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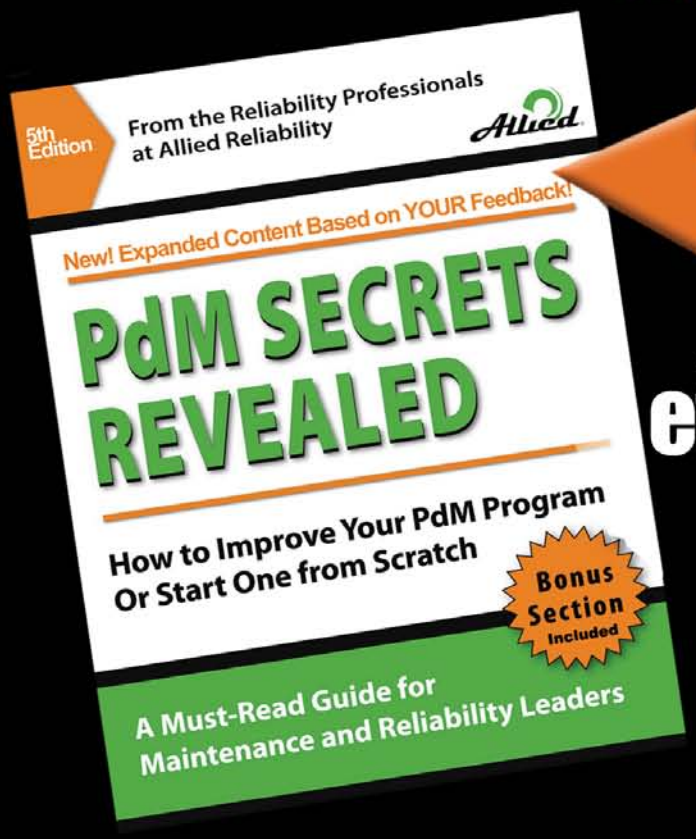

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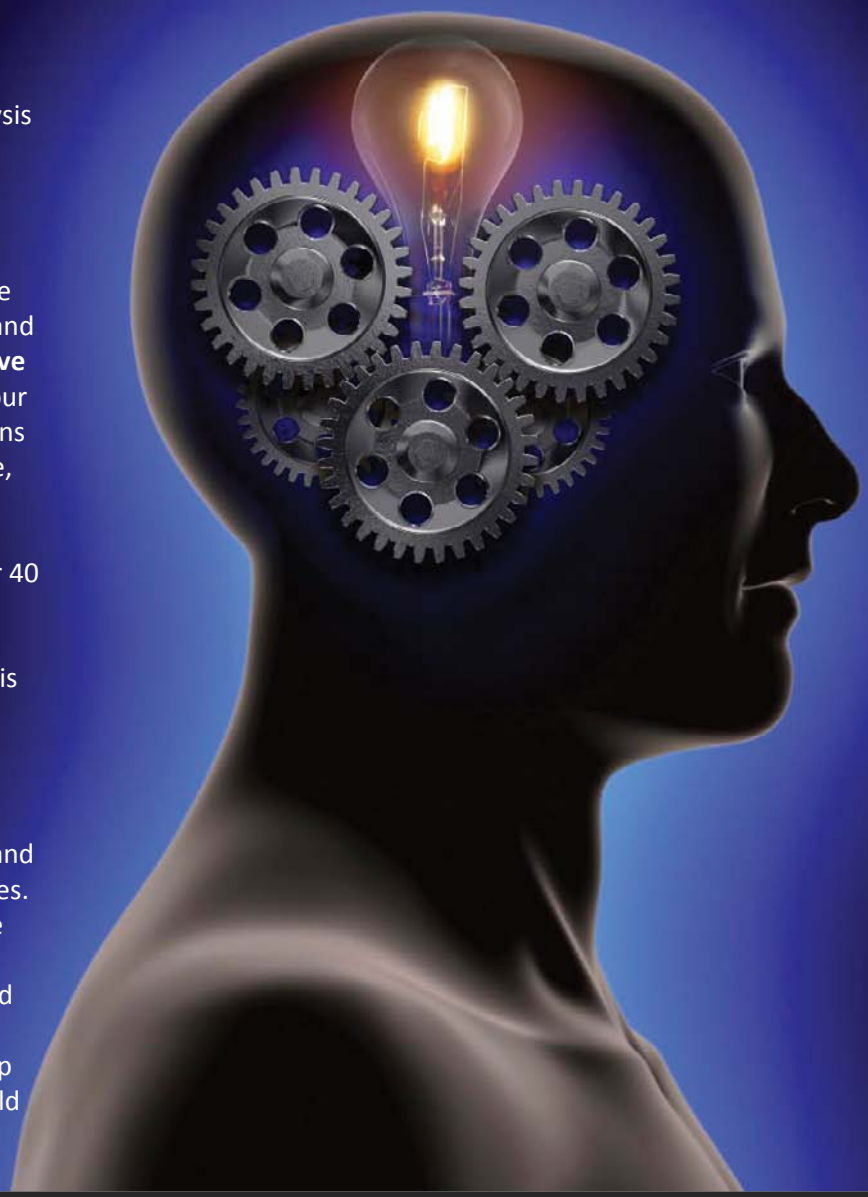

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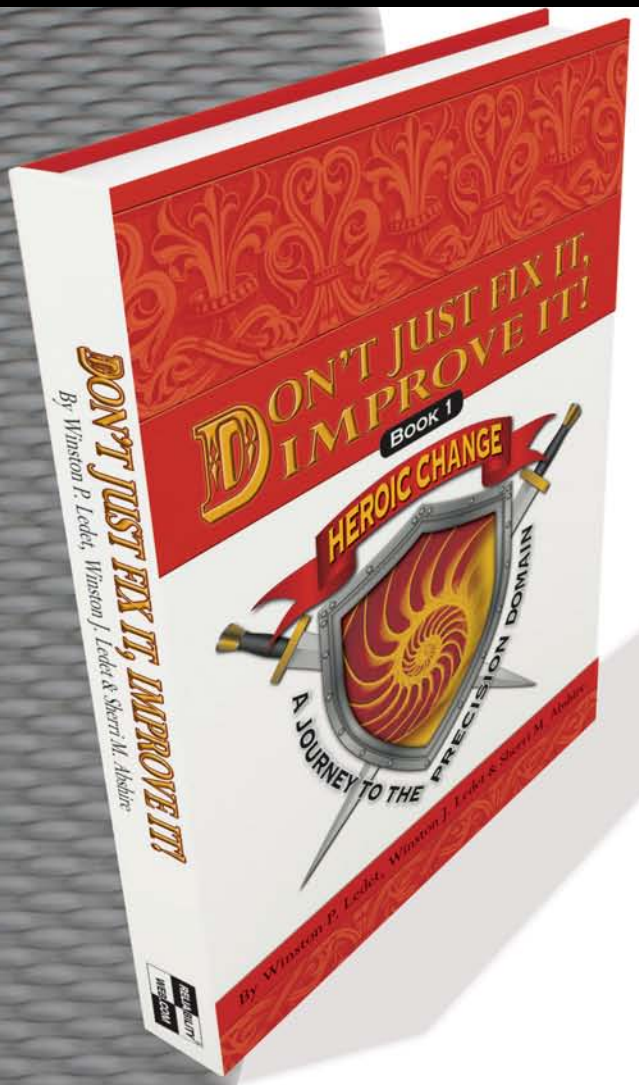

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It brought back a lot of memories and I found myself getting excited about what it is possible to accomplish if you can get the right people focused on the right things. Can't wait for Book 2!!"

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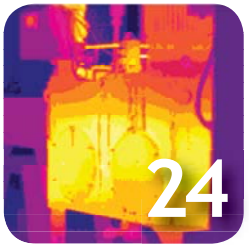

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Sharing to Learn, Learning to Share

When you think about the maintenance and reliability community around the world, it really is a pretty small group. It is made of professionals who share a common, simple goal - to make the equipment that we are responsible for run better and to make it more reliable.

My job is fun and rewarding because I try to collect articles that I think will help the professionals in our community learn more about their craft and perform their jobs better. I also want to express my personal thanks to all of the authors who contribute their knowledge, time and effort to make Uptime the magazine that it is.

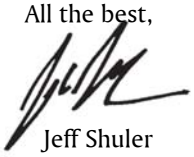
There is actually a great deal of creativity in coaxing more reliability out of machinery. For instance, in reading the feature story, you will learn how to expand the use of ultrasonic inspection to mobile assets. Ultrasound is a technology that has been around quite a long time, but I would wager that the majority of organizations are not utilizing it to protect their mobile resources. Hopefully the article opens some creative pathways for readers, not only to see the benefits of utilizing ultrasound on mobile assets, but to also think of other interesting uses to which this versatile technology may be applied. Thank you to Allan and Gus for sharing their story.

I hope the collection of other stories in this issue will also prove beneficial for you. From finding the ROI in infrared, to the business case for PdM programs and a fine overview of lubrication basics, it is a smorgasbord of info that is ripe for the picking.

Speaking of sharing, this year's Reliability 2.0 conference is taking place April 20-22 in Ft. Lauderdale. The lineup of maintenance and reliability experts is star-studded. They will be sharing all sorts of information that can open your mind to new ways of doing things. Reliability 2.0 is an excellent opportunity to connect with other members in our community, to learn and share experiences that will help us all improve our performance. Hopefully, we will see you in Ft. Lauderdale, where you will not only learn a great deal, but also get energized by a host of new ideas, techniques and applications.

I hope you enjoy this issue. As always, thank you for reading. We appreciate your support, and hope you find value within these pages, the digital issue and on our website. If you have any questions, comments or suggestions that will make Uptime more useful to you, please let us know.

All the best,



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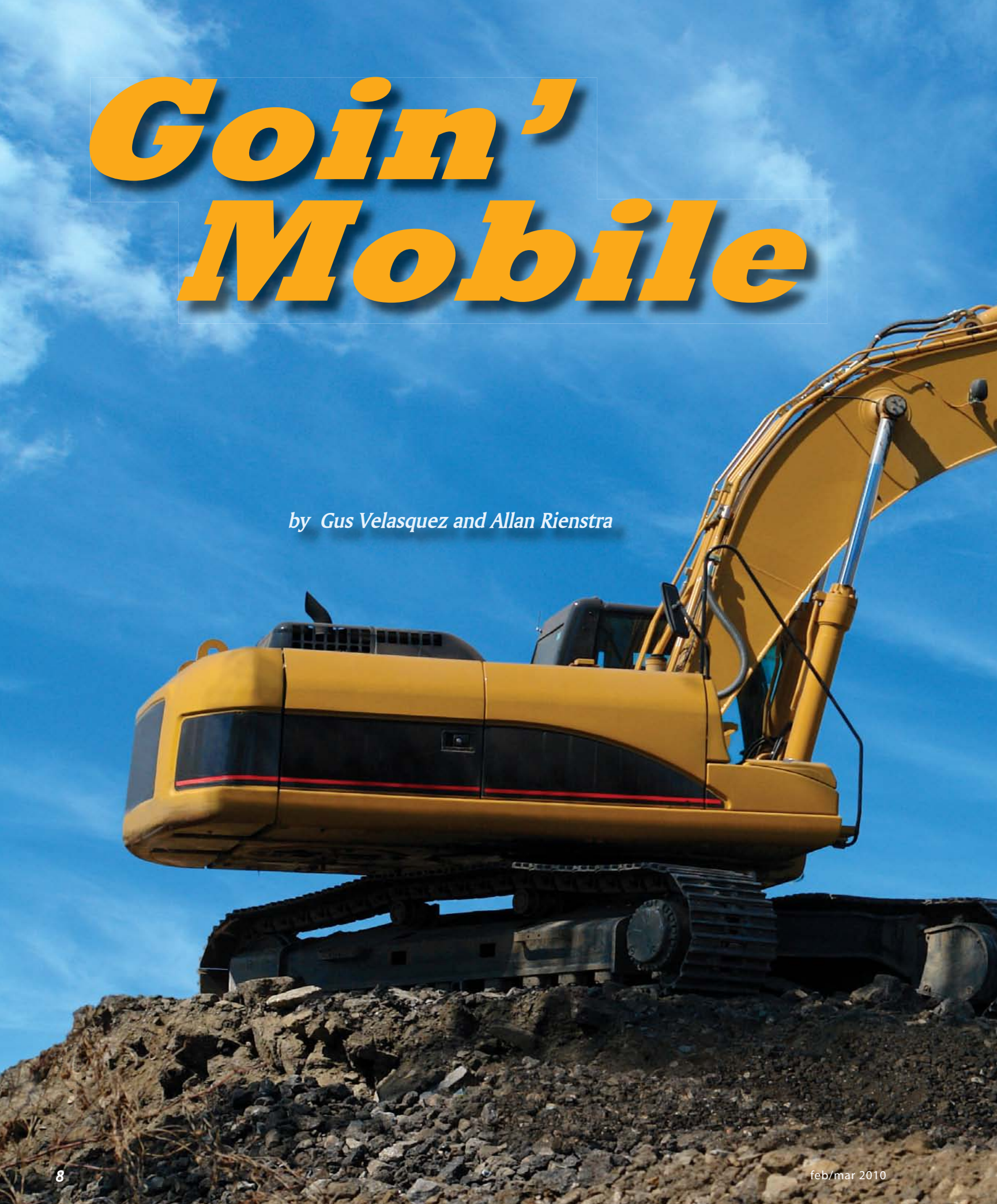
Goin' Mobile

by Gus Velasquez and Allan Rienstra



Extending Ultrasonic Inspections to Mobile Assets Drives Expenses Down, Profits Up

Ultrasound as a predictive maintenance tool is used successfully for many applications in industries of all kinds. Ultrasound is useful as an inspection tool for detecting positive and negative pressure leaks, which are commonly found in compressed air and vacuum systems. Some industrial processes use ultrasound to identify failed steam traps, and all facilities derive safety benefits from its ability to find electrical faults. Most recently, PdM professionals have opened their eyes to the benefits ultrasound offers as a predictive technology. Ultrasound often gives an early alert that an impending problem is developing in a bearing or helping to optimize the lubrication of rotating equipment.

All of these valuable applications contribute to billions of dollars saved in downtime, energy efficiency, and improved product quality. Is there room for even more savings? Well, just consider the fact that most of these inspections are carried out on fixed assets only. Are additional savings possible for mobile assets? At many companies such as mines, cement production, quarries, civil engineering contractors, industrial farms, commercial fleets, and oceanic vessels, the production cycle depends on heavy vehicles, loaders, off road vehicles, and seagoing ships. Surely, there must be benefits that Ultrasound inspection could realize on these mobile assets as well.

These vehicles have a wide range of applications like moving goods from land points to sea ports and beyond. They are used to plant, maintain, and harvest crops, excavate earth and move thousands of tons of raw materials in quarries and open pit mines. Although their size can vary between 30 tons to more than 350 megatons, they all have in common an internal combustion engine to provide the power to move the vehicle and power the hydraulics.

Most have a cabin to keep the operator safe, dry, warm, or cool, while others have storage volumes which must be weather tight, at the least, and hermetically tight in the case of chilled container transports. And in many cases, compressed air systems are used for braking and suspension systems.

To protect the investment in these mobile assets, preventative and predictive maintenance is performed on a regular basis. Most fleet managers rely on oil analysis for predictive maintenance, while other PdM technologies (Ultrasound, Vibration, Infrared) are seldom considered. Additional investment in these technologies is not currently considered a priority. There are several important applications that can be served with ultrasound technology, but are not currently understood, and definitely not employed by most mobile asset repair shops. These applications fit the PdM tool box perfectly for any maintenance department responsible for keeping a commercial fleet running flawlessly.

Most PdM technologies are symbiotic, which is to say that when used in concert they provide a more complete picture, but when used alone vital data can be overlooked. The purpose of this article is to educate about some important applications where the combination of ultrasound testing and oil analysis can predict major premature engine failures, as well as speed up the inspection time required to find and fix problems. This article also discusses some secondary applications that address issues related to safety of these vehicles, protection of cargo, and comfort for the operator. Hopefully, you to learn the important role that ultrasound technology serves for fleet maintenance managers and mechanics.

Figure 1 - Ultrasound Testing plays a huge role in predicting failures in factories, refineries, and on other fixed assets.

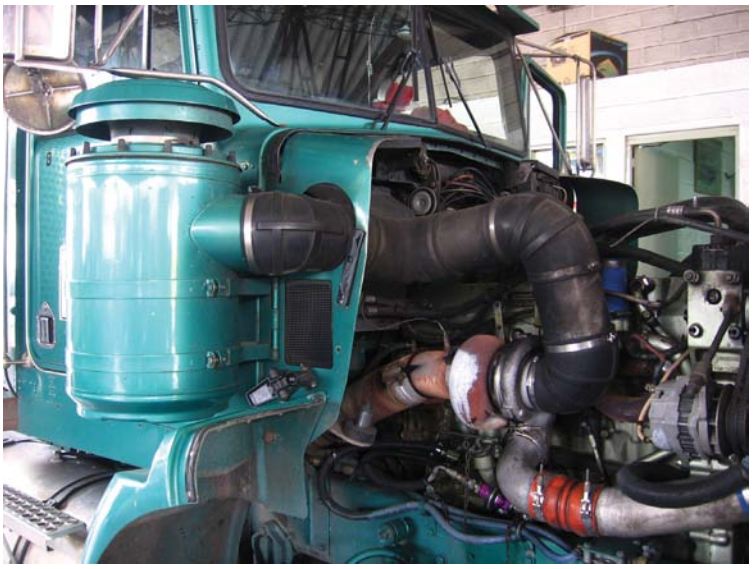


Figure 2 - Overall View of Typical Air Breather on Heavy Truck

Ultrasound Testing...What Is It and How Does It Work?

Many people in maintenance departments responsible for fixed assets of factories know that the principle source of ultrasonic waves is turbulent flow, friction and discharge related to electrical problems. They also know that ultrasound waves are sound waves vibrating over 20,000 Hz, which is impossible for humans to hear without the help of special ultrasonic instrumentation.

Ultrasonic instruments detect potential problems that can lead to shut down of a process or factory. They also detect sources of energy waste and issues that impact negatively on product quality (Figure 1). Many early stage problems produce ultrasonic signals that are transmitted from the source as pressure waves. Ultrasonic instruments detect these waves and translate them into an audible signal that can heard by the inspector, all the while measuring the ultrasound signal so that it can be compared and trended to determine gradual deterioration. Even if that sounds complicated, its really not.

Today in factories with fixed assets, there are thousands of trained ultrasound inspectors working who are extremely sharp and creative when it comes to detecting sources of ultrasound inside their processes, and fixing the problems they find.

Unfortunately, the demographic of qualified and skilled ultrasound inspectors is poorly represented in the mobile maintenance shop, where the technology is virtually unknown. Sadly, many cost saving applications have not been revealed. If you are working in the maintenance department and are responsible for mobile asset maintenance, you will be pleasantly surprised by the applications revealed in this article.

Applying Ultrasound Inspection to Mobile Fleets

We will discuss using ultrasound techniques in several different applications within mobile fleets, including diesel engines, hydraulic cylinders, air braking systems, air suspensions and cabin tighness.

Diesel Engines – Internal combustion engines burn fuel and, regardless of size, they require air - preferably clean air. The air we breathe is the same air engines breath. No matter where we are on the planet, air contains particles in suspension. Some of these particles are harmless but others represent a serious danger. Silica ranks as one of the hardest elements on earth, only surpassed by topaz, corundum, and diamond. Silica is very damaging if it reaches the inside of an engine. Silica also ranks as one of the most abundant elements on earth and ever present in dirt and dust, which is made airborne in the conditions where mobile machines operate. Therefore, engines are equipped with high efficiency filtration systems to prevent silica and other contaminants from reaching the combustion chamber (Figures 2 and 3).

Figure 3 - Typical Air Breather System on Heavy Trucks

All diesel engines have primary and secondary filters fitted between the air intake vents and the turbocharger (Figure 4). When the engine is operational a negative pressure is created in the air intake system and any leaky orifice (loose clamps, cracked hoses, thinned metal, pin holes) downstream of the filters means the engine is breathing without filtra-

Figure 4 - Typical Turbo Charger System

tion. This means air full of silica can reach the pistons, rings, sleeves and other engine components causing damage and premature failure. Depending on how much silica is ingested, the life of the engine is dramatically reduced, sometimes lasting only a few days! Oil analysis is used as a predictive tool that compares the metal content and silica in parts per million (PPM) found in the oil sample against limit values set according to the engine manufacturer. The acceptable silica content is very low, ranging from 15-50 PPM. When a sample shows values over the limit, the source of the contamination needs to be found quickly, and the mobile asset must be removed from service to avoid further costly damage. This introduces the added cost of downtime and lost productivity.

Finding the leaks calls for an exhaustive visual inspection of the entire air intake system. This can take several hours to inspect, and after the inspection, it's not uncommon to have found nothing. The next oil sample will still show high silica levels and increasing wear metal values indicating the problem is getting worse. As a companion to visual inspection, ultrasound testing to find the leak will net results much faster, and is also useful to confirm the repairs to the leak were performed correctly. Progressive mobile mechanics use ultrasound inspection after any service work is completed on the air intake system.

Figure 5 - Potential Leak Sites on piping between air breather and turbo charge

There are two methods for finding problems in the air intake system with Ultrasound.

- Inspection with the engine running
- Inspection with the engine turned off

Inspection with the Engine Running – Using this method of inspection is based on the premise that any turbulent flow from a potential leak produces ultrasonic sound pressure waves, which are, in turn, detected with the ultrasonic detector. Turbulent flow is produced between two adjacent volumes when those volumes have a) differential pressure, and b) a leak path. Turbulent flow will exist at the leak path for as long as there is differential pressure between the volumes.

Start the engine and leave it to idle. With noise attenuating headphones in place adjust the sensitivity of the ultrasonic instrument according to the ultrasound sources near the engine. Using the flexible sensor for safety (if you have that accessory), inspect the entire intake system starting from the air breather

and ending at the turbocharger. Any air ingress will produce an ultrasonic signal that sounds like the hissing, swooshing sound you know from a compressed air leak. A well trained ear will pick out this sound quickly, despite competing noises that may come from the engine itself. Additional training teaches ultrasound inspectors how to deal with parasite noise and harsh environments, and is highly recommended for mobile mechanics that are adopting ultrasound testing symbiotically with oil analysis. Techniques known as "shielding", "covering", "blocking", and "positioning" are learned keys that assist inspectors in high noise areas.

Inspection with the Engine Turned Off – The air intake system can also be inspected for leaks when the engine is not running. In fact, this may be a more desirable method because parasite noise from the engine is loud and can interfere with the inspection.

When the engine is off there is no differential pressure and consequently no turbulent flow. No turbulent flow means no natural ultrasound signals are present at any leak sites. In lieu of turbulent flow you can generate artificial ultrasound signals directly in the air breather system. This is accomplished by means of an ultrasonic transmitter, like the SDT 200mW Bi-Sonic Transmitter, which is a small accessory that generates a 40 kHz signal powerful enough to fill small volumes. The ultrasound signal can be heard and measured directly through the various membranes that make up the air breather system. Wherever the possibility of air ingress exists, the signal detected by the ultrasonic receiver is significantly louder. This is noted in the headphones and the decibel level measured by the instrument.

A large mining company in northern Canada recently shared their experience of inspecting the air intake on a LeTourneau production loader. In response to very high levels of silica and iron from oil sampling on one of their production loaders (Figures 6 and 7), an attempt was made to determine if there were any leaks in the breather system of the loader which would cause the severe dusting. A visual inspection of the breather system failed to produce any definitive results. Then they conducted a second check of the breather system, this time using airborne ultrasound with a transmitter.

