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Clean, Green and Reliable or Fat, Sick and Almost Dead

A reliable plant is a green plant.

I am not a radical environmentalist – but I am ho peful for a clean and healthy planet to leave to my children, grandchildren and generations to follow. All of us can and should recycle, use energy efficient lighting, use water wisely, drive more efficient cars and trucks, and keep air conditioning and heat at reasonable levels. However, I am not convinced that consumer behavior alone can change the dangerous path we are on.

Industrial energy use is a huge component of the global equation. Maintenance reliability professionals are in a great position to make a HUGE difference. I have yet to enter a plant where steam traps are not blowing or compressed air is not leaking at a tremendous rate, just to name two gigantic energy conservation opportunities.

We have put together a powerful collection of articles in the current issue of *Uptime* designed to make maintenance reliability professionals act to save energy dollars and support their companies in creating a more sustainable and profitable future. Each ***green*** reliability article is clearly marked to ensure you read it and pass it along to other energy stakeholders in your workplace.

During the creation of this issue, I happened to watch "Fat, Sick and Almost Dead," a 90-minute documentary about a 40-something Australian overweight/obese man with a variety of medical conditions who flies to America for a 60-day journey and search for health. He describes his journey as a "reboot" and carries on conversations about his approach to health with hundreds of Americans as he travels across the country.

The thing that struck me is that everyone he talked with knew they, and only they, were responsible for their overweight and non-healthy lifestyles but they lacked the knowledge to make changes. The things we see on supermarket shelves and the things we see and hear on television are not making healthy food choices obvious. Get the movie to see the story and learn the outcomes and you may find yourself on your own journey to better health.

I think there is a correlation with reliability. Management and workers know they are the ones responsible for the level of reliability. They would definitely choose reliability over unreliability if they could. The problem is what they have been told and what they think they know is often simply wrong. The more they try to apply what they know, the worse the situation gets.

Eating more micronutrient foods like fruits and vegetables and consuming less processed and macronutrient foods combined with increased physical activity is a system of health. You cannot simply exercise while eating unhealthy if you want to have energy and health. You have to do a number of things most of the time to gain and sustain high performance human health as you age.

The same goes for reliability. It is not just effective planning and scheduling. It is not simply vibration analysis. It involves a system of many elements done well most of the time for high performance reliability.

Like the people in the documentary who learned about human nutrition and exercise and lost hundreds of pounds and rebooted to live a sustainable, healthy high performance life, you might want to learn some new information about effective maintenance reliability and asset management and then REBOOT your reliability improvement efforts.

Maybe we will get a chance to meet you during your reliability reboot at Terry Wireman's Maintenance Strategy Master Class or another learning event at the Reliability Performance Institute in 2012.

Warmest regards,

Terrence O'Hanlon, CMRP
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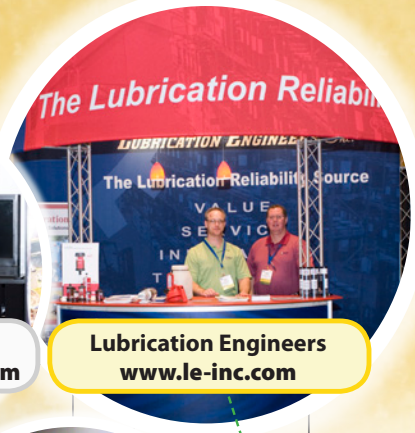

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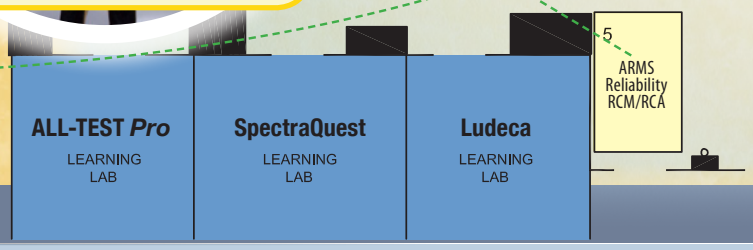

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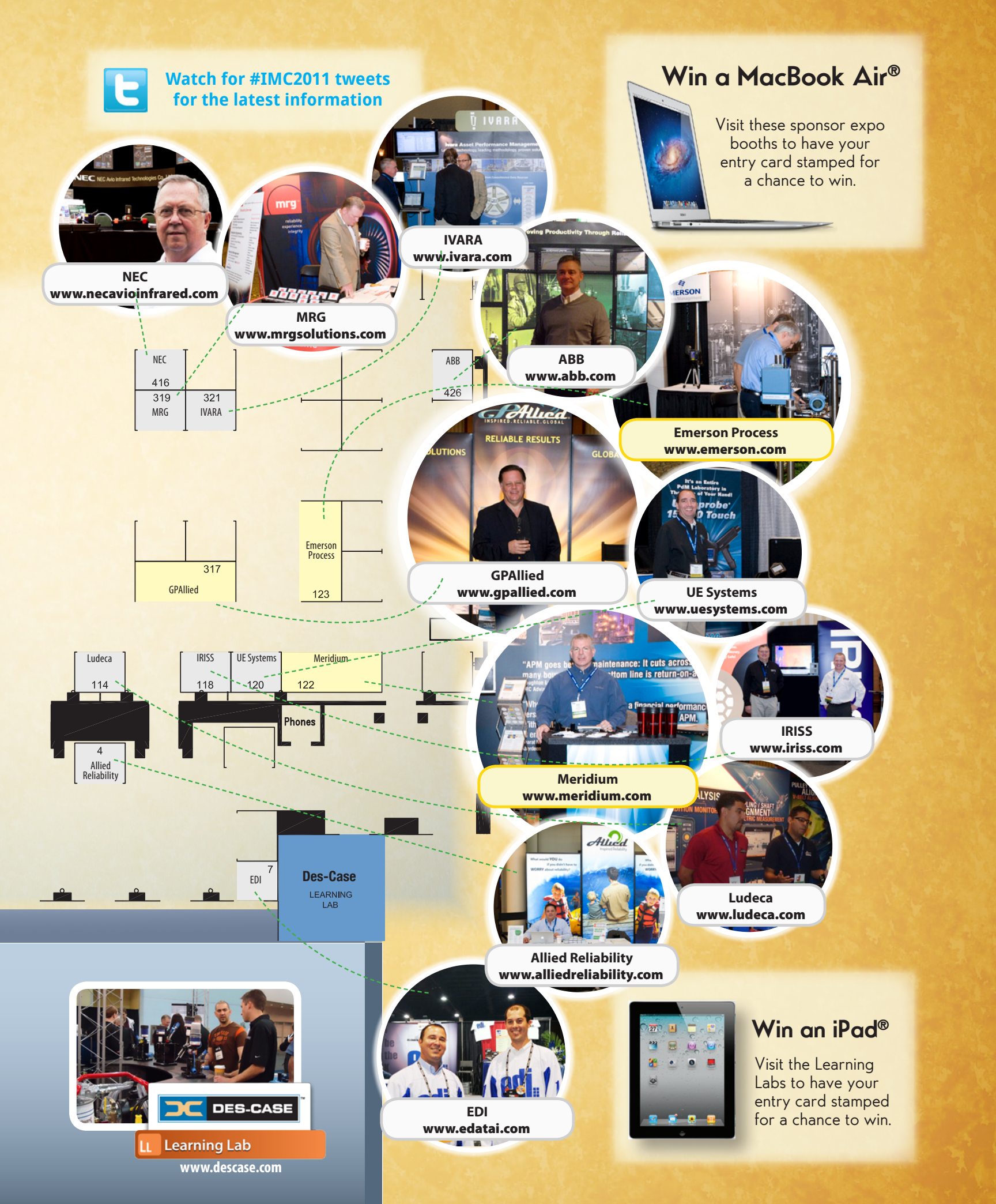

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Green Concepts

Who Will Leave Their Mark in the Reliability World?

Paul G. Campbell Jr., Senator, South Carolina

Foreword from the Book: *Clean, Green & Reliable*

The metals smelting industry is one of the largest energy users in the world. As president of the Southeast region for Alcoa Primary Metals, I saw power bills for smelters exceeding $150 million per year for a single smelter, with some months costing as much as $15 million at one plant. These are staggering sums costing as much as a third of the entire cost to produce primary aluminum. In fact, aluminum's highest manufacturing expense is power. Consider that a 1 mV decrease in our energy usage translated into an annual savings of $20,000 or more. Suffice it to say that like other Alcoa executives, I became an energy expert. I spent a career dissecting production processes in an effort to continuously improve our energy use profile. We scrutinized any and every process that used energy. What we learned is that before you can get truly green and lean, you have to embed reliability engineering into your manufacturing operations. So what does that mean? Everyone wants to be green and lean and save energy, but how exactly is that done? How is reliability engineering incorporated into an industrial plant? The answers to these questions are provided within these pages for a wide range of industrial venues.

For those new to the concept, reliability engineering is a methodology to maximize the performance of a given component at a given rate, time and set of circumstances. In other words, reliability approaches aim to leverage the function, time and cost variables of an industrial system for maximum return on investment. It's a money saver that happens to do a lot of other good things. As a science, reliability engineering is practically new. It began in the early 1990s, when industries first developed protocols for reducing maintenance overhead and extending the useful life of their equipment assets in response to increasingly competitive pressures from the global market.

In a very real sense, the reliability domain was a green enterprise from the start. The act of extending a product's or system's useful life is a fundamental green practice. But the earliest reliability measures tended to target the bottom line alone. The current practice evolved to address other beneficial outcomes, including reducing adverse events, reducing demand maintenance and saving capital expenditures. Industries' perceptions of benefits also evolved. As

In fact, aluminum's highest manufacturing expense is power. Consider that a 1 mV decrease in our energy usage translated into an annual savings of $20,000 or more. Suffice it to say that like other Alcoa executives, I became an energy expert.

recently as 1995, many industry leaders viewed reduced energy costs as merely an incidental benefit, whereas today the seeds of green energy savings fall on very fertile ground around industry boardrooms. People are becoming aware of the power of reliability. As well they should, considering that corporate pledges and demonstrations for the responsible stewardship of our planet's shared resources are today's social, operational, marketing and public relations imperatives. The good news is that reliability practices help everyone and they unanimously improve every single facet of industrial manufacturing processes. A few of the holistic returns include:

Manufacturing—Reliability is the cornerstone for green and lean manufacturing. Overall equipment effectiveness (OEE) reduces run time to make product. Less run time reduces energy consumption and compensation. Less scrap and rework mean less spent energy. Reduced product variation translates into gains in market share and better utilization and improved quality, equaling greater value for the customer.

Energy Profile—Reliability processes reduce energy expenditures in all production processes. Run time is optimized with fewer stops and starts. Energy losses resulting from poor alignment, out-of-balance issues, and poor contact points and electrical joints are reduced. Premature failure of hardware and equipment is prevented. Fewer support staff and utilities are needed, such as additional personnel to address steam leaks and boiler run time and maintenance. Process interruptions related to refrigeration and hydraulic-system down time are minimized. Reduced power demand premiums reduce dependence on power plants.

Productivity—Fewer process interruptions increase the productivity of operators and crafts people; increase the morale, time on project and *esprit de corps* among operators and maintenance staff; and improve the retention of employees.

Market/Sales—Market share improves as manufacturing processes become more efficient, customer appreciation increases and industrial segment leadership develops. As the bottom line improves, market share expands, as does the need for more jobs.

Capital Costs—Less power demand translates into lower capital expenditures. Lower capital costs, in turn, reduce the demand for energy raw materials.

Safety—As reliability profiles go up, safety and lost time instances decrease.

Community—Better community relations and corporate image.

Industries should ask themselves, "What am I losing?" "Can I reduce wasted expenses from 25% to 5%?" "What is my hidden plant?" Your hidden plant is your true capacity. It is the amount of production capacity underutilized because of process inefficiencies. Instead of building a new plant, reliability engineering helps you postpone that capital expense. The science has caught on to make this option viable.

Having more units with the same hardware further spreads fixed cost, driving down unit cost and both improving competitive positions and mitigating (or at least delaying) needs for new capacity. Reliability is indeed the new frontier in manufacturing. Just think: If you are not adopting reliability concepts, your competitors are. This should be a scary thought!

Read, study, apply and become more competitive. Reliability concepts work!

Paul G. Campbell Jr., Senator, South Carolina. In Senate since August 7, 2007. Mr. Campbell is the Retired Regional President of Alcoa.


WRONG
RIGHT
RIGHT
WRON

What Tool? When? Some Thoughts

Ron Moore

Companies are bombarded daily with recommendations from various sources regarding the tools they should use for improvement, leaving most people in a quandary regarding their selection and application. Unfortunately, there are any number of tools being offered, with little guidance regarding which one is best in a given situation, how the tools might relate to each other, or perhaps more importantly, the enabling practices or readiness that any given organization might need in order to effectively apply the tools.

While it may be acceptable in the short term to proceed with any particular tool that is deemed appropriate by management, there are more strategic issues that also must be addressed to assure that the organization can effectively apply the tools and sustain their benefits. These issues include leadership, alignment, teamwork, innovation and managing cultural change. If you do these well, the tools are much easier to apply, and far more successful. If you do not, success with any tool will, at best, be fleeting. Let's consider these issues briefly:

Leadership. There are numerous books on leadership, but my favorite definition is:

"Leadership is the ability to inspire ordinary people to consistently perform at an extraordinary level." - *Ron Moore*

How? They must feel that they are part of something greater than themselves. This enables a certain pride that goes beyond their personal performance and reinforces and sustains that performance. They also must enjoy their work, perhaps not as in seeing a good movie, but more so as in taking satisfaction in a job well done, particularly the difficult ones. They must be given the time, tools and training to be effective in their work. Finally, and most importantly, they must trust that their leaders are acting in the best interest of every employee and are always dealing openly and honestly with them, particularly during the difficult times. The opposite of this is believing that management is only interested in management and shareholder well-being. So pride, enjoyment, and most of all, trust, are paramount in a good leadership model.

At the highest level of the organization, leadership requires vision and a greater sense of purpose, yet being grounded in reality. Leaders put people first, treating them with dignity, respect and appreciation. Leaders have a passion for excellence, set high work and ethical standards, and create a caring, disciplined and proud environment. Leaders are demanding and supportive, simultaneously. Leaders set the example and have the courage to support and defend their basic values and principles. As you get closer to the actual work, management principles also must be applied – managers must administer and maintain, get things done right, manage to budgets, measure and control, hold people to standards, and constantly look for ways to improve. Leadership and management can require a very different skill set. The higher you are in the organization, the more you must be a leader.

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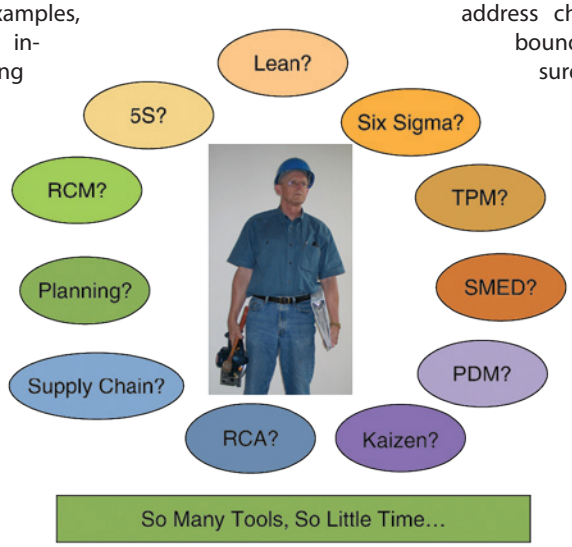
Alignment. As Edgar Schein observed, "*Alignment is critical where task **inter**-dependence makes collaboration essential for organizational effectiveness,*" for example, between production and maintenance; between shifts; or between marketing and manufacturing. Most organizations are not well aligned, exhibiting excessive "silo" behavior within each division or department. Granted, some of this is appropriate, but when the behaviors damage the overall performance of the business, then it becomes clear that an organization is not aligned. A few examples, among hundreds, include the purchasing department buying cheaper material, for which they are rewarded for "saving money," but which then results in greater costs to production; or production running equipment poorly to make production schedules, for which they are rewarded, but which results in additional downtime and maintenance costs. To counter the tendency toward "silo" behavior, the corporate strategy, along with superordinate goals, must be clearly defined and communicated repeatedly, and lower levels must give deference to these higher level goals and focus on system level performance. Moreover, misaligning issues, such as CEO pay and initiative overload pay, must be addressed. CEO compensation must be perceived as internally equitable and as a fiduciary of the corporation. The CEO must put corporate and employees' interests above his or her personal interests by building trust with employees. Initiatives must be consistent with the overall strategy and purpose of the organization, and must be introduced at a rate that the organization can absorb and effectively implement and sustain.



Teamwork. Teamwork, under-penned by the organization's superordinate goals, is a must. Teams must have a clear purpose and direction - a sense of meaning - aligned to corporate vision/direction and to individual interests; boundaries for the team's goals and self-determination within those boundaries; openness and a willingness to share conflicting views; the skills to achieve the goals or training needs thereto; discipline and measurement of their effectiveness as to the impact on the business; continuing feedback and support; and flexibility to address changing needs, e.g., boundaries, training, measures, etc.

Innovation. This must not be something that is only done by the R&D function. Within the organization, and particularly at the shop floor, everyone must be constantly doing "little innovations," that is, looking for ways to do things better, applying rigor to the change process. This will lower costs and help fund "big innovation" in the R&D that creates improved products and processes. Our people are indeed our most important asset and we must treat them as such – they are our human intellectual capital and are more valuable than our equipment.

Managing Cultural Change. In this Darwinian world of capitalism, constant change through adaptation and improvement is a must. The heart of managing cultural change lies in routinely engaging all employees in the change process. It's often said that "people don't want to change." I disagree with this. People don't want to ***be*** changed, but they **do** want to change, **IF**:

1. Given compelling reasons for change.
2. There's something in the changes for them, e.g., less stress, less risk, better pay, or a more secure future.
3. They participate in creating the changes, so they have a sense of ownership and purpose in the change process. This means, for example, that we must have periodic, structured improvement time; routinely solicit and act on their ideas for improvement; and remove obstacles to their success.

All three IFs must be met to effectively manage cultural change.

Addressing these issues and getting good in each area is a must. These must be considered enabling activities to assure organizational readiness for effectively applying and sustaining the tools. With this in mind, we're now ready to look at a nominal hierarchy for applying the most popular tools.

Nominal Hierarchy for Application of Strategy and Tools

Figure 1, below, is offered as a model for the order in which the most popular tools should be applied. It is based on decades of experience in working with many, many companies, some of which applied these tools effectively, but, sadly, most did not, primarily in my view because they were poor at addressing the enabling issues and practices discussed above. Let's review this hierarchy.

In this model, an additional part of organizational readiness is applying an overall philosophy and strategy patterned after the Toyota Way, that is:

1. Long term thinking is the beginning and the foundation of business excellence, even if it is at the expense of short term profits.
2. Mapping and understanding your processes is key, including having a clear picture of where value is added and where waste is incurred and driving out the waste.
3. Engaging and challenging your people and suppliers. Being simultaneously encouraging and demanding of your people is a big challenge, particularly in getting the balance correct. Doing so is a requirement.

With these kinds of enabling activities in place, the tools for improvement can be more readily selected and effectively applied.

In my view, initial priority should be given to Kaizen principles, with a focus on 5S – sort, straighten, scrub, systematize and standardize – so you can sustain. Most companies do 4S, that is, they sort, straighten, scrub and *stop*, making their improvement *un*sustainable. More importantly, the focus of 5S is ***not*** housekeeping. That, along with a safer work environment, is a *byproduct* of 5S. Rather, the 5S focus is defect detection and elimination, workplace discipline and mistake proofing. Along with 5S comes standardization, or standard work. For example, every shift operates the process *exactly* the same way; every coupling is aligned to a strict standard, and so on. "Go and see" assures that supervisors and managers understand the details of the processes, and more importantly, they get a first-hand understanding of the problems being encountered by the workforce. The Five Whys method is a simple, easy way to engage the entire workforce in thinking and problem-solving, not just a select few who are trained in the more comprehensive forms of root cause analysis. Quick changeover reduces lost production time. Having a visual workplace makes it easier for the workforce to spot defects and manage them. Of course, having Kaizen or improvement activities assures that people have structured improvement time for problem-solving. In these improvement activities, it's a good idea to use Deming's Plan, Do, Check, Act management method and/or Imai's modification of it – Standardize, Do, Check, Act – to assure rigor in the improvement process.

In my view, initial priority should be given to Kaizen principles, with a focus on 5S – sort, straighten, scrub, systematize and standardize – so you can sustain. Most companies do 4S, that is, they sort, straighten, scrub and stop, making their improvement unsustainable.

