own internal history that may be less than stellar. What drives your business will always be the key factor. In other words, what goods or services do you provide and how do you measure success? We link time to that pesky thing called productivity, a term that at first simply means to cut staff. In reality, the metrics used to create that staffing cut is really a modern way of saying common sense business. Use the number of people you need to accomplish your budgeted production rate and just to make it interesting, let's try to do that in a cost effective manner so the price we have to charge for our product or service falls within acceptable limits for the consumer.

So where does this lead us? The answer is not as clear as the question. To see where we are, we must have some kind of history that calls for review. Our PM had to wait, so we had yet another failure that required replacement of a part. A few weeks later, we perform our PM that calls for replacing the part that we just replaced. Since the part is only a few weeks in service, we don't need to change it, do we? What if the part was a bearing and when we replaced it on the breakdown, we only replaced the one bearing and no one performed an analysis to see why it failed? We just potentially created a breakdown that has not happened yet. The common sense of the situation has eluded us and we move happily along the path of, "Hey, the thing is running, right?"

The culture most of us are probably used to is "keep it running" at all costs. When we break down, how fast can we get running again? The old adage of "time is money" hits this one dead on. Our comfort level changes based on downtime and leaves us fast when the line is down. So the 64-thousand-dollar question is: How do you move beyond your own culture when implementing a reliability process? First, there has to be a team effort from the very beginning. Maintenance and production have a partnership and both must be actively involved in the implementation process if you have any chance at success. Maintenance cares for the equipment, but who owns it? Correct, production owns their equipment in the same way that you own your own vehicle. When you have issues with your car, you call the service center and schedule an appointment at a time that works for every one. The service center will ask a few brief questions to glean a bit of data and the rest is up to the mechanic. The service center will schedule the mechanic's time on any given day and all of a sudden we see planning and scheduling in action. During the phone call, a few questions from the manager helped with his investigation to try to determine how much time the repair will take. Service center personnel will also use their knowledge of your type of vehicle to know which components typically fail on that model.

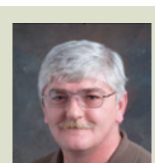
There are many successful reliability models that we could try to emulate, yet in true blue American style, we select pieces of a multifaceted process and provide half the resources required, yet somehow we make it work. We are amazed that progress takes as long as it does, but when we see results and improvements, we all get that "atta-boy" we want.

Similarly, to create cultural change in any industry, start the process of improvement by adopting a game plan based on accepted world-class standards and comparing it to your current culture. Create a process that includes:

- **Teamwork and ownership – cross-functional**
- **Analysis as a simple tool – basic questions**
- **Metrics and understanding – what do you measure and is it understood**
- **Preventive maintenance timelines, procedures, skill levels**
- **Work orders and equipment history – what is it telling you**
- **Replacement parts original equipment versus aftermarket – Unit cost or total cost**

Utilize cross-functional teams to make improvements that people can take ownership in and understand. Your process does not need to be complicated; it does, however, need to be understood. When you build small successes, there will be a hunger for more improvements that the cultural roadblock cannot stop. When all parties involved become excited about what is happening, you gain a greater hunger. This feeds the desire and receptiveness to purchase some of those services and products that can provide even more results.

Manufacturing excellence can provide great results if we are willing to take that step. The real key to cultural business change is a chain of successes that fuel more change. At our time in the industrial revolution, we have the potential to advance far beyond the vision from 80 years ago. The tools are right in front of you. The question is, Will you pick up those tools and put them to work?



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Part 3

Establishing Ultrasound Testing as a CBM Pillar

Knowledge represents power for the one. Sharing that knowledge empowers us all.

We were recently reminded of a quote from Sir Arthur Conan Doyle's *Sherlock Holmes:* **"It is always dangerous to reason from insufficient data." In Part 3 of** *Establishing Ultrasound as a Pillar of Your CBM Program,* **we assert it is even more dangerous to reason from insufficient data that is poorly communicated.**

Allan Rienstra and Thomas Murphy

Being tasked to gather data about machine condition is an important responsibility, but it is only one component of the condition-based maintenance (CBM) routine. Having a computer full of facts and figures is not much good to anyone if the data cannot be mined and shared in an efficient way. There is a certain power and consequence responsibility in the knowledge gained from CBM data collecting. Finding meaningful ways to share that knowledge empowers the entire team and is the final piece of the CBM puzzle.

In Part 1 of this series, we identified what condition-based maintenance is and some of the reasons for implementing it. We asserted that CBM represents a change of thinking where work orders are driven by data rather than lapsed time. The importance of carefully planning condition-monitoring tasks was highlighted, while we stressed the necessity to think beyond rotating assets when compiling asset lists to survey. Aligning the expectations of upper and middle management, as well as frontline staff, is another key ingredient for success. Part 1 reputed the simplicity and versatility of ultrasound testing as a CBM pillar. Ultrasound answers the one question that every planner asks: "Is it okay?"

Part 2 took us beyond the "what is it?" and "why we need it?" message to tackle a much more formidable question: "How do we do it?" We revealed the secrets to avoiding early frustration and not overwhelming your initiative by taking too big a bite. We also showed how to keep at bay naysayers whose negativity remains a constant threat to your success. The central message of Part 2 teaches us to categorize the types of problems we will encounter. Sort which defects are binary (good/bad), which defects are trendable and which defects are best identified with dynamic signal analysis. Only then can we begin to build a useful database.

We began Part 3 of this series by stating that "knowledge is power." We also asserted that sharing knowledge empowers us all. So it should come as no surprise that the final piece of the CBM puzzle is COMMUNICATION. Remember, condition-monitoring data is really just gathered intelligence that suggests something is about to go really wrong. To maintain alignment between the expectations of upper management, middle management, production and frontline workers, how can CBM data best be conveyed so it means something to everybody? Let's start by looking at the objective of good reporting.

Reporting

The objective of good reporting is to inform the people who need to be aware. They need to know what work they must do to bring an asset back to best condition. They need to know when that work should be done and the consequences of not acting on the work in a timely fashion. The job of the report generator can be compared to that of a translator. This job normally falls on the person responsible for collecting condition-monitoring data. CM data is the machine, the valve, the pump, the motor, the "whatever it may be" talking to you in an ultrasonic language. You are trained to understand that language. It is your job to translate what the asset is telling you into meaningful information that the planner, the repair crew, production and management can understand. That is what a good report should be; a product of considered engineering opinion based upon the facts you have gathered.