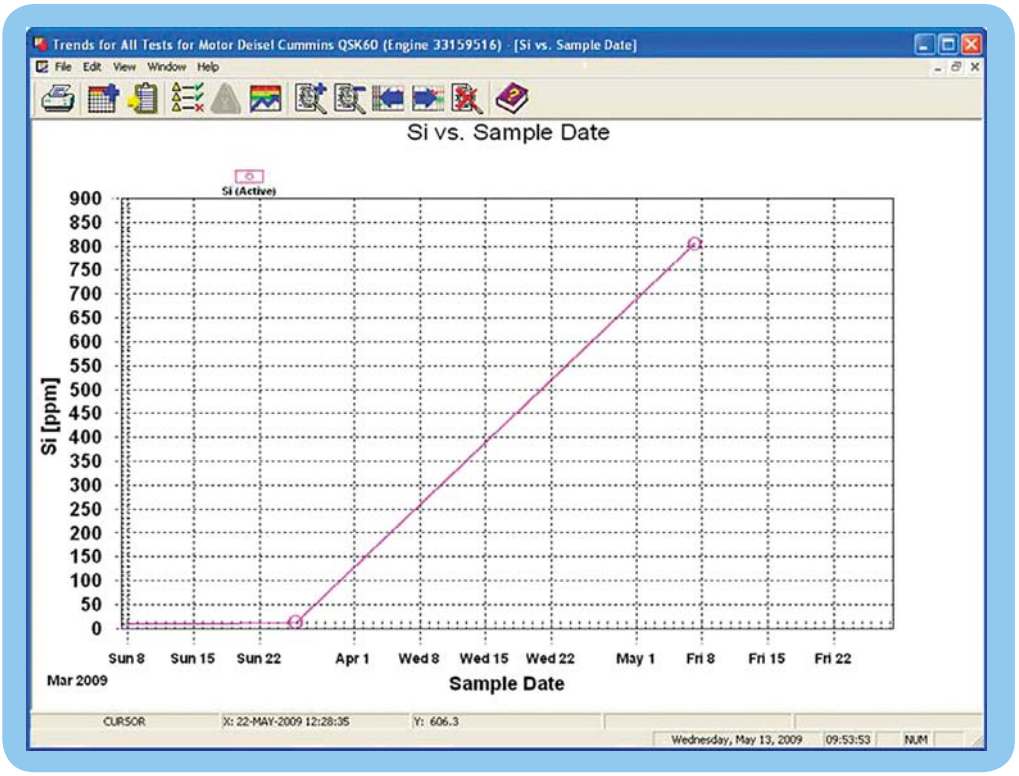


Figure 6 - Silica levels are 800 PPM indicating motor dusting

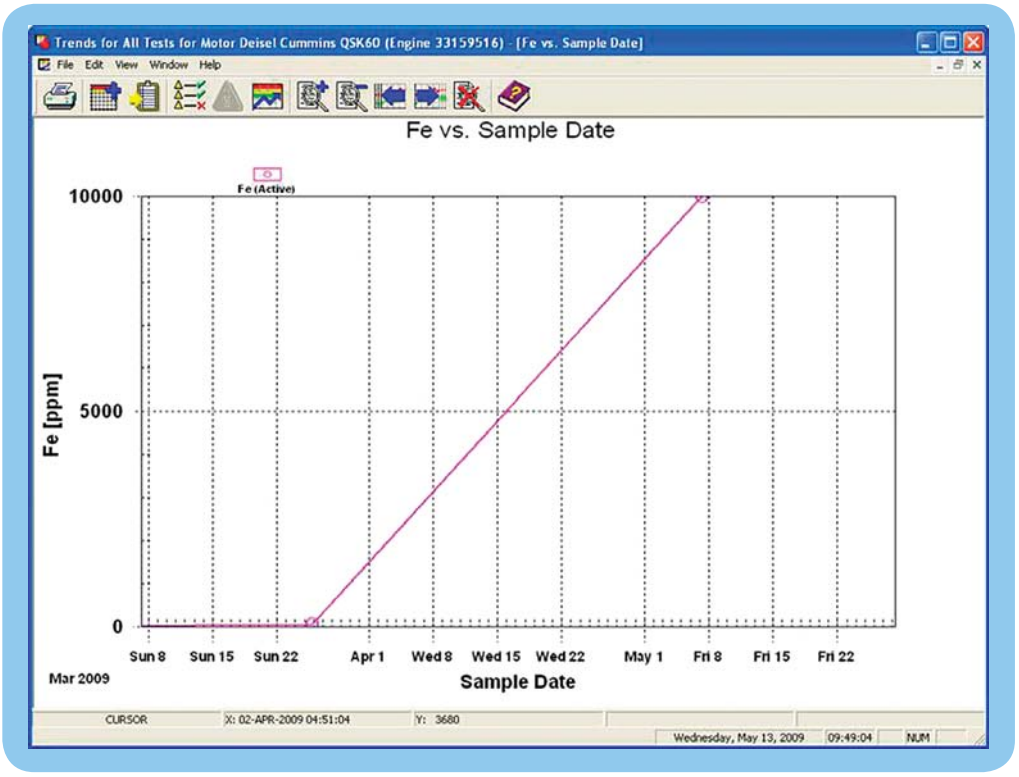


Figure 7 - Iron levels are 10000 PPM indicating motor dusting

"Finding the leaks was easy," the mining company reported. A 200mW Ultrasonic Transmitter was placed inside the inner air filter. Both air filters were replaced and the breather system was sealed up. The entire breather system from the filters to the engine was probed with the ultrasonic receiver (see Figure 8). All locations along the breath-

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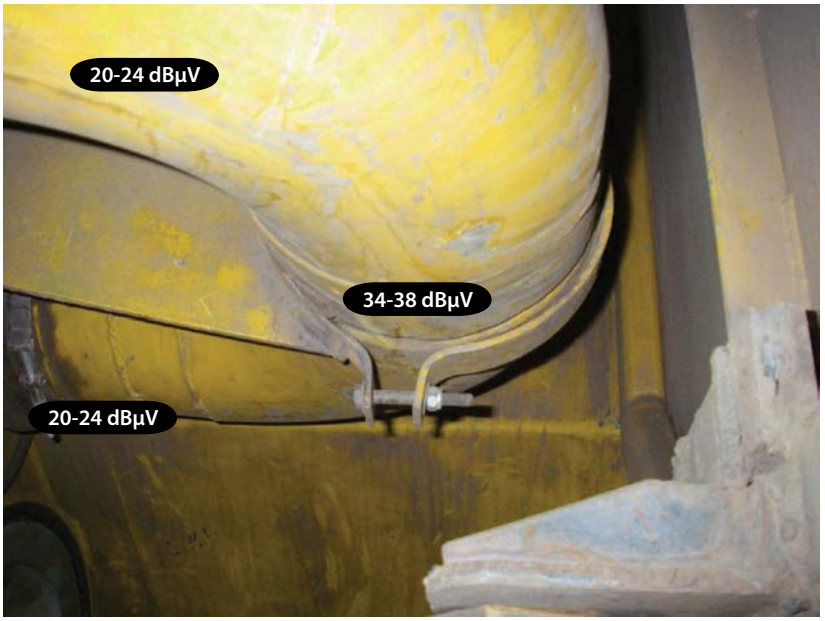

Figure 8 - The breather system was ultrasonically scanned from filters to turbo charger. One location was significantly higher than all others.

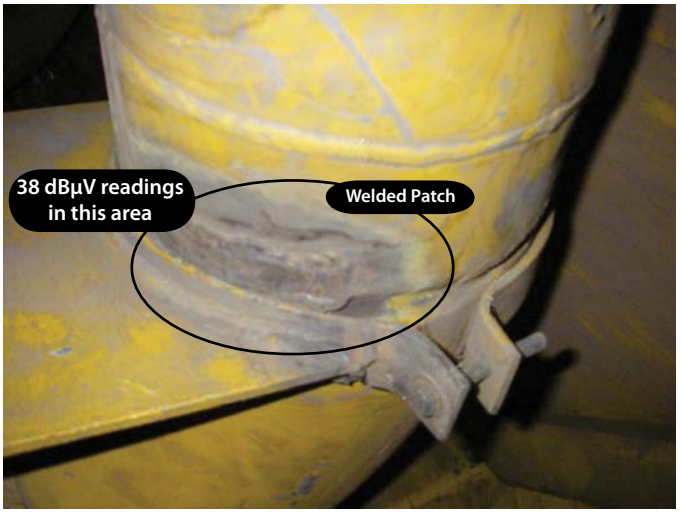

Figure 9 - A leak was dicovered where a previous problem had been addressed with a welded patch.

er piping and joints displayed ultrasound readings from 20 to 24 dBμV, except for one. The location inside a clamp on the right hand side of the loader gave readings of 34 to 38 dBμV. That is an increase of 14 decibels. 38 decibels is 5 times louder than 24 decibels. This is a strong indication of thinned metal combined with the possibility of pinhole leaks under or around the clamp. Images shown in Figures 8 and 9 indicate where baseline ultrasound readings of 20-24 dBμV were registered versus the leak site, where 34-38 dBμV were observed.

The mechanics at the mobile repair shop reported that, once the leaks were discovered, the fix was relatively simple. And finding the leaks with ultrasound inspection was far quicker than any other method previously used. There was a weld patch where the pipe had been previously repaired. It was removed and the existing patch inspected and rewelded. The pipe was reinstalled on the loader, filters replaced and it was recommended that the loader return to operations for a 12 to 24 hour period. Fresh oil samples would then be taken again, and the results analyzed for further dusting problems.

The production loader's oil was re-sampled on May 22, 2009, after approximately 48 hours operating in the field, and test results were received back from the lab six days later. All indications of dusting had disappeared from the oil sample results. As can be seen in Figure 10 comparing the before and after samples, substantial drops in aluminum, nickel, chromium, iron, copper, lead, & silica (see Figure 11) were observed, indicating the air leak had been patched successfully, and was indeed the cause of the dusting. It was suspected that the contaminants in the initial samples were a combination of dusting ingress and wear particles from engine components.

Test Element	Level Before Repair	Level After Repair
Al	3	11
Ni	<1	9
Cr	<1	83
Fe	4	>9999
Cu	<1	59
Pb	2	15
Sn	<1	<1
Si	4	805

Figure 10 - Oil Analysis Report

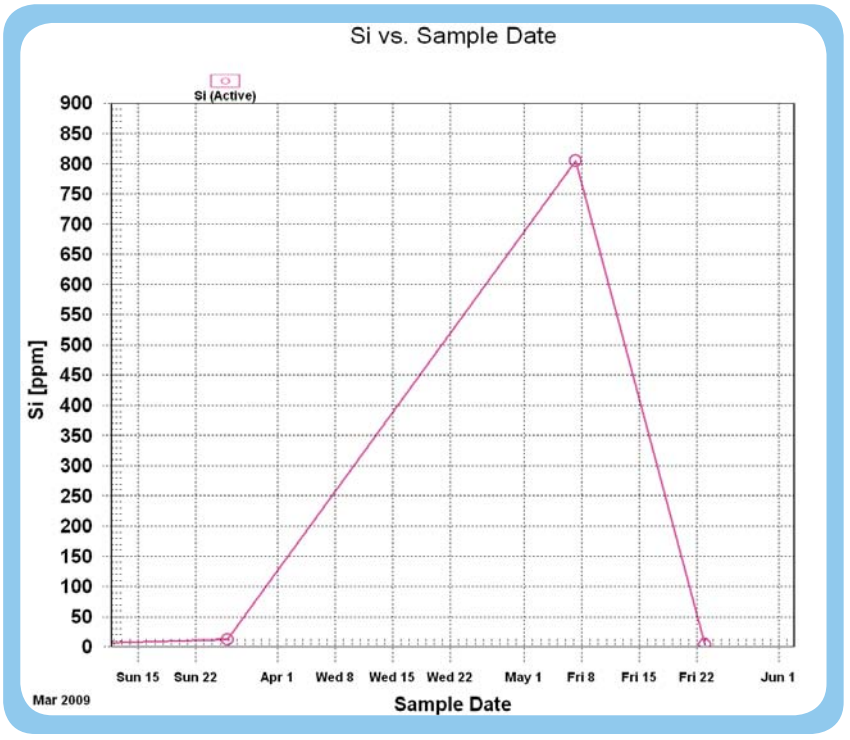

Figure 11 - Silica samples showed normal after 48 hours in service

Bottom Line Savings

This is an easy procedure to implement at any mobile repair shop because of the relative cost of good quality ultrasound inspection equipment. I say "relative cost" because the dollars spent on ultrasound equipment and training can save a company millions. As an example, this northern Canadian mining operation reported savings well in excess of one million dollars only a few months after implementation of ultrasonic testing.

Their numbers are pro-rated estimates based on expected remaining engine life and do not include any additional labor costs. In other words, the remaining value of only the engines after depreciation. The equipment was the one Letorneau 1850 Production Loader we just discussed and four Komatsu 830E Haulage Trucks. All of the engines are Cummins QSK60's and the dusting issues were discovered and repaired between May and November 2009 using a combination of Oil Analysis and Airborne Ultrasonic Inspection. The cooperation of these two predictive technologies contributed to a savings of $1,147,029 over this time period. Actually, business analysts at the company put the figure much higher as they included all possible costs such as labor, parts, and downtime etc..., but this additional cost savings could not be disclosed.

Figure 12 - Breather pipes, which should be at least 1 inch apart, are too close together.

Figure 13 - Rubbing and leak discovered when pipes were pulled apart.

Let's now discuss the Komatsu 830 E Haulage Trucks. To give you an idea oh how difficult it is to find these tiny air breather leaks with visual inspection, take a look at Figures 12 and 13.

The two pipes that are touching in Figure 12 are supposed to be separated by at least an inch. However, in the field, they were actually touching, which caused rubbing. Now look at Figure 13. These breather pipes are 10" in diameter. Once the leak site was detected with ultrasound they were pried apart with a 4' crowbar. This could have caused hundreds of thousands of dollars in engine damage and downtime. Ultrasound inspection of air intake systems is now standard practice at this Canadian mine site, as are some other interesting applications.

Hydraulic Cylinders

Hydraulic cylinders (Figure 14) are used in fixed and mobile hydraulic systems. They provide force through a linear stroke. Their operation is based on Pascal's Law, which states if you apply pressure to confined fluids then the fluids will transmit the same pressure in all directions at the same rate. Hydraulic cylinders are an efficient way to multiply force and move heavy loads.

Seals are one of the most important components in hydraulic cylinders. They create a barrier between the high pressure chamber and the low pressure chamber. When the integrity of seals is compromised, the cylinder no longer transmits its full force potential.

Symptoms of Problems in Cylinders

A sure symptom that the cylinder has problems is a loss of power and or slow operation. In severe cases the cylinder can stall even under light loads. An increase in pump noise and temperature is also a sign of leaking cylinders. The leading cause for hydraulic system failures is contaminated hydraulic fluid. Hard contaminants in the fluid, such as silica, wear out the barrel and the seals making it hard for the hydraulic pump to maintain the necessary pressure.

Figure 14 - Typical Hydraulic Cylinders on shovel loader.

How to Troubleshoot the System

A conventional method to check for leaks in hydraulic cylinders requires an operator to run the piston to one end of its stroke and leave it stalled in this position under pressure (Figure 15 on following page). Then he would crack open the fitting at the same end of the cylinder and check for fluid leaks, which would indicate hydraulic oil has passed the wiper seal. After checking, the fitting is retightened and the procedure is repeated on the other end, and the middle of the stroke. This procedure is quite time consuming and requires the asset to be out of service for a longer time than necessary.

Ultrasound speeds the time required for the inspection, and in many instances, the inspection is performed in the field, avoiding the cost and delay to float the equipment back to the repair bay. This has added benefit if the inspection reveals a leak, and the leak can be repaired in the field.

Using ultrasound, the inspector places the contact sensor or magnetic sensor over the barrel near to the piston (see Figure 16). The system is put under pressure and the sensor scans around the barrel 360° while listen-

Figure 15 - Hydraulic cylinders blocked in open position at end of stroke.

Figure 16 - Place sensor on barrel of cylinder near piston.

ing for the characteristic sound produced by a leak when the fluid passes from the high pressure to low pressure chamber. This sound could be that made by small bubbles of oil bursting on the non-pressure side of the wiper. In the case of larger leaks, the sound is more like a squishing sound as oil is forced across a small orifice in the seal. The point where the signal is most intense indicates the integrity breach of the seal.

Air Operated Brake Systems

Air break systems are primarily used in all types of trucks, buses and rail cars (see Figure 17). For an efficient and safe operation, the system must be absolutely tight. Brake systems manufacturers establish guidelines for pressure, and this working pressure must be maintained under all circumstances.

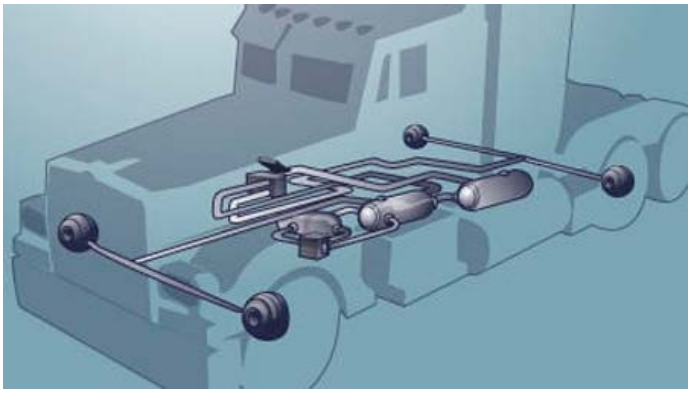

Figure 17 - Typical air brake system on heavy truck.

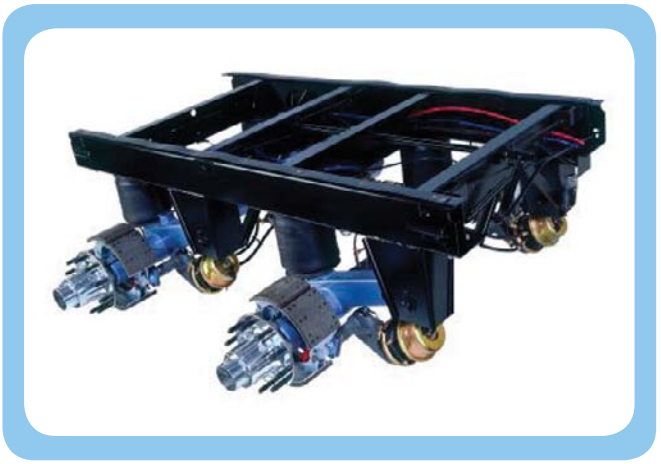

Figure 18 - Typical air suspension system.

Air break systems have several parts including the compressor, an air dryer, valves, air reservoir tank, pipes, fittings and the brake system itself. All of these components are susceptible to leaks. The compressor is designed to run loaded up to 25% of the engine's running time, but air leaks can cause the running time to increase, adding operational costs in the form of fuel and maintenance. Of course, this is not as important as the fact that leaks cause the braking system to be an unreliable safety risk.

Trouble Shooting the Brake System

Finding leaks in the compressed air system in any mobile equipment is easy and fast. In fact, many manufacturers, including Volvo Trucks and Mack Trucks already use SDT170 detectors on the assembly line to ensure leak free brake systems. Start the engine and let the compressor run until the required pressure is reached in the system. Turn off the engine, and using the ultrasonic instrument with the flexible sensor, scan from the compressor side to the brakes in the wheels. The hissing sound of any leak will be easily heard, and, because it is ultrasonic, it is directional, and, therefore, easy to localize.

Air Suspension Systems

Air suspension systems (see Figure 18) provide a much smoother ride, which can add protection to cargo that is sensitive to transportation shocks. The air spring is basically a bellow filled with compressed air and runs off of the same compressor that the braking system uses. Leaks in the air suspension system affect the smooth ride, but can also draw on the brake system, making it unreliable, and, therefore, unsafe. Of course, this adds risk for a vehicle transporting several tons of cargo. When the air spring loses its pressure there is the chance of balance loss and tipping.

Troubleshooting air suspension systems is essentially the same procedure as that used for braking systems.

Cabin Tightness

The final application to discuss here is an equally important one where ultrasound inspection is usefully employed to ensure the tightness of cabins and cockpits. In smaller vehicles tightness is important to prevent noisy interiors from wind noise and water leaks. On larger mobile assets like loaders and tractors, keeping micron sized dust particles out of the cabin is a comfort and health issue for the operators. On ships and other oceanic vessels, weather tightness is vital to ensuring safety of crew and preventing damage to cargo.

The inspection is similar to, and as simple as, the procedure used for inspecting air breather systems with artificial ultrasound. Place the 200mW tone generator inside the cabin and close all windows, doors, and vents. Using the ultrasound instrument and flexible sensor, scan the outside seals on all windows and doors. The artificial ultrasound source is powerful enough to fill the entire cabin, but it is also powerful enough to transmit directly through glass and steel. Use the following procedure to understand the difference between a leak and non-leak.

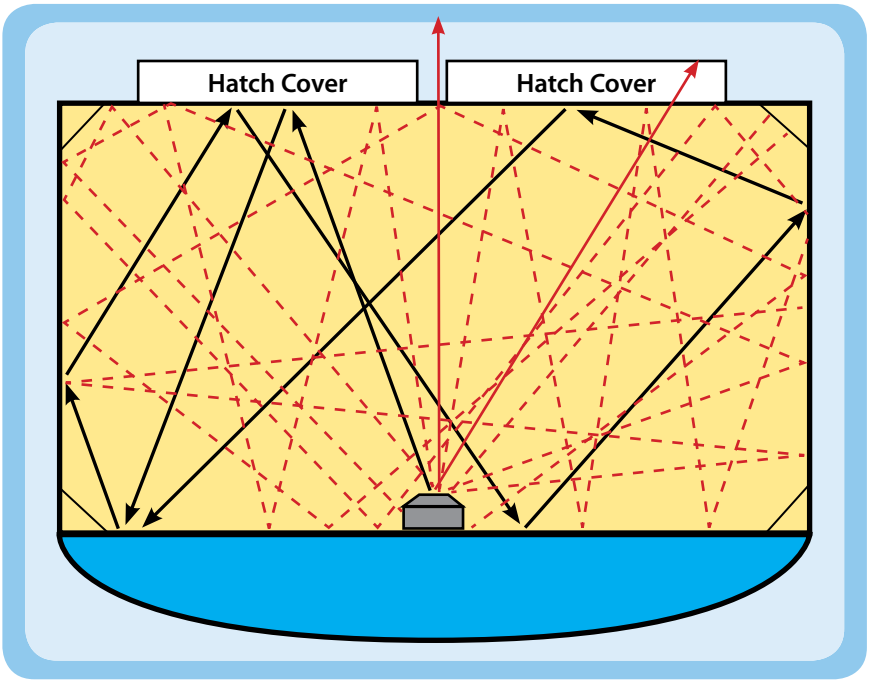

Figure 19 - Typical configuration of ultrasonic transmitter in ship hatch.

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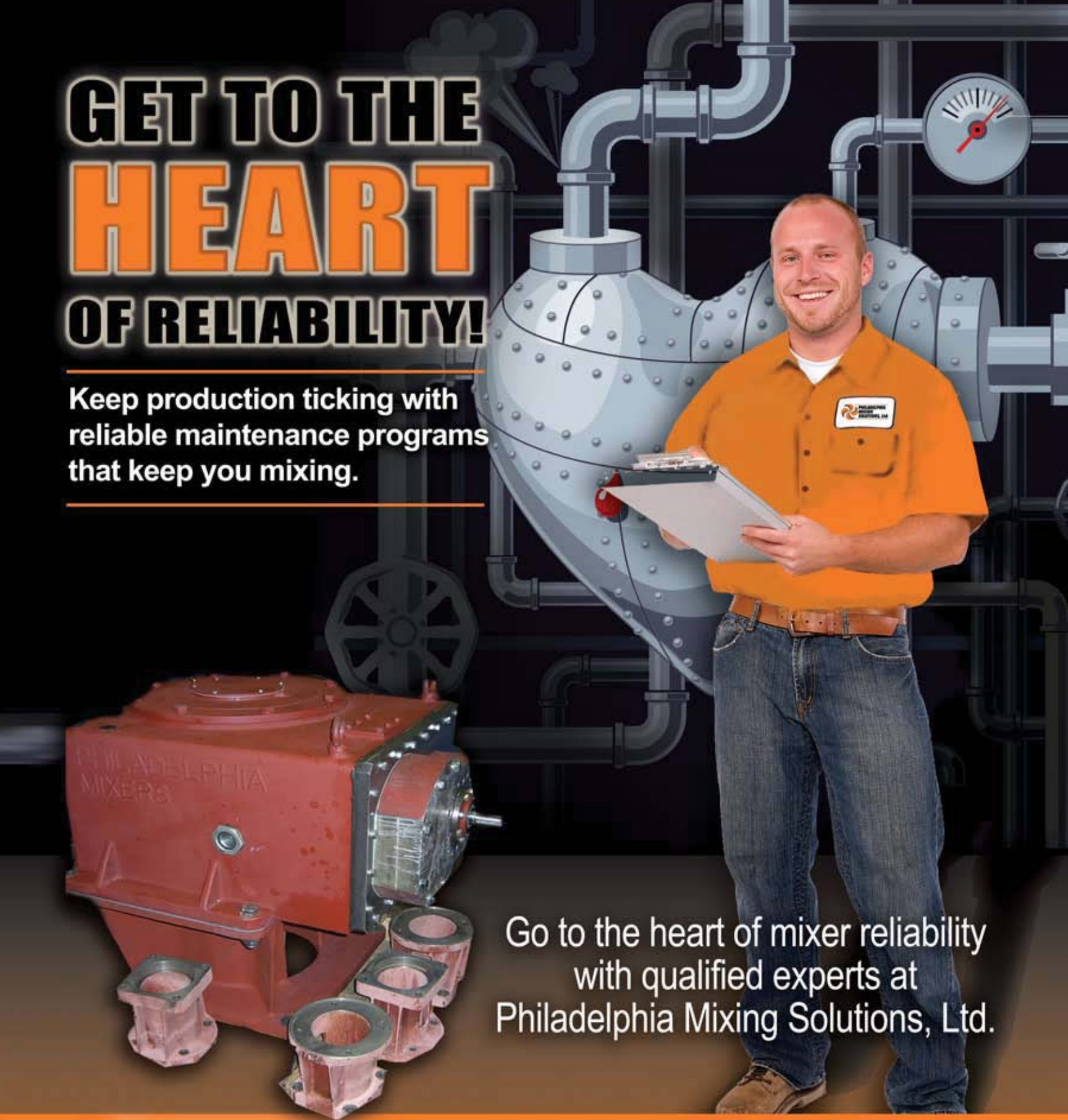

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1. Set the 200mW transmitter inside the cabin.
2. Take a dBμV reading through an open door or window. That is your OHV (open hatch value).
3. Now close the doors and windows and take a dBμV reading at an area where there could not possibly be any leak (the middle of the door glass will suffice). That is the CHV (closed hatch value).
4. Now scan around doors and seals with the flexible sensor. The baseline reading will hover around the CHV. Listen in the headphones and when you hear a signal louder than CHV observe it. Does it approach the OHV? If so you have found a potential leak path.

This article has covered four reasons to implement ultrasound inspection for major fleet maintenance centers. The inspections discussed have positive impact for cost reduction through faster inspections as compared to traditional methods. They also aid in the prevention of premature failure in diesel engines which, as we learned from our Canadian mining operation, saved more than one million dollars over a seven month period.

Figure 20 - Ultrasound inspector checks for tightness of tractor cab at SIAC do Brasil with his SDT170 and SDT08 ultrasound transmitter.

Ultrasound inspection already shares a symbiotic relationship with vibration and infrared inspection of fixed assets. The examples here cite an excellent argument for marrying ultrasound inspection and oil analysis data for better control of internal combustion engines.

Finding hydraulic issues is time consuming. If ultrasound inspection can isolate leakage in the wiper seals, it makes sense to implement the technology to win more inspection time and find additional problems faster.

Finally, inspecting cabins for tightness enhances comfort and safety for the operators. Tightness of refrigeration units means less drain on the compressor motor and better fuel efficiency. Tightness of hatches on cargo carrying ships means dry cargo arriving in port on safer ships.

While great progress has been made applying ultrasound to inspections on fixed assets, we have learned from this article that there are equal wins to be gained from applications on mobile assets. As ultrasound technology proliferates around the globe, we can't help but wonder what other simple applications exist that will help save the next million dollars.

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Allan Rienstra is the CEO of SDT Ultrasound Systems. He has been involved with airborne ultrasound methods for nearly two decades and has helped thousands of ultrasound inspectors achieve inspection greatness through his unique coaching techniques. He is co-author of two certification training manuals, founder of the SDT certification training and implementation guide. His writing appears in maintenance journals around the world. He lives in Cobourg, Ontario Canada with his wife and two sons. Allan can be reached at 905-377-1313 x 221 or allan@sdtnorthamerica.com

Finding the Best of Both Worlds

Calibration Management and Your ERP

by Bryce Johannes

With recent pressures to improve information flow and collaboration driving consolidation of activity through ERP systems, companies have struggled with questions about what they are willing to compromise in order to achieve this harmonization. Particularly for companies in heavily regulated industries, like those regulated by the FDA, where the compliance issues around calibration management are more sensitive, compromises in calibration management functionality have been hard to swallow.

This article will provide some insights into deciding when to integrate with a 3rd party calibration management solution and how workflow typically occurs between the two applications in an integrated solution.

Introduction

The era of departments operating in silos without one knowing or caring what the other is doing is coming to an end. New regulations and pressure to improve efficiency, reduce waste and increase profitability are driving greater collaboration and harmonization. Companies are now looking for solutions to facilitate this collaboration, reduce redundant data entry and improve information flow.