Next, priority should be given to Total Productive Maintenance, or more accurately, Total Productive Manufacturing, or TPM principles. That is, measuring your overall equipment effectiveness, or OEE, with a specific focus on *managing all losses* from ideal so they can be minimized. TPM includes having operators apply TLC (tender loving care) doing tightening, lubricating and cleaning, monitoring equipment and process condition, and having consistency of operation, particularly across shifts. It includes having best practices in preventive maintenance (PM), predictive maintenance (PdM), and planning and scheduling, which are an inherent part of maintenance excellence. It includes restoring equipment performance to a like-new condition or better. No patching is allowed in TPM. When functionality is still insufficient

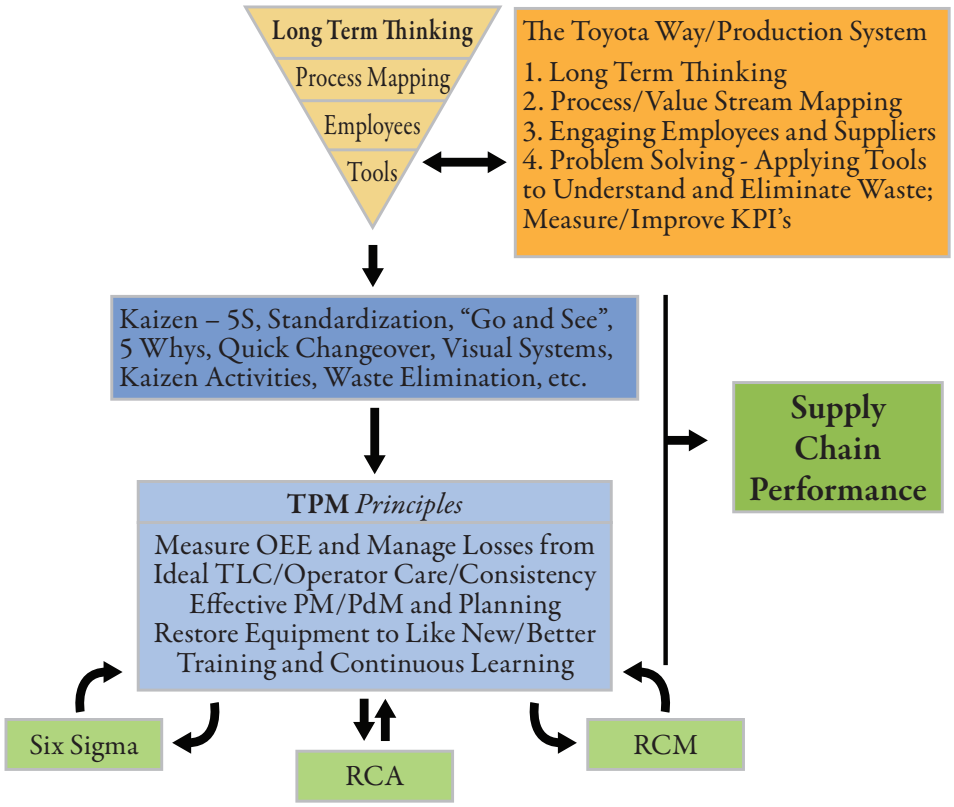


Figure 1 Nominal Hierarchy for the Application of Tools and Strategies

> "Go and see" assures that supervisors and managers understand the details of the processes, and more importantly, they get a first-hand understanding of the problems being encountered by the workforce.

for business requirements, equipment and process design changes are made. Training and continuous learning are an ongoing part of TPM.

The last priority is given to Six Sigma, reliability centered maintenance (RCM) and root cause analysis (RCA), as appropriate, for the more complex problems. The appropriate tool is selected based on the nature of the problem or issue at hand. For example, if we've applied the Kaizen principle of standard work but still have excess variability, then Six Sigma would typically be used for the more complex process and system level problems. Or, if after applying 5 Whys the problem becomes more complex than anticipated, or requires a more comprehensive review, then a more comprehensive RCA method would be used, including Ishikawa diagrams as necessary. RCM would be used to identify failure modes and consequences, allowing for the optimization of PM and PdM practices, and for greater operator involvement in tasks related to minimizing these failure modes and solving more complex equipment problems. Each of these tools requires a feedback loop to foster and sustain continuous learning and improvement on the use of the tools. Unfortunately, most people start with something like Six Sigma or RCM before they get the basics in place, making the use of these tools more problematic, particularly with regard to sustaining the results of their use.

Doing all this supports excellence in supply chain management, particularly when suppliers are treated with respect and as a partner in your business. This is particularly true when it is combined with an alignment effort between marketing and manufacturing for rationalizing various products, and even customers, to the marketplace, and truly addressing supply chain issues – suppliers, manufacturers and customers working in a "chain" to optimize supply chain performance.

Finally, it's important to highlight that these are *nominal* priorities for the application of the tools. In any given circumstance, it may be appropriate to apply RCM, Six Sigma, or RCA to a problem as part of applying Kaizen principles, TPM, or a combination of tools as needed under the business circumstance. However, the hierarchy and priorities shown will best serve most companies in their improvement efforts.

Ron Moore is the author of Making Common Sense Common Practice: Models for Manufacturing Excellence (in its 3rd edition) and of What Tool? When? - A Management Guide for Selecting the Right Improvement Tools (in its 2nd edition), both from the MRO-Zone.com, as well as over 40 journal articles. www.MRO-Zone.com

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Shaft Alignment, Soft Foot & Energy Savings

Alan Luedeking

"Does misalignment waste energy?" is a question often asked. The answer, emphatically, is yes! General Motors Corporation and Ludeca Inc. performed and published a study on this issue in 1993 which showed conclusively that energy savings (Real Power savings) of 2.3 percent could be obtained on loaded machines. On unloaded machines, the savings ranged as high as 9 percent! At ICI Chemicals, a UK chemical plant in the north of England, a carefully controlled doctoral research project revealed even higher savings. Other studies suggest averaged savings of 4 to 5 percent.

In late 1993, Infraspection Institute in New Jersey demonstrated in a carefully controlled study conducted at Miller Brewing Company that misalignment generates heat and wastes energy. This was clearly demonstrated in the comparative infrared signatures obtained on the same machines when running in an aligned and misaligned condition with different types of couplings (see Figures 1 and 2.) Precise magnitudes of misalignment were very carefully set with an Optalign® laser system and the results meticulously examined with calibrated thermograms recorded for each case.

Clearly, the energy required to accommodate the increased sliding velocities from misalignment within flexible couplings must come from somewhere, and this wasted energy comes at the direct expense of the efficiency of the rotating machines. While the percentage of savings may not seem very significant, a plant that reduces energy consumption by 4 percent on an energy bill of $50,000 per month would save $24,000 in just the first year, more than enough to justify the purchase of a higher-end laser shaft alignment system.

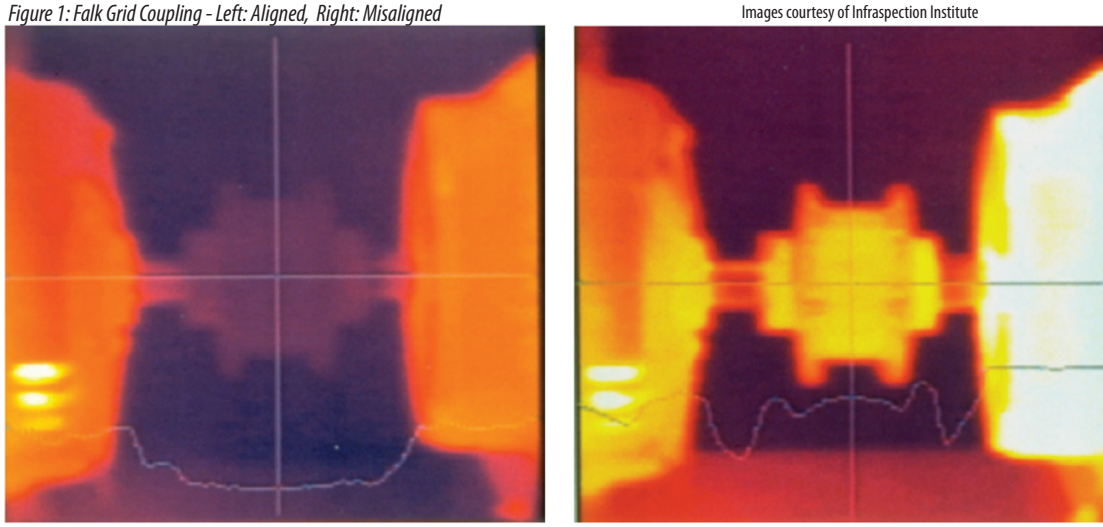
In addition, this energy savings comes on top of all the other benefits resulting from better alignment, such as reduced wear and tear on bearings, seals and couplings, and the reduction in unscheduled downtime and repair expenses. The savings from these items (particularly reducing unscheduled downtime) can dwarf those obtained from just the reduction in energy consumption. A classic example of this occurs in a paper machine: With an estimated loss of production from unscheduled downtime at $1,500 per minute, one critical pump swap-out for a seal replacement lasting one hour would cost the mill $90,000. Better alignment can vastly increase the life of seals and bearings.

Moreover, better aligned machines also result in improved production quality from reduced noise and vibration that can affect manufacturing processes. This is particularly evident in the manufacture of delicate products, or those requiring precise uniformity with exacting tolerances, such as film and optics, and certain delicate types of paper.

The following is a direct quote from Miller Brewing Company staff, cited in the study: "…if you wanted greater machine reliability, longer life, less maintenance, less downtime and less cost, there is no other problem you could focus on that would be as beneficial as eliminating shaft misalignment. There is absolutely no other area in machinery maintenance [for]

Figure 1: Falk Grid Coupling - Left: Aligned, Right: Misaligned

Images courtesy of Infraspection Institute



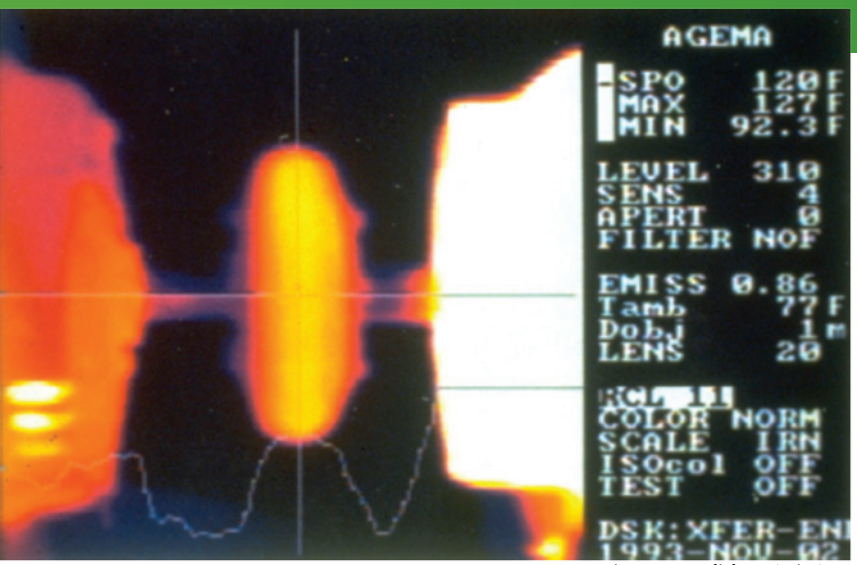


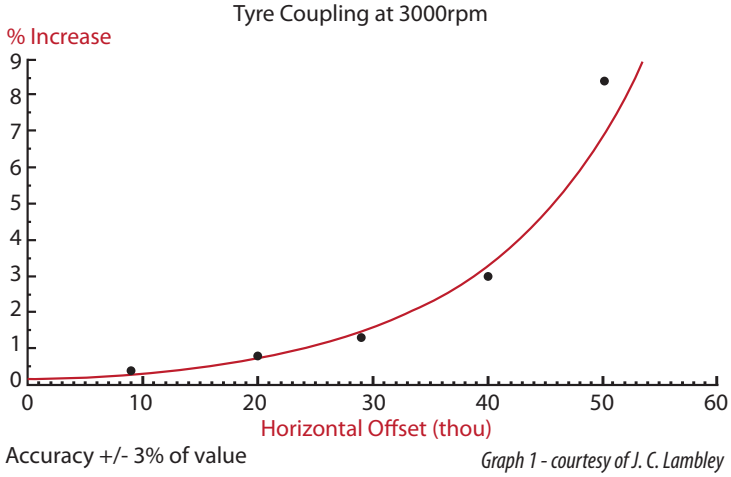
Figure 2: Dodge Coupling: misaligned

Image courtesy of Infraspection Institute

which you will get more 'bang for your buck' in terms of reliability, longevity, productivity and reduced overall maintenance cost than eliminating shaft misalignment."

In Figure 2, we see Infraspection Institute's infrared thermogram from the Miller study for a misaligned Dodge "rubber donut" type coupling. It clearly shows that the energy wasted in overcoming the forces produced by misalignment is significant. It should be noted that some of the heating of the motor on the right can be attributed to the axial force imposed on the bearings by the centripetal forces acting on the coupling, which tend to thin the coupling and pull the shafts inwards.

Effect of an Offset on Power Consumption



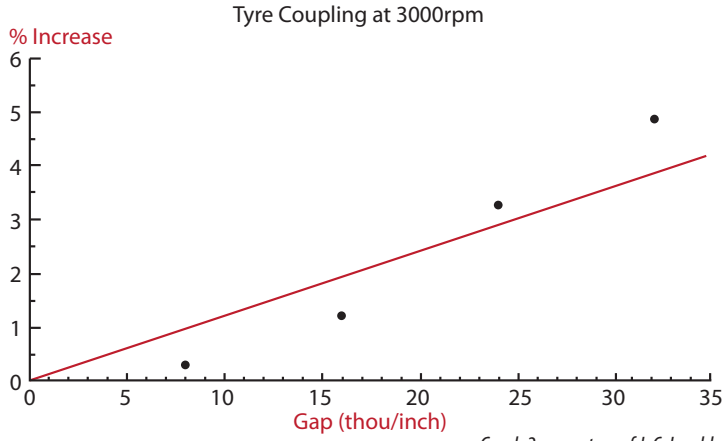
Graph 1 - courtesy of J. C. Lambley

The ICI Chemicals study (also known as the Runcorn study) by J. C. Lambley bears out these findings. Lambley carefully contrasted the increase in real power consumption from the two main types of misalignment - offset and angularity - by deliberately and carefully misaligning the 3000 RPM motor driving an NK 32-200 centrifugal pump pumping cold water in a closed loop system. The study was conducted using an Optalign® laser system and two types of couplings, one a pin-type and the other a rubber tire type, similar to the Dodge coupling in Figure 2. Graph 1 illustrates the increase in power consumption with the rubber tire coupling resulting from increasing offset. Graph 2 illustrates the same for increasing angularity.

Soft foot, otherwise better described as machine frame distortion, is another large energy hog. Finding, diagnosing and eliminating soft foot are essential steps in the overall shaft alignment task. Alfred Olsen of SAVO Electronics conducted a study that demonstrated conclusively that the twisting or distortion of a motor frame and the consequent eccentricities in the air gap between rotor and stator produce "hot spots" that result in very significant efficiency and energy losses. His careful study showed that a twisted motor can increase power consumption by as much as 17.4 percent!

A good laser shaft alignment system and training are key ingredients for achieving the green goals of reduced power consumption, downtime and repair expense. The laser alignment system you invest in should offer the capability to diagnose soft foot (not just measure it) and allow for the simultaneous input (when necessary) of both thermal growth data at the machine supports and target specifications at the coupling. Your alignment training program should instill a thorough understanding of soft foot diagnosis and thermal growth targeting. The results of both ingredients will be energy savings that pay for all of it.

Effect of Angular Misalignment on Power Consumption



Graph 2 - courtesy of J. C. Lambley

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PART 2 The Business of Asset Management

Terry Wireman

In the last issue of *Uptime* Magazine, we discussed the importance of managing assets from the initial investment planning to the design phase of an asset's life. The focus of the last article was to show how to maximize the return on investment a company receives for the life of the asset, thereby increasing shareholder value. This article focuses on moving the discussion from the drawing board to the shop floor.

In the previous article, the Investment Planning (Needs and Feasibility Assessments for Assets) and the Project Definition (Design of Assets) phases of an asset's lifecycle were discussed as illustrated in Figure 1. This article begins with the construction, acquisition, or enhancement of an asset.

3. Construction, Acquisition, or Enhancement of Assets

In this phase of an asset's lifecycle, it is actually created, produced, or acquired. The initial construction/acquisition cost is actually incurred at this time. If the asset is constructed internally, all of the design documents, capacity studies, reliability and maintainability specifications, regulatory requirements, etc., are utilized to construct an asset that will provide the company with the maximum Return on Assets (ROA)/Return on Invested Capital (ROIC) for their shareholders/stakeholders. This is the case, whether it is a building, a process, or a production line that is being constructed.

If the asset is to be purchased, all of the same design documents, capacity studies, reliability and maintainability specifications, regulatory requirements, etc., are provided to the vendor constructing/providing the new asset. The company will audit the delivered asset against the specifications to insure the proper asset has been supplied by the vendor.

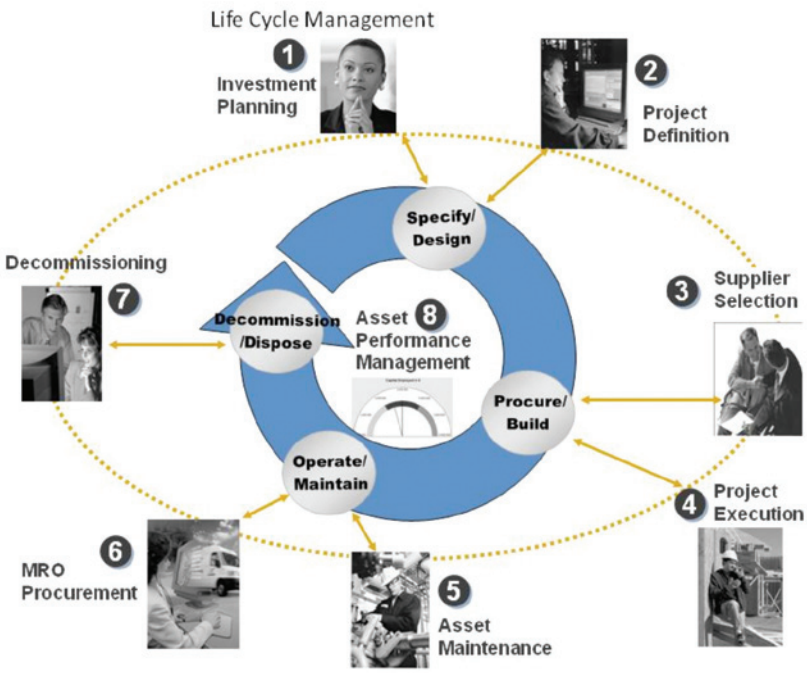


Figure 1 The lifecycle of an asset. Diagram used courtesy of SAP-AG

If existing assets are to be redesigned/modified to meet the business plan, then all the same specifications that would have been developed for a new asset (whether constructed internally or purchased externally) are used during the modification of existing assets. At the end of the redesign or modification, the assets should be capable of delivering their design capacity at specified costs.

4. Project Execution of the Asset

In this phase of the asset's lifecycle, the asset, whether it is built, purchased, or retrofitted, is installed in the plant or (if a building) actually built. This is a construction or installation project. There is some divergence, based on the philosophical leaning of the author, professor, or practitioner. The following Equipment Life Cycle Phases diagram is used by Professor Ben Blanchard in his Engineering Masters program.

The diagram rolls the construction, acquisition and installation of the asset into one phase. However one chooses to combine or separate these phases, the project phase involves the installation of the equipment or construction of the building. This phase is critical since poor installation/construction practices can diminish the design reliability and maintainability of the asset. For example, poor foundations under equipment can make it virtually impossible to achieve its reliability and maintainability design specifications.

During this project phase, commissioning also occurs. In a building setting, the final in-

spection and walk-through occurs before the asset ownership transfers from the builder to the company purchasing the building. In an equipment setting, all of the asset's capacities are tested to insure they meet all the design specifications.

Once the commissioning component is achieved, the asset ownership now passes from the supplier (internal or external) to the company. All documents, manuals, drawings, etc., are transferred to the company. In many cases, all documentation is provided to the company electronically. This also may include the requirement for the supplier (internal or external) to enter all the data for the new asset into the company's CMMS/EAM system. At this time, the asset moves into the maintenance/operations phase of its lifecycle.

5. Operations and Maintenance Phase of Asset Lifecycle

This phase is where the asset actually starts providing the business service or production it was envisioned to provide back in the first phase of its lifecycle. It involves much more than allowing occupants into a building or pushing a button to turn on a production line/process. It is ensuring that it delivers the design specifications. There are two aspects to this – Operations and Maintenance.

From an operations perspective, whether the asset delivers the design capacity/capabilities is evaluated. For example, using the building example, these questions are explored: Can it hold all the occupants it was designed to accommodate? Is the HVAC adequate to keep everyone comfortable? Do the restrooms provide satisfactory service? Is the lighting sufficient? If any of these systems fall short, the capacity of the building is diminished. From an equipment perspective, the questions that need answering include: Does it achieve the design capacity? Does it produce at the rate for which the original design specified? Does the asset meet the "operability" that was specified in the initial design documentation?

From a maintenance perspective, the asset was designed with certain reliability and maintainability parameters. Questions designed to measure these parameters include: Does the equipment achieve the designed mean time between failures (MTBF) - reliability - and the designed mean time to repair (MTTR) - maintainability? If not, why? Do the specified maintenance policies and procedures ensure that the design specifications can be achieved? If not, why? It was mentioned previously that up to 90 percent of the asset's lifecycle cost will be incurred during this phase of the asset's life. These costs are commonly divided into labor costs, materials costs and contractor costs.

Do the specified maintenance policies and procedures ensure that the design specifications can be achieved? If not, why? It was mentioned previously that up to 90 percent of the asset's lifecycle cost will be incurred during this phase of the asset's life.

Some companies try to reduce these maintenance expenditures to a level where the asset is not properly maintained. When this occurs, the asset either fails to produce the design reliability or the maintainability. In some cases, catastrophic failures occur, creating a negative image of the company (and financial penalties have involved numerous companies lately). Due to insufficient maintenance expenditures, par-

ticularly in buildings, an asset will fail to achieve its full design life. This leads to premature major overhaul/refurbishing or even decommissioning expenditures. In these cases, the original ROA/ROIC that was promised to shareholders/stakeholders will never be achieved. Eventually share prices in the company's stock will likely suffer.