A report should NOT be data spewing. Time signals and spectra are merely hieroglyphics to most and while they may look pretty to techies, they will not impress upper management. Should they be included? Absolutely, but only as supporting illustrations to your clear explanation of the problem. What message should you be conveying then? Your report should start by stating the problem:

"There is an issue with this machine, or this valve, or this bushing, or this transformer. Additional follow-up with vibration analysis and an oil lab report is recommended to confirm the problem."

Identify the asset and identify the issue. Then clearly state what needs to be done to bring it back to best condition. A good report should also include a message about the consequence of doing nothing:

"You can fix it now and the cost for the repair, including spares, labor and scheduled downtime, will be $500. Or, you can leave it alone, however, besides continuing to impact production and product quality, the cost to fix it on an emergency basis will be $50,000."

What is wrong with writing a strong messaged opinion such as this in your report? Is it politically incorrect to make that assertion and state the blindingly obvious? Or is there lingering fear of making a bad call. The latter is a confidence issue that relates either to distrust in the technology used for CM or the person charged with collecting the data. Both can be addressed through expert training.

Specific Reports

Compressed Air Surveys

What should be included in a compressed air report? First off, the report should identify the location of the leak and if it is tagged, the serial number of the tag. Why was the leak tagged in the first place? State the reason why it couldn't be fixed there and then. Maybe the part was not available. Perhaps the leak could not be fixed without interrupting production. If you are going to write a report about an air leak, and part of fixing it means turning the air off, then make sure you write enough description for them to find the leak. We've lost count of the number of plants we visited where air leak tags are hanging from this year's survey and right behind them is the previous year's survey tag. You have to wonder why energy is being spent to find leaks that are not being fixed. And if you are curious, then write that in the report, too. It may be the only way to communicate to upper management that your efforts are being wasted.

Steam Trap Surveys

The first few times doing a steam trap survey, you will generate a huge list with lots to fix, especially if a survey has not been done there. Can steam trap problems correlate to production problems? Do you have complaints like, "I can't maintain temperature in the autoclave," "I can't maintain temperature in the oven," or "energy costs from the boiler are 25% higher than a year ago?" Can any one issue be tracked back to a specific steam trap? If yes, this is quite useful in terms of your "what happens if I do nothing" calculation for your report:

"If we do nothing about steam traps we can't carry on with production, or product quality."

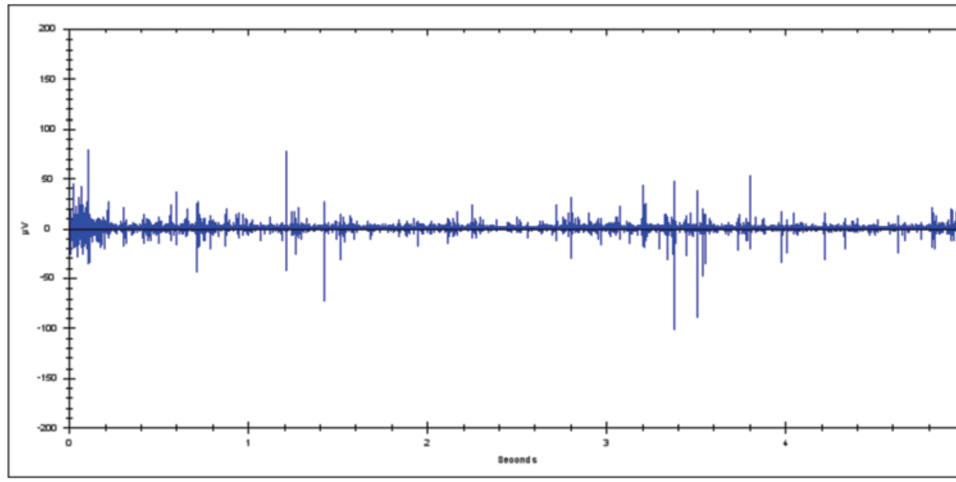

Figure 1 – A 60cm valve closed, time domain scaled; Note there is very little noise and some random peaks could be caused by expansion/contraction of steel body.

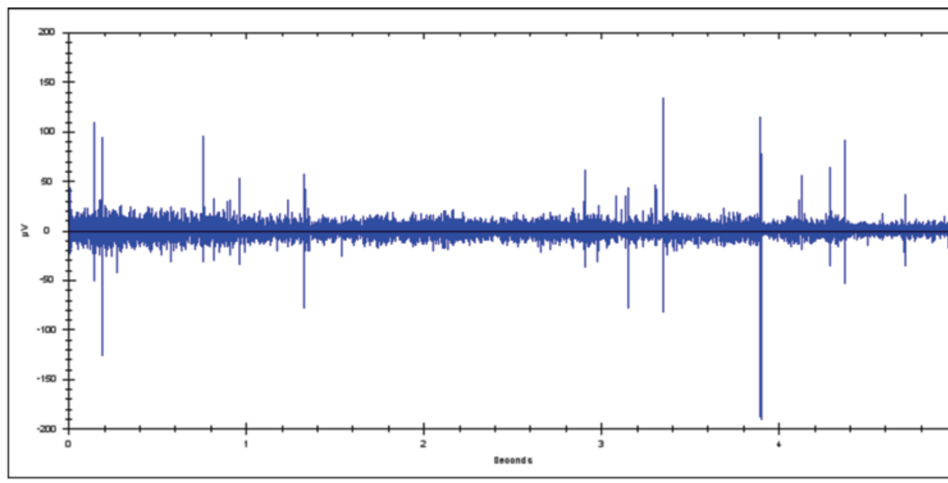

Figure 2 – A 60cm valve 10% open, time domain scaled; Note carpet value noise is significantly higher when compared to scaled dynamic signal in Figure 1.

Press the play button to hear the sound bite for Figure 3a

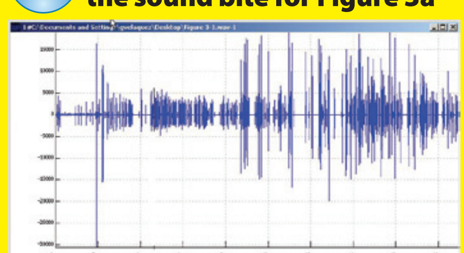

Figure 3a - Corona discharge prior to cleaning on a three-phase bushing

Press the play button to hear the sound bite for Figure 3b

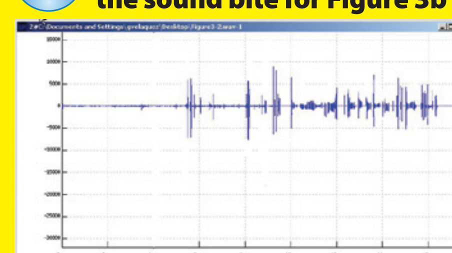

Figure 3b - Corona discharge after cleaning on a three-phase bushing

Valve Inspections

Not all valves operate all the time, so scheduling needs to play into data collection, not just repairs. Valves are a very typical binary defect. They either work or they don't. However, the use of dynamic signal analysis is useful in determining if a valve is closed or partially leaking, as you can see from the time signals in Figures 1 and 2. Both dynamic time signals were taken on the same valve body of a 60cm recycle valve. The first signal was captured with the valve closed and the second when the valve was cracked open ten percent. The signals sounded very similar to the ear, yet the dBµV measured value was 41 when closed and 67 when opened. The difference of 26dBµV means the signal is 18 times louder when opened.

