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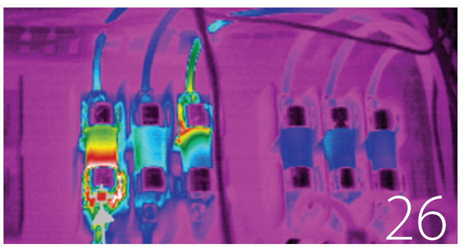

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Understand Failure

Our sympathies are with our friends in Japan who suffered a devastating earthquake, the tsunami that followed, and the Fukushima Daiichi nuclear plant disaster. *Uptime Magazine* has made a donation through the Red Cross to assist.

Scientists can give us a very detailed and precise understanding of the causes of earthquakes even if they cannot predict that kind of failure event with any precision. Understanding the nature and causes of this failure, and the associated risks, has driven the Japanese to develop rigorous earthquake mitigation strategies when constructing new buildings, bridges, water systems, and other infrastructure. We have seen the effects of a non-rigorous approach to building in an earthquake zone in places like Haiti and China, where many more people perished when buildings simply collapsed as the earth shook. In Japan, through understanding, this huge force of nature has not caused the damage it was capable of.

The causes and nature of the tsunami wave that followed are also well understood, although systems to mitigate the effect seem less effective than what they might be with earlier and more efficient warning alarms to prevent loss of human life. It is certain that much root cause analysis around the loss of life and property will be conducted, and better processes and procedures will be developed for the future.

Enter politics, money, energy, and national interest, and you have the disaster at the Fukushima Daiichi nuclear plant. I shake my head when I hear pundits state that this plant has operated safely for 40 years, and that it is only recently that the reactors began to overheat and leak radiation. That is like saying, Besides the ending, how did you enjoy the play Mr. Lincoln?

It appears that a root-cause analysis traces the current crisis back to the failed diesel generators. The March 11 earthquake and tsunami knocked out electricity to the plant, triggering the activation of diesel generators that stopped operating within hours. At that point, cooling water was no longer pumped into the reactors to prevent the fuel rods from overheating.

As to why plant operator Tokyo Electric Power Co. (TEPCO) and the Japanese regulatory body did not anticipate this failure mode, we cannot say at this point. You would think that this failure potential would be known and could have been anticipated, as current nuclear plant designs have failsafe cooling designs and automated shutdown systems to prevent such incidents.

Perhaps the powers that be did not understand the potential failure, or perhaps they did. If they did, were the design decisions simply a matter of calculated risk?

If so, it sure seems like a bad bet as of today.

Like the Deepwater Horizon disaster that damaged the credibility of the entire offshore oil industry, the Fukushima Daiichi nuclear plant incident affects the entire global nuclear industry.

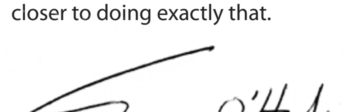
These and projects like them contain a great deal of amazing engineering resources and talent. The potential business gains are well understood from business and engineering standpoints. One wonders if an equal amount of attention and resources is paid to the risks and potential failures.

When a young couple has made a decision to wed, their minds may cross to the potential for failure for short moments in time, but the majority of their focus will be on their bright future.

When it comes to industrial contexts that have consequences relating to global survival, we need to understand the potential failure modes and failure effects and the decision-making policies of the responsible organizations. That should be part of the charter we grant these corporations to operate.

Specifications like BSI PAS55 (soon to be an ISO standard) begin defining and formalizing asset management policies and create a transparent decision tree that can be understood and followed from the plant floor to the C-Level suite. Please join us at the new Reliability Performance Institute for North America's first PAS55-focused conference, held on July 11-14 in Fort Myers, Florida (details at www.maintenanceconference.com).

The lesson you can take from these events is: Understand your failures if you want to gain control of your maintenance. I hope this and other issues of *Uptime Magazine* bring you closer to doing exactly that.



Best regards,
Terrence O'Hanlon

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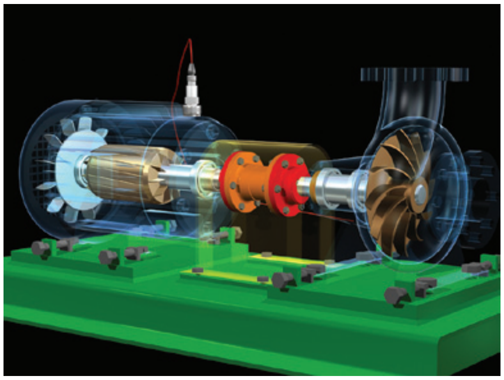

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Business Case for Data Integrity

Robert DiStefano and Stephen Thomas

Business Case for Data Integrity

Robert DiStefano and Stephen Thomas

Introduction to the Business Case

A vast and growing amount of data is being accumulated in businesses today, yet many people in business intuitively know there is not a corresponding improvement in reliable information on which to base good decisions. In fact, in many cases just the opposite is happening—despite more and more data, finding information that can be trusted is increasingly difficult.

Let's be honest. To many people, no business subject is more dull than the subject of "data." Nevertheless, the subject of data integrity is written about in business journals more often than many other seemingly more interesting topics. Furthermore, many surveys reveal a growing concern among business executives related to the ability to take advantage of the reams of data that are being collected.

Your intuition may tell you that there are large benefits associated with bringing integrity to your business data. We must admit, however, that intuition is not enough to garner the proper level of senior management support and resources to improve the data. You need a convincing business case whose development can prove to be very challenging for several reasons. First and foremost, the business case for data integrity is so vast, so far-reaching, so all-encompassing, and so pervasive in every aspect of business that knowing where to start, and how much of the story to tell, is a daunting proposition. We think the best approach is to frame the case in broad terms, citing specific facts and some quantitative examples that support the intuition that the business case for data integrity is huge. Armed with this information, you should then be able to personalize the case for data integrity in your firm or plant.

Information Overload

Consider this: The average installed data storage capacity at Fortune 1000 corporations has grown from 198 terabytes to 680 terabytes in less than two years. This is growth of more than 340%, and capacity continues to double every ten months! That statistic puts into objective terms what we all instinctively know about our data—we have huge quantities of it, and we are accumulating more and more every day.

Searching for Data

What else do we know about our data? In an article in *Information Week* (January 2007), writer Marianne Kolbasuck McGee found that average middle managers spend about two hours a day looking for data they need. The study does not comment on how often the search ends successfully, but we can assume that at least some of that time is wasted. Why? There are several reasons.

First, the volume of data is too large and most of it is not needed. To arrive at the needed data, one has to cull through reams of irrelevant or unnecessary data.

Second, the quality of the data—or data integrity—is generally poor. Much of the data is inaccurate, out of date, inconsistent, incomplete, poorly formatted, or subject to interpretation. Therefore, even when you do arrive at the needed data, can you trust it? If you have to hesitate to answer that question, you're undoubtedly spending some time deciding whether the data you have finally found (assuming you actually found it) is trustworthy and whether you can rely on it to accomplish your task at hand.

There are other reasons, but these two alone are compelling. Let's try to quantify these phenomena. The U.S. Department of Labor's Bureau of Labor Statistics indicates that in May 2006 approximately 142 million workers were in the U.S. workforce. Assume conservatively that only 10% of those workers are middle managers. Also assume conservatively that only 25% of the two hours per day spent searching for data is wasted (many studies indicate the actual percentage is higher). The amount is 1,633,000,000 hours (that's right … billion!) that are wasted annually in the United States alone—equivalent to about 785,000 man-years annually!

To put these figures in financial terms, suppose $40 per hour is the average loaded cost rate for middle managers. Then $65,320,000,000 is wasted every year—that's $65.32 billion annually, just in the United States! Imagine what this number is when calculated worldwide!

Can we put those 1,633,200,000 freed-up hours per year (or 785,000 workers per year) to good use? Most certainly!

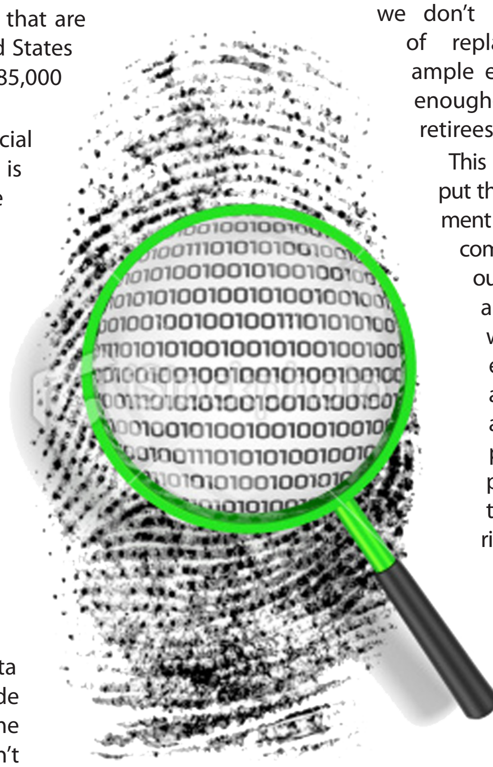
Retiring Baby Boomers

Assuming we can fix the data integrity problem nationwide and free up these hours, some of the retiring workers won't have to be replaced. Thus, the cost structure of the company will go down. According to the U.S. Department of Labor's Bureau of Labor Statistics, approximately 22.8 million people aged 55 and older are in the U.S. workforce today—approximately 16% of the entire workforce.

Assume conservatively that the number of workers in this category does *not* increase. Further assume that the 22.8 million of them will retire evenly over the next ten years. In short, approximately 2.3 million workers will retire each year in the United States (the actual estimated number is higher). The freed-up hours related to data integrity could account for about a third of that. Thus, one-third of those retired workers would not have to be replaced—assuming we solve the data integrity problem.

Again, our assumptions in this example are conservative. It is entirely possible that simply fixing the data integrity problems could go a long way toward solving the aging / retiring workforce debacle in the United States and elsewhere.

This analysis deals strictly with an efficiency gain. We have not yet talked about the effectiveness of our efforts or, to put it another way, the impact of the "Brain Drain" on the knowledge residing inside the corporation.



The Brain Drain

More than 80% of U.S. manufacturers face a shortage of qualified craft workers. This shortage is because of the retiring workforce phenomenon, and the fact that fewer new workers are entering the skilled trades, or even technical degree programs. As a result, we don't have a feedstock of replacement workers ample enough—or skilled enough—to replace the retirees.

This challenge should put the onus on management of our industrial companies to figure out how to leverage a potentially smaller workforce through eliminating wasted activities. It should also challenge them, perhaps more importantly, to institutionalize and memorialize the knowledge currently in the heads of the workers in the company's systems and data sources. Wouldn't meeting this challenge head-on facilitate and accelerate the accumulation of skills and knowledge on the part of new less-skilled workers?

In addition, the institutionalization of knowledge and information could facilitate the same work being satisfactorily accomplished by less-skilled workers. In other words, it is possible that we won't have to completely replace the retiring workers in-kind. The combination of better systems, automation, information, procedures, guidelines, training media, etc. with less-skilled workers could represent a game-changing step change in how we go about doing the work in our manufacturing and industrial companies! That step change could permanently and favorably impact the cost of doing business.

Much of the data is inaccurate, out of date, inconsistent, incomplete, poorly formatted, or subject to interpretation. Therefore, even when you do arrive at the needed data, can you trust it?

A Business Case Example

Many studies in the maintenance and reliability (or physical asset management) field, including several conducted by Management Resources Group, Inc., have pointed consistently to an estimate that between 30 and 45 minutes per day per maintenance worker is wasted searching for spare parts because of poor catalog data integrity. Spare parts represent just one narrow area of the many aspects of physical asset management, but they provide a helpful example. (Incidentally, according to research presented in *Maintenance Planning and Scheduling Handbook*, by Richard (Doc) Palmer, the total amount of unproductive time on the part of an industrial maintenance worker is, on average, 5 hours and 45 minutes per day! That means that productive time, on average, is only 28%! Not all of that unproductive time is related to data integrity, but some of it certainly is.)