In this phase of the lifecycle, information management is critical. Tracking all of the data in a CMMS/EAM system guarantees that the proper level of maintenance activities are being performed on the assets to ensure they deliver their design functions at the designed costs. This data is essential in a later phase of the lifecycle if any business improvements related to the assets are to be achieved.

6. Rehabilitation or Retrofitting of Assets

Some texts, professors, companies, etc., will break this section out as a separate lifecycle phase, while others incorporate it into the maintenance and operational phase. The activities surrounding shutdowns, turnarounds and outages are focused on restoring deteriorated assets to an acceptable baseline to ensure that the original design capacities can be achieved. In the cases of buildings, they are refurbished to bring any deterioration to an as-new condition, assuring the structure is fit to purpose.

There are also certain thought leaders that will move reengineering or retrofits of existing assets into this phase of an asset's lifecycle. Others will include it in the maintenance and operations phase. This activity is to take an older asset and reengineer it to upgrade it to current market standards. It may be to meet new building codes or new production specifications.

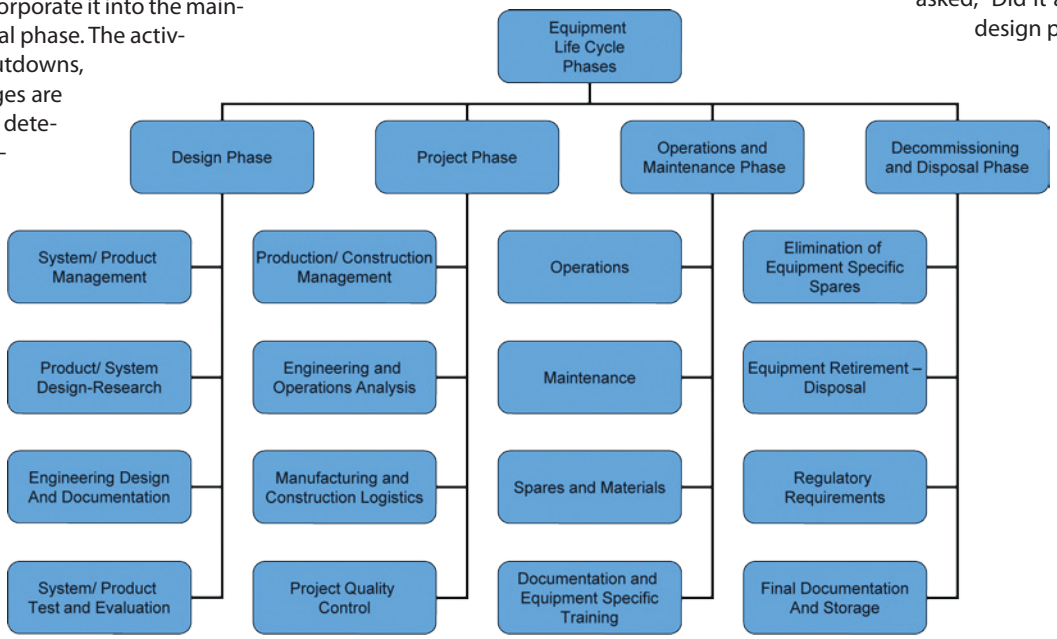
If the asset needs to be replaced, it moves into its final lifecycle phase.

7. Decommissioning, Retirement, and/or Disposal of Assets

In this phase of an asset's lifecycle, it is time to decommission and dispose of it. In some cases, decommissioning is nothing more than writing it off the books and gradually selling off components of the process/manufacturing line. In some situations, when a process/manufacturing line is decommissioned, it is "cannibalized" for similar parts for other assets that are still operating somewhere else in the plant or facility. When this occurs for a time period, the remaining components will eventually be sold off for scrap.

Selling the asset to another company is another popular option for disposing of an asset. This occurs frequently when a company has decided to divest a certain product or a certain part of its current market. Another company will purchase the asset, may retrofit it and continue production of the product or a similar one.

In most cases, it is unlikely that a facility (such as a building) is "cannibalized" for parts, but rather it is sold off as a method of disposal. Often, vacant structures quickly become a legal liability. This encourages a company to sell the asset rather quickly.



Based on Life-Cycle Cost and Economic Analysis - Benjamin S. Blanchard
Professor of Engineering-Emertius at Virginia Polytechnic Institute and State University

Depending on the asset, there also may be regulatory considerations when it is decommissioned. If it was part of an environmentally hazardous process, then there will be regulations that must be met. Depending on the country in which the asset is located, the range of remediation activities will vary dramatically. In the United States, there are OSHA, EPA and other state and local regulations that must be met.

Eventually, through whatever process a company has in place, the asset is decommissioned, written off the company register and finally disposed.

8. Performance Management

This aspect of an asset's lifecycle is often overlooked. However, if you refer back to Figure 1 in this article and its center circle, performance management is critical throughout the life of the asset. While there are many different aspects of performance management, if a company does not measure the performance of an asset, it cannot be improved in the next generation of asset evolution.

Performance management is key in many aspects. For example, each company asset was originally conceived (as part of the asset base to provide a new product or service) and designed to perform a task in the plant or facility. Some performance measures must audit the installed and operating asset against what it was conceived and designed to perform. Whether it was a building that was supposed to house 500 people for 8 hours a day, 5 days a week for 40 years, or a pump that was supposed to provide 100 gallons of flow per minute for 24 hours per day, 7 days a week for 15 years, the question must be asked, "Did it achieve that level of design performance?"

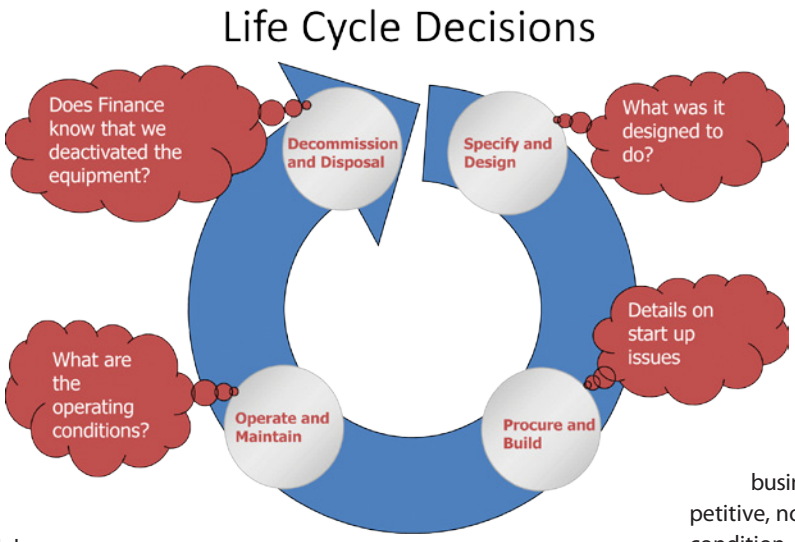
If it did, then the performance was satisfactory. If it did not, then why? This is where a typical CMMS/EAM system is used to monitor performance. A typical system will track MTBF and MTTR. It tracks the labor and material costs (whether internal, contractors, or a combination) that the asset requires to keep it at design performance.

Without getting into high level specifics, there are multiple aspects that need to be measured during asset life to enable future improvements. After this information has been tracked through the lifecycle, it is fed back into the "conceive" and "design" phases of the next generation of assets for the company. Any weaknesses in the prior assets are corrected in the new design or specifications for the next generation of assets. Without this performance measurement feedback loop, companies will not be able to improve their competitive positions in their respective marketplaces.

The following Life Cycle Decisions diagram is another way to look at questions to be asked during an asset lifecycle.

Conclusion

Why is this information important to any organization considering or pursuing certification with an asset management standard? The first is the point made at the beginning of the article in the last issue of *Uptime* magazine: "They must have a 'line of sight' and connect the benefits of achieving a standard to the business needs of a company."



If a company is to be realistic, there are literally thousands of standards (worldwide, ISO, ASTM, etc.), yet how many of them are widely adopted and used by companies? There are some that are specifically focused on a certain process, industry, or facility that have acceptance in that particular business. However, an asset management standard is different. In fact, the closest standard to an asset management standard for all inclusiveness and worldwide impact is the ISO-9000 series. This connection is realistic, since most ISO-9000 certified companies have assets that enable them to achieve certification.

Lessons can be learned from the history of the ISO-9000 series or standards. At first, quality as an important business process did not gain wide acceptance, despite the fact that quality gurus W. Edward Deming, Joseph Juran, Phillip Crosby and others had been pontificating about the business benefits that almost perfect quality allowed a company to achieve. It was not until it became a business requirement, mainly driven by European companies, when supplying certain companies with a product. It continued to grow in acceptance until it caught on in the U.S. automotive industry (all suppliers included). U.S. automotive companies initially had their QS standards, but eventually adopted the ISO standards. Now, almost every company is ISO-9000 compliant.

There is a similar pattern developing with an asset management standard. There have been individuals and organizations pontificating about asset management (or at least one of the component phases) for over a decade. However, it was not until PAS-55 (a British asset management standard) came along before the whole effort began to get traction.

PAS-55 started connecting asset management practices and policies to the financial benefits that were achieved by complying with the standard. This started to get the attention of many executives, particularly in the U.S. utility industry. This "line of sight" approach will resonate with most executives. However, acceptance of any asset management standard is not a given in the worldwide business community. If there are components of the standard that do not lead to financial benefits, executives will be slow (if ever) to adopt any asset management standard. Crosby said it best about quality: "No one did anything about *Quality* until someone figured out what was the cost of *non-Quality*." Companies will not develop a serious asset management policy until they realize what the lack of such a policy is actually costing them.

Unless an asset management standard becomes a requirement to do business (like ISO-9000), no asset management standard will be widely accepted. While many asset management professionals worldwide are involved in an effort to develop an international asset management standard, if they fail to achieve a "line of sight" approach that connects top line to bottom line, the effort will not be successful. After all, the goal should be trying to produce a standard that helps the business community become more competitive, not to negatively impact their financial condition.

Terry Wireman, CPMM & CMRP, Senior Vice President Vesta Partners, LLC (www.vestapartners.com) has authored dozens of books, including the new Maintenance Strategy *series published by Reliabilityweb.com and sold at: www.mro-zone.com.*

Can a CMMS/EAM Solution Really Solve All Your Problems?

Johnny Bofilios

After working in the CMMS/EAM software world for almost 16 years, I recently switched to an engineering consulting firm focused on helping clients implement reliability best practices. I've developed a fresh perspective on what it takes to implement CMMS/EAM software successfully.

From a software perspective, the message was simple: You can justify the investment because you will save money by improving maintenance labor productivity and equipment uptime, while decreasing MRO and energy costs. All asset management software companies talk about these ROI metrics. But when it comes time to implement their solutions, unless their customers have a good handle on asset management best practices, their solutions will never get implemented correctly and the expected results won't materialize.

In my software world, I thought I knew everything there is to know about enterprise asset management (EAM). But I needed to know more about reliability best practices. For me, the lightbulb came on when I attended a course called Reliability Excellence for Managers (RxM). How were my customers going to implement an asset management software solution without a blueprint of what they wanted to achieve?

At the end of the day, the reason a maintenance organization exists is to keep equipment running. Typically, operations sees maintenance as a nuisance, unless it needs the maintenance department to get their equipment back up and running.

At the end of the day, the reason a maintenance organization exists is to keep equipment running. Typically, operations sees maintenance as a nuisance, unless it needs the maintenance department to get their equipment back up and running. At the RxM workshop, I learned that operations and maintenance need to trust each other and create a pact that will allow them to work closely together. By doing this, they reduce maintenance problems and improve productivity.

What department typically purchases a CMMS/EAM software solution? The IT department. The CIO is looking to consolidate disparate installations of their company's asset management tools into one system, making it easier to manage and reducing IT costs. The problem with this is that IT may not have a full understanding of how the maintenance and operations areas function. The only way to end up with a software system that is a solid investment for managing assets is for the organization to take the time to evaluate their top critical equipment and create a risk-based asset management strategy *before* implementing an asset management software solution.

Why does an organization need an asset management software solution? The answer now is simple – the software is just a tool. It's designed to be a repository for the information that is being captured by asset management best practices and corrective and preventative work management activities, and to manage inventory more effectively by making it easier for users to get to those parts and to better man-

age automated information coming from smart equipment. Asset management software is not a magic wand that will solve your organization's maintenance and equipment reliability problems.

Let's look at two examples of ACME Corporation:

In the first example, ACME publishes an RFP for asset management software because they have 15 plants using different asset management software products. The RFP requirements include standard system capabilities: track maintenance labor, work management, inventory management, equipment history, etc. Three different software vendors compete for the RFP and one wins the sale. The software company services team that will implement the solution installs the software and asks ACME how they want the system to work.

Wow! How do you want the system to work? Do you see the problem? If ACME Corporation took the time to assess where and what their problems are, define the areas of opportunity and put together a plan on how to achieve operational excellence, then no matter what software they purchased, they would implement it around those best practices and achieve promised results.

In the second example, ACME decides to take the reliability excellence route. They conduct a meeting that includes all the stakeholders: management, operations, maintenance, engineering and IT. They create an asset template, which they send to each plant to get a list of all their assets. Then with the information they receive from this audit, they identify the top 20% of critical assets that run 80% of their business. From there, they create a risk-based asset management strategy for each one of those assets.

There's no shortcut for learning and adopting reliability best practices. Without a solid risk-based asset management strategy in place, implementing a new software solution may not be a solution at all.

They define the functional hierarchy, conduct Failure Modes and Effect Analysis (FMEA), develop a comprehensive equipment maintenance plan, develop job plans, perform critical spare analysis and develop a bill of materials. Once they select their new asset management software, their work is more than 75% complete. All they need to do is load this information into the installed software and they can begin tracking the performance of their risk-based asset management strategy.

What I now clearly see is if you don't have a grasp of reliability best practices around your assets (and your processes and your people), you will never achieve reliability excellence. Reliability excellence is a holistic approach to continuous improvement that achieves sustainable world-class performance by maximizing the useful life and daily output of physical assets, improving the stability and repeatability of key business and work processes, and creating a well-trained and engaged workforce that relentlessly pursues waste elimination.

So as you embark on your journey of purchasing or improving your asset management software system, think about what you are trying to accomplish with this software. Software is just a tool. What you are probably really trying to accomplish is to move closer to achieving reliability excellence. There's no shortcut for learning and adopting reliability best practices. Without a solid risk-based asset management strategy in place, implementing a new software solution may not be a solution at all.

Johnny Bofilios is Director of Reliability Solutions at Life Cycle Engineering (LCE). He has spent more than 15 years in the software and consulting services industry, helping clients achieve sustainable improvements in asset performance. www.LCE.com.

Implementing ESA as Part of Your Predictive Maintenance Program to Improve Electrical Reliability

William Kruger

Why Predictive Maintenance?

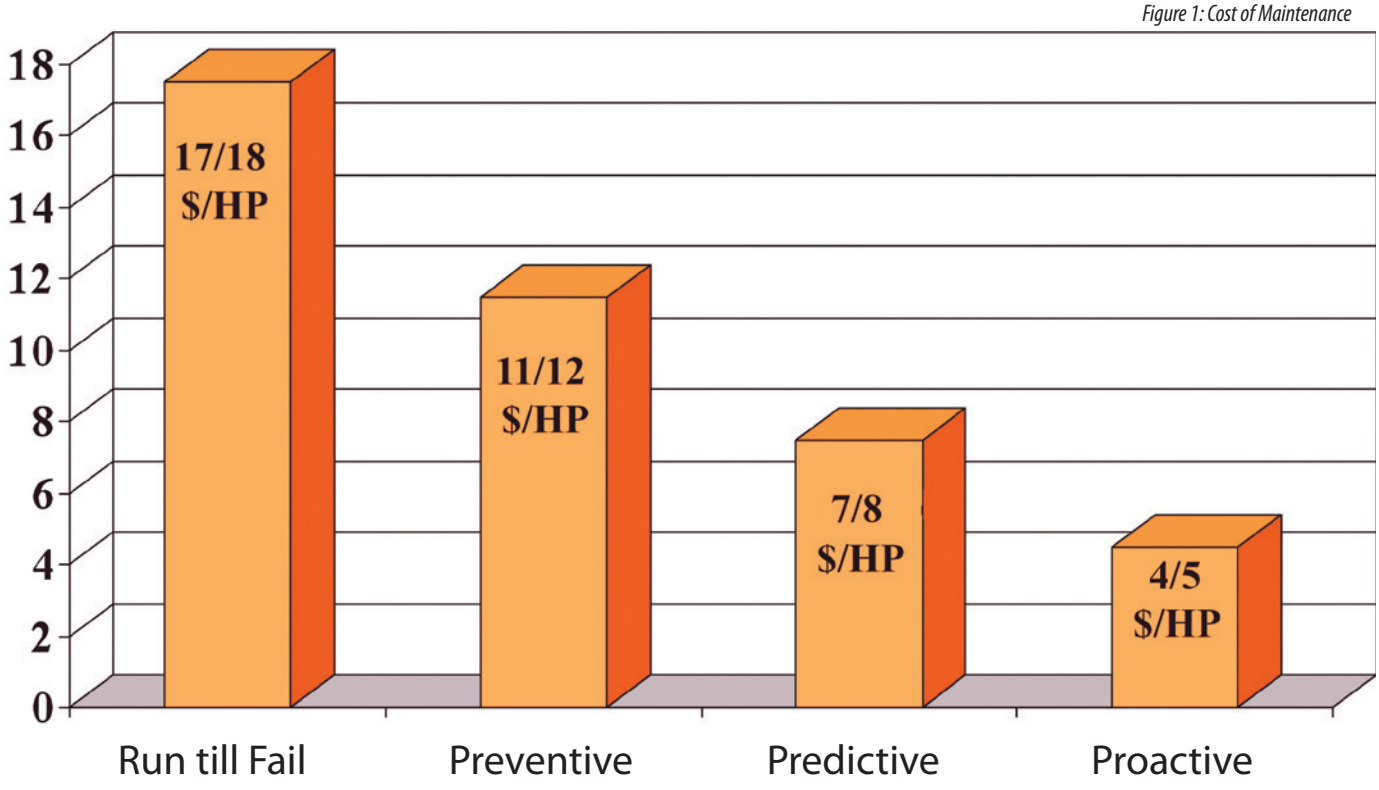
Predictive Maintenance (PdM) resulted from studies that determined that Preventive Maintenance (PM) programs are only effective for the 11 percent of machine failures that are age related. This means approximately 89 percent of machine failures are random in nature and time-based maintenance programs are ineffective on these random types of failures.

Multiple Technologies

There are many different PdM technologies, but the most successful programs use multiple technologies to provide the most information and consequently the highest probability of identifying a machine with a developing problem.

Some of the most common PdM technologies are machinery vibration analysis (MVA), infrared thermography, ultrasonics, oil anal-

Figure 1: Cost of Maintenance



ysis, motor circuit analysis (MCA) and electrical signature analysis (ESA). Common characteristic among the most successful PdM technologies are that they are easy to perform and provide non-destructive, repeatable measurements.

However, regardless of the technology being used, the most successful programs recognize that there are three phases in a successful predictive maintenance program:

1. Detection
2. Analysis
3. Correction.

Following is a brief review of the three phases of successful PdM programs.

Detection Phase

The detection phase is the most critical phase and the basis of most successful PdM programs. The main purpose of the detection phase is to identify "bad" machines or conditions that can lead to future machine failure. "Bad" machines are machines that are in a deteriorating condition.

Analysis Phase

Accurately determining the condition of the machine or more completely defining the cause of the change in the machine's condition is the main purpose of the analysis phase. The analysis phase involves taking additional or perhaps even different types or more in-depth data than the detection phase. This additional data may require more specialized techniques or technologies. It may require testing at different operating conditions or using completely different technologies.

Correction Phase

The main purpose of the correction phase is to determine the correct action based on the machine's condition change. This involves taking the action necessary to correct and eliminate the problem triggered by the change in the machine's condition. Additionally, the correction phase should verify that the corrective action did actually fix the problem(s). Alternatively, plant operations may dictate that the best action may be to simply continue monitoring at reduced test intervals.

Machine Selection

Selecting the machines that are going to provide the biggest payback from a PdM program seems obvious by classifying machines either by size or application. Most plants that have embraced predictive maintenance classify machines based on their application.

Critical Machines

Plants that classify machines based on application define critical machines as machines that are very critical to the plant's operation. In other words, if the machine shuts down, the entire process will stop. This, in many cases, results in lost production. Additionally, the product in process also may be lost. When classified by size, these machines are often the largest in the plant, usually greater than 300 HP (225 KW).

Semi-Critical Machines (Production)

Semi-critical machines are defined as machines that if shut down, will cause a partial loss of production. Losing these machines, although not causing a complete plant shutdown, may limit its output and therefore its availability. Some of these machines may have built-in spares or use two or three machines to operate at full unit capacity. These machines are medium-sized, typically 150 to 300 HP (110 to 225 KW).

Balance of Plant Machines (Non-critical)

These machines have little or no effect on plant production. These machines are usually the smallest in the plant, typically 5 to 150 HP (3½ to 110 KW) and spares are readily available.

Motor System

Any motor system has two subsections:

1) The electrical subsystem consists of the power coming into the plant, the plant distribution system and the electrical section of the motor.

2) The mechanical subsystem consists of the motor shaft and coupling, the driven machine and the process itself.

A fault anywhere in the motor system can prevent it from performing the intended function. This may result in reduced or lost production, excessive maintenance, or operational expenses. These two subsystems directly affect either electrical or mechanical reliability.

Electrical Reliability

Electrical power is one of the most important raw materials used in industry today. Not only must we have a continuous flow of power, it also should be clean and balanced. Yet, this important commodity is also one of the least inspected raw materials supplied to the plant.