With the increasing flexibility of Enterprise software applications, more and more companies are considering application consolidation. The ability to configure fields and forms to your liking and map your own unique business processes in the software have made it possible for people to consider expanding the use of their existing applications into new departments and uses. It's no longer farfetched, for example, to use an EAM for IT asset management or even as a CAPA (Corrective and Preventive Action) system. However these applications have not evolved to the point where the decisions are no-brainers. In most cases, consolidating applications involves significant compromises. An EAM not designed for IT asset management in mind may cover 80% of the functionality required, but fall short on some key details. An asset-centric quality management system with an EAM instead of a CAPA system as its foundation will provide incredible data and history for assets, but may fall short on some of the more sophisticated analysis tools.

ERP systems have faced challenges trying to expand into new areas. Whole articles have been written specifically about whether any of the ERP's maintenance management modules are robust enough to kick out a purpose-built CMMS. The question remains unresolved, with companies opting to retain a separate CMMS, with some going to the effort to integrate the CMMS with the ERP. While the maintenance management modules in the ERPs are improving, calibration has not, generally speaking, been given the same attention. Therefore, the decision process for calibration management is unique from that of maintenance management.

What's the Motivation Behind Consolidation?

The reasons and motivations behind the consolidation of applications are fairly straightforward. Part of the motivation comes from simple IT and financial considerations. Purchasing, installing and maintaining one application is expected to be easier, and less costly, than purchasing, installing and maintaining multiple applications. Particularly if a company already has the ERP implemented, it will often become the incumbent for any additional need it claims to satisfy.

Generally speaking, however, the greatest motivation is the free-flow of information. Recent financial scandals have increased the responsibility for top management to stay informed of any issues that could impact the company's financial viability. Likewise, the current economic situation and new competitive threats continue to make key performance indicators of interest to multiple layers of management and decision makers. Linking more departments into the same application links their information and cost factors in as well. In the case of asset management, that means being able to summon a more complete total cost of ownership picture for a specific asset or asset classes from a single application.

Another important motivation is the potential for improved collaboration between and within departments. Again, returning specifically to the case of asset management, there are a number of different departments and individuals involved throughout the lifecycle of an asset. There are many people and a great deal of information involved in justifying the need for a piece of equipment, and the decision as to which model to choose. There is then often another group involved with the purchase.

And then a whole team becomes involved in the commissioning of the equipment. While the asset is in use, however, is when the collaboration really kicks in. You've

got a cast of characters servicing the asset; including maintenance, metrology and validation personnel. And you've got an even larger collection of stakeholders, including asset owners, quality managers, process owners, operations, purchasing (for spare parts) and, of course, management.

Software systems are getting much better at keeping all interested parties informed with what they need to know through configurable views into the data and automatic notifications to proper individuals when certain conditions exist or certain work is completed. On the one hand, this sort of collaboration can bring productivity gains from eliminating manual routing of information and coordinating schedules to avoid having to reschedule or redo work because of something another department did. On the other hand, it can also offer a way to control and ensure processes required for compliance are followed, transferring that responsibility to a computer system that can enforce processes and eliminate some of the opportunities for human error.

Finally, there remains the simplest of reasons for consolidation of applications, and that is the elimination of redundant data. If a company maintains two separate and unconnected systems with asset information they will need to store much of the same information about those assets in two separate systems. This redundancy not only implies duplication of effort to enter and maintain information in two systems, but also brings up serious regulatory and compliance questions, in addition to the practical matter of possible discrepancies between the two systems.

ERP All The Way

Once a company sees the benefits of collaboration and consolidation, the first instinct is usually to try to do it all in the ERP, particularly if the company is using one of the top-end ERP systems. The ERP system, given its functionality and how it is typically sold into a company, encourages a top-down approach to most questions. In many cases, it may start as a need for information at the top that trickles down as a call to extend the use of the ERP system into new areas of an organization.

With the flexibility of applications explained above, it's possible for many ERPs to promise functionality in an area like Metrology. But it is rarely deeper than a single line item checkbox for "Calibration". So, as far as the Chief Financial Officer knows, it's the perfect solution for reducing the total number of applications used, and therefore, reducing support costs, and improving information flow, such as total cost of ownership, up through the organization. The problem comes in the details.

Even for high-end ERPs, Calibration functionality is usually limited to being able to schedule calibration work orders and record that they've happened. In some cases, custom development is required within the application to get this far, and trying to duplicate such common Computing Center Management System (CCMS) functionality as measurement data collection and reverse traceability is either impossible or too cumbersome to be practical. The cost to develop this functionality in the ERP approaches the cost of a best-in-class CCMS integrated with the ERP and still wouldn't offer the robust feature set of a purpose-built CCMS.

SAP's model is instructive in this case. Some time ago, SAP defined a set of core functionality for the SAP® software. It was, to be sure, a broad core, including their Plant Maintenance (PM) module, but they developed a mechanism for deciding where to invest development effort. In areas outside of the core where demand still existed, they would partner with other companies to integrate their solutions into the SAP software to fill out the solution. They invested heavily in making those integrations easier. Calibration was one of the areas SAP targeted for partnership, particularly calibration for industries with higher standards for calibration like the regulated life sciences. So they found a best-in-class calibration software solution and developed a certified integrated solution to fill what they refer to as a "white space" in their offering.

Best-in-Class CCMS

As mentioned above, ERP systems now have a certain degree of flexibility to allow customers to develop basic calibration management functionality. But calibration has not been an area of focused development, so the ERP systems cannot provide the depth of functionality available in existing best-in-class CCMS solutions. For this reason, most companies will still need to maintain a separate CCMS in order to satisfy quality and compliance needs in metrology.

The driving purpose and value of metrology is to ensure that instruments used in research, and even more critically in production, continue to provide the accuracy required by defined processes. To achieve this end, metrologists will work with their colleagues in other departments to establish those process tolerances. From those tolerances, they will determine a calibration interval and calibration tolerances for each critical instrument to help them determine when adjustments are required. When the calibration comes due, the metrologist will first determine the state of the instrument, see if it requires adjustment based on the calibration tolerance. If adjustments were made, another run of measurements for each set point will be made to ensure the adjustments were successful.

The area within metrology where ERP systems disappoint most is this measurement data collection. Generally, it's possible to create an input grid for data collection within an ERP system, but they do not provide the richness of measurement data common to a CCMS. If two measurement data grids, for both "as found" and "as left" data, are even possible, they are usually very awkward to navigate between. Additionally, unlike within a CCMS, there are no warnings within an ERP system when a measurement is outside of tolerances. It cannot, therefore, automatically spark an out of tolerance investigation based on the actual readings. More sophisticated measurement data concepts such as: asynchronous tolerance levels, multiple readings per set point with statistical summary and reading tolerances, standard tolerances, and calculation of correspondences between instrument and standard units would be well out of reach of an ERP system. At best, some of this measurement data functionality could be achieved, but with an incredible amount of custom development in the application.

Management and control of this measurement data collection process is another area that would be difficult to replicate in an ERP system. Within a CCMS, measurement data templates are generally created for similar instruments so that all the set points and tolerances are pre-populated and ready to go when each instrument is being calibrated. This not only provides a dramatic time savings when it's time to perform the calibration, but can also help ensure that the proper measurement data points are being followed consistently, and the appropriate stakeholders sign off on the process tolerances. These relationships between records and measurement data configurations and sign off procedures would be difficult, if not impossible, in an ERP system.

Another area of disappointment within most ERPs is standards management. Whenever a calibration is performed, a standard is used to provide a known value against which to test

the unit. The CCMS must be able to not only ensure that the standard being used has itself been successfully calibrated on time, but also should enforce the proper standard to use based upon what is being measured and the accuracy required. And, if a problem with a standard is discovered, it is necessary to be able to determine which instruments were calibrated based on that standard since it was last known to be reliable. Having the ability to perform such a reverse traceability is a requirement in some industries and a good practice everywhere.

This is just a limited review of the unique functionality that metrologists rely on to ensure quality and compliance without needing to fall back on costly manual and paper-based workarounds more common in years past. The CCMS also simply allows metrologists access to the information they need to do their work in a way that better suits their needs, thus improving productivity, eliminating many extra steps usually required in managing and recording calibrations in an ERP system.

Integrated Systems

Some companies, whether motivated by compliance, quality, productivity, or some combination, insist on the best of these first two options. They need the best-in-class calibration functionality of a CCMS and the information flow benefits of a single solution. For them the only option is the integration of the CCMS with the ERP system. In some cases, this means integrating a complete asset management system including both calibration and maintenance, in others using the maintenance functionality of the ERP system with a system designed for calibration.

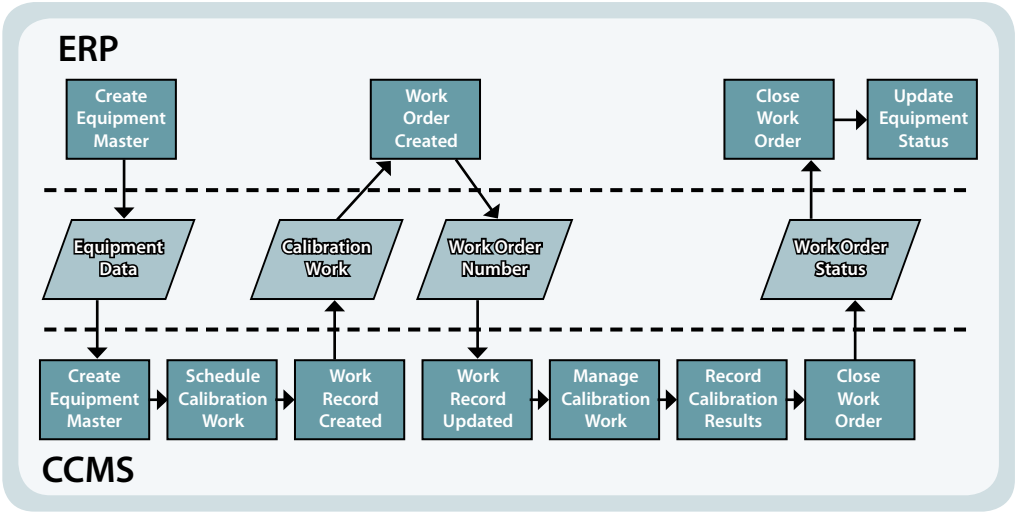

Figure 1 - One possible workflow between CCMS and ERP system.

One of the early steps in the integration process is to determine what sort of information should be passed and under what conditions. The ideal in this case is to enable business processes to continue across applications. Because of this and the variations in how companies will configure both the ERP system and

the CCMS, any integrated solution will tend to require custom integration to meet a company's specific business and technical needs.

In a typical scenario, new equipment entry would be centralized within the ERP system. Calibration work is then scheduled within the CCMS, with an official work order number obtained from the ERP system. This way calibrations can continue to be managed with a more instrument-centric approach while still reporting the work back within the ERP system's work order system. The metrologist uses the CCMS to organize his work and to collect the appropriate information from the calibration. Once the work is completed and reviewed, the work order status is updated and cost tracking data and performance indicators are passed up to the ERP system for aggregate analysis for better business decisions.

From these basic parameters, the degree to which the integration will be taken will depend on the vision and objectives of the company and the capabilities of the specific software packages. Some of the questions to be answered are: What information is common to both systems and which system is the master record for the information? How will work flow through the applications? How do users of the ERP system need to interact with users of the CCMS? What information is required from the CCMS to be analyzed or reported in the ERP system?

Choosing Between the Options

Which of the three options (shown in Figure 2) a company should choose depends on two primary criteria. The first is the quantity and criticality of the company's instruments. The second is the returns the company can expect from improved information flow and productivity. These are balanced against the costs of the different options.

In most cases, the ERP system is a given and a sunk cost by the time of these calculations. For many ERP systems, using the system to also schedule calibrations would involve little additional costs. In many cases, therefore, using the ERP for everything can often, at least on the surface, appear to be the low-cost option. However, given the limitations in the calibration management functionality of the ERP systems detailed above, whatever the productivity gains from improved information flow and collaboration, they will generally be offset by productivity and information loss from accommodations made to use the ERP system beyond its strengths, especially if the company has even a modest number of critical instruments.

For many companies, in the short and medium term, the best option may be to maintain two separate and not integrated systems, handling collaboration and information flow manually. This is, of course, far from ideal but only a few companies put a premium on information flow and collaboration that is greater than the cost of integration. Nor can most companies afford to compromise on calibration management functionality, because of the impact on compliance, quality, productivity, and even morale.

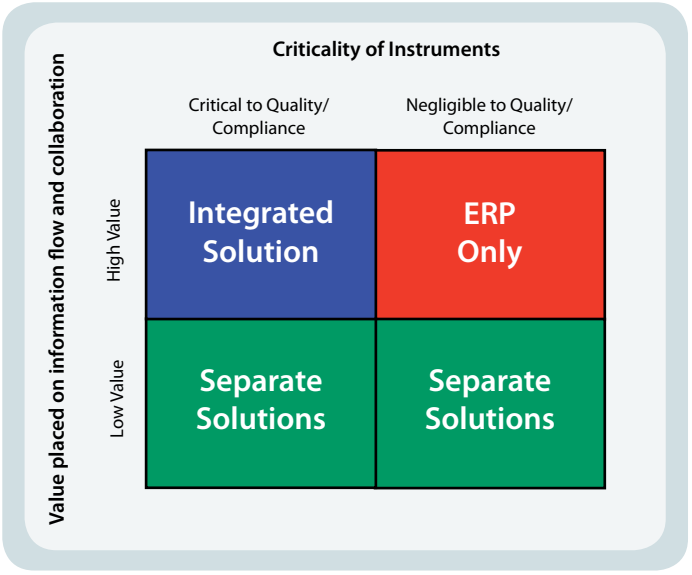

Figure 2 - Matrix for choosing the right approach.

But in the separate systems model, there are still significant decisions to be made, as well as opportunities for collaboration and information flow. The main decision is where to break between the two systems. Once a company decides to go with separate systems, it may be worth considering a single system for both calibration and maintenance, bringing all the regular asset management tasks together. There are systems out there today that allow these two departments to work together without either having to compromise. The automatic information flow is more limited than a greater consolidation, but there may be greater benefits from collaboration between maintenance and calibration than from maintenance and financial departments, for example.

Industry leaders, regardless of size, tend to favor capital investments to reduce operating expenses and are willing to be more aggressive in their IT stance. It is for these companies that integration of a best-in-class CCMS with their ERP system makes sense. They have a vision of everyone – from top management and financial management through to facilities and quality managers, to maintenance engineers and metrologists – having the information they need immediately at their fingertips so they can perform their job efficiently. If considered part of the investment in the ERP, integration between the CCMS is a small part of a larger picture. The greatest stumbling block for justifying this expense is trying to justify it from a metrology standpoint alone. The payback comes in giving everyone the system that makes the most sense for them while still allowing information to flow and collaboration to occur.

In the case of integration, just as with separate standalone systems, the decision about where the system responsibilities should break needs to be made early on in the process. Interactions within a single application will be smoother than between integrated solutions. The decision should, therefore, be made where that seamlessness is most valuable. Should, for example, maintenance management be handled seamlessly within the ERP or seamlessly as part of a complete asset management solution? This decision may have some impact on software product selection and certainly impact decisions on the integration points.

Bryce Johannes is Director of Marketing at Blue Mountain Quality Resources, Inc., a developer of technologically advanced asset management software solutions for FDA regulated life sciences organizations since 1989. The company's flagship product, Blue Mountain Regulatory Asset Manager is a comprehensive browser-based solution that enables the collaboration of maintenance, calibration and validation personnel with asset owners to maintain assets and processes in a controlled and validated state. In his role of Director of Marketing, Bryce keeps up with the latest industry trends, authoring articles and white papers as well as presenting webinars on a broad range of topics. He can be reached at 814-234-2417 ext. 122, marketing@coolblue.com

It Pays To Take Pictures

Seeing ROI With Infrared, Even In A Down Economy

by David Doerhoff

The sluggish economy is taking its toll on many areas of industry. Manufacturers are looking for smart, cost-effective ways to help their facilities operate more efficiently and save money without sacrificing product quality and performance. Infrared (IR) thermography has proven itself to be a valuable tool for predictive maintenance and process monitoring system applications for many industries – even in sub-par economic times.

Infrared thermography is the production of non-contact infrared or heat pictures from which temperature measurements can be made. By detecting anomalies often invisible to the naked eye, thermography allows corrective action to be taken before costly system failures occur. Portable infrared imaging systems scan equipment and structures, then instantly convert the thermal images to visible pictures for quantitative temperature analysis.

Infrared thermography is being used by manufacturers for the predictive maintenance of a wide range of applications, including mechanical systems, electrical systems, and building diagnostics – making it a smart investment for its versatility. Typical mechanical systems monitored in a predictive maintenance infrared program include bearings, motors, pumps, compressors and conveyor idlers. For electrical applications, infrared thermography can detect loose connections, corrosion, and load imbalances.

Manufacturers are seeing favorable ROI with infrared thermography programs as the technology enables them to take corrective action before problems occur – thereby saving money and other resources. Types of savings include: reduced PM inventory because problems are detected early, labor savings by taking immediate corrective action, energy savings – both from making sure that equipment is running optimally and sealing building leaks, decreased downtime, increased production, reduction in waste and scrap parts, quality assurance during the process via real-time process control, and much more. This article provides examples of how IR programs save money, and are justified by their ROI.

Infrared Inspection Economics

During an economic downturn, a knee-jerk reaction in many companies is to cut expenses across the board. When it comes to predictive/preventative maintenance (PPM) activities, the philosophy may be: "We've cut production, so the equipment is being used less and we can cut back on PPM." That's questionable logic in general, but especially in the case of infrared (IR) inspections, where an immediate payback is possible from increased use of the technology. Even if IR inspections haven't been part of a PPM program, investing in an IR camera can provide an almost instantaneous ROI.

PPM is like an insurance policy, and insurance companies aren't known for laying out money needlessly. One of them, CNA Insurance, has made it their business to save their clients (and themselves) a lot of money by making IR inspections an integral part of their services[1]. CNA performs extensive economic analyses of the savings that can be gained from this activity. A few of its 2008 loss/cost savings estimates appear in Table 1 on page 26.

Taking corrective action before outright failures occur saves money in many other ways. These include:

- Reduced inventory of maintenance parts
- Labor cost savings by avoiding serious equipment failures
- Energy savings by optimizing equipment operation, and sealing building leaks
- Savings from decreased downtime (i.e., increased output)
- Reduced waste and scrap parts by improving equipment operation
- Increased quality and/or production through real-time process control
- Safer working conditions (i.e., reduced injuries to maintenance and operating personnel)

Chemical Manufacturing Switch Gear Example

An IR scan of switchgear in a chemical plant spotted a high temperature on the surface of the connection at the A-phase lead of an air compressor circuit (Figure 1, top view,). This temperature was 420.7°F hotter than the maximum temperature of the surrounding area. Using CNA's criteria, the thermographer identified this as a Critical fault. If that fault had resulted in an arc flash event, or even 'just' started a fire that destroyed the switchgear, the facility could have lost 100% of its operations for a

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- Rick, Electric Utility Company

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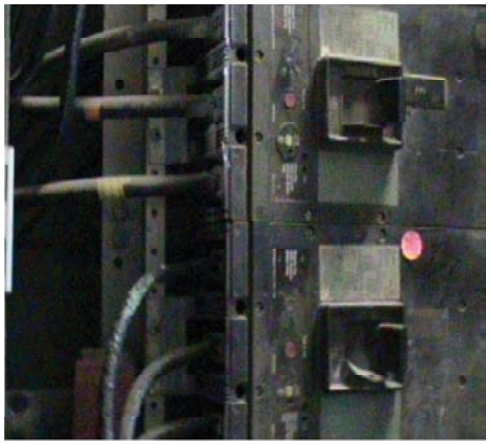

Figure 1 - IR image (top) of air compressor circuit breaker A-phase lead. Visual image (bottom) of same circuit breaker.

week. That was estimated to be worth about $1million, plus tens of thousands of dollars in direct repair costs. Even without such a catastrophic event, the bad connection was costing the company money in excessive energy consumption for every minute of operation.

While on the subject of arc flash, it should be noted that these events quite frequently have catastrophic results. Each year, arc-flash events in the U.S. cause millions of dollars in equipment damage, ghastly injuries, and deaths. When electrical circuits open due to overheating, the fault current that flows across the resulting air gap forms an electric arc plasma (highly ionized gas). This can result in a bright flash, tremendous heat, a high-pressure blast, vaporized metal, and shrapnel traveling at over 700 miles per hour. The strength of the arc depends on the amount of electrical energy available in the circuit that feeds it. It is not uncommon for arc temperature to exceed 35,000°F, and blast pressure to exceed 3000psi.

Low Cost Hydraulic System Fix

Hydraulic systems are another example of equipment that typically heats up to excessive temperatures before failure. This was the case on a transfer line at a diesel engine manufacturer (Figure 2, facing page).

Electricians for the cylinder block line were being called repeatedly to this operation to reset high temperature faults on the hydraulic system. All pressures and flows were found to be within specifications. A predictive maintenance team checked the temperature using an IR camera and found that the power unit was operating near its 117°F fault setting, as shown in Figure 2 (top view).

Further analysis revealed that the hydraulic system was slightly undersized for this particular application. Subsequently, another gage station had been added to the machine, which increased the system load. Whenever the ambient temperature went high enough during the summer, the high temperature faults would occur.

While this is a rather simple situation, the costs of solving the problem can range from cheap to expensive, depending on circumstances. Upsizing a hydraulic system that works fine 10 months of the year is expensive.

Estimated Electrical Cost Savings from Infrared Programs by CNA Insurance

Electrical repair cost savings are estimated at $500 for Minor or Intermediate faults and $3000 for Serious or Critical faults, based on typical industry experience. A fault condition is placed in one of these three categories based on Electrical Power Research Institute (EPRI) guidelines. (See note below.)
Energy savings can be estimated based on a company's own experience and model, or you can use the model developed by CNA. Essentially, energy savings vary by temperature differential and current (amps). A number of sample calculations have shown the following to be reasonable estimates – $1.50/day for Critical faults; $0.75/day for Serious; $0.40/day for Intermediate; and $0.15/day for Minor. CNA updated the cost to $0.15 per KWH to develop the estimates but energy costs may be higher in some areas. CNA uses 250 working days in a year (10 holidays) to estimate annual energy savings for each fault.
Electrical fire risks are reduced by correcting faults discovered during IR surveys. The chance of an electrical fire is estimated at 2% for Critical faults and 1% for Serious faults. We do not calculate or estimate fire losses for Intermediate or Minor faults. Using [Risk = probability times consequences], the monetary risk from electrical fires can be calculated. Insurance loss statistics over 9 years (from mid 1990's) showed "average" electrical fire losses (property damage (PD) and business interruption (BI) included) to be $200K for circuit breakers; $500K for switchgear; and $1 million for MCC rooms. A reasonable "average" electrical fire loss would be about $750K (updated in 2008 using inflation factors and recent CNA loss experience).
CNA uses the "average" electrical loss of $750K, or the specific loss by type (circuit breakers, switchgear, MCC rooms) for every Critical and Serious fault discovered during an IR survey. If the fault is on a specialized piece of equipment (like a transformer), we use specific replacement cost information for the type or piece of equipment.
BI estimates are based on % of operations lost for number of days (divided by 365). The basic electrical fire risk estimates above include both PD and BI loss numbers. CNA focuses on Critical and Serious faults only for specialized equipment. Not every fault will have a BI estimate associated with it. CNA also focuses on key equipment with BI potential for plant or facility operations. Examples are power transformers and boilers. A reasonable minimum BI loss estimate for Critical and Serious faults is a one-day loss of 100% of operations.

Note: EPRI severity criteria are based on a component's temperature rise in °C above a similar component under similar load and environmental conditions, as follows:

Critical >75°C, Serious >35°C – 74.9°C, Intermediate >10.1°C – 34.9°C, Minor >1°C – 10°C

Table 1 - CNA Insurance Estimates of Electrical System Cost Savings from IR Inspection Programs

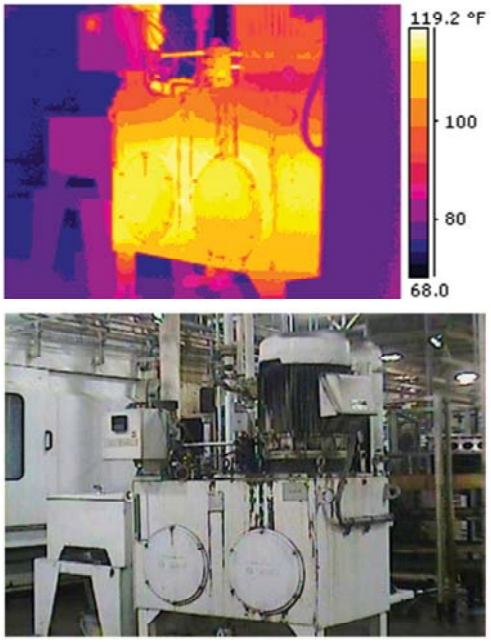

Figure 2 - IR camera thermograph (top) and visual photo (bottom) of an overheated hydraulic power unit reservoir.

So is the purchase of a new chiller unit for the existing system. A trained thermographer on the maintenance team came up with a simple, ingenious, and low cost solution. The thermographer recalled one of the laws of thermodynamics taught in Level I thermography, that is:

Energy In = Energy Out + Energy Stored

The problem was that more energy was stored in the system, indicated by a higher temperature than was desired. So if the energy output rate of the system could be improved, then the temperature would go down. This basically amounted to increasing the heat transfer from the object. One of the easiest and most cost effective ways to do this is by increasing the emissivity of the surface of an object. By simply painting the hydraulic power unit and all its piping flat white, the paint increased emissivity, allowing heat to dissipate better, instead of being trapped inside. For the cost of a few cans of spray paint, the temperature of the system was reduced by about 10°F. This was enough to avoid the expensive alternatives, and provided a nice ROI for their IR camera.

Steam and Condensate Line Troubleshooting

Besides the obvious electrical components, power generation stations have a lot of equipment to worry about. One of these stations in the southwest U.S. started noticing worrisome symptoms on one of its steam turbine generators. The first indication was a decrease in electrical load. The control valves were open more than normal, and there was an increase in steam flow to generate the same load as before the problem was noted. Along with these problems, it became apparent that with the increased flow, all of the turbine pressures had also increased, including the condenser backpressure.

