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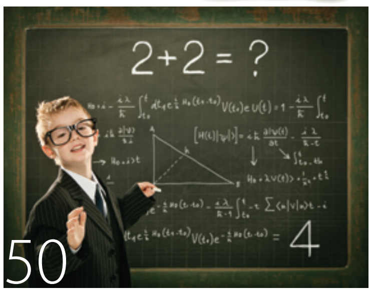

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Editorial

Us versus Them

If you find maintenance reliability continually at odds with operations or purchasing, or some other functional department in your organization, you should work hard to find out where the friction is and how it is misaligned with the aim of your organization.

Internal competition can suboptimize company performance. Think about it. Who cares if maintenance has the best performance metrics in the world if operations is not meeting its goals, and the company is not profitable or loses a large customer?

We see this today as Democrats versus Republicans, Northerner versus Southerner, USA versus China, Wall Street versus Main Street, Packers versus Steelers, etc. . . . The tendency in modern Western society is to draw lines, create silos, pick a side, and identify with the team we are on. While there are certainly big benefits to being on a team and competing, when it erodes or does not serve the aim of the larger organization, serious questions should be raised. Prior to defining ourselves so rigidly by the "teams" we are on, it would be useful to reflect on the more universal teams we are on.

For instance, we are all humans, and we all belong to the "human race team." We all live on this ball floating in space and share its air, water, and resources, so we are also on the "residents of earth team." When someone damages the water or air anywhere, it damages it for all of us.

From there, we can find it useful to define ourselves further—but this is where "us versus them" starts.

In organizations, we need to be fully aware of the ***aim*** that management has set and design our activities to support that aim. For example, the United States of America's aim is established in the Constitution, and all leaders should be subservient to the ideals expressed in that document. It is when leaders put themselves and their interests ahead of the aim that the trouble starts. To have winners means there has to be losers.

In companies, having operations win while maintenance reliability loses is not a formula for success. Every system within the organization must be aligned with the aim of the organization, and when it is not, you should be doing everything you can to ensure the area you can control is aligned with the organization's aim.

In this issue of Uptime, I am totally pumped up because all authors, editors, layout artists, managers, supervisors, webmasters, and administrative support team members created another collaborative work that is as close to the pure aim of Uptime as we have ever gotten. The aim of Uptime is to provide information—in an effective format—that assists maintenance reliability professionals in doing their jobs safer, easier, and better.

Our team extends this to you, our reader. You will make the final determination as to how well we met the aim of Uptime Magazine.

I hope we are all aligned, and I look forward to hearing from you as we continue to make improvements in the magazine. So shout out to tohanlon@reliabilityweb.com and tell us what we can do better, or what you think we should do next.

Dig in and read EVERY page of this issue. It is filled with the greatest information available.

Thanks for reading.

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Maintenance Tips

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Failure modes

There are always discussions surrounding failure modes, functional location failures, and run-to-fail strategies, but it really comes down to what strategies your facility can survive—yes, survive. Simply put, a failure is when an asset can no longer perform its intended function. This leaves the interpretation to the individual facility. Definitions of failures are as vital as criticality. When you do the criticality analysis, failure modes and the effects of those failures are integral to the process. Make sure that your team understands the "intended" function of an asset so a proper failure mode strategy can be put in place. Some assets can run to full failure while others need attention if performance away from optimum is degraded.

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The success of your RCM effort is totally dependent on task implementation. Experts in Reliability-Centered Maintenance around the globe all agree that in order for your RCM effort to be successful, the tasks from each RCM analysis must be implemented. As soon as you complete your RCM analysis, you should immediately develop a plan for implementation that identifies a specific individual assigned to each task, and a due date for when the task should be completed. If you want your tasks to be implemented, remember—never assign them to a job title such as planner or supervisor.

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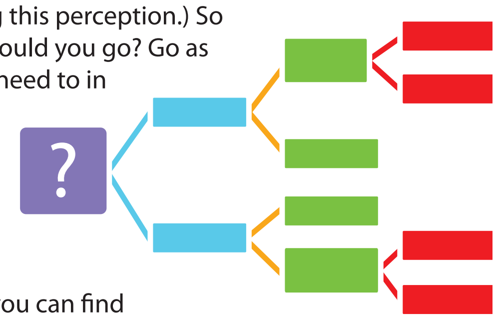
RCA – Causal Analysis

It seems obvious that causal analysis is an important part of Root Cause Analysis, but it is an area that is often performed badly. A common mistake is that people stop asking why too soon. People often assume that if they ask why too much, they'll get too much detail. (The 5 Whys do some harm in promoting this perception.) So how far should you go? Go as far as you need to in order to have a good understanding of the causes. If you can find a solution that prevents recurrence of the problem, and meets your goals within this causal set, then you have gone far enough. If you have not found a good solution, you need to go back to the cause chart and challenge the causes!



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Uptime Magazine PdM Program of the Year Award

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Dr. Peter Martin, Keynote - Real Time Information to Support Maintenance Decisions

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US Sugar CEO Robert Buker, Jr., Keynote Address

Dance Party at Solutions 2.0

Florida Sunset Meet and Greet Reception

Conference Organizer Terrence O'Hanlon sneaking a bite to eat

Karaoke at Solutions 2.0

Casino Night at Solutions 2.0

Your program for promoting networking was quite successful, and I did enjoy meeting several new people as well as a few old friends.

Anthony M. Smith, Author, *RCM: Gateway to World Class Maintenance*

Congratulations on the event. It was really a powerful learning experience for me.

Marta Martín Matos
Manufacturing Engineer
Valpak

My involvement in the event has made me a stronger person, I have grown from the experience and I have learned a lot. I have taken with me some great memories.

Joe van Gils
Mechanical Assets Specialist
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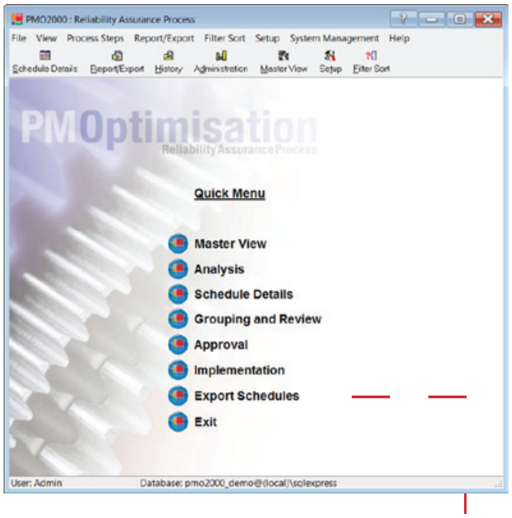

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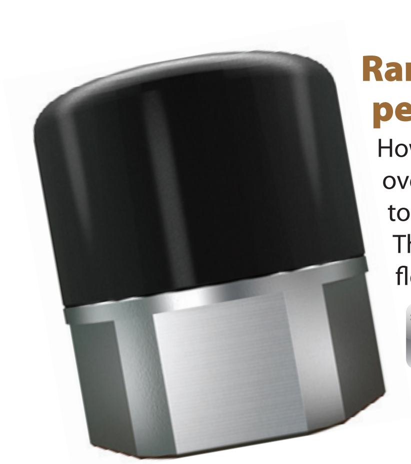

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The R^5 Model works for any type of improvement initiative and is compatible with multiple tool kits like Root Cause Analysis, LEAN, and Theory of Constraints. The R^5 Model becomes a standardized project management system that encompasses several characteristics: It is executive-sponsor supported, data driven, business-case governed, and includes gated processes.

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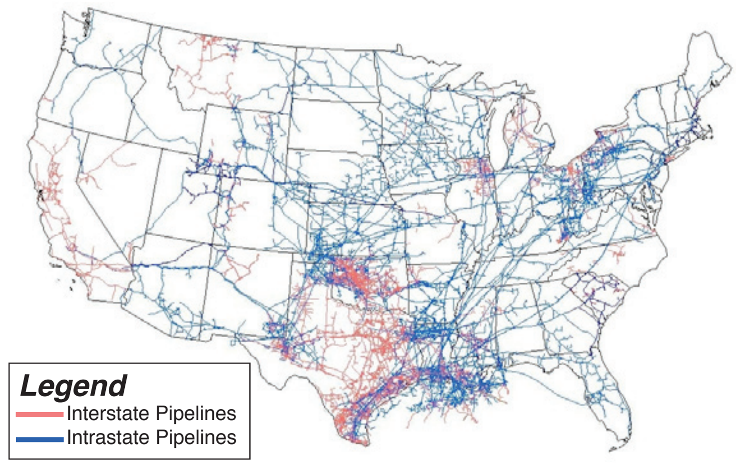
Cooking Reliability with Gas

System Reliability at NiSource Gas Transmission & Storage: Integrating Engineering Strategies and Defect Elimination to Achieve Organizational Reliability

Matt Parks, John Cox, and Bill Butterworth
NiSource Gas Transmission & Storage

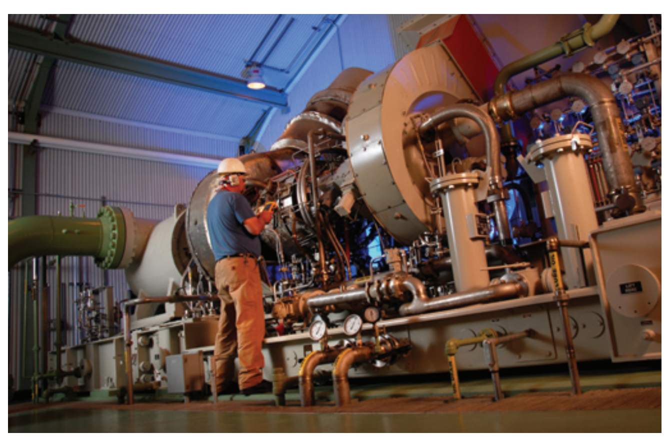
Winston P. Ledet
The Manufacturing Game



Source: Energy Information Administration, Office of Oil & Gas, Natural Gas Division, Gas Transportation Information System

Right:
Pipeline connections at an NiSource compressor facility.

It is estimated that natural gas transmission companies in the U.S. own and operate over 300,000 miles of interstate and intrastate natural gas pipelines and over one thousand compressor stations integrated with numerous strategic underground storage systems. Natural gas is a major fuel for multiple end uses: electricity generation, heating, industry, and other increasingly innovative options. The unconventional gas resource of shale formations in the U.S. alone is massive with current mean projections of recoverable gas estimated to be approximately 650 Tcf (trillion cubic feet).



Operations personnel monitoring turbine engine performance.

With natural gas deposits now being extracted from previously unattainable shale formations, natural gas transmission networks throughout North America are required to be more dynamic in terms of transportation receipt/delivery points than anytime in the past 50 years. New production sources must access interstate transmission and storage lines to deliver natural gas to market. System modifications and constraints require that a regulated service business built on excess capacity must now demonstrate a high degree of system reliability.

NiSource Gas Transmission & Storage (NGT&S) has commissioned an initiative to review the current state of their natural gas transmission system, identify the future desired state, quantify the tangible gap between the two, and execute in the pursuit of best-in-class system reliability. It is important to note that the representative information contained in this article is applicable to "non-pipe" assets, i.e. compression, regulation, and metering within the transmission network, and not the underground pipeline. The NGT&S Integrity Management department governs such activity and is in quick pursuit of world-class status as a targeted effort.

As with any competitive industry, natural gas transmission and storage service providers must continue to evolve in terms of balancing market demands with the economic challenges of reliable service. Historical dynamic customer requirements based on ambient temperature fluctuations across North America drive the daily service requirements. This fact alone creates a difficult environment for establishing a holistic system reliability plan with both effective and efficient execution.

For the first time in the past 50 years, the production sources of natural gas requiring transmission to market are growing on an expanding large scale. Many areas of past non-strategic importance are now becoming critical receipt points. This source expansion and diversity is causing flow direction of many pipeline systems to either reverse or become subject to bidirectional flow based on daily market demands.

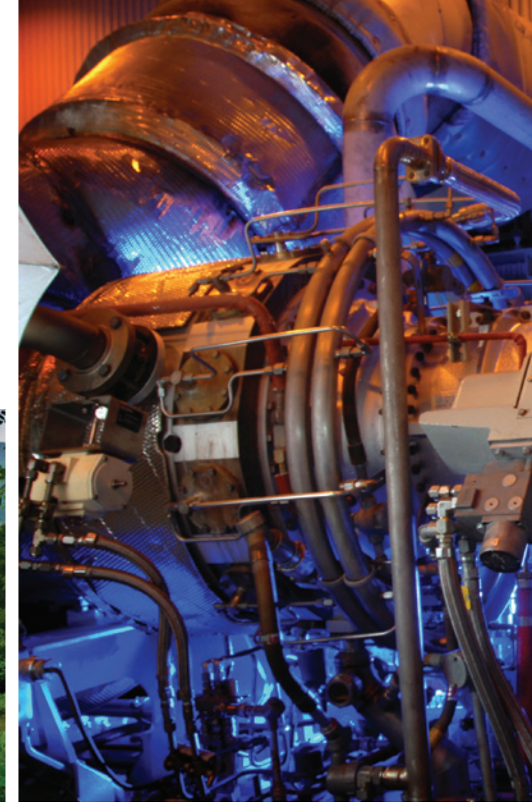
Production of natural gas trapped in shale formations is now economically attractive to gather by engineered fracturing, directional drilling, and other moderately recent technology advancements. Historically, the dynamic nature of the industry was managed by latent compression horsepower and pipeline operating capacity. That is to say that system design included an "overriding" capacity to handle the market fluctuations based on somewhat static producer locations. This capacity was not contractually required and in turn, allowed for mitigation of most system delivery issues as unplanned events occurred—or unreliability.

With new production sources and directional flow modifications affecting the marketplace, capacity constraints are now forcing transmission providers to achieve measured system reliability with tactical actions where and when maximum operational capacity is required.

With foundations in classical reliability program techniques, NGT&S has adopted two simultaneous and complimentary strategies to deliver mass flow rates to market under contract specifications and flexible options. The first initiative focuses on engage-

ment of the enterprise in an autonomous manner, and the second initiative relies on classical engineered solutions for effective risk management.

Clockwise from top right:
Maintenance personnel removing a panel for an internal inspection.
Typical NiSource prepackaged reciprocating compressor units.
Operations personnel collecting compressor data.
Typical NGT&S pipeline right-of-way.



Strategy 1:
Defect Elimination by Empowered Workers

In an effort to achieve long-term reliability growth, the *first foundational strategy* of defect elimination is adopted. Nothing is more critical to success in any endeavor than the tasks of engaging and empowering the stakeholders that are most affected by the daily processes and procedures to ensure positive results. Establishing a foundation and protocol to address "defects" in the system at all levels is fundamental to achieving a reliability culture in any service business. By definition, as related to the NGT&S process, a defect is a condition that inhibits or impedes the designed operation of a system, asset, or component in a manner that an individual or small group (fewer than five individuals) can work independently to rectify with in-house, local activity and minimal outside resources.

The intent of such activity is to empower employee stakeholders in an autonomous manner with the least amount of restrictions possible to maintain the physical assets in a "like new" manner. Considerations for regulation and safety oversight are paramount. Engaging outside services to educate the enterprise on defect elimination through game-type instruction has proven to be effective as a culture modification catalyst. Oftentimes, especially in large complex organizations, management truly is the obstacle to tangible improvement.

Defect Elimination Process/NGT&S Protocol:

A. Hold a workshop to establish foundation principles of defect elimination benefits through a common language and vocabulary via an interactive game environment.

B. Form defect elimination teams to identify real defects and potential solutions and resources.

C. Empower teams to execute projects.

D. Report out of project for tracking and compliance with mini mal constraints on all involved parties.

E. Improve and repeat process.

As of November 2010, NGT&S has conducted simulation workshops to engage over 150 employees representing 30 locations. sdfjsdlAdditional workshops have been scheduled to continue the defect elimination program throughout the enterprise.

The following are just a few examples of teams eliminating defects within NGT&S:

- In Mississippi, a section of rigid conduit was changed to eliminate shorted wiring that was caused by vibration.
- Adding capacity to a compressed air system in Pennsylvania improved system reliability and eliminated call-outs to the station.
- A defect elimination project in Virginia eliminated a path for coolant to migrate to other units that were not running, and another team improved the reliability of a station valve operation by relocating magnetic switches.

Station operator Johnny Gochenour said: ". . . no one in management knows what needs to be addressed at the stations like we do. . . . It (the defect elimination program) has given us the opportunity to correct the small problems. It is one of the best things we have ever done."

As defects are eliminated prior to evolving into sustained functional degradation or catastrophic failure, system reliability growth is experienced over time from these efforts alone. The fewer negative issues there are to contend with in the future, the less planned and unplanned work there is to address.

Strategy 2: Structured Reliability Growth

The second strategy adopted is strategic reliability growth through daily procedures and protocols. Fitting to the nature of natural gas

transmission networks, four collaborative focus areas are identified and developed.

First:	*Critical Assessment and System Strategy (CASS)*
Second:	*Core Reliability Protocol*
Third:	*Real-Time Data Systems (RTDS)*
Fourth:	*Modernization and Automation*

First Focus Area: *Critical Assessment and System Strategy (CASS)*

What does NGT&S want the asset to do? With current contractual market demand and future corporate marketing strategy considerations being complex, it is critical that a single source (group or department) govern the communication of the subsystems that are required to be available to Gas Control (the central monitoring and control office that ensures customer demands are met) with reasonable resolution. In simple terms, determine when a specific compression unit is required to be available to Gas Control, and define when it is needed based on the constraints—current and/or future—for a specific pipeline segment. A subsystem or segment with redundant capacity will not be considered as critical because a negative event will have little or no impact on the systems service capability during a particular season, month, or other defined time segment.

A major developmental milestone for the system reliability plan is the acknowledgment that the complexity of our reticulated transmission system configuration relative to a particular day's market demand allows for a seemingly infinite number of operational strategies for any given day. However, we know that if defined asset functions are readily available to Gas Control when assigned to be available, we will deliver on all firm customer requirements without exception.

Second Focus Area: *Core Reliability Protocol*

Foundational to these activities are the processes and procedures that govern the Computerized Maintenance Management System (CMMS) including all preventive and predictive activity. Planned and unplanned work types and guidelines for assignment and tracking are to be documented, communicated, and offered in training sessions to system users.

No activity is more essential to system reliability than preventing asset decline and maintaining efficient performance of critical assets. By association, detecting functional degradation in a structured manner with sufficient lead time to mitigate negative impact to the overall system is no less important. By definition at NGT&S, *functional degradation* is the state of a system, asset, or component that is degraded from "like new" status in a manner that will require significant resources, both collaborative and/or financial to return to optimal function or mitigate the source of failure. Robust process education and compliance is not only regulatory in many areas but necessary to operate a system with optimum economic and safety considerations.

Third Focus Area: *Real-Time Data Systems (RTDS)*

From a business management as well as regulatory mandate, reliability of pipeline distribution and receipt points in real time are critical. However, the nature of inclusion of real-time systems as related to system reliability is rooted in an alternate focus. Real-time condition monitoring protocols for both functional degradation detection as well as execution of performance analytics serves the base requirements. Protocols and procedures for identifying critical data elements, standard Graphical User Interfaces (GUIs), data archiving and transmission to central servers, etc., must be defined and documented. Prognostics program evolution is reliant on the compliance of these defined systems as is the real-time reporting of key performance indicators (KPIs) and key performance parameters (KPPs) relative to multiple stakeholders in proper resolution. The complexity of a seasoned control system is daunting in terms of obsolescence, integration platforms, and basic communication. If an RCM strategy for a critical asset is to monitor functional degradation and performance parameter creep, it is imperative that the data system work properly to manage the risk of high value asset loss and overall system impact.