Electricity is required in almost all areas of the plant to provide the driving force that either operates the equipment that produces the products or provides the services that the plant's equipment were built to perform. Electricity is a unique product in itself in that it requires continuous flow, cannot be conveniently stored and is normally not inspected prior to use.

Most people believe that electrical reliability ends with the successful delivery of power to the plant. But in many cases, the quality of the power supplied to the motor system may be the cause of a breakdown or failure. The result of poor "power quality" is usually long term and often overlooked as the source or contributor to the problem.

Power is normally generated far from the point of use, the reliability of the original generation is unknown and it is combined on the grid with many other generators. Many of the generating plants are smaller and privately owned. The power is transported through several different transformers and many miles of overhead and underground cabling before arriving at the plant. Many of these electrical distribution systems are owned, managed and maintained by several different entities. Once bad or "poor quality" power is placed on the grid, it cannot be removed or even rejected by the user.

Work to standardize and regulate power quality is in progress. Many states have their own specialized standards and regulations. However, generated power does not stop at the borders of the state where it is generated.

Mechanical Reliability

Mechanical reliability has long been a subject of maintenance departments, and considerable improvement has been accomplished by understanding the importance and benefits of improving machinery balancing and alignment tolerances. The balance and alignment condition of a machine is measured and determined using mechanical vibration analysis (MVA). In many cases, machines exhibiting unacceptable vibration levels are removed from service and faults such as unbalance, misalignment, soft foot, mechanical looseness and other faults are corrected before mechanical failure occurs. Although MVA has proven very effective for identifying mechanical faults in the motor or the driven machine, it has proven ineffective in detecting the condition or quality of the power applied to the motor.

Additional limitations of MVA exist. First, it relies on measuring the motion of the machine's bearings or bearing housings to identify developing faults. The force generated during the early stages of most faults is insufficient to cause measurable movement. Secondly, faults that occur at locations remote from the bearings are usually undetectable with MVA. Faults in overhead fans or vertical pumps are normally undetectable using MVA. To identify faults on the entire motor system requires making multiple measurements at each bearing location. An average machine survey varies from 7 to 10 minutes.

If a motor burns up or if a breaker trips, technicians conduct electrical and mechanical inspections on the motor and the driven machine. The motor is then rebuilt or replaced and the whole process repeats. Faults that are caused by electrical problems, such as harmonic distortion, voltage unbalance, or any other electrical faults, are undetectable using MVA.

Electrical Signature Analysis

Electrical signature analysis (ESA) is a PdM technology that uses the motor's supply voltage operating current to identify existing and developing faults in the entire motor system. These measurements act as transducers and any disruptions in the motor system cause the motor supply current to vary or modulate. By analyzing these modulations, it is possible to identify the source of these motor system disruptions.

ESA measures all three phases of current and voltage at the motor controller while the machine is in normal operating condition. ESA performs a simultaneous capture of all three phases of voltage and current, performing a complete indication of the incoming power quality and motor power. It calculates motor efficiency and motor power factor. ESA also performs a Fast Fourier Transform (FFT) on the voltage and current waveforms.

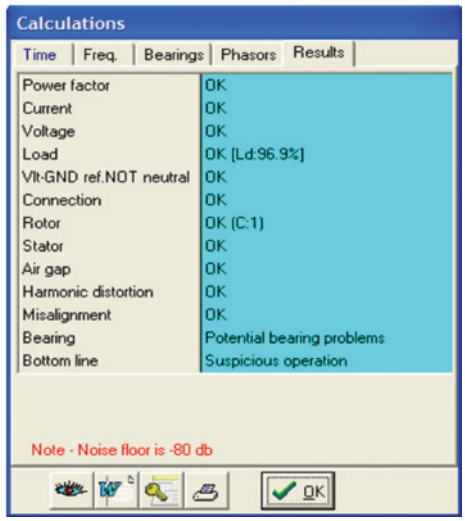


Figure 2: Power Quality Table

The detection phase is the most critical phase and the basis of most successful PdM programs.

ESA is proving to be a very effective technology for detecting faults anywhere in the motor system during the PdM process. The FFT allows ESA to identify all the mechanical faults that MVA finds in the motor, the driven machine and the process itself. It also provides better diagnostic capabilities for identifying and analyzing developing electrical faults within the motor electrical subsystem. In addition, it performs a complete power analysis to identify any power issues that can lead to premature failures in the electrical subsystem of the motor system.

The automatic analysis performed during the ESA process can be far more accurate than MVA since measuring the motor voltage and current allows for accurate determination of the running speed. This accuracy is usually within one or two RPMs. Additionally, ESA uses the motor current as its transducer and very small changes in any part of the motor system causes modulation of the motor current. This increased sensitivity allows for early detection of developing faults anywhere in the motor system. ESA has successfully detected faults in vertical pumps, overhead fans and loose bearing housing on machines driven by belts.

Summary

Successful implementation of PdM programs requires a thorough understanding of the PdM process and the efficient utilization of highly trained PdM personnel together with special and often expensive equipment. Reliability engineers agree that developing faults need to be identified as early as possible and ESA fulfills this requirement. As a detection tool, ESA usually identifies most mechanical faults in the motor system

Plant Name: ****
Coordinator: ****
Date: 06/24/2010 22:03:04
File name: C:\ATPOL DATA\ESA 6.1\EX3\EXERCISE 3_000(HI)

Equipment:****
Analyst:****

ALL TEST Pro OL 6.2 Analysis Results

PERFORMANCE SUMMARY

Bottom Line

_____This induction motor is operating normally, no action is required.
_____This induction motor exhibits suspicious operation, trending of the induction motor is warranted.
_X_____This induction motor exhibits abnormal indications, action is warranted, NOW.

Power Factor Commentary

_X_____Power factor exceeds 0.85.
_____Power factor is below 0.85, see detailed report.

Current Commentary

_____Current variation is within normal limits.
_X_____Current variation is beyond normal limits, see detailed report.

Voltage Commentary

_X_____Voltage variation is within normal limits.
_____Voltage variation is beyond normal limits, see detailed report.
_____RMS voltage differs from nameplate by more than 5%.

Load Commentary

_X_____Load on the induction motor is consistent with nameplate values.
_____Load on the induction motor exceeds nameplate values, see detailed report.
_____Load on the induction motor is less than 25%.

Phase Connection Commentary

_X_____Connections are normal.
_____Voltage ground reference is NOT neutral.
_____Loose connection.

Rotor Commentary

_____Rotor bar health is normal.
_X_____Rotor bar health is questionable, see detailed report.
_____Load is insufficient to determine rotor bar health, at this time.

Stator Commentary

_X_____Stator health is normal.
_____Stator electrical health is questionable.
_____Stator mechanical health is questionable. .
_____Turn to turn short.

Rotor/Stator Air-gap Characteristics

_____Dynamic or static eccentricity indications do not exist.
_X_____ Indications of static eccentricity exist .
_____ Indications of dynamic eccentricity exist.

Harmonic Distortion Commentary

_X_____There is no evidence of harmonic distortion.
_____There is evidence of harmonic distortion, see detailed report.

Misalignment Indications

_X_____There are no indications of mechanical problems like misalignment or unbalance.
_____There are indications of mechanical problems like misalignment / unbalance. Perform vibr. survey to identify and correct the cause.

Bearing Commentary

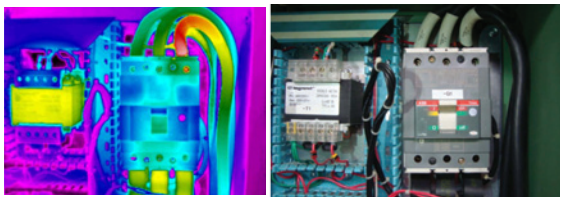
_X_____There is no evidence of bearing problem.
_____Indications of potential bearing problems, perform vibration survey to verify.

Figure 3: Motor System Analysis Report

before mechanical methods like machinery vibration analysis (MVA). Additionally, ESA accurately identifies electrical problems in the motor system that MVA or other PdM technologies cannot identify. In the analysis phase, ESA more accurately determines the system's rotational speed and more precisely identifies the mechanical and electrical faults that lead to reduced plant availability and uptime.

William Kruger joined ALL-TEST Pro, LLC as the Technical Manager in 2005. Since joining ATP, Bill has traveled the world teaching the Theory and Application of Motor Diagnostics, helping Fortune 500 Companies implement Predictive Maintenance Programs. With his combined work in the field as well as with ALL-TEST Pro, Bill has over 40 years of proven experience in the practical engineering and predictive maintenance field. www.alltestpro.com

Infrared Thermography: Making Wasted Energy Visible



Wayne Ruddock

Infrared thermography is one of the best tools available for identifying areas of energy losses in both building and process applications. Beginning with the first truly portable infrared system in Sweden back in the early 1970s, it was determined that infrared could detect a number of conditions that contributed to the waste of energy used for both heating and cooling residential and commercial building envelopes.

As a result of the 1973 and 1979 oil crisis, the Canadian federal government made a large investment in infrared technology to inspect many federal government buildings to identify areas of excess energy loss. Repairs made to areas identified by this program resulted in signifigant energy cost reductions.

In the U.S., the Weatherization Assistance Program (WAP) enables low-income families to permanently reduce their energy bills by making their homes more energy efficient. Funds are used to improve the energy performance of dwellings of needy families using the most advanced technologies and testing protocols available in the housing industry. Infrared thermography is one of the tools used. The U.S. Department of Energy (DOE) provides funding to states, U.S. overseas territories and Indian tribal governments that manage the day-to-day details of the program. These governments, in turn, fund a network of local community action agencies, nonprofit organizations and local governments that provide these weatherization services in every state, the District of Columbia, U.S. territories and among Native American tribes.

The energy conservation resulting from the efforts of state and local agencies helps our country reduce its dependence on foreign oil and decreases the cost of energy for families in need while improving the health and safety of their homes. During the past 33 years, WAP has provided weatherization services to more than 6.4 million low-income households. Families receiving weatherization services see their annual energy bills reduced by an average of about $437, depending on fuel prices.

In Europe, there is also an energy conservation program in effect, where infrared thermography is one of the tools employed. The 2002/91/CE Directive of the European Parliament and Council related to the energy performance of buildings directive (EPBD) complies with the European energy strategy and is a useful legal tool, on a European level, to improve the energy performance of buildings in an effective way.

In fact, the EPBD has:

- Brought the issue of energy performance of buildings to the attention of citizens and to public body agendas within member states;
- Introduced the energy certification tool in order to ensure compliance with the energy requirements established by law;
- Established that energy certification of existing buildings shall include suggestions regarding possible interventions aimed at improving energy efficiency;

- Included energy certification among the required documents to be included with real estate sales deeds or tenancy contracts so the real estate market can become more transparent and develop a virtuous mechanism where offer and demand concern increasingly efficient buildings;
- Engaged member states in organizing information campaigns targeted at citizens that focus on the energy efficiency of buildings so their choices will take into account not only the aesthetic aspect of a house, but also the associated energy costs.[1]

The main purpose of insulation in exterior building walls is to keep the energy used by the HVAC system inside the structure, dedicated to the purpose for which it was created - to either heat or cool the interior. Insulation efficiency is based on the integrity of the millions of tiny dead air pockets in the insulation material. Conduction is the mode of heat transfer by which energy is transferred from one side of a material to the other by the intimate contact of the molecules. The denser the material, the better the conductor. For example, gasses are the poorest conductors, or good insulators, while solids and liquids are better conductors than insulators because the molecules in both these states of matter are fairly dense and close together.

A perfect insulator would allow no energy to be transferred from the interior of a heated building to the cold exterior of a cold climate such as the northern areas of North America. In the south, the job of insulation is exactly the opposite. It is used to keep the hot exterior energy from transferring through the structure into the cooler air conditioned interior. Although there is no such material as a perfect insulator, many materials, such as fiberglass insulation and styrofoam insulation, serve the purpose and signifigantly reduce the amount of energy wasted or not used to perform its intended task. In the case of wet insulation, the water molecules inside the insulation act as a conductor (Figure 1). Heat transfer is also much greater where there is no insulation in place and also results in wasted energy.

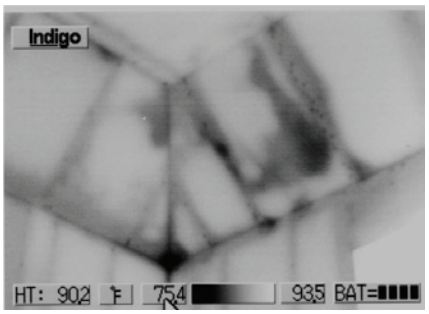
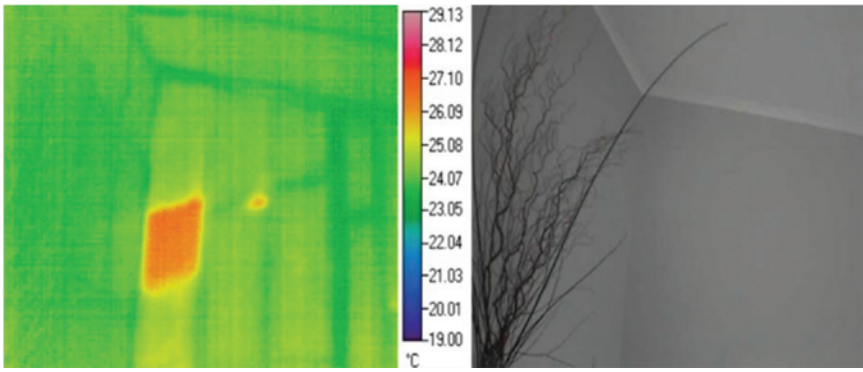


Figure 1: Black and white infrared image of wet insulation from the inside of a heated structure on a cold day. The darker areas represent cooler areas where wet insulation is present.

Infrared thermography can identify:

1. Missing Insulation (Figure 2)
2. Damaged insulation
3. Water ingress/wet insulation
4. Air infiltration
5. Air exfiltration
6. Excessive thermal bridging
7. Leakage in hot water heating systems.

Figure 2: Color infrared image of missing insulation in a home which is air conditioned on a hot day. Square warm pattern is indicative of a missing bat of fiberglass insulation.



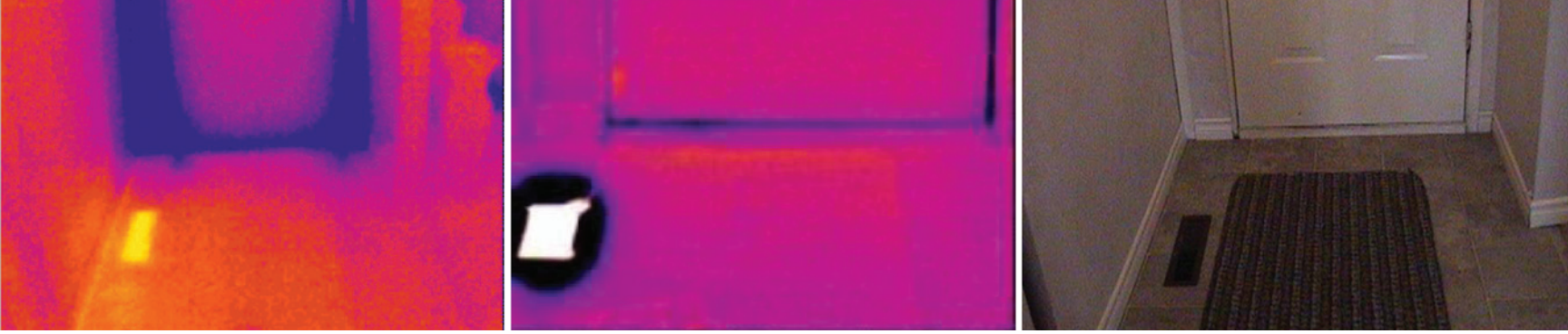


Figure 3: A color image of air leakage around an outside door caused by missing weather stripping both before and after retrofit.

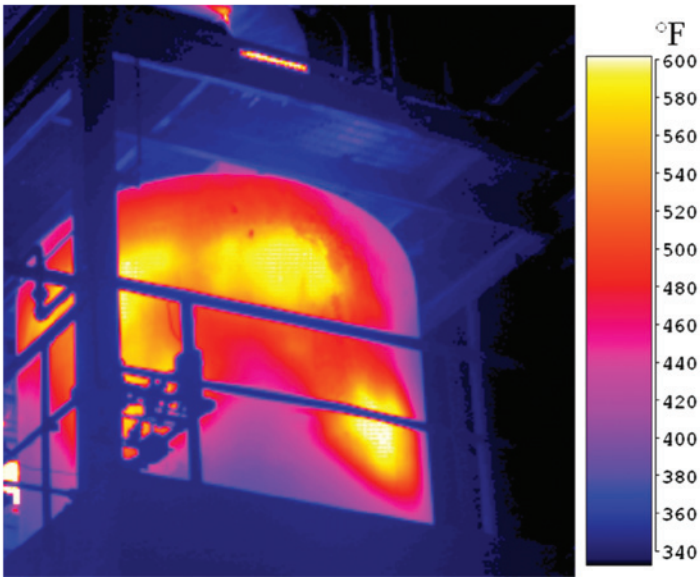


Figure 4

Convection is the transfer of energy by the movement of a fluid, which can be either a gas or a liquid. "Drafts" caused by air infiltration/exfiltration (Figure 3) often cause inhabitants to "turn up the heat," which increases the amount of energy used to heat a house.

In industrial processes, the same principles apply. When the brick refractory in a heated process vessel thins or falls out, the energy meant to heat the process to a specific temperature is wasted as it heats the exterior of the vessel rather than the process. This can be very easily detected by infrared thermography, as can be seen in Figure 4.

An area often overlooked in industrial commercial situations is the energy wasted when an electrical component heats up due to higher resistance, loading issues, or induced heating. The main focus today is that of electrical safety. The National Fire Prevention Association (NFPA) has recommended that all electrical equipment be inspected a minimum of once per year with infrared thermography to identify any areas of potential electrical fires and safety issues.

Often, the amount of energy wasted is thought to be inconsequential. The first law of thermodynamics tells us that energy cannot be created or destroyed in a closed system; it only can be changed from one form to another. The heat we see with our infrared systems while doing an electrical inspection is simply electrical energy that is being converted to thermal energy and not being used to perform the work it was designed to do. Therefore, it is really wasted energy. In Figure 5, we have a case of induced heating. How much electrical energy is being wasted in order to heat these ferrous bolts to a temperature in excess of 100 degrees Celsius by means of induced heating?

Another question one might ask is, How much energy is being wasted by high-resistance connections such as the one in Figure 6? This heating is a product of electrical energy being converted to thermal energy rather than being used to power the equipment to which it should be directed.

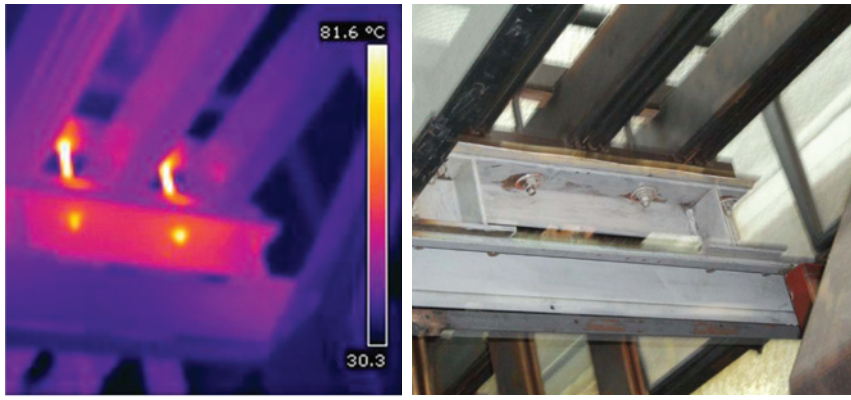


Figure 5

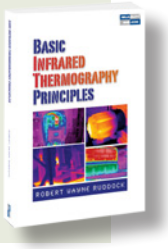
Figure 6

If you are involved in residential, commercial or industrial energy management programs, infrared thermography is a tool that is indispensible. No matter what the cause of the heat loss, an infrared camera can quickly identify heat loss locations. With the accurate temperature calculations available with most modern infrared systems, a financial feasibility study can be undertaken to determine the cost benefits of remedial actions.

References:

1. Source: "Comparison of Building Certification and Energy Auditor Training in Europe", ENFORCE - European Network for Energy Performance Certification of Building, Sept. 2010.

Wayne Ruddock has been involved in Infrared Thermography and Infrared Thermographic Training since 1979. He is a seasoned veteran of hands-on infrared inspections, giving him the ability to teach real-life thermography. He has been conducting Level 1 and Level 2 training courses throughout the world since 1980. He has written and presented many thermographic papers at conferences over the last 30 years, and he is the author of Basic Infrared Thermography Principles, *available at www.mro-zone.com.*



50,000 Hour Off-Highway Diesel Engine Rebuilds: They Are Possible!

Mark Barnes

From dozers to graders and loaders to haul trucks, diesel engines are everywhere. For companies who rely on diesel power to make their living, there's no greater emphasis than diesel engine reliability. But when it comes to diesel engines, they also have some of the shortest life expectancies.

Compared to fixed equipment, where mean-time-between-rebuilds is measured in years, most diesel engine original equipment manufacturers (OEMs) recommend an engine overhaul or rebuild every 12,000 to 15,000 hours. Even with oil analysis, which allows the rebuild interval to be optimized, 20,000 to 25,000 hours is about as good as it gets for engine life in off-highway applications.

So why is it that an engine has such a short life expectancy? The issue is less about maintenance than it is about the operating conditions and environment of a typical engine. With temperatures close to 200 degrees F, severe duty and shock loads, internal contaminants like soot, acids and wear debris, and the possibility of fuel or glycol leaks, engines have a tough life.