As a first step in troubleshooting the problem, infrared thermography of the crossover piping and two sides of the condenser was taken and analyzed. Figure 3 contains three ther-

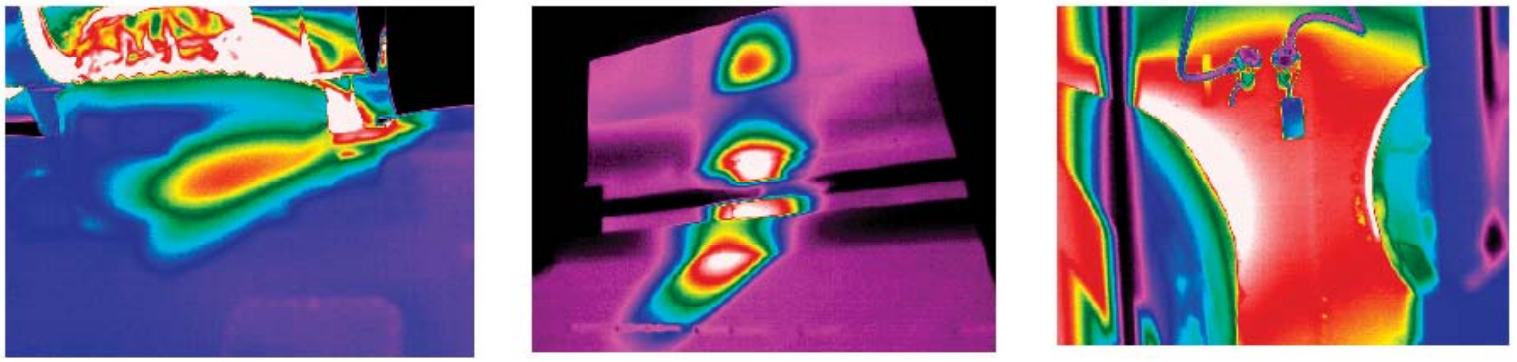

Figure 3 - Abnormal thermal patterns on parts of a steam turbine condenser: cross-over piping (left), condenser west side (middle), and condenser east side (right).

mograms showing abnormal heat patterns on parts of the turbine condenser. All indications, measurements, and IR imagery pointed to a steam breach in the lower region of the low-pressure (LP) turbine. Because this problem could lead to serious damage, the unit was taken out of service for further inspection and repairs.

The problem identified was that an expansion joint from the #3 extraction to a feed water heater had failed in the LP turbine, causing steam to impinge on the condenser walls, neck and adjacent piping. The failed expansion joint threw shrapnel throughout the condenser neck which pockmarked several other pipes and components. The loose pieces of metal and large volume of steam at 500°F, in a vessel that normally operates at 110°F, could have caused a serious event to occur. Shrapnel from the expansion joint could have also lodged in the condenser tube bundle and caused tube failures immediately, or in the future, due to the vibration and constant abrasion of the pieces of metal against the tubes.

Subsequently, all the expansion joints affected by the failure of the #3 extraction joint were replaced in an effort to avert any other failures. Maintenance personnel observed that had infrared imagery been taken when the turbine was originally installed, this would have provided baseline data for subsequent IR scans. Baseline images allow for more expeditious troubleshooting, and helps spot problems before they become more severe.

Thus early intervention minimizes damage to equipment that can cost millions of dollars to replace or repair. An important lesson here is that baseline IR scans are a tremendous enhancement to IR camera ROI.

IR Thermography Complements Mechanical Diagnostics

Many companies just scan their electrical equipment with IR cameras because they have other technologies to test motors and other rotating machinery. However, using IR scans on mechanical components improves IR camera ROI by capitalizing on one of the strengths of thermography. It can quickly detect temperature differences on mechanical equipment via non-destructive, non-contact temperature measurements (Figure 4). Using handheld IR cameras, thermography is a very fast and efficient method to scan many pieces of equipment quickly, searching for thermal anomalies. With baseline scan records, trend analysis of motors and bearings provide early warning of impending problems.

While thermography may not always point to the root cause of a problem, it does let you know one exists. Thus, it complements ultra-

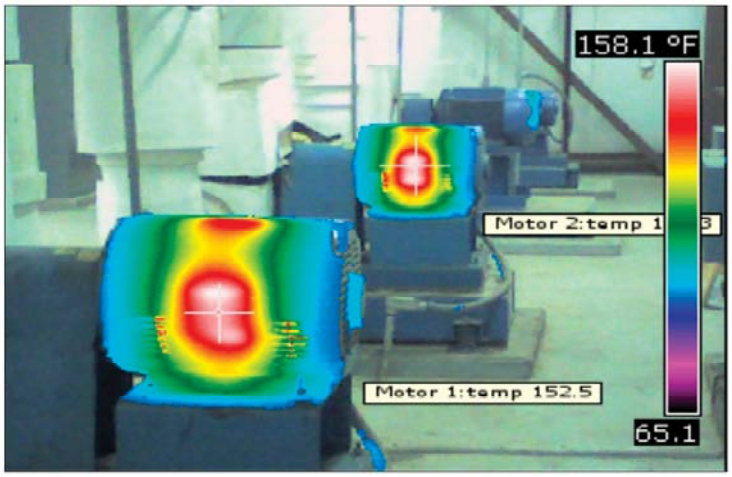

Figure 4 - Heat signatures of overheated motors. A large number of components can be rapidly scanned and their temperatures recorded with handheld IR cameras.

sound, vibration, and electrical circuit analysis tools. These are a potent arsenal in the hands of competent technicians. Intelligent use of these tools has a synergistic effect on the ROI on all of your PPM diagnostic equipment.

Justifying the Cost

If you are not already using IR thermography in your PPM operations, the hardest part about starting a program is justifying the cost of the camera, software and training to do the infrared inspections. Naturally, management wants some idea of the program's ROI. Gathering the data to provide a reasonable estimate can be time consuming, but knowing where to look can help shorten the process. Start by using online searches to look at other companies' business cases that will provide examples.

Internally, use your company's computerized maintenance management system (CMMS), which tracks maintenance inventory, work orders, purchasing, etc. Look for details regarding equipment failures, root causes of the failures, and the cost of the completed repairs. If you're lucky enough to have access to this information, sort all the equipment failures for one year into mechanical and electrical equipment. Just the data on electrical equipment alone can often cost justify a new infrared program.

For instance, total the cost of all the electrical equipment materials. Don't include the labor cost for the repair, but just the equipment replacement cost. Use the lowest equipment replacement cost when there is a range of costs. Leave off the labor cost to replace the failed equipment since this will offset the labor cost to fix (for example, loose or improper electrical connections on the equipment before it fails). This repair-before-failure category generally involves "disassemble, clean, and retighten to manufacturers' specifications", which are relatively inexpensive activities. On average, about two-thirds of electrical equipment failures are due to loose or improper connections that are easily spotted with IR scans. So, multiply the total electrical equipment replacement costs by two-thirds, because you're finding those bad connections before the components burn up. You may want to factor this down a little if you assume that some of those bad connections won't be found.

Now ask the following questions: Is the total cost avoidance enough to justify starting an infrared program? Given this cost avoidance total, will an infrared program pay for itself in 6 months, 1 year, or 2 years? (The ROI question). This calculation is extremely conservative, and most importantly, can be verified by the company's accountant. Remember, this is only a small part of the ROI picture. We have not even considered lost production, downtime, safety or mechanical equipment costs. Even though these other pieces of the ROI puzzle are usually much greater in numbers and totals, they are also less quantifiable, so they are a potential source of disagreement.

If your company does not track equipment failures and replacement costs, or you need additional cost avoidance numbers, look at what preventive maintenance routines your company currently implements. Two preventive maintenance procedures to look closely at are:

1. Tightening all electrical connections once a year (many electrical connection problems are actually caused by this approach).

2. Periodically replacing equipment before it fails, even if it does not have a problem (presumably to avoid unplanned outages).

An IR scan program can eliminate or reduce the cost of these pre-emptive PPM activities. Even if your company runs all equipment to failure, IR scans can provide a "heads up" warning on what equipment has a problem or is about to fail, enabling the company to inventory spare parts for when they're needed.

For established IR programs, be sure to keep a record of cost avoidance and other cost benefits of the program. These should be reported to management at least yearly, preferably ahead of budgeting activities. The savings garnered through the program provide a running tally of its ROI. These numbers are important anytime, but especially so during a business downturn.

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It's As Easy As ABC

Helpful Hints to Increase Reliability Through Lubrication

by Brian Thorp, CLS, MLT II

You always hear about establishing goals, setting ISO code cleanliness, getting some training, setting up an oil analysis program, and all the other things you need to do to have a successful lubrication program. In a perfect world we are set and ready to go. Well, I hate to be the one to tell you, but really there isn't a 'one size fits all' plan out there. So let's have a practical discussion about some of the methods and equipment that can be used to achieve, and then maintain, our vision.

Just what is the right oil type and why? What is the best way to properly store oil, and the preferred distribution methods to get it from storage to the equipment? Are all filters and breathers created equal? What are the advantages and disadvantages of different styles and types of filters and breathers? How about the importance of correct oil levels, both high and low, and just what is the proper level in all these different types of sight glasses? Why do we do oil analysis, what should we test for, what can be gained from the tests and how can you get the most from the information of your tests. Finally, how do you do Condition Based Maintenance based on your oil analysis?

With the ever increasing costs of lubrication products, why not get the most out of them? Do you really need to change that oil every six months? Just because it's been done that way for years, or the OEM manual that hasn't been updated in twenty years says to do it that way, does it really need to be done? Hopefully, the next few pages will provide you with some information about how to get the most bang for your buck, while helping to preserve a valuable resource and reduce disposal and waste. Why not start something that will help reduce your operating costs, while increasing the reliability of your equipment? In a perfect world, this would be an easy task to accomplish. In the real world, there are constant bumps in the road, curve balls, and hiccups to contend with.

Lubricant Types

Well, unfortunately, a lot of people would be content to say that oil is oil. (Hopefully, not anyone who reads this magazine though.) Actually, there are a host of variables to consider when choosing a lubricant. Let's start off by briefly discussing some of the different types of base stocks used for lubricants.

GROUP I – These are your solvent refined mineral based lubricants. People figured out pretty quickly that crude oil from the ground left a lot to be desired if it were to be used as a lubricant for equipment and engines. The solvent refining method removed some of the impurities from the crude which made it better.

GROUP II – This process utilizes hydro-cracking of the molecular structure on mineral oils to remove impurities and other undesirables from the crude oil. Group II base stock has become the main stay for lubricants in today's market.

GROUP III – These are still a mineral oil, but are considered a synthetic due to the severe hydro-cracking and processing the crude oil undergoes. These were deemed a synthetic through a law suit between Mobil and Castrol, in which the courts decided that since the mineral oil was so severely processed, the original molecular structure was no longer anything like its original structure. Therefore, it could be called a synthetic. While these are better than group II oils in most respects, they still lack some qualities of a true synthetic lubricant.

GROUP IV OR SYNTHETIC – Polyalphaolephins (PAO), Organic Esters, Phosphate Esters (Fire Resistant), Polyglycols and Polyolesters are the common types of synthetic oils. PAO's are the most commonly used base stock, while each of the others have very specific applications in which they work best.

Oil is not just oil. In Figure 1, we can clearly see that not all oils are created equal. They have different specific gravities, additive packages, base stocks, and thus, different purposes and uses. The other old adage, "something is better than nothing" is not always true either. Using the wrong oil or mixing incompatible oils can cause as many, if not more, problems than running an incorrect oil level. This difference in oil types clearly demonstrates why there is no 'one size fits all' scenario, and, thus, the importance of specifying the correct oil for a particular piece of equipment.

Finished lubricants consist mainly of a base stock, with some additives to extend the life of the base stock and enhance it for specific applications. Turbine oils generally have the least additives (about one percent); while automotive oils usually contain the highest amounts of additives (around thirty percent). Typical additives consist of: antioxidants, corrosion and rust inhibitors, detergents

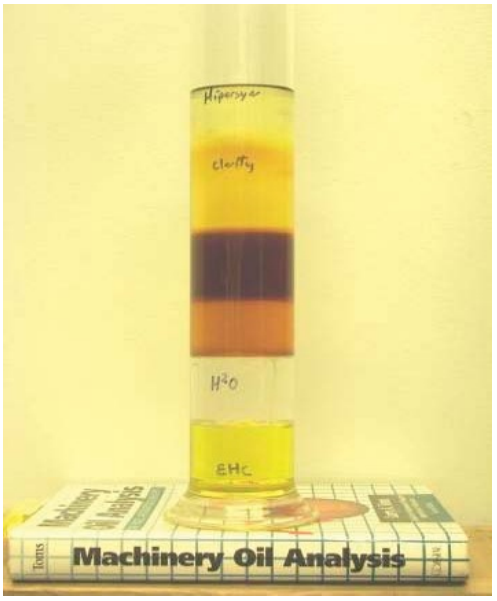

Figure 1 - Oil is not just oil. It comes in many variations, and choosing the right one for each piece of equipment is essential to enhancing reliability.

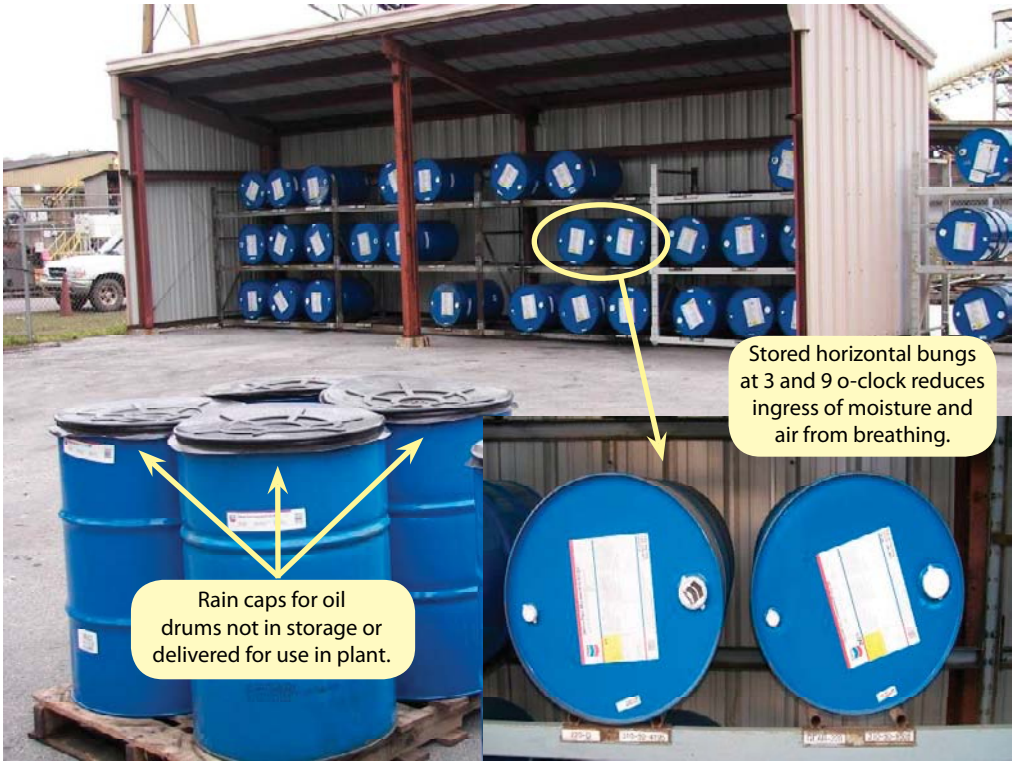

Figure 2 - Easy steps to take that will increase shelf life of lubricants by keeping contaminants at bay.

and dispersants, anti-wear and extreme pressure agents, viscosity index improvers, pour point depressants, defoamers, demulsifiers, and friction modifiers. Each of these additives has a specific purpose in the finished product. They enhance the base stock for a specific application of that lubricant in a piece of equipment. Almost all oils have a rust and oxidation inhibitor at a minimum, to help preserve the base stock.

Now that we know oil is not just oil, and that there are many different types of oils with specific properties for specific applications, let's discuss some of the preferred storage and distribution methods.

Storage and Handling

Oil comes in many different sized containers, from quarts, drums, totes, and bulk tankers. When manufactured, most oil is clean. However during handling, shipping, and storage is where we develop most of our problems. All oil should be tested for acceptance before placing it into your system for use. This is especially true with bulk shipments, as you can't always be assured what was in the tanker before your load of oil. Drums and smaller containers are not as critical to be tested before use, but random testing should be performed to have a baseline for comparison with your in-use products. Lubricant formulators will change additive packages in products without notice, which can leave you wondering about a possible problem seen in your oil analysis that might only be a formulation change in the product.

Bulk storage tanks need to have breathers and secured hatches to reduce ingress of moisture and debris. If it is a large volume of oil located outside, a dry air head space or nitrogen blanket might be helpful to keep the water levels down in your new oil. Totes should be stored out of the weather if possible, or at least under a roof with all openings closed and a desiccant type breather installed rather than a loose plug or fitting to allow air to come in as the product is drawn out.

With drums, they should be stored inside if possible, even though this usually isn't done. The preferred method of storing a drum is on its side (horizontal) with the bungs located at the three and nine o-clock position. Figure 2 illustrates this method of storage. This method reduces the amount of ingress through the bungs as the drum breaths due to temperature changes. If a drum is left standing, this allows not only air but any water that might be on top of the drum to be pulled into the drum, through the bungs, as it cools. Occasionally, a bung might leak slightly when stored on its side, so you pull the seal and tighten it to stop the leak. Even if a drum is stored inside, the preferred method is still on its side if it will be stored for any length of time. This reduces the amount of air exchange that will accelerate the oxidation of the lubricant. If you can't store drums on their side, then preferably they should have rain caps on them or be tilted so bungs are not located to the bottom of the tilt. This will allow any water to run off the drum top without the chance of it being sucked through the bung into the drum as temperature changes. Also, since we never know when it might rain, when the drums are sent out for use, rain caps are a good idea.

For small volumes of oil, there are several products to get the oil from the storage area to the equipment. (See Figure 3, next page for some examples.) Safety cans have been around for a long time and provide a positive closing lid or cap, but usually require a funnel to get the product into the equipment. The newer versions have larger openings, positive closures, pump versions, long and short spouts, flexible spouts, and labeling systems. One draw back is they are only available up to two gallons in size. Of this newer style, Oil Safe products were first on the market, with others following such as the I-can and Lube Rite.

Funnels are great tools and a necessity to get a product to the specified place. Unless they were properly stored in a plastic bag, steel or plastic funnels usually sit around waiting to be used, doing what they do best, collecting

dust and dirt. There are disposable paper and cardboard funnels available from various manufacturers that eliminate the storage and cleaning issue of hard funnels.

Figure 3 - Safety cans (bottom) and iCan are two of many products used to store oil.

Since most stored and handled lubricants are not up to equipment target ISO code specifications, we need to filter them before installing them. There are many different types of filter carts and filter systems to accomplish this task. Figure 4 shows a lube oil room setup with air pumps and filters in line with the metering heads.
The oil can be transferred from the drum into smaller containers for top ups and smaller quantity needs. For larger volume needs, filter carts or drum filter carts can be used to pump the product from the drum or tote into the equipment. It is much easier and less expensive to clean the new oil as it is installed, rather than try to clean it once it is in the equipment.

Filtration and Breathers

The main function of a filter is to remove ingressed or generated debris from a lubrication system. Very careful consideration should go into the original selection of a filter for a piece of equipment; based on micron size, BETA rating, flow rate, and operating pressure, just to list a few. A lot of newer equipment is coming equipped with side stream or kidney loop filtration rather than full flow filters. They provide valuable benefits with smaller micron sizes and, thus, better filtration, without the worry of flow restrictions. There are many aftermarket filters available on the market today. Always consult a reputable source if changing from an

Figure 4. Lube oil room with air pumps and in-line filters for metering heads.

OEM filter or filtration system to assure you are getting an equivalent filter. Don't leave it to the purchasing department to go with the cheapest element available, as this could cause serious detrimental effects to the equipment.

Filter carts can provide excellent filtration without disrupting the operating system. These too, must be properly chosen for the fluid viscosity, flow rate, and micron rating. Otherwise the filter will just be running in bypass, and not really

accomplishing much. Most filter carts are designed for lower viscosity fluids (i.e. hydraulic oils). There are a few on the market that are designed to handle high viscosity fluids (i.e. gear lubes). These generally have a lower flow rate and larger or more filters to increase the surface area to reduce flow restriction. So, when choosing a filter cart, be sure to explain what you will be filtering so you can get the proper unit for your needs.

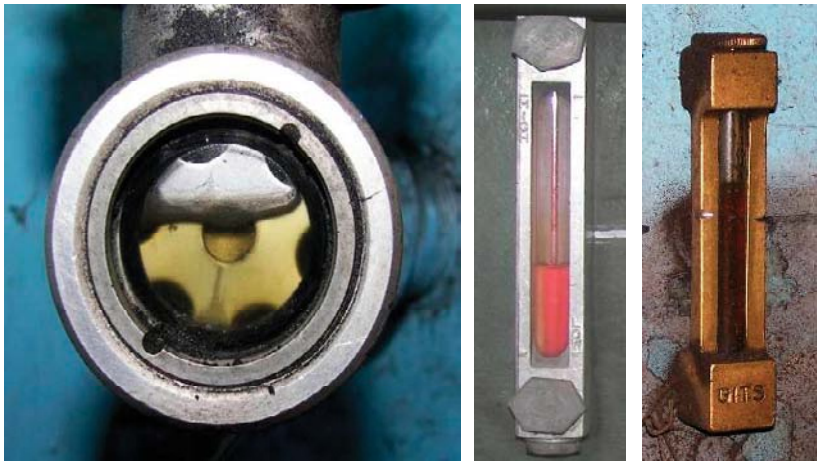

Figure 5 - There is a wide variety of sightglasses available. Bullseye (left), tube type (middle) and bolt on tank type (right) are just a few.

Breathers play an essential part in helping to reduce ingress into reservoirs. Older systems merely had snorkel pipes or screen mesh caps that worked fine to keep large particles and bugs out of the fluid. Modern breathers are rated for two to three micron particulates and usually have some form of moisture removal. There are still several OEM fill caps and breathers that only utilize a fiber mesh to catch the larger stuff. (Although, sometimes this is because of the air exchange rate required for the reservoir.)

As with filters, if you choose to upgrade to a better breather type, do your homework first to establish the air exchange rate in the reservoir or damage and system malfunctions can occur. On an average, a disposable desiccant type breather can handle about 15 CFM. By using a manifold, these breathers can be grouped together to handle higher air flows. There are also either larger metal-type breathers that have replaceable desiccant, or breathers with regenerative moisture removal crystals that can handle much higher air flows (up to 45 CFM), that can be used.

Sight Glasses and Correct Oil Levels

There are many types of sight glasses. Figure 5 shows three, from the round bulls-eye (left), tube type (middle) and bolt on tank type (right). The main purpose of these is to allow a quick easy check on fluid level in a reservoir. They can also provide a window into the condition of the fluid by observing the color of the fluid in the glass.

In a bulls-eye type glass, the half to three quarters level is considered the correct level. In most oiled electric motors, the slinger ring, which carries the oil from the reservoir to the top of the shaft for bearing lubrication, is usually less than one inch below the bottom of the sight glass; so, this doesn't leave much room for error for a low level. A high oil level can allow the shaft to churn the oil causing aeration which can reduce the correct oil film between the shaft and bearing. A high oil level can also create leaks which can get into the motor windings and cause extensive problems.

On a stick or tube type sight glass, the middle third is considered the correct level. These are sometimes used on gear reducers to replace an oil level plug for ease of checking the level. When this is done, the sight glass must be installed below the level plug so the correct oil level is represented in the sight glass. If the sight glass is placed in the oil level plug hole, this will cause the gear reducer to be overfilled causing loss of efficiency, aeration, leaks, and excessive heat generation.

The bolt on tank type of sight glass is generally used for reservoirs. These usually have a generic high and low mark on them which might be incorrect for the proper level. In one case of an aeration problem, it was found that when the oil level was in the middle of the sight glass, the fluid was less than a half inch above the suction strainer, thus the cause of aeration. The correct level was marked on the tank beside the sight glass and problem solved.

There are several constant level lubricators, of which the Trico Optimatic (Figure 6) and Watchdog oilers are probably the most common types. The Optimatic does not have a sight glass as such, but as long as it has oil in the bulb there should be oil in the equipment. One of the more critical parts of the Optimatic is the adjustment assembly, which supports the oil bulb. Care must be taken to set this adjustment assembly properly as this establishes the oil level in the equipment. If this adjustment assembly is left out or incorrectly set, this will cause an incorrect level to the bearing, which can cause failure.

The Watchdog oiler installs in the bulls-eye type sight glass location. These require no adjustment since they work off an angle tube, which establishes the oil level in the center of the sight glass. These need to be correctly sized and not used with a reducer bushing which can cause a false level indication.

Oil Analysis Sampling

Oil analysis not only monitors the health or condition of the oil, it also monitors machine wear and contamination levels. The sampling process is probably one of the most important parts of a good oil analysis program. If you don't get a true representative sample of the lubricant from an in-service piece of equipment, you are limiting your available data. One of the best samples is a live sample from a supply line upstream of the filter, located in a turbulent area of the piping (Figure 7). This can be accomplished with the use of a sample fitting, a number of which are available from several companies such as; Donaldson, Trico, Minimess, and Checkfluid to mention a few.

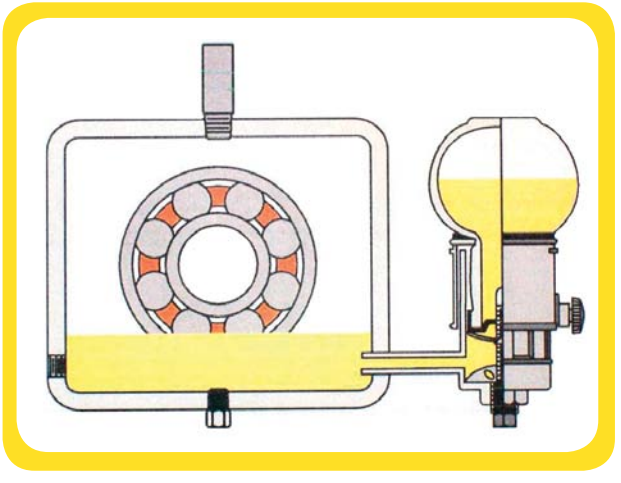

Figure 6 - The Trico Optimatic is a popular constant level lubricator.
(Image courtesy of Trico literature.)

These can be used in static as well as pressurized locations. Once again, do your home work to be sure you get a properly suited fitting for the viscosity and pressure of the system. A lot of new equipment is coming equipped with sample fittings, or if you have any input into specifying new equipment, request a sample fitting in the spec.