Fourth Focus Area: *Modernization and Automation*

These two actions are addressed in the final subgroup in spirit to support the other three charters. While RTDS is only focused on data, automation encompasses the control of such assets. It is easy to connect the need for automation upgrades and useful life support from OEMs. How automation serves IT-based data systems is the primary consideration from this scope. As for modernization, capital improvement—ROI assessments in coordination with CASS—is the primary collaborative point. However, options for short- and long-term asset upgrades and improvements related to overall system reliability are considered the central focus. Documented processes and procedures where applicable yield the most consistent and unbiased allocation of human and financial resources.

Measures of Effective and Efficient Execution

Up to this point, the focus has been primarily on the effective structure of a system reliability plan for natural gas transmission networks. For balance and optimal achievement in any form, an assurance of efficient actions and overall program execution is required. Excessive maintenance can have extreme negative effects on the economic health of any enterprise. With a large repertoire of performance indicators to choose from, many will be adopted with proper resolution at key points within the overall system. Consideration of both leading and lagging KPIs where applicable in a real-time environment is the key to leveraging resources with value.

Conclusion

By combining the power of these two strategic initiatives, NGT&S intends to not only remain a top natural gas transmission system in the U.S., but also gain important ground in continuously improving reliability, minimizing operations and maintenance costs, and mitigating issues with service. The overall goal is that of increasing the company's attractiveness in terms of gaining new contracts for production receipts and expanding the delivery markets in the progressively competitive gas transmission arena.

For the sake of evaluation of these strategies, dominant measures of the localized outcomes of the accomplishments will be in system availability. The major system's inherent availability will be economically weighed against the same system's achieved availability. More definitive key performance indicators will include comparisons and trends of quantified work orders and maintenance hours required to maintain the desired levels of achieved availability to ensure that stakeholder expectations are not only met, but continually exceeded.

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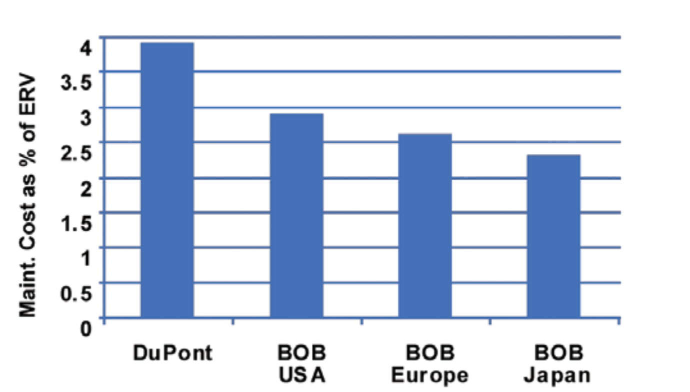
Eliminating

Winston Ledet

The basis for our approach originated in DuPont in the late 1980s. Faced with a decentralization of their maintenance department, DuPont was interested in how to sustain their functional excellence in maintenance. DuPont, normally an inwardly focused company, did something fairly unusual at the time. They engaged A.T. Kearney to benchmark their performance against the "best-of-the-best" in the U.S., Europe, and Asia (Figure 1).

DuPont found that they didn't need to worry about losing functional excellence because they did not have it to begin with. The most dramatic difference in performance was with the Japanese who had much lower costs with greater reliability and lower stores inventory.

Figure 1: Best-of-the-Best (BOB) Maintenance Perfromance (1986)

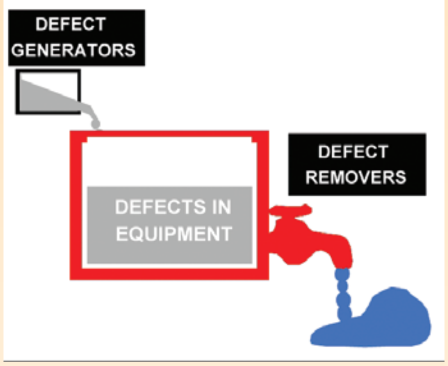


Up to this point, the focus of the benchmarks had largely been on the maintenance function and maintenance cost. Statistical analysis of the benchmarking data seemed to indicate that just a few variables in the benchmarks accounted for almost all of the variation in performance, but all of these variables were fundamentally cost variables. The implication of this analysis was: Focus on cost reductions to achieve "best-of-the-best" performance. However, the benchmarking team who had participated in the site visits during the benchmarking knew that the best performers did not focus on cost much at all. They had a suspicion that these improved cost factors were the *result* of good maintenance and not the *cause,* so they began to dig more deeply into the structure of reliability.

DuPont decided to use System Dynamics Modeling to better understand the structure of reliability. System Dynamics is a discipline that came out of MIT in the 1960s and was created by Jay Forrester in 1961. It has gained popularity in the last twenty years with the publication of *The Fifth Discipline* by Peter Senge (1990), and the introduction of easier-to-use computer modeling tools. System Dynamics Modeling focuses on discovering and articulating the underlying structure of a system, and then looks for key leverage points to change the system. Instead of simply showing a snapshot of what performance might look like at the end of the journey, like a benchmark does, it shows the journey itself.

What DuPont discovered through this effort was that maintenance and reliability could best be described as a process of *defect* management. A simplified view of this "mental model" is presented in Figure 2.

Figure 2: Managing the Flow of Defects

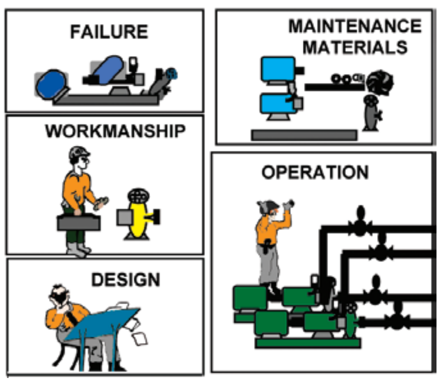


We define a defect as "any deviation from perfection" to avoid long arguments about whether a scratch 1" long or 2" long is a defect. By this definition, all equipment has defects; it is just a matter of degree. Defects can come from several sources, discussed in detail later, and the greater the level of defects, the more reliability problems the site will have. Defects are removed through maintenance work either reactively once the equipment fails, or proactively through Preventive or Predictive Maintenance. Through this effort it became apparent that the "best-of-the-best" in the U.S. and Europe achieved their results primarily by removing defects more efficiently through better planning, scheduling, skills in their tradesmen, and predictive technologies. DuPont discovered that it was critical that these things be done in a coordinated manner and not just one program at a time. What was interesting was that the "best-of-the-best" in Japan did not simply have a souped-up version of these higher efficiency techniques. They had a fundamentally different approach; they removed the defects early in their life or avoided putting defects in the equipment in the first place which eliminated the work that came with these defects.

The Sources of Defects

To eliminate defects it is important to understand where they come from. Figure 3 shows the five major sources of defects.

Figure 3: The Sources of Defects



Defects from quality of materials. DuPont found that one in three spare parts had a defect of some sort. These defects can be manufacturing defects that the vendor put in, but they can also be defects in the way parts are stored, handled and sourced. (Example: corrosion on a part from storing it outside.)

Defects from workmanship. These defects come from failing to do a proper repair job. At times these defects come from skill gaps in the mechanics, but just as importantly, they can come from failure to apply the skills that are known. In a typical reactive plant there are usually a host of policies, systems, and cultures that keep mechanics from doing the best job they know how to do. What counts in workmanship is the quality of the work you actually do, not the quality of the work you know how to do. (Example: failing to align a pump before bringing it back on line.)

Defects from failure events. When a system of equipment fails, extra energy is typically directed to another part of the system. This extra energy will often add new defects that can be the source of future failures. (Example: a bearing seizes, causing a slight bow in the shaft.)

Defects from design. To whatever degree the design of equipment does not fit the *current* needs of the business, there will be defects from design. These defects can come from poor initial design, but usually are the result of changes in the business that do not get reflected in the operations. As the business and operation change over time, the requirements of the equipment will change as well. If the design is not updated and modified to fit the new conditions, defects will be added to the system. (Example: the flow through a certain pump is cut way back causing it to run back on the curve and tear itself up.)

Defects from operations. By our definition of a defect, any equipment that is operated will accumulate some defects from normal wear. However, as any reader with a teenage driver can attest, the way you operate something has a huge impact on the level of defects that are introduced. Many of the defects that ultimately lead to failure are either introduced through operations or are detectable by operations long before they will cause a failure. (Example: cavitating a pump, ignoring excessive vibration.)

A traditional maintenance-focused, technical approach to reliability will focus on the first three sources through preventive maintenance, predictive technologies, vendor audits, parts inspections, and skills training, but will typically ignore the last two sources. When you focus on limiting all of the sources of defects as well as eliminating the defects currently in your system, the performance improvement can be dramatic. More recently, the Lima Refinery taught us that the best philosophy was to incorporate defect elimination into the regular work of maintenance, operations, design, and purchasing. They named this philosophy "Don't Just Fix It, Improve It," which is the name of our book on defect elimination.

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A New Opportunity for the Maintenance Reliability Community

John S. Mitchell

A new term has risen above our horizon. It is being embraced by companies committed to being the best and has great interest and cachet at the highest executive levels. Further, it states a clear objective that must be achieved to remain successful in today's fiercely competitive industry. The question is whether we, the maintenance reliability community, will embrace the term, recognize its ability to mandate broader activities that are absolutely essential to achieve and sustain real success, and utilize the principles to gain value and results that really matter.

Hopefully we'll do better than we did over the past ten or twelve years when a similar term, Asset Management, presented a similar opportunity. Instead of embracing the initial concept of Asset Management to expand horizons, emphasize value and effectiveness, engage the entire organization, and gain greater acceptance for our contribution to business success, it was

continually reduced and diminished. Today, mention Asset Management to an executive and it is immediately interpreted as a fancy euphemism for maintenance—a shadow of its original intent.

What about maintenance? In all but the very best companies maintenance is considered a non-core competency, a necessary evil, an activity to be avoided, and a cost to be minimized; certainly not a value-producing business activity. Lest anyone think that this is solely the view of an out-of-touch author, many have voiced a similar frustration. A recently reviewed proposal from Italy expressed identical sentiments.

Probably the most poignant illustration was at last year's Solutions 2.0 conference. Shortly before being honored for their achievement, winners of one of the Best Program awards were notified that their entire program had been eliminated and all laid off as a "cost-saving" measure. Unfortunately this is not an isolated incident. Success endangers the most successful reliability programs. Many have heard some version of: "We don't have breakdowns or need greater availability; reduce costs by eliminating all those superfluous reliability programs and either get rid of the people or put them back to real work fixing things." Of course we all know how this turns out. Mayhem returns, failures reappear, availability slips, costs rise and the programs and people that were terminated a few short years in the past must be reconstituted at great cost and lost time.

We do have a second chance; but only if we broaden our horizons, think well beyond increasing the efficiency of maintenance activities, and adopt a business focus. How do our activities contribute to business value and success? What is the sightline between maintenance reliability and business value? What is the definition of value from the executive suite? While maintenance excellence, excellence in Planning and Scheduling, precision work, and effective stores management are all part of the tapestry, they do not link to a financial executive concerned with profitability and shareholder value. Just as you can't visualize the picture in a complex jigsaw puzzle from a few pieces, a financial executive holding our future in his/her hands can't see our contribution to corporate value from performance in a few specialized practices. In our own world, what good is excellence in Planning and Scheduling if there are excessive failures? Should scarce resources be devoted to developing and executing robust maintenance practices to counter excessive failures? How do you define excessive failures? Is the definition shared throughout the organization?

You can't get maximum production/operational effectiveness without optimal contributions from asset and process efficiency! The maintenance reliability community hasn't communicated that message very effectively. We must improve!

Fortunately the maintenance reliability community seems to have a second chance—if we will only grasp and run with the golden opportunity being offered. The opportunity is a term and program gaining attention at the highest levels of the very best companies and those striving to be the very best: ***Operational Excellence.*** What is Operational Excellence? One leading company defines it this way:

"Operational Excellence is the systematic management of safety, health, environment, reliability and efficiency to achieve world class performance." (Chevron Operational Excellence Management System)

Under the heading of Operational Excellence, another greatly admired global company states:

"Ensuring the safety and reliability of our operations is fundamental to our business success and a critical challenge that ExxonMobil takes on every day." (ExxonMobil 2008 Annual Report)

Operational Excellence is the systematic management of safety, health, environment, reliability and efficiency to achieve world class performance.

In an Operational Excellence workshop conducted during Solutions 2.0 in 2009, approximately two-thirds of the participants' companies had or were about to implement Operational Excellence initiatives. A larger percentage of participants in the Operational Excellence workshop conducted during Solutions 2.0 in 2010 had Operational Excellence initiatives in effect.

How can a term improve visibility and support for the maintenance reliability community? Here's how:

First and foremost, Operational Excellence is a term of interest at the highest corporate levels. It clearly states an imperative objective to assure success in a competitive environment. Corporate executives are seeking definitions and implementing methodology to gain the objective. Principles, definitions, and implementation are reasonably well established and presented at workshops such as those conducted at Solutions. Of course doing so is the really hard part!

Second, Operational Excellence elevates thinking within the maintenance reliability community beyond specialized activities to its essential role and contribution to overall business success. It demands transcending many barriers such as divisions between operations, maintenance and engineering, lack of sponsorship by executive management, goals and metrics based on activity rather than results that contribute value, short-term thinking, and too much reliance on technology and computer systems. The list goes on. We really need to focus energy and efforts on the sightline from maintenance reliability to business success, how we create value, and our specific contribution to business success.

Third, the definition of Operations Excellence must include the concept of maintaining equipment assets in a "satisfactory manner." This is the one part of the definition that can cause industrial teams to miss a huge opportunity. It is important to drill down on what is meant by "satisfactory manner" in order to gain the full value that can be delivered through the maintenance reliability organization. For some equipment, just keeping the equipment operating produces acceptable production results, although possibly not optimal value. For other equipment, just keeping it operating is not good enough. For example, in process plants, heat exchangers are common equipment for heating and cooling liquids and gases. They are also typically unspared, which means that any deviation from "satisfactory" affects the entire process. In operation, a heat exchanger is far more efficient and creates maximum value if it is well maintained to provide optimal heat transfer. Just keeping it operating may not produce the desired production results or necessary value. In this example, and others as well, reliability and maintained state of equipment are important aspects for the value gain of the production process. Determining what is satisfactory with respect to equipment maintenance must be determined by evaluating the maintained state of the equipment relative to the financial gain it provides across its maintenance and operating spectrum. This can be done by simply modeling the financial functions against the operating and maintained state functions and evaluating the optimal operations, maintenance, and repair/replace strategy to drive the greatest financial returns.

Fourth, nearly every high-level definition of Operational Excellence includes a commitment to reliability that is broadened to include organization, data and information, processes and procedures. All are absolutely necessary to assure success.

Let's take a more detailed look at some requirements:

Corporate executives are generally enthusiastic about the term Operational Excellence and its promise. They are looking for implementing methodology. Most definitions, including the two quoted, stress reliability without a real definition. Let's begin with an accepted definition of reliability:

"Consistent, predictable results; the probability that a system, equipment, or product will perform its required functions in a safe, satisfactory manner for a given period of time when used under specified operating conditions." (Physical Asset Management Handbook)

Leading professionals within the maintenance reliability community understand the preceding definition as well as the elements needed to achieve the objectives. It certainly requires far more than good maintenance. To name four: safe, reliable operating procedures rigorously followed; operators and maintenance people constantly on the lookout for anomalies; documentation accurately defining operating requirements, and; processes to monitor and assess current performance. With that perspective, who is better positioned than maintenance reliability in an operating organization to define requirements for Operating Excellence?

As outlined previously, success in manufacturing—Operational Excellence requires two vital ingredients. The first is process efficiency. The ability to convert raw materials into finished goods with maximum efficiency and minimum waste is a given that has been accepted for decades. Total Quality Manufacturing, LEAN, and the huge resources expended to increase production process efficiency testify to the importance of this area at the highest levels of executive management.

Second is the effective availability to meet demand. Methodology for process efficiency often makes a very flawed assumption—that the means of production is available to meet demand, or only experiences average unavailability over a given period. Average availability isn't a very good descriptor of performance if an entire year's unavailability is concentrated in one event!

It should go without saying that if the means of production isn't available to meet demand, all the production efficiency in the world won't produce essential value and business success. Thus, production process efficiency and asset effectiveness must be viewed as two perpendicular vectors with production effectiveness as the resultant. You can't get maximum production/operational effectiveness without optimal contributions from asset and process efficiency! The maintenance reliability community hasn't communicated that message very effectively. We must improve!

A great opportunity is presenting itself. Publically Available Specification 55 (PAS 55) initially published by the British Standards Institute in 2003, is being converted to an ISO Standard by an international working group. At this point, visionary professionals need to become involved to expand and direct the ISO implementation of PAS 55 from primarily maintenance program administration into a comprehensive documenting framework for Operational Excellence listing all elements necessary for success. Expanding PAS 55 into an ISO foundation for Operational Excellence will significantly accelerate the drive toward Operational Excellence, the effectiveness of the vital program itself, and will greatly add to acceptance and credibility from the highest levels of executive management.

Sooner or later the maintenance reliability community must face up to the fact that at the upper levels of a corporation, value is financial. Maintenance reliability professionals must be able to monetize contribution or be viewed as a non-value-add cost. Operational Excellence will produce optimal maintenance; optimal maintenance may not produce operational excellence or the value needed to assure corporate success. The adoption of Operational Excellence as a corporate credo provides an opportunity, perhaps the last, for the maintenance reliability community to define the process and demonstrate conclusively the necessity for, and business value created by what might be called Asset Operational Excellence.

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Don't Underestimate PQ's Impact on Reliability and Process Uptime

Ross Ignall

Industrial facilities are finding new respect for power quality issues as a result of proliferating non-linear loads and other factors. As a result, sales are up for power quality monitoring and analysis instruments for identifying and characterizing PQ problems as a first step to applying the fix.

The increased demand for productivity improvements in the global economy has clearly resulted in an escalating need for the reliable operation of electronic and electrical equipment. Unfortunately, the grid's aging and often overloaded electrical infrastructure, along with that of many facilities, makes operations more vulnerable than ever to power system disturbances.

At the same time, there is also a widening knowledge gap. Many of those in the electric industry power quality groups, who have until now been responsible for understanding the sources of problems and providing solutions, have either retired or been reassigned to other tasks. Thus, there is an increased need for plant electricians, electrical contractors, facility managers, and others who may not have an electrical engineering background to prevent and/or solve PQ-related problems.

Solutions for doing so abound, but first it is perhaps instructive to see how some of these power quality issues manifest themselves in the real world. To that end, the following mini case studies illustrate how power quality issues can impact plant operations, and how everyday solutions can be applied to fix them.

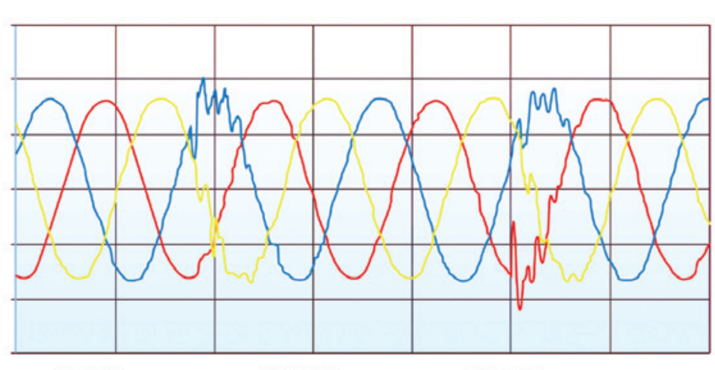


Figure 1. Screen capture from a power quality analyzer reveals that the culprit behind the ASD shutdown was an over-current trip caused by a secondary PQ event.