But perhaps the biggest engine killer is external contamination in the form of dust and dirt, sucked into the engine each minute of operation through the air intake. Particle contamination can be lethal for engines - even microscopic particles no bigger than a red blood cell can result in a significant reduction in an engine's life expectancy. In fact, studies by General Motors, Cummins, Inc., and other engine OEMs have proven that particles in the 0 to 5 and 5 to 10 microns size ranges are three times more likely to cause wear in critical piston rings and bearings than larger particles (Figure 1). To put that into context, particles that are less than a tenth of the diameter of a human hair are enough to reduce an engine's life expectancy by one half or more! These particles, which are often called silt-sized particles, are so small that a large percentage of those ingested into the engine air intake manifold pass straight through the air filter, which, by comparison, is really only equipped to take out rocks and boulders.

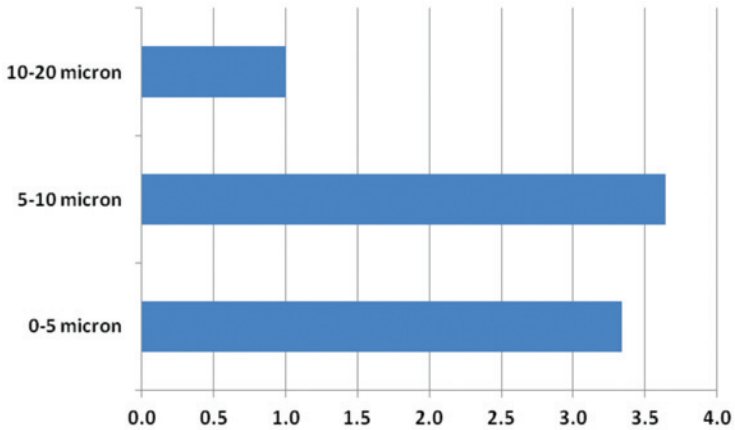


Figure 1: Relative wear rates for engine rings and bearings versus particle size distribution (Ref: Cummins, Inc.).

Armed with these facts - which are widely known by OEMs, lubrication engineers and filter manufacturers alike - why is it that most full-flow engine oil filters are at best 70 percent efficient at removing 10 um particles and are effectively useless at removing silt-sized particles? The answer is largely a question of flow. With any filter, there is always a balance between flow rate and filter efficiency. With most filters, as the micron rating and filter efficiency improves, the flow rate drops off significantly. This should be fairly obvious: the smaller pore sizes necessary to trap smaller particles create a greater barrier to oil flow. But the problem is exacerbated by simple physics: For most mechanical filters, halving the micron rating, say from 10 to 5 microns, would require a four-fold increase in filter surface area to maintain the same flow rate. Because of this and due in part to the physical limitations in the size of an engine filter, it is almost impossible for filter manufacturers to reduce the micron rating to be more efficient at removing silt-sized particles while maintaining adequate flow rates.

So that's it right? We're stuck with accepting the fact that the most harmful particles to an engine are going to be present in an engine with no hope of removing them? Wrong! By thinking outside the box a little, silt particles can be removed from engines effectively, with a dramatic impact on engine life. To illustrate the effect, consider the following example:

Case Study

A maintenance team at a 25,000-acre surface coal mining operation in Montana was seeking to improve profitability by lowering direct maintenance costs and extending the operational life of the engines. They were well aware that the service life of their engines was being cut short by particles that the OEM full-flow filtration was not designed to remove. Starting with their CAT 992G bucket loaders equipped with CAT 3508B engines, the mine developed an approach to reduce silt-sized particles from the engines. Initial oil analysis data on one 992G in the mine's fleet indicated a particle count of 22/21/18, with copper and iron levels at 118ppm and 53ppm

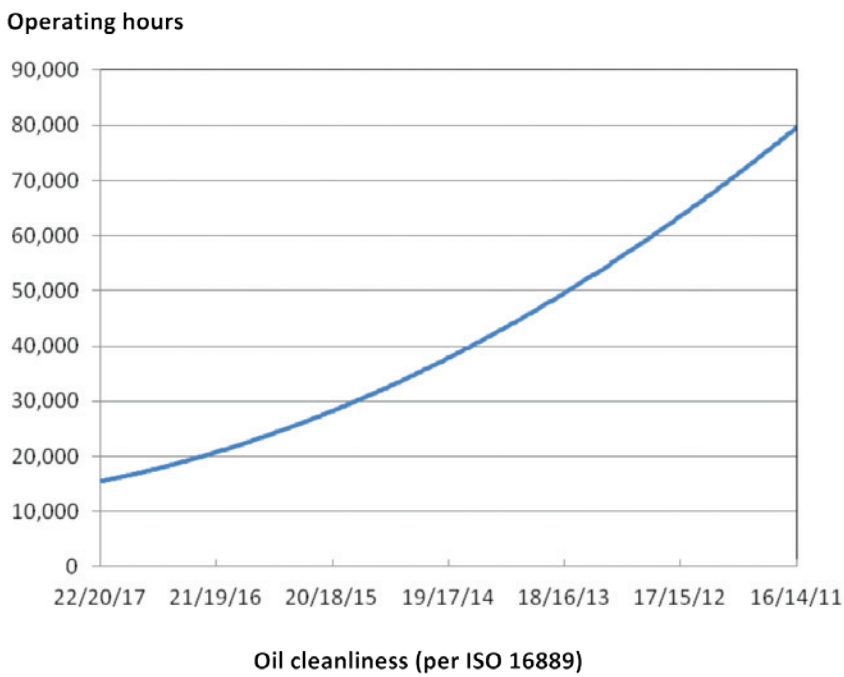


Figure 2: Projected engine life, with oil analysis.

	Before Standard OEM Filtration	After Secondary Filtration with ENG-2
ISO Cleanliness Code	22/21/18	17/16/13
Hours on oil	306	931
Soot Levels		≤0.1%
Iron Levels	53ppm	7ppm
Life Extension		4x
Annual overhaul costs	$9,733	$2,433
5-year Net Present Value (NPV) Savings (6 loaders)		$129,841
Internal Rate of Return (IRR)		216%

Table 1: Oil analysis data and investment analysis for CAT 992G (3508B engine).

respectively, levels commonly found across the rest of the fleet. Maintenance personnel also indicated that a typical engine "top end" overhaul interval was approximately every 12,000 hours and when engines were torn down, they were typically very "dirty" inside with evidence of scuffing on the cylinders. The team set about lowering in-service contamination levels through an aggressive contamination control strategy.

Exactly 931 hours after improving their oil filtration, an oil analysis was conducted to evaluate if any improvements had been made in oil cleanliness. To their surprise, ISO cleanliness levels went from 22/21/18 (c) to 17/16/13 (c), soot levels were maintained at or below 0.1% volume and iron levels dropped from 53ppm to 7ppm. Based on this and the standard life-extension tables (Figure 2), the mine has projected a four-fold life extension, resulting in a savings of $129K over five years, equivalent to a 216 percent return on their investment (Table 1). This is just one of many examples that demonstrate the effect of improving slit particles in engines.

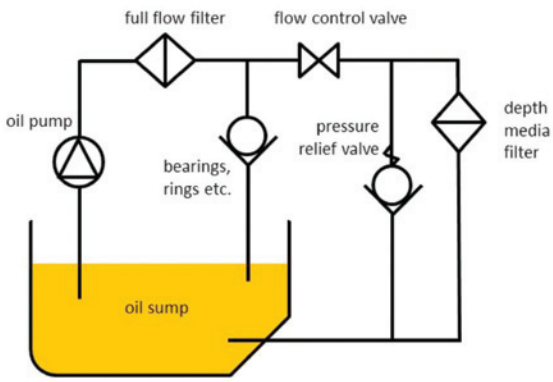


Figure 3: Schematic illustration of engine oil side stream filtration.

Bypass Filtration

So how did they do it? The answer is fairly straight forward as illustrated in Figure 3. Without changing the flow of oil within the engine, a small slipstream of oil is taken after the full-flow filter using a flow control valve. By regulating oil flow through the valve, only 10 percent of the total oil flow is removed at any given time, which is not high enough to cause any harm to the engine. This side stream of oil is passed at normal engine oil pressure through a depth media filter with an efficiency rating of 99.9 percent at 3 microns (β3(c)>1000). The oil is then returned to the sump. For safety, a relief valve is included to avoid over pressurization of the bypass filter during start-up.

Conclusion

Engine overhaul and rebuilds are a significant cost to diesel engine maintenance budgets. With few exceptions, significant improvement in engine life can be achieved by controlling silt-sized contaminants.

Mark Barnes, CMRP, recently joined Des-Case Corporation 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. www.descase.com

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The Maintenance Storeroom: Keys to Efficient Maintenance Operation

Jeff Zeiler

Besides being the central hub for maintenance, the storeroom also provides functions that are absolutely critical to the maintenance operation. These functions are so important that when the storeroom is operating in a best practices mode, the rest of the maintenance operation can excel. In other words, the storeroom is the enabler.

Put another way, if the storeroom is run improperly (such as poor inventory accuracy, parts unavailable when needed due to poor replenishment and procurement practices, etc.), the rest of the maintenance operation has no chance of achieving high service levels of equipment availability and reliability.

The sections that follow provide methods and practices for achieving storeroom excellence, which, in turn, enable excellence in the entire maintenance operation.

The Storeroom as Service Provider

If you follow the flow of technicians and materials in a typical maintenance operation, a common pattern emerges. In general, you have a central hub and the spokes of a wheel - where the hub is the storeroom and the spokes are the paths to the equipment or machinery in the facility or site that are undergoing maintenance. The number of work centers on site multiplies the actual material flow. This analogy illustrates the pivotal role of the maintenance storeroom.

More than playing a pivotal role, however, is the main function of the storeroom - provide parts quickly when needed. This function places the storeroom in the position of a service provider, with the rest of the maintenance organization (and by extension, manufacturing operations) as the customers. As anyone who has ordered food from a fast-food restaurant can attest, there are times when service is good (the right food, the right price, ready to go) and there are times when service is not so good (wrong food, cost too much and long delays).

Perhaps one of the main ingredients of success for a service provider (besides fundamentally delivering what is promised) is to manage expectations of its customers. This is done in a deliberate way through various forms of communications so customers not only understand *what* service they will receive, they also understand *how* the service will be performed. Again, in the restaurant business, if food is promised in 60 seconds and it takes 5 minutes to be delivered, you have a dissatisfied customer. The customer received the exact same food in either case, only now they are dissatisfied because their expectation of timeliness was not met.

In the maintenance world, there is an implied expectation of parts availability. For many parts, that expectation can be easily met. But for some classifications of parts, that expectation is unrealistic either due to cost of the part, reliability profile (mean time between failure and mean time to recovery), or other characteristics of the part. Those responsible for maintenance and the storeroom must communicate to the facilities and operations organizations the reasonable expectations of service from the storeroom. These expectations of parts availability are the result of analyzing the impact on downtime, the likelihood of failure and the carrying costs of the parts.

Ideally, the time to decide on whether parts should be stocked is when new equipment is placed in service. Manufacturing and the parts suppliers can work with maintenance in recommending the spare parts to stock as the new equipment is being purchased. Thereafter, maintenance can use historical usage data in deciding adequate inventory levels, or even to discontinue carrying certain items. In a larger maintenance and parts organization, a parts inventory planner is the decision maker when it comes to the stocking level, timing of re-orders and replenishment trigger levels of a part.

Storeroom Organization for Productivity

The storeroom is like any other business area when it comes to productive operation – the area must be organized in a physical sense. This means:

- The parts storage area is sized and equipped appropriately for the types and volumes of parts to be handled by maintenance.

- The parts storage area must be free of debris and clutter in the aisles to permit personnel quick access to the locations.
- The locations must be labeled so that time searching for parts is minimized.
- Stepladders, stools and carts must be parked in an area that is out of the main flow.
- The area needs to be physically separated from the main plant, either by walls or with a secured cage. This separation is to discourage theft and to enforce recording of parts receipts/issues for inventory accuracy purposes. Access procedures must be in place for parts needs after hours.
- Lighting in the area must be sufficient to permit counting of parts in the aisles – whether for parts issued to a work order or for cycle counting.

Another aspect of storeroom organization is the staffing and job requirements of the storeroom personnel. There are distinct work elements within the storeroom that should be combined into jobs that make the most productive use of the staff's time. Where possible, and if the volume of parts transactions justifies, limit the number of different work elements in a particular job. Combining too many different work elements into a job is counterproductive as there is time lost when shifting from one work element to another.

If job variety is important, then the staff should be cross-trained so they can move to different jobs on different days. In any case, the realities of the storeroom mandate that the staff is cross-trained anyway, since unplanned work will necessitate all storeroom staff being able to accomplish any function.

One of the critical success factors for the storeroom is achieving a high level of inventory accuracy. Accurate inventory is defined as the correct part and the correct quantity physically in a storeroom location being the same as that shown on the inventory control system or CMMS.

The Importance of Inventory Accuracy

One of the critical success factors for the storeroom is achieving a high level of inventory accuracy. Accurate inventory is defined as the correct part and the correct quantity physically in a storeroom location being the same as that shown on the inventory control system or CMMS. Minor variances between actual and system counts are tolerated, such as with nuts and bolts. However, if the part, quantity, or location is not correct when matched against the system, then that location is counted as an "error" for purposes of tabulating inventory accuracy.

Inventory accuracy is important for a number of reasons. The consequences of inaccurate inventory are:

- If the actual inventory is lower than the system record, then the risk is high that an out-of-stock condition can occur because parts will not be ordered on time.
- If the actual inventory is higher than the system record, then parts will be flagged for reordering by the system even if not needed.
- If actual inventory is not accurate, then maintenance technicians and machine operators will lose confidence in the inventory control

system or CMMS and benefits from using other functionality in the system will be lost.

- A growing of proliferation of bench stock (stock held on the floor or in cabinets/shelves outside the storeroom) can occur if technicians do not have confidence in the service levels of the storeroom. This inventory is "off-the-system" and results in excessive total inventory levels.

It is critically important that others besides the storeroom operators understand the importance of inventory accuracy. Maintenance technicians, maintenance planners, operations personnel and plant management should also understand the importance of inventory accuracy since these groups will be impacted by procedures designed to improve inventory accuracy. For example, achieving high levels of inventory accuracy requires:

- Recording all parts receipts against purchase orders or outside repair orders.
- Recording receipts of parts returned to the storeroom that were previously issued to a work order but not actually used.
- Recording parts serial numbers, lots, or other important information at the time of receipt.
- Recording parts putaway locations.
- Recording all parts issued to a work order, employee number, or other account.
- Performing routine and accurate cycle counts.

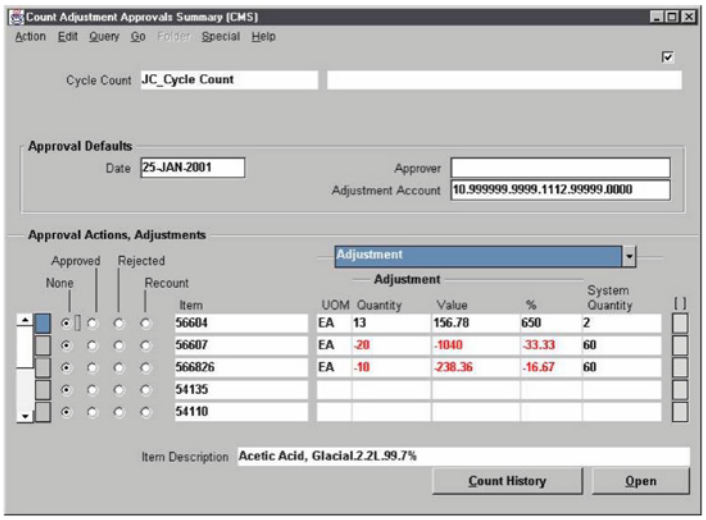


Figure 1: Example of Cycle Count Adjustments

Cycle Counting Parts

While cycle counting has been accepted and implemented for a long time, the details of a cycle counting program are subject to many variations. For example, a part can be counted based on numerous criteria, such as part movement, part value and part criticality. Also, cycle count timing can change from part to part, varying in frequency from daily to yearly.

Besides setting up the cycle counting routines - which generate the daily cycle tasks - it is necessary to establish procedures for handling counts that are out-of-tolerance. Typically, the counting is performed by personnel who are designated to count as their main responsibility. Again, this depends on the volumes of parts that flow through the storeroom. The counter will receive a listing of parts and loca-

tions to count throughout the workday based on the part and count criteria established in the cycle count setup routines. Ideally, the cycle count tasks will be performed in real-time so that parts movement throughout the day does not impact counting accuracy.

When the counter enters the count to the system, the counter will not know if the entered quantity matches the system quantity. If there is a mismatch within an acceptable tolerance, then the system quantity is updated. If there is a mismatch outside the tolerance level, the counter is asked to recount. Again, if there is a mismatch, then the system flags that part and location as an error count but does not yet update the quantity. The counter resumes counting other parts and the discrepancy is referred to a designated inventory control person to research and resolve.

Approval of large cycle count mismatches is done on the system after the inventory control person verifies the discrepancy. The effect of the approval is to adjust accounts on the system for the over/under quantity of inventory. An example of approving cycle counting errors (performing the adjustment) is shown in the screen print on the opposite page (Figure 1).

Effective cycle counting not only provides higher inventory accuracy, but also serves as a daily reminder to the organization that there is accountability for inventory among all employees. Each part is subject to cycle counting and counts not accurate will be investigated.

Slotting Inventory Correctly

Real productivity savings in the storeroom can be gained from the correct slotting of parts. Slotting of inventory is the assigning of a part to a location based on the part's movement, amount of inventory to have on hand, and physical characteristics, such as size and weight. Parts that are slow movers should be stored near the back of the storeroom and fast movers near the front of the storeroom for quicker access. For example, a motor that is a critical spare and needed once a year should be slotted in the rear of the storeroom, while filters and gaskets that may be needed for frequent preventive maintenance tasks should be located near the front of the storeroom.

Other aspects of slotting involve determining the number of bins to assign a part. This depends on the quantity to hold in stock and the size of the part itself. If a six-month supply of a part is required, then two or three bins may be required to assign to the part so when the part is ordered and received, there is a place for the part to be put away. On the other hand, a six-month supply of other parts may still only require a single bin – it all depends on the movement history of the part.

There are many different storage and retrieval methods that can be employed to handle parts, and each can be appropriate depending on the volumes and characteristics of the parts. For example, dense storage, narrow aisle man-up vehicles may be appropriate for either heavy parts on shelves or for small parts on shelves.

Other alternatives for storeroom parts storage include a vertical lift module, which is a vertical carousel. The distinct feature of this technology is that it provides for parts coming to the operator, significantly reducing travel time to locate parts.

The less mechanized, but still very efficient, options for parts storage and slotting include case flow lanes, static shelves and small parts bins.

No matter which storage technology is chosen, the important issue is that parts history

must be analyzed to determine the movement. There will be different payback points for each alternative as labor and productivity savings offset the capital investment.

Finally, another common element of slotting, regardless of the storage and retrieval methods or technology used, is that each location is unique and referenced in the inventory control system or CMMS. Using unique locations enable the use of an automatic identification system to streamline parts handling.

Use of Auto ID

The introduction of automatic identification (auto ID) technology into the storeroom has resulted in a significant contribution to storeroom productivity, inventory accuracy and error elimination. Whether for parts put away, parts picking, or cycle counting, using auto ID is now a best practice.

The days of looking on the system for a part, writing down the part number and bin number on a slip of paper or clipboard and taking that to the location are dwindling. Now, the operator receives the information directly and there are no transcription errors to worry about when writing down long sequences of number and letters. The two main methods of communicating information to the operator are via a handheld display on a scanner or a voice-directed headset. Both use radio frequency (RF) technology to communicate the information.

With the advent of the personal digital assistant (PDA), the functions of the scanning gun and the organizer have been merged. This is particularly useful for maintenance technicians who need to access real-time information and fill out work orders in the field.

PM Kit Building

One of the functions of the storeroom is to provide parts, tools and supplies for the technicians to perform preventive maintenance tasks. As a way to level out the storeroom workload and provide better service (higher availability of parts) to the technicians, the storeroom can build preventive maintenance (PM) kits in advance of the scheduled PM time. This requires access to the PM schedule by the storeroom and a way to track and hold parts inventory prior to issuing them to the PM work order.

One way to do this is to use a mobile cart with multiple kitting bins (locations) onboard. The parts listed on the PM work order are picked from the storage locations and placed into one of the kit bins. These kit bin locations are an extension of the static storage locations, so the inventory control system or CMMS can track these kit bin locations with a "staged" status. When picking is completed, the entire cart is moved to a kitting hold area and scanned into the hold location.

When a PM is scheduled for work, the technician presents the PM work order to the storeroom. The system will show that the inventory has been picked already and is in the kitting hold location. The kitting bin can be scanned to the work order and the technician can take the PM kit to the job. From the technician's perspective, the entire process of retrieving the parts for the PM is very fast.

In the event an emergency work order situation arises and the only part in stock has been picked to the kit bin, the system can locate the part and remove it from the PM kit through a move transaction.

Parts Receipts and Parts Issues

As mentioned earlier, every part movement must be accompanied by a transaction on the inventory control system or CMMS. Of particular importance are the parts receipts and the parts

issues. Parts receipts should be recorded to offset either a purchase order or a work order for outside services, while parts issues should be used to tie a part to a work order, technician identification, or an account code. Failure to record these transactions will waste the efforts set forth for increasing storeroom efficiency, productivity and accuracy. The maintenance organization must embrace the inventory control system or CMMS, use the transactions that are provided and view it as the tool to a successful operation.