If you are not familiar with this aspect of physical asset management, be aware that inventory catalog descriptions are generally not formatted consistently or in a way that facilitates rapid searching and finding of the needed spare part. Searchers often become frustrated because they cannot easily find the part in question. Sometimes the time spent searching doesn't even result in a successful find, let alone a rapid one. Typical problems include: the system indicates that the needed part is in stock, but when visiting the bin there are actually none in stock; the indicated bin location is wrong; the searcher spelled a search word differently than the myriad of ways it exists in the catalog material master records (e.g., Bearing, BRG, Brg).

Referring to the U.S. Department of Labor's Bureau of Labor Statistics' *May 2006 Occupational Employment and Wage Estimates*, it is estimated that the United States has approximately 5.45 million industrial maintenance workers today. The same data indicates that the mean hourly wage rate for these workers is approximately $20. A loaded cost including fringe benefits would be approximately $26 per hour.

If each of these workers is wasting conservatively 30 minutes per day searching for spare parts, then we are wasting 626,750,000 hours per year in the United States. That's over 300,000 workers per year, or 5% of the industrial maintenance workforce. At the mean loaded cost per hour, that equates to $16,295,200,000 annually—$16.295 billion!

Are we suggesting that the primary manifestation of these potential gains is a reduction in head count? Not necessarily, although the natural attrition generated by the Baby Boomers' retirements will present opportunities to reduce head count without having to lay off any workers.

In addition, you gain the real opportunity to redeploy the freed-up resources to more value-added activities that will drive higher equipment reliability and lower maintenance costs. The consensus of the expert community in asset management is that most industrial plants rely too heavily on time-based preventive maintenance (PM) procedures as a primary maintenance strategy. Based on the results of thousands of PM Optimization initiatives, approximately 60% of existing preventive maintenance activities in existence are inappropriate strategies for the assets in question. Thus, a very large portion of the maintenance workforce is engaged in low-value or zero-value work. Expert analysis of equipment failure behavior, using proven tools like Reliability Centered Maintenance (RCM) and Failure Modes and Effects Analysis (FMEA), dictates that the vast majority of assets in a typical industrial complex—about 89%—do ***not*** observe a predictable time-based failure pattern. Only about 11% of assets do so, as Figure 1 clearly shows.

The failure curves depicted in Figure 1 are accepted and proven knowledge dating back to studies that began in the 1960s. Keep in mind that the curves in this figure show the probability of failure on the basis of time (the *x*-axis is time in these curves). What these curves tell us is that it is impossible to predict failures of 89% of the assets in a plant *on the basis of time*. That does not mean we cannot predict failure for these classes of assets—it simply means that we cannot do so on the basis of time.

If the failure behavior of a specific class of asset shows that the asset fails randomly on the basis of time, how can we accurately define an interval for preventive, or time-based, maintenance? We can't! Yet that is exactly what we have tried to do for the past fifty years. Typically, we have guessed what the correct and safe time interval should be for preventive maintenance based on the actual historical failure behavior of that asset.

Consider an asset that over a 5-year period ran for 1 year before its first failure, then after repair it ran for 6 months before its next failure, then 3 months, then 18 months, then 5 months, then 16 months. What time interval would we set to do preventive maintenance on this asset if we wanted to prevent failure? If the asset is critical to operations, we'd have to take a risk-conservative approach and say that we should do something to this asset every 3 months. Based on the actual 5-year failure history of this asset, that would mean that we would have done preventive maintenance much too often.

Not only did the machine not need a PM during many of those runs, but as we can see from Figure 1, we may have introduced defects that actually induced failures that otherwise would not have occurred. This phenomenon is referred to in the reliability profession as Infant Mortality. Many people have probably heard the phrase "if it ain't broke, don't fix it." Well, this adage has more merit than you would think.

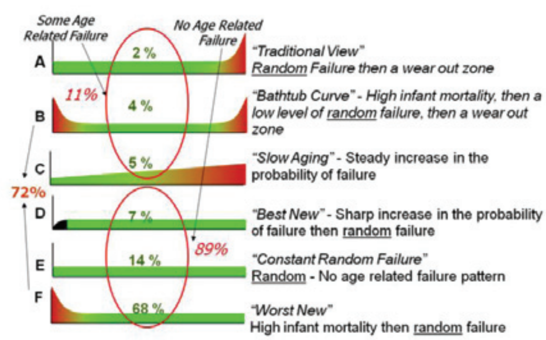


Figure 1: Asset failure behavior patterns
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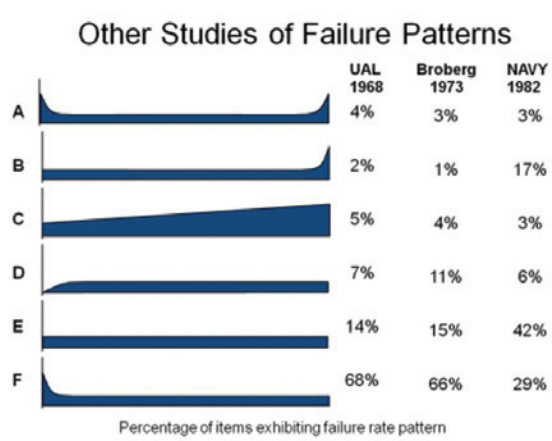

Figure 2: Studies showing asset failure behaviors

As you can see in Figure 2, there is significant basis and proof, dating back to the 1960s, to support elimination of many existing PMs. This elimination would free up significant manpower, potentially to be used to hedge against the loss of knowledge with retiring Baby Boomers, or to redeploy to perform other value-added tasks that would be required to enhance asset performance.

Most equipment does not observe a time-based failure pattern, Therefore, should we do no maintenance at all on the 89% of assets and simply wait for them to fail? Absolutely not. In fact, while we cannot predict failure for these assets on the basis of ***time***, we most certainly ***can*** predict failure of these assets on the basis of ***condition***—using a variety of sensitive technologies and tools designed to detect early warnings of impending failures. These sensitive technologies and tools are commonly referred to as *Predictive Maintenance* and *Condition Monitoring*. Examples of such tools include vibration analysis, infrared thermography, oil analysis, and ultrasonic inspection. There are others that we don't need to go into here.

The trick to Predictive Maintenance (PM) optimization (reduction) and proper deployment of predictive maintenance tools is first to know how to categorize the assets, using analysis methods designed to understand likely and costly failure modes. Then, with that knowledge, review the existing preventive maintenance procedures. Eliminate those that either are not addressing failure modes or are applied to asset types that don't observe any time-based pattern. Once these steps are undertaken, the appropriate PM strategies must be deployed. The result of this optimization of the maintenance program invariably results in a significant reduction in work, with the attendant reduction in labor and spare parts usage. In turn, these results drive significant cost savings and enhanced asset performance.

You may be asking yourself at this stage, "What does this all have to do with data integrity?" Well, how can you possibly accomplish this optimization if your foundational data sources lack integrity and quality—i.e. are incomplete, inconsistent, and inaccurate? If you don't have an accurate and complete equipment list, for example, you lack a fundamental prerequisite to unlocking these technical benefits. The answer is that without asset data integrity you cannot accomplish the optimization described here, particularly if you want to do so both efficiently and effectively.

Consistency or Lack Thereof

Most corporations have allowed different industrial plants in the company's asset fleet significant autonomy in choice and use of systems, formatting of master foundational data in those systems, maintenance strategies, etc. It is typical today that multiple plants in one corporation have similar, if not identical, assets, yet these assets are described differently from plant to plant. The maintenance strategies that are deployed for these assets also vary dramatically from plant to plant. Wide variation in maintenance strategy across a fleet of like assets results in a corresponding variation in the operating


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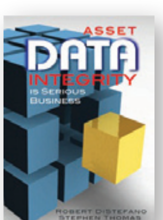
performance of these similar assets. Some assets operate more reliably, whereas other assets of similar or identical class operate unreliably.

Based on our knowledge of best practices, why would we allow this in any company? Wouldn't we want to use sound analytical methods to classify our assets, analyze their failure modes, and apply somewhat consistent maintenance strategies across the enterprise (taking into consideration that some differences are warranted given operating context, etc.)? It seems logical and makes common sense to want to do so. But how can we undertake these steps efficiently if our assets are not described with a consistent taxonomy across the enterprise? Once again, we can't.

For those who may not be familiar with the term "taxonomy," it refers to the system of classification that guides the consistent formatting and nomenclature assignment used to describe whatever is being classified. A consistent taxonomy allows you to identify the like assets across the fleet and then measure and solve for the variation. An inconsistent taxonomy seriously impairs your ability to optimize your asset maintenance strategies and achieve consistent, reliable operation of your assets across the fleet. At the most basic level, this is a data integrity issue that must be solved in order to tap into the potential cost savings and improved asset performance that are waiting to be unlocked. Without data integrity, a significant entitlement of business benefits is locked away and unattainable.



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Steve Thomas has 40 years of experience working in the petrochemical industry. He has published six books through Industrial Press, Inc., and Reliabilityweb.com, the most recent being Asset Data Integrity is Serious Business *and* Measuring Maintenance Workforce Productivity Made Simple.

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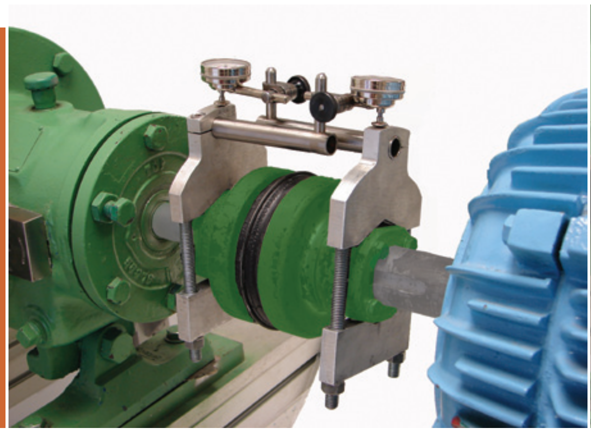
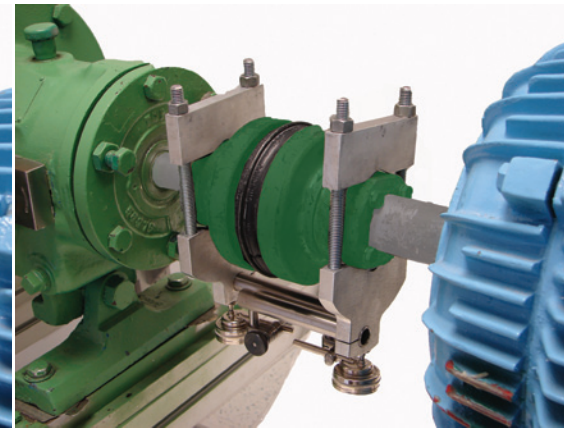




Do You Do the Verti-Zontal?

The use of lasers in measuring misalignment has improved the shaft alignment process. Literally thousands and thousands of laser-based measuring tools have been sold over the past 20-some years. No doubt, laser systems have eliminated many errors and simplified the process used to measure misalignment. However, after all these years, we haven't dramatically changed or improved the basic process used to correct misalignment. The way we have been correcting misalignment is inefficient, time consuming, and frustrating to those who have to move machines to make proper alignments.

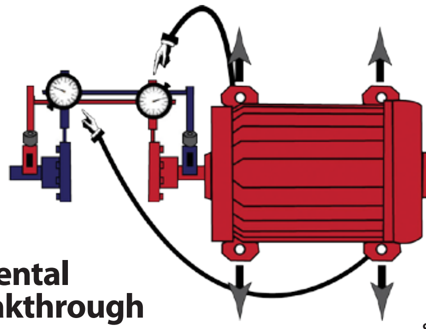
Does This Seem Familiar?

The night shift has just finished the repair, and all that is left is the final shaft alignment. The plant alignment guy and two mechanics head out to the job full of energy and enthusiasm. They are ready. Pre-alignment steps are done. Soft foot is corrected and the laser guy mounts up his equipment on the shafts. The shafts are rotated, and the first set of data is displayed on the screen.