The problem is the cost of overhauling the valve is $50,000, regardless of condition. Producing a report that clearly identifies this passing valve must convince all concerned that the overhaul is necessary. By providing the measured dBµV delta of 26, you give quantitative data. By providing the scaled time domain graphic, you provide a visual illustration of a closed valve versus a suspected leaking valve.

Electrical Surveys

Combining ultrasound with your infrared (IR) scans makes for a more complete inspection. Both technologies will find things the other may miss. Combining a time signal alongside the thermal image in your report adds a

Press the play button to hear the sound bite for Figure 4

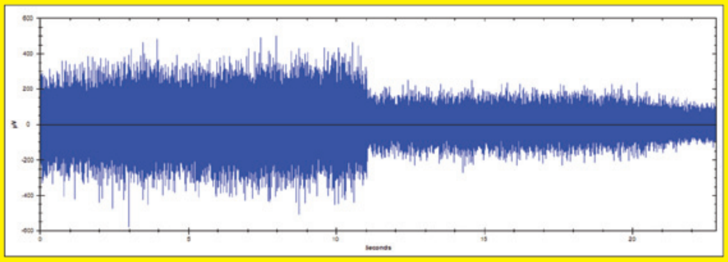

Figure 4 - A dynamic recording of a bearing as it receives the required shot(s) of lubricant

visual impact that may otherwise be missed. Take for example the time signal in Figure 3 showing a three-phase transformer connection with corona activity. The images illustrate the problem as found and the positive effect simple maintenance played in improving the situation. These types of images serve as an excellent visual addition to your reporting.

Lubrication Surveys

So you've been out checking a number of bearings for your pump survey and found a list of those that need greasing. Provide a trend graph (Figure 4) that shows static ultrasound readings increasing over time to the point where relubrications are required. Reinforce the decision to lubricate by attaching a time domain graph showing before and after affects of properly applied lubrication. And finally, by attaching the actual wave file to the report, everyone in the office can listen to what you heard in the field.

Final Thoughts

If proper thought and planning are not given to reporting, all our best efforts to implement condition monitoring come crashing to the ground. The primary purpose of good reporting is to translate what the machine is telling us about its health, what condition it is in today and how long we have to fix it properly with minimal consequence to production and profitability. We must produce reports that are clear about what the issue is, where the machine is located and what must be done to bring the asset back to best possible condition. Finally, a report must tell all who read it what will happen if no action is taken. If data and historical trends suggest that failure is three weeks or less, what will be the consequence and cost of delaying action to a shut down scheduled four weeks out? Be clear, be concise and know the interpretive capabilities of everyone who will read

Allan Rienstra is the President of SDT Ultrasound Solutions and co-author of Hear More; A Guide to Using Ultrasound for Leak Detection and Condition Monitoring. *He has spent the past 19 years helping manufacturers around the globe establish world class ultrasound programs. www.sdthearmore.com*

Tom Murphy is a Chartered Engineer with a degree in Acoustics and 29 years of postgraduate experience in predictive maintenance using vibration, infrared, and ultrasound. He is the co-author of Hear More.

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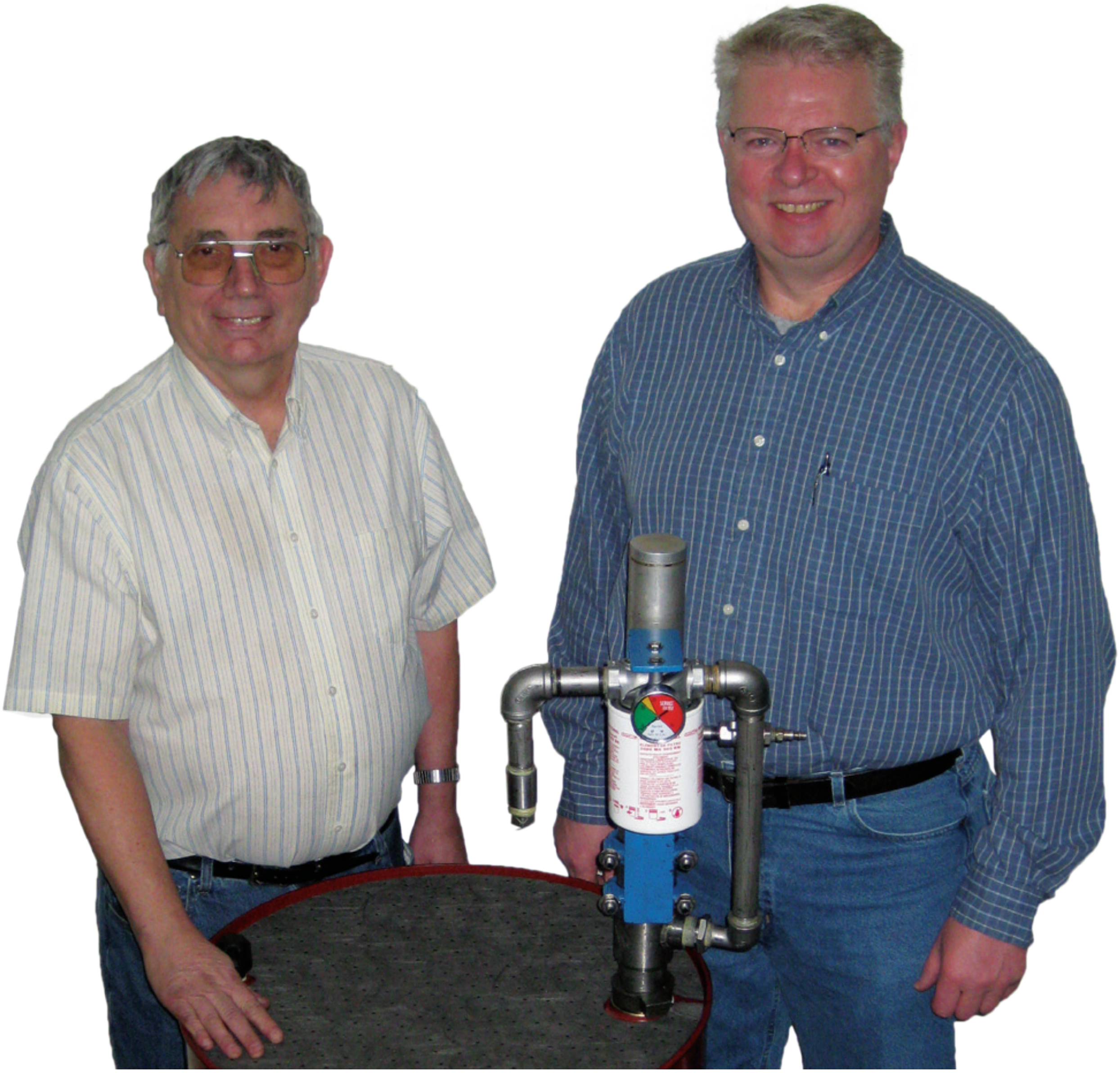