In many storerooms, the discipline of entering these transactions breaks down under the pressures of the day, especially if there are emergencies that need to be addressed. There also may be a culture of "take what you need" that can undermine the efforts of increasing inventory accuracy and accountability. Through education and enforcement, these obstacles can be overcome, but it takes time and effort. Remember, cultural change is an ongoing process and not a one-time program.

Measures and KPIs

Every operation needs a means to gauge performance, and the storeroom is no different. There are several measures and key performance indicators that point to an efficient storeroom operation. They are:

- Inventory accuracy (cycle count adjustment/total cycle counts);
- Percentage of stockouts (number of stockouts/total parts issues);
- Percentage of inactive inventory (parts inactive in the past year/total parts);
- Growth rate in number of parts and numbers of suppliers;
- Plant replacement ratio (parts inventory value/plant replacement value);
- Parts to labor ratio (parts inventory value/maintenance labor cost).

When measures and indicators are recorded over time, they become a benchmark for the organization. Continuous improvement efforts then can be launched to improve upon these standards, with the desired result being cost reduction and higher productivity. Without tracking performance, it is impossible for the storeroom to know whether improvements have indeed been worth the effort.

Conclusion

This article has presented several areas of focus for best practices in the maintenance storeroom. Included among the best practices are the following:

- Adopt the idea that the storeroom is a service provider.
- Organize the storeroom and staff for efficiency.
- Become obsessive about inventory accuracy - it is of utmost importance.
- Perform routine and daily cycle counting as part of the storeroom duties.
- Properly slot parts based on part volume and characteristics.
- Use auto ID to streamline data entry and reduce errors.
- Build PM kits in advance to enable quick PM of equipment.
- Be sure to record all parts moves, receipts and issues.
- Create, track and use measurements and KPIs.

As each company is unique, so too are the storerooms. Different storerooms require their own combination of solutions. When the storeroom operates in a best practices mode, then it is easy to see productivity gains not only in the storeroom, but also throughout the organization.

This article was previously presented by Jeff Zeiler at the International Maintenance Conference.

SKF Flowery Branch


SKF Flowery Branch

Management Excellence: Our Journey Towards Energy and Sustainability

Sam Rundell and Eric Huston

SKF was founded in 1907 and grew to become a global company, present in more than 130 countries. The Flowery Branch factory joined the SKF Group in 1986. SKF Flowery Branch is a bearing manufacturing plant located one hour north of Atlanta, Georgia. The site occupies 64 acres with 200,000 square feet of manufacturing and office space near Lake Sidney Lanier, employs 268 full-time people and last year produced over eight million bearings of various types and sizes. We are committed to a culture of sustainability and are always looking for new innovations to further that effort.

Some of the basic methods we use include conservation, recycling, reuse and point source reduction. Our journey to sustainability is guided by our Group Environmental, Health and Safety Policy, an ISO 14001 environmental management system, our BeyondZero™ initiative and business excellence practices.

The parent company, AB SKF (commonly referred to as the "Group") issued our first environmental policy in 1989 that evolved into the Group Environmental, Health and Safety Policy in 2005. The policy states:

"The Group's overall objective is to attain long-term and sustained profitability. The main task related to this objective is to develop, produce and market products and services that satisfy the needs of our customers and at the same time are safe for their intended use. They should be efficient in their use of energy, protective of the environment, and recyclable or safely disposable."

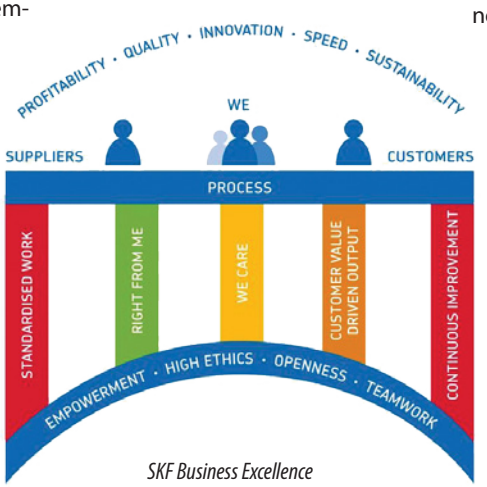
The policy goes on to describe SKF's commitment to health, safety and the environment, both internally and externally.

The issuance of the policy strengthened and encouraged sustainability activities at Flowery Branch. We began our journey toward sustainability with obvious and rather simple activities, as many other companies have. A recycling task team was formed to expand our efforts beyond oil, steel and cardboard. We began recycling all metals, wood, plastic, carbide and diamond tools, grinding wheels, batteries, electronics, and more. An energy efficiency task team began to explore conservation opportunities. Both areas ultimately contributed to cost reductions, as well as environmental considerations.


Sam Rundell next to cardboard and plastic.

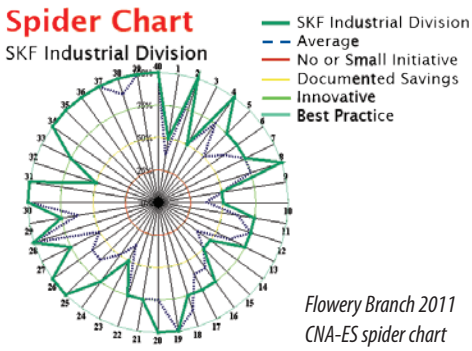
SKF Group obtained ISO 14001 certification in 1998. This certification required the formation of an environmental management system for each facility within the group. This management system provided structure for our sustainability activities that we did not have before. Programs became documented and assessable. The new organization provided a roadmap for our sustainability activities that permitted them to continue despite changing circumstances and personnel.

An annual Aspect/Impact Analysis provided a method to prioritize activities and establish objectives and targets for the following year. Our HVAC system was modified for better control; heat exchangers were installed to make use of ambient temperature water for cooling when available; high energy consuming lights were replaced with energy efficient fluorescent fixtures; waste grease and the plastic drum liners are used for engineered fuel consumed at a cement kiln; ash generated from the combustion becomes part of the raw material for the next batch of cement, which results in zero landfill; and disposable shipping containers were replaced with returnable ones. The system also facilitates sharing information between SKF locations, as well as with local community organizations. Activities flourished and expanded beyond what we had originally envisioned.



SKF Business Excellence

To further achieve environmental excellence, SKF Group launched an ambitious and challenging target called BeyondZero in 2005. With this target, SKF aims to be the role model for sustainability in the industry. SKF challenges the limitation of conventional environmental targets, which typically drive only for zero negative impacts on nature. In combination with our internal efforts to reduce negative environmental impacts, we aim to exceed the "zero" target by contributing positively to the environment and going *beyond* the *zero* target.



Flowery Branch 2011 CNA-ES spider chart

The BeyondZero initiative is our contribution to maintaining a healthy planet by continuously minimizing the negative impacts on the environment from our operations AND at the same time helping our customers in achieving and maximizing their environmental performance. We work continuously and intensely to develop a portfolio of products, solutions and services to help our customers in energy efficiency with quantified examples. We offer our customers the power of engineering knowledge through innovation and technologies while helping to protect the environment at the same time.

The BeyondZero ambition is embedded in our approach to business excellence practices which began at Flowery Branch in 2009. The SKF Bridge of Business Excellence includes sustainability as one of the program drivers along with profitability, quality, innovation and speed. The values are: empowerment, high ethics, openness and teamwork. The principles of standardized work, right from me, we care, customer value driven output and continuous improvement can all be associated with sustainability initiatives.

Reference to business excellence helps to keep sustainability activities at the forefront of management's agenda. Manufacturing systems are examined and modified where needed. Only the material needed for an operation is used, eliminating waste and contributing to point source reduction.

As a status check on our business excellence journey, in early 2011 the Flowery Branch team conducted an assessment and benchmarking exercise using the commercially available SKF Client Needs Analysis for Energy and Sustainability (CNA-ES). Through a facilitated workshop involving cross-functional disciplines, the CNA-ES helped us identify and reflect on our best practices gained from prior improvement activities, our current performance and areas of potential for future improvement. Some examples include:

- Compressed air leaks were repaired and an inspection program was instituted to keep them in check.
- We were able to optimize our heat treat furnace utilization and eliminate the need to operate and maintain an entire heat treat furnace line.
- Condensate from air conditioning is collected and used for make-up water in the central grinding coolant system.
- Occupancy sensors were installed to turn off lights when not needed.

Each task undertaken has made positive contributions to both internal and external environments and our profitability. Continuous improvement directs us to avail ourselves of new techniques and innovations as they develop.

Shared information from other SKF facilities and local entities are the source of many ideas and innovations for the future. Skylights and solar tubes, LED lighting, solar panels, and biomass are just a few ideas under consideration. Improved recycling and reuse methods are implemented as they become available. In addition, we are considering implementation of the newly released ISO 50001 energy management standard. We continually strive to identify and eliminate waste in our manufacturing processes. Indeed, the best way to conserve a resource is to not consume it in the first place.

Sustainability is an important part of our lives at SKF Flowery Branch. Our Group Environmental, Health and Safety Policy, ISO 14001 environmental management system and business excellence practices have been instrumental in guiding us on our journey to sustainability. Through continuous improvement, we will strive to become more efficient in our use of resources and be good stewards of the environment while also achieving our financial objectives. Sustainability and profitability are not mutually exclusive; we can achieve both, as long as we continue to include sustainability in our agenda and sustain it as part of our culture.

Sam Rundell is the Environmental, Health and Safety Administrator at SKF Flowery Branch, Georgia. He has over twenty years experience in manufacturing and plant engineering with SKF. www.skf.com

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The Truth Untold

Not All Oil Analysis Reports Are Created Equally

Evan Zabawski

As we see the trend of both on and off-highway heavy-duty diesel engines switching to multi-grade oils, it becomes more and more important to check the 40°C viscosity, as well as the 100°C viscosity, in the used oil analysis. While both numbers may be reported on a used oil analysis report, the lab may have chosen to only measure one and merely calculate the other.

Measuring both the 40°C and 100°C viscosities allows calculation of the viscosity index (VI). The VI of an oil relates to the stability of the oil's viscosity against temperature. It is a unit less number of about 100 for mono-grade oils, around 140 for SAE 15W-40s and >180 for SAE 0W-40s. Higher VIs are achieved using premium base oils and a VI improver additive. The defining difference between mono-grade and multi-grade, as prescribed by the SAE J300 standard, is principally achieved using VI improver additives.

This additive is a long-chain polymer that contracts at cold temperatures and relaxes or unfurls at higher temperatures, which offsets the expected decrease in viscosity when oil is heated. The advantage to using VI improvers is that oils may operate in a wider temperature range, but the disadvantage is that this molecule is susceptible to mechanical shearing. For example, an SAE 15W-40 oil is formulated using an SAE 15W base oil, but with the additive, it will meet the viscosity requirements of an SAE 40 oil at 100°C. However, since no SAE 40 oil is used in the blending, the oil reverts to nearly an SAE 15W oil as the oil is sheared, possibly leading to premature failure due to an insufficient lubrication film.

Extensive idling may lead to fuel dilution, but high-loads may cause shearing as well.

Shearing is very common and even expected in most multi-grade applications, thus the tendency for oils to be formulated towards the thicker end of the allowable range. However, extreme conditions (load, environment, temperature, speed) or extended intervals may cause excessive shearing to the point where the oil falls out of grade and thereby voids warranty claims and leads to excessive wear or possibly failure.

The best way to monitor used engine oils for adherence to grade is to monitor the 100°C viscosity, noting any significant decreases. However, shearing does not cause all decreases. Water/fuel contamination or mixing of products also may be the culprit. In addition, increases in the viscosity due to soot contamination or general oxidation may mask shearing. The only way to be certain that shearing is not excessive is to include a 40°C viscosity measurement, which shows larger numerical deviance.

Having both the 40°C and 100°C viscosities allow calculation of a conclusive VI. No matter how much contamination is in the oil, the VI will not change without something happening to the VI improver first. So even if the 100°C viscosity remains in grade, it will still be possible to see if the oil has suffered significant physical damage.

However, another error may be compounded into the report if fuel dilution is correlated from the viscosity results as well. This correlation often assumes a fixed viscosity for fuel, which is reasonably fair if the decrease in viscosity is only due to fuel and not shearing, and if neither soot contamination nor oxidation are masking the results.

Let's examine two examples using the same measured 100°C viscosity, but one assuming VI is constant and calculating the 40°C viscosity, and the other with a measured 40°C viscosity.

The results in Table 1 suggest an approximate 1% fuel contamination in the calculated example, but none in the measured example. While the fuel level is not elevated enough to suggest an immediate corrective action or mechanical issue, it is misleading nonetheless. More importantly, the true measured value shows significant shearing, suggesting the need for an oil change and possible reduction in future drain intervals.

TABLE 1	40°C Viscosity	100°C Viscosity	Viscosity Index
New oil baseline	110.7	15.00	142
Calculated 40°C value	89.0	12.76	142
Measured 40°C value	100.7	12.76	122

TABLE 2	40°C Viscosity	100°C Viscosity	Viscosity Index
New oil baseline	110.7	15.00	142
Calculated 40°C value	101.0	14.08	142
Measured 40°C value	115.5	14.08	122

The results in Table 2 suggest a minor decrease in viscosity in the calculated example, but significant shearing in the measured example. The viscosity decrease in either example is not enough to suggest an immediate corrective action. However, due to masking by either soot contamination or oxidation, shearing is evident when the 40°C viscosity is measured and becomes obvious when the VI is included.

Going forward, it is imperative that end-users ask their labs precisely what is being provided to them. Both viscosities must be measured and reported in order to maximize the value of routine oil analysis, and having the VI reported enables faster and more correct interpretation.

Evan Zabawski is a Fourth Class Power Engineer with a diploma in chemical engineering. Prior to joining Fluid Life, Evan gained previous experience as a manager of a tribology lab before moving into the field of power generation fluid maintenance. www.fluidlife.com

Are You Proactive?

A Day in the Life of a Maintenance Technician

Ricky Smith

What is a Proactive Maintenance Technician?

A proactive maintenance technician is a highly-trained professional who is an expert in his or her skills area, has knowledge of other skills areas, including safety and production, and has a desire to learn more. This professional knows and can implement a failure modes driven maintenance strategy for any piece of equipment. A proactive maintenance technician uses knowledge and experience to ensure the maintenance process is optimized by making constructive recommendations to management concerning improvement areas.

To ensure success, a proactive maintenance technician is proactive in everything he or she does. This person constantly reviews information to ensure procedures are accurate and issues are resolved quickly and does what is required to ensure the work is repeatable. Such a professional leads by example and takes responsibility for training new employees on how to be a proactive and effective maintenance technician.

A successful proactive maintenance technician follows known best repair practices in all tasks and has a suitable reference book as part of his or her tool set, such as *Industrial Machinery Repair: Best Maintenance Practices Pocket Guide* from MRO-Zone. A proactive maintenance technician is certified as a lubrication specialist and knows and follows best lubrication practices.

On a daily basis, a proactive maintenance technician begins work on time, ends work on time, takes the allotted break(s) without taking additional time and always makes the best use of time. He or she knows the applicable planned and scheduled work for the week and inspects the next day's tools and parts for the scheduled work. Wrench time is high (55 percent and greater), as shown in Figure 1, because the maintenance technician identifies scheduling delays and makes recommendations for improvement. Additionally, a proactive maintenance technician makes sure the work site is clean and safe when completing work. Work safety is always a priority.

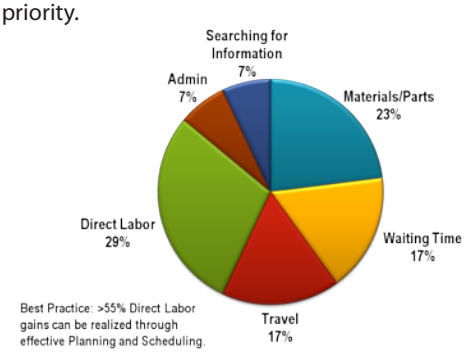

Figure 1: Sample Wrench Time Study Results

Perhaps most importantly, a proactive maintenance technician is always proud of the work he or she conducts or influences. No pat on the back is required, just the personal satisfaction in knowing that the job was completed successfully.

What Does a Typical Day Look Like for a Proactive Maintenance Technician?

A proactive maintenance technician begins the day by pulling a job package from the scheduled work box, goes to where the parts are kitted, pulls the required parts and tools, and leaves for the job site. Because the planner has made sure that all special tools, parts and procedures are at the job location, the maintenance technician can begin on time since all the equipment, parts, tools and procedures are ready to execute.

The maintenance technician arrives at the job site and is greeted by a production worker, who has cleaned and cooled down the equipment per the maintenance schedule so the maintenance technician has the optimum amount of time to perform preventive maintenance, corrective maintenance, etc.

At this time, the maintenance technician performs the particular work to specification. Following all procedures, the maintenance technician cleans the area and releases the equipment back to production in a "like new" status according to the definition of maintenance:

Once production operates the equipment to standard, the maintenance technician closes out the work order with the proper failure codes, failure causes, time taken to complete the job and any other information required in the synopsis.

Before Shift Ends

Prior to leaving for the day, the maintenance technician reviews the work scheduled for the next day from the job plan package left by the planner/scheduler. This ensures that the proactive maintenance technician knows the job and validates that the parts are in the kitted area. The maintenance technician also participates in a tool box training session (Figure 2) concerning safety, new work instructions, or technical training ideas to increase his or her knowledge base and help teammates by sharing this knowledge.

What Value Does a Proactive Maintenance Technician Provide to a Proactive Organization?

As previously discussed, a proactive maintenance technician is always on time, performs work to standard, makes recommendations to improve work for the next time it is executed, ensures tools are operational, verifies production has started up the equipment to standard and on time, and performs all work in a safe en-

vironment. In addition to all of this, a proactive maintenance technician adds value by working with production and operations as a team to resolve equipment problems, whether maintenance or production related, to optimize asset reliability and increase capacity.

The effect of a proactive maintenance technician's ability to conduct preventive maintenance as a "controlled experiment." Because the proactive maintenance technician always takes the time to make repairs accurately, they are more often than not sustainable with no rework required.

A proactive maintenance technician is capable of correcting defects and making repairs using repeatable, effective procedures that reduce rework. A maintenance technician also has the ability to write effective, repeatable procedures following company guidelines to ensure other technicians have the tools to perform quality work.

With a focus on safety, the proactive maintenance technician ensures all work places are free of hazards and is skilled at using the tools required to reduce potential hazards. In-depth training in the identification of failure modes and their causes for all equipment in the maintenance technician's area and vast knowledge on how to prevent or identify failures early are key components for preventing a failure. Furthermore, the proactive maintenance technician is trained and can execute specific advanced maintenance tools, such as ultrasound, infrared and laser alignment tools, with precision when needed, thus reducing the need for additional personnel.

A proactive maintenance technician is confident in providing management with metrics that show asset reliability is improving. Further, he or she has the ability to make recommendations for equipment improvement based on failure reports and metrics (Figure 3).

Measuring the Effectiveness of a Proactive Maintenance Technician

The metrics listed in Table 1 should be used by the maintenance technician solely to expand knowledge and improve skill sets in a certain area. If a metric is going in the wrong direction, the maintenance technician should go to the maintenance supervisor for guidance. Management must ensure that all areas listed in Table 1 are fully supported by the maintenance supervisor, production supervisor, storeroom manager and planner/scheduler, as well as reliability and maintenance engineering.