Over-current Trip Shuts Down Manufacturing Process

Located in an industrial park, a medium-sized manufacturing facility experienced the sudden shutdown of several adjustable speed drives (ASDs), an unanticipated event that wreaked havoc on key process equipment. At approximately 6:00 each morning, the utility-owned power factor capacitor kicked on to compensate for the inductive loads prevalent in many of the park's manufacturing facilities. The ASDs were conditioned to anticipate this scheduled power quality event and typically rode through the problem. So when one of the ASDs closed down and interrupted the continuous-stream manufacturing process, the facility manager needed to instantly find out why, correct the problem and prevent it from happening again.

As Figure 1 shows, a second, unanticipated capacitor-switching event occurred shortly after the first. This event was categorized by the facility's permanently installed power quality monitoring instrumentation which enabled the facility manager to pinpoint the exact source of the problem. Further analysis revealed that the ASD shutdown was the result of an over-current trip that was quickly remedied, thus preventing several hours of downtime, calculated at approximately $10,000 per hour.

Harmonics Generated by the Utility Transformer

Despite their differences, continuous or batch-process industries all share at least two characteristics in common: (1) continuous operations by definition represent substantial start-up costs and time, and; (2) they can be interrupted or disrupted by seemingly minor fluctuations in power quality. Any disruptions to the product stream mean lost productivity, lost product, scrapped material and a substantial financial drain.

As one well-known manufacturer of sausage, salami, bologna, and other meat products demonstrated, power quality problems are not always created inside the facility itself. In this particular plant, most of the process load consisted of HVAC and refrigeration for approximately 6000 sq. ft. of cold room storage. Additional loads included grinders, slicers, presses and other machinery. The facility was powered by a 120/240V service fed through a utility-owned 500 kVA high-leg delta transformer that was also shared by another factory.

Plagued by frequent interruptions when the main 1200 amp circuit breaker tripped, sometimes several times a day, previous measurements had not shown the cause of the events. The highest current measurement was only 760 amps, which was below the threshold that would cause the breaker to trip. From the power quality recordings, the following was noted:

- At times the peak current exceeded the breaker's 1200 amp rating without causing it to trip. An interruption that was tied to such a peak current was detected only once during the measurement period. Further investigation from the captured waveforms revealed that the voltages were distorted during such times, which resulted in the nuisance tripping of the other breakers and caused the capacitor banks to fry.
- A long-term measurement conducted with a power quality analyzer showed that the capacity of the breaker could be reached when a combination of tasks occurred at the same time.
- Since most of the load at this site is linear, no harmonics were generated from within the facility. When the investigation turned to looking outside the factory, the cause of the distortion was traced to a faulty power transformer.

The problem was solved after the utility replaced the transformer, which enabled the factory to increase its capacity and production.

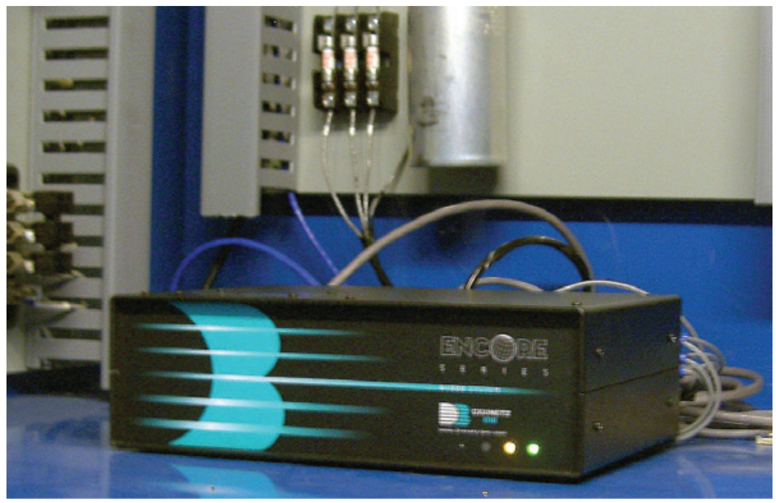


Figure 2. Permanently installed power quality analyzers like the Dranetz Encore system are extremely useful for monitoring power quality, energy (kWh), demand (kW) and other parameters. This Web-browser-based system offers advanced features, user interface advantages, communications options, and a highly flexible design for configuration to specific or evolving application needs.

Inrush-induced Sag Prevents Motor Start

An industrial customer operating a pair of 1250 hp motors on a 4kV circuit was stymied when the motors refused to start. To determine the problem, a power monitor was installed at the motor input. The power monitoring instrument quickly identified the motor itself as the source of the problem. In fact, the motor start caused a deep sag to occur, which impacted the motor control circuitry and prevented the motor from starting. In effect, the motor was "shooting itself in the foot," creating a cycle of non-performance.

The customer was presented with several mitigation options, including adding more capacity to the circuit, installing a constant voltage transformer, or installing an uninterruptible power system (UPS). The customer selected the UPS option, which was installed to protect the motor control circuitry during motor start-up and verified by the power quality analyzer (Figure 2).

Inrush currents like those associated with motor starts can cause interaction problems with other loads. When motors are started, they typically draw 6-10 times their full load, which often results in voltage sags that can dim the lights, cause contactors to drop out, disrupt sensitive equipment and, as in this example, affect the successful start of a motor. Power quality monitors that can capture waveforms during long-duration start-ups are quite effective for characterizing and optimizing motor starts.

Conclusion

What is important to remember is that the characteristics of the power required by the load is compatible with that of the power being supplied, whether by the utility or some type of mitigation equipment. Everything must play together harmoniously or problems will surface. And when they do, chances are the call will come for you, the facility engineering professional, to ride in and save the day.

The good news is that there are many excellent solutions out there to help you do just that. Dranetz and others, for example, not only offer a breadth and depth of power quality monitoring and analysis solutions, but expert applications engineering assistance is only a phone call away, so that you will never feel like you're out on a limb, winging it alone.

Ross Ignall is Director of Product Management at the Edison, NJ-based Dranetz, the leading provider of intelligent handheld and permanently installed monitoring solutions for electrical demand, energy, and power quality analysis. Visit www.dranetz.com.

Dave Brown

Using IR for **Condition-based Monitoring: Back to the Basics**

Consider the following scenario: A large refinery identifies a problem involving a vacuum leak in a steam-driven crude oil feed pump turbine. After many other test methods fail to pinpoint the problem, infrared thermography finds the issue in minutes: a few loose bolts that need to be tightened. Fixing this problem saves the company millions of dollars annually.

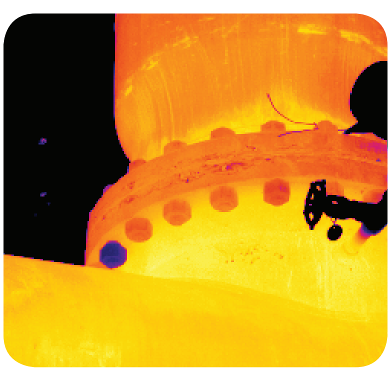


Figure 1. Thermal image revealing a loose bolt.

Infrared thermography has been used for everything from military applications to residential energy audits to animal science. The core user group, however, consists of maintenance professionals who use their cameras to detect thermal anomalies that might indicate potential failure points in electrical and mechanical components.

As a reliability and maintenance professional, you are probably aware of the use of infrared cameras in the field of condition-based monitoring, even if you have not used one yourself. But do you know how they work and why? Do you understand not only their capabilities, but their limitations as well? In this series of articles, we will discuss the theory behind the cameras and the importance of understanding not only what they do, but how they do it.

Many maintenance professionals use a spot radiometer to provide a digital readout of the temperature of a specific spot on an electrical or mechanical component. An infrared imager essentially combines a large number of these spots into an array of pixels, each one of which displays the level of infrared radiation as a color on the screen based on a user-selected color palette. Combining these pixels on a screen provides us with an image that makes it easy to see thermal patterns over a two-dimensional area, rather than just a temperature readout of a single spot. This can provide a significant advantage in an environment where anomalies may be found on multiple devices and over very large areas.

For example, one of our customers has facilities containing 79 miles of conveyor belts with a set of idler bearings every 12 feet. This means that there are over 30,000 possible failure points which, prior to the advent of infrared imaging technology, would have been extremely difficult to monitor. With an infrared camera, the thermographer can look along the length of a belt segment and easily spot the bearing operating at a higher than average temperature. (See Figure 2.)

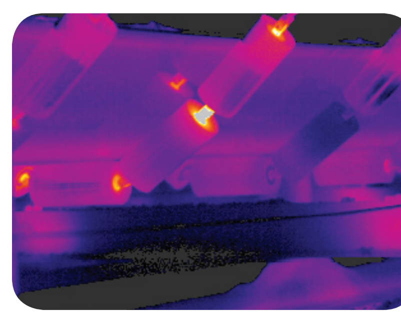


Figure 2. Overheated idler bearing in a conveyor belt.

In other cases, when performing diagnostic tests from a distance is an unavoidable necessity, infrared camera lens options can significantly improve the thermographer's success rate. Interchangeable lenses can effectively change the optical resolution of the camera, yielding a higher quality image and better measurement accuracy as can be seen in Figure 3.

Figure 3. Switchyard disconnect: standard lens, top; telescopic lens, bottom.

Of the various color palettes available on most cameras, iron or "ironbow" (Fig. 3) is the most intuitive palette for new thermographers due to the way it simulates iron glowing at different temperatures. Most of the commonly used palettes follow a similar pattern; higher relative temperatures appear in brighter colors and low temperatures appear darker (although some cameras do allow the colors to be inverted). Depending on the palette and the subject, some IR images, such as in Figure 4, can appear to be deceptively similar to visible images. One of the biggest challenges to the new thermographer is understanding the differences.

For example, we do not need a visual image to see that the subject of Figure 5 is a small SUV. Most non-thermographers, however, might instinctively guess from the brightness of the headlights that they are on. The IR image indicates that the surface of the lights are warmer than most of the rest of the vehicle, but it cannot tell us whether they are actually on. By the same token, we cannot tell from this image whether the defroster and engine were running when the image was saved. All we know for sure is that the windshield and engine bay are warmer than the surrounding areas. It important for the thermographer to understand both the camera's capabilities and its limitations. Familiarizing ourselves with infrared radiation and how the cameras work will help us understand these concepts.

NOTE - **"Resolution" vs. Resolution**: *The higher the number of pixels in the detector, the higher the quality of the infrared image.* When shopping for an infrared camera, be aware of the distinction between detector resolution and display resolution. Some manufacturers advertise "640 by 480 resolution" displays on cameras whose detectors have only 320 by 240 resolution. This promotional messaging could lead the less experienced thermographer to believe that these cameras provide a superior infrared image to other 320 by 240 cameras. Imaging and measurement performance are governed by detector resolution, not display resolution.

Figure 4. This thermal image looks deceptively similar to a black and white photo.

Figure 5. Thermal image of this SUV does not reveal whether the lights are on.

What is Infrared Radiation?

Infrared radiation forms a part of the electromagnetic spectrum, along with visible light, radio waves, ultraviolet, and X-rays. Visible light takes up only a small sliver of the EM spectrum. Just beyond visible light is a wide range of wavelengths we refer to as infrared. Infrared wavelengths vary from very short waves (also known as "Near IR") such as those used by the remote control in your living room and in night vision goggles, to the wavelengths detected by these longwave infrared cameras.

Every object with a temperature above absolute zero (effectively, every object in the known universe) radiates infrared energy. Perhaps one of the best ways to "translate" infrared images is to imagine that while in the visible world only a few things (such as light bulbs and stars) glow, in the infrared world, everything glows. This glowing is a function of radiation, one of the three forms of heat transfer.

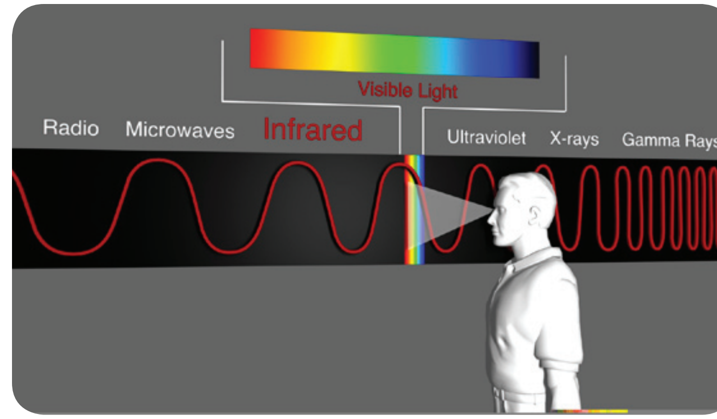


Figure 6. Graph of the electromagnetic spectrum.

Three forms of heat transfer

Heat always flows in one direction—from warm to cool—and can be transferred in any of three ways: conduction (through a solid or between solids that are touching); convection (from a solid to a gas/liquid); or radiation (from any object to any other through EM energy).

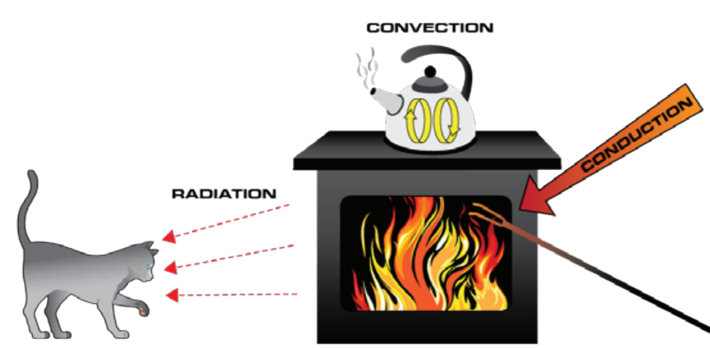


Figure 7. The cat absorbs most of her heat from the stove through radiation.

Heat transfer is occurring constantly. Our own bodies, for instance, conduct heat energy to our seats, convect to the air, and radiate to the surrounding walls. We tend to think of heat transfer mostly in terms of the first two, conduction and convection. In fact, most heat transfer occurs through radiation. On a cold winter day, the amount of heat your body loses through radiation to the outside walls accounts for about 70% of the total loss. An infrared camera works by detecting that infrared energy.

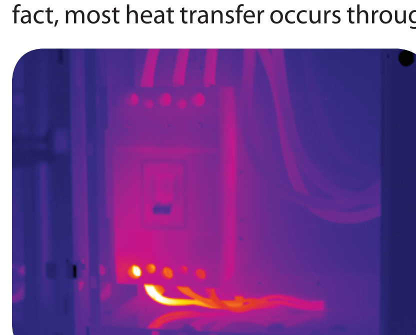


Figure 8. Thermal image reveals a termination rather than a load issue.

Although radiation is the most important form of heat transfer, it is important to

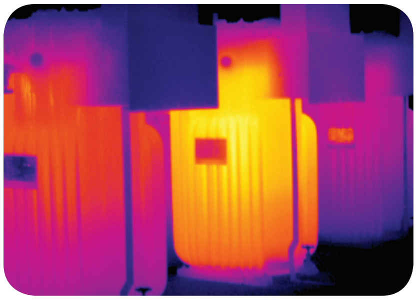


Figure 9. Small temperature differences on the outside of massive targets can indicate much larger temperature differences on the inside.

understand the concepts of conduction and convection as well. By way of example, conduction is the key to analyzing the issue in Figure 8. The temperature gradient on the wire on the left shows us that the source of the heat is near the termination, rather than along the length of the entire wire. This indicates that the issue is caused by a termination problem, rather than a load problem (which would result in a uniform heating pattern along its length, as well as on the line side).

NOTE - A study by the National Fire Protection Association has found that 85% of all electrical fires are caused by electrical termination problems! Hotspots on electrical components are the thermographer's "low hanging fruit." A minimal investment of time and resources can yield a significant return in terms of safety and reliability.

Convection plays a role as well. In the oil-filled transformers in Figure 9, we can use the surface temperature to calculate the temperature of the source using convective heat transfer formulas. For our purposes, it is sufficient to understand that even a very small temperature delta in such a massive component indicates a very high temperature at the source.

Radiant Properties

All materials have three properties with respect to incoming ("incident") infrared radiation. They can transmit it (i.e. allow it to pass through), reflect it, or absorb it. Due to the laws of thermodynamics, anything that was absorbed by the material will have to be emitted as well. Thus, the infrared radiation leaving the surface of the same material ("exitant" radiation) is either reflected, transmitted, or emitted energy. So we can summarize the three radiant properties using the terms: transmissivity, reflectivity, and emissivity.

The key concept here is that the camera cannot distinguish between the energy that is emitted versus that which is transmitted or reflected. It simply displays the sum of all three, which we refer to as "apparent" temperature. One of the most important tasks of a thermographer is to adjust the settings on the camera to compensate for the transmitted and reflected radiation to yield a "true" emitted temperature.

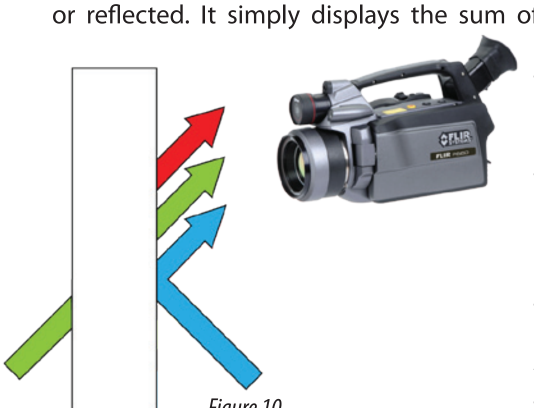


Figure 10

Transmissivity

In the visible spectrum, glass is nearly 100% transmissive. In the longwave infrared, however, it's completely opaque. In fact, materials that transmit infrared energy are very rare, most notably, silicon and germanium (from which most infrared camera lenses are made) and a few plastics.

Since so few materials transmit infrared energy, the thermographer is concerned mostly with the other two radiant properties: reflectivity and emissivity.

NOTE - **X-Ray Vision?** Contrary to popular belief, longwave thermography cameras cannot see through walls (or clothes or even windows). No matter how many times Jack Bauer has done it on "24," it is not possible to detect human bodies inside a building using infrared from the outside. Images that seem to simulate X-ray vision, such as shots of a wall that clearly show the stud locations, are merely showing minute temperature differences on the surface of the material. It is usually the conduction properties of the materials behind the surface that create this illusion.

Figure 11

Reflectivity

Most metals are highly reflective in the infrared spectrum. The block of aluminum in Figure 11 reflects almost as well in the infrared spectrum as a glass mirror does in the visible. Highly reflective surfaces such as this are very difficult to measure accurately.

Figure 12 illustrates how reflectivity might fool a less experienced thermographer. Based on the image, the connection on the top appears to be significantly warmer than the other. In the image on the right, however, the relative temperatures seem to have reversed. In fact, both are emitting the same amount of energy. It is only the reflection of the thermographer's warm body that has changed. The experienced thermographer is always aware that heat patterns that follow human movement are most likely reflections.

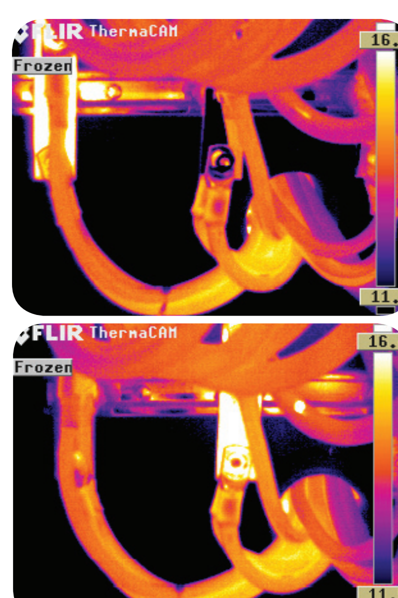


Figure 12

Emissivity

The term emissivity refers to a material's ability to radiate; the more efficient a radiator, the higher its emissivity. For "opaque" materials that do not transmit in the infrared, emissivity is inversely proportional to reflectivity.