Pat Akins (right), Lubrication Champion and Bob Gay, (left) Facilities Lubrication Specialist

Q&A

Uptime Magazine CEO/Publisher **Terrence O'Hanlon** recently caught up with **Pat Akins**, Reliability Leader of paper maker Kimberly-Clark, for a question and answer session about the development of the Lubrication Program at the Everett Mill over the past three years.

Q ***Pat, will you please describe what your team has done to improve the Lubrication Program at your mill?***

A The work in the past three years represents our second step to advance the lubrication practices at this facility. We began in 2006 with three focus areas that included route and equipment documentation, oil analysis and contamination control. By 2008, we were delivering positive results from this work with sufficient sustainability and chose to improve our lubricant storage and handling, focusing on regulatory compliance, current best practices and cost controls. Our objective was to implement the changes with clear constraints consistently throughout the facility, yet provide end users with appropriate freedom and responsibilities.

Q ***Did everyone support the transition to a centralized Lubricant Storage and Handling process from the previous state?***

A The success of our previous work resonated positively with the management team, but varying levels of support existed in some areas. The concerns related to the access personnel would have to their preferred lubricants and the quantities to be kept on hand. Past practices had permitted individual areas to procure and maintain the products they deemed necessary with few guidelines and restrictions.

Q *How did you go about building credibility to make believers out of the early doubters?*

A A deliberate course of action was followed to provide resources and develop the implementation plan.

A comprehensive position description for the facilities lubrication specialist was developed, which included opportunities to expand the workload and support other areas once the process had matured. Support grew by ensuring clear responsibilities that included training expectations and responsibilities for area support. The decision-making process regarding equipment requirements, specific practices and work procedures in the new role would wait until the successful bidder could be involved. This increased credibility by confirming the company's commitment to the work.

The implementation plan development required three meetings with a thoughtfully selected team. First, we would educate the team regarding the task at hand, then allow team members to identify opportunities in our current practices and finally, develop a plan that would close the gap. A week was allowed between each session to allow team members time to talk with coworkers, address minor issues and consider potential possibilities and solutions. This further increased credibility by allowing the affected parties to determine their path forward.

Finally, the lubrication champion and facilities lubrication specialist resourced much of the implementation plan, providing materials and manpower to quickly establish area lubrication stations with minimal area interruption. This ensured credibility and a timely implementation.

Q *How important was training and certification to your efforts?*

A Training was instrumental in successfully transitioning to this new mode of operation and was conducted in several ways. The training format changed from instructor-led to peer-led and from a classroom setting to field work. Certification efforts reinforced commitment and strengthened credibility.

Training during the first meeting fully explained the opportunity and boundaries. This session was led by the site lubrication champion to review key points of previous lubrication training, outline overall objectives of this initiative and explain the opportunities to incorporate current best practices. Other speakers included the site environmental and asset protection engineers to explain applicable regulatory requirements and compliance needs pertaining to containment, sprinkler coverage, spill protection, etc. These three subject matter experts attended all the meetings and made themselves available throughout the process for questions. Feedback from the attendees was incorporated to improve the presentation and increase buy in. During the annual spill protection training, this presentation was shared with all personnel on site.

Next, area surveys and documented inventories illustrated opportunities in a non-threatening manner and reinforced this training with team members. The chance to address some of the worst situations beforehand was a plus and working with their peers helped to minimize uneasiness.

Finally, team members and area personnel, when available, were invited to participate in monthly inspections. These sessions were ideal for establishing understanding, clarifying intent and ensuring consistency across the site. Condition as left was much improved with this approach and continued improvement in scores indicate practices were maintained.

Coincident with this work, informal training and self-study resulted in successful completion of two machinery lubrication technician exams and one machinery lubrication analyst level I certification exam. The experience and knowledge gained from this work has benefited the facility since.

Central Lube Storage and Used Oil Rooms Inspection

Revised 1/29/10

Date: ____________

Inspected By: ____________

		Score	Acceptable
Central Lube Storage Room			
1	Is exterior signage present and legible?	3	______
2	Does room appear neat and organized overall?	5	______
3	Are all lights illuminated and ventilation acceptable?	5	______
4	Is sprinkler protection present, unimpaired and intact?	3	______
5	Is the room dry with stable temperature?	3	______
6	Are floors swept, free of spills and debris?	5	______
7	Is area in front of electrical panels open for 36"?	5	______
8	Is Flammables Cabinet clean and neatly organized?	5	______
9	Is Fire Extinguisher accessible and with current inspection?	5	______
10	Is trash can usable and not overflowing?	5	______
11	Is desk/work area neat and oranized?	5	______
12	Is Hoist Inspection current?	5	______
13	Is Used Oil Container present, closed and labelled?	5	______
14	Is Used Oil Absorbent Pad Container present, closed and labelled?	5	______
15	Is floor drain free of oil and debris?	1	______
16	Are drums properly positioned, clean, labelled and closed?	5	______
17	Do dispensing oil drums have round absorbent pads on top?	5	______
18	Do dispensing oil drums have filtered breathers and pumps?	3	______
19	Are cabinets found closed and clean?	5	______
20	Are sufficient Square White Pads (KC 1286210) present?	3	______
21	Are sufficient Round Drum Pads (KC 794948) present?	1	______
22	Are sufficient Paper Towels present?	3	______
23	Is work table neat and organized?	5	______
24	Is parts washer clean and serviceable?	5	______
25	Are Fork Truck and Delivery Pallets clean and serviceable?	5	______
Used Oil Room			
1	Is exterior signage present and legible?	3	______
2	Does room appear neat and organized overall?	5	______
3	Are all lights illuminated and ventilation acceptable?	5	______
4	Is sprinkler protection present, unimpaired and intact?	3	______
5	Are floors swept, free of spills and debris?	5	______
6	Is area in front of electrical panels open for 36"?	5	______
7	Is Fire Extinguisher accessible and with current inspection?	5	______
8	Is trash can usable and not overflowing?	5	______
9	Is Hoist Inspection current?	5	______
10	Is Used Oil Transfer Tank serviceable?	5	______
11	Are Used Oil Absorbent Pad bins present, closed and labelled?	5	______
12	Are Used Oil Filter Element bins present, closed and labelled?	5	______
13	Is floor drain free of oil and debris?	1	______
14	Are empty drums properly positioned?	5	______
15	Is cabinets found closed and clean?	5	______
16	Is parts washer clean and serviceable?	5	______
17	Is containment area swept and free of debris?	5	______
Central Lube Storage Room			
1	______		