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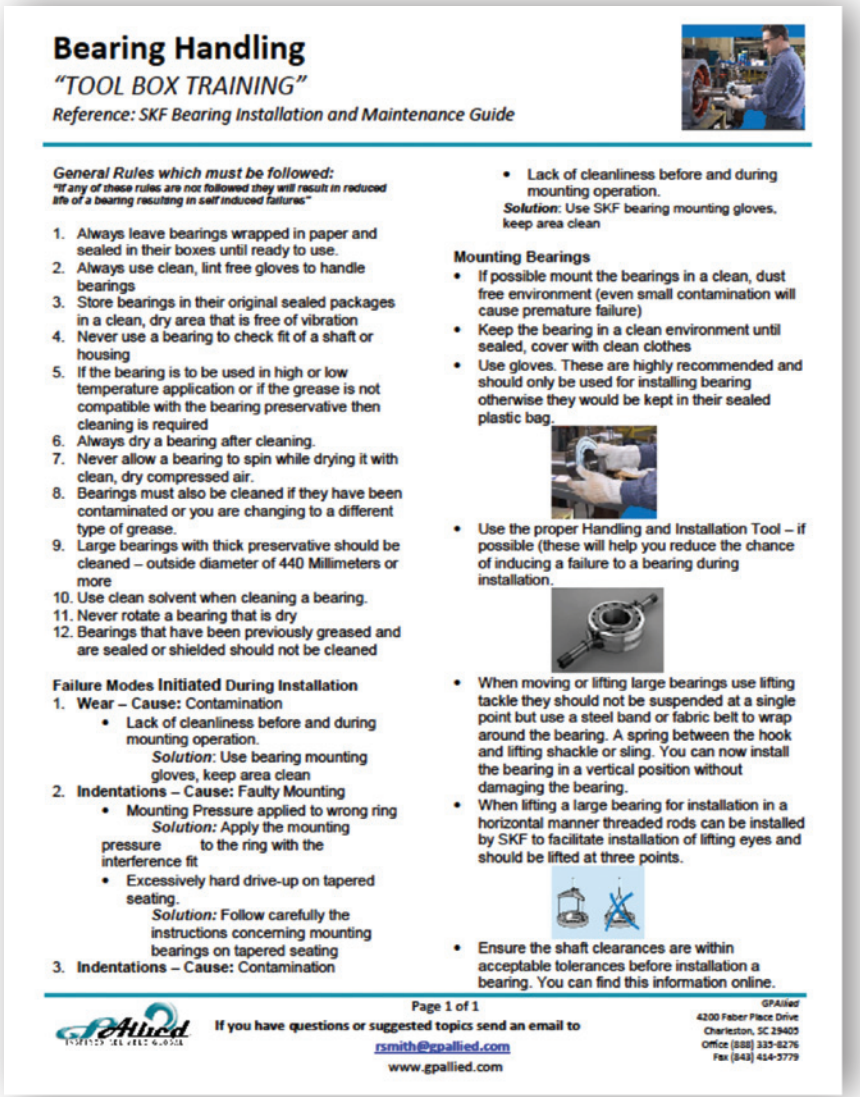

Bearing Handling

"TOOL BOX TRAINING"

Reference: SKF Bearing Installation and Maintenance Guide

General Rules which must be followed:
"If any of these rules are not followed they will result in reduced life of a bearing resulting in self induced failures"

1. Always leave bearings wrapped in paper and sealed in their boxes until ready to use.
2. Always use clean, lint free gloves to handle bearings
3. Store bearings in their original sealed packages in a clean, dry area that is free of vibration
4. Never use a bearing to check fit of a shaft or housing
5. If the bearing is to be used in high or low temperature application or if the grease is not compatible with the bearing preservative then cleaning is required
6. Always dry a bearing after cleaning.
7. Never allow a bearing to spin while drying it with clean, dry compressed air.
8. Bearings must also be cleaned if they have been contaminated or you are changing to a different type of grease.
9. Large bearings with thick preservative should be cleaned – outside diameter of 440 Millimeters or more
10. Use clean solvent when cleaning a bearing.
11. Never rotate a bearing that is dry
12. Bearings that have been previously greased and are sealed or shielded should not be cleaned

Failure Modes Initiated During Installation

1. **Wear – Cause:** Contamination
   - Lack of cleanliness before and during mounting operation.
     Solution: Use bearing mounting gloves, keep area clean
2. **Indentations – Cause:** Faulty Mounting
   - Mounting Pressure applied to wrong ring
     Solution: Apply the mounting pressure to the ring with the interference fit
   - Excessively hard drive-up on tapered seating.
     Solution: Follow carefully the instructions concerning mounting bearings on tapered seating
3. **Indentations – Cause:** Contamination
   - Lack of cleanliness before and during mounting operation.
     Solution: Use SKF bearing mounting gloves, keep area clean

Mounting Bearings

- If possible mount the bearings in a clean, dust free environment (even small contamination will cause premature failure)
- Keep the bearing in a clean environment until sealed, cover with clean clothes
- Use gloves. These are highly recommended and should only be used for installing bearing otherwise they would be kept in their sealed plastic bag.
- Use the proper Handling and Installation Tool – if possible (these will help you reduce the chance of inducing a failure to a bearing during installation.
- When moving or lifting large bearings use lifting tackle they should not be suspended at a single point but use a steel band or fabric belt to wrap around the bearing. A spring between the hook and lifting shackle or sling. You can now install the bearing in a vertical position without damaging the bearing.
- When lifting a large bearing for installation in a horizontal manner threaded rods can be installed by SKF to facilitate installation of lifting eyes and should be lifted at three points.
- Ensure the shaft clearances are within acceptable tolerances before installation a bearing. You can find this information online.

Page 1 of 1

If you have questions or suggested topics send an email to rsmith@gpallied.com

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Figure 2: Tool Box Training Example

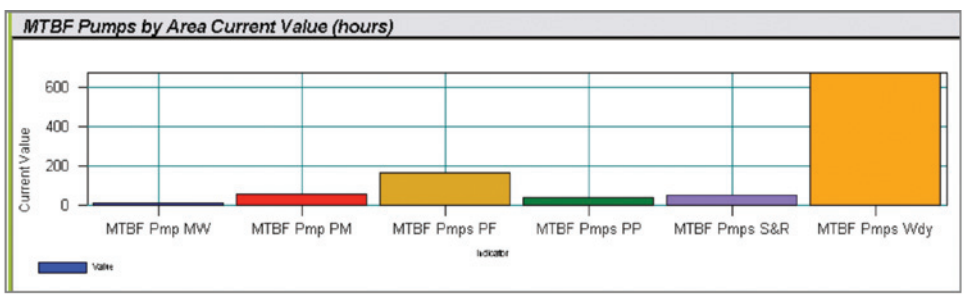


Figure 3: Mean Time Between Failure of Different Pumps in a Specific Plant

Table 1: Technician Balanced Scorecard

Metric	Indicator
Percent of rework	Lack of effective planning and scheduling
Schedule compliance	Lack of effective scheduling
Mean Time Between Failure (MTBF) for area of responsibility	Lack of effective procedures; operator error
Safety occurrences	Lack of safety awareness or compliance
Mean Time Between Repairs on assigned equipment	Lack of effective procedures
Number of times in storeroom by month	Lack of effective planning
Reduction in energy in area of responsibility	Lack of an effective maintenance strategy

SNAKES, HAZARD RECOGNITION & RPN

What Is a Hazard?

Stan Moore

Any situation that could result in a preventable injury or illness.

Expounding on that, a hazard is any situation or condition that could present a threat to equipment, the environment, limb, or life. Hazards can be caused by human actions, or they can exist in the environment and pose no safety issues until there is interaction.

For example, I live in the south where we see the occasional copperhead snake. On a cool fall evening, the snakes will, on occasion, stretch out on the blacktop pavement and soak up the heat. Hazard? Some would say yes, regardless. But if I am not present, then there is no resulting interaction. However, if I am taking a stroll around the neighborhood at dusk and unknowingly step on the stretched out snake, then there is interaction, which could be very unpleasant, possibly for me, certainly for the snake. So how do I mitigate the risk in this example to an acceptable level? Assuming I can't eliminate snakes altogether, there are still several possibilities:

1. Take strolls in the daytime when visibility is better.
2. Take a flashlight.
3. Walk with my border collie who hates snakes.

Any one of these three options would mitigate the risk to manageable levels. But how do I even know to be on the lookout for snakes? What if I had just moved here and was not even aware of the need to look or even think about the possibility? A similar line of thinking exists in our work environments as well. How do we identify and manage hazards? How is work accomplished safely? Lots of questions, now let's look at some answers.

The safe execution of work is no "accident." It requires constant attention and focus on the task at hand. Training, procedures and corporate leadership are certainly necessary to lay the foundation for a safe workforce, but ultimately, attitude and awareness are the most critical components of an injury-free workforce.

Safety performance is often monitored in many ways and most of them are lagging indicators. Near miss reports, injury reports and root cause failure analysis (RCFA) are good examples of lagging indicators. While good, they are lagging and just like the stock market, past performance does not necessarily guarantee future success. Leading indicators, if not already in place, are necessary to make a fundamental shift in the safety culture. One such leading indicator is hazard recognition. Recognition is fundamental and foundational, allowing for risks associated with hazards to be mitigated and managed to acceptable levels. A key focus area is the proactive identification and elimination of hazards by employees that are engaged and empowered.

The classic safety pyramid is used to illustrate the importance of seemingly small and insignificant hazards. Unchecked, and without recognition and mitigation, they can stack up and ultimately lead to serious injuries or even fatalities. Recognition of a hazard is only part of the solution and if not addressed, leaves that hazard for exposure to someone else. To fully capitalize on the benefits of early hazard recognition, one must also take actions to eliminate the hazard. By proactively identifying and eliminating hazards, the potential for more serious and severe injuries is reduced.

An engaged workforce is paramount and foundational to safety. Procedures are important, yes. Rules are necessary, to be sure. But the real key to safety is the individual ownership and responsibility to daily take on the mantle of safety and consciously plan to be safe. Employers have the responsibility to provide a safe workplace by either eliminating risks or instituting measures to effectively manage the risks. Employees also have a personal responsibil-

ity for their own safety at work. The employer provides an environment that promotes and encourages safety. The employee is responsible for being engaged in the work that he or she is doing, namely situational awareness, and focused on safely conducting the task. There are many safety programs that have been used and are being used in industry. They help communicate the expectation for safety and provide tips and tools to become more safety aware. However, in the final analysis, it takes both the employer and the employee, working in unison to not only have a safe work environment, but also to work and be safe. While it may not be possible to totally eliminate all hazards, all accidents are preventable. Zero injuries are not only possible, but achievable.

Zero is Possible!

Hazard recognition and injury prevention also can be tied to situational awareness, or to use another phrase, inattentional blindness. Inattentional blindness, a phrase coined by psychologists Arien Mack and Irvin Rock, is an inability to see or recognize something that is within one's field of view while attention is focused on another task.

To illustrate this phenomenon, psychologists Daniel Simons and Christopher Chabris, discuss this in their book, *The Invisible Gorilla: And Other Ways Our Intuitions Deceive Us*.[1] In one experiment, a viewer is asked to watch a video of several people passing a basketball. The viewer is asked to count the number of times the basketball is passed from one player to another. During the short video, a person dressed in a gorilla suit enters the scene and stands in the center of the group of players for several seconds, pounds his chest and then exits the scene. Surprisingly, a large percentage, roughly half of the viewers, did not see the gorilla. Their attention was focused on another task and totally missed the "gorilla in the room."

Awareness is an important element of hazard recognition, not only on the task at hand, but also being aware of what is going on around you. Expect the unexpected. One way we expand our awareness is the routine review and sharing of safety data from other plants and industry sources. For example, the Chemical Safety Board (CSB) publishes findings and video simulations of actual events, making this an excellent learning tool. Our site's maintenance team also "mixes it up" by taking a supervisor from one area and having them conduct a safety/housekeeping audit in another area. This does two things, it affords the opportunity for the visiting supervisor to see and observe others and it provides the owner with another fresh set of eyes.

Another area that needs to be discussed is our own individual perception of risk and how much risk each of us is willing to take. The acceptance of risk, or the willingness to take risk, is subjective. What is acceptable to me may not be acceptable to you. What may seem too risky for you may be acceptable to someone else. For example, people who invest in aggressive mutual funds are willing to take more risks than those who do not. Rock climbing, or even bungee jumping, is enjoyed by many and is "relatively" safe, but few of us participate in the sport due to the perceived risks. However, according to the National Highway Traffic Safety Administration (NHTSA) 2009 statistics,[2] an average of 93 people died each day in motor vehicle crashes in 2009, an average of one every 16 minutes. Yet we get into our automobiles every day and accept that risk. Due to our varied backgrounds and life experiences, we often perceive risk in varied and different ways. By understanding our risk tolerances better, we can prevent injuries.

When it comes to working in an industrial setting, personal acceptance of risk needs to be normalized and standardized through the use of policies and procedures. This written documentation establishes the minimum expectations for working safely and minimizes the exposure to hazards. Employees are expected to know and observe the safety policies and procedures that are in place. An employee accepting a risk that is outside the scope of what company policies allow is not acceptable, even if the employee is willing to personally accept that risk.

Hazard recognition and injury prevention also can be tied to situational awareness, or to use another phrase, inattentional blindness.

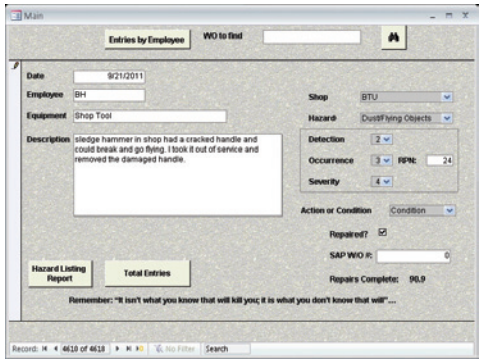
In early 2009, a simple Microsoft® Access database was developed to track hazards. This database tool is based on a variation of the classic reliability centered maintenance (RCM) risk priority index (RPN). RPN is a ranking tool that is the product of severity, occurrence and detection or S x O x D. Tailored for hazard recognition and ranking, each element of the RPN was taken and redefined with focus on safety as shown on the left.

The intent is to document and track the identified hazards. A screen shot of the input screen is on the next page.

SEVERITY		
Value	**Severity**	**Criteria**
1	No Effect	No first aid, near miss, or environment incident.
2	Very Slight Effect	Very slight possibility of a near miss, first aid, or environment incident.
3	Slight Effect	Slight possibility of a near miss, first aid, or environment incident.
4	Minor Effect	Minor possibility of a near miss, first aid, or environment incident.
5	Moderate Effect	Moderate possibility of a near miss, first aid, or environment incident.
6	Significant Effect	Significant possibility of a recordable injury or environment incident.
7	Major Effect	Major possibility of a recordable injury or environment incident.
8	Extreme Effect	Extreme possibility of a life-threatening recordable injury, environment incident and/or regulatory fine.
9	Serious Effect	Potential hazardous effect. Potential loss of life or limb, multiple environment incident, or regulatory fines.
10	Hazardous Effect	Hazardous effect. Fatality

OCCURRENCE		
Value	**Description**	**Criteria**
1	Almost Never	Injury or near miss unlikely. History shows no past injuries or near misses.
2	Remote	Rare number of injuries or near misses likely.
3	Very Slight	Very few injuries or near misses likely.
4	Slight	Few injuries or near misses likely.
5	Low	Occasional number of injuries or near misses likely.
6	Medium	Moderate number of injuries or near misses likely.
7	Moderately High	Frequent high number of injuries or near misses likely.
8	High	High number of injuries or near misses likely.
9	Very High	Very high number of injuries or near misses likely.
10	Almost Certain	Injury almost certain. History of injuries and near misses exists from previous similar design.

DETECTION		
Value	**Description**	**Criteria**
1	Almost Certain	Current controls almost always will detect the situation. Reliable detection controls are known and used in similar processes.
2	Very High	Very high likelihood current controls will detect the situation.
3	High	Good likelihood current controls will detect the situation.
4	Moderately High	Moderately high likelihood current controls will detect the situation.
5	Medium	Medium likelihood current controls will detect the situation.
6	Low	Low likelihood current controls will detect the situation.
7	Slight	Slight likelihood current controls will detect the situation.
8	Very Slight	Very slight likelihood current controls will detect the situation.
9	Remote	Remote likelihood current controls will detect the situation.
10	Almost Impossible	No known controls available to detect the situation.



Using the RPN, the risks associated with hazards can be quantified and communicated. I have observed that recognizing the hazard and then following up and communicating to others is essential in the daily quest for a safe workplace. The data from these entries are periodically imported to Microsoft Excel, charted and reviewed with the workforce. While a basic quota of identifying and documenting hazards is required, most employees exceed that. While initially concerned with the quota approach, after three years into the program, interest and participation remains high. The 5,000 plus entries tracked to date show that most of the hazards have relatively small RPN values, which would be consistent with the classic safety pyramid. However, the few that do have higher RPN values are those "nuggets" that truly can drive improvements in the safety culture and risk management. Another key learning tool is feedback on the progress of an identified hazard. Periodic updates on the status are important and show management commitment to the process. To date, about 90 percent of the findings have been eliminated or mitigated. Often, the hazard is eliminated by the individual who identified it, while a few require work orders that are entered and tracked in SAP.

Safety and environmental stewardship is an expectation, a choice and a responsibility. The early identification and elimination of hazards prevent near misses and injuries. Identify, document and correct conditions that can be hazardous. Be proactive, not reactive in all aspects of environment, safety, security and health.

Believe it, Expect it, Live it

References:

1. The Invisible Gorilla: And Other Ways Our Intuitions Deceive Us, Simons & Chabris, 2010.
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Good Green Hunting

Managing Steam Systems with Ultrasound

Allan Rienstra

Writing about ultrasound's role in helping industries operate "green," I am reminded of an article provided to *Uptime* Magazine in January/February 2009. The subject of that piece, "When Green is Good Business, Sustainability through Ultrasonic Energy Conservation" looked at the paradox of sustainability. The term sustainability was born of corporate social responsibility and the need for big business to be perceived as environmentally conscientious. Business was good. And so it was fashionable to invest in green programs. Reducing carbon footprint, conserving energy, and most importantly, painting a picture of responsible big business by putting the needs of the planet ahead of the needs of its shareholders' wallets were in vogue. Then it fell apart.

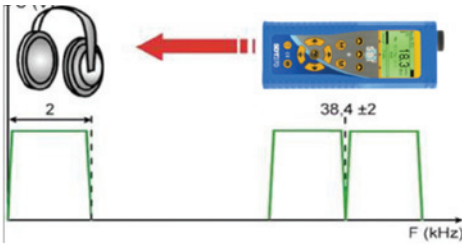
By 2009, chaos reigned and most were just holding on for dear life. Factories closed and jobs disappeared as the credit crisis catalyzed a global recession that smacked America hardest. Corporate social responsibility and sustainability were promptly redefined as "doing whatever it takes to keep our doors open for business."

As we enter Q4 2011, much has changed yet uncertainty still lingers. Perhaps with the debt crisis shifting to EU countries, "green" is back in focus. Chatting with maintenance and reliability managers, the topic of good green hunting seems once again relevant. But this time there is less zeal and effort to conceal the true meaning(s) about "going green." As sustainability makes another curtain call, I wonder if this time it will be as much about remaining competitive as it is about reducing our environmental footprint. Probably both and I remain excited that ultrasound testing will prove a helpful technology for those that grasp the diversity of its applications. Let's focus on steam systems maintenance as an often overlooked and misunderstood point of use for ultrasound.

Ultrasound inspection plays a useful role in gathering condition-based data for steam systems maintenance. Power generation, pulp and paper, and food processing are just a few industries that apply. Maintaining a healthy steam system has equal benefits for green initiatives, cost management and overall reliability. Efficiency helps retain heat, which lowers operating costs through reduced fossil fuel consumption. That obviously impacts the carbon footprint in a positive way. It also means a purer steam system so less corrosion, fewer breakdowns, longer component life and greater reliability are additional beneficial spinoffs.

Just because steam systems don't have a lot of rotating components does not mean opportunities to employ condition-based monitoring (CBM) don't exist. Steam leaks, failed steam traps, blocked and passing valves, and tube and shell leaks are common issues that, left unchecked, will impact the greenness of your plant. There will be those who insist that CBM cannot exist without checking **something** that rotates. For you, we conveniently add boiler feed pumps and the electric motors that drive them to the list of CBM assets to check. If we add feed pumps to the list, then you may just as well use your ultrasound data collector to check for electrical faults in the MCC panels controlling them.

For readers new to ultrasound, let me briefly explain. Ultrasound detectors hear high frequency sound (between 36 and 40 kHz typically) and convert it to representative audible sound while maintaining the characteristics and qualities of the original. The original sound can be



listened too, measured (and therefore trended), and where necessary, recorded and analyzed. Ultrasound detectors do this while remaining ambivalent to the noise and clatter of your factory floor, thus allowing ultrasound inspectors to carry out CBM during peak production. For more information, an excellent resource entitled, "*Hear More, A Guide to Using Ultrasound For Leak Detection And Condition Monitoring*" by Thomas J. Murphy and Allan A. Rienstra (available at mro-zone.com), will fill in the blanks.

Ultrasound is perfect for listening to friction and turbulence, whether it is airborne or structure borne. Both friction and turbulence have peaks in the ultrasonic frequency range. By gathering CBM data ultrasonically, we find problems at the earliest stage. This provides a bigger window to take action or schedule additional data collecting with complementary technologies that may not react as early as ultrasound, but can validate findings. As soon

as data is definitive, it is my hope that needed action can overrule the CMMS work order process since it can only be triggered by calendar events, not condition events. Alas, that is a discussion for reliability managers and the topic of an entirely different article.

Steam leaks, especially those from high pressure steam, can be deadly. Using a rag on a stick is an old school method of detection. A much safer procedure is to use a remote ultrasound sensor. Two good choices are either a flexible wand or a parabolic dish with a targeting function built in. If using a flexible wand, be sure to follow safe inspection practices. First and foremost, protective gloves must be worn. Secondly, high pressure steam can damage ultrasound sensors if they come directly in front of the steam's path. Choose a flexible wand with an easily replaceable sensor head as opposed to sensors that are hard wired. Parabolic sensors with laser sighting allow for high pressure steam leak detection at safer distances. These sensors can detect leaks from 5-20 meters. The impact on your green initiative is exponentially increased with high pressure steam leaks. For example, a 1/4-inch leak at 25 psi has an implied loss of approximately 500 million Btu/year while the same 1/4-inch leak at 120 psi loses 2,750 Btu/year. The conclusion is that all steam leaking into the atmosphere should be attended to; however the low hanging fruit, the leaks with the highest implication for green savings, must be high pressure.

Steam traps offer the greatest opportunity for green wins. Traps are necessary to maintain the healthy operation of the entire steam system.

Steam traps offer the greatest opportunity for green wins. Traps are necessary to maintain the healthy operation of the entire steam system. They purge air and condense steam, CO_2 and other impurities from the system. The number of traps used, their size and type, and their placement in the system are all carefully detailed by engineering.

When traps fail, either stuck open or stuck shut, the original design is compromised and the entire system becomes an energy wasting pig.