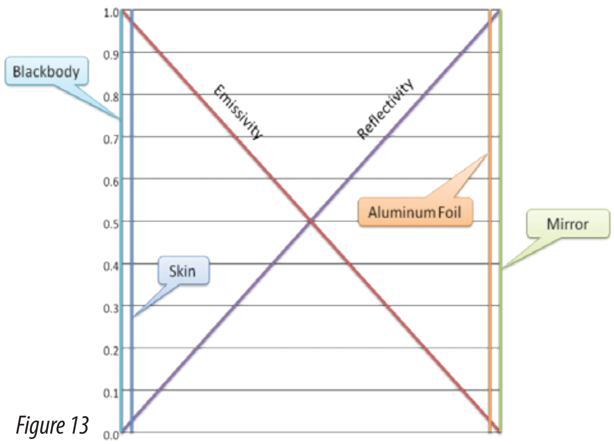


Figure 13

Since it is the emitted radiation that can be used to calculate a material's temperature, the higher the emissivity, the more accurate the temperature measurement. Conversely, the higher its reflectivity, the more difficult it is to get an accurate temperature measurement. Some thermographers use the adage, "Low emissivities lie!"

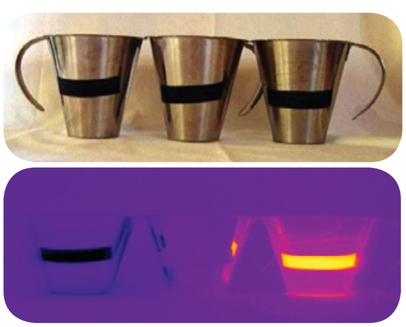


Figure 14

The stainless steel cups pictured in Figure 14 illustrate this principle. The cup on the left is filled with cold water, the middle with no water, and the right with hot water. Stainless steel, while a good conductor, is highly reflective in the infrared, i.e., a very poor emitter. Thus, the steel surface of all three cups appears to be very similar in temperature.

Polyvinyl-chloride tape (otherwise known as electrical tape), on the other hand, has a known emissivity level of .95 (95% emissive).

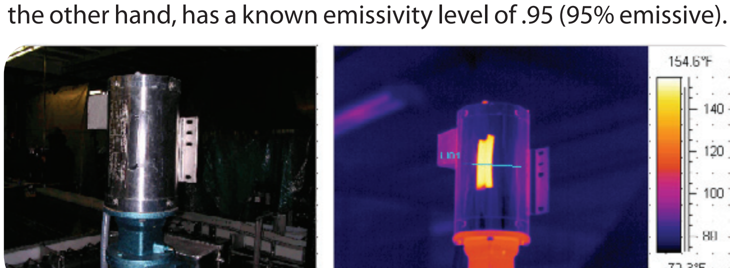


Figure 15

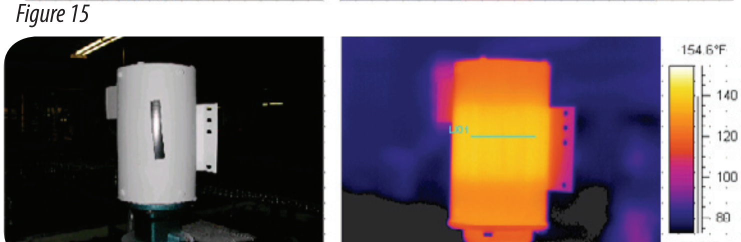


Figure 16

By affixing electrical tape to the cups and using a camera set to the same emissivity level, we create targets that provide much more accurate temperature measurements.

In this case, the tape on the leftmost cup appears significantly colder than the ambient temperatures whereas the tape on the right appears much warmer. Interestingly, the tape on the middle cup is almost invisible since it is at the same ambient temperature level that is being reflected by the cup.

Thermographers frequently use electrical tape to provide accurate measurement targets on objects that otherwise might "lie" about their temperatures. *Note: Use common sense and prudent safety practices when approaching electrical and mechanical components.*

One compelling example of the impact of emissivity in an industrial environment involves a mixer motor at a large food processing plant. This motor was problematic from the day it was installed. In compliance with EPA regulations, it was constructed of stainless steel, which is highly reflective and a poor emitter. Thus, any heat generated inside of the motor stayed inside the motor as is shown in the thermal image on the right in Figure 15, instead of being radiated into the environment.

By adding a coat of high emissivity paint which allowed the motor to radiate more efficiently, the operator was able to reduce the operating temperature by over 10 degrees—enough to bring the motor to a fully functional state as shown in the thermal image on the right in Figure 16. This example also illustrates the relationship between conduction, convection, and radiation.

Emissivity is probably the single most important concept for the thermographer to understand. In future articles, we will discuss factors other than surface material that can affect emissivity.

Summary

The key points to remember are:

- Infrared is the portion of the electromagnetic spectrum just beyond visible light. All objects radiate infrared energy. For any given material under fixed conditions, the higher its temperature, the more infrared energy it radiates. This is the principle that allows infrared cameras to calculate temperatures.
- Radiation is one of three forms of heat transfer. The other two are conduction (within or between solids) and convection (within a gas or liquid).
- The three exitant radiant properties of a material are transparency (rare in the IR spectrum), reflectivity, and emissivity. The primary function of a thermographer is to compensate for any transmissivity or reflectivity in order to measure the emitted radiation as accurately as possible.

Operating a typical infrared camera is relatively simple, but accurately interpreting the images requires knowledge and practice. When budgeting for an infrared camera, consider including a Level I Thermography class with a reputable provider.


Dave Brown is an ITC Level II Thermographer who brings over 20 years of experience as an educator and training professional to his role as Director of the Infrared Training Center at FLIR Systems, the world's largest manufacturer of infrared imagers. Prior to joining FLIR, Dave managed several training programs at companies like PricewaterhouseCoopers. He resides in Nashua, NH. Visit www.flir.com

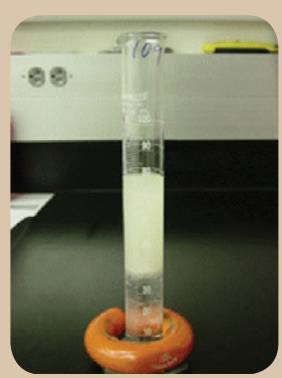
MIXING Oil & Water: A Recipe for Downtime!

Mark Barnes

While conventional wisdom would hold that oil and water don't mix, in reality, they do! Even clean, dry oil can hold minute amounts of water in the dissolved phase. Dissolved water can be thought about in the same terms as water vapor in the atmosphere.

While we know there's always some water in the air, provided the concentration is low enough and the temperature high enough, we don't see visible evidence of the water in the form of condensation (dew), fog, or rain. But as soon as the levels of water in the atmosphere increase or the temperature decreases, water starts to visibly come out of solution. This is why on a cool spring morning we often start the day with fog or mist, particularly in coastal regions, where water levels tend to be higher.

Oil is no different. Small amounts of moisture are readily attracted to oil, a term we sometimes refer to as *hygroscopic*. Hygroscopic simply means that the material—in this case, oil—has an affinity for moisture. The degree to which an oil will absorb moisture will depend on a number of factors including base oil type and age, additive composition and the level of contamination.



The degree to which an oil will absorb moisture will depend on a number of factors including base oil type and age, additive composition and the level of contamination.

Typically speaking, the more polar the base oil, the more water can be held in suspension. For this reason, high polar base oils such as phosphate esters or polyalkylene glycols are significantly more hygroscopic and hence hold more water in the dissolved phase than petroleum oils. Likewise, highly refined mineral oils and synthetics will hold less water in the dissolved phase than less highly refined Group I or II mineral oils due to the absence of cyclo- aromatics, naphthenes, and other impurities that tend to absorb moisture more readily. Aged fluids also tend to hold more water in solution due to the by-product of base oil degradation, which tends to be more polar than the base oil molecules themselves.

Aside from base oils, additive composition also has a dramatic effect on an oil's affinity for water. In lightly additized oils such as turbine and other R&O type oils, there are very few additives and thus there is minimal change in the ability of the oil to absorb moisture. Other fluids, however, such as hydraulic fluids and gear oils, contain polar additives which tend to increase the amount of moisture an oil will hold in the dissolved phase. Very heavily additized oils such as engine oils or tractor fluids have an even greater affinity for moisture since they typically contain additives anywhere from 15–30% by volume, many of which are polar.

Engine oils in particular are prone to water absorption since most engine oils contain detergent additives. Detergent additives are designed to have both polar and nonpolar ends which causes them to serve as a "bridge," binding water (polar) and oil (nonpolar) together into what is commonly called an emulsion. An emulsion is the cloudy oil-water mixture we've all seen that sometimes looks like chocolate milk. Emulsions can be described as either stable or unstable. A stable emulsion refers to an oil-water mixture that is tightly bound with little-to-no tendency to separate, while an unstable emulsion will tend to separate back into oil and water phases, particularly at elevated temperatures. Generally speaking, lightly additized oils do not form emulsions, and if they do, they tend to be unstable. Heavily additized oils on the other hand are far more prone to forming a stable emulsion. In fact, as little as 500 ppm (0.05%) of diesel engine oil contamination in a turbine oil can completely destroy the turbine oils ability to shed water—a property usually referred to as *demulsibility*.

With the exception of oils used for insulating electric equipment, dissolved moisture in an oil is of little concern to the lubricating quality or performance of the lubricant. But when water comes out of a solution, and forms either an emulsion or free water on the bottom of the sump, the reliability of equipment can be seriously compromised. In rolling contacts such as those found in rolling element bearings, the presence of water in the emulsified phase can result in as much as a 75% reduction on bearing life (Figure 2), while in hydrodynamic contacts such as journal bearings, reducing water content from 1000 ppm to 250 ppm can increase bearing life by as much as 50%.

Water in oil affects machines in a variety of ways. The first is purely mechanical. Put simply, water doesn't lubricate as well as oil! In situations where the lubricant is subjected to a sudden change in pressure, flash vaporization followed by rapid condensation of the water can occur. Under such circumstances, the rapidly condensing vapor can form a microjet of steam which implodes at the machine surface. A common example of this occurring is in a hydraulic pump where the hydraulic fluid and any entrained water rapidly cycles from low pressure on the suction side of the pump, to very high pressure on the discharge side. When this occurs, mechanical damage to the pump can occur—an effect referred to as *vaporous cavitation*. A similar effect can be seen when oil under fairly low pressure enters a hydrodynamic contact such as a journal bearing. Again, a sudden change in pressure can result in flash vaporization of the water and subsequent damage to the bearing surfaces.

But water has other deleterious effects on a lubrication system. For example, as a lubricant degrades, oil soluble by-products are formed. While these are usually in solution in the oil, in the presence of free or emulsified water, these by-products can be drawn out of the oil causing a sticky, resinous material to form in the system. While not always the case, oftentimes, sludge and varnish formulation together with the resultant problems such as valve stiction or restricted oil flow can be directly attributed to the presence of moisture in the oil.

In some types of fluid such as ester-based synthetics, water can chemically react with the base oil under certain conditions, a process known as *hydrolysis*. Left unchecked, hydrolysis can result in the formation of sludge, acids and deposit throughout the system. Electrohydraulic control (EHC) systems in steam turbines which historically have used phosphate ester fire-resistant fluids are particularly susceptible to hydrolysis.

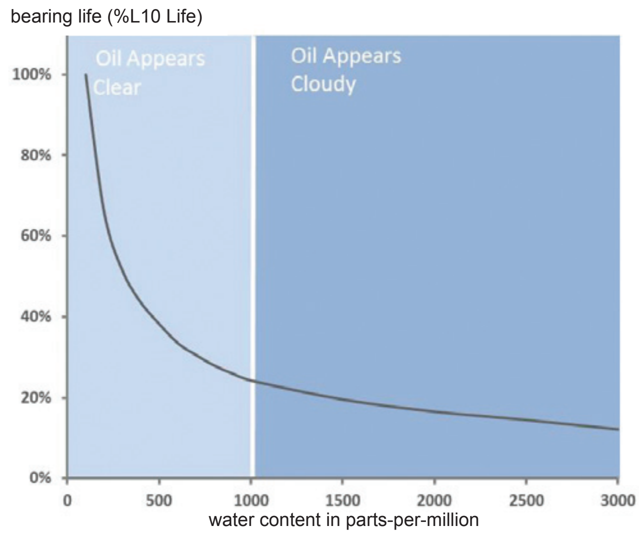


Figure 2: Life Expectancy of Rolling Element Bearings Versus Water Content

Even in petroleum-based fluids, water has an effect on the base oil. While water itself will not react with hydrocarbons, it does help to promote and catalyze base oil oxidation, particularly in the presence of certain catalytic wear metals such as copper, iron, and tin. In fact, as little as 0.1% water in oil can increase an oil's oxidation rate up to ten times under certain conditions.

Finally there are the direct chemical effects on the machine's surfaces, most notably rust. Rust causes loss of surface profile, embrittlement of the surface, and deposit formation as rust particles flake off of surfaces and fall into the lube oil system. Not only does this destroy the surface finish, but the rust particles then circulate throughout the system causing particle-induced failures such as 3-body abrasion or fatigue.

While all machines are at risk, of particular concern are those that operate in high humidity environments and/or have cycling temperatures. The reason for this is quite simple: the solubility of water in oil is temperature dependent—the hotter the temperature, the more water can be dissolved in the oil. Of course this only goes so far. Once you approach the boiling point of water (212^{0}F at atmospheric pressure), water will start to evaporate from the oil. But since most of our machines don't operate this hot, water will readily dissolve in the oil if it is present either from the process or ambient environment.

Humid environments are particularly troublesome because air and oil in contact try to maintain the same relative humidity. This is based on Henry's law which states: *"At a constant temperature, the amount of a given gas (water vapor) dissolved in a given type and volume of liquid (oil) is directly proportional to the partial pressure of that gas in equilibrium with that liquid."* Put simply, if the headspace above a lubricant is saturated, the oil will also be saturated, meaning much of the water present in the oil will be either free or emulsified.

This can be of particular concern for stop-start equipment where production shifts or intermittent usage mean that oil temperatures cycle from operating (high) to ambient (low) frequently. While the oil may be below saturation during operation, as the temperature cools down, water comes out of solution and becomes free or emulsified. As an example, a circulating lube oil at 140^{0}F may have 500 ppm of water (0.05%) present in the dissolved phase, but cooling that oil down to 80^{0}F may result in as much as 400 ppm coming out of solution!

So don't just take water for granted just because your process uses water, or your equipment operates in high ambient moisture conditions; look for ways to eliminate moisture to help extend equipment life. Stay tuned for Part 2 of this article, when we'll discuss techniques for eliminating moisture.

Mark Barnes recently joined Des-Case Corporation, a leader in the field of contamination control and lubrication management as Vice President of the newly formed Equipment Reliability Services team. 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 and is a Certified Maintenance and Reliability Professional (CMRP) through SMRP. Visit www.descase.com

Editors note: *Dan Dewald is a frequent Reliability Roadmap Web workshop leader. To view recorded web workshops visit* ***www.reliabilityweb.com>tutorials>Category MRO/Spares***

Daniel DeWald

Repairable Spares: The Complete Program

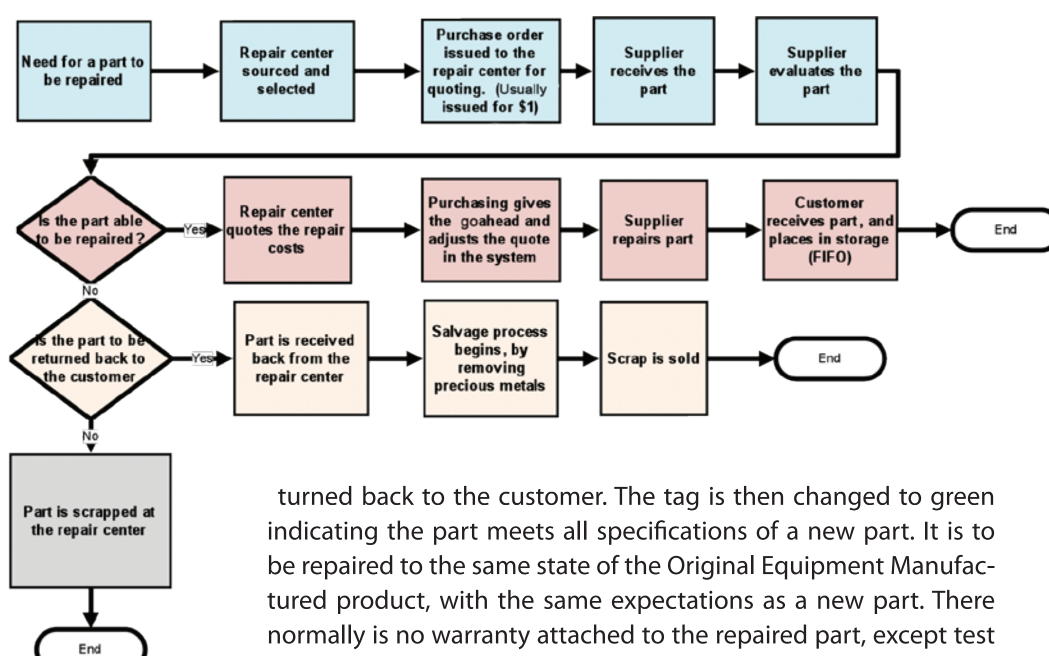
The establishment of a repairable spares program is essential to complete a solid MRO (maintenance parts, repair, and operating supplies) management program. Repairing parts before the point of failure is a strategy that reduces maintenance costs, reduces purchasing dollars in buying new equipment, and reduces the need for an increased capital budgeting process.