The team attacks the vertical misalignment first. The required shim packs are laid out, the bolts are loosened, the machine is lifted, and the shim packs are inserted. The bolts are retightened, and once again the shafts are rotated. The second set of alignment data is displayed. The laser guy says, "We're just a little out of specification on the vertical, so we need to make one more shim adjustment." The shimming process is repeated and bolts are tightened once again. The third shaft rotation and subsequent data set has the laser guy giving the others a thumbs up.

"OK, the vertical is good to go. Now we need to make the horizontal move." The laser is put into a live function. The bolts are loosened once again. The horizontal adjustment is performed. The bolts are re-tightened. The alignment is re-measured and . . . the machine is once again unacceptable in the vertical axis. **You get the picture.**

Think about it: this process is rooted in dial indicator methods. Dials are set to zero at 12:00 and rotated to 6:00. The total indicator readings are plugged into a formula or plotted on graph paper to determine the vertical correction at the machine feet where shims are added or removed. The process is repeated until the dial values are acceptable in the vertical axis. Then the horizontal misalignment is corrected. Lasers have offered new ways to measure misalignment, but we are still correcting misalignment the same old way.



A Mental Breakthrough

About 15 years ago, when I was teaching a reverse rim dial indicator course, I had an "Aha! Moment" about correcting horizontal misalignment. I had been teaching folks to calculate the horizontal misalignment at the feet and to place dial gauges at the feet to correct horizontal misalignment. People would often disturb the dials during the process, and the misalignment would need to be re-measured and re-calculated.

It dawned on me that if after sweeping the dials from 9:00 to 3:00, I could adjust the dials ½ of the way back toward zero, they could then be monitored as I moved the machine horizontally. The breakthrough came when I discovered that I could use the dial closest to the movable machine to monitor the front foot adjustment and the dial closest to the stationary machine to monitor the rear foot adjustment. I called this the **near-near, far-far principal**.

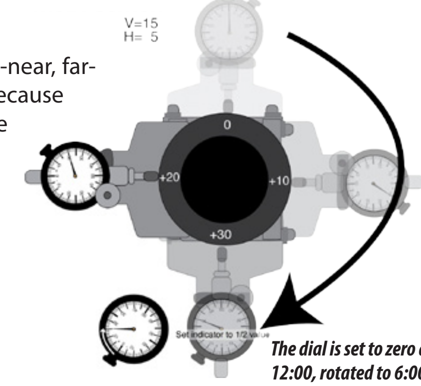
True Position

I'm pretty sure that the near-near, far-far idea is my original idea, because I've never seen anyone use the technique. By halving the dial values after 180 degrees of rotation, what I was doing was turning TIRs into what I now call **true position**.

A few years later, I had another epiphany while pondering the validity of the rule: if dials are set to zero and then read every 90 degrees, the sum of the vertical values will equal the sum of the horizontal values.

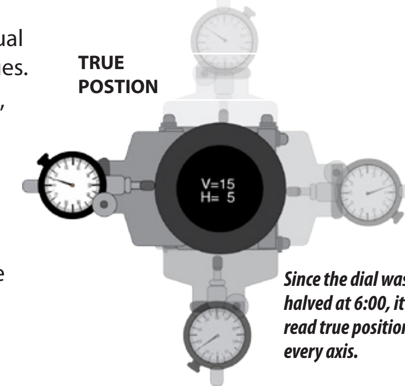
Ergo, if dials are set to zero, rotated 180 degrees and then halved, they become true position sensors. The dials can then be rotated and will read true shaft position in whatever axis they are pointing.

TIR TO TRUE POSTION

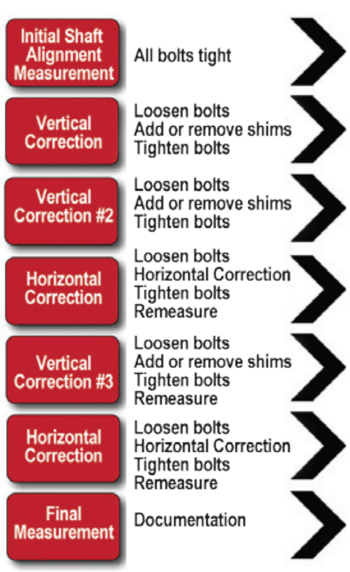


The dial is set to zero at 12:00, rotated to 6:00 and the value is halved.

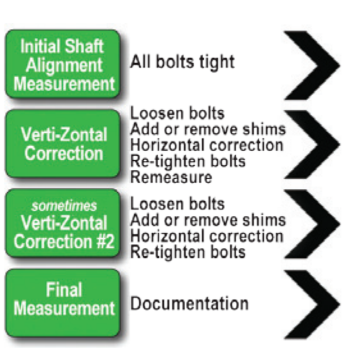
TRUE POSTION



Since the dial was halved at 6:00, it will read true position in every axis.



The old scenario that is currently used



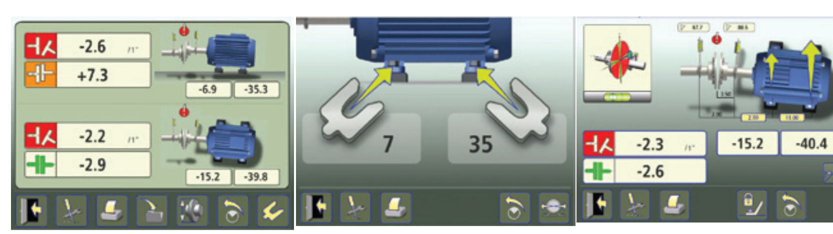
Since the dial was halved at 6:00, it will read true position in every axis.

Verti-Zontal is Born

After I realized that dials could become true position sensors, it dawned on me that we are going about the correction process all wrong. If we can correct both the vertical and the horizontal axis with one set of data, we can save ourselves a lot of work and get better results. Most aligners realize that most of the work in the shaft alignment process is not in measuring, but rather in moving the machines into the correct position.

Imagine a completely different scenario:

1. Rotate the shafts. 2. Make a shim change. DO NOT tighten the bolts. 3. Use a live function to make a horizontal correction. 4. Tighten the bolts. 5. Rotate the shafts to remeasure. 6. Document final results. I call this process the **Verti-Zontal compound move**. Does this sound too good to be true? In fairness, it may take one additional Verti-Zontal compound move to achieve an acceptable alignment.

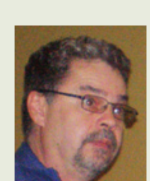


Fixturlaser Adopts the Verti-Zontal Compound Move

In all new Fixturlaser shaft alignment systems, the Verti-Zontal compound correction is incorporated into their process. After results are presented, the shim icon will lead the user to a vertical correction screen that graphically shows the shim adjustment. The user is then prompted to make a live horizontal correction. After doing the Verti-Zontal, the user is prompted to remeasure.

Doing the Verti-Zontal

I have been correcting misalignment this way for several years. Correcting both axes as a compound move is a great time saver. The people I have shown this to love doing alignment this way, especially the wrench turners who can get truly worn out when aligning large machines. They love that they have to turn the wrenches many fewer times. The Verti-Zontal compound move can be adopted with most laser systems and works nicely with reverse rim indication. If you are skeptical, I suggest you try this. You will find it makes the whole alignment process more efficient.



David Zdrojewski is the founder and CEO of VibrAlign, Inc. An alignment teacher for almost 30 years, he has written several books and papers on the subject. His articles and papers have been read and enjoyed by at least 14 people. www.vibralign.com

decision support

AhM asset health management

Achieving a Higher Level of Maintenance and Reliability

Augie DiGiovanni and John Renick

When a critical asset in a highly complex production system fails without warning, the cost in damage and downtime can be heavy – not to mention the potential risk to personnel and the environment, as demonstrated in several recent and highly publicized safety-related incidents. Asset reliability is becoming a competitive business differentiator causing organizations to rethink how they can leverage existing resources to improve the performance of their critical production assets.

Progressive companies already implementing predictive maintenance are looking for proactive solutions to manage asset performance.

Over the years, an ever-increasing volume of data on the condition of critical production assets has been generated by smart field assets connected to advanced automation systems. While this data has reduced machine breakdowns and associated costs, asset availability and uptime often remain below targeted levels. To facilitate an understanding of the reasons behind this problem, let's examine how asset data is used within an organization.

Personnel in plants with thousands of pieces of equipment generally have no good way of knowing if routine maintenance is being done too frequently or not often enough. Nor can they easily identify the "bad actors" -- those few machines and field devices that cause the most problems. According to the Boston-based ARC Advisory Group, plants in the process manufacturing industries "typically operate 20 percent below full operational capacity," and equipment reliability issues have been identified as one of the largest sources of loss.[1] Additionally, organizations struggle to answer:

- Are people spending their time on the right things every day?
- Are the predictive tools being fully utilized?
- Are maintenance dollars being spent correctly to achieve high reliability?
- How can maintenance practices be changed to produce better results?
- What equipment fails most often, and what's behind that failure frequency?
- Which assets represent the greatest risk to availability and safety?

The answers to these questions, as most managers know, have remained hidden in their existing asset-related data. However, new technology now offers the means to aggregate, analyze, and leverage this information, enabling end-users to uncover significant opportunities for improving reliability and asset performance.

Moving to Asset Management

Diagnostic information generated in the field by intelligent instruments and condition monitors provides critical information on plant assets in order to:

- Raise alarms when signs of impending failure appear so immediate corrective action can be taken to avoid unplanned downtime, reduce maintenance costs, and increase equipment reliability.
- Enable plant personnel to determine with some precision if repairs can be delayed until the most favorable time, such as a scheduled maintenance shutdown.

Predictive maintenance has proved to be less expensive than preventive maintenance and far less costly than reactive maintenance. Given the significant advantages associated with using predictive technologies for asset care, organizations are now looking for ways to more fully utilize the huge volume of their existing field-based data to develop optimal strategies for the management of their assets. According to Aberdeen Group's October 2010 report, *The Role of Software in Asset Performance Management*, "Linking Enterprise Asset Management (EAM) with performance management, analytics, and predictive maintenance are critical components/functionalities of an Asset Performance Management (APM) solution enabling companies to understand the value of both production and maintenance data which is critical to the success of any reliability driven strategy." The report stated that 44 percent of survey respondents are planning on investing in this type of solution.

The Changing Landscape

What does the asset management world look like when utilizing an integrated asset performance management approach capable of linking predictive intelligence with asset reliability information? Figure 1 displays an APM home page, which can be customized for each user, providing a quick view of the current state of asset performance, availability, and maintenance in a specific plant. Also displayed are historical charts showing monthly results for overall equipment effectiveness, availability, and maintenance costs. Users can obtain greater detail on any of these factors simply by clicking on one of the dials.

To learn about critical asset failures and how much they are costing the plant, the user moves the cursor to the "Linked Reports" box in the lower left-hand portion of the home page and clicks on "Critical Asset Failures and Cost Summary." The Critical Asset Failure and Cost Summary screen (Figure 2) shows where maintenance time and money are being spent, pinpointing ten pieces of equipment by tag number. Failure information pulled from predictive diagnosis applications and cost information from CMMS records are used to illuminate these "bad actors."

The bars on Figure 2 indicate the number of time-consuming failures suffered by each asset over the past year, and the green line shows the total maintenance cost of each piece. By clicking on tag number GC0036-083 (a gas compressor), the user finds out why that particular unit is costing more than $200,000 per year to maintain. Five failure modes for the compressor are highlighted on the subsequent screen, along with exactly which root cause is most costly. These reports can be updated as frequently as required by the end-user, so decisions can be made in real time.

By clicking on "Risks to Reliability" in the "Linked Reports" box, the user can access a report showing the highest priority assets with degraded health. All plant equipment is prioritized on the basis of failure modes and effects, understanding its operational significance, and the risk of failure.