Where a pressurized sample is not available, sample fittings are still a preferred method for a consistent sample point. These can be obtained with a drop tube, through a reservoir wall or level check plugs (Figure 8). An additional item you will need for static sampling is a vacuum pump to withdraw or suck the oil into the sample bottle. Never get a sample from a drain line (unless you want a bottom sample to see what type of sediment you have), as these are not truly representative of the fluid in circulation. Sample fittings are also a significant time saver in the sampling process, reducing route time by half or more on average. They can also be labeled with the equipment ID or sample information to avoid confusion during the collection process.

Figure 7 - A good location for a sample fitting to gather oil for testing.

Figure 8 - A drop tube, through a reservoir wall or level check plugs allow for good representative samples.

Sensory and In-House Oil Analysis

Now that we have a good representative sample what do we do with it? Some larger facilities have the luxury of having an on-site oil lab to do the analysis. There are some self contained mini labs that test for specific things in the oil such as; viscosity, dielectric strength, and particle counts. These can provide a good idea of lubricant and machine condition. And, of course, there are off-site professional oil analysis laboratories that can perform many specific tests for lubricants.

The first line of defense is sensory analysis; color, look, and smell, go a long way during the collection process. This is where training and a well trained, dedicated person are invaluable. Many problems with the oil or the equipment can be spotted before the sample is ever formally analyzed. Even with sensory analysis the samples should be sent to the lab for formal analysis for data and trending purposes. A good example of sensory analysis that wouldn't be caught by the lab would be air entrainment. This would be obvious in the sample when it was collected. However, the air would release before the lab ever got the sample. The lab may report an increase in oxidation, but this would be minimal compared to the visible air in the sample at time of collection. If you don't have the option of an on-site lab, there are a few tests that are inexpensive, easy to do, and provide invaluable immediate information that can save a costly repair.

Water can be very damaging to most equipment. A well trained technician can usually spot water with sensory analysis; however the crackle test (Figure 9) is an inexpensive way to provide a definite answer. The test utilizes a hot plate heated to 300°F, and generally provides positive results for water above 1,000 ppm. Put a few drops of oil on the hot plate, and if it splatters and bubbles, you most likely are above 1,000 ppm water. If it looks like a volcano erupting you have some serious problems. This can also be done with a spoon or piece of tin foil and a lighter; anything to boil the water out of the oil. There are also several commercial test instruments available for use in the field that can provide exact data or just a positive for water results.

A patch test kit (Figure 10) allows you to pull a sample of oil through a selection of membrane filter patches, which have different ratings from 0.5 microns to 5 microns for general use. While these can be used for quantitative particle counts, I find them more useful for debris analysis. There are many charts that provide information on what different particles of metal, dirt, silica, etc look like when magnified for you to compare to; as well as comparative patches for ISO code reference. When doing debris analysis it is very helpful to know what type of metals the equipment is made of, and what type of airborne particles might be ingressed.

Since viscosity is considered the most important property of a lubricant, an instrument to measure viscosity is a must have. There are many of these available from sophisticated to

Figure 9 - A hot plate for water crackle test.

Figure 10 - A patch test kit.

Figure 11 - A visgage for testing viscosity.

the simplistic visgage (Figure 11).

There is one last simple in house test that will make you wonder about its use. It involves a blender and a stop watch. Now don't laugh, it's a good test. With the simple version of this test you are doing a comparison between new oil and the in-service oil in question. The blender can be used for air release and demulsibility testing for quick results.

As with any in house test, repeatability is your safeguard to good results and a sample should still be sent to the lab for formal testing.

Oil Analysis Laboratory Tests

There are many different tests available for formal oil analysis. Several of these should be performed for all samples such as viscosity, spectral, water, FTIR (Fourier Transform Infrared Spectroscopy), and particle count. Other tests, such as acid number (AN) and base number (BN), are performed depending on the equipment. Tests that are usually completed on an as needed basis are analytical ferrography, demulsability, air release, RVPOT (rotating vessel pressure oxidation test) and some newly designed tests for varnish potential such as the Ruler and the MPC (still under development by the ASTM D02.C committee). Below we will discuss briefly the above listed tests.

Viscosity: A measure of oils resistance to flow

Spectrographic Analysis: A comprehensive lube oil analysis which measures elemental concentrations in the sample such as, wear metals, additives, and contaminants. Common methods are; Atomic Emission, Atomic Absorption, X-ray Fluorescence.

Water Content: Determines the percent of water content.

FTIR: Determines by infrared light absorption the amount of soot, sulfates, oxidation, nitro-oxidation, glycol, fuel, and water present in the sample.

Particle Count: The number of particles per milliliter of fluid normally stated in ppm and reported in a ISO code of $>4\,\mu$m, $>6\,\mu$m, and $>14\,\mu$m

Acid Number (AN): Determines the level of acidity.

Base Numbers (BN): Determines the oil's acid resistance.

Analytical Ferrography: A microscopic inspection of the size, shape, and origin of the wear metal and contaminant particles for oil and grease.

Demulsability: The ability of oil to separate from water.

Air Release: The ability for entrained air to release from oil.

RPVOT: Determines the useful life of the anti-oxidant in the lubricant. New oil minutes versus used oil minutes.

RULER: Plots aromatic amines and hindered phenol antioxidants against a new oil or base line reference sample to determine a relative concentration. Used to determine useful life left in a lubricant.

MPC: Measures the amount of soft contaminants in a lubricant. This is performed by a color comparison of membrane patches. (This test is still under development by the ASTM D02.C committee) A method for determining varnish potential in a lubricant.

There are numerous other tests available to identify specific problems you may be experiencing. These tests can either be looked up by ASTM method listing, or discuss them with your lab to decide which is the right one to use.

Condition Based Maintenance

The goal of CBM (condition based maintenance) is to fully utilize the information from your oil analysis and other predictive maintenance technologies. When properly performed, it can be viewed as both proactive and reactive. It is proactive when the routine data is used to defer normally scheduled PM's for equipment maintenance or a lubrication change, based on the fact that everything is OK and doesn't need any work at that time. It becomes reactive when the routine data indicates an upcoming problem, but this data allows you to schedule the maintenance for a time of least economic impact or avoid a catastrophic failure.

There are many advantages to the use of CBM such as, cost savings, deferring normally scheduled or frequency based service, reducing the human intervention factor on good running equipment, a reduction on our natural resources, and disposal problems and their associated costs. There are very few things today that can save the kind of money that a properly utilized CBM program can. Just on deferred oil changes alone for the equipment monitored at our plant we save over $150,000 per year. This figure is based on seven times the cost of new oil per gallon to include the associated costs of receiving, handling, changing and disposal. If you could easily track the other costs not incurred by doing almost nothing, that figure would be significantly more.

Conclusion

Hopefully through this rapid overview of the many topics discussed, you have learned some of the many opportunities available from a properly managed lubrication program. Over the past few years the importance of lubrication has taken the main stage instead of the minor role it once played as 'just a disposable commodity'. There are many resources available to help guide you along your journey to not only a successful lubrication program, but the financial rewards, and increased equipment reliability that can come from it.

So what are you waiting for, start your reliability journey through lubrication today.

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Brian Thorp has been involved with mechanics and maintenance for over 30 years. His range of knowledge includes automobiles, trucks, heavy equipment, and power plants. In his earlier years, he received extensive training in engines, transmissions, gear trains, hydraulics and pneumatics. His current position is as a Predictive Maintenance Technician with Seminole Electric Cooperative Inc, where he is responsible for the lubrication and analysis for a combined total 1300 MW coal fired power generation plant. His current certifications include, CLS, MLT II, Level I Infrared Thermographer, Level I Vibration Analyst, Level I Certified Airborne Ultrasound Inspector and he previously attained STLE, OMA I. He has also attended numerous seminars on root cause failure analysis, failure analysis and laser alignment. He has made several presentations, and authored several articles, related to lubrication, predictive maintenance, and reliability issues.

The Anatomy of a PdM Program

A Business-Based Approach to Developing an Effective Program

by Krzysztof (Kris) Goly

Over the last decade, there has been a general consensus throughout the industry that modern maintenance and plant asset management require the implementation of predictive maintenance techniques. In most instances, predictive technologies are implemented in the form of a Predictive Maintenance (PdM) Program. PdM programs are designed and implemented through various approaches. This article presents a business-based approach that has been utilized successfully by Siemens throughout the world and across various industries.

The idea behind the business-based maintenance approach is that every PdM Program, as well as all the functions of a maintenance organization, must support business goals, work within business-specific parameters and undergo a continuous improvement process.

Predictive Maintenance Program - What is It?

During discussions or while reading technical magazines and papers, we often encounter the term "Predictive Maintenance Program". What exactly does it mean? If we asked a number of people, we would probably receive several different answers. We define a Predictive Maintenance Program as follows:

A Predictive Maintenance Program is the routine and cost-effective measurement of a number of parameters indicative of machine and equipment condition, which are trended over time, correlated and used to make decisions about the type and timing of maintenance corrective actions within economical parameters of the business.

In addition, Predictive Maintenance Programs provide historical data for root cause analysis. Let's analyze the definition and explore its implications.

Routine Measurement and Data Trending

The goal of any Predictive Maintenance Program is to assess machine condition and predict any impending failure. This requires data to be collected on a regular basis and results trended. Any deviation from the usual state indicates deterioration of the system. Frequency of data collection is a function of the equipment failure modes, equipment criticality and business parameters.

There are a number of mistakes commonly made in the frequency of data collection including: collecting data too often, collecting data too infrequently, incorrect intervals and rigid, fixed frequency of data collection.

Over collecting, or collecting data too often, is expensive. Time and resources are wasted by collecting data that does not carry useful information. The frequency of data collection, in this case, cannot be justified by equipment failure mode or economics.

Similarly, collecting data at long-time intervals carries the risk of "missing" faults. This may prove costly for the business, as well as the reputation of the PdM Program. There is nothing worse than having a major failure during peak business time. Lost production, lost profit opportunities, and, perhaps, environmental and safety issues are all examples of "missed" calls. These are usually much more costly than the cost of data collection.

Ideally, the frequency of data collection should be adjustable. It should change during the course of equipment lifetime. For example, a baseline reading should be recorded after installation. This provides a good starting point for trending later on and, more importantly, serves as a quality tool, ensuring that the installed equipment does not have inherent faults and repairs have been performed according to the specifications.

After the "infancy" stage, the frequency of data collection can be extended. However, this again is a business decision, as not all equipment conforms to the theoretical bathtub curve due to many real-life process and maintenance variables. Extending data collection intervals may lead to missing impending and costly failures. A ratio of success rate to cost of data collection/analysis should always be considered. A good PdM Program will be one that collects enough data for trending and analysis purposes and is still cost effective.

Number of parameters indicative of machine condition
There are many predictive maintenance technologies available. Vibration monitoring, tribology (oil analysis), infrared thermography, ultrasonic monitoring (both contact and airborne) and motor circuit testing are the most commonly employed technologies.

Less frequently used (and often not regarded as predictive maintenance tools) are electrical, process and

performance measurements. This is unfortunate because these technologies have the potential to provide a wide range of information about equipment, machinery health and condition and, thus, assist greatly in predicting failures.

Which technologies to employ depends on two factors – failure mode and economics. Modern predictive maintenance technologies, in correlation with process measurements and other test results, can detect almost any possible impending failure. However, the challenge is to use the most cost-effective ones and to monitor only the minimum number of parameters that will still achieve the goal of detecting failures.

Make decisions about the type and timing of maintenance actions within the economical parameters of the business.

Once we have data from all the predictive maintenance technologies and have correlated the data, we may find there is a fault. If the machine is going to fail, our recommendation as predictive maintenance specialists is to shut it down immediately and replace the damaged part. Now these questions arise: Have we considered the economic aspects of the machine going out of production? Have we considered the economics of the business? Have we considered the possible loss of profit? Is the machine really going to fail? What if the business parameters are calling for an extension of the production cycle due to unexpected additional orders?

The flow chart in Figure 1 shows the business-based approach developed and adopted by Siemens. The significance of the model presented is the decision-making process for the type and timing of maintenance actions. The model introduces business parameters, which influence the final decision.

Typical Program Startup Process

There are a number of steps that need to be considered during the startup of a Predictive Maintenance Program. Most of the tasks, however, can be divided into two groups – program design and program implementation. Each of the phases is unique and requires careful planning and execution for success.

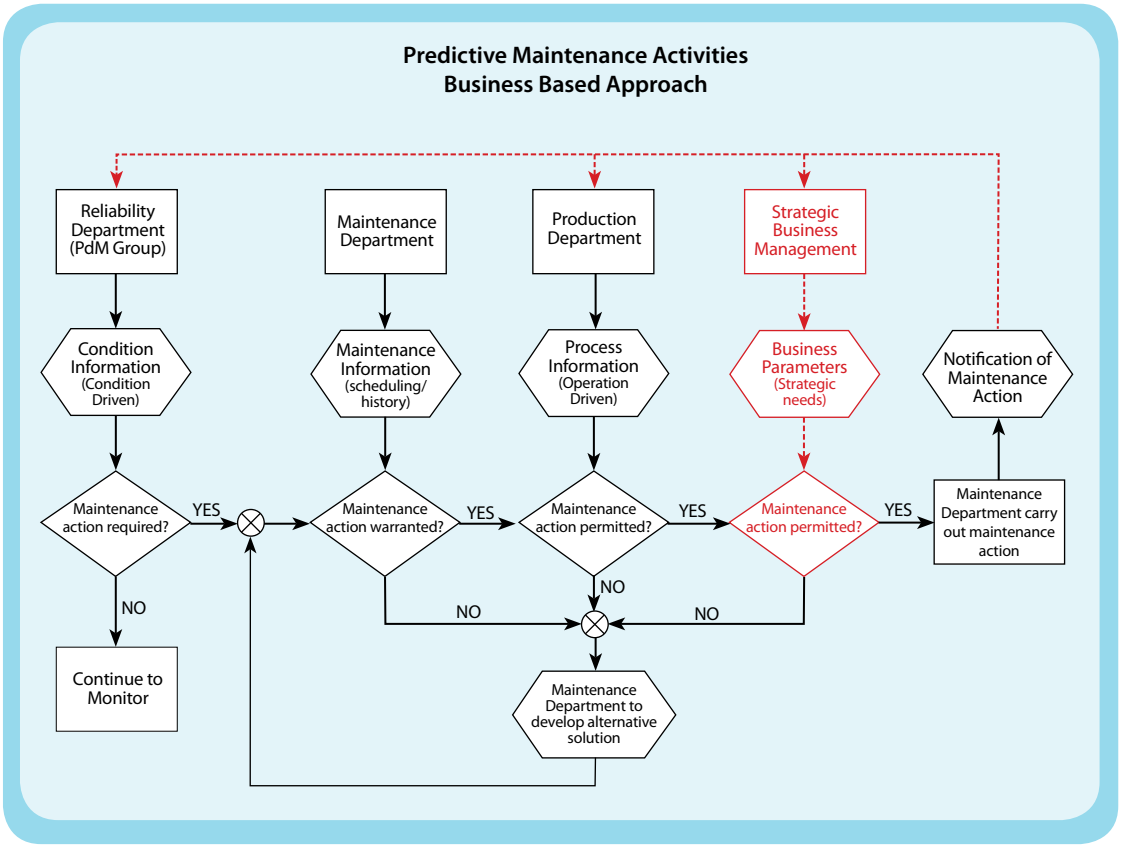

Figure 1 - Predictive maintenance decision-making process, business-based approach.

Program Design

A good PdM Program should be a result of the maintenance strategy development process. In instances where maintenance strategy has not been developed, a simplified process of designing a PdM Program can be employed. Such a process is described below.

Develop a List of Plant Equipment – In most cases, the list already exists and can be obtained from maintenance departments, operations, etc. It is important to review the list for completeness. This task will most likely require walking through the plant and physically checking each item. Experienced employees with good knowledge of the plant usually provide invaluable help.

Assign criticality of the equipment – There are many factors influencing criticality of the equipment. In many cases, the process will consume plenty of time and resources. For the purpose of designing a PdM Program, a simplified approach should be used. One of the best starting points is to use a single line diagram of the process and input from experienced maintenance and operations personnel. This way, assigning criticality to the equipment can be accomplished quickly and cost-effectively.

Identify equipment suitable for monitoring – So far we have developed an equipment list and assigned criticality. The next step is to select the equipment suitable for monitoring. This decision is based on equipment criticality and failure mode. There is little to be gained by monitoring equipment of low criticality or equipment whose failure modes prevent prediction of a failure (equipment with random failure distribution function).

Select cost-effective predictive maintenance technologies – There are many predictive maintenance technologies available to maintenance practitioners. When properly used, they can provide invaluable information about the condition of the monitored equipment, and many of them are capable of monitoring for different types of faults. In addition, many types of faults can be monitored by the same predictive maintenance technology. The challenge is to select a cost-effective technology that is most suited for a particular type of

equipment. The number of technologies used should be limited based on return-on-investment calculations.

Assign data collection/monitoring frequencies – Monitoring frequencies depend on technologies assigned and on failure modes. The optimum frequency is capable of detecting impending failures early enough to allow for effective maintenance action planning while remaining cost-effective. The monitoring frequency should be adjustable, i.e., it should be changed based on equipment condition, technologies applied, criticality, failure modes, p-f function, etc..

In-House Cost		Outsourcing Cost	
Software Purchase	$	Database Setup	$
Test Equipment Purchase	$	Monitoring Points Preparation	$
Software and Test Equipment Maintenance/Upgrade	$	Collection of Baseline Readings	$
Personnel Training	$	Develop Reporting Procedures	$
Personnel Wages	$	Ongoing Services Cost	$
Database Setup	$		
Monitoring Points Preparation	$		
Collection of Baseline Readings	$		
Development of Work Instructions	$		
Development of Reporting Procedures	$		
Personnel Attrition Cost	$		
TOTAL COST	**$**	**TOTAL COST**	**$**

Table 1 - Tangible Costs of Starting a PdM Program.

Develop standard procedures and work instructions (documentation of the PdM Program) – One of the least understood and most neglected aspects of PdM Programs is documentation. It is often perceived as a waste of time and resources, so documentation is never developed. Well documented, structured PdM Programs provide consistent results. All PdM activities are documented and historical data is available for statistical analysis and program effectiveness. We will discuss this further in "Continuous Improvement Process".

Program Implementation

We have now designed a PdM Program, or more precisely, developed requirements for equipment condition monitoring including the technologies and frequency of monitoring. The next step is implementation. Even though the design stage is important, the implementation is what makes any predictive program a success or a failure.

There are basically two ways of implementing a Predictive Maintenance Program – outsource all or some of the services or do it in-house. Both ways have advantages and disadvantages, but cost-effectiveness should be thoroughly examined.

The following are the cost elements, which need to be considered when deciding on the program startup and implementation:

a. Purchase of predictive maintenance equipment and software
b. Upgrading and calibrating software and test equipment
c. Personnel training
d. Personnel cost
e. Predictive maintenance database setup

Score	Management and Organization	Technologies	Documentation
5	There is a well defined PdM function. All personnel are aware of importance of PdM.	Predictive maintenance technologies form an optimal, fully correlated mix for the type of industry. Process data is integrated into PdM data.	Fully operational documentation system is in place. Results are documented and accepted.
4	Responsibility for PdM tasks form an integral part of the maintenance function.	Predictive maintenance technologies are applied based on effectiveness. The results from various technologies are fully correlated.	PdM documentation exists and is updated. Results are documented but not yet accepted.
3	Responsibility for PdM tasks are spread out and not clearly defined.	Most of the applied predictive maintenance technologies are based on effectiveness. Most of the results from various technologies are correlated.	PdM documentation exists for the most critical part ff the PdM program. Some results are documented.
2	Organization is aware of PdM. PdM function and responsibilities are not defined.	Predictive maintenance technologies are applied according to vendors advice. There is little correlation between various technologies.	Some documentation exists. No results are documented.
1	There is little awareness of PdM.	Predictive maintenance technologies are used without a rationale.	There is little or no documentation.

Table 2 - Predictive Maintenance Audit summary results.

f. Selection and preparation of monitoring points
g. Collection of baseline readings
h. Establishing preliminary alarm levels
i. Development of work instructions/ procedures
j. Development of reporting procedures
k. Ongoing cost
l. Personnel replacement cost
m. Availability of suitable personnel

Considerable cost is likely to be incurred with elements a, b, c and d. More importantly, there are the ongoing costs. Table 1 is a template to establish tangible costs associated with a PdM Program startup. It has been developed to help in the decision-making process.

In addition to the tangible costs contained in Table 1, there also are intangible costs that should be considered. These include:

- Response time
- Program ownership
- Geographical location
- Corporate culture
- Demography

Continuous Improvement Process

Every Predictive Maintenance Program is designed based on certain assumptions. They are the result of knowledge and past experience with similar equipment and the current state of predictive maintenance technologies. Equally important, and yet often neglected, are the business parameters, which should also be considered.

As all parameters are constantly changing, it is important that the PdM Program changes as well. To accomplish change, a continuous improvement process must be employed.

A continuous improvement process can be achieved by periodically reviewing and auditing the PdM Program. This process should be governed by written procedures. A Predictive Maintenance Program audit can provide the necessary tool. It is important that the result of the audit is trendable and repeatable, so improvement can be measured over time.

There are a number of areas that should be reviewed. These include:

Program Management – Having a clear management commitment and organizational structure in place is key. Management with clear vision will drive Predictive Maintenance Programs and ensure their success.

Predictive Maintenance Technologies – The Predictive Maintenance Program is designed based on current available technology. As time progresses, new and improved technologies become available on the market. Therefore, it is important to periodically review the technologies for their effectiveness. Consideration should be given to incorporating any new technology available on the market into the program. A correct mix of technologies, correlated with results, is usually the most effective predictive maintenance solution.

Documentation – Each Predictive Maintenance Program should be designed as a process. Hence, every step should be documented. Accurately written work instructions and procedures ensure that the results are not influenced by individuals, and are repeatable. All reports, failure analysis findings and potential savings should be well documented, and documents should be stored for future reference. This will allow an effective continuous process.

A predictive maintenance audit should be conducted on an annual basis, and its finding should form the basis for a continuos improvement program. Table 2 shows results of a typical Predictive Maintenance Program audit. The shaded area represents the actual score.

Summary

Predictive Maintenance Programs have gained widespread acceptance throughout the industry. However, there are still a lot of misconceptions and misunderstandings about predictive maintenance, and its role in the cost-effective asset management process. The described business-based approach to predictive maintenance allows for a seamless integration of the technology into the business process, and close and continuous alignment of the PdM Program with business goals. Furthermore, predictive maintenance specialists need to learn the business language to "sell" the results to the management, which will ensure the future of the program and benefit the plant.

Krzysztof (Kris) Goly has more than 25 years of experience in the field of maintenance and reliability. His experience includes positions as maintenance and engineering manager, reliability manager and, currently, principal consultant for Siemens Industrial Services based in Alpharetta, Ga. Goly is a Certified Maintenance and Reliability Professional. He can be contacted at kris.goly@siemens.com

The Big Opportunity for Savings

Motor Management Programs and an Auto Industry Success Story

by Howard W Penrose, Ph.D., CMRP and Robert Varcoe

A variety of concepts related to the term 'motor management' have been presented within industry since the 1990s. Many of these programs are actually 'energy-efficient electric motor retrofit or repair versus replace' ideas which make up only a small portion of the overall opportunities when properly managing electric motor systems. Such things as preventive maintenance, condition-based maintenance, and other motor-system opportunities are left out of programs that have very narrow views of the overall system. While it is important to view energy and environment when making motor decisions, it is more important to the success of a company to focus on the reliability, life-cycle, and business-related considerations.

In the 2003 "Electrical Motor Diagnostics and Motor Health Study," produced by SUCCESS by DESIGN and ReliabilityWeb.com, a survey of motor decision makers found that only 3% of those considered energy as part of their motor programs, while over 70% considered reliability as the first consideration (Figure 1). Even in the present energy environment, while statements are made related to efficiency improvement, if a plant is in a reactive failure condition, the first consideration is getting equipment back online and production running. With over 60% of companies operating their Reliability and Maintenance (R&M) organizations in a reactive mode, energy policies related to manufacturing and support equipment become secondary. Therefore, in order to develop a healthy motor system maintenance and management program, and to improve energy consumption, a robust R&M program must be in place.

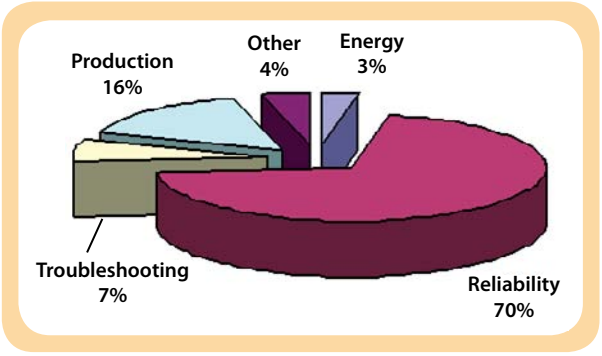

Figure 1 - Survey of Motor Decision Considerations

The impact of a full motor-system maintenance and management program, or Reliability-Centered Motor Management (RCMM) program, is multi-fold. In the United States alone, approximately $1.2 Trillion is invested in maintenance programs with up to $750 Billion of that amount the direct result of poor R&M practices. An additional $2.5 Trillion in potential business opportunity is lost, per year, as a direct result of poor R&M practices, or 20% of the USA's annual GDP. A majority of the systems that fall under this issue are plant motor systems.[1] Energy efficiency in electric motor systems also presents a significant opportunity. In a US Department of Energy report provided by Xenergy, "In 1994, electric motor-driven systems used in industrial processes consumed 679 billion kWh – 23% of all electricity sold in the United States… Implementation of all well-established motor system energy efficiency measures and practices that meet reasonable investment criteria will yield annual energy savings of 75 to 122 billion kWh, with a value of $3.6 to $5.8 Billion…"[2] and the reduction of 74 mega-tons in greenhouse gas emissions. "Drivepower users and utilities have made significant investments in recent years to improve the efficiency of motor-driven systems. The longevity of these measures – as well as the amount of energy they save – depends heavily on the quality of the maintenance they receive. Although it is usual to think of motor system maintenance as an activity that follows other drivepower decisions, it is actually the first step for most facilities moving towards more efficient motor systems…The efficiencies of mechanical equipment, in general, can be increased typically 10 to 15 percent by proper maintenance."[3]

To understand the scope, the motor system must be defined:

1. Incoming Power: the power supply, power quality, distribution system, and other components related to supplying power to the motor controls. Depending on how the plant interacts with the power utility, this part of the system may also be a component of overall rotating machine reliability;
2. Controls: whether these controls are starters, control circuits, variable frequency drives, etc., this component involves any part of the system that controls the operation of the electric motor system;
3. Motor: the converter of electrical energy to mechanical torque;
4. Coupling: connects the motor to the driven load. The coupling may be direct, belted, geared, or other;
5. Load: is the component of the system that the motor drives such as a fan, pump, conveyor, compressor, etc.; and,

6. Process: the overall process with which the motor system is associated.

In this article we will discuss both the development of an RCMM program and how it relates to energy.