There are four areas to discuss concerning the repair of spare parts and equipment:

- The repair work process flow
- The salvage process
- Sourcing and selection of a repair center
- Purchasing equipment on the secondhand market

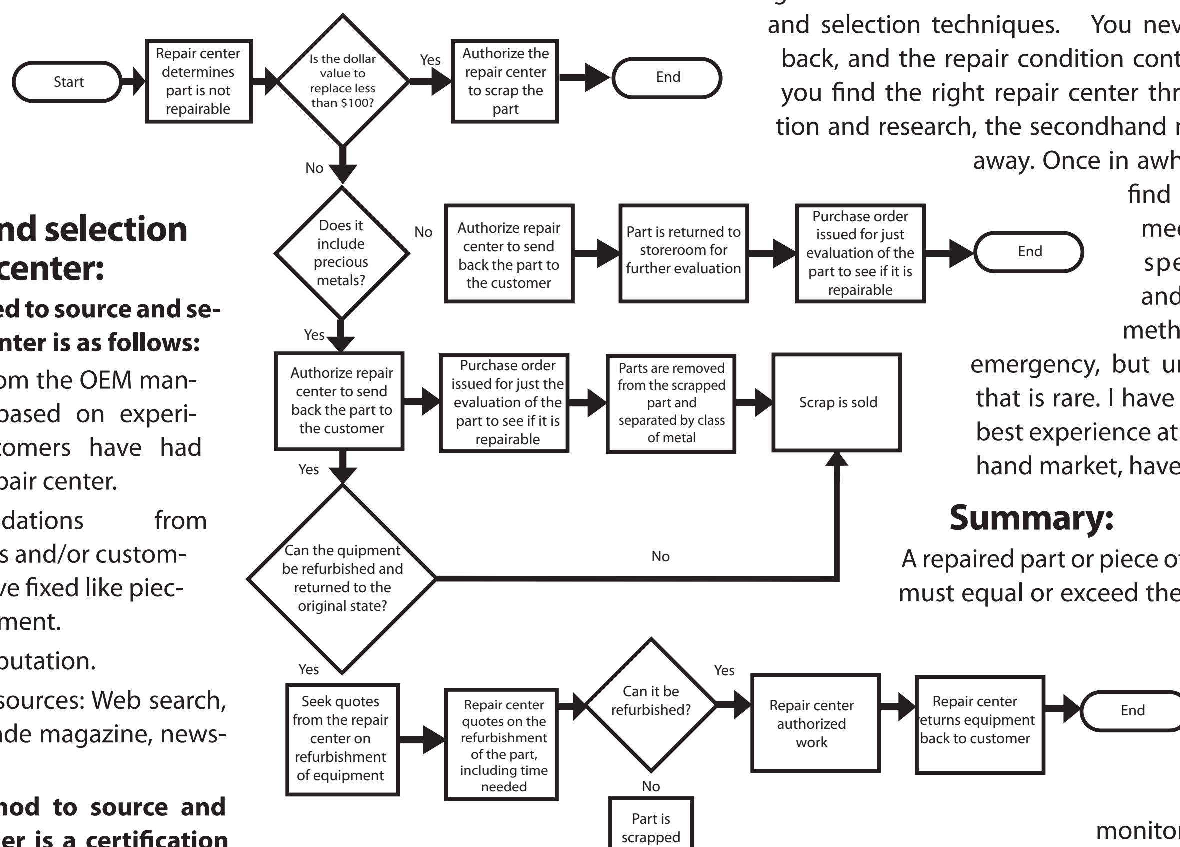
The repair work process flow:

Once you have determined that the component is in need of repair, it is sent to a selected supplier to evaluate whether it can be repaired, and to provide a quote to do the repair. The control of the part needing repaired and being sent to a supplier includes a red repair tag, which identifies the part number, the description, the purchase order number for the supplier to evaluate the component part or equipment, and the reason for the need of repair. Once the part is received by the supplier, and it is determined that the part can be repaired, a quote is prepared to evaluate by the customer. Once a go-ahead is received by the repair center, the tag is changed to yellow, meaning "in process," and the part is repaired. The part is returned back to the customer. The tag is then changed to green indicating the part meets all specifications of a new part. It is to be repaired to the same state of the Original Equipment Manufactured product, with the same expectations as a new part. There normally is no warranty attached to the repaired part, except test results indicating the part specifications. The part is then binned, and placed as a "First In, First Out" rotation, since repair parts are needed to be picked and used first.



The salvage process:

When the part is determined to be unusable from the evaluation by the repair, the next step is to determine the best means to salvage the part. There are three decisions—having the repair center scrap the part at their facility; having the repair center send the part back to you for you to scrap; or having the part sent back to your salvage facility to break down the components to bring the most dollars in scrap value back to the plant. Each time, the dollar value of the part must be evaluated in order to make that decision. High dollar parts, with precious metals, need to be brought back to the salvage center and broken down into components. Once the part is scrapped, the buyer goes into the market to purchase new equipment and/or components. Safety stock and defined min/max points help to reduce the pressure of expediting parts to replace the original parts.



Sourcing and selection of a repair center:

The criteria used to source and select a repair center is as follows:

- Referrals from the OEM manufacturer, based on experiences customers have had with the repair center.
- Recommendations from competitors and/or customers who have fixed like pieces of equipment.
- Industry reputation.
- Least best sources: Web search, industry trade magazine, newspaper, etc.

The best method to source and select a supplier is a certification process:

- Current and potential repair centers go through an objective visitation at their site, evaluating each part of their process.
- The suppliers are ranked in each category. The main categories to be ranked are facilities, organization, work flow processes, inventory management, storeroom management, receiving and shipping, market pricing, quality of repair, service after the sale, and delivery meeting due dates.
- The supplier is placed in one of four categories—Certified (top supplier), Preferred (near the top supplier), Qualified (average supplier), and Non-conforming (do not want to do business with that repair center).

The visitation at the facility of a potential service center holds a great deal of weight, and makes the decision-making much easier. It takes time and effort to locate the centers, but this approach makes the selection and sourcing much improved. Testing and instrumentation are also a part of the process, which means that the repaired equipment has to meet the strict guidelines of the OEM.

Purchasing on the secondhand market:

I avoid this as much as possible and exhaust my source and selection process before I go into this market. Even when a component or piece of equipment is advertised with a price attached to it that sounds good, there is no guarantee that this is not a come-on, and that it actually exists. I spent hours locating a secondhand market part in Kansas, and found it shipped from the East Coast. When received, the part did not meet my specifications. The secondhand market company would not take it back, but instead wanted to sell it at a discount, of course. My time would have been better spent doing the hard work as discussed above in sourcing and selection techniques. You never get time back, and the repair condition continues. Once you find the right repair center through visitation and research, the secondhand market goes away. Once in awhile you may find a part that meets your specifications and testing methods in an emergency, but unfortunately that is rare. I have not had the best experience at the secondhand market, have you?

Summary:

A repaired part or piece of equipment must equal or exceed the OEM specifications. Warranty costs are to be monitored so that no additional dollars for the repair are applied if it is under warranty. The repair work flow should be mapped and followed. A salvage program should be established to support the repair program. Repair centers should be ranked and evaluated prior to selecting them to quote jobs. The selection should be based on both objective and subjective criteria, and may be the result of the supplier's recommendation, industry reputation, and visitation at the facility. The secondhand market is available as a last resort. The repair process is a key work flow in the MRO process.

Daniel DeWald has spent the last seven years in project management affiliated with Life Cycle Engineering, NFI industries, and DMD Solutions. He is currently working as a consultant for GP Allied as an SME in Materials Management. He has over 30 years experience in warehousing and distribution, production control, materials management, logistics, supply chain management, and purchasing. He has served as a chapter president in APICS, and has earned a CPIM, (Certified Production Inventory Manager).

Ways to Waste Money

Being the self-described humorist that I like to think of myself as, I have pulled together my "Top Ten" money-wasting things I have seen, heard, and regrettably, even witnessed. Living in the "consulting world," I have been exposed to a lot of things: good, bad, evil, and just downright funny things. Hope you get a chuckle or two from my collection, but more importantly, you come away with the messages buried beneath the humor.

Dave Bertolini

Number 10: When engaging with a consultant, ensure you ignore what they recommend. You're only paying them to advise you. After all, what is it they know that you don't already know?

Ideally, you have formed a partnership with your consultant and the total focus is on your organization's success. A wise person once told me if you can't solve a problem in three days, get someone from the outside to look at the issue, because you'll never solve it on your own. It requires a leap of faith to place your trust in "an outsider," but if you have chosen your partner wisely, mutual respect and trust can quickly be achieved and real results can happen. Remember, at the end of the day you've engaged with this individual to guide and advise you based on his/her knowledge and past experiences. More importantly the things you see and do every day are natural to you, but perhaps you can't see the forest through the trees… when they might be able to. We all need someone to come by and pull our heads out of the mud puddle and tell us which way they went once in a while.

Number 9: Only empower and engage a small number of employees. It's easier to manage and you won't have to deal with a large group trying to change and move too quickly.

If there was ever an adage that would fit nicely here it would be, "The more, the merrier." Engage all you can. Empower people to make a change. The key to successful change is to paint the picture of the future, give them the tools to get there, and reward for the right results. A change initiative was once described to me that it's like a big, long, fully loaded train. Once it gets up the steam and starts moving

The key to successful change is to paint the picture of the future, give them the tools to get there, and reward for the right results.

don't try to stop it, because you can't easily get it started again. The best thing one can do is to ensure the tracks are clear and the switches are set for the proper routing, and then enjoy the ride to the destination.

Number 8: Don't waste money on training people. There are tons of free books at the library that people can check out to obtain the necessary skills to improve their performance and knowledge.

Does anyone really think when we hire an employee that they have signed on with all the skills they will ever need for their tenure within the organization? Hopefully not, however, most organizations end up treating people that way. Evaluate your training program; if there isn't one, establish one. If not, you will always get what you have always gotten. Remember, all roles within the organization require some level of training to improve upon their fundamental skill sets. I heard a great saying somewhere along the way: "Remember, ignorance can be corrected through education; however, stupidity is forever."

Number 7: Ensure you tackle the easy problems first. Remember the easy stuff can be accomplished quickly, and it gives a great "false sense of security" that everything is easily accomplished.

Let's not fool ourselves. The easy things that are out there—well, most of them—have already been tackled. Go back to Number 10; consultants could be invaluable here. Remember, you partnered with them because of their knowledge and experience. This is where that pays off, and what's difficult for you to see and do may be broken down into easier steps with their guidance. I wasn't going to use the old "Eat the elephant one bite at a time" adage, but it just might fit here. Oh yea, bet you've heard this a few times, too: "Nothing in life is easy . . . unless you work hard at achieving it."

Number 6: Do not develop a plan to guide your improvement efforts. It presents a visual reference that people can see. And remember, if they can see it, they can ask questions. It's a tool for management to hold you accountable for when there is no measurable progress. . . . Who needs that?

I often wonder how the pioneers of the old west days made it across the country in wagons (not station wagons) and no GPS. The journey you may want to take your organization on will require a detailed plan that identifies the steps necessary to get you there. (That will be your GPS.) This plan should be shared and posted throughout the organization so it is visible to all. Encourage questions; if they're asking, they're learning. They may also have valuable input to make the journey easier. It should be a shared responsibility for the execution of the plan, but with responsibility comes accountability. All assignees of tasks or activities must be responsible and accountable for their actions or in-actions. Progress should be updated routinely so the organization knows where they are on the journey. Although there are some that still manage to get lost with a GPS in hand, let's just enjoy their contributions . . . they're fun to watch.

Number 5: Whatever you do, never establish Metrics or Key Performance Indicators (KPIs). It works hand in hand with Number 6, that pesky opportunity to ask questions or to supply answers (factual or not) and then, of course, that dreadful accountability issue.

Each organization must establish Metrics or Key Performance Indicators to monitor their progress, identify their successes and failures, and set measurable standards. Numerous publications and Web sites have hundreds of these indicators available. Pick the ones that fit right for your organization. Train all on how to interrupt the information and how their activities affect the measurement. Share the information across the organization; again, if they're asking, they're learning. These should be considered the organizational behavior drivers. Explain them, measure them, post them, and treasure them.

Number 4: Never audit; it only makes people nervous and uncomfortable. They know what they are doing; after all, they have been doing it this way for years. Everyone knows we have refined everything and there are no remaining improvement opportunities left.

I have seen people visibly shake just by saying the word "audit." For some reason when we audit activities or processes, people tend to take it as a personal audit. Organizations must embrace auditing as part of the continuous improvement and growth process. How can one improve without measuring what has or has not been achieved, and auditing to ensure the defined processes where followed? The goal of auditing should be to ensure the processes are sound and the results are what the organization desires. Now, continuous improvement processes can be applied and yield positive results. There's always room for improvement; we just have to go find it.

Number 3: Don't waste time planning and scheduling maintenance activities. The message that planning saves you big dollars is folklore. This myth and folklore was even told around the camp fires at consultant's camp.

Everyone realizes planning is important; in fact, it has become so important that in many organizations, everyone is focusing some amount of time on maintenance planning. Unfortunately, it's with most of the wrong roles involved. What's seen in numerous organizations is that maintenance managers, maintenance supervisors, and even maintenance crafts are consumed throughout their days planning work. Now, for those organizations that have dedicated maintenance planners, well they spend their days finding parts, compiling reports, and sometimes fetching coffee for those planning. It's been repeatedly proven that planning saves money, but not when everyone is doing it. A trained and dedicated planner can plan for up to 30 maintenance crafts, save money, and allow maintenance managers and supervisors to dedicate themselves to their respective roles. If you do not have a dedicated planner, add a line item in your plan to establish one. It's easy money to be saved. Now, if you're one of those rare breeds that think money is evil, feel free to send all that offending money directly to me.

Number 2: Never invest in a CMMS or EAM; they provide a focal point for data collection.

Everyone knows data is bad; it's difficult to tell your story when the data says different. This also works hand in hand with those pesky questions and accountability things we all hate.

Every organization that has a maintenance budget, maintenance resources, or would like the opportunity to find cost savings measures, must have this tool. Maintenance is an extremely repetitive business; however, we fail to recognize or even look for the frequency of the repetition. Let me put that into other terms: We act surprised in new ways each time the same things happen to us again and again. This tool is necessary for successful work management, inventory management, and maintenance management. Your Metrics or KPIs should come as a direct result of the utilization of this tool. This is your site's historical archive and if data is harvested routinely, it's a crystal ball of your future. Think GPS for maintenance here.

Number 1: We don't need to do anything, after all we have been around a long time, and will be around for a long time in the future . . . right?

In today's competitive and global market, just doing what we have always done will only lead to disappointment and perhaps a 20-second blurb on CNN or FoxNews. The best analogy I have ever heard is, "If we are not green and growing, we're brown and dying," and I heard it years before being "green" was a popular term. What have you got to lose? Go try and make a change for the better in your organization, and remember if you take two steps forward and one step back . . . well, at least you have most of the dance steps for the electric slide mastered.

No animals were harmed in the writing of this article. Continuing to do what you have always done may cause indigestion, heart burn, insomnia, cramps, disgruntled employees, unemployment, upset stockholders, or, even Chapter 11…

Dave Bertolini is a Managing Principal with People and Processes, Inc. He has over 30 years experience in improvement initiatives. He is recognized as an industry expert in the implementation and utilization of Computerized Maintenance Management Systems (CMMS). www.peopleandprocesses.com.

Garry Sands

Combining In-House & Outside Laboratory Oil Analysis

Most companies rely on outside laboratories to analyze there time-based oil samples. Every six months, or perhaps once per year, oil samples are gathered and sent out for routine time-based analysis. So, for instance, we will be able to say a certain hydraulic reservoir has been sampled every six months, or once yearly, and then we at least know the condition of the oil at that point in time.

But is this enough? Can we really feel comfortable about knowing what condition our oil is in only once or twice a year? Let's not forget, this sample also reflects the condition of our equipment. A false sense of security or feeling comfortable about the condition of our oil and equipment may exist when using only this method of testing. We have a feeling of everything being under control, but is it?

For the most part, barring any changes to the environment, the operation of the equipment, or any changes to the oil in general, this might be sufficient. In an ideal world, it may seem like nothing is wrong with scheduled oil sampling of this nature.

However, it is not an ideal world that our equipment runs in, now, is it? In the real world there is what I call "accelerants." What are accelerants? Accelerants are anything that can enter your lubrication system and prematurely stop the lubricant from doing its job. This may happen over a long period of time, allowing us to react, but usually not. Accelerants can take over in a fairly short period of time. Now we only have a short period of time to react.

When considering all the contaminants that are seemingly just waiting in line to enter our lubrication systems, we need to be ready to react. Even at six-month sampling,we are putting ourselves at a disadvantage.

Water can cause catastrophic failure in a matter of only hours. Failed seal, failed heat exchanger, or even an overzealous hose down can cause nightmares for a PM department.

Heat is another accelerant. Lower viscosity can lead to a lack-of-lubrication failure. Rapid oxidation caused by high heat can break down the additive package. The additives such as extreme pressure, antiwear, demulsifiers, antifoaming agents, and others can no longer protect. If unchecked, three-body wear begins, rapid wear starts and this can speed the process of failure exponentially.

Ingression of dirt through a failed breather is a common occurrence. Soot, fine windblown sand, or anything else usually transported through the air qualifies as dirt. It is the abrasiveness of this dirt that continually wears on all parts and clogs filters.

So, we can see all that is waiting to enter a hydraulic system, gearbox, or bearing unit. It can be challenging to know at all times, the condition our oil is in. Is it clean? Is it dry? Is there any reason at all I should be concerned about premature failure? We need to be able to say yes or no to these questions as often as possible.

Of course, there needs to be a balance in the amount of effort and expense we put forth to stay on top of things. For instance we would not require a sample taken from a power end containing one gallon of oil be sent for analysis every month. Conversely, we would not allow a complicated, high-cost, money-saving, critical hydraulic lubrication system to go unchecked for an entire year.

So let us focus on what we need to know and when we need to know this valuable information.

First of all, one of the main reasons to have a daily lubrication inspection route is to spot, identify, report, and correct any changes developing on our equipment. The oil level and condition of that oil should be one of the first things we look for. Pumps make up much of the equipment on our daily route. Today, many if not all of these power ends are fitted with BS&W sight glasses. Most contaminants sink to the bottom of oil reservoirs rather fast when able to get out of the agitation zone. These sight glasses are in fact an oil sample bottle and can be checked for contamination at a glance. Side level sight glasses can provide a window into the condition of the oil as well, but it may take more time to determine the severity. This type of sampling is visual only, but very effective, taking no more time than checking levels.

The cost of replacing equipment goes up when we move on to gearboxes, both small and large. They are a bit more complicated than housings containing a shaft and two bearings. With a lot more going on in these housings, the condition of the lubricant can either maintain reliability or shorten it in a hurry.

Small gearboxes make it difficult to monitor the condition of oil due to the lack of room available for mounting accessories. A small gearbox containing less than eight gallons of oil could be put on a time-based oil change. Caution needs to be taken when trying to determine the correct length of time permitted between oil changes. The equipment's environment plays a big part in this decision, and environments can change daily. Now here is where the experienced lubrication technician earns his or her money. Knowing what is going on around a specific piece of equipment can give a good idea as to what is going on inside that equipment. Checking a dipstick or fill plug can shed some light on the condition of the oil. The lube tech can then plan for and execute a condition-based oil change while referring to a time-based oil change as a backup system and reminder.

Accelerants are anything that can enter your lubrication system and prematurely stop the lubricant from doing its job.

It can actually be easier to monitor the oil condition in large gearboxes because accessories can be installed as tools for monitoring. More space is usually found around these units to accommodate valves, bottom sediment, and water sight glasses. Sample tubes or ports to pull oil from the unit for in-house or outside analysis to be performed are a must.

Hydraulic units require very clean lubricating oil. Sample ports can easily be used at various locations. Standard practice for oil sampling with outside laboratories once or twice per year may be good enough. But does it give us enough time to react? This is where in-house oil sample analysis can fill in the gaps.

With an inexpensive microscope, having 40 to 60 power magnification is all that is needed to identify or at least give us a good idea as to what is in our oil. A patch test kit with a vacuum pump that can double as a sample extraction pump completes the kit for particle identification. Monthly oil sampling with the ability to correct any anomalies with off-line filtration is a winning combination. Filter carts are considered a must-have to maintain cleanliness levels of your choice and can also absorb a modest amount of dissolved water with the use of desiccant filters.

Water saturation testing is a test needed to be sure our oil is and remains dry. Portable water sensors are certainly more expensive but the cost is easily justified in a very short period of time. Changing oil need not be the only solution. Consider the cost of new oil, added to the cost associated with the disposal of used oil, only to find out in two weeks your back to square one. Vacuum dehydrators, air strippers, or centrifuges can be purchased or rented and in a very short period of time can pay for themselves.

Outside oil analysis performed annually is, of course, better than no analysis at all. Today our equipment is running faster with closer tolerances, so it stands to reason we need to know, not guess, at what is in our lubricating systems. In-house oil analysis performed often with outside laboratories confirming or eliminating our suspicions seems, to me, to be the best way to go.

Please note: The Off-Line Filtration Schedule and the Water Saturation Monitoring Chart was developed with the assistance of my then supervisor, Mr. Brian Thompson, so that a history could be maintained. I was able to keep track of eight filter carts and a vacuum dehydrator along with the types of oil that were being filtered.