What kind of improvements did you make to the lubrication program most recently?

With the lubricant storage and handling work, we made several improvements. All new oil was filtered at least once prior to dispensing, closed containers were implemented for new products and lubricant storage areas were formalized throughout the facility.

Manual and air pumps used for dispensing lubricants were equipped with filter assemblies with 5 micron elements (10 micron if 460 cSt and above) and beta efficiencies of 200 or greater. Filtered breathers (10 micron rating) were installed on every drum. Several different electric pumps were also available for remote filtering and product transfer.

Closed containers replaced the open and repurposed ones across the site. A readily available product was distributed across the site, with a small quantity of each stored conveniently for future needs. Durable tags were attached to each; many of these are available for a nominal fee from the lubricant manufacturer and the remainder is made in-house and laminated. To ensure effective cleaning, a dedicated parts washer was procured, featuring a rotating turntable and multiple jets that sprayed pressurized soapy water at 140° F and 40 gpm.

Several storage areas were created in this initiative with specific purposes for each. The Central Lube Storage Room stores the lubricants prior to usage, plus other supplies including labels, closed containers, spill control products, etc. The Used Oil Room stores spent products removed from service for recycling, such as oil drums, absorbent pads, filter elements and used oil. The Area Lube Stations provide ready access to new products for each area and an intermediate storage location for spent products.

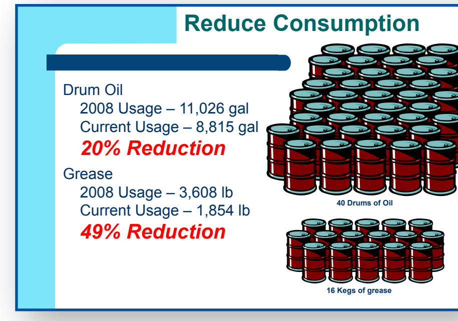
Ok – the Lubrication Program sounds great and the team is making a lot of improvements, but is the program also generating other financial results, like lowering overall maintenance cost or increasing the production output?

Reductions in inventory and operating expenses delivered the majority of the cost savings. It was a pleasant surprise to make so much progress on a cost neutral basis.

The lubricant inventory found during the second team meeting became our baseline. All products were evaluated to determine suitability for operation, applicability to equipment on hand and storage until needed. Usage data was evaluated to determine reorder points using standard storeroom formulas and reductions were made accordingly. These calculations were repeated periodically as additional data was compiled to improve accuracy. After calculating the reorder points, the results were checked against the highest issued amounts and practical experience before implementing. Progress to date finds reductions of 78% in drum oil and 64% in grease inventory levels.

Consolidation efforts have reduced the number of different products from 52 initially to 24 currently. Duplicate or redundant products were the first to be eliminated. Next, was a review of the usage data to identify products with minimal or no issuance. Finally, a comparison of specifications on the remaining products with the equipment manufacturer's requirements was conducted to identify any other products that could be substituted without risk to the equipment. Progress to date has been the elimination of 28 products from the site.

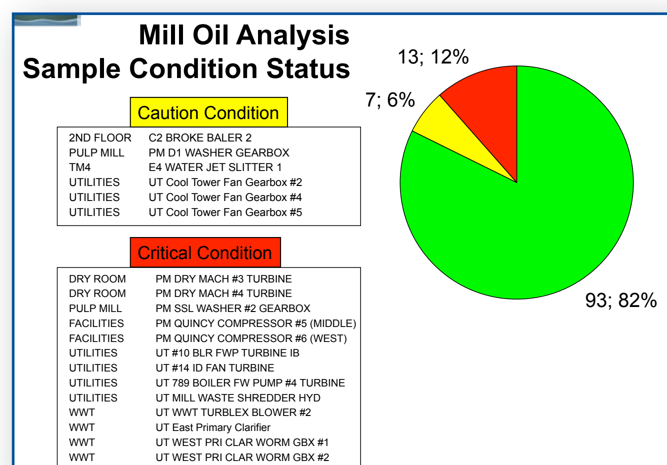
Product consumption has been reduced in several ways as well. The systems included in the oil analysis program were migrated from time-based to condition-based change frequencies, with lubricant conditioning used wherever possible. Oil drums are completely drained prior to recycling in place of disposal when the pump stops drawing. Grease containers have been reduced in size to minimize opportunities for contamination and spoilage. Progress to date finds reductions of 20% in drum oil and 49% in grease consumption levels.



In total, the inventory reductions returned more than $50,000 to the business, while a reduction in usage averages in excess of $60,000 annually. A portion of the former amount was directed back into the initiatives to limit additional investment, while the latter offset the ongoing cost of the facilities lubrication specialist.

How do you communicate the results of the Lubrication Program over time?

Monthly metrics are distributed electronically to employees throughout the site. Initially, this included oil analysis report status, contamination levels and preventive maintenance (PM) route completion values. Following implementation of the storage and handling work, these were joined by inventory volumes and age, usage amounts and housekeeping scores. Additionally, housekeeping scores were distributed separately with specific notes added.



What advice would you share with Uptime readers who are looking to build a Lubrication Program like yours?

Strong leadership skills are needed any time a culture changing initiative is undertaken. In the book, "Good to Great," author Jim Collins says the most effective leaders exhibit high levels of humility and will, whose primary ambitions are for the good of the institution rather than themselves. These qualities are especially important for a site lubrication champion, an essential role for this work if not already in place. The champion must be sure to include all affected parties, provide the necessary training and ensure open communication. This role also will be a resource reference, ensure standardization and eliminate hurdles as they arise.