The problem is that failed traps do not exhibit symptoms that are obvious. Traps failed shut may create some back pressure. Traps failed open may detract from the quality and purity of steam. But I've seen many steam systems continue to operate with hundreds of failed traps; albeit at great expense to the plant and

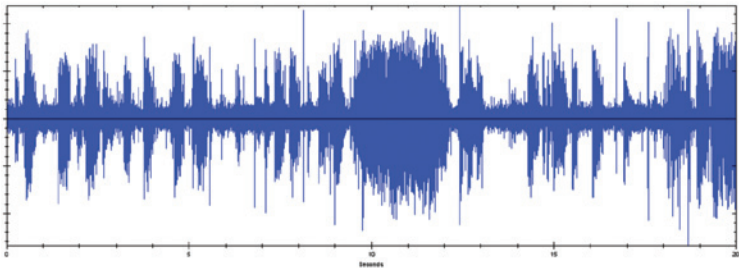


Figure 1 - Steam trap purging

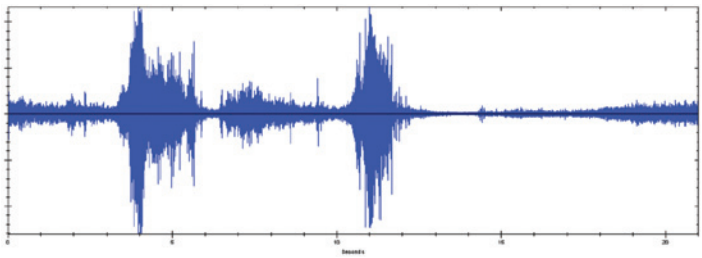


Figure 2 - Steam trap failed due to stuck open trap

the planet. It is only after severe water hammer damage or reported higher than normal energy bills combined with poor product quality (paper mills especially) that action is taken to locate and replace failed traps.

Combining upstream and downstream temperature and ultrasound measurements is the industry standard best practice for steam trap inspection. New generations of ultrasound systems do more than simply listen and record dB levels of steam traps. The most advanced ultrasound detectors can record scalable, comparable time signals. Now instead of just listening, ultrasound inspectors can compare. See the two time signals above (Fig. 1 and 2). Even to the untrained eye, it is quite obvious which trap is purging and which one has failed. Listening to the sound file and having this visual leave little guesswork at all as to which traps must be replaced.

Heat exchangers are used throughout many process industries to efficiently transfer heat energy from one fluid to another without allowing the fluids to come in contact with each other. They help companies control energy costs, and therefore promote green initiatives by recovering wasted heat or cooling energy. Recovery here allows the energy to be efficiently channeled back into processes, or even building heating.

In power generation, surface condensers maintain turbine efficiency while promoting long, healthy lifespans for boiler room components. Spent steam from the turbine is condensed back to its liquid state where it is collected in a hot well before being pumped back to the steam generator to repeat its cycle. The cooling water is kept separated from the purified condensed steam and the cooling process creates a significant vacuum which helps maintain turbine efficiency. While I've oversimplified the explanation for the sake of brevity for this article, (for a more detailed description of the process, please refer to pages 103 onward of "*Hear More, A Guide to Using Ultrasound For Leak Detection And Condition Monitoring*"), I have identified two significant jobs for our ultrasound inspector to do. Both jobs are related to tightness and both require an ultrasound inspector with patience, proper training and a good understanding of the process.

Vacuum is a by-product of the cooling process and lends to turbine efficiency. Vacuum leaks are going to negate that by-product. Employ-

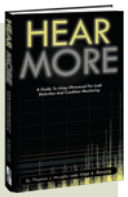
ing ultrasound to detect vacuum leaks is not unlike detecting positive pressure leaks in your compressed air system. In both instances, we are listening for the turbulent flow at the site of the leak. However for vacuum leaks, much of the turbulent flow is drawn into the leaking body. We simply adjust our detection method by getting closer to the source of the leak. Shielding techniques also are helpful.

Tightness of the tube and shell of heat exchangers is a more complex issue and, in many cases, a more vexing one as well. There are several methods for ultrasound inspectors to use, depending on circumstances. External tightness testing is used to inspect all joints, fittings, valves, valve stems, inlets and connectors. Check the steam jet vacuum pump ejectors as well, using the same flexible wand prescribed for high pressure steam leaks.

Inspection of the shell for tightness will verify end plate seals and inlet/outlet piping. Inspecting the tube bundle will depend on whether the system is online or offline. For online inspections, only the contact mode is useful and only the periphery tubes can be adequately checked. Offline inspection means removal of the end plates is possible. This exposes the tube ends to the ultrasound inspector. Pressurize the shell by connecting low pressure air through the inlet/outlet piping. Plug all other inlets. Then, listen for turbulent flow in each tube using a flexible wand. Identifying cracked, leaking tubes and either plugging them or replacing them (dependent on downtime allotment) will improve overall green efficiency and maintain the purity of the water circulating through the boiler room.

A more detailed description of the inspection methods for steam systems exists through Level One certification training, onsite implementation training, or in the earlier cited publication, "*Hear More, A Guide to Using Ultrasound For Leak Detection And Condition Monitoring.*"

Be it sufficient to say here that condition-based maintenance data gathered with your ultrasound technology improves your overall steam system with benefits that are immediately measureable. A more efficient steam system is a steam system that has fewer component failures. A reduced workload on your maintenance engineers in the steam system means more time for planning additional green initiatives outside the boiler room.



*Allan Rienstra is the General Manager of SDT Ultrasound Solutions, providing ultrasound solutions to maintenance professionals since 1991. As co-author of the book "*Hear More, A Guide to Using Ultrasound For Leak Detection And Condition Monitoring,*" Allan is recognized as a subject matter expert in the field. www.sdthearmore.com*

The 2011 Uptime Magazine Awards will be presented at IMC.

Q&A

Uptime magazine Publisher and Editor Terrence O'Hanlon recently caught up with the following Uptime Award winning companies and asked them: "How did you get management's approval to move forward with this program and support you through the journey which eventually led to winning this award?"

Hibbing Taconite Company Managed by Cliffs

Best Maintenance Reliability Program

"Cliffs and Hibbing Taconite management have always supported proper maintenance and asset management because they complement our continued efforts to provide an injury-free work environment for employees. The key was to figure out how to move from a reactive maintenance program to a proactive maintenance program. Communicating maintenance metrics and showing continuous improvement to both PM and schedule compliance, as well as showing increased equipment availability and greater mean time between shutdowns, were key to our achievements. Individual accountability, continuous improvement and constant communication built the program we have today."

Teck Coal Ltd.

Best Emerging Maintenance Reliability Program

"Teck is a diversified resource company committed to responsible development with major business units focused on copper, steelmaking coal, zinc and energy operating in North and South America. Very early on, our senior management recognized maintenance as an opportunity for improvement. We engaged maintenance leaders throughout Teck to better understand our culture and business conditions and to create a model for improvement. Shortages of skilled people, rising costs and the desire for growth were catalysts for change. The next step was to demonstrate the value of maintenance through an earlier implementation of a reliability program at our Trail Operations and a pilot at Elkview Operations, one of our steelmaking coal mines. Then we engaged all vice presidents and general managers in a workshop that reviewed internal and external case studies and debated barriers for change. The end result was an agreed upon model that is now being rolled out to all our sites. Our next step is to continuously and effectively engage all levels of management and employees. It's a 'game of inches.'"

Domtar Espanola

Best Asset Health Management Program

"Communication, education and an abundance of determination are critical requirements in driving a reliability improvement initiative. How did we gain approval and support from management? First, we performed an audit to identify strengths and opportunities. Then, we created a business plan complete with measurable goals and estimated value of improvement. From there, we communicated the importance of a reliability improvement initiative in the language of operations (dollars and production). We reported on positive results and posted graphs, KPIs and success stories to let people know how much their support was appreciated. Communication efforts also included sending out newsletters and sharing articles on best practices. These efforts also supported our education initiatives. Our culture became a knowledge is power mindset. All employees were committed to never giving up and being relentless in implementing best practice!"

DMAX, Ltd.

Best Infrared Thermography Program

"Our PdM program started in 2005 as a mandate from GM as part of its maintenance process. DMAX is a team concept plant, so the program is driven from the ground up with the ownership in the hands of the predictive team. Buy-in from management came relatively easy at DMAX; all it took was a catastrophic failure on a spindle that we predicted would fail and management ignored. The failure sold management on these hocus pocus technologies, and with the continued cost savings and improvements in uptime, management has become PdM's biggest fan. This affords us many training opportunities to improve our skills so we can be the best at what we do and, in turn, help make DMAX the world's #1 diesel engine manufacturer."

Luminant Mining

Best Nondestructive Testing Program

"Our company has always been a leader in continuous improvement and utilizing new technology. In 2006, we implemented aggressive reliability centered maintenance (RCM) and condition-based maintenance (CBM) strategies to help reduce equipment and component costs. We looked at what was working and where we could improve our inspection procedures and processes to reduce premature failures. Through new scan chats and technology in non-destructive testing (NDT), we were able to prevent major component failures, therefore preventing the resulting collateral damages. Along with well-documented cost savings, we were able to show that more reliability and condition-based asset management was the path forward for Luminant Mining."

WellSpan Health Facility Management Department

Best Design for Reliability Award

"Being in healthcare, we decided to make the pitch to leadership relevant to the environment in which we work by setting up an analogy between the assessment of a patient and reliability centered maintenance using the following corollaries. A doctor uses pulse (vibration analysis), temperature (infrared thermography), blood tests (oil analysis) and a stethoscope (ultrasound) to assess the patient. The analysis and expert interpretation of these results lead to a specific course of treatment. We just wanted to do the same for our equipment. With intense financial pressure in healthcare, this also was the most economical approach to staffing."

Merck & Co.

Best Green Reliability (Sustainability) Program

"The establishment of a formal reliability engineering department at Merck's facility in Rahway, New Jersey, was very easy as it was developed in conjunction with the implementation of SAP as its ERP system across the globe. A great deal of time and resources were put into this implementation, so our management developed our department to help ensure the benefits of the new CMMS would be quickly realized and sustained. While the main focus of our department was on proactive maintenance, we soon found that there was a direct correlation between things like equipment reliability and energy consumption. Understanding the pressing need for cost reduction, our team made a concerted effort to document the savings we achieved with every project we completed. Because of our success stories, our management supported us on all improvement initiatives with very little hesitation."

TransAlta Corporation Alberta Thermal Power Plants

Best Vibration Analysis Program

"In the late 1990s, the plant was having numerous large motor failures. The average life of our critical motors was about seven years, with some failing as often as three to four years. There were many issues at play; however one of them was the fact that many of the failures were caused by mechanical issues. It was relatively easy to justify the cost of doing some vibration analysis when compared to the losses we were incurring on this equipment. At the time, the program started with the use of a contractor, but within one year we were able to justify the costs of hiring our own analyst and doing the testing in house. The program now consists of four vibration analysts. Annual estimated prevented losses that can be directly contributed to the vibration program are nearly $3 million per year. The vibration analysts work very closely with the maintenance departments. We also document very well the saves that we make. This has led to the continued growth of the vibration department and the support of our managers over the past 10 years."

New Braunfels Utilities

Best Lubrication Program

"This is a great question and I can literally write pages on this topic, but for the purpose of this article, I am going to keep it brief with a three-part formula. First, commitment. Managers must be willing to pour their heart and soul into everything they do every day. This level of commitment and pride is infectious. It will easily spread throughout their staff if it is genuine. The second part of the formula is gain credibility. Every company and every process will have easy to spot issues or bottlenecks. It is important for a manager to find the low hanging fruit, fix the issues and capture the positive gains created by this effort. The final part of the formula is provide management with useful information. A manager's time is valuable, so when you have the person's attention, make the best of it. Provide your leaders with facts, benchmarks, cost analysis, gap analysis and a well thought-out plan. So, how did I get management's approval to move forward with this program? I committed myself to building a solid reliability program for NBU. I gained credibility by following through with everything I promised and I provided my executive management team with the information they needed to make a confident decision to move forward."

A doctor uses pulse (vibration analysis), temperature (infrared thermography), blood tests (oil analysis) and a stethoscope (ultrasound) to assess the patient. The analysis and expert interpretation of these results lead to a specific course of treatment. We just wanted to do the same for our equipment.

WellSpan Health Facility Management Department

Sasol Mining (Pty) Ltd.

Best Condition Monitoring/Predictive Maintenance Program

"In 1991, personnel from the engineering team at Brandspruit Colliery invited a supplier to demonstrate their vibration analyzer on an electrical motor that had a broken rotor bar. Needless to say, the supplier (unaware of the broken rotor bar) identified the broken rotor bar with the analyzer he proposed Brandspruit Colliery to purchase. This demonstration was the basis of the motivation from Brand spruit's personnel to purchase the equipment. Over the next two years, the condition monitoring department was established and successfully implemented the vibration and oil analysis technologies. They resulted in the proactive prevention of rotating equipment failures and subsequently winning warranty claims based on scientific facts. Due to the successes achieved by Brandspruit Colliery, the rest of Sasol Mining's six mines and two plants bought into the condition-based maintenance strategy. This resulted in Sasol Mining's reduced maintenance costs, improved reliability and self-imposed safe working practices. Successes achieved led to senior management's buy-in and support for establishing a central based condition monitoring team and integrating predictive and proactive maintenance into the total Sasol Mining maintenance strategy. Management's support was further enhanced through the persistence and passion of the central condition monitoring team which established a proven track record for meeting their business plan commitments that then resulted in the effective implementation of new condition based techniques. The effective predictive maintenance recommendations experienced by the artisans also brought about upward pressure on management to continue supporting the condition monitoring techniques throughout the journey. Management acknowledged that the condition monitoring department evolved over time in support of Sasol Mining's vision and strategy."

Vibration Analysts Save the Planet

Jason Tranter

If you look under the shirt of the average vibration analyst, you might just see a blue, skin-tight bodysuit with a large red "S." You already know that vibration analysts are heroic in their responsibility of avoiding catastrophic machine failures and the downtime and safety risks that follow. But did you know that vibration analysts are saving the planet, too?

In this article, we will explore some of the ways they do just that. Among the measures vibration analysts use to help the environment include reducing secondary damage and improving the life of rotating machinery (which ensures that resources are not wasted); reducing machine failures that may lead to environmental damage; lowering vibration levels and improving balance and alignment to reduce energy consumption; monitoring pumps, turbines and other equipment to ensure they are running at peak efficiency; and monitoring wind turbines to ensure continued supply of renewable energy. Of course, if vibration analysts also perform oil analysis, motor circuit analysis and other condition-monitoring tasks, they can contribute even more environmental benefits.

Reducing Secondary Damage

When a bearing fails, additional damage can be done to the machine; shafts, seals, impellors and other components also may be damaged and therefore need to be replaced. While this results in a longer period of downtime (and potentially overtime labor) and a larger repair bill, it also results in waste. The energy and resources required to manufacture and transport those components have been wasted.

The vibration analyst plays a key role in minimizing the secondary damage. Early and accurate diagnosis and the provision of clear, actionable information ensure that the replacement can be managed in the most cost-effective manner.

Improved Reliability

Normally when we discuss improvements to reliability, the focus is on reducing downtime (and overtime hours and parts inventory) and improving safety. But from an environmental point of view, improving reliability results in less waste because fewer parts are being replaced over the lifetime of the machine. Although your plant may have a recycling program, there is no doubt that having a bearing remain in service for 10 or more years is far better for the environment than using multiple bearings during the same period.

The vibration analyst is responsible for detecting the bearing fault and ensuring that the bearing does not fail catastrophically. But the most cost-effective and environmentally responsible activity that a vibration analyst can perform is to ensure that the bearing does not develop the fault in the first place. These activities include:

1. Making sure the machine is precision aligned and balanced.
2. Ensuring belt tension is set correctly and machines are not resonating.
3. Checking that machines are lubricated correctly.
4. Making sure that bearings are installed (and stored and transported) correctly.
5. Ensuring that the plant has an effective acceptance testing program.

As a separate, but definitely related issue, the vibration analyst should attempt to influence the design, engineering and purchasing process. For example, if new equipment is designed to be reliable and high efficiency

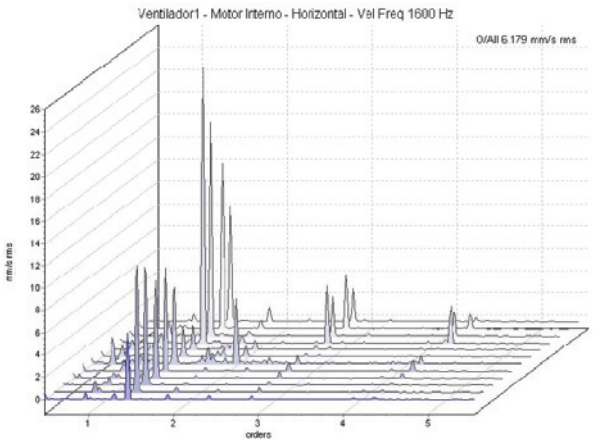
motors that are rated correctly for the application are purchased, then reliability will be improved and the environment will benefit.

In addition, the vibration analyst should play a key role in the root cause failure analysis process. When a problem develops, such as in a bearing, rotor, or any other component, the vibration analyst should be part of the team that determines why the fault developed and what can be done to ensure it does not happen again.

Environmental Damage

If the reliability of a machine is improved and the vibration analyst is utilizing all of the tools correctly, then machine failures should be reduced drastically. If a pump fails and toxic material is leaked into a stream, the environmental consequences are obvious. Pumps in the petro-chemical, sewage/waste water, pulp/paper and other industries clearly represent a risk. Fires that start as a result of failure also impact the environment.

The Sayano–Shushenskaya hydroelectric power station accident[1] in 2009 represents one of the more extreme examples. Increasing vibration levels were not acted upon and ensuing failures resulted in tragic loss of life and substantial environmental damage. The environmental impact was four-fold: massive amounts of water rushing down the river; 39 tons of transformer oil contaminating the river; destruction of 390 tons of cultivated trout in riverside fisheries; and the need to power smelters and other facilities with diesel generators due to the lack of power supply from the 6400 MW hydroelectric power station.



Spectra show that build-up on the fan increases unbalance. Regular cleaning resolves the problem. The closest data is the most recent data.

High Vibration Amplitude: Unbalance and Misalignment

There is some debate about this topic in certain forums,[2] although I personally do not understand why. If a machine is properly balanced and aligned and is running with "low" vibration readings, it is reasonable to conclude that the bulk of energy consumed is being used for the intended purpose: pumping the fluid, compressing the air, moving air, etc. However, if the vibration amplitude is increased due to unbalance or misalignment, the motor has to do more work.

In the following case study, a belt-driven fan used in the production of breakfast cereal was determined to be out of balance. After balancing the machine, the current draw was reduced by 5 amps. The motor was a 75 HP US Motor operating at a nominal speed of 1800 RPM. If you know what you pay per kilowatt hour and the voltage of the motor, you can readily determine what those 5 amps are costing you, day-in and day-out.

When a machine is misaligned, the motor is fighting against the offset and angle between the shafts - the "bind" that occurs twice per revolution. While the forces related to unbalance and misalignment reduce the life of the machine, they also result in additional energy consumption.

There are a few papers that discuss this issue with varying conclusions.[3-6]

Vibration and Product Quality

In a number of industries, vibration relates to product quality. Reduced product quality can result in waste and, of course, waste is bad for the environment. Here are a few examples:

- Corrugation or "barring" in rolls (or felt) on paper machines (and other similar processes) results in paper that is not a consistent thickness. Rejected paper may be recycled, but the energy consumed in creating the pulp and drying the paper is wasted. Vibration analysis can be used to detect the condition and determine the root cause.
- When timber is cut into boards, any vibration on the saw blade results in a cut that is thicker than necessary – which results in waste. The same situation exists in other cutting operations, for example, cutting silicon wafers used in solar collectors.
- In general, vibration in a production process can result in poor quality for a variety of reasons. In the printing, biosciences, semiconductor and aerospace industries and in applications where lasers and sensitive optics are involved, vibration must be kept to a minimum. Vibration analysts are involved in reducing vibration, both by taking care of unbalance, misalignment, resonance and other vibration sources, and by designing isolators.

Renewable Energy – Wind Turbine Monitoring

Wind turbines represent a major opportunity to generate energy using a free and clean source of energy. Wind turbines are amazing structures and the drive train (the main bearing, planetary gearbox and generator) are a feat of engineering. But they operate in tough environments; fluctuating load and temperature extremes in a housing (the nacelle) that is vibrating, flexing and resonating. Failure of the gearbox and other components results in very high costs that threaten the viability of wind projects; and when there is a failure, the wind turbine is no longer generating energy.

Vibration analysts will play a key role in ensuring the success of this industry. By detecting faults at an early stage, the wind turbine can continue to operate (possibly generating less energy) until the repair can be scheduled. Given that the majority of wind turbines are in remote locations or out at sea and will require a very expensive crane if there is major damage, the success of the condition monitoring program is vital.

Other Condition Monitoring Technologies

Vibration analysts are often skilled in other technologies that also can result in reduced energy consumption, reduced waste, or less pollution. Here are some examples:

1. Lube oil is an important resource and disposal of the oil can be hazardous to the environment. When it is replaced on a schedule based purely on days of operation, "perfectly good" lube oil may be wasted. Oil analysis tests can quickly determine the condition of the oil and whether its cleanliness and lubricating properties still meet the requirements.
2. Voltage unbalance results in current unbalance. Current unbalance results in heating and damage to windings. Heat represents energy loss and damaged windings can result in reduced life and even fires. There are a number of excellent articles and papers[7] on the benefits of improving motor efficiency and the cost associated with reducing current draw.
3. Infrared thermography can detect a number of electrical problems that could cause or be a result of voltage or current unbalance or electric motor faults. An increase in temperature represents wasted energy and results in reduced life.
4. Performance monitoring can be used to determine if, for example, a pump is being operated at its best operating point (BOP). Incorrect operation of the pump can result in reduced life and inefficient operation – another waste of energy.
5. Using ultrasound, steam and compressed air leaks can be detected, thus reducing the energy consumed to provide the required amount of steam or air. It is also possible to determine if steam traps are operating correctly.

Conclusion

Whenever you meet a vibration analyst, take the opportunity to thank the person for the great job he or she is doing for your organization and the environment. Analyzing vibration can result in reduced energy consumption, improved product quality (and therefore reduced waste), improved process efficiency and improved reliability.

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