Equipment #	Filter Cart	Date On	Date Off	Oil Type	Hydraulic/Gear Oil
530-270-505 #1D.W.Press				Nuto68	Hydraulic
530-270-504 TRP#2,2				Nuto68	Hydraulic
520-263-501 Imp. Preheat Plug Screw				SHC320	SHC
520-263-502 Imp. Plug Screw				SHC320	SHC
520-263-503 Primary Plug Screw				SHC320	SHC
530-270-506#2D.W.Press				Nuto68	Hydraulic
520-271-503 Primary Ref. Hyd.				Mobil 626	Gear
520-271-506 Sec. Ref. Hyd.				Mobil 626	Gear
520-271-507 Rejects Ref. Hyd.				Mobil 626	Gear
520-271-501 Primary Ref. Motor Lube				Nuto32	Hydraulic
520-271-502 Sec. Ref. Motor Lube				Nuto32	Hydraulic
520-271-503 Rejects Ref. Motor Lube				Nuto32	Hydraulic
530-270-502 TRP#2,1				Nuto68	Hydraulic
530-270-501 TRP#1,1				Nuto68	Hydraulic
530-270-503 TRP#1,2				Nuto68	Hydraulic
520-270-506 Rej. W.Press				Nuto68	Hydraulic
530-245-501 MC Tower				Mobil 320	SHC
530-245-503 Sec stage bleach tower				Mobil 220	SHC

Fig. 1. (Above) Off-Line Filtration Schedule *Fig. 2. (Below) Pall Water Sensor 04 (Temcell2)*

Garry Sands is currently employed at Tembec Inc., a pulp and paper industry located in Temiscaming, Quebec, Canada. He is in the vibration analysis department in the sulphite division at the Temiscaming site.

Pall Water Sensor 04 (Temcell 2)

Date	Primary Refiner	Primary Refiner Motor	Reject Refiner	Reject Refiner Motor	Secondary Refiner	Secondary Refiner Motor	Reject Wash Press	TRP #1 1st stage	TRP #2 1st stage	TRP #1 2nd stage	TRP #2 2nd stage	Dewatering press #1	Dewatering press #2	#1 Conflo	#2 Conflo
	520-271-505	520-271-501	520-271-507	520-271-503	520-271-506	520-271-502	520-270-506	530-270-501	530-270-502	530-270-503	530-270-504	530-270-505	530-270-506	520-271-508	520-271-509
	Mobil 600XP68	nuto 32	Mobil 600XP68	nuto 32	Mobil 600XP68	nuto 32	nuto 68	nuto 68	nuto 68	nuto 68	nuto 68	Mobil SHC 525	Mobil SHC 525	nuto 46	nuto 46

management

Ps planning and scheduling

__Editors note:__ We have invited our good friend and world-famous author Ricky Smith to write a series of articles on a Day in the Life of a... for the various roles in maintenance reliability. Please e-mail me if you want to write about a day in your life at __tohanlon@reliabilityweb.com__

Ricky Smith

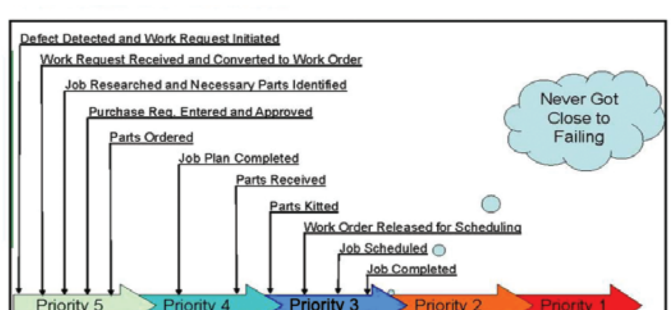
A Day in the Life of a Proactive Maintenance Supervisor

A Daily Planner for Effective Maintenance Supervision

Maintenance supervisor updates equipment status and production/ operation changes.

A maintenance supervisor should know the work scheduled for their maintenance staff a week prior, and then review the work the afternoon prior, and at the start of his/her shift. The process on the afternoon prior involves reviewing the next day's schedule with the planner/scheduler to ensure the next morning all maintenance technicians are aware of their work for the day; parts are staged, tools are available, and all coordination has been previously completed. If changes need to be made to the planning or scheduling, they can be adjusted at this time.

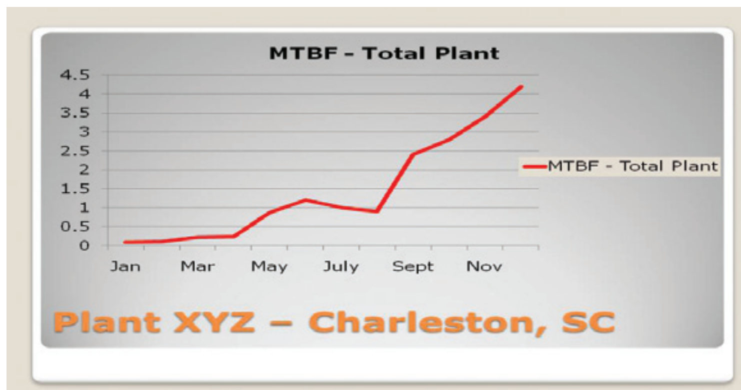
One hour before the morning shift, a maintenance supervisor ensures nothing has changed before their technicians are ready for work. The maintenance supervisor will receive an update on production or equipment conditions, or any problems that happened overnight from their shift personnel and production/ operations supervision. This ensures the work scheduled for the day will go as planned when the technicians arrive at work. Any last minute changes can be made prior to his/her technicians arriving for work.



The goal is to ensure maximum utilization of all resources with little confusion at the start of the day's shift. "In a horse race, if a horse walks when the race begins he/she will end the race last; maintenance technicians are the same." A maintenance supervisor wants his/her technicians to begin their shift out of the gate running, and thus run all day effectively and efficiently.

Maintenance supervisor visits job sites to ensure no problems exist that will cause problems with the execution of the maintenance schedule. *(Change the time you execute this function day to day so your staff does not know your schedule.)*

The maintenance supervisor makes his/her rounds to ensure all work has started on time and no problems exist. If personnel are at a remote location, a call on the radio or text on the cell at a specific time validates that either everything is on schedule, or "we have a problem."



While the supervisor is making his/her rounds they should be performing QA/QC checks on the work being executed. Is the maintenance tech following a repeatable procedure? Is he/she using the right tool for the job? etc.

If a maintenance tech is working on a critical job, then he/she should call or text at a specific time to update whether everything is OK, or if there is a problem. This is key to the success of a critical job, otherwise maintenance techs get involved in the problem and think they have it resolved, however it continues on until it is too late and production or operations is impacted. It is important to always know in advance of a problem so it can be resolved quickly, possibly with more resources or coordination from production or operations.

Meeting with maintenance planner/scheduler, or both if they are different people.

It is best for this meeting to be held after the maintenance supervisor walks around checking on the work. In this meeting, we are looking forward to ensuring that planning and scheduling is effective.

This meeting is typically held in the morning to discuss or review any work that is required for the following week, new requests from management, projects in each area of responsibility, etc. This may require a visit to a job site which is to be planned and scheduled in the future.

Validating work order close out.

Sometime during the day, the maintenance supervisor should validate that all work from the previous day is accounted for by a work order and ensure the work order codes are accurate before any work order is closed. If a problem exists with the work order codes and information, the maintenance tech or techs should hold a meeting a few minutes before the end of the shift to ensure the codes are corrected and that the maintenance tech knows why they need to be changed.

Afternoon review of job packages for next day.

The planner/scheduler arrives at the supervisor's office for 10-20 minutes to ensure the job plan for tomorrow will be executed without a problem. This was talked about at the beginning of the article.

Metrics / KPIs or Dashboard for the maintenance team.

As a result of the maintenance team's actions and the planner/scheduler's hard work, the team should know if their work is making a difference. A few Key Performance Indicators (KPIs) should be posted in the shop for all to see. If a KPI is not showing positive results, a maintenance team meeting may be scheduled for the next day. A maintenance supervisor wants the maintenance techs to identify the problem and identify a solution to improve the KPI. This requires patience and leadership.

A few KPI ideas are Mean Time Between Failure of critical assets, systems, etc., Mean Time Between Repair, and Equipment Availability. These should be posted in a line graph so trends can be seen. A correlation analysis should be completed monthly of these KPIs to validate if they impact production/operations KPIs.

This article was based on my experience as a maintenance supervisor and years of helping other maintenance supervisors become successful. If you have questions, comments, or want to receive my Tool Box Training Sessions, please contact me at rsmith@gpallied.com.

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

Ricky Smith

Accurate Work Order Close Out

"TOOL BOX TRAINING"

Reference: ISO 14224

Accurate Work Order Close Out is important for the continuous improvement of any organization. The objective of accurate data collection is to assist management in making the right decisions at the right time.

General Rules:

1. Work Orders should have at the minimum: the correct code (breakdown (1), urgent (2), etc.); the correct equipment number, at the right level; the maintenance person's accurate total work hours charged to this work order; the start time and complete time on the job; comments from the maintenance person as to what work was performed, or any recommendation to changes to maintenance strategy or plan; any parts used whether from the storeroom or not; and the maintenance signature.

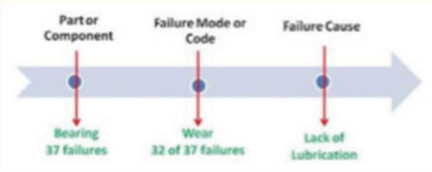
   Without this information one cannot determine:

   - Actual maintenance cost for specific assets.
   - Mean Time Between Failure
   - Mean Time To Repair
   - Mean Time Between Repairs
   - Rework
   - If a PM Procedure is effective.
   - If a specific type repair is effective.
   - If a maintenance strategy meets the intent of maintenance.

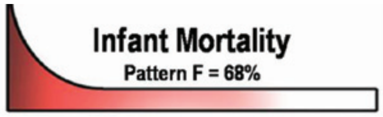
2. Repair or Corrective Work orders must have everything as stated above, plus component code, failure code, and cause code.

   Without this information one cannot determine:

   - Dominant Failure Thread—which component has the most specific failure modes with a specific cause across multiple assets.

   - Dominant Failure Pattern—which failure pattern is the most dominant, and what the major causes of failures for this pattern are. This allows one to develop strategies to eliminate unacceptable failures which impact the organization.

   Random = 89%

3. What should a Work Order have on it for Preventive Maintenance or Predictive Maintenance?

   - The method to prevent or predict known failure modes. (Failure mode—how something fails)
   - On a PM procedure, it should have specific steps and specifications on what is to be done to known best practices.

     Example: Lubricate Bearing:

     Step 1: *Clean the grease fitting.*
     Step 2: *Clean the end of the grease gun.*
     Step 3: *Insert 4 grams of lithium grease (two shots).*

   - Comments on the procedure as to the effectiveness of it or recommended changes required.

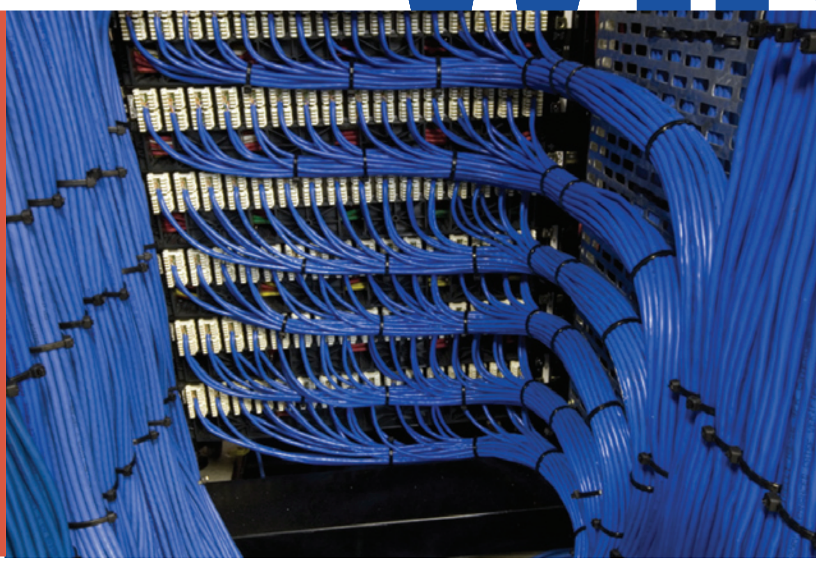
If you have questions or would like to receive the Tool Box Series, send me an e-mail to rsmith@gpallied.com

decision support

cMms computerized maintenance management system

WIRING Your Assets for Success

Tracy Smith and Clay Bush



Introduction

Does your control system (e.g., SCADA, BAS, HMI, Historian) pass critical asset performance data, such as run-time readings, energy consumption and operating condition, on to your Enterprise Asset Management (EAM) system?

If you answered "no," you are not alone. Our experience reveals that the majority of industrial and facility control systems do not communicate and share data with the EAM system. This is unfortunate and places the maintenance organization at a disadvantage.

The Problem

Asset performance data fuels predictive, condition-based and reliability-centered maintenance strategies. Capturing run-time readings, energy consumption, condition and qualitative data in the EAM system on a *real-time* basis can save time, reduce maintenance costs and improve asset reliability. Obtaining quick and efficient access to asset performance data should be mission critical for every asset management operation.

However, asset performance data contained in the control system rarely makes it to the EAM system, which tracks maintenance and repair activities. **The most important information about the asset – its run-time, energy usage and condition information – never gets to the place where it is needed most: the EAM system and into the hands of the maintenance organization.**

Therefore, maintenance organizations are required to perform activities with an incomplete picture of asset health. Handicapped by a lack of real-time asset performance data, this problem creates a significant informational gap between the operational and business layers of the organization, compromising both production and asset management operations.

Asset performance data fuels predictive, condition-based and reliability-centered maintenance strategies. Capturing runtime readings, energy consumption, condition, and qualitative data in the EAM system on a real-time basis can save time, reduce maintenance costs, and improve asset reliability.

The Solution

The fix seems readily apparent.

- Integrate the EAM system with the control system.
- Pass asset run-time, energy usage and condition data directly to

the EAM system for tracking, alerts, auto work-order generation, and analysis.
- Achieve a one-stop shop in the EAM system for all asset maintenance and cost information.
- Utilize the EAM system they way it was intended: a data repository, a hub for which ***all*** asset data, past and present, are captured, tracked, and analyzed.

Easy, right?

No, it has not been that simple. To date, system integration has historically been perceived as complex, expensive, risky, and only in the realm of the large company IT departments or system integrators. Different types of databases, table structures and system constraints have added costs and headaches to the process of getting systems to communicate. These difficulties have spawned an effort toward system consolidation (a one "software jacket" fits all approach), implemented at the expense of system functionality and the user base.

However, this environment is rapidly changing. Advancements in technology, service-oriented architectures, and the use of open XML (Extensible Markup Language) communication standards are bringing down the costs and simplifying system integration efforts.

Maintenance organizations can now realize both the benefits of best-in-class EAM system functionality and the sharing of critical asset information without breaking the bank and causing IT migraine headaches. Connecting maintenance systems to operation control systems is fast becoming a standard within reach of all sizes of businesses. Database management technologies and platforms are now making condition-based maintenance a reality, not just a lofty concept preached at maintenance excellence seminars. Technology is driving this reality and revolutionizing how maintenance organizations manage their assets.

Client Example

Stratum recently integrated the Des Moines Waste Water Reclamation Authority (WRA) EAM system with their SCADA (Supervisory Control and Data Acquisition) system. Abnormal equipment readings set off e-mail alerts and auto-generate work orders to notify their maintenance department of the potential problem. This helps keep assets running at their peak efficiency. Additionally, their energy usage data is converted to dollars and associated with the asset's maintenance costs. Now EAM can report to WRA the total operating costs of the asset.

By connecting the EAM to their SCADA system, WRA expects to improve the operating efficiency of their blowers and main pumps, which will translate into $41,584 of savings per year.

Summary

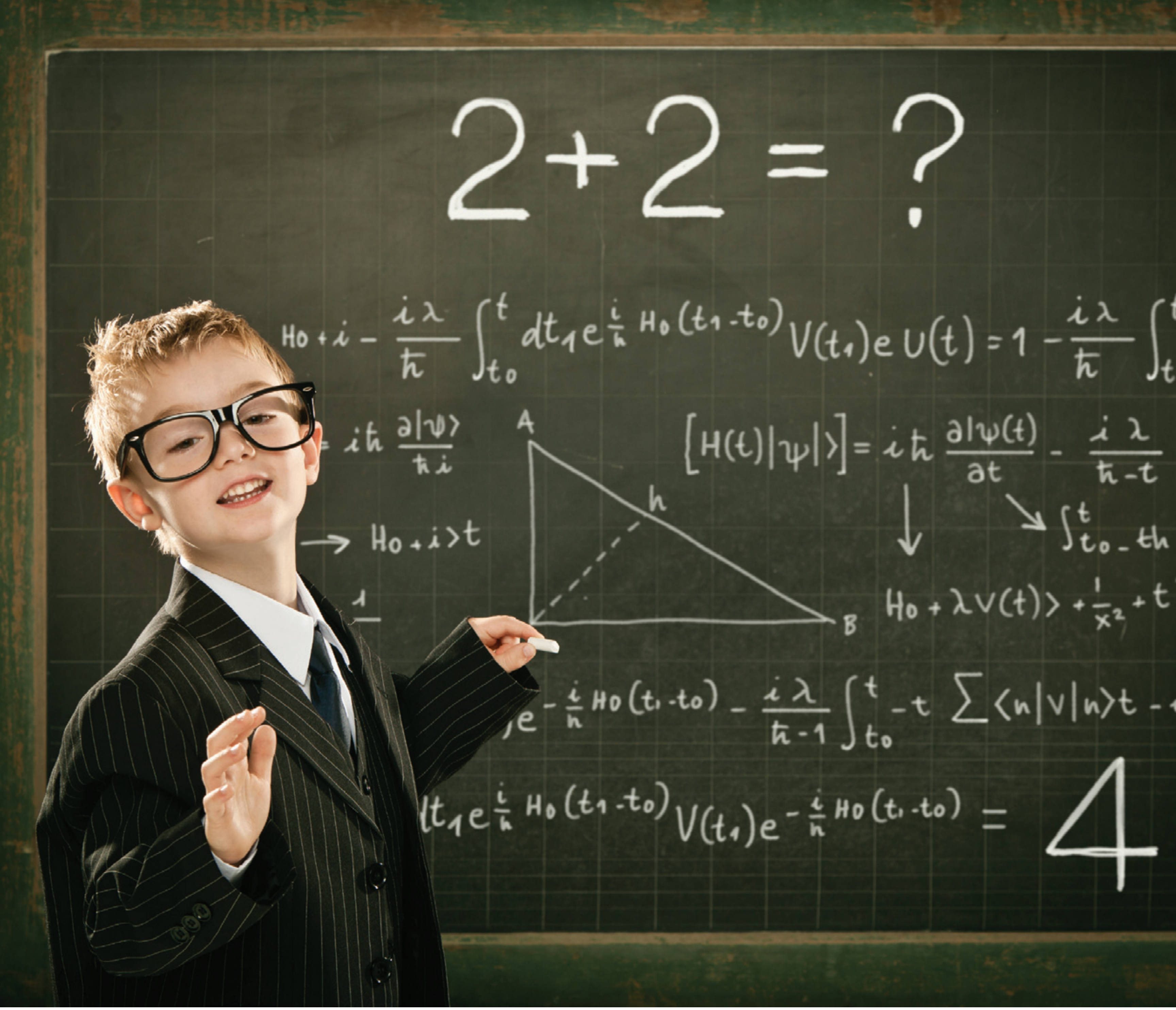
Integrating the EAM software application with external data sources is critical to the long-term success of the asset management operation.