Lastly, don't hesitate to utilize the outside resources at your disposal, including lubrication engineers, manufacturers, vendors, oil analysis laboratory personnel and training providers. Each possesses a wealth of knowledge to share from differing backgrounds and perspectives.

Patrick Akins, CMRP, has worked in the maintenance and reliability field for more than 25 years. Pat resides near Seattle, WA and holds several vibration analysis and lubrication certifications. He currently focuses on Industrial Maintenance and Safety training; previous roles include Reliability, Systems and Maintenance Management with Fortune 500 companies.

Temporary Mounting of Proximity Probes

Ken Singleton and Barry Cease

Measuring the shaft vibration of machines with fluid film bearings is a well documented best practice in industry. But, what to do when there are no permanently installed proximity probes in the machine exhibiting symptoms of a problem? For many years, practitioners have used dial indicator magnetic bases or brackets bolted to bearing housings to temporarily support proximity probes. Wooden sticks with a V notch were also used to measure shaft vibration. Now, a unique magnetic mounting device has been developed to address this problem of temporary proximity probe mounting.

The eddy-current type non-contact proximity probes are typically installed on bearing housings of most critical turbomachinery equipped with fluid film bearings. Machinery utilizing fluid film bearings includes gearboxes, steam and gas turbines, compressors, expanders, generators, pumps, motors, forced draft (FD) and induced draft (ID) fans, etc. Don Bently of Bently Nevada (now GE Bently) developed the eddy-current non-contact probe system in the 1950s. In 1970, the American Petroleum Institute's (API) Mechanical Equipment Subcommittee adopted the eddy-current proximity probe as the measurement device for determining acceptable shaft vibration during factory acceptance testing. This requirement was added to API 617, the centrifugal compressor standard, which became the forerunner of API 670. As a result, shaft vibration measurement

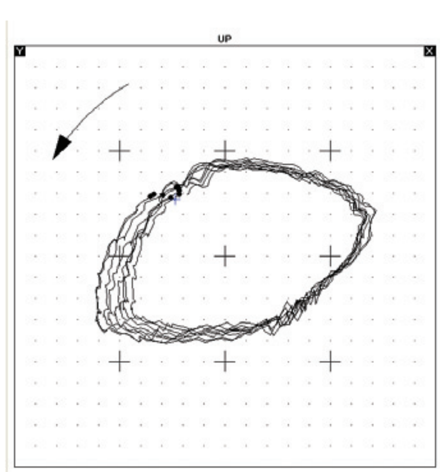


Figure 1: Orbit plot from steam turbine #1 journal
(Data acquired using GE Bently ADRE System©)

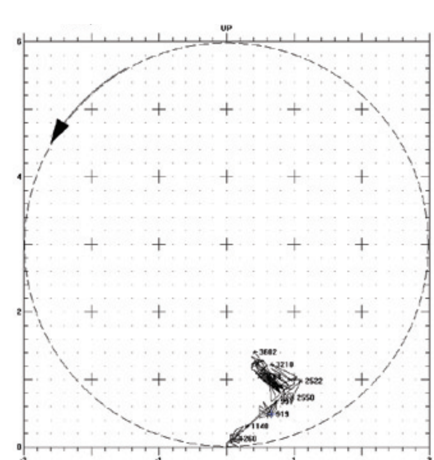


Figure 2: Average shaft centerline plot of steam turbine journal #1 during spin up to speed
(Data acquired using GE Bently ADRE System©)

As useful as the proximity probes are, there remains a large number of older equipment with fluid film bearings that has never been retrofitted with these probes.

with eddy-current proximity probes emerged as the industry standard for turbomachinery acceptance testing and machinery protection.

The damping of fluid film bearings is significantly higher than that of rolling element bearings. In many cases, this high damping causes turbomachinery equipped with fluid film bearings to not transmit shaft vibration to the bearing housings very well. As a result, housing vibration measurements made via accelerometer do not accurately represent true shaft vibration. This is especially true for turbomachinery with relatively light rotors and massive bearing housings and supports. Casing or housing vibration measurements with accelerometers or velocity probes are still recommended to detect problems, such as structural resonance, loose bolts, foundation problems, etc.

Normal measurement involves two radial proximity probes (X & Y) installed 90 degrees apart at each bearing. When the probe signals are plotted against each other, the result is the orbital path of the shaft centerline within the bearing clearance, as shown in Figure 1. The average shaft centerline position within the bearing clearance also can be measured as shown in Figure 2. Adding another probe to measure a once-per-revolution event, such as a keyway, provides valuable phase information. Data plotted in Bode format from the #1 journal of a steam turbine during spin up through a critical speed is shown in Figure 3.

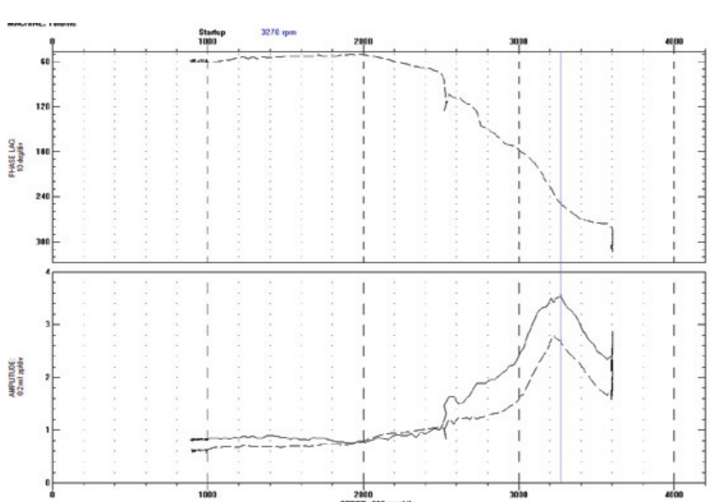


Figure 3: Bode plot of turbine journal #1 during spin up and passage through a critical speed (Data acquired using GE Bently ADRE System©)

The coast-down data is considered more useful for plotting the amplification factor of critical speeds than spin up data since no torque is applied to the rotor. The amplification factor provides a measure of the damping of the rotor bearing system at a critical speed.