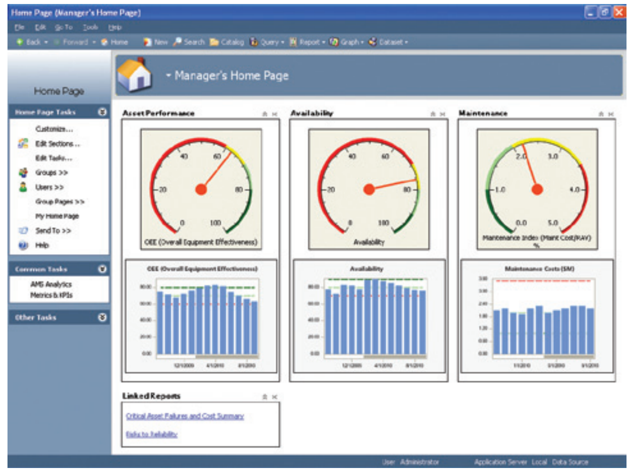


Figure 1

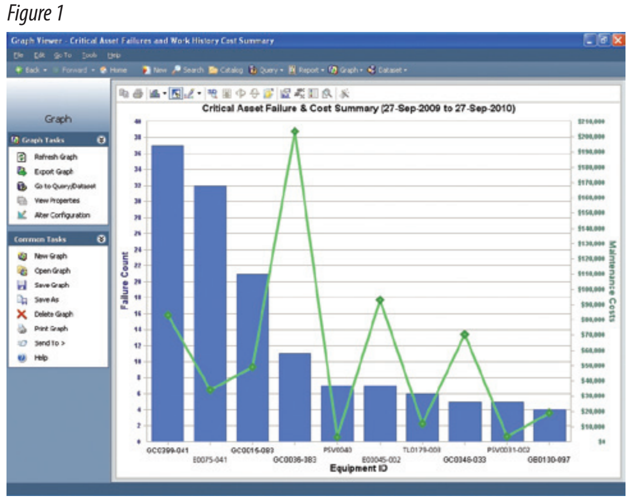


Figure 2

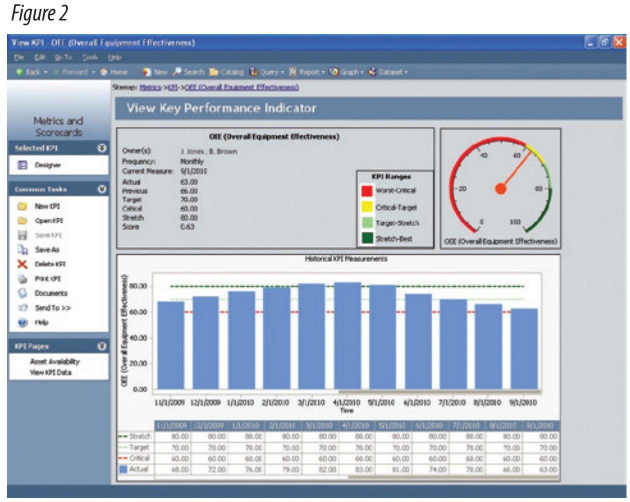


Figure 3

Each piece of equipment is then given a criticality rating. Appearance on this list is a strong indication that the asset is critically important to overall production and performance goals, which would be adversely affected by its failure.

Overall Equipment Effectiveness

System customization allows specific objectives to be established and tracked. For example, once key performance indicators are identified, a manager can very quickly determine whether the targets are being hit or missed.

As indicated earlier, higher level performance, including overall equipment effectiveness (OEE) and availability, is reflected on the home page, with details available by drilling down. For example, if OEE is declining as seen in Figure 3, the specific assets that are contributing to the decline can be identified with a single click, so the manager knows instantly where to focus attention to reverse the trend. The same is true of critical asset availability.

Reported benefits from organizations using this type of approach to asset management include:

- **Maintenance savings** of $10M within a year of implementation, related to the identification of "bad actors"
- **Reductions in reactive maintenance** by 40 percent in less than a year
- **Improvements in availability** totaling $3-5M per plant, per year

Conclusion

Predictive maintenance was a pivotal first step in increasing reliability and lowering costs. Now, organizations are identifying the necessity for a more comprehensive approach to the management of their critical production assets. Linking EAM with performance management, analytics, and predictive maintenance can offer an organization the opportunity to leverage their existing asset-related data to identify optimal asset strategies in support of their key business drivers.

1 Woll, Dave. "Emerson and Meridium Partner to Help Resolve the Asset Performance Management Puzzle," November 1, 2010. http://www.arcweb.com

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www.emerson.com

John Renick is the Partner Solutions Manager for Meridium, Inc. He has over 12 years of experience working with asset-intensive industries. In his current role, John oversees Meridium's partnerships and ensures those partnerships deliver valuable solutions. Prior to serving as Partner Solutions Manager, John was the Product Manager overseeing Meridium's APM framework, Production Loss Accounting Module, Mobile Framework, and Meridium mobile solutions.
www.meridium.com

reliability

eR electrical reliability

The Dreaded Saturday Phone Call

Noah Bethel

What's worse than a slip ring flashover on a critical wound rotor motor? A slip ring flashover on a critical wound rotor motor. . . on a Saturday!!! Yes, the dreaded Saturday phone call came to Flanders Electric from a local mine when a coal conveyor motor blew the slip rings. Unfortunately, the motor was not repairable in the field. However, the mine was in luck. They had a spare motor in place and ready for exactly this type of situation. The mine personnel were thinking the problem was behind them and couldn't get any worse, at least not until they pushed the start button.

The conveyor motor at the heart of this problem is a 4160 volt, 805 HP, wound rotor motor. On the bright side, the wound rotor motor is perfect for a belt application, as it provides good speed control and plenty of torque at low rpm. Looking at the other, not so bright side, the wound rotor motor is expensive and requires significant maintenance to ensure reliability.

At 2:30 p.m. on the Monday following the failure, the crane was finally in place and the damaged motor was lifted off the deck in preparation for replacement with the spare motor. By 7:00 p.m., the coupling had been removed from the failed motor and was being installed on the new motor. At 12:00 midnight, the motor was aligned, wired up for high voltage, and ready to start. This moment would have been an ideal time to apply the first start rule: *On the first start of a motor, always let the new guy push the start button.*

The motor growled, blew a fuse, and appeared as if it was trying to turn in reverse of the desired direction. The rotation was changed and another start was attempted. Another $1000 fuse blew in a different phase. The resistor bank and relays were op-tested satisfactory. The rotation was reversed again for a third start, resulting in a growl, followed by what appeared to be a near start, followed by another $1000 fuse blowing in phase B.

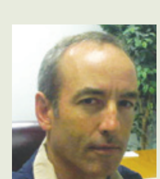
At 4:30 a.m. on Tuesday, more advice was requested, resulting in the removal of the capacitors to no avail. At 2:00 p.m., low-voltage (480v) three-phase power was applied to the stator windings with the brushes lifted to check for a balanced induction on the three-phase wound rotor. Sure enough, there was an electrical imbalance on the rotor, but it shifted phases with rotor rotation, creating uncertainty as to the root cause. At 7:00 on Tuesday night, it was determined that the spare motor needed to be sent to the shop for further inspection. However, one more idea was presented before going through the long arduous effort of bringing a crane back on site to remove the spare motor. The technicians at Flanders Electric utilize the MCEMAX electric motor test equipment for reliability testing and troubleshooting, and they were hoping that the wound rotor motor testing module would offer some assistance in determining the root cause of the fuse-blowing party.

The MCEMAX performs tests on electric motors while the motor is running or when de-energized. With the motor de-energized, the test equipment applies high and low frequency AC, as well as high and low voltage DC, for a variety of analysis techniques. With the motor running, the MCEMAX enters a passive mode, acquiring AC and DC voltage and current signals to facilitate analysis of the motor, power circuit, and power supply. Fault zones analyzed during this testing include the power quality, power circuit, stator and rotor ground wall insulation, stator and rotor turn insulation, rotor bar and lamination integrity (squirrel cage induction motor), and air gap symmetry.

With hopes high, the MCEMAX arrived on scene at 8:30 a.m. on Wednesday. The very first test using de-energized equipment on the stator windings indicated a large inductive imbalance. Finally, a break in what seemed like a steady stream of failed attempts to identify a problem. Another key piece of information was that the imbalance was not varying with rotor position. This locked the focus squarely on the stator windings. Knowing the problem must be stemming from the stator windings prompted a detailed visual inspection of the stator winding connections, resulting in an eye-opening discovery. Rather than the normal wye configured connection, the #2 and #5 leads were reversed, causing a phase inversion. This error creates a reverse torque opposing the normal rotation, which explains the motor's inability to start rotating from a standstill.

The leads were corrected, and a follow-up test was performed with the MCEMAX to verify the balance of the stator windings. Aha! The MCEMAX was reporting a perfect balance on the de-energized stator windings. The only thing left was to start the motor with fingers crossed. With the MCEMAX connected for energized testing, and following a realignment, the motor was restarted with great success. All voltage and current values were normal, balanced, and flowing in the right direction.

Ask the tired technicians, who spent four days in an effort to troubleshoot and repair not one, but two wound rotor motors, what they would do differently. You might hear that performing MCEMAX quality control testing of the spare wound rotor motor would be a good start. In fact, the right approach for motor reliability using the MCEMAX includes the triangulated attack of quality control, trending, and troubleshooting. Quality control verifies the manufactured or repair integrity of the motor upon receipt. Trending gives you advance notice of conditions conducive to failures so they can be corrected early, thereby extending the life of the motor. And finally there will be a time, usually a Saturday, when something fails and you need a troubleshooting tool to rapidly diagnose and isolate the root cause to minimize production losses. Without the MCEMAX, use the first start rule: *On the first start of a motor, always let the new guy push the start button.*



Noah P. Bethel, CMRP, has over 18 years of broad operations and electrical systems maintenance experience in industrial, commercial, and military settings ranging from nuclear submarines to world-class amusement parks. His experience includes high and low voltage, AC and DC, power generation, power distribution, motors, and motor controllers. Noah is currently in charge of product development of new and existing PdM technology for PdMA Corporation. www.pdma.com

The Truth about Infrared

Wayne Ruddock

There are many misunderstandings about infrared, both in the general public and amongst the practitioners of infrared in the industrial world. Hollywood portrays infrared falsely as a technology that can see through walls and windows and investigate the interior of buildings. It incorrectly depicts it as a technology that will allow you to see if there are any occupants in a building and where they are located, due to their "thermal signatures." This has been seen in a number of Hollywood movies and now has trickled down to television programs such as "CSI."

The reality of any infrared technology is that it "sees" infrared radiated energy only. This radiated energy comes from the first one thousandth of an inch of the surface of most solids and liquids. This form of electromagnetic radiation will travel through a gas or a vacuum only. When you look at a building wall with an infrared camera, the image that you see is a representation of the energy radiated from the paint or whatever material makes up the surface that you are viewing. You do not see into or through the wall. Those are the facts.

Even the manufacturer's representatives often mislead the end user about the physics of infrared. Educators in the infrared thermography field have often, over the past 30+ years, seen disbelief and even shock in students' faces when it is explained and demonstrated to them that the infrared gun or spot radiometer that they and their colleagues have been using for the past decade does not measure temperature. There is no infrared device in the world that actually measures temperature. They all work on the same principle. They view and measure radiated energy, as mentioned above. In devices such as spot radiometers and the newer generation of uncooled predictive maintenance cameras, the onboard computer or microprocessor takes the energy value measured by the infrared detector and computes or calculates a corresponding temperature.

In most predictive maintenance applications, the radiated energy comes from two distinct sources. A portion of the energy is emitted from the surface of the object, viewed as a function of the surface temperature of the object. The rest of the energy is reflected off of the object's surface from the background. The simple formula E + R = 1 describes the total amount of energy the camera views from the surface of an object. E represents the portion of energy emitted, while R represents the portion of energy reflected. The lower the emissivity of the object of interest, the greater the effect of background reflection on the image displayed by an infrared camera.

To arrive at a temperature with any infrared device, we must account for the rate of emission and also the amount of reflected energy, which is not related to the temperature of the object of interest.

Theoretically, if an object had no reflection it would be a perfect emitter. This theoretical object is called a black body. When it comes to the emittance of infrared energy, the concept of the black body is the gold standard to which all real world objects are compared. It would have an emission rate of 1 and a rate of reflection equal to 0. Unfortunately, in the real world there is no such thing as a black body.