Concepts of the Program

There is a particular system associated with the development of a program that starts with knowing what you own. In effect, before doing anything else, the equipment that is to be included in the program must be known. It is also important that a 'pilot' area is set up for the development of the program, and expansion of the program is implemented in small chunks, as a majority of false starts occur when programs are initiated that try to take on too much, too soon.

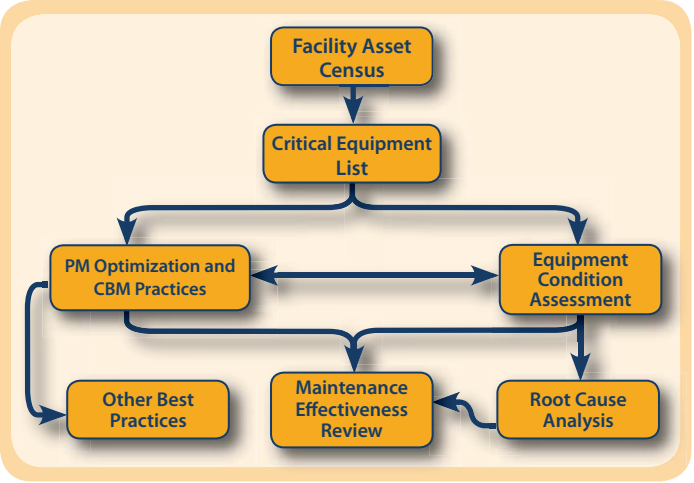

Figure 2 - Development of the Program - The RCMM Map[4]

Once a census is completed, then critical systems can be selected based upon specific criteria that may include:

1. Personal Safety: if the system involves personal safety if it should fail, then it must be considered critical equipment;
2. Regulatory: if the impact involves regulatory issues such as the environment, then it must be considered;
3. Production: systems that impact production must be included. Some analysts will select production equipment based upon its impact on the overall production within a facility. The greater the impact, the higher the ranking;
4. Cost impact: if a system surpasses a repair or replacement value cost threshold then it should be considered. The average industrial value for consideration is $25,000;
5. Other Impacts: such things as working environment, marketing/sales considerations, or other systems deemed important by the organization must be considered. This concept is often at odds with many RCM (Reliability-Centered Maintenance) and similar programs.

The next step is an equipment condition assessment where the condition of critical equipment is evaluated. The tests and inspections may be the ones selected for routine testing through maintenance practice development processes such as RCM. The results should be kept on record and equipment that is in poor condition should be scheduled for repair or replacement, at which time significant energy improvements can be considered.

The equipment condition assessment should be performed in parallel with a Preventive Maintenance Optimization (PMO) and development of Condition-Based Maintenance (CBM) practices. The PMO process can be as simple as a review of the existing processes to eliminate redundancies to more advanced commercial PMO processes. In almost every case, from 1/3rd to 2/3rd of existing planned maintenance procedures can be eliminated or combined. The remaining PM's should be compared to the results of a CBM review involving processes such as RCM or a Maintenance Effectiveness Review (MER).

A MER involves a review of the existing testing that is being performed and comparing that to the failure rate and modes of the equipment. If the failure rate and modes exist and are as high or higher than they were prior to the application of CBM, then improvements to the programs should be considered. The process also provides the opportunity to decrease maintenance as well as identify new inspections, tests, or processes. A MER should be applied periodically and which equipment is included in the MER is a decision generally made by an experienced RCM analyst.

Root-Cause-Analysis (RCA) procedures should be selected and personnel trained such that basic RCA can be selected and used by all personnel and more advanced processes can be used by teams with internal or external facilitation. In either case, all personnel should be made aware of the concepts and application of RCA so that when the process is necessary, the required evidence is maintained.

In addition to best practice procedures developed around the above processes, other process-based best practices must be investigated and applied. These best practices must include:

- Motor Repair Versus Replace Decision-Making;
- Motor Repair Specifications;
- Lubrication;
- Storage; and,
- System Energy Improvements: right sizing, application of VFD's, use of MotorMaster Plus, AirMaster, PSAT, and other programs.

All of the findings and feedback feed each of the other parts of the overall program map.

Key Performance Indicators (KPI)

When applying an RCMM program, the appropriate best practices and a method of measuring the application of the program must be considered. At the maintenance manager level of responsibility, a series of KPIs that relate to the components of the program must be developed. The minimum KPI's that must be considered include:

1. Electrical Maintenance: in order for a program to succeed, a healthy electrical maintenance program must be in place. The following components must be considered, at a minimum:
   a. Documentation and drawings that cover critical equipment;
   b. General electrical maintenance practices;
   c. Arc flash and personal protective equipment program;
   d. A review of load and power quality of critical equipment;
   e. An active electrical RCA program;
   f. Electrical safe work practices and corporate safety program; and,
   g. An emergency repair plan for critical equipment.
2. Motor and Driven Equipment Selection Program: a process must be in place for the selection and specification of components for the motor system. This includes right-sizing, selection of controls and VFDs, optimal selection of driven equipment. The use of US DOE best practices in the selection of systems for the complete motor system;
3. Commissioning: new and repaired equipment must be subject to a process of inspection and testing prior to application or storage. This ensures the reliability of the component and ensures changes have not been implemented which may reduce the energy efficiency of the component;

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SDT270 the evolution of ultrasound

TITLE, DATE, LOCATION & WEBSITE

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MOBIUS

TITLE, DATE, LOCATION & WEBSITE

Introductory Vibration Training (Category 1)
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www.mobiusinstitute.com

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commtest The Revolution

TITLE, DATE, LOCATION & WEBSITE

Implementation Success Training (IST)
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www.commtest.com

For more information and additional training listings, please log onto www.reliabilityweb.com and then click on the 'Events' menu tab.

4. Operations and Maintenance: includes repair versus replace decision-making, maintenance training, failure analysis, testing technologies, lubrication, and inspections;
5. Electric Motor System Repair: repair processes, procedures, and specifications, including qualification of the repair shop for specific equipment types and sizes. The primary purpose is to ensure no reduction of reliability or energy efficiency;
6. Plant Inventory and Records: motor system components in operation and maintained as spares. Includes storage procedures and processes; and,
7. Utility Management: the energy efficiency component of motor management programs. This should include the selection of motor systems for evaluation for immediate energy improvement opportunities within the financial project constraints of the company. This includes the use of US DOE best practices for fan systems, pump systems, motors, compressed air, and others from the industrial technology website.

Exact details of each component within the KPIs are selected based upon the company and company goals.

RCMM Team

Through the development of the program, a team must be selected to develop the program and to be involved in the RCM and MER processes. Members must include both in-house and external stakeholders in the motor management program, including:

- R&M Management
- R&M Technicians
- Utility or Energy Management
- Purchasing
- Operations Managers
- Information Technology
- Associated Vendors
- Others, as necessary

When the program is initiated, the team should meet as a whole once per month, at a minimum. As the program matures, this time frame should be able to expand so that team meetings are happening quarterly. Assignments should always be given to teams within the RCMM team at the completion of each meeting.

Case Study: Automotive Transmission Manufacturer

An Indianapolis-based transmission manufacturer has implemented a motor management program since 2001. The focus has been on the condition-based inspection, testing, vendor storage, motor repair practices, and RCA practices. The RCMM team consists of internal personnel and skilled trades as well as the contracted electric motor repair facility. The team meets monthly where the repair facility reports volume and repair cost reduction and provides recommendations for reliability improvements in the motors that have been repaired. The internal tradesmen perform RCA and a similar process referred to as 'repetitive failure analysis,' in which they investigate any instance where equipment fails more than once in a given period.

When the initial testing and inspection portion of the program was initiated, the repair and replacement costs of the program increased as equipment in poor levels of reliability were identified and corrected. Once the dust settled, it was determined that the average repair or replace decisions per year averaged 720 electric motors. With the focus on just three of the seven KPIs, the number of repair or replace decisions dropped to just over 120 repairs per year with a majority of those being minor repairs. The impact on overall equipment availability has been measurable with the cost per unit manufactured dropping significantly.

The Impact of Warranty Recovery

The silent killer, and opportunity, within many of these programs is warranty recovery. In particular, with both new motors and the repair process, most companies forget to investigate warranty opportunities in failed equipment. The average motor repair vendor warranty is one year with many repair shops increasing their competitiveness by offering warranties as high as five years! New, premium efficient, electric motors will have warranties that range from five to seven years.

Part of the reason that both new motor and repair facilities feel comfortable presenting these warranties is that many companies will not track warranty opportunities. In a great number of facilities, the missed opportunities are not in the thousands of dollars, but actually in the $100's or even $millions in unclaimed warranties. Tracking warranty dates in CMMS programs or third party software can provide immediate impact on the motor management program.

Final Considerations

At this time, a growing number of large and medium sized utilities and industrial companies have noticed, and begun to focus on, the number one R&M improvement opportunity: electric motors. The impact of all aspects of improvements, partnerships, equipment storage, implementation of best practices, repair standards, energy improvements, and robust maintenance programs have had an impact on overall energy consumption and plant capacity increasing competitiveness and profitability.

While a handful of companies have identified this significant opportunity, reaping immediate impacts on the bottom line with even more significant impacts within 12 to 24 months of program implementation, the vast majority of companies has not yet realized these opportunities. In this time of rising energy costs, corporate fiscal issues, the need to improve competitiveness and capacity, motor system maintenance management provides one of the most significant improvements. Take advantage now.

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Relieving The Tension

The Impact on Bearing Life of Overtensioned Belts

by Jeremy Davis and Hunter Golden

One of the leading causes of premature bearing failure can be attributed to overload and overstress conditions. A common catalyst for this type of condition is improper belt tensioning. Increasing the radial load on a bearing will drastically reduce the expected bearing life span and can be graphically illustrated as $y=1/x$ $(0<x<\text{infinity})$. In order to achieve optimal design expectations, procedure based, precision maintenance practices must be utilized. Test methods and precision tools ought to be employed to allow for quick, accurate and repeatable measurements rather than using inaccurate tools. In some plants, the most common malpractice in belt tension measurement is the use of the "calibrated thumb" technique.

Most maintenance professionals understand that there is a correlation between bearing life and belt tension, but what is that correlation numerically and can it be determined? Will just a few pounds of extra tension really do anything? The answer is yes. Actually, belt tension should be tight enough to prevent slippage on a sheave, but not any tighter. In some instances, a 10% increase in tension (which is a very common mistake) may reduce bearing life by up to 50% depending on the system. The purpose of the Bearing Life Reduction Calculator is to quantify the potential drastic decrease in bearing life as a result of over tensioned belts. Ultimately, by using the Bearing Life Reduction Calculator the positive effects of precision maintenance can be accurately quantified.

Background

The motivation for the development of the formulas to evaluate and illustrate the effects of improper tensioning, stem from a specific problem with an air handling unit (AHU). This particular AHU exhibited several bearing failures since its commissioning, with the first occurrence just six months after installation. After the first incident, the bearings were replaced without any type of failure analysis and the unit was immediately put back into service.

Six months later, the bearings failed again. This second failure initiated a failure investigation in which the cause of bearing failure was determined to be excessive loading in the primary load zone of that bearing. The excessive loading of the bearing was determined to be the result of over tensioning of the belts. While working with the technicians during the installation of new bearings, the reliability group on site stressed the importance of accurate and proper belt tension. The technicians complied and were confident that the belt tension was accurate according to the readings they gathered from their tensiometer pen. Six months later, the bearings failed again due to overloading.

Following the second failure, a new belt tension meter was purchased which measures belt natural frequency as an indication of tension characteristics. Natural frequencies vary based on the stiffness of the belt and can be measured by plucking the belt and reading the frequency response of resulting vibration. The tension meter comes with a tuning fork that vibrates at a known frequency and the meter can be tested for accuracy by reading the vibration of that tuning fork. Due to the nature of this tension meter, values can be recorded in Hz and may be converted to Lbs using the following formula:

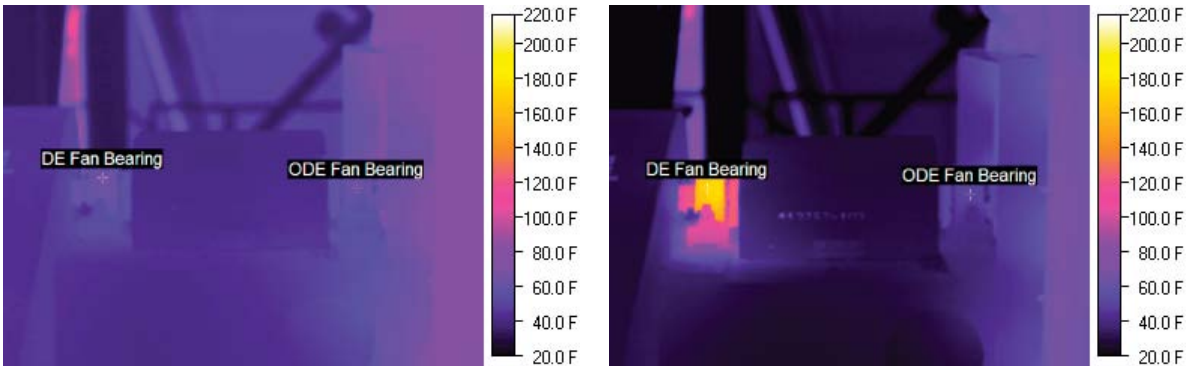
$$\text{Tension (lbs)} = \frac{4 \times \text{Belt Density} \times \text{Belt Span Length}^2 \times \text{Frequency}^2}{}$$

Findings

While using the new tension meter to tension the belt after the third failure, it was difficult to tension all three belts to the same value due to slightly misaligned and worn sheaves. At this point the decision was made to tension all three belts to slightly different degrees and to insure the belts were tensioned just above the slippage point on the sheave. As a result if this concession, some belts had to be slightly over tensioned, but how would slight over tension affect bearing life? The Bearing Life Reduction Calculator was developed to answer this question. The calculator uses the principles of the L10 Bearing Life formula and takes into account belt data, bearing data, bearing load zones, and system data all which can be found through inspection or manufacturer specifications. Currently, the Bearing Life Reduction Calculator yields extremely accurate values for systems where a rotor is center-hung or over-hung

(note: for systems where the rotor is over-hung additional inputs are required).

After the belt on this air handling unit was tensioned appropriately with the new belt tension meter, the system has been running without failure for slightly over a year, double the previous runtime. Although the effects of precision maintenance are apparent and successful, the Bearing Life Reduction Calculator uncovered a design problem for this particular AHU. Based on the output of the Bearing Life Reduction Calculator, the optimal bearing life for this system is slightly over one year. After analyzing vibration data points over the period of one year, outer race defects were recently observed in the vibration spectrum of the faulty bearing. The Bearing Life Reduction Calculator predicted accurately, suggesting that there is need to replace the current bearing and use a bearing more suitable for this particular application.



Figures 1a (left) and 1b (right) - Thermographs showing the direct mechanical effects of over tensioned belts.

In addition to using the Bearing Life Reduction Calculator to quantify the effects of over tensioned belts, belts were intentionally over tensioned on another unit so the mechanical effects could be measured by thermography. Figure 1 shows two thermography images. The image on the left is taken when the belts are accurately tensioned, and the image on the right when the belt is over tensioned. The image to the right shows the direct mechanical effects on bearings due to over tensioned belts. As the picture indicates, the bearing undergoes more load when belts are tighter which decreases the life of that bearing. The heat increase of the bearing indicates the greater stresses and friction on the bearing purely caused by belt over tensioning. Over tensioning not only causes adverse mechanical effects, but environmental effects as well. By pulling belts too tight, additional amperes are drawn off the motor causing an increase in power needed. In this particular case, amperage increased by roughly 1 ampere due to the over tensioned belts corresponding to a yearly 2000 kWh increase. While this increase seems minimal for an entire year, it is important to recognize that this is just one system. Considering that the entire site has roughly 100 air handling units, site wide savings in energy costs could be roughly $20,000 each year, purely by purchasing more accurate tensioning tools and then training the maintenance personnel to use these more accurate tools appropriately.

Initially, the motivation to provide site wide training in accurate belt tensioning was to increase asset health and minimize downtime of air handling units due to overloaded bearing failures. Although the energy impact does not seem significant, it does add up over time. Not only are emissions lowered but energy costs are reduced as well. For a very simple method of tensioning belts accurately, savings in energy alone will more than pay for the tools and training; however, savings in healthier equipment and downtime reduction will be the most significant.

Recommended Solution

Based on the findings of the experiment with this air handling unit, the recommendation is to purchase an appropriate tension meter that yields accurate results. Using a precision tension meter, with established procedures and acceptable parameters, will ensure that qualified technicians will be able to perform these tasks consistently and effectively. The single most important thing about a precision belt tension meter is that the results must be repeatable. In many cases, different technicians may record different values of belt tension using the exact same tool; however, by using a tension meter that measures the natural vibration frequency of a belt, different technicians will record the same value of tension. After purchasing the appropriate tools, technicians must be trained to not only use the tools, but also be trained on the drastic effects that over tensioned belts have on bearing life. Quantifying the reduction of bearing life due to over tensioning allows technicians to see visually and numerically how important it is to tension belts properly.

Results of the Bearing Life Reduction Calculator:

Inputting all of the required values of the Bearing Life Reduction Calculator will generate the following outputs:

- Expected bearing life with optimal belt tension
- Expected bearing life with a specified value of belt over tension
- Percent of bearing life reduction due to over tensioned belts

Additionally, these plots are produced in the Bearing Life Reduction Calculator:

- Bearing life in days with the corresponding value of over tension (Figure 2)
- Percent life reduction with corresponding value of over tension (Figure 3)
- Chart of the bearing load zones (figure 4)

Figure 2

Figure 2 on the following page illustrates the estimated potential effect on bearing life due to over tensioning. A graphical representation is depicted in Hz as well as Lbs so that a correlation can be observed regardless of the measurement method used. As discussed earlier, the shape of this plot resembles the

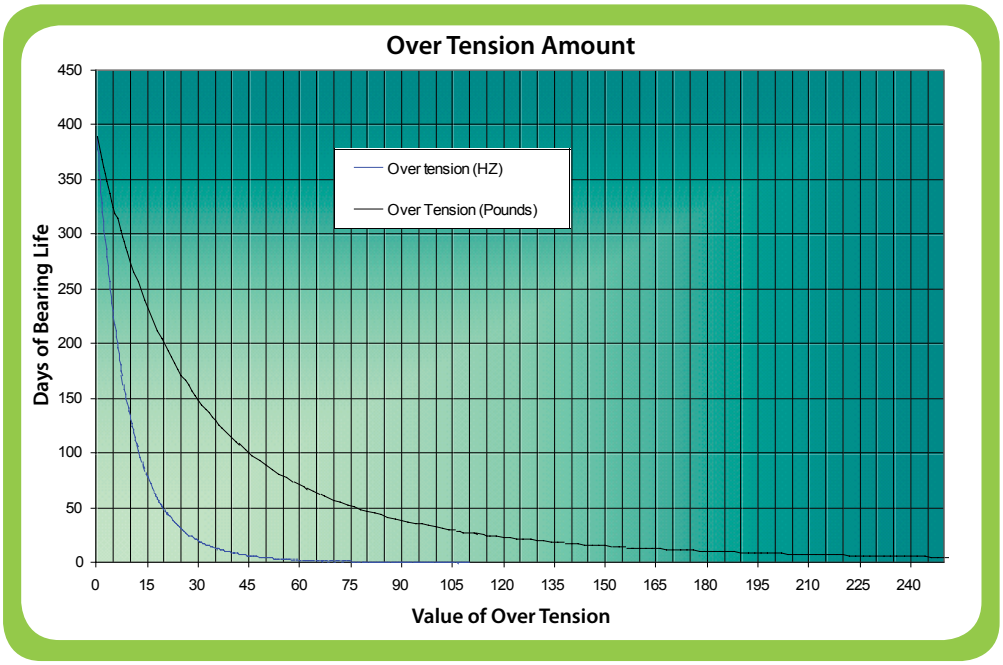


Figure 2 - Effect of Over Tension Amount on Bearing Life

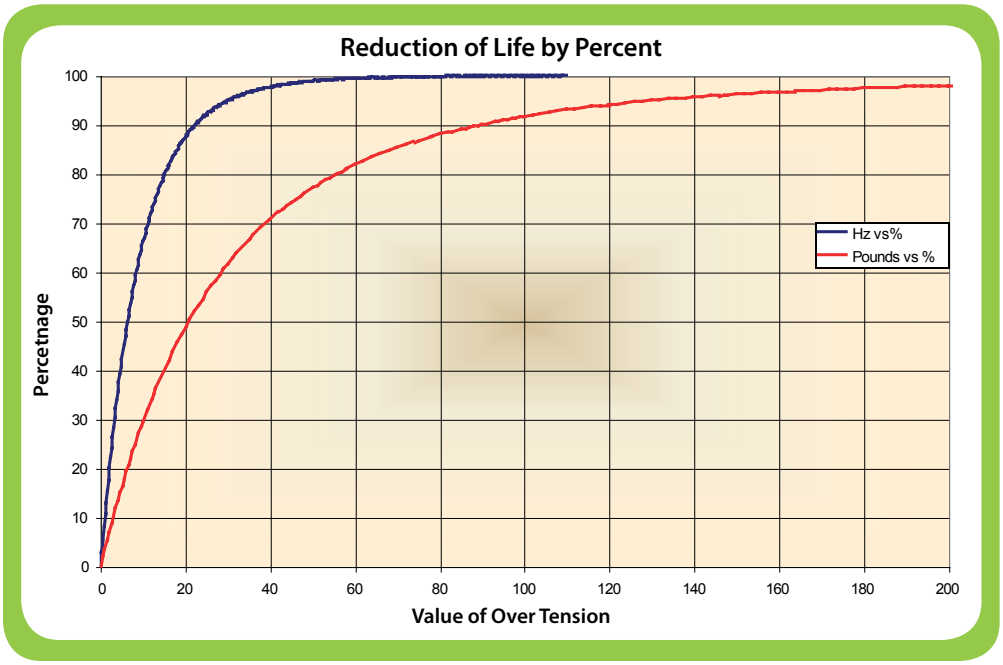


Figure 3 - Over Tension Effects on Bearing Life in Percentage

shape of the plot of y=1/x. The purpose of this plot is to show the adverse affects that over tensioning has on bearing life and is to be used as a reference sheet for technicians in the field. By having a visual image of the damage that may be caused by over tensioning, technicians will be careful during the tensioning process and be less inclined to use the badly practiced "calibrated thumb" technique to measure belt tension.

Figure 3

The two lines depicted in figure 3 represent the over tension value in Hz and Lbs as compared to percent estimated bearing life reduction. As with the previous plot, this graph can also be used as a tool in the field to illustrate the importance of precision maintenance practices. This plot is logarithmic in nature and it approaches its horizontal asymptote of 100% fairly quickly in this particular system.

Figure 4

Figure 4 on the following page depicts the three different load zones on the bearing. The vertical black line indicates the vector direction of the load zone due to the weight of the rotor. The blue line indicates the vector direction of the load zone due to the force of the tension of the belt. The red line indicates the vector direction of the sum of the rotor load and belt load vectors when the belt is tensioned to its optimal amount. The bearing will see the most load in the direction indicated by the red line when a belt is tensioned to its optimal amount. The green line indicates the new direction of the combined vector load when a belt is over tensioned. In this case, the overloaded bearing sees the most load in the direction indicated by the green line. Figure 5 is included to assist in visualization of the vectors referenced in Figure 4.

Going Forward

The Bearing Life Reduction Calculator has successfully quantified the importance of accurate belt tension, but it has also significantly improved awareness regarding precision maintenance on site, specifically for power transmission drives. By combining the successes with the aforementioned air handling unit and the Bearing Life Reduction Calculator, precision maintenance techniques are proliferating and culture is shifting to focus on the I-P interval of the I-P-F curve (see Figure 6, page 49). Precision maintenance practices regarding belt tensioning have been introduced to all of the maintenance teams and the technicians are eager to begin using the new tools to help reduce bearing failures caused by overloading. Precision maintenance is the best strategy to use to increase site reliability because it increases the time from installation to a potential failure as demonstrated in the I-P-F curve. By increasing the I-P time interval, site reliability will increase and production will be able to function with less failures and downtime.

Additionally, the increased awareness about precision maintenance due to the Bearing Life Reduction Calculator has reached upper level management. Based on the adverse effects of improperly tensioned belts, manage-

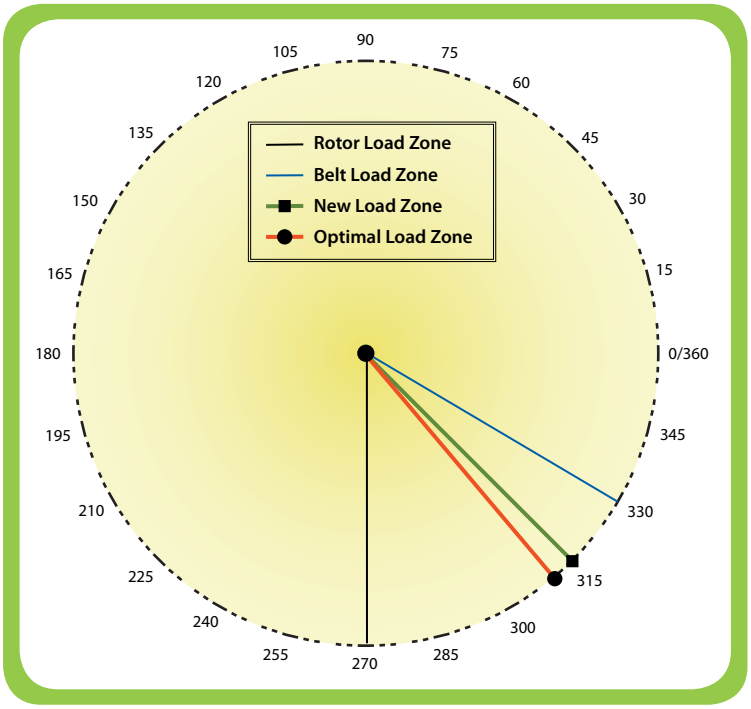


Figure 4 - Three Load Zones on Bearing

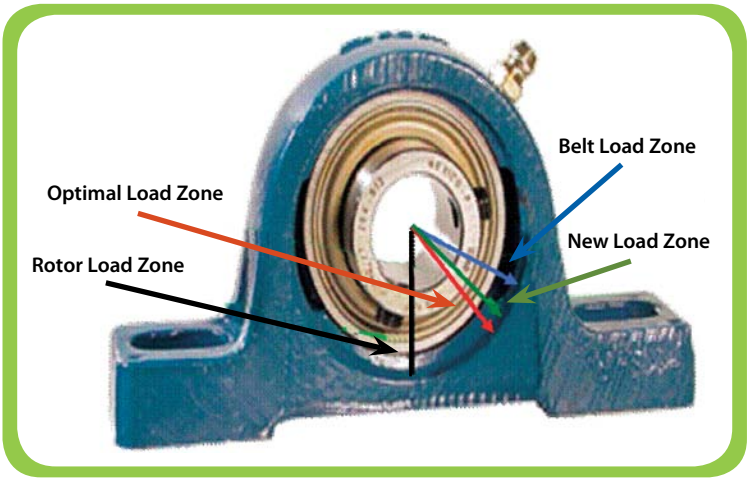


Figure 5 - Visual Representation of Bearing Load Zones

ment suggested training of all maintenance technicians in precision maintenance techniques involving power transmission drives. Precision maintenance technique training for maintenance personnel in power transmission drives will not only increase bearing life, but system life will increase as well. By expanding the knowledge and experience of those who work on the equipment, asset health will improve, and, ultimately, the bottom line will increase.