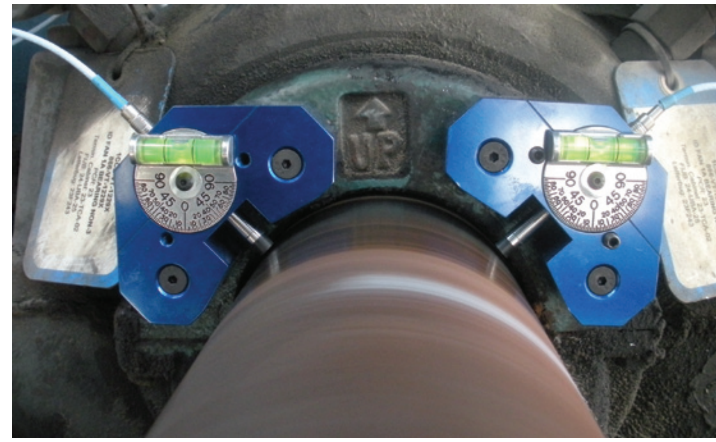


Figure 4: ID fan with the removable proximity probe mounts installed on the bearing housing

The shaft orbit and average shaft centerline position data are very useful to diagnose rotor dynamic problems, such as unbalance, misalignment, rotor rubs and bearing instability problems like oil whirl or oil whip.

As useful as the proximity probes are, there remains a large number of older equipment with fluid film bearings that has never been retrofitted with these probes. Installing permanently mounted proximity probes can be cost prohibitive due to requirements of an extended outage, machining bearing housings, running conduit and signal wire, as well as the cost of purchasing the systems themselves.

Many people (including the authors of this article) have attempted to solve this problem by temporarily attaching indicator brackets to a bearing housing. Magnetic bases, commonly found in machine shops, also have been used to temporarily mount the probes. Results from this type of mounting have been mixed due to occasional movement of the base itself and vibration of the arm holding the probe. Wooden shaft riders also can be used to briefly measure the shaft absolute displacement. The V-shaped stick with an accelerometer or velocity probe stud mounted to the end is held by hand against the rotating shaft. It is possible, although difficult, to hold two sticks at 90 degree angles to measure the shaft orbit. However, the sticks can only remain against the shaft briefly due to the heat of friction.

A recently introduced device addresses the problem of temporarily mounting eddy-current proximity probes. Removable proximity probe mounts (patent applied), as shown in Figure 4, have two powerful flat rare earth magnets that firmly attach the probe holders to the end of a machine's bearing housing. The removable proximity probe mounts in Figure 4 are installed on an ID fan. These mounts provide a means of installing X/Y proximity probes temporarily on important rotating machinery to measure data during startup, shutdown, or load changes. Permanently mounted proximity probes are no doubt preferred, but for those machines where this is not feasible, temporary probe mounts are a low cost, excellent alternative.

A recently introduced device addresses the problem of temporarily mounting eddy-current proximity probes.

A bubble level with a rotating protractor (Figure 5) provides the ability to set the probes at

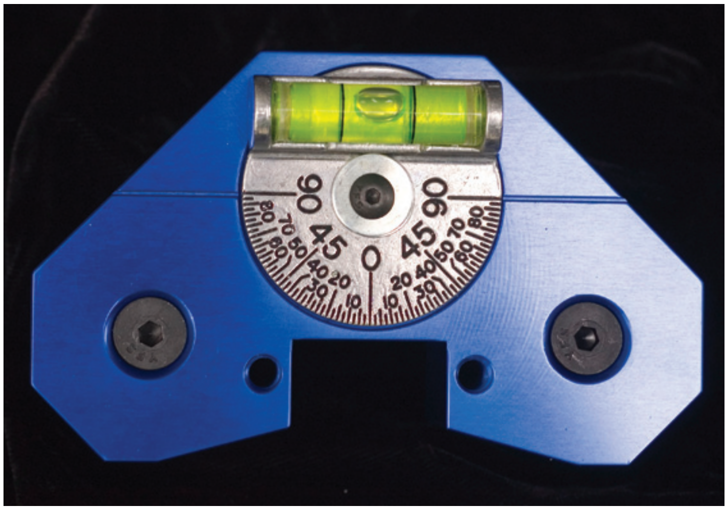


Figure 5: CMS proximity probe mount showing the movable protractor and bubble level

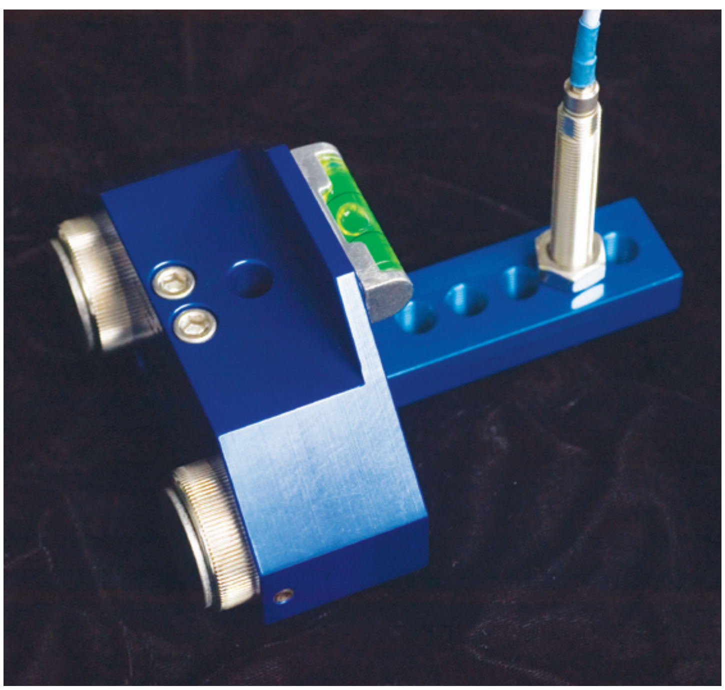


Figure 6: CMS proximity probe mount with extension bracket

exact angles, such as 45 degrees left and 45 degrees right. Extension brackets provide a means of locating the probe at various distances from the end of the bearing housing (Figure 6). This feature is particularly helpful when portions of the shaft are damaged.

Users have been very innovative with removable proximity probe mounts on non-traditional equipment that includes vertical pumps (Figure 7) and a balancing machine (using proximity probes to measure shaft run-out at the probe tracks). Typical equipment applications include FD and ID fans, steam turbines, generators, motors, boiler feedwater pumps and gearboxes.

Notable Features of Removable Proximity Probe Mounts:

- Adjustable bubble level with protractor angle gauge allowing accurate positioning of brackets;
- Two strong, flat permanent magnets hold the mounts firmly to the bearing housing;
- Machined surfaces on exterior of mount to allow ease of mount positioning;
- Two jacking screws provided for ease of mount removal;
- Extension bars provided to allow movement of the probe to a more desirable portion of the shaft;
- Anodized aluminum construction for lightweight, corrosion-resistant operation;
- Mounts fabricated to accommodate either 5 mm or 8 mm standard probe sizes.