To arrive at a temperature with any infrared device, we must account for the rate of emission and also the amount of reflected energy, which is not related to the temperature of the object of interest. To do this, we must enter the correct emissivity of the object of interest into the onboard microprocessor in our infrared device. Emissivity is defined as the rate at which an object emits energy as compared to that of a black body at the same temperature and in the same wavelength. Without knowing this value and correctly entering it into your infrared system, you will never arrive at an accurate temperature with any infrared device.

In order for the processor to correctly subtract out the amount of energy that is a function of reflection, we must measure the amount of energy coming from the background and reflecting off of our object of interest and striking the infrared detector(s). The infrared camera or spot radiometer sees right through the atmosphere in most cases, so the ambient air temperature is usually not a true representation of the background reflected quantity. To arrive at this value, you must measure the background reflection with your infrared device. We do not want to enter a true temperature reading, but we want to enter a false value that represents accurately the total radiated energy coming from the background. To arrive at the correct reflected value, we can use the following procedure.

1. Determine the area from which the reflection will come off your object of interest. This can be done by imagining bouncing a ball off the object of interest, then imagining where it would bounce back to.
2. Set the emissivity on your system to 1. We do not want the actual temperature, but we want to determine the amount of energy coming from the background. With the emissivity set at 1, the camera will give you a false temperature value that represents the actual total radiated energy from that background area.
3. With your system, image the area from which the reflection will come and use a measurement function, spot meter, isotherm, or area function and determine what the general average value of the background is.
4. Enter this false temperature into the ambient reflected function in your system.

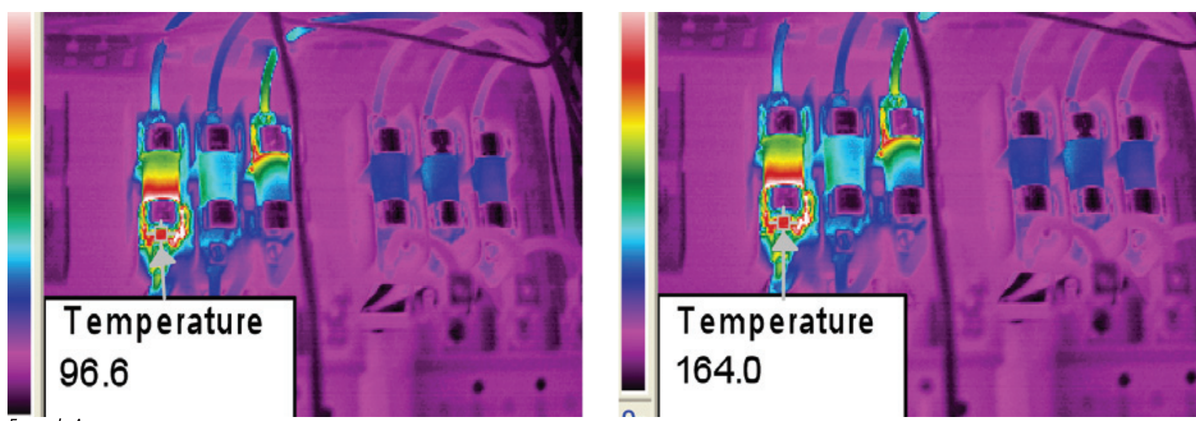
The bottom line is that if you do not enter the correct emissivity and background reflected quantity into an infrared device (camera or spot radiometer), you will never get an accurate temperature displayed on the device. Example A shows how far off the displayed temperature can be, using an incorrect emissivity value and background.

Which one is correct? It is the one where the correct emissivity and background were entered into the camera.

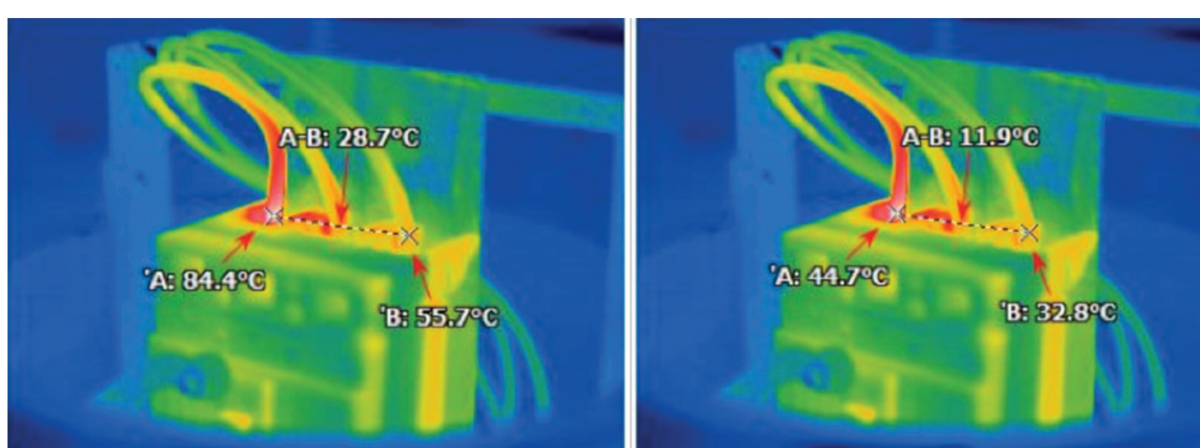
I have often heard it said that if you are doing electrical inspections and are mainly interested in component-to-component rise calculations, you can just leave your emissivity at .9 and you will get the right phase-to-phase or component-to-component comparisons. This is a false assumption and totally incorrect. If your actual values are wrong due to using the incorrect emissivity value of .9, your comparisons will be wrong also. Example B illustrates this principle.

If your infrared device does not allow you to enter both emissivity and background reflection, it is not suited for quantitative infrared applications. These devices also cannot be relied on to do temperature trending.

It must also be remembered that we do not see temperature patterns or true thermal patterns with an infrared camera; we only see radiated energy patterns that may or may not have anything to do with the actual temperature of an object. The infrared technician must have a good knowledge of emissivity and background reflection to interpret infrared images.

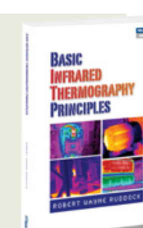


Example A



Example B

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



Mark Barnes

MIXING Oil & Water: Part 2

Strategies for Removing Water

Water is a pervasive contaminant. Present in all but the most arid environments, the impact of water on equipment health and machine reliability can be devastating. In Part 1 of this article (Feb/March 2011), we examined the impact that water has on both the lubricant and its ability to support dynamic loads. In Part 2, we'll look at how we can control moisture under even the most extreme conditions.

Like any contaminant, the key to controlling water is to restrict its ingression as much as possible. While that may be easy to say, the reality of actually preventing water from entering a machine can be challenging, particularly in environments where water is used either as part of the manufacturing or cleaning process, or in ambient operating environments where moisture and humidity are commonplace.

The first place to start when trying to prevent water ingress is to look at access points, such as vents, breathers, fill ports, and seals. Most standard breathers or fill ports supplied by OEMs do a very poor job of preventing external contaminants from entering the machine and typically do nothing to eliminate water ingression. Breathers need to be upgraded to include both particle removing and desiccating media to help prevent both solid contaminants and moisture from entering the machine. In addition, fill ports need to be modified to allow oil to be added without opening the machine to the ambient environment. This is easy to achieve using quick-connects and custom adapters that replace conventional fill ports (Figure 1).

Figure 1: This fitting can be used to replace a standard fill port on a hydraulic or lube oil reservoir to allow for the non-intrusive addition of make-up oil. The breather port on top is fitted with a desiccant breather capable of excluding both particles and moisture.

In industries where severe levels of water or humidity are present, the use of hybrid breathers are recommended on any non-circulating system. This type of breather includes an expansion chamber, which serves to keep the machine sealed from the outside environment, while allowing for volumetric changes due to fluctuations in operating and ambient temperature (Figure 2).

Figure 2: Hybrid breathers help to keep non-circulating systems sealed from the outside environment.

Aside from breathers and fill ports, seals are the next most likely ingression points. Often, our machines are equipped with simple lip seals that offer little to no barrier to atmospheric moisture ingress. Where practical and where the cost can be justified, seals should be upgraded to exclusion seals, such as labyrinth or magnetic face seals.

In some industries, such as food processing or pharmaceuticals, sanitation is a fact of life. Often requiring the use of 300 psi of water pressure, elevated temperatures, and harsh chemicals and cleaners, sanitation is one of the leading causes of mechanical failure in any food production environment. Left unchecked, machines become "target practice" for errant hoses as the sanitation crew go through the nightly ritual of cleaning.

As much as possible, the sanitation crew should receive some very basic instruction on which parts of the machine to avoid with water spray. While not always possible, shaft seals, breathers, and fill ports are all areas that should not be directly sprayed if it can be avoided. If not possible due to the proximity to the production process or degree of contamination on the machine, provision should be made to plumb the fill port or breather to a location where sanitation is either not required or doesn't need to be directly sprayed. In some cases, a similar result can be achieved by using passive shielding: simple stainless steel covers that prevent moisture from hitting the machine surfaces.

Even with the most diligent efforts to exclude moisture, inevitably water will get into the machine in high-humidity or wet-process applications. So how can we remove water once it's been ingested? The answer depends on a number of factors, including lubricant type, sump capacity, and the ultimate level of water that is tolerable.

Where only gross water contamination control is required, it may be sufficient to allow the oil to sit on the bottom of the sump and be drained off periodically, particularly if the oil has good demulsibility and a long residence time in the tank. But in most cases, the oil will not de-train water fast enough, or water levels need to be kept much lower than simple gravity separation/drain will allow.

Under these circumstances, we need to look for other separation techniques, such as those outlined below and summarized in Table 1.

Coalescing Systems

Coalescing units come in many different sizes and designs. However, they all ostensibly work in the same way, containing an element or media that has an affinity for water. As the oil-water mixture passes through the element, the water is attracted to hydrophilic (water-loving) media. Once sufficient water has been absorbed onto the surface of the media, small water droplets combine to form larger droplets, which fall under gravity to the bottom and can be manually drained off. Effective for continual removal of gross water contamination from low-viscosity oils, coalescing units don't do so well when the water is held in a tight emulsion, which can occur with highly additized, heavily contaminated, or degraded oils .

Figure 3: Example of a skid mounted vacuum dehydrator

Water Removal Elements

For removal of water from smaller sumps, such as small pumps and gearboxes, water removal elements can be effective. Typically used in a filter cart or offline filtration unit, water removal elements contain a material that has an affinity of water. However, unlike coalescing units, water is absorbed directly into the media. Media include cellulose, molecular sieves, and special polymers similar in functionality to the polymers found in baby diapers that absorb and swell to trap water. Most elements can hold as much as a gallon of water and can be effective at removing free and emulsified water from smaller sump systems.

Centrifuge

Centrifuges are used in numerous applications to separate materials that have different specific gravities. Since most hydrocarbon oils typically have a specific gravity in the range 0.85 - 0.90, compared to 1.0 for water, centrifuges can be effective at removing water continuously, particular with lightly additized, low-viscosity oils. Centrifuges become significantly less effective where additized composition, oil age, or other contaminants create a tight oil-water emulsion, but they do a good job of removing gross water contamination in larger sump systems.

Vacuum Dehydration

Vacuum dehydrators work on a very basic principal: water and other liquids will boil at lower temperatures when the pressure is reduced. To illustrate this concept, consider the difference between the boiling point of water at sea level and in the mile-high city of Denver, Colorado. While water boils at 212 °F (100 °C) at sea level, water boils at around 203 °F (95 °C) in Denver due to the reduced pressure at elevation. Most vacuum dehydrators work at a pressure of -25 to -28 inHg, which is equivalent to just 1/15th the pressure at sea level. At -28 inHg, water will boil at just 80 °F (26 °C). In essence, a vacuum dehydrator is nothing more than a vacuum chamber with a vacuum pump and heating element. By lowering the pressure to -28 inches of mercury, while simultaneously heating the oil to 140-150 °F, water is literally boiled off of the oil without causing the oil to oxidize. Vacuum dehydrators come in a number of different sizes and configurations, from small ½ GPM portable units to larger 40-50 GPM permanently mounted units, but they all contain the same basic elements.