Figure 6

The I-P-F curve represented in Figure 6 (on page 49) shows asset health as time progresses. Implementation of precision maintenance techniques at the time of installation will lead to prolonged equipment life and

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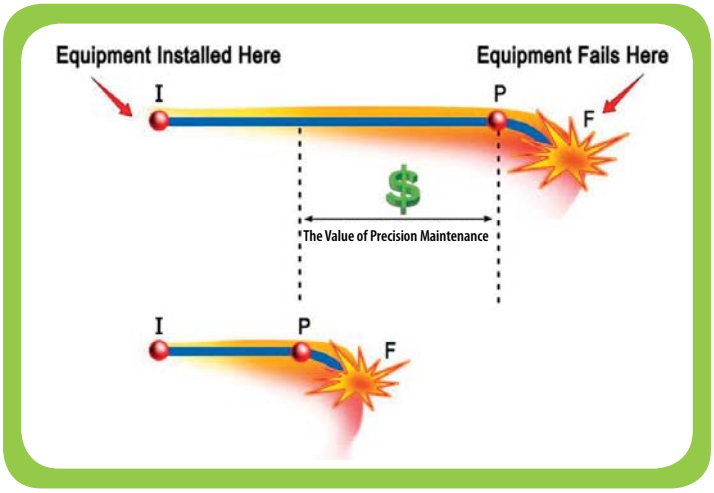

Figure 6 - The I-F-P Curve illustrating the value of Precision Maintenance.

possibly reduce the risk of failure entirely. In order to effectively succeed in extending equipment life, precision maintenance techniques must be used in multiple areas. Belts must be tensioned properly and thoroughly inspected and sheaves must be accurately inspected and aligned at installation. Practicing these precision maintenance techniques will greatly increase the I-P interval, effectively expanding equipment life for the least cost to the company.

Summary

As stated previously, one of the most common causes associated with premature bearing failure is excessive loading caused by belt over tension. Using the Bearing Life Reduction Calculator to quantify the effects of over tensioned belts will help illustrate the importance of precision maintenance practices and their effects on Asset Health. Not only will technicians perform better in the field by using the appropriate tools and procedures, but equipment reliability will be improved by implementing simple tasks centered on precision maintenance practices. As inconsequential as belt tension may seem, over tensioned belts have drastic negative effects on an entire system and even contribute to environmental harm. Using precision maintenance techniques on belts and other aspects of power transmission drives will greatly increase reliability at any manufacturing plant.

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Blast Off to Reliability

The RCM Process at United Space Alliance

by Catherine C. Kammerer

United Space Alliance, LLC (USA) is the Space Processing Operations Contractor (SPOC) for NASA at Kennedy Space Center (KSC), Marshall Space Flight Center (MSFC), and Johnson Space Center (JSC). In that role, United Space Alliance uses Reliability-Centered Maintenance (RCM) to optimize maintenance practices for the upkeep of tens of thousands of pieces of critical ground support, launch, and flight control equipment. USA has an institutionalized RCM process with a company policy, functional organization procedures, periodic review of performance, and metrics to track the performance. In addition, regular management reviews of RCM programs are promulgated to provide corrective and proactive direction that will ensure appropriate implementation of the RCM program.

Introduction

Reliability Centered Maintenance, RCM, is a process that identifies the optimum mix of applicable and effective maintenance tasks needed to maintain the inherent design reliability of systems and equipment at minimum cost. RCM provides logic for determining objective evidence needed to select the appropriate type of maintenance (e.g. predictive, preventive, or corrective). The process also is used to extend task periodicity, select alternative maintenance tactics (e.g. redesign, etc.), or eliminate unnecessary scheduled maintenance requirements based on operating experience. RCM is a proven process that increases system availability by achieving its inherent reliability and safety while reducing maintenance cost. Major benefits have been achieved by focusing on maintenance that preserves function, eliminates duplicate tasks, and decreases incidental damage through the broader use of non-intrusive inspection and predictive monitoring techniques. Other benefits include improved operating performance, increased safety, environmental protection, and a longer productive life for expensive items.

The USA Reliability Centered Maintenance program differs from traditional RCM programs because various methodologies are utilized to take advantage of their respective strengths for each application. Based on operational experience, USA has customized the traditional RCM methodology into a streamlined lean logic path and has implemented the use of statistical tools to drive the process. There are two RCM methodologies in practice – Classical and Streamlined - and both incorporate statistical tools. Regardless of the method, the USA RCM process takes you through a series of questions about a particular failure mode, which leads to one of five possible outcomes for dealing with a failure mode – predictive, preventive, failure-finding, redesign, and "run-to-failure". All USA RCM methodologies meet the requirements defined in SAE JA1011, Evaluation Criteria for Reliability-Centered Maintenance (RCM) Processes.

A sound analysis is produced by a team effort using the knowledge and expertise of the design and systems engineer, technician, and RCM mentor/analyst. The people who design, operate, and maintain the systems and equipment all participate in the RCM analyses. The USA Reliability Centered Maintenance Team serves as a central point of contact for RCM expertise, tools, analysts, and educational materials. It is the resource providing training, facilitation, analysis, and mentoring in RCM for any organization. The team also provides evaluations and recommendations for RCM products and tools, and networks with outside industries in this field.

RCM Basics

RCM examines the different ways a system can fail and the appropriate maintenance tactics to manage that type of failure. Using RCM decision logic, the analyst can determine the best maintenance strategy for a particular failure mode. The RCM analysis process gives judicious consideration to determining (a) the exact system or equipment function, (b) the functional failures that are likely to occur, (c) the likely consequences of these functional failures, and (d) the actions that can be taken to prevent these functional failures. Based on these considerations, the particular types of maintenance strategies, rather than being applied independently, are integrated to obtain maximum benefit of their respective strengths. Consequently, hardware and equipment operability and efficiency are maximized within given constraints.

There are a number of fundamental principles that characterize RCM. First and foremost, RCM is function-oriented. It seeks to preserve system or equipment function rather than merely maintaining operability for its own sake. Also, RCM prioritizes system functions by being more concerned with maintaining system functions than individual component functions.

RCM is reliability-centered. It is more concerned with conditional probability of failure at specific age brackets than with simple failure rate. Additionally, RCM recognizes that design – not maintenance – controls inherent reliability, and that the inherent design reliability is rarely achieved in use. Maintenance feedback can attain the original design reliability and, hence, improve operational reliability.

RCM is driven first by safety, which must be assured at any cost, and thereafter by economics, whereby cost-effectiveness becomes the guiding principle.

Last, but not least, RCM is a Living Process. It gathers data from the results achieved and provides lessons learned feedback to improve design and future maintenance. This feedback loop is an important part of the Proactive Maintenance element of the RCM program.

The prominent benefits of an RCM program are the following:

Reliability – RCM places significant emphasis on achieving equipment inherent reliability, mainly through the feedback of maintenance experience and equipment condition data.

Cost – Although there are initial investments in technological tools, training, and baselining of equipment condition, the increases in maintenance costs are temporary. Over time, reactive maintenance costs, as well as total maintenance costs, decrease as failures are prevented and preventive maintenance tasks are replaced by condition monitoring.

Scheduling – A condition-monitoring program forecasts maintenance and provides time for planning, procuring replacement parts, and arranging environmental and operational conditions prior to maintenance. RCM, through the implementation of Predictive Test & Inspection (PT&I) practices, reduces the unnecessary maintenance performed by a solely time-scheduled maintenance program.

Efficiency/Productivity – RCM's multi-faceted approach promotes the most efficient use of resources. The equipment is maintained as required based on its functional characteristics and the consequences of its failure.

The traditional approach to RCM acknowledges three types of maintenance tasks plus run-to-failure. The maintenance tasks are time-directed (Preventive Maintenance), condition-directed (Predictive Testing and Inspection), and failure-finding (one of several aspects of Proactive Maintenance). Time-directed tasks are scheduled as appropriate. Condition-directed tasks are performed when conditions indicate they are needed. Failure-finding tasks detect hidden functions that have failed without giving evidence of a pending failure. Additionally, Run-to-failure, often called Reactive Maintenance, is applied to small non-critical items, as a conscious decision. The RCM methodology identifies the optimum mix of applicable and effective maintenance tasks needed to maintain the inherent design reliability of systems and equipment at minimum cost. Further, RCM provides the basis for providing objective evidence in the selection of the appropriate maintenance strategy for a particular equipment or system.

The four acknowledged maintenance strategies are defined as follows:

Condition-Based Maintenance – Maintenance tasks that are performed to detect impending failures by using non-intrusive testing techniques, visual inspection, and performance data to assess equipment condition.

Preventive Maintenance – Maintenance tasks that are performed to minimize the probability and severity of lost or degraded functions. These tasks are performed on a recurring basis related to calendar time, equipment age, or operating time without regard to equipment condition.

Failure-Finding – Maintenance tasks that determine if a piece of equipment has failed when it would not be evident to the operator during normal operations. Failure-finding tasks are performed on a time and/or cycle basis to determine if a hidden functional failure has already occurred so the equipment can be repaired and is available to perform its function.

Corrective Maintenance (Run-to-Failure) – Maintenance tasks that are performed after a failure has occurred to restore an item to a specific level of performance.

A true RCM process answers the following seven questions in the sequence shown:

1. What are the functions and associated desired standards of performance of the asset in its present operating context (functions)?
2. In what ways can it fail to fulfill its functions (functional failures)?
3. What causes each functional failure (failure modes)?
4. What happens when each failure occurs (failure effects)?
5. In what way does each failure matter (failure consequences)?
6. What should be done to predict or prevent each failure (proactive tasks and task intervals)?
7. What should be done if a suitable proactive task cannot be found (default actions)?

Furthermore, a true RCM method must be based on a detailed Failure Modes and Effects Analysis (FMEA) and is used to determine appropriate maintenance tasks which identify each of the failure modes. The FMEA includes a detailed description of the asset function, the functional failures possible for that asset, the modes which likely cause each functional failure, and the consequence of each failure mode. Finally, an RCM method must have a decision logic which determines which of the maintenance tasks are both applicable and effective for an analyzed asset.

The USA RCM process encompasses this classical philosophy and these general principles and has been customized in accordance with SAE J1011 to optimally meet the needs of the maintenance program for aerospace and ground support system operations.

Classical RCM

The Classical RCM approach is applied to new or complicated systems or equipment. The FMEA is reviewed to determine if latent failure modes are present. If the equipment does not have an associated FMEA, the RCM team will generate one. A component level FMEA is created and failure mode mitigation tasks are identified. The FMEA prioritizes the tasks based on the consequences of failure identified by the Risk Priority Number and these tasks are then documented. Any existing maintenance documents are then compared to the results of the classical RCM and modified as required.

USA utilizes a commercial off the shelf software program called "RCM WorkSaver™" by JMS Software for performance of classical RCM and to capture the results of the analyses.

Streamlined RCM

Early in the RCM implementation phase, USA faced a unique RCM challenge: to analyze thousands of pieces of equipment with widely varying attributes. USA planned to analyze the maintenance procedures associated with over 30,000 items. The equipment varied greatly in cost, complexity, criticality, and age. This mix of challenges required an RCM analysis technique with seemingly dichotomous capabilities: to be fast and effective for simple and non-critical equipment, yet thorough and rigorous for complex, expensive, and critical equipment. A less intensive, more consistent approach than was offered by the Classical RCM methodology was determined to be essential for broad implementation of an RCM program.

The USA RCM Team developed a modified RCM approach: the Streamlined Process. The process includes a logic tree similar in intent to the traditional RCM decision logic, but with key differences to address the challenges previously mentioned, and it offers the efficiency and consistency to produce high quality analysis results.

As with Classical RCM, the input to the Streamlined Process is a failure mode and the output is a recommended maintenance tactic. A failure mode is a specific way in which a component might fail, including the material condition that led to the failure (e.g. a gear tooth might break due to excessive wear).

A difference from Classical RCM is the use of a "procedure-based approach" to identifying failure modes. With this approach, analysts examine maintenance procedures to determine what failure mode is being prevented. The analysts can do this with confidence when equipment has an established operational history and an existing FMEA which has been incorporated into the maintenance document. Any dominant failure modes not covered by existing maintenance can be deduced from the equipment's failure history or from the maintenance personnel's knowledge.

The Streamlined Process "Logic Tree" consists of two parts: a filter section and a tactic section. The filter is designed to quickly eliminate from consideration failure modes that do not benefit from maintenance. For failure modes not eliminated by the filter, the tactic section determines the optimal maintenance approach. This model forms an efficient yet effective process. Many failure modes can be eliminated from unnecessary tactical analysis while others receive the attention they deserve.

The filter section consists of considerations relating to risk, economics, and age degradation. If a failure mode presents an insignificant and negligible risk and economic consequence, then maintenance designed to prevent the failure is not worth the effort. If the failure mode exhibits no age degradation (i.e. the failure is random), then maintenance tactics based on age or usage are useless and they are eliminated from consideration. All the elements of the filter section increase the efficiency of the process by eliminating unnecessary tactical analyses. With some train-

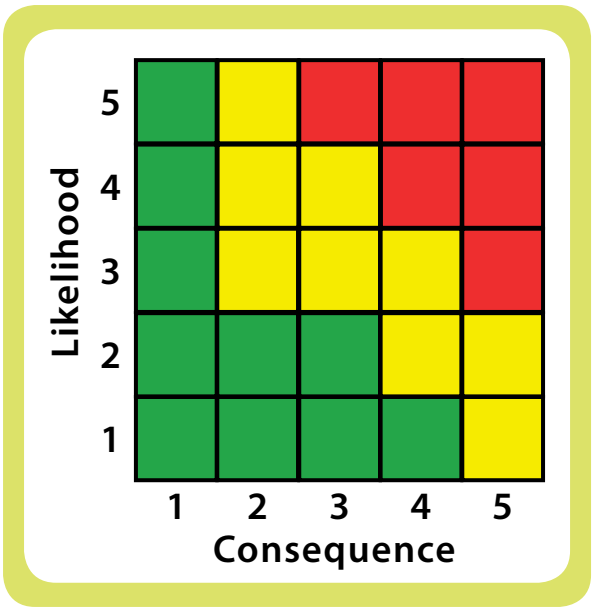

Figure 1 - Risk Scorecard

ing, anyone with a technical background and knowledge of the equipment can assess the economic and age considerations consistently. The risk consideration is prone to interpretation and error.

An early question in the Classical RCM decision logic is, "Could the failure have a direct, adverse effect on safety?" The answer is never simply "yes" or "no." Also, since Classical RCM offers no standard by which to quantify the risk, each RCM analyst might answer this question differently for the same situation. The intent of the question is to avoid unnecessary analyses in situations where no safety risk exists. Additionally, risk is not limited to safety. Also important are risks to the schedule, supportability, and cost.

USA operates within a total risk management system, which encompasses both the traditional risk management efforts of the aerospace industry and innovative quantitative approaches for measuring and analyzing risk. A Risk Scorecard (see Figure 1) is utilized to quantify the magnitude of failure risk based on the likelihood and consequences relative to safety, mission success, supportability, schedule, and cost of recovery.

The more comprehensive and quantifiable the result of the risk consideration, the more optimal and efficient both the analysis and the results will be. USA RCM recognized the Risk Scorecard could address the remaining problem associated with the Classical RCM methodology. The tool brought clarity to the safety risk question, primarily through its clear definitions for severity and probability.

For this reason, USA inserted the Risk Scorecard into the Streamlined Process. With this tool, the team can assess the severity and probability of the risk and, therefore, the magnitude. If the magnitude of the risk falls into either the red or the yellow zones, then the team is compelled to enter the tactical section of the analysis. Only if the risk is clearly in the green zone would the overall answer to the safety risk question be "no." The analyst can quickly answer the question "yes" or "no" and move on with the rest of the tactical section of the analysis thereby increasing efficiency.

The purpose of the tactical section of the Streamlined Process is to select the optimal maintenance tactic for a given failure mode. If the risk falls into either the red or yellow zone, then the goal of the maintenance strategy would be to reduce the risk to green. The purpose of predictive, preventive, and failure-finding maintenance strategies is to reduce the likelihood of a risk, and thus, its overall magnitude. These tactics cannot affect the severity of a failure mode. Only its probability of occurrence is affected. For example, a solenoid valve might stick due to the accumulation of contamination, causing a failure. Without preventive maintenance, this failure will have a higher likelihood of occurrence. Preventive maintenance, such as periodic cleaning and lubrication, will reduce this probability of failure, thus reducing the overall risk of failure. However, the consequence of failure will remain the same. Only redesign of the equipment can reduce the severity of a failure mode. In the case of a failure mode with a medium or high risk, the selected maintenance tactic(s) will hopefully reduce the risk to an acceptable level and eliminate the need for redesign.

The USA RCM team uses the "USA Streamlined RCM Database" which consists of an SQL database with a Cold Fusion web interface to capture the analysis results.

Lean Six Sigma Tools

United Space Alliance is a proponent of the Lean Six Sigma (L6S) approach to process improvement. The tools utilized in the Measure, Analyze, and Improve phases of a Lean Six Sigma project lend themselves to application in the RCM process. USA RCM has integrated many of the L6S tools into both RCM methodologies. This tool capitalizes on the existence of data and uses statistical processes to optimize maintenance protocols for maximum operation with minimum downtime.

Often solutions to maintenance problems may not be evident or readily understood. By beginning an RCM project with a process map, the steps of a process, their inputs and outputs, and decision points are identified and provide insight into process disconnects and the value of each step. L6S tools make RCM a "data-driven approach" to identifying failure modes and selecting maintenance tasks and can be used as a supplement to both the Classical and Streamlined RCM methodologies. The process map helps guide the analyst in determining what data are needed. With this approach, analysts examine operational history to determine predominant contributors to unplanned maintenance or operational time lost for non-value-added maintenance. Collected data are statistically analyzed to determine the biggest contributors, degrees of variation, and maintenance process capability. The analyst uses the data to answer a series of questions about a particular failure mode which, via the scorecard, leads to a tactic for dealing with a failure mode.

The statistical tools used can vary depending on the nature of data available and the scope of the equipment maintenance problem. An analysis may incorporate control charts to aid in the identification of variations and their sources. Stratified data charts and Pareto charts provide pattern recognition tools which enable the analyst to target root causes and/or major contributors. Regression Analysis may be used to determine the benefits of a tactic by producing a prediction equation. Correlation tables and analysis of variance (ANOVA) may be used to determine the best tactic by evaluating the relationship between the inputs and outputs. The Weibull distribution may also be used to characterize failure modes and forecast time-to-failure.

RCM At USA

The goal of USA RCM is to preserve system functionality while optimizing maintenance requirements and resources. To achieve this goal, applicable RCM methodologies are used to select the type of maintenance to be performed, extend maintenance periodicity, select alternative tasks such as condition-based maintenance, and/or eliminate unnecessary


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scheduled maintenance.

The USA RCM Toolbox – which includes the USA Streamlined RCM methodology, Classical RCM methodology, and Lean Six Sigma Tools – has proven to be very beneficial to USA's outstanding performance in the SPOC. USA strives to capitalize on its superior work force, drawing on their collective system knowledge. Analysis teams are formed and lead by an RCM Mentor for facilitation of the RCM analysis. The USA RCM process places strong emphasis on high quality training and mentoring for system engineers, technicians, analysts, and technical support personnel. Mentoring of RCM Teams and the subsequent harnessing of the work force operational knowledge base has proven to be the key to the successful application of these tools and the institutionalization of RCM.

Additionally, the Reliability-Centered Maintenance and Predictive Maintenance Engineering Lab (PMEL) groups are joined in the same organization to promote the interaction of their functionalities. The predictive technologies utilized by the PMEL are then integrated into current maintenance processes where applicable. These technologies consist of:

- Laser Shaft Alignment & Dynamic Balancing
- Motor Circuit Evaluation
- Oil Analysis:
  - Ferrography
  - Spectral Analysis
  - Elemental Analysis
  - Particle Count
  - Viscosity
- Thermography
- Ultrasonic Noise Detection
- Vibration Analysis

The RCM methodology coupled with a mentor and team approach maximizes the benefits derived from the USA RCM process. Each method is supported by software and a database to capture results including cost and savings, risk reduction, and schedule adherence. The RCM methodology becomes a Living Process with analysis results being implemented and tracked for verification of benefits and for continuous improvement.

USA has a robust foundation in the development of implementation plans, expertise maturation and consolidation, and wide-ranging training of personnel. USA also has a proven infrastructure for applying and continuously improving Reliability Centered Maintenance in all of its maintenance activities.

Catherine Carlisle Kammerer serves as a senior engineering manager of Materials & Maintenance Engineering for United Space Alliance, LLC at Kennedy Space Center. In this role, she is responsible for Reliability Centered Maintenance, Materials & Process Engineering, and the Predictive Maintenance Engineering Lab. Prior to joining the space program in 2003, Catherine worked in production and maintenance for Aleris Rolled Products and Norsk Hydro serving in a variety of engineering and management roles. She graduated from the University of Missouri - Rolla (Missouri University of Science & Technology) in 1994 with a bachelor's degree in Metallurgical Engineering. She can be contacted at catherine.c.kammerer@usa-spaceops.com or (321) 861-8123.

Refining the Refiner

Enhancing Safety and Equipment Protection with 4-20 mA Monitoring

by Ed Nisbett, Tim Gilliss and Tom LaRocque

In their mill that is located in East Millinocket, ME ("The Town that Paper Made"), Katahdin Paper Company, LLC, produces pulp, which is used in the production of directory paper from two paper machines. Prior to paper production, the characteristics of the wood pulps are adjusted accordingly by passing them through a refiner with patterned rotating plates (see Figure 1).

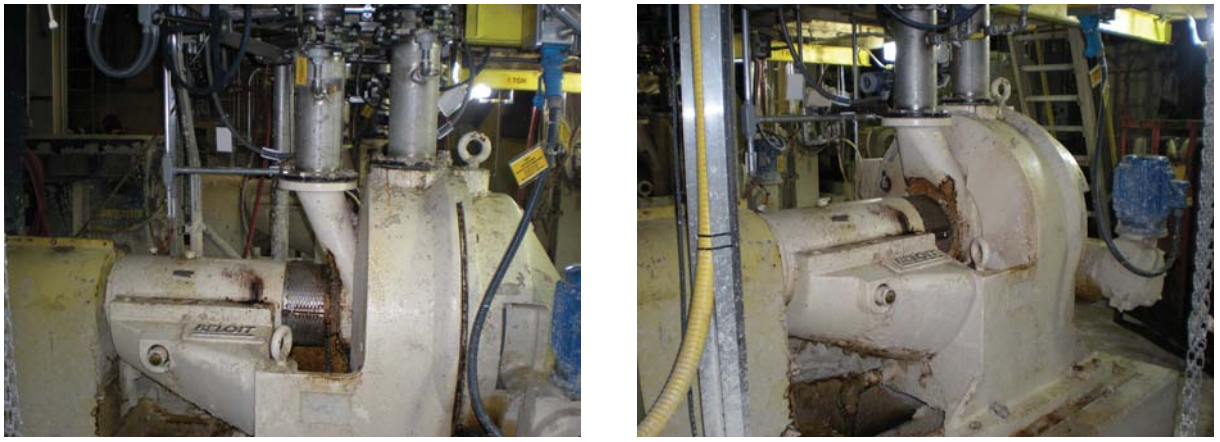


Figure 1 - Images of the Refiner at Katahdin Paper Company.

Protection Concept

If the refiner plates contact each other during the refining process, significant damage to the plates and the motor could occur. Katahdin needed a plan so they could avoid potential loss of life or serious injury that could occur if the plates were to catastrophically fail, not to mention their desire to avoid the costly damages involved, potentially ranging up to $100,000 for replacement of damaged equipment. Their final concept utilized vibration sensors mounted to the machine to measure any such events. They determined that using overall vibration signals, and converting them to a 4-20 mA output signal, was the best course of action to prevent such damages.

Why Use 4-20 mA Signals

Today's modern systems offer flexibility in sensor selection, and use standard 4-20 mA current loops for most applications. Process control provides a wide variety of monitoring options, time based trending, and control applications to keep machines performing efficiently and running at their required capabilities. 4-20 mA current loops are inherently low in noise and signals can be transmitted over long distances, making an ideal combination for industrial applications. Sensor outputs converted through vibration signal conditioners are proportional to current with 4 mA representing a zero level, and 20 mA representing a maximum level over a given range. The 4-20 mA signals are integrated into a controller system, which can be set up to alert operators if refiner plate contact occurs, and can also be integrated into a shutdown system, which will turn off the equipment prior to catastrophic damage.

Vibration Considerations & Mounting Locations

There were two vibration sources of interest on Katahdin's refiners: the inboard bearing, and the outboard housing.

Inboard Bearing – The inboard bearing was selected for monitoring because unbalance was the primary fault that could be detected. It is a low speed (600 RPM), low frequency bearing point, with velocity being the main measurement type, and 1x running speed measurements of primary interest. A low frequency, 500 mV/g accelerometer was selected for mounting to the bearing housing (see Figure 2).