Getting EAM and the operation control system to communicate allows maintenance to be performed based on objective evidence of need or the condition of the asset—not solely on historical work orders and worst-case failure rates. This communication improves equipment effectiveness, increases labor productivity, and helps capitalize on the full life cycle potential of equipment.

Wiring the EAM system directly to the performance of your assets has never been easier and more affordable. Connecting EAM to the operation control system places the right data into the hands of the right people, at the right time, supplying maintenance organizations with all of the data they need in order to optimize their asset management operations.

Tracy Smith is Stratum's managing partner and leader of business process services. Mr. Smith has fifteen years of experience implementing asset management Best Practices for some of the largest companies in the world. Mr. Smith has led and been heavily involved with the successful implementation of Best Practices and EAM system implementations for over 100 companies. www.stratumcp.com

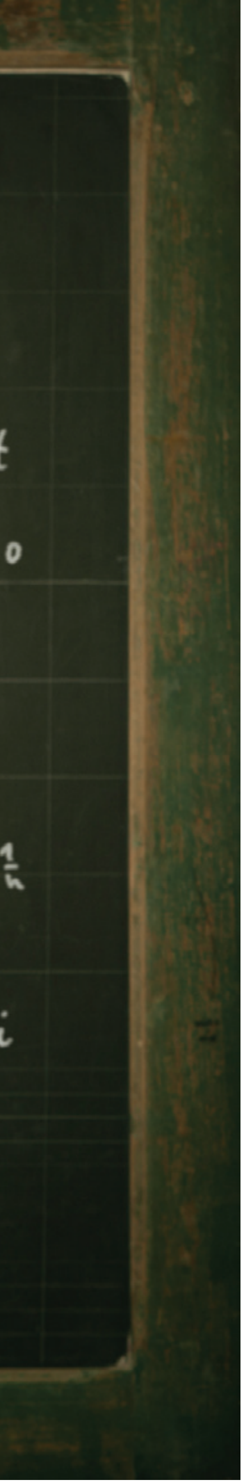
Clay Bush founded Stratum Consulting Partners in 2003. Mr. Bush's roles at Stratum include company operations and client satisfaction, consulting in Business Intelligence, Mobility Applications, Enterprise Asset Management, and related services. www.stratumcp.com



High Operational Autonomy A Formula

Ron Moore

+ Low Financial Autonomy: for Failure



Editors note:* When asked about what book to read to prepare for maintenance professional certification, I recommend Ron Moore's** Making Common Sense Common Practice ***first. After you read this new article by Ron Moore you will have an idea why. –Terrence O'Hanlon

Background and Introduction

During a recent meeting, a mid-level manager with a large petroleum company was asking my opinion about which manufacturing and industrial companies were the best in the world. My reply was that most large organizations had manufacturing plants that covered the spectrum ranging from very poor to excellent, but none that I had direct experience with stood out to me as being consistently excellent in their manufacturing practices across the board— that is, in most all plants. As part of that discussion, he also asked, "How much autonomy do site managers have (in the organizations you've seen)?" I had to think for a moment, at which point I said, "They have very little financial autonomy, and nearly complete operational autonomy, a recipe for highly variable performance, and ultimately, failure." I'll explain my view.

I've have the good fortune to have been in several hundred manufacturing and industrial operations, across a variety of industries, e.g., automotive, chemicals, food, mining, paper, petrochemicals, petroleum, power generation, refining, smelting, waste water treatment, and so on. In each of the large organizations I've observed, the range of performance across their operating plants has typically been from very poor (dangerously so in some cases) to excellent, as demonstrated by a number of measures. As you might expect, the worst ones were typically nasty and had low morale, while the best ones were very neat, clean and highly motivated. Why is it then, that within a given organization, you can have such a wide range of performance? Aren't they driven by the same policies, standards, practices, and leadership? And, if so, shouldn't the results at each of the plants be substantially closer to the mean? And, shouldn't the mean be substantially above that of their average competitor? Apparently not, or at least I haven't observed it yet.

The Cause

Why is this? While the causes are numerous, I believe that a major contributor to this high level of variability and general overall mediocre performance within a given organization, is the low degree of financial autonomy that occurs simultaneously with a high degree of operational autonomy. I also believe this higher level of variability results in a higher degree of failure. Mathematically speaking, High Operational Autonomy + Low Financial Autonomy = Overall Mediocrity + Frequent Failure. As Deming said, "Consistency of process and constancy of purpose are essential."

In my years working with clients, there has always been pressure to reduce costs, and this pressure has only intensified as the years have passed as the globalization of capitalism has taken a strong hold on the world. This pressure is particularly severe when a downturn in the market place occurs, as it has over the past two years. The drive behind this is simple—we, as consumers, tend to buy the cheapest goods that meet our requirements. This drives prices, and necessarily costs, downward. While it's not an absolute truth, it is a dominant human behavior. Manufacturers know this, and so they work really hard to put the cheapest item in front of us, and still make a profit. This tends to drive down prices, and so costs have to come along with that, keeping the pressure on reducing costs.

Now, let's combine that with a tendency to move managers around, for example, changing plant managers every two or three years as is common in many organizations. And, finally, let's top that off with minimal financial autonomy and maximum operational autonomy. It's a recipe for failure. Let's consider this further.

It's been my experience that the site managers at most of these operations have very little financial autonomy. For example, it's common that a site manager running a $500 million operation (capital replacement cost), that is likely spending $300 to $400 million per year in labor, raw materials, energy, contractors, etc., would have to get approval from the VP of operations for a $25,000 capital improvement; or to hire even one additional person; and sometimes to even hire replacements for those who have left, leaving an open employment slot within the organization. On its face, this seems absurd to me. If a manager is good enough to manage such a large operation, shouldn't that manager be good enough to have wide autonomy when it comes to capital and personnel decisions, and to actually manage the business? It would seem so. While I may have only been exposed to those that take this approach, my experience has been that site managers typically have little financial autonomy in this regard.

While having limited financial and personnel authority, it's also been my experience that a typical site manager has wide operational autonomy. What standards are applied? What practices are in place? How well are those practices employed? How do we know what best practice is? And so on. There is a high degree of variability in the application of policies, principles and practices at each plant. For example, in working with a large Fortune 500 manufacturing company, we found that the range of scores in a review of their manufacturing practices, normalized to a 100% scale, was from 36% to 82%, more than a factor of two between the worst and best. We also found that their manufacturing costs (cost of goods sold, in accounting language) for similar products ranged from 50% to100%, also a factor of two.

How can this be, particularly with regard to their practices? It's easy enough to understand structural advantages at a given plant giving it cost advantages, e.g., lower energy and/or raw material costs, being closer to market, having lower labor costs in a given area, etc. However, what is more difficult to understand is the wide variation in actual practices. Repeating from above, don't they have the same policies, principles, practices, and leadership? Apparently not, is the short answer. There is a huge variation in the practices at each plant. And very little financial autonomy.

Let's pretend you're a new plant manager and you only expect to be in a given operation for two or three years. It might take 6 to 12 months to get to know your job—the plant, people, product mix, etc. On top of that, let's add intense financial pressure. Will you be thinking about the impact of your decisions on the business in 3 to 5 years? Not likely, particularly if you know you're only going to be there for 2 or 3 years. You're just hoping to get through the next couple years unscathed. So you're more likely to do short-term things that cut costs, without much consideration given to the long-term impacts. Some examples include reducing training and employee development, delaying projects, delaying major shutdowns and overhauls, delaying infrastructure work, delaying other maintenance (indeed, cutting maintenance budgets).This works for a while, long enough to get you through to your next job. You have no financial autonomy, so you cut what you can, irrespective of policies and practices. You manage budgets on a monthly and quarterly basis; not business performance on an annual or bi-annual basis. Sadly, the longer term result of this is typically poorer performance. But since most organizations do this, competitive parity prevails and everyone ends up at or near the same level of performance.

The Solution

My view is that site managers should be given more financial autonomy and less operational autonomy, and kept in their positions for a minimum of 5 to 7 years, so that they will reap the rewards, or bear the consequences, of their decisions in earlier years.

Give them less operational autonomy. What I mean here is, for example, at the corporate level, high operational standards developed in cooperation with the sites *must* be followed, much the same as safety standards *must* be followed. For example,

More importantly, production and maintenance would work as a team, and would have cross-functional teams and measures to assure this.

operating standards would include: a) every shift running the process *exactly* the same way for a given process and product—no shiftly "tweaking of the dials"; b) a definitive shift handover process and alignment of all shifts to a specific standard and set of goals that are reviewed briefly each day/shift; c) standards for operator care, tours, ownership and monitoring of equipment condition; d) a process conformance model for assuring process stability for all key process variables and minimizing nonconformances; e) training, development and demonstration of skill sets required for each job; f) production plans which *include* the maintenance plans, and the production manager being held accountable for meeting this plan; g) routine checks for the quality of, and adherence to, startup, shutdown, and operating procedures and checklists.

Similarly, maintenance standards that *must* be followed would include, for example: a) high-quality lubricants that are filtered to a specific ISO standard for each applica-

tion, including storage, use, color coding, etc.; b) balancing and alignment of rotating machinery to a specific ISO standard for each machine; c) work management and planning and scheduling standards, along with disciplined adherence to that plan (remember that production will be held accountable for meeting this plan as well—no finger-pointing); d) excellence in condition monitoring to detect pending failures early enough to minimize their consequence, and a strong link into maintenance planning; e) excellence in routine PM and inspections, with specific standards/criteria for determining if a defect is present, or absent (for example a PM that says "check motor" would be ***un***acceptable); f) stores and spare parts fully integrated into maintenance planning. The list goes on, but this should be sufficient to illustrate the point of having high standards that must be followed.

All this would be combined with a challenge to all functional groups to work together toward a higher purpose—business success. These standards would be reviewed and assessed periodically by corporate support groups that are competent to support each area identified for manager who is responsible for $300-500M in capital replacement value, and/or $300-500M in cost of goods sold, would have signature authority for $1M in capital and for hiring additional people (or reducing people) within 2–5% of the existing levels, or of the levels approved in the annual plan. A good manager needs some flexibility in managing cash and expenses while simultaneously being held to a high standard for

As Deming said, "Consistency of process and constancy of purpose are essential."

operational excellence. No "seagull" audits—swoop, poop, and squawk—would be allowed. The support groups would "own" the problems they found and help the sites to eliminate them, and be held accountable to measure their progress in doing so. More importantly, production and maintenance would work as a team, and would have cross-functional teams and measures to assure this. For example, production would be held accountable for PM compliance, and maintenance would be held accountable for on-time delivery. Thus if maintenance wanted to do PM that affected delivery, they would think twice. Likewise, if production wanted to ignore PM to meet delivery, it would think twice. This list goes on as well, but I hope the points are made.

Give them more financial autonomy. While the actual numbers will vary from one business to another, perhaps a site operating practices, with these practices being audited annually in the first 3 to 5 years, and perhaps bi-annually after demonstrating they can hold their performance to that high standard. They must deliver consistent results to the business in terms of gross profit contribution, on-time delivery, and quality product, while maintaining high inventory turns, and high operational standards that are demonstrated to be sustainable over the years.

Ron Moore is the Managing Partner of The RM Group, Inc. He is the author of Making Common Sense Common Practice: Models for Manufacturing Excellence, *and of* Selecting the Right Manufacturing Improvement Tools: What Tool? When?, *from the MRO-Zone.com, as well as over 40 journal articles.*

condition monitoring

ViB vibration

Successful Solution *to the Challenge of* Low RPM Bearing Monitoring

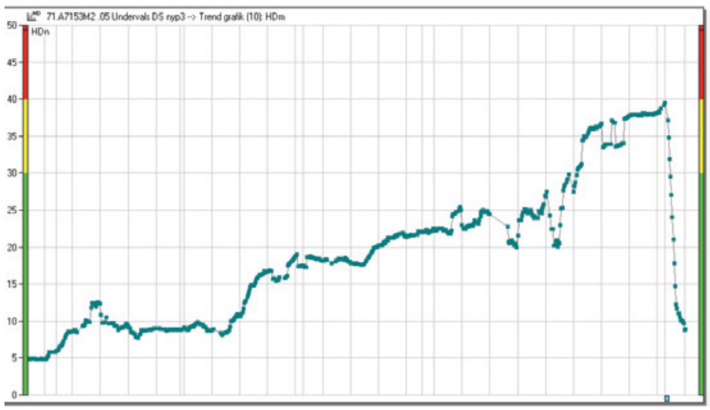
Tim Sundström

Low RPM applications have been notoriously difficult to monitor with traditional vibration-based techniques. The energy involved at RPMs below 50 is very low, making it a difficult task to extract meaningful information from the measured signal.

Using the newly developed SPM High Definition (SPM HD) method, we have been able to reveal never-before-seen details at very low RPMs (< 5 RPM). The SPM HD method is based on the fact that in the interface between the rolling elements and the raceways in an antifriction bearing, elastic, very short duration waves are generated. Damage—for example, a spall or a crack—will generate a high number of elastic waves due to the metal-to-metal collision when the rolling elements pass the damaged area. Using a transducer sensitive to these elastic waves makes it possible to record and quantify the waves. The transducers should be permanently installed, either mounted in drilled, countersunk mounting holes on the bearing housings, or glued onto the surface. For best results, the transducers should be mounted close to the bearing load zone.

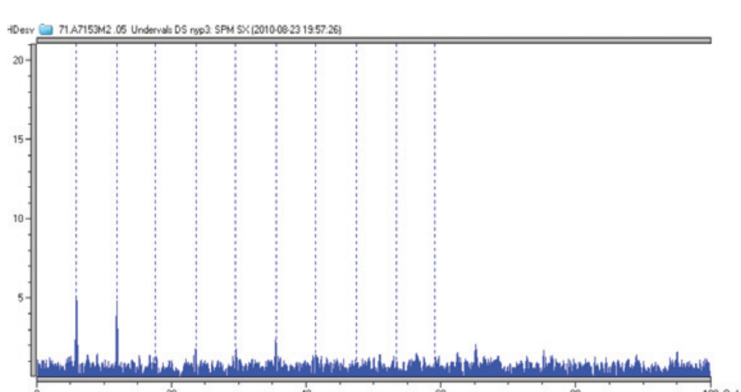
At Holmen Hallsta paper mill in Sweden, a field test on four twin wire presses (used in the pulp industry for dewatering purposes) has been running for nineteen months. During this period, thirteen bearing faults have been successfully identified. There are examples from the test period where the pre-warning time has been over fourteen months between the first damage indication and replacement of the bearing. A more typical pre-warning time is about six months. Typical RPM ranges from 7 to 16. The system is taking measurements every 6 hours and a typical measuring time at this RPM range is about 10 minutes.

Using a real case example from the twin wire press application, Figure 1 is an account of the different stages of the bearing deterioration process, detected with the SPM HD method.

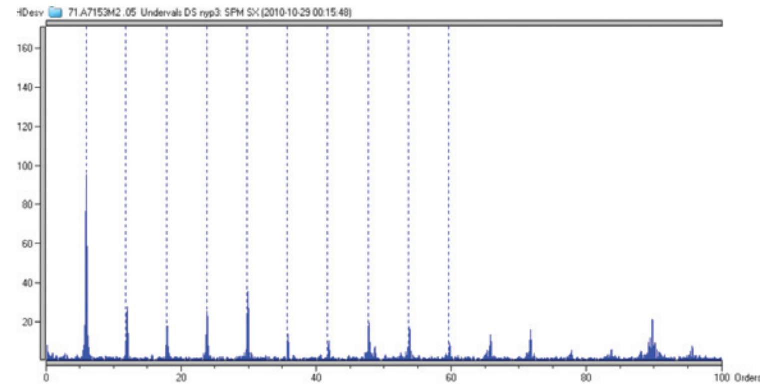


Above: An SPM HD trend spanning between mid-June, 2010 to end of November, 2010, showing 624 readings taken approximately 6 hours apart. The graph shows the primary parameter produced by the SPM HD method: the strongest impact found during the measuring time. The Y scale is logarithmic.

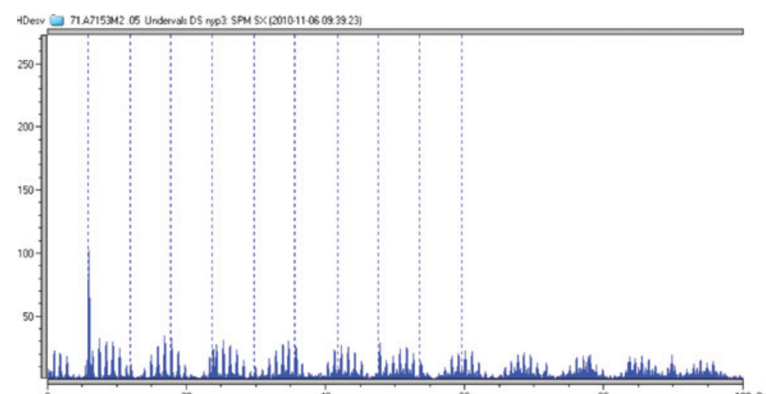
The difference between the lowest and the highest value in the trend graph is about 30 dB (30 times on a linear scale). The drop in the value from 40 dB to 8 dB is after bearing replacement. A moving average filter has been applied with 10 average values. This explains why the values seem to decrease slowly after the replacement. Note the typical pattern of increasing values followed by a period of decreasing values. This behavior is caused by fresh spalling followed by a period of mechanical softening of the sharp edges around the spall. When the rolling elements collide with the sharp edges of the spall, strong elastic waves will be generated at the point of collision. After some period of time (a couple of weeks in this application) the sharp edges wear down and the metal-to-metal collisions become less strong, hence decreasing the strength of the elastic waves. The next spall will then generate a similar pattern.



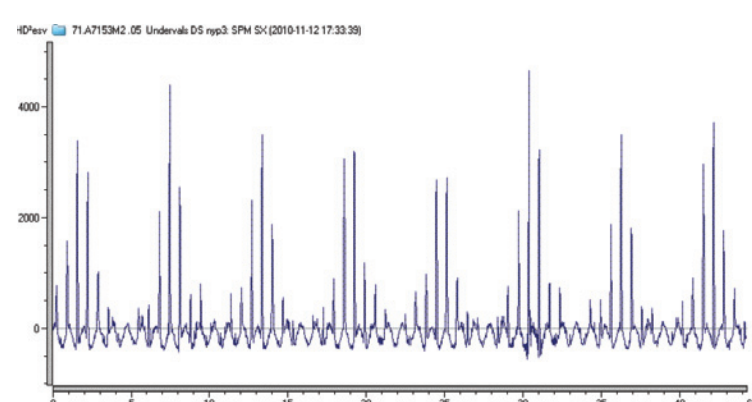
Above: An SPM HD Spectrum taken in a very early stage of the bearing deterioration process. The Y scale is linear and 5 harmonics to the BPFO line can be seen. The reading was taken on August 23, 2010 and RPM on this occasion was 9.39.



Above: An SPM HD Spectrum measured on October 29 at 10.84 RPM. The outer race signal is clear, with several harmonics. The amplitude has increased 20 times indicating more severe outer race damage.



Above: On November 6, 2010, a new frequency component becomes visible in the spectrum, directly corresponding to the BPFI. The outer race frequency is still there, and the typical 1X modulation of the inner race signal is obvious. This measurement is at 10.85 RPM. This behavior of an initial steady increase of the outer race signal, followed by a distinct inner race signal, has been found in several places on this application.