While vacuum dehydrators can be slow at removing large volumes of water, there can be little doubt that when it comes to removing water to low levels, vacuum dehydration is probably the best option. For lightly additized oils, such as turbine oils and transformer fluids, vacuum dehydrators can remove as much as 90-95% of all dissolved water, as well as free and emulsified water, resulting in levels of water often below 10-20 ppm.

Even with the most diligent efforts to exclude moisture, inevitably water will get into the machine in high-humidity or wet-process applications. So how can we remove water once it's been ingested?

In some industries and environments, water can be one of the leading causes of premature failure. Left unchecked, it can effectively reduce equipment life to just a fraction of its design life. But with some simple care and attention, water can be controlled, removed, and eliminated from machines, no matter how severe the environment.

Mark Barnes recently joined Des-Case Corporation, a leader in the field of contamination control and lubrication management, as Vice President of the newly formed Equipment Reliability Services team. Mark has been an active consultant and educator in the maintenance and reliability field for over 17 years. Mark holds a PhD in Analytical Chemistry and is a Certified Maintenance and Reliability Professional (CMRP) through SMRP. Visit www.descase.com.

	Water Removed		
	Free	Emulsified	Dissolved
Gravity Separation	yes		
Coalescers	yes		
Polymer Media	yes	yes	
Molecular Sieve	yes	yes	
Cellulose Media	yes	yes	
Centrifuge	yes	yes	
Vacuum Dehydration	yes	yes	yes

Table 1: Comparison of water removal methods

management

MrO

mro-spares management

MRO Inventory Rationalization and Optimization

Ralph Rio

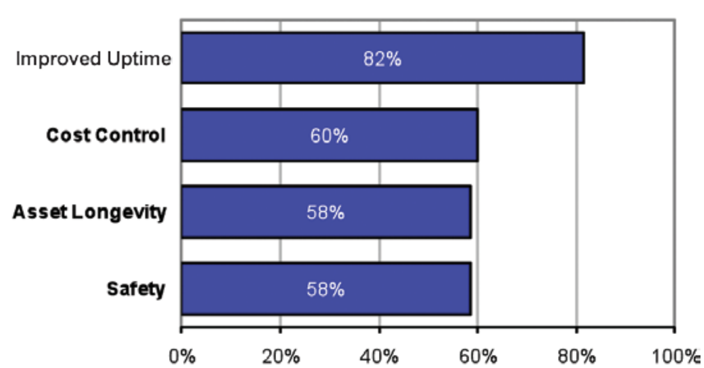
MRO materials inventory often has many thousands of stocking units (SKU) in small quantities with multiple stocking locations and unpredictable demand – making inventory management difficult. Maintenance organizations tend to focus on work orders and the equipment while giving lower priority to managing MRO inventory. The lack of inventory optimization results in higher inventory levels, carrying costs, and operating disruptions.

C-Suite Metrics

Senior executives, particularly those in the C-suite, have metrics driven by the P&L statement and balance sheet. When proposals connect to a positive impact on these financial statements, they are more likely to obtain executive support. Financial ratios can affect the share price, the executives' income, and, potentially, their job security. An example of a common financial metric for risk is quick ratio (or "acid test"):

Quick Ratio = (cash + marketable securities) / current liabilities

Reducing inventory and adding cash to the numerator improves the quick ratio. Similarly, using these funds to reduce liabilities in the denominator improves the ratio. The improvement makes an investment more attractive, raising the stock price and overall stockholder value. Since investors use this ratio to evaluate risk, an improvement will also reduce interest rates on the company's debt and improve profitability.



Primary Metrics for Maintenance
Source: ARC Advisory Group Survey

Through optimization and less inventory, additional cash improves financial measures, stockholder value, and executive metrics. Improving your boss' metrics is often a good career move.

MRO Material Categories and Policies

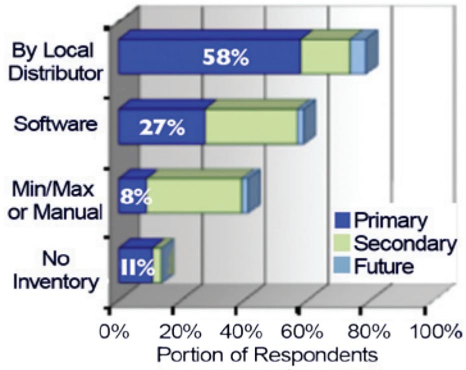
Particularly in asset-intensive industries, replacement parts can represent a significant portion of operating costs; some utilities have reported expenses as high as 15 percent of revenue.

To provide clarity for this analysis, MRO replacement parts are bifurcated into two distinct usage patterns. **Repetitive parts** (like filters) wear, requiring regular replacement. **Critical spare parts** are stocked to control the risk of a lengthy interruption should a part fail in vital equipment required for production to operate, particularly those parts with a long lead time. This segmentation, **repetitive** and **critical,** helps reveal two corresponding and very different inventory management policies.

Repetitive Items Inventory Management

Min/Max Inventory Management: Items used repetitively have a demand history used in traditional min/max inventory management. The demand history, inventory carrying costs, and lead times drive a calculation for reorder point (min) and economic order quantity (EOQ). ERP and EAM systems have features that provide these calculations.

Vendor Managed Inventory: A core competence of a distributor includes inventory management with a high fill rate (otherwise, they do not last long due to cash flow and customer satisfaction issues). Vendor managed inventory (VMI) agreements with a local distributor offload the inventory and its management. The distributor's systems



How Is MRO Inventory Managed?
Source: ARC Advisory Group Survey

manage reorder point, EOQ, and the associated supply chain.

Critical Spare Parts Inventory Management

A combination of theory of constraints (TOC) and reliability centered maintenance (RCM) determines the critical equipment and associated critical spare parts for stocking. Many consider RCM too time-consuming to use to apply to every asset. Instead, they focus on the critical equipment identified by TOC or safety concerns.

With critical spares, using VMI is inherently risky. Keeping an item in inventory that has no demand goes against a distributor's systems, metrics, core competence, and culture. When one of these parts is sold, its people will celebrate getting rid of a "dog." When the next need for the part occurs, it will not be available.

Causes of Sub-Optimized Inventory

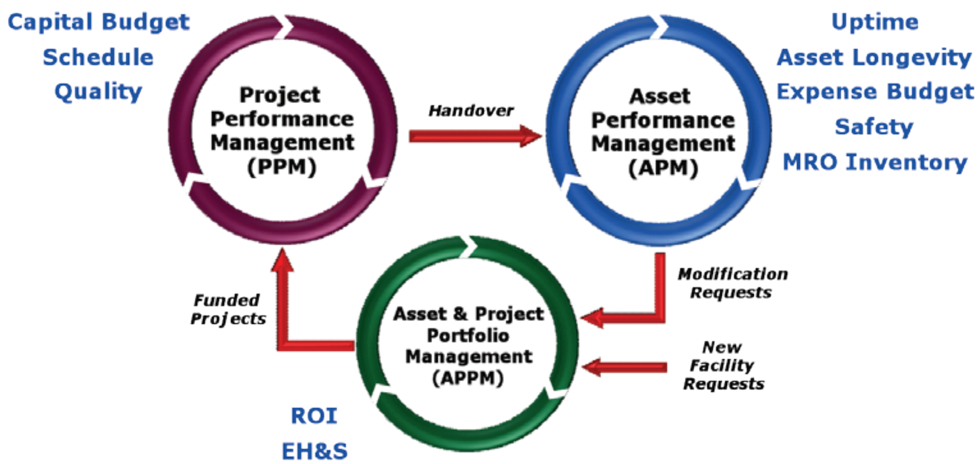
Asset management functions segment into three groupings, with the key metrics as shown with ARC's model for Asset Lifecycle Management (ALM). Conflicting metrics drive dysfunctional organizational behavior. This maxim applies to asset management.

For an upgrade, the project team key metrics focus on budget, schedule, and meeting specifications. Selecting parts from a catalog of existing MRO items takes additional time with no benefit to the engineers. It is often easier and faster to create a new part number. At handover, a massive information transfer occurs from engineering to operations with little incentive or methodology for engineering to avoid part number duplication. Neither the project nor operating teams rationalize duplicate numbers, resulting in a huge problem that worsens with time. Each upgrade adds to the "dirty data" and compounds the MRO inventory management problem.

Growing asset diversity, including new designs and technologies, compounds this part number duplication. In the new design, many of the old part numbers continue to exist, with a few new ones added for the improvements. Occasionally, all of the parts are assigned new numbers even though few are new. New technologies provide new types of equipment with an entire set of new part numbers. Together, these changes drive more SKUs for MRO inventory.

Duplication creates multiple instances of the same inventory. Also, after an upgrade, the spare parts associated with the removed equipment are no longer used but remain in stores. In reality, the parts could be used elsewhere in the plant if the duplication was identified, or sold while they still have value.

The dollar amount tied up in inventory continuously expands. As more cash becomes inventory, financial metrics for the corporate balance sheet erode and negatively affect shareholder value.



Model for Asset Lifecycle Management with Key Metrics

Inventory Optimization

Data cleansing and inventory optimization provide an opportunity to reduce costs. Initial steps in MRO inventory optimization are:

Part Number Rationalization: Part number rationalization establishes a strong foundation for further improvements. Many organizations successfully outsource this rationalization. Well-defined and proven methodologies provide structure to each description and the associated part number assignments. With this structure, duplicates become much easier to identify. Part number rationalization also provides a standardized description format that technicians, dispatchers, planners, and even project engineers can interpret to identify the needed parts. The rationalized part numbers become a master parts catalog.

Business Process Management: Examine business processes (particularly handover) to avoid the creation of new, duplicate part numbers. For example, while designing a modification, the engineers should choose parts from the master parts catalog. Also, examine the ALM business processes for those authorized to add a new part number or edit an existing one, and provide visibility for these changes.

Data Cleansing: Optimize the re-order points and EOQs for each item in MRO inventory based on demand history.

Recommendations

Often, maintenance people focus on the equipment with much less attention given to materials management. The steps for MRO inventory optimization are:

Part Number Rationalization: Examine part numbers and apply a standardized part number assignment schema.

Identification and Disposal of Obsolete or Overstock Items: For duplicate items tagged for removal, use a two-tier hierarchy until the inventory is gone. Put a hold on buying additional parts and enter the replacement item in the "Alternate" field. This continuously uses excess inventory while reducing the size of the item list. For items with no application, sell the inventory

Dirty Data:
Duplicate part numbers
Obsolete part numbers
Incorrect re-order points
Old EOQ or an estimated order quantity
Re-ordering of declining-use inventory
Purchase a commodity from OEM rather than part manufacturer (like bearings)
Overstock due to fear of downtime

Added Costs:
Equipment downtime due to stock-outs
Increased shipping costs for expedited delivery in reaction to stock-outs
Carrying costs with excess inventory
Premium pricing with small order volumes across many suppliers – lost opportunity for volume purchases and commodity line grouping
Protracted procurement process to find correct part number, supplier, and alternatives
Lost opportunity to sell obsolete items while they still have value to someone

Data Cleansing and Optimization Issues for MRO Inventory

back to the supplier or through eBay.

Prevention of New Duplicate Part Numbers: For the remaining rationalized part numbers, create an MRO parts catalog. Examine the business processes for creating a part number and assure that the preferred choice is in the catalog before creating a new SKU.

The benefits of MRO materials optimization include lower spending, reduced unit costs, less expedited delivery costs, and recovering obsolete inventory. Also, fewer stock-outs improve uptime. Optimization of this inventory should have a positive impact on the balance sheet and P&L statements – and your career.

Ralph Rio is the Research Director for ARC Advisory Group. His focus areas include Enterprise Asset Management, 3D Laser Scanning Systems, and Continuous Improvement Programs. Ralph has 35 years of experience with manufacturing applications, and he's been with ARC Advisory Group for 8 years. www.arcweb.com precision maintenance

sT skills training

Ron Gavrin

MENTORING PROGRAMS - Attract and Retain High-Quality Staff

Mentoring Background

What organizations today aren't challenged to attract and retain skilled knowledge staff? The aging work force is retiring, and the challenging economic climate is intensifying competition for the remaining staff. This situation is causing a resurgence of people-focused programs to mitigate the erosion of knowledge. Not least among these is the "ancient" art of mentoring.

Mentoring is indeed ancient. It was described in Homer's *The Odyssey*, and in fact, is named after Mentor, who was the advisor for Ulysses' son during Ulysses' long absence.

Mentoring is the activity of experienced staff (mentors) providing formal or informal guidance to less-experienced staff (mentees).

It is not "on the job" coaching by a supervisor, nor is it counseling to improve inadequate "on the job" performance (though these are often confused). Nor is the mentoring program discussed here an in-house apprenticeship program. It is assumed that an appropriate apprenticeship program is already in place, because this is essential to any technical operation.

Mentoring programs have remarkably similar characteristics even in very different business environments. They are fairly easy to set up and have demonstrated success in attracting and retaining key staff.

Mentoring Program Participants

Three key participants in mentoring programs are:

1. the mentor,
2. the mentee, and
3. the mentoring program manager.

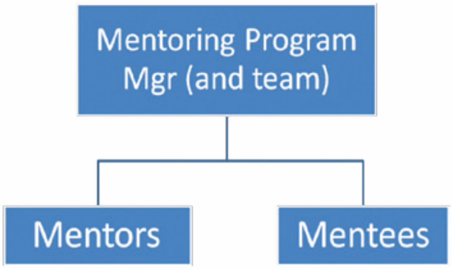


Figure 1: Mentoring program participants

The most commonly recognized trait of a great mentor is excellent listening. Equally important, mentors must mute their own egos so the mentees can express themselves freely.

The ideal mentee should be eagerly accepting of constructive critique. Also, somewhat surprisingly, it is the mentee, rather than the mentor, who should control the direction of the discussions.

The program manager ensures the smooth progress of the mentoring program. The manager must be aware of the beneficial aspects of the program, as well as the potential hazards. The manager has the most work and is responsible for the program meeting its deliverables.

Mentoring Program Life Cycle

Mentoring programs have a definite life cycle, with the following phases usually present, depending of the formality of the program:

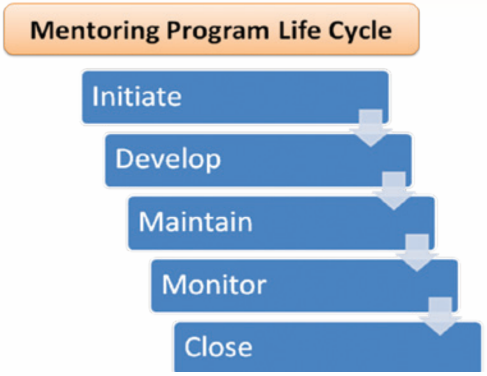


Figure 2: Mentoring program life cycle

Initiate:

- Determine program needs and documentation requirements and objectives.
- Establish process and documentation.
- Solicit participants and propose pairings based on application information.

Develop:

- Hold a kick-off meeting to introduce pairs and train participants in mentoring.
- Pairs complete documentation.

Maintain:

- At their first meeting, pairs establish the relationship basis and build trust.

- Pairs continue meeting throughout the established mentoring period.

Monitor:

- Mentoring pairs continually monitor progress against their objectives.
- The program manager monitors progress and arranges periodic group meetings so all pairs learn from each other.

Close:

- The manager holds a close-out meeting to review lessons learned and to help pairs formally close out their relationships.

Mentoring Program Characteristics

Mentoring programs are surprisingly similar; the main difference is the level of formality (i.e. documentation, structure).

The programs can range from very formal in rigid corporate/organizational settings to very informal professional "friendships" that develop between two members of an organization.

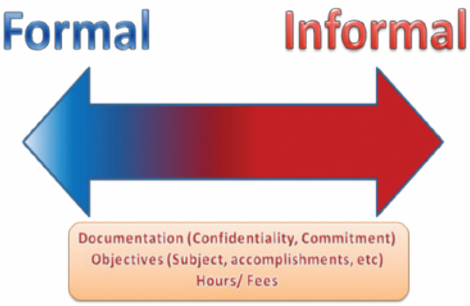


Figure 3: Mentoring program formality continuum

Mentoring Program Valuation and Risk

The benefits and costs of any program are based on how well the program addresses stakeholder objectives. If the program offers a high benefit, the host organization is more willing to invest more resources in the program. Therefore, it's important to understand the context and value of each mentoring program.

The benefits of a mentoring program can be based on many factors, which may include:

- Personnel with special skills, which are important to the organization's success.
- Retirement of an aging work force, increasing the value of the knowledge of remaining staff.
- Difficulty of obtaining special skills and knowledge (e.g., long studies, long job experience, etc).
- Increased competition for skilled workers in the industry/organization.
- Reduced interest in entering the industry. For example, young people may be less interested in entering the trades or certain industries, so more effort will be needed to attract and retain these staff.

The risks of a mentoring program must also be addressed:

- The program might fail to achieve its business objectives.
- The program could be tainted if mentors are seen to give bad advice.
- Discrimination or harassment issues could arise.
- The program could be branded as favoritism.

Conclusion

Whenever economic conditions enhance the value of staff with skilled knowledge, mentoring programs are viewed more favorably by their organizations. Mentoring programs are returning to popularity due to their success in attracting and retaining key staff. Therefore, today organizations are more willing to invest in mentoring programs.

Mentoring programs are easy to set up and have common features. Although not all steps and documents are needed in all mentoring programs, there is a surprising similarity among different programs.

In the past, organizations declared that their successes were based on their people. The best corporations, organizations, and governments now realize that their success does indeed depend on their people. In addition, the people themselves realize that their value can be enhanced through training, education, and competent guidance, so they are increasingly seeking out help in these areas and investing their time to improve themselves.

The more everyone sees the benefits in mentoring programs, the more they are prepared to invest in these programs. In fact, for executives on a fast track, there is even a growth industry of paid mentors who have themselves demonstrated executive success.

In this economic climate, knowledge-based organizations cannot afford to be without mentoring programs for their key knowledge staff.

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Eliminating Moisture Damage to BEARINGS on Critical Steam Turbines

John Harms and Chris Rehmann

Executive Summary

Mosaic Fertilizer, Louisiana Operations, produces phosphate fertilizer. Steam turbines are used as primary drivers (in place of electric motors) to utilize steam produced by waste heat generators. During normal operations, steam leaking past the carbon rings caused moisture ingress into the bearing housings that the OEM standard seals could not effectively stop.

Mean Time Between Repairs (MTBR) for the turbines was only 4-12 months with the OEM seals. Turbine rebuilds cost $35,000 and up.

Several seal designs were tried to exclude the moisture from the bearing housings, but none were successful.

Mosaic installed labyrinth-style bearing protectors designed specifically for steam turbines on a Terry GAF4 turbine. The results have been excellent, with zero water in the oil, and no repairs required over the last 24 months (and counting). Mosaic has selectively scheduled Labtecta retrofits for all steam turbines with chronic moisture lube oil contamination and is aggressively retrofitting critical acid service pumps and gearboxes that have root cause failures associated with lube oil contamination.

Labyrinth Bearing Protector Design

Labyrinth bearing protectors have been gaining popularity and replacing lip seals as the preferred form of sealing bearing housings at reliability-focused plants over the last 25 years. Recent design improvements have greatly improved the labyrinth seal's ability to contain valuable lubricating oil and to exclude moisture and other contaminants. The basic elements of any rotating labyrinth isolator are (a) a stationary portion that fixes to the machine housing and contains the lubricating oil, (b) a rotary portion that fixes to the shaft and excludes moisture and dirt, and (c) a "shut-off" mechanism that seals the oil chamber when the machine is stopped, but that allows the air in the oil chamber to expand outward during operation. The basic design of a rotating labyrinth bearing protector is shown in Figure 1.

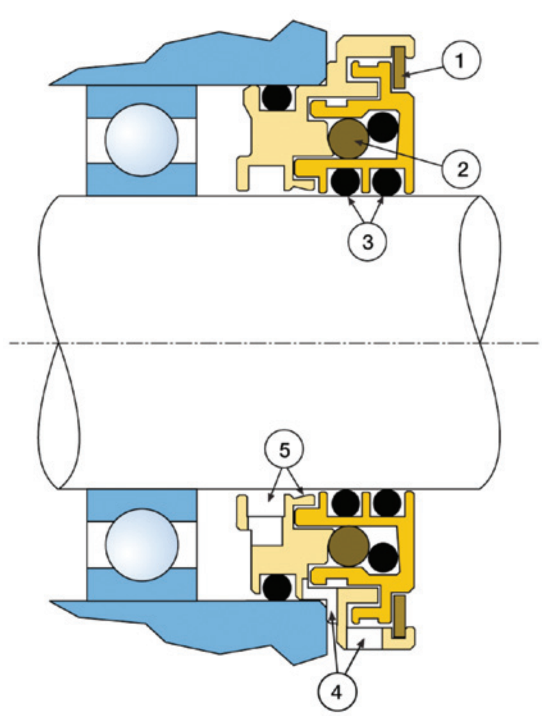


Figure 1: Modern rotating labyrinth bearing protector (diagram courtesy of AESSEAL, Inc)

5 important design features:

1. Removable/replaceable ring for easy field-refurbishment,
2. Two shut-off O-rings that land on a smoothly-contoured surface,
3. Two drive O-rings on the shaft providing better drive and more stability,
4. Two water expulsion ports, and
5. Two oil-retention mechanisms.

The seal in Figure 1 is widely used on pumps, motors, gearboxes, fans, pillow-block bearings, etc. This design has been adapted to fit the narrow space envelope and special operating conditions of a steam turbine, as shown in Figure 2. You can see that this seal also utilizes two drive O-rings, two shut-off O-rings that seal on a smooth surface, and easy refurbishment capability. But the steam-turbine isolator has two unique adaptations as shown in Figure 2. First, a ring of graphite packing has been placed on the side nearest the steam to help protect the Aflas O-rings from the intense heat. Second, the design of the rotating unit has been changed to create a "steam deflector" that repels the impinging steam.

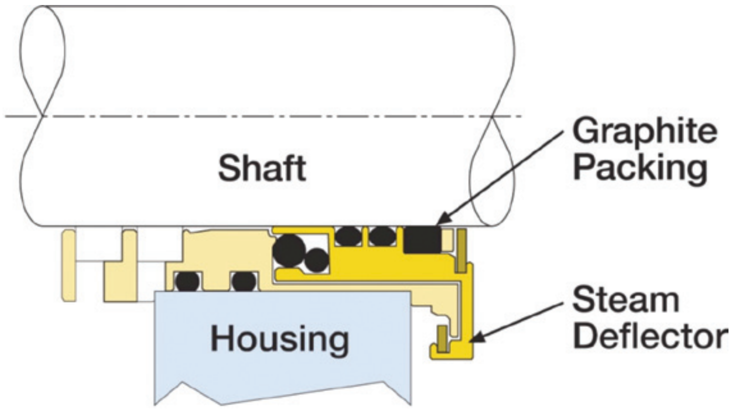


Figure 2: Modern rotating labyrinth bearing protector design for a steam turbine (courtesy of AESSEAL, Inc).

Figure 4: Steam turbine bearings operate in a difficult steam-laden environment.

The Problems With Steam

Like many other types of rotating equipment, steam turbines have bearings that support the axial and radial loads. These bearings must be properly lubricated in order to achieve L10 life cycle. Turbine bearings are exposed to high temperatures, high transient thrust loads, long states of idle readiness, and a moisture-laden environment. These are severe operating conditions at best. Of all operating environments, the state of idle readiness introduces the highest level of contamination exposure to a turbine bearing and lube oil system because the rotor and, in most cases, lubrication system are in a static state while live steam leaks past the carbon shaft seals. As the steam makes its way past the OEM labyrinth bearing housing seals, which function properly only in the dynamic state (i.e. when the shaft is rotating), it condenses on the cooler inner surfaces of the bearing housing and collects in the sump. When the turbine is put in service, the bearings will fail prematurely due to moisture contamination. The location of the escaping steam can be seen in the turbine cross-section diagram of Figure 3, which shows the rather simple, stationary labyrinth isolators (in circles) that are provided by some OEM steam turbine manufacturers. Figure 4 is a photo of the actual environment a steam turbine operates in, which is literally a "cloud of steam."