Attaching proximity probes to the bearing housing of a machine for which data from the shaft is desired is just part of the setup. The proximity probes require a driver, -24 VDC power and cabling. Such a system can be provided by Custom Machinery Solutions (CMS) and utilizes a Connection Technology Center (CTC) brand NEMA enclosure, proximity probe drivers and a 120VAC/-24VDC power supply.

A typical application is shown by the schematic in Figure 8. Two removable probe mounts (X & Y) are mounted on each bearing of a machine. Extension cables are then connected to the probe cables and the probe drivers. The probe drivers are housed in a NEMA enclosure (yellow). The probe drivers are powered by a -24V DC power supply (grey) connected to 120VAC power.

Figure 7: CMS removable probe holders mounted on vertical pump

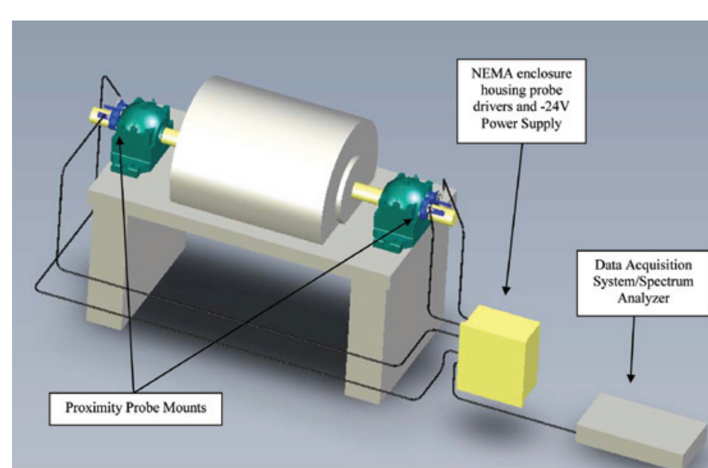


Figure 8: Typical application showing bearings, proximity probes, mounts, cabling, NEMA enclosure for driver & power supply and data acquisition system/spectrum analyzer

The shaft displacement (AC & DC signal) is measured from BNC outputs on the probe drivers. A once per revolution signal is required to measure the phase lag angle. This signal may be generated by either an optical tachometer sensing reflective tape or a proximity probe sensing a keyway.

Typically, a multi-channel data acquisition system is used to record the data. Data acquisition may be for a few minutes, hours, or several days depending on the circumstances.

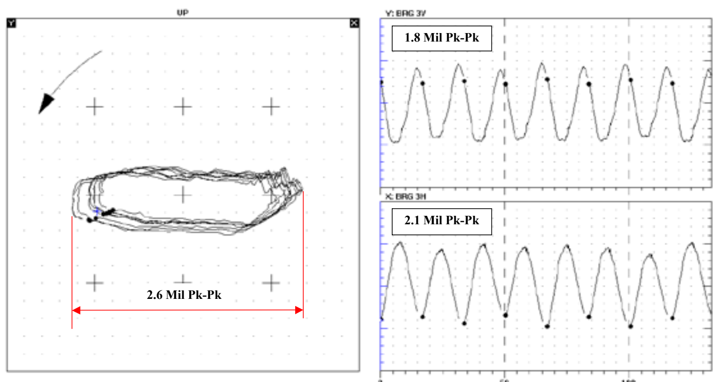


Figure 9: The true maximum shaft displacement is determined by measuring the long axis of the orbit.

A simple, two-channel analyzer capable of generating orbit data also can be used. Data may be acquired from each probe set at each bearing for a given speed/load condition. Comparisons between proximity probe data and data from accelerometers at identical orientations also can be helpful. Coast-down data from two x-probes or two y-probes also would be possible using only a two-channel analyzer. Gathering true orbit data from each bearing allows easy measurement of the true maximum shaft displacement (Smax) preferred by standards, such as ISO 7919, for accurate measurement of machine condition. If the long axis of the orbit is not aligned with one of the probes, as shown in Figure 9, the maximum amplitude is greater than indicated by either the X or Y probe.

There are many fluid film bearing machines in service that were never equipped with permanently mounted proximity probes. Now there is a device available that will permit temporary attachment of proximity probes to measure the shaft vibration on many of these machines.

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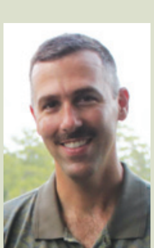

Barry Cease is the President of Cease Industrial Consulting, LLC, Charleston, SC. Mr. Cease earned a B.S. in Mechanical Engineering from N.C. State in 1990, a M.S. in Mechanical Engineering from Georgia Tech in 1992. He spent 14 years as an engineer in the Paper & Pulp Industry where his work focused on predictive maintenance & reliability. In 2006, he started his own company "Cease Industrial Consulting" which provides predictive maintenance & reliability services to customers. www.custommachinerysolutions.com

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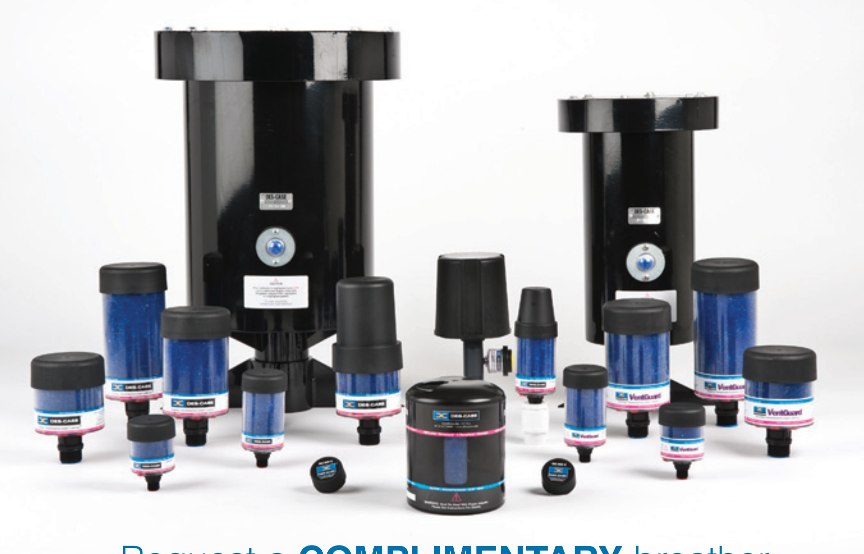

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