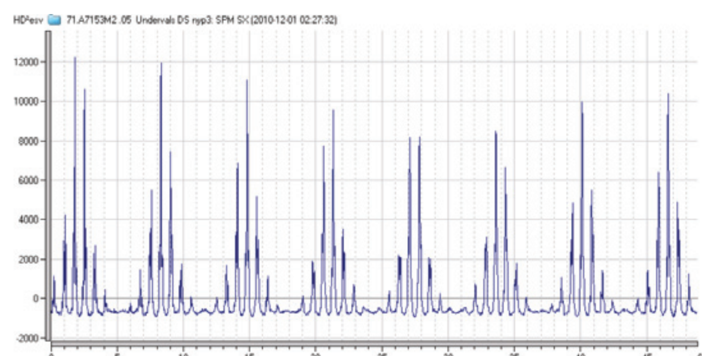


Above: An SPM HD Time signal with extraordinary sharpness.

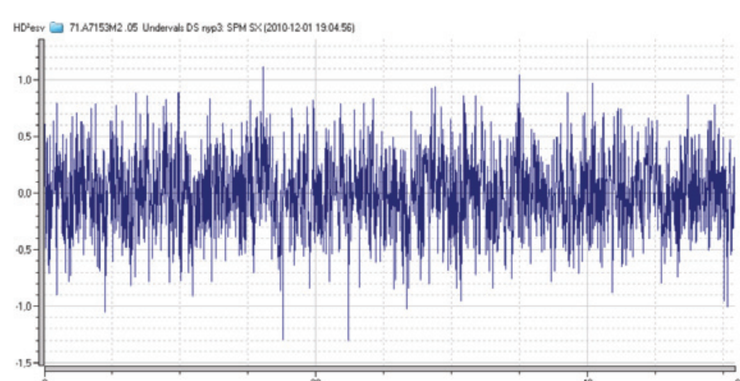
The reading was taken on November 12, 2010 and clearly shows an inner race and an outer race signal in combination. The RPM is 10.84. Note the inner race modulation where the distance between the "bursts" is exactly 1 revolution. Also note the smaller signals from the outer race.

The typical time signal pattern from an inner race damage as seen in this picture is explained by studying a bearing load zone. When the inner race damage enters the load zone, it will collide with the rolling elements. In the middle of the load zone, the forces are strongest, hence producing the strongest impacts. When the damaged area of the inner race leaves the load zone, the impacts will decrease again.

The fact that the strongest impacts are not constant in amplitude is an interesting observation. Studying the picture above, it is clearly seen that the strongest impact from each "burst" exhibits a cyclic change. The explanation can be found in bearing geometry. Sometimes, the damaged area, the maximum load zone force, and a rolling element coincide, producing a strong collision. Sometimes they will not coincide, resulting in a lower amplitude impact.



Above: SPM HD Time signal immediately before bearing replacement.



Above: SPM HD Time signal immediately after bearing replacement.

In the two figures above, note the amplitude compared with the picture from before bearing replacement. The amplitude difference between a damaged bearing and a new one is obvious.

As mentioned earlier, this is but one example from the twin wire press application. The other twelve cases are similar to this one. In most of the cases, the increasing/decreasing trends are more pronounced. Based on the twin wire press application as well as other low RPM applications, our experience is that due to the increasing/decreasing trends, measuring with handheld equipment is not advisable for low RPM applications. There is an obvious risk that the measurement was taken during a period where the edges of a possible spall are "soft," and therefore produce low amplitude impacts. Unless measured very frequently with handheld equipment, we strongly recommend continuous measurements using online equipment.

Disassembled bearing with spallings.

Conclusions

The SPM HD method enables measuring results with exceptional clarity. Even on low RPM applications, spectrums and time signals are crisp. In field tests running for more than nineteen months, we have been successful in the identification of bearing damages, typically with six months pre-warning time before the actual bearing replacement.

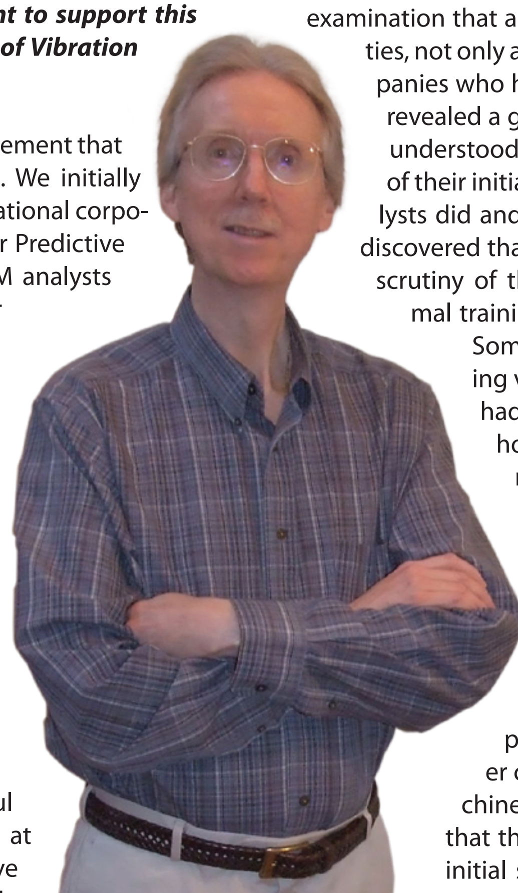
Tim Sundström, born 1964 in Sweden, has a M.Sc. degree in Applied Physics and Electrical Engineering from Linköping University, Sweden. For over twenty years, he has been specializing in electronics development and has held managerial positions in the field since 1992. In 2001, he joined SPM Instrument as head of Research and Development, where he has been deeply involved in SPM HD development and field evaluations. Visit www.spminstrument.com

Q&A

Terrence O'Hanlon, Publisher at *Uptime* magazine recently caught up with entrepreneur **Jim Berry of Technical Associates, whose company has now certified 10,000 Vibration Analysts.**

***Q** Jim, we understand that your company, Technical Associates of Charlotte, has just certified its 10,000th vibration analysis student. That is quite an accomplishment and aligns well with Uptime Magazine's mission of promoting professionalism in the maintenance reliability community.*

What is the secret to getting management to support this important employee development resource of Vibration Analyst Certification?



A It is primarily plant and corporate management that has driven certification of vibration analysts. We initially encountered this in early 1989 when a multinational corporation needed to get a solid feel on how their Predictive Maintenance (PdM) programs *and* their PdM analysts stacked up in comparison, not only with their own plants worldwide, but also how they compared with PdM programs in other corporations both here and abroad. Thus, we initially conducted PdM program audits (benchmarks) at various facilities of this one corporation, then expanded our audits to encompass programs implemented at a number of other corporations. After completing this comprehensive study, one big question remained in the mind of management: "How do we evaluate the knowledge and expertise of our own PdM analysts at each of our plants?" After much deliberation, Technical Associates was asked to develop a meaningful vibration examination that could be given at their plants worldwide to gauge the relative knowledge and skills of a large number of such analysts. When this initial exam was developed and given, the results proved to be very revealing. There were obviously some analysts who possessed a high skill set in vibration while others had much to learn.

A request was then made for an even higher level of vibration examination that again was given at a wide number of facilities, not only at this corporation, but also at outside companies who had PdM programs. This higher level exam revealed a great difference in what analysts knew and understood, and allowed management to obtain one of their initial objective assessments of what their analysts did and did not know. Near the end of 1989, we discovered that the biggest single factor revealed under scrutiny of the examinations was the amount of formal training such persons had or had not received. Some plants had analysts who had been doing vibration for many years but unfortunately had not received formal training (other than how to use an analyzer or PdM software, but not on how to detect problem conditions or faulty components from the data being captured). These analysts were doing the same thing for many years but were predominantly building large PdM databases requiring much storage; however, they were not benefiting from making diagnostic calls, evaluating problem severity, and recommending proper corrective actions on a wide variety of machinery types. On the other hand, it was found that those analysts who successfully passed this initial set of vibration examinations had for the most part received at least some training on how to interpret the data, find problems and make recommendations. Audits of programs at such plants showed much more effective PdM programs that were achieving substantially higher savings in maintenance costs and increased machine reliability and availability. Thus, "the roots" of vibration certification were born, and in 1990, our company began to give them to analysts from a wide array of industry types under the watchful eyes of both individual plant and corporate management.

Q ***How have you been able to certify over 10,000 vibration analysts?***

A Technical Associates was the first organization to offer vibration certification beginning in 1990. Since then, we have worked with certification-test psychometricians on several occasions, not only to ensure our examinations met strict professional requirements, but also to assure our tests met requirements of published standards that stipulated what was to be taught in seminars and what was to be evaluated in accompanying examinations (see information on such standards below). When we initially offered such examinations in the early 1990s, only about 25% to 30% of students elected to take them. Later, as management began to realize what certification testing could do for them, more and more students took these tests. Today, approximately 85% to 90% of students take the exams following our public seminars, and most all clients desiring in-plant (on-site) classes elect to have their analysts tested. It is interesting to note that this percentage grows higher as our students take higher level certification exams, with the highest percentage being at ISO Category IV (the highest available certification level). *Currently, only two organizations in the United States now offer ISO Category IV certification—Vibration Institute and Technical Associates*. It is a prestigious certification level.

Another thing setting us apart is that each of our instructors not only teach, but also go into the field and perform vibration analysis on a regular basis using a wide variety of analyzers and accompanying software. "If you do not use it, you will lose it."

Some persons have asked "Why is vibration certification important?" Certification serves as documented evidence that an analyst has successfully comprehended the topics and techniques taught to him or her within formal seminars. Certain corporations have begun to require certification in order for analysts to remain within a PdM team (not only for vibration, but also for other PdM technologies). In addition, some companies require that all consultants, like Technical Associates, have a minimum certification level (or "category" in the case of ISO). Finally, beginning approximately 15 years ago, certain insurance companies began requiring a minimum certification level by at least one person on a plant site to even provide coverage; and some providers began to offer discounted premiums to facilities who had a certified vibration analyst of a minimum level on site (typically Technical Associates Level II or ISO Category III).

Q ***Is Vibration Certification based on any published standards?***

A Probably the leading two published standards of today are ISO 18436 entitled "*Condition Monitoring and Diagnostics of Machines—Requirements for Training and Certification of Personnel*"; and the ASNT SNT-TC-1A document entitled "*Recommended Practice No. SNT-TC-1A: Personnel Qualification and Certification in Nondestructive Testing*" established by the American Society for Nondestructive Testing, Inc. The main purpose in adopting and complying with ISO 18436 and ASNT SNT-TC-1A is to have a worldwide recognized set of standards that stipulates what topics are to be taught in class and evaluated by certification exams.

Q ***How has Vibration Certification changed since the ISO 18436 standard was published?***

A Probably the biggest change ISO 18436 brought about was the introduction of an additional certification level—ISO Category IV. Category IV was a notable step above Category III, requiring much more in-depth understanding and proficiency with more sophisticated techniques and analytical tools. Even though many of these more advanced techniques and topics were taught by various training organizations, many of them had not yet developed certification exams of these topics. ISO Category IV requirements forced such development of exam questions and answers (in our case, we had taught "Advanced Vibration Analysis" for nearly 15 years but had never developed a test to evaluate how well students comprehended the topics taught). The other change ISO 18436 required was greater emphasis in Category IV on some topics not formerly covered in-depth by certain training organizations. Such topics included rotor dynamics, experimental modal analysis, torsional vibration, etc. Finally, one other positive thing ISO 18436 brought about at all category levels was standardization of seminar topics to be taught and evaluated on certification exams worldwide.

Q ***Is Vibration Certification only for technicians and engineers, or should managers consider earning certification?***

A At first thought, one would not normally think a manager would need to be certified at any level in a technology such as vibration analysis. However, our experience has proven to be different, particularly at lower certification levels. The problem that has plagued programs worldwide has commonly been that management initially supports PdM when a number of the more obvious problems are caught and corrected by the PdM team. However, after this initial success and visibility, many programs have fallen into oblivion if management is not continually kept informed of problems detected and cost savings achieved by the PdM Team. This is particularly the case with vibration analysis since it is not normally well understood by most all management (even degreed engineers) since universities do not typically teach rotating machinery vibration analysis. Thus, most managers do not understand what it is their vibration analysts are doing when they acquire their data with their "black boxes" and somehow find a number of problems that cannot necessarily be seen or heard.

What will the future hold? Only time will tell but it appears future developments will bring even more focus upon vibration training.

Q What methods do Technical Associates of Charlotte employ that set them apart from other training organizations?

A One thing separating Technical Associates from other training providers and consultants is that we maintain a whole staff of highly experienced vibration analysts and engineers here in our Charlotte office (called the Analytical Group). Each of our Analytical Group members (including both instructors and those who only go into the field) are experienced analysts having from 10 to 35 years vibration experience. Another thing setting us apart is that each of our instructors not only teach, but also go into the field and perform vibration analysis on a regular basis using a wide variety of analyzers and accompanying software. ("If you do not use it, you will lose it.") This is a decision we made when we began doing vibration training in 1988. Our instructors do vibration diagnostics, implement PdM programs, conduct acceptance tests, etc. We have been told by corporate management on several occasions that this is why they have chosen Technical Associates as their training provider (due to our continuing availability after a seminar is over and our remaining updated with the latest vibration analysis techniques and analyzers).

All of our instructors have been teaching vibration analysis seminars for at least 10 years for us and not only have considerable vibration experience, but also the ability to transfer their knowledge to our students. We also have the wonderful opportunity of working with hardware and software from many different major PdM suppliers and have even been allowed multiple opportunities to offer input into the development of such vibration products/tools. This gives our instructors broad expertise with many PdM systems, which benefits our seminar students who use vibration analyzers and software from a wide variety of suppliers. In addition, many years ago, Technical Associates made a commitment to hold virtually every public seminar we scheduled—and have been able to keep this commitment by holding approximately 98% of the classes over the past decade (teaching at least 100 classes per year for the last 6 consecutive years). Finally, when the class is over and the students have returned home, there is always someone here at our office from our Analytical Group to provide assistance and answer questions. This is an important point since students inevitably will have questions when they begin trying out the new techniques they have been taught using a wide variety of analyzers and supporting software (most of which we likely have).

Q Have you seen the need for training grow or contract since the recent economic downturn?

A In our particular case, the need for vibration training actually grew in 2010 despite the recession that most all the world has suffered. Probably the main reason is that during such times, unscheduled shutdowns of critical production or utility machinery cannot be afforded. Therefore, those plants and corporations who realized the power of vibration signature analysis made moves to ensure their PdM teams received the training they needed to detect faults and to prevent unscheduled failures or shutdowns. In our case, since we have the opportunity to teach so many persons holding management positions, and likewise are asked to speak at many corporate reliability conferences attended by key managers, engineers, etc., we had the distinct privilege of persuading noteworthy numbers of influential persons to persevere with (or even to enhance) their PdM programs during such difficult times. As evidence of this, during the period from October 1 through December 17, 2010 (normally a somewhat slow period), we held 31 seminars in a 10-week span (excluding Thanksgiving week), including both public and on-site classes. Our clients often told us during this time they needed such training to ensure they could maximize reliability and uptime of their machinery.

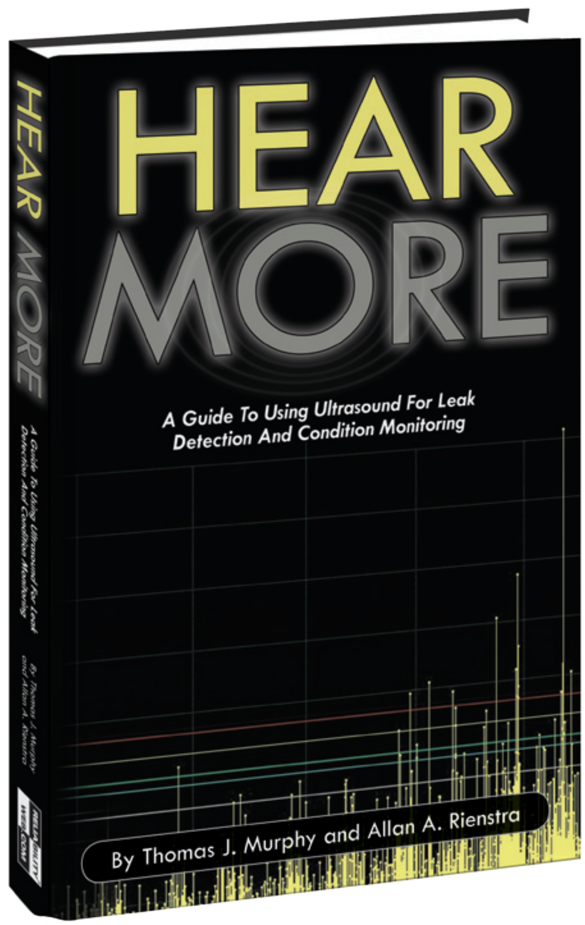
What will the future hold? Only time will tell but it appears future developments will bring even more focus upon vibration training. The need for elevating from Condition Monitoring to true Predictive Maintenance (wherein we will actually be able to predict time to failure for certain key components) is great. Work now being accomplished will demand training on how this will be done in this fascinating technology called vibration analysis.

Readers interested in more details should visit Technical Associates online at www.technicalassociates.net.

Book Review

Hear More

Reviewed by TOM BATZER



When first introduced to the world of airborne ultrasound testing nearly ten years ago, I found myself searching for a resource that I could refer to again and again, a book that was loaded with practical examples on the various uses of airborne ultrasound and which was also easy to read and comprehend. Well, Thomas Murphy and Allan Rienstra have produced just such a book.

By using this book as a reference, an end user can go to a particular chapter and find a step-by-step guide to performing a number of testing applications.

Hear More is laid out with a logical progression of topics. It starts out with the basics, including an introduction to ultrasound and the principles of sound and spends some time explaining amplitude and decibels in-depth. The authors cover various types of sensors that can be employed with airborne ultrasound, how they are useful for each particular application, as well as their limitations.

Murphy and Rienstra delve into the various applications of airborne ultrasound, such as air leaks, mechanical inspections, electrical inspections, tightness testing, friction for lubrication purposes, impacts, and linear motion. Each chapter discusses the application in detail and includes testing procedures for accomplishing these applications. Also included in each chapter are real-life examples of how airborne ultrasound is being used throughout industry and elsewhere.

With each successive chapter, the authors further explain how airborne ultrasound is a very complementary technology, working hand in hand with infrared thermography and acoustic vibration technologies, and "actually makes performing electrical inspections safer." In the chapter titled "Impacts," the authors expound on the "demystification of vibration and utilization of ultrasound," including how to record ultrasonic sound samples and use that data. The book ends with perhaps the most important task in any maintenance program: Implementation. Without implementation, it is just another tool in the toolbox; with proper implementation it is a program.

While the chapter titled "The Principle of Sound" would be easily understood by engineers, a more simplified explanation of sound would be helpful to many mechanics. That said, I strongly feel that *Hear More* will be the resource I will use often and recommend to others in the field.

While this book is not a replacement for level one or two certification, it does accomplish what its subtitle states; it is a "*guide* to using ultrasound for leak detection and condition monitoring."

Murphy and Rienstra have produced a book which would be a worthy complement to any RCM toolbox.

Tom Batzer has worked for the Smithsonian Institution for over 25 years, starting out as a building operating engineer. He currently works in the Systems Reliability Branch of the Office of Facilities Maintenance and Reliability. He holds a level 2 certification in airborne ultrasound.

MRO connection

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The art and science of optimizing your MRO investment

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The MRO Best Practices Symposium is the first and only event dedicated exclusively to MRO lifecycle management and supply chain best practices, such as:

- The quality and accuracy of MRO data – material descriptions, order points/quantities, lead times, and more
- How data is collected, delivered and integrated into EAM/CMMS/ERP systems
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Keynote Speaker

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