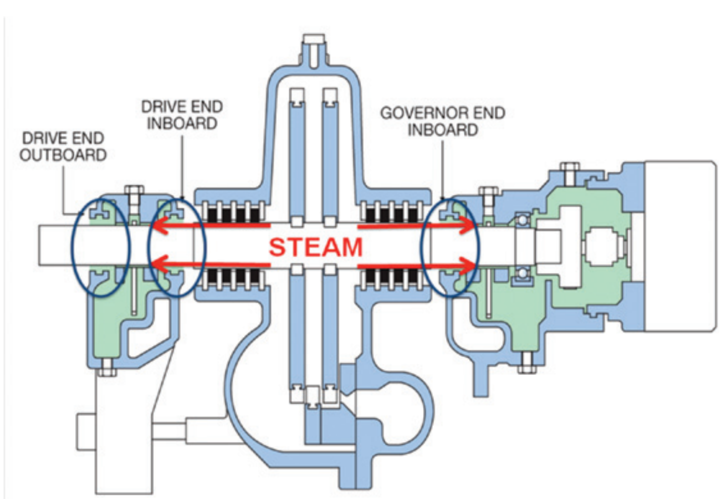


Figure 3: Cutaway diagram of a typical steam turbine, showing the escaping steam (red arrows) passing by the split carbon rings and simple OEM labyrinth seals (in circles), and entering the bearing housings.

Mosaic Fertilizer, Louisiana Operation's reliability engineer has studied MTBRs and performed root-cause failure analysis on a wide range of rotating equipment failures (turbines, pumps, gearboxes, trunions, etc), and concluded that bearing failures were frequently caused by lube oil contamination that was the result of the steam in the operating environment entering the bearing housings (see Figure 5).

Mosaic Faustina Ammonia Plant's Terry GAF4 steam turbines were suffering from water contamination of the bearings, leading to an MTBR of as little as 4 months. This had been a chronic problem for the last 40 years. Just replacing the bearings on this turbine costs $14,000. A full turbine rebuild costs about $35,000. An emergency rebuild in August 2010 of an Elliott EPG-4 turbine & 90P single-stage compressor due to water-related failure cost over $300,000. A solution was needed to stop this frequent and expensive damage.

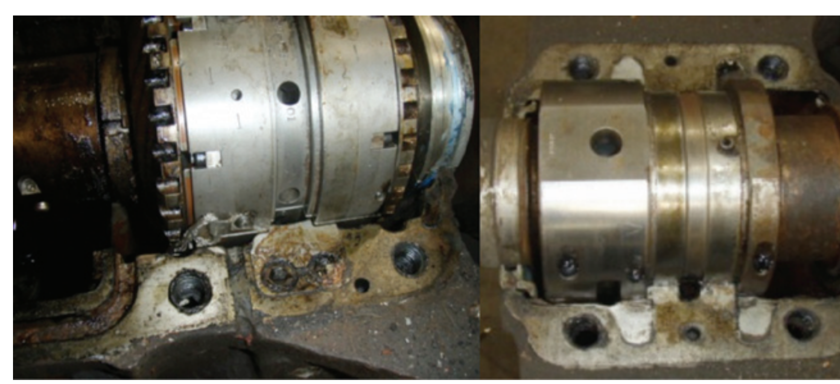


Figure 5: Photo of thrust bearings (left) and drive end bearings (right) after one year of service with inadequate bearing protectors. Note severe corrosion. (Photos courtesy of Mosaic Fertilizer.)

To reduce the ingress of moisture, and improve the MTBR of the turbine bearings, Mosaic attempted the following modifications:

- Tighter running clearances of the OEM labyrinth seal;
- Air buffer porting;
- Low pressure reducing baffle;
- Instrument air purging the oil reservoir, to prevent ingress of moist air;
- Nitrogen purging the oil reservoir, to prevent ingress of moist air;

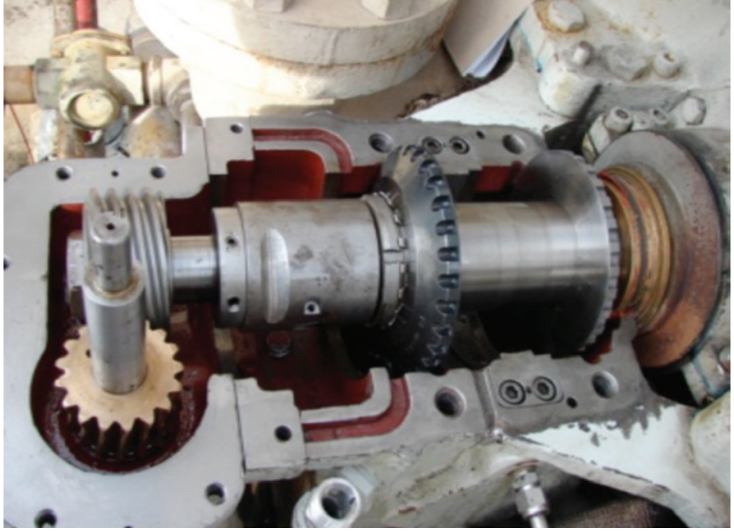


Figure 6: Pristine condition of the thrust bearing side after one year running with modern labyrinth isolators. (Photo courtesy of Mosaic Fertilizer.)

- Desiccant vent filters, to dry the air entering the housing;
- Vent check valves, to allow one-way flow of air from the housing; and
- Synthetic lubricants, with improved moisture separating qualities.

None of the above modifications were completely successful.

Several well-known after-market bearing isolators were then investigated and tested. Most labyrinth isolators showed some improvement over the OEM seal, but none fulfilled all of Mosaic's requirements (i.e. no oil leakage out, and no water entry in).

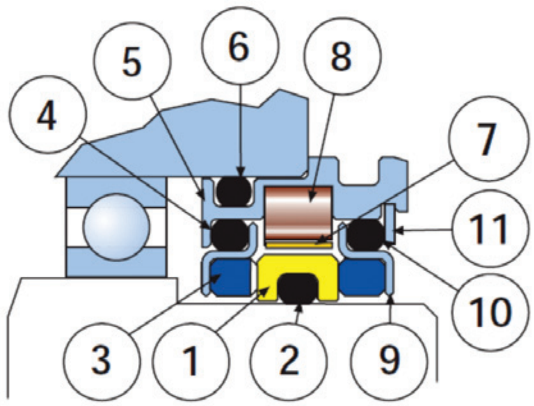
The Solution to the Problem

In July 2008, a set of 3 Labtecta bearing isolators (Figure 2) were installed on a Terry GAF4 turbine. The cost for these isolators was $2,400. This turbine is still running fine after 24+ months, and Mosaic estimates that for this initial investment in state-of-the-art bearing protection, it has avoided at least three turbine repairs over this time period, for a total savings of $100,000. This results in a ***payback period on the initial investment of less than THREE WEEKS,*** with ongoing ***savings of $50,000 per year*** thereafter. Weekly oil samples taken from this steam turbine with modern labyrinth isolators continue to show ***zero moisture in the oil***. Turbines with Labtecta isolators that are taken out of service for other reasons have no corrosion and pristine conditions inside the bearing housings (Figure 6).

Using an asset criticality matrix and tribology study, Mosaic's reliability manager identified turbine seal upgrades with the most profitable ROIC. In addition to steam turbines, Mosaic has also standardized on this bearing isolator design for all rotating shafts up to 3.00" diameter on pumps (Ash, Wilfley, Denver-Orion, GIW), gearboxes (Falk, Marley, Philly, Lightnin'), and trunions. Shafts over 3.00" diameter are evaluated by the Rotating Equipment Engineer on a case-by-case basis. Bearings that are lubricated with oil mist are sealed with a contacting face-seal, magnetically-energized type of bearing isolator (see Figure 7).

Conclusions

Steam/moisture entry into the bearing housings of steam turbines and other rotating equipment was a major source of costly bearing failures at this plant. The OEM bearing protectors were determined to be inadequate for the severe conditions surrounding steam turbines.



MagTecta™ Range Parts List

Item	Description	Material
1	Rotary Seal Face	Tungsten Carbide
2	Rotary Elastomer	Viton® / Aflas® / EPR / Kalrez®
3	Stationary Seal Face Assy	Ant.Car-S/S
4	Stationary Elastomer	Viton® / EPR / *Kalrez®
5	Outer Body	Stainless Steel
6	Outer Body Elastomer	Viton® / Aflas® / EPR / Kalrez®
7	Shroud	Phosphor Bronze
8	Magnet	Metal
9	Stationary Seal Face Assy	Ant.Car-S/S
10	Stationary Elastomer	Viton® / EPR / *Kalrez®
11	Circlip	Stainless Steel

* Items 4 and 10 are available in Kalrez® from inventory.

Figure 7: Magnetically-energized face-seal bearing isolator used on API 610, 10th ed. oil mist applications at the Mosaic River plant (courtesy of AESSEAL, Inc.).

Mosaic River tried numerous housing design and lubricant changes to eliminate or at least minimize the effect of the water in the oil. Mosaic investigated and tested a number of different bearing housing seals and isolators and standardized on the modern labyrinth design shown in Figure 1 for its pumps and gearboxes, and Figure 2 for its steam turbines.

The payback period for a set of three labyrinth seals for one steam turbine was less than three weeks, with documented savings of $50,000 per year per turbine afterwards.

Labyrinth seals installed in July 2008 are still running fine as of the time of this writing, 24+ months later. Turbines that contain labyrinth seals and that were torn down for other reasons show absolutely pristine condition of the bearings and bearing chambers.

Oil samples are taken from the turbines and evaluated weekly and show ZERO water in the oil on steam turbines that have modern labyrinth isolators installed.

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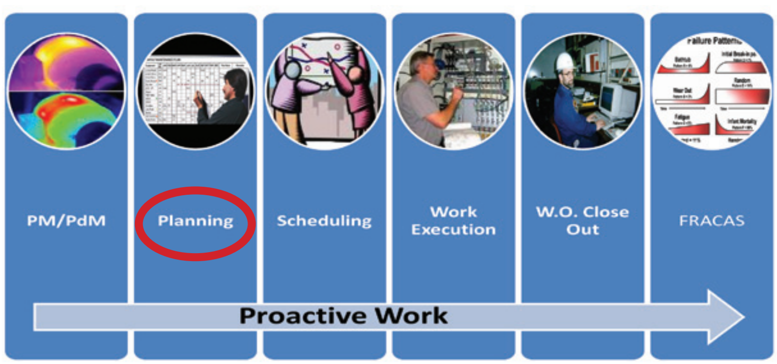
John Harms is Reliability Engineer at Mosaic Fertilizer, Louisiana Operations, Faustina, LA. He has 2 years of oil & gas industry field maintenance experience and 34 years of maintenance experience.

A Day in the Life of a Proactive Maintenance Planner



"Without Proactivity in this Process, Chaos Will Dominate"

Ricky Smith and Jerry Wilson

Where does proactive work come from?

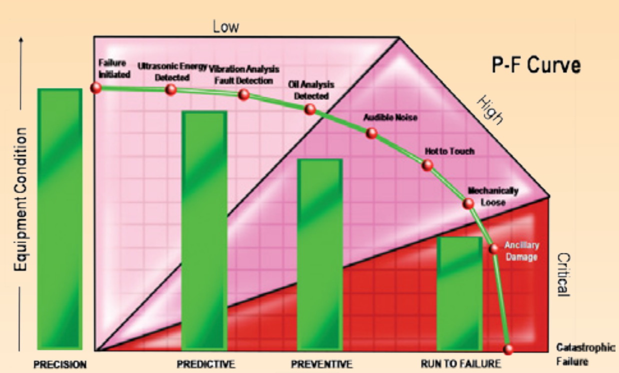
Proactive work orders or requests come from an effective preventive maintenance and condition monitoring program. Here is how it breaks out:

PM Execution: 15% of Work
Results from PM Execution: 15% of Work
(Typically identify Functional Failures)