Outboard Housing – For the outboard measurement, axial measurements were the focus, with particular interest in detecting when the refiner plates were starting to make contact. A general, multi-purpose 100 mV/g sensor was selected for this measurement point. What made this measurement unique is the location

Figure 2 - Sensor Mounting Location - Inboard Bearing

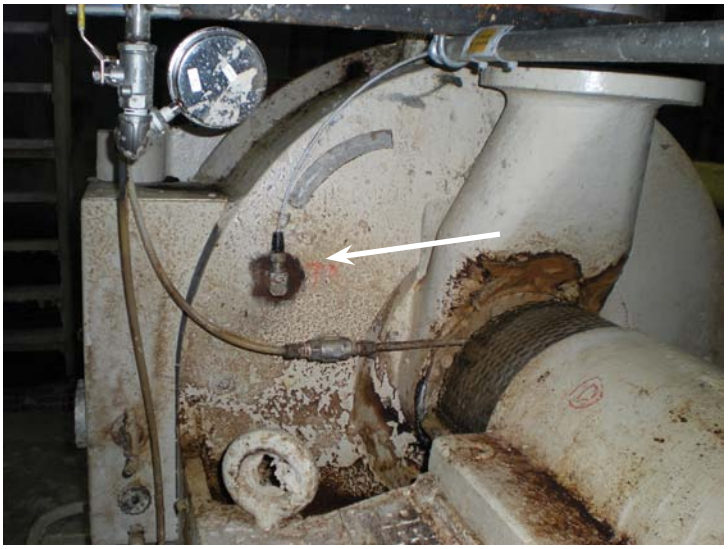


Figure 3 - Mounted Sensor - Outboard Housing

– the accelerometer was mounted on the housing around the plates (Figure 3), and acceleration was measured in order to detect the force of the clashing plates.

Monitoring & Alarming Considerations

The ability to access the raw vibration data was very important. The use of the vibration signal conditioners permitted easy access to that vibration data, while providing a 4-20 mA analog output to the controller system in the plant, which allowed for continuous monitoring. A signal conditioner enclosure was utilized to consolidate multiple signal conditioners into one NEMA 4X enclosure that allowed for easy access to the vibration data, as well as a protected

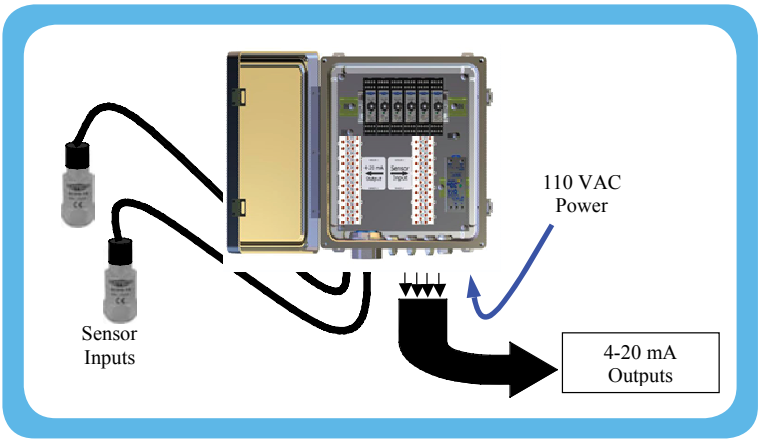


Figure 4 - Model of the basic system setup.

environment for the signal conditioners. Further consideration was given to adding a junction box to the system to allow for the easy collection of time waveform data from the sensors without needing to access the signal conditioner enclosure.

Based on historical vibration data from previous trending and analysis, alarm levels were set for the equipment being monitored. The alarms were set up for an increase of up to 50% of overall vibration from a baseline vibration signal based on the historical vibration data. The use of historical data was very important in identifying these alarm points. Too low of an alarm would cause either the shutdown or the unnecessary analysis of the equipment; whereas too high of an alarm might not alert the operators or maintenance staff that there was a potential issue. Because the signal is displayed on the main floor display, the alarm levels are also accessible to the operators, alerting them to any vibration issues.

Hardware Selection

Sensors – Sensor selection was determined by type of equipment being monitored - accelerometers were used for the selections. For the inboard bearing location, where the running speed was very low, a low frequency, side exit 500 mV/g accelerometer was selected for mounting to the bearing housing. For the outboard housing, a standard side exit 100 mV/g accelerometer was selected.

Cabling – Due to the environment in which the refiners are located, the cable connecting the sensors to the signal conditioner enclosure needed to be robust, chemical resistant, moisture resistant and reliable. A low cost composite connector with a silicone o-ring and threaded locking ring provides the seal required to protect against the environment. Due to its low cost and high performance, a flexible, Teflon jacketed twisted shielded cable was chosen to carry the signal from the accelerometer to the enclosure.

Enclosure – A junction box provides convenient, direct access to the vibration data for the analyst, as well as a protected housing for the signal conditioners (see Figure 5 and 6). A NEMA 4X enclosure with

Figure 5 - Junction Box Mounting

Figure 6 - Signal Conditioning Enclosure

water-tight cable entry into the enclosure was recommended to ensure that the water would not collect inside the enclosure. Additionally, a secondary junction box was utilized for ease of access to the vibration data (see Figures 7, 8 and 9). This also allowed the signal conditioner junction box cover to remain closed at all times, reducing the effects of environmental issues inside of the enclosure.

Figures 7, 8 & 9 - Remote Access of Vibration Points

Solution

Signal conditioners can also be used in conjunction with standard dynamic accelerometers, piezo velocity sensors, or displacement probes. The signal conditioner accepts the dynamic input and converts it to a proportional 4-20 mA output for the PLC, DCS or SCADA system. This type of application has many benefits. The signal conditioner can be adjusted in the field so that the scaling and filters match the application. The dynamic vibration signal is available via the standard BNC connection on the front of the signal conditioner, or as an optional output from the terminal block.

Modern control schemes like the PLC, DCS, and SCADA systems integrating multiple sensors, inputs, and outputs in operations centers, offer the flexibility in sensor selection. For the Katahdin Mill, a controller system was utilized to take the 4-20 mA analog output from the signal converter in order to fulfill the monitoring and alarming requirement.

Summary

Katahdin Paper Company utilizes 4-20mA solutions to protect equipment against

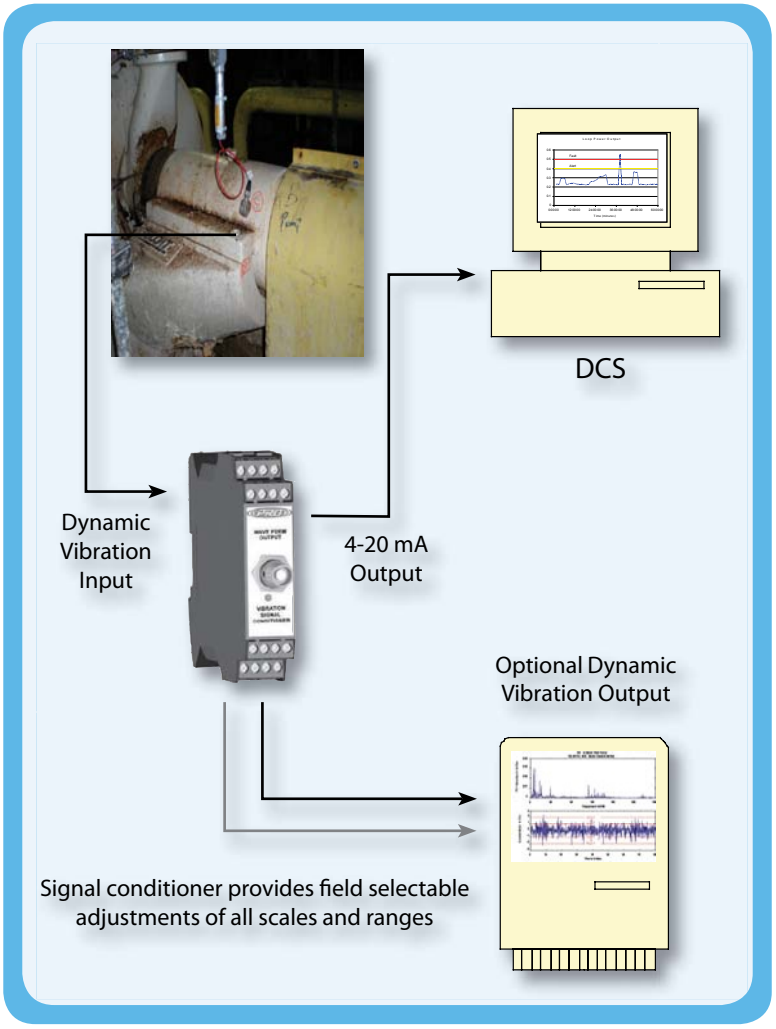


Figure 10 - Typical Layout for Signal Conditioner

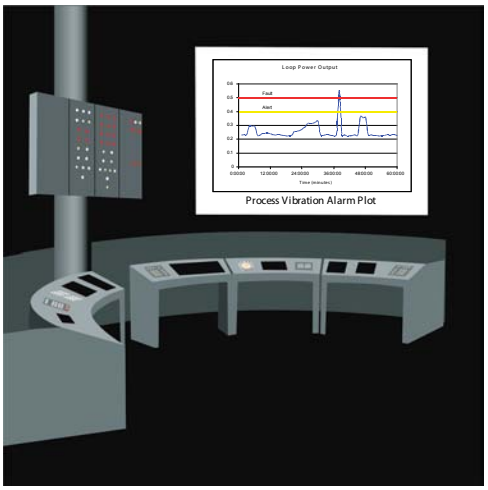


Figure 11 – Typical Control Interfaces

catastrophic failures by incorporating the outputs into their controls systems to shut down high speed, critical equipment if there is a significant vibration issue or event.

If potential problems are identified through process monitoring, the fault can be investigated and addressed in more detail. Vibration analysts can access the dynamic signal for detailed analysis using industry standard vibration analyzers and portable accelerometers, or in conjunction with the dual output loop power sensors, or signal conditioners, the analyst can use the dynamic vibration signal available to them.

Ed Nisbett is a vibration analyst that has 24 years of experience in the predictive maintenance field. Ed has attended numerous vibration courses presented by SKF, and has been on the forefront of many product improvements, developments and releases.

Tim Gilliss is a process engineer at Katahdin Paper Company, and is responsible for the implementation of the 4-20mA output signals into Katahdin's control system.

Tom LaRocque is the Engineering Manager, for Connection Technology Center, Inc. He has been involved in the design, manufacturing and quality of vibration analysis hardware for 11 years, and is currently the research and design engineering manager at CTC. He is a Certified Vibration Analyst Category III from the Vibration Institute, and graduated with a Bachelors of Science degree in Engineering from Clarkson University. Tom can be reached at 585-924-5900 Ext. 817 or tlarocque@ctconline.com

The next leap in lubrication analysis is upon us. And its happening in grease. Even though its use is quite common, and vital, in facilities across the globe, grease analysis has lagged far behind oil analysis. A simple-to-use device is now opening the door to better grease analysis. Meet ...

The Grease Thief

Grease is important. There is an enormous amount of machinery out there that depends on grease to operate. This means that there are a host of companies, across widely varied industries, that are dependent upon grease to keep their coffers well lubricated.

We caught up with the mastermind behind Grease Thief, Rich Wurzbach, of MRG Power Labs, to learn a little more about this small tool that just may, with its unique ability to easily open up so much previously hard to gather information, change the grease industry forever. Rich has over 20 years of experience in developing diagnostic technologies for industrial equipment and PdM programs, with a particular expertise in infrared thermography and oil and grease analysis.

If you are responsible for any equipment that is lubricated with grease, by all means read on....

The Grease Thief simply fits into an electric motor drain port to replace the use of drain plugs. It then not only allows grease to purge from the drain port which protects the bearing shield and seal, but also provides a protective pathway for the grease to be captured for analysis.

Let's start with you telling us why, traditionally, grease analysis is so far behind oil analysis.

Grease lubricated components are a significant sampling challenge, and when a sample is obtained, there may not be confidence that it is representative. Historically, folks rely on technologies such as ultrasound, vibration and infrared to evaluate grease lubricated components. Therefore, grease has generally only been analyzed following a significant failure, when the components have been disassembled and are accessible.

The second issue is limitations in available grease tests. Until recently, the grease analysis methods available have required very large quantities of sample. In most cases, there simply hasn't been enough grease sample to go around.

Now why don't you tell us what the Grease Thief actually is and how it can help solve the grease analysis problem.

The Grease Thief is a sampling tool specifically designed to overcome these challenges. The Grease Thief is a small, cylindrical syringe – like tool used to sample various types of equipment. Special kits have been designed to optimize the sample collection process for various machine configurations, including electric motors, motor operated valves / gearboxes and pillow block bearings. Once sampled, the full Grease Thief is submitted to the laboratory for analysis.

The Grease Thief then becomes the center of an integrated analysis process that enables a full slate of tests to be performed with just 1 gram of grease. The analyzer can quickly and effectively measure consistency changes in the grease by extruding the grease through an orifice slot. Simultaneously, the grease is prepared as a thin-film on a plastic substrate to perform additional laboratory tests to measure for wear, contamination and oxidation.

Give us a brief explanation of how the Grease Thief works.

In an electric motor application, the Grease Thief can be used to replace an existing drain plug. Instead of the plug being removed during the greasing of the bearing, and needing to be replaced sometime later in the day after grease purges, a Grease Thief can be mounted in place of the plug and catch any grease that may purge from the bearing, whenever that might happen. Greasing activities no longer require two separate visits to the motor, one to grease it, and the other to re-install the plug. Also, instead of returning to find a clump of grease lying on the base be-

The Grease Thief with stinger probe shown in a motor operated valve application.

low the motor, the purged grease is captured for inspection. The clear body of the Grease Thief allows the mechanic to visually monitor the grease, and can prompt the mechanic to remove the Grease Thief and send it to the lab for analysis. The analysis can include consistency changes and anti-oxidant levels, to determine if the relubrication frequency is optimized or may need to be revised to ensure the re-greasing is taking place at the proper interval.

For other applications such as motor operated valves or other gearbox applications, there is a second type of Grease Thief designed to allow a sample to be taken at a set depth within a housing. Using the integrated T-handle, the Grease Thief can be extended into a housing until it contacts a bearing or gear. Being able to sample the grease from the area immediately adjacent to a bearing or gear allows for the most accurate analysis of what is actually going on inside the housing.

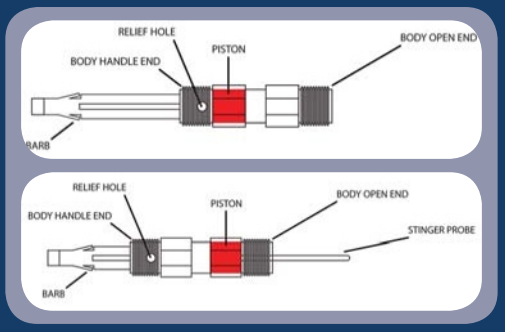
The pillow block bearing kit is designed to take samples from not only pillow block bearings, but is also designed as an all-purpose sample kit. This kit contains a syringe and spatula which allows use of one end of the spatula to scrape away any non-representative or externally dirtied grease, and the precision end to extract the grease that is freshly exiting the bearing. The syringe is used to fill the Grease Thief and submit it to the lab for analysis.

What types of bearings and other equipment will the Grease Thief work with?

The Grease Thief will work with electric motors, motor operated valves, gearboxes, pillow block bearings and other similar components. It has been used successfully in cranes, HVAC equipment, transportation applications, pumping systems and production equipment. Industries such as mining, power generation, food processing, metals, wastewater and manufacturing are prime candidates for showing the value of grease analysis.

What kind of impact do you think the Grease Thief can have on overall plant and machinery reliability?

Usually the first and immediate use of grease analysis is in identifying and eliminating causes of recurring failures in grease lubricated equipment. In some cases, just a few samples have been sufficient in identifying root-causes of failures, providing a path for immediate reliability improvement and cost-avoidance. The greater overall benefit lies in adopting a targeted routine sampling and analysis strategy that will complement existing diagnostic technologies. In addition to enhanced component wear monitoring, routine sampling and analysis of greases will add a missing dimension of identifying "grease-caused" failures, that result from the use of degraded greases, inadequate relubrication practices, and the widespread problem of mixing of incompatible greases.



Two Types of the Grease Thief. Top shows Type I, used for electric motors and pillow block bearings. Bottom shows Type II, with a stinger probe, used for MOVs, gearboxes.

What are the three top reasons a company should consider using the Grease Thief?

The Grease Thief is cost-effective, easy to use, and provides important data not currently available to maintenance decision makers.

What's the time frame a company can expect for a return on their investment in Grease Thief?

Many of our customers using the Grease Thief to address recurring grease lubricated component failures see immediate payback on the first investigation. Cost savings from an aggressively implemented routine grease sampling program can be realized in the first year. Commercial laboratories adding the Grease Thief Analyzer to their collection of analysis tools can leverage an existing lab infrastructure to generate positive returns on Grease Analysis after just 500 samples.

Give us a success story or two from companies that are using Grease Thief now.

We recently helped a pharmaceutical company solve problems with premature failures of air handling units. By utilizing the Grease Thief to analyze grease samples we identified consistency changes as well as signs of grease mixing in the small 1 gram samples submitted. Further investigation discovered a second organization was lubricating these bearings, and with a grease that was incompatible with the maintenance department grease. They were able to eliminate this failure mode and improve the reliability of these units.

In another instance, a food manufacturer submitted samples to evaluate a bearing application with a high failure rate. Along with elevated concentrations of ferrous debris, significant quantities of food material were found in the grease, which effectively increased the consistency of the grease and prevented proper lubrication. By installing improved shielding between the process and the bearing, the opportunity for this contamination was minimized.

Do you want to share any plans for the future you have for expanding the Grease Thief offerings?

We recently unveiled the Grease Thief Analyzer and are currently accepting applications from laboratories to participate in the Beta Testing of the unit. The Grease Thief Analyzer performs automated grease consistency testing, as well as preparing the thin-film substrates that can be analyzed in most existing oil analysis laboratories.

A new method for grease analysis is under development, and will be presented at the upcoming STLE conference. The use of visible light spectroscopy for greases has significant value, both for identification and quality control of new greases, as well as an additional method for identifying and trending grease contamination.

To continue to educate about the advances in grease analysis, we will be scheduling periodic Webinars on the GreaseThief.com website, and publishing our latest advancements in grease sampling and analysis.

How can interested people get more information about the Grease Thief?

Those folks who are interested can call us at the lab at 717-699-2908 or email info@mrg-corp.com. There is also a lot of information on the website www.greasethief.com including video demonstrations of sampling techniques, blogs, and sample reports.

Green Laser Pulley Alignment Tool

The award-winning SheaveMaster now features a Green Line Laser for optimum visibility under extremely bright sunlight conditions. The waterproof Greenline mounts magnetically to the face of a pulley. A permanently calibrated green laser beam fans out striking 3 magnetic targets on the opposite pulley and measures angular, offset and twist misalignment of the drive. It can be used equally well on chain driven sprockets. Traditional methods are cumbersome and require two people. One person does it easily and more precisely with the battery powered SheaveMaster! Better alignment reduces belt wear, noise, vibration and downtime. http://www.ludeca.com/prod_greenline.php

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Compact, Powerful UV Lamp Is Perfect for Tight Areas

The C-100PA high-intensity ultraviolet lamp has a lamp head measuring only 7 x 9.5 inches (18 x 24 cm) — roughly half the size of other 100-watt inspection lamps! This makes it easy for NDT inspectors to check for cracks, defects, contamination and surface flaws in confined places that are inaccessible to larger lamps. The C-100PA features a 100-watt, mercury vapor spot bulb with a nominal steady-state long-wave UV-A (365 nm) intensity of 6,000 µW/cm² at 15 in (38 cm). The lamp's visible light emission is less than two foot-candles (0.2 lux), and it easily meets MIL and ASTM specs for FPI and MPI. The bulb has an average rated life of 5,000 hours. The C-100PA lamp has a lightweight, comfortable, stay-cool pistol grip, which provides hours of fatigue-free use.

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New 6000 Series DAQ Modules for Temperature and Voltage

IOtech has released three new data acquisition modules in the 6000 Series of Advanced Measurement Products. These products combine high- performance, Ethernet-based DAQ modules with powerful, easy-to-use software. The 6222 is a 12-channel, simultaneously sampled, thermocouple input module. It features 24-bit resolution, for accurate temperature measurements. The 6230 and 6231 are 12-channel, high-speed, isolated voltage input modules. Also included with each 6000 Series module is Encore interactive measurement software, which combines an intuitive user interface with robust functionality.

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Emerson Process Management announces the release of the Fisher® EZHSO Series Regulator as well as Whisper Trim® Cage options to the EZH and EZHSO Series. The EZHSO design incorporates a patent-pending spring cartridge that offers a fail-to-open alternative, ensuring gas delivery and maximizing uptime. The Whisper Trim® Technology provides efficient noise prevention at the source and the cage can be easily retrofitted in the field.

The Type EZHSO and EZHSO-OSX (slam-shut) regulators are available in 1, 2, and 3-inch sizes. These new offerings provide the same benefits as Emerson's proven Fisher Type EZH regulators. such as:

The Whisper Trim Cage option is available for 2, 3, and 4-inch sizes, opening a broader application range for this product family.

www.fisherregulators.com

Bilsing Automation has announced that its line of carbon fiber (CF) tooling for robotic applications can reduce cycle times and improve cadence as compared to aluminum and steel tubing, because carbon fiber weighs less than half of traditional materials, yet is stiffer, stronger and settles more rapidly. This enables robot motion paths to occur more quickly with less vibration and idle time as tools settle. Potential CF applications include crossbar beams, loading and unloading beams, destacking beams, panel loading t-booms, and tooling supports for bodyshop, pressroom, injection molding and other operations.

Bilsing's round carbon fiber profiles are compatible with a wide variety of popular brand standard vacuum, gripper and power clamp components, making it easy for companies to switch to a CF solution. To help customers make informed decisions,, the company offers a free carbon fiber applications guide

Bilsing Automation North America
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NEW ERGONOMIC LOCTITE(R) 50 ml TUBE SQUEEZE DISPENSER

Allows Controlled Positioning of Anaerobic Adhesives and Reduces Material Waste

For dispensing anaerobic flange and gasket sealants in 50 ml tubes, Henkel Corporation has introduced the Loctite(R) 50 ml Tube Squeeze Dispenser, an easy-to-use, trigger-controlled dispense gun that provides smooth and consistent adhesive flow. The ergonomic Loctite(R) 50 ml Tube Squeeze Dispenser eliminates tube squeezing and provides controlled adhesive positioning. This manual dispenser completely empties the tube, reducing adhesive waste and saving material costs. An easy-to-open, pivoting tray makes tube changeover fast and easy.

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Endevco Debuts Ultra Low-Noise Remote Charge Converter

Endevco Corporation has announced the launch of new model 2771C-XX, an ultra-low noise remote charge converter (RCC), designed for use with charge output piezoelectric sensors within mechanical system health monitoring, nuclear power plant/regenerative energy and environmental testing applications. Model 2771C-XX offers a rugged two-wire (IEPE), single ended design that operates from constant current power (4-20 mA). Both RCC signal output and current to the RCC are carried along the same wire. Housed in a rugged, small package, the charge converter offers broadband noise range down to 5µ Vrms, with a frequency response of 0.4 to 50 kHz. Units are designed to withstand shock loads of up to 100g peak, and are radiation tested to 1.0 Mrads.

www.endevco.com

IRISS Announces Release of Next Generation Website

IRISS, Inc., manufacturer of the world's only "industrial-grade" infrared window, is pleased to announce the release of our next generation website. The new site has been redesigned with a fresh new look and has been updated with information about the latest products and services. Additionally, the new site will provide support and information to answer our customer's most common questions.

" We are so excited about the launch of this new site which offers six main areas for our customers and visitors: Product Information, Technical Support, IRISS News, Interactive Tools, Knowledge Center and our newly added Blog" comments Tammi Pickett, Marketing Director. "Our goal is to be the hub of information for the IR Windows Industry and I believe we have exceeded that goal."

Martin Robinson, CEO states, "The new website significantly improves navigation and is a more comprehensive source of company information and services. I am very pleased to have such an innovative and interactive website."

www.iriss.com

Measurement Computing Corporation, a leading manufacturer of value-priced data acquisition hardware and software, has added a new thermocouple device to its line of OS-independent DAQFlex products designed for OEM applications. The USB-2001-TC is a single-channel, 20-bit, thermocouple data acquisition device for measuring temperatures over the ranges defined by NIST J, K, R, S, T, N, E, and B thermocouple types. It has a 250 ms conversion time, and features integrated cold junction compensation. Under the new DAQFlex framework, the USB-2001-TC is supported under both Windows® and Linux® operating systems, and provides open thermocouple detection. The USB-2001-TC unit itself is a compact 0.8 high by 1.5 wide by 2.5 inches long, with a captive 2 meter-long USB cable attached to one end, and a socket on the other end for receiving industry-standard thermocouple miniplugs. The USB-2001-TC gets power from the host PC via the USB cable, and requires no external supply.

www.mccdaq.com

Sherborne Sensors has announced the launch of the A200 Series, a family of high-precision, gravity referenced linear servo accelerometers, offering measurement resolution down to 0.05 mg. A200 series accelerometers are available in ranges from ±1 to ±20g, and are designed to reliably operate over a temperature range of -55 to +95°C (-67 to +203°F). The design of the A200 series incorporates a closed-loop balance torque mechanism, allowing sensors to reliably measure vector acceleration, and operating as a complete servo measurement system. The A200 series may be used in a wide variety of applications, including flight test monitoring, structural health monitoring, flight simulators, mass transit system braking control, road bed analysis and low frequency analysis and many more..

www.sherbornesensors.com

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SKF Basic condition monitoring kit provides essential measurement tools for machine assessment

The essential measurement tools for assessing the overall performance of machines used in industrial manufacturing plants are now collected in the SKF basic condition monitoring kit. The SKF basic condition monitoring kit includes tools used to inspect and assess overall machine condition, as well as to test bearings, pumps, motors, compressors and other components that affect machine functionality.

The SKF basic condition monitoring kit includes the SKF Machine Condition Advisor, which measures machine vibration signals and temperature simultaneously to assess bearing condition; the SKF External Sensor Kit, which is an accessory that includes a magnet to make external vibration analyses on hard-to-reach surfaces more convenient, as well as providing more repeatable and accurate measurements with the SKF Machine Condition Advisor; the SKF Infrared Thermometer, which is a dual laser-sighted, non-contact instrument for long-range temperature assessments; and the SKF Inspector 400 Ultrasonic Probe, which measures pressure and vacuum leaks in valve seats and exhaust systems. The SKF Inspector 400 Ultrasonic Probe also inspects steam traps, gearboxes and general mechanical performance; tests bearings, tanks and pipes; and is an invaluable tool for trouble shooting heat exchangers, boilers and condensers.

The SKF basic condition monitoring kit is packaged in a light, durable aluminum case.

www.skf.com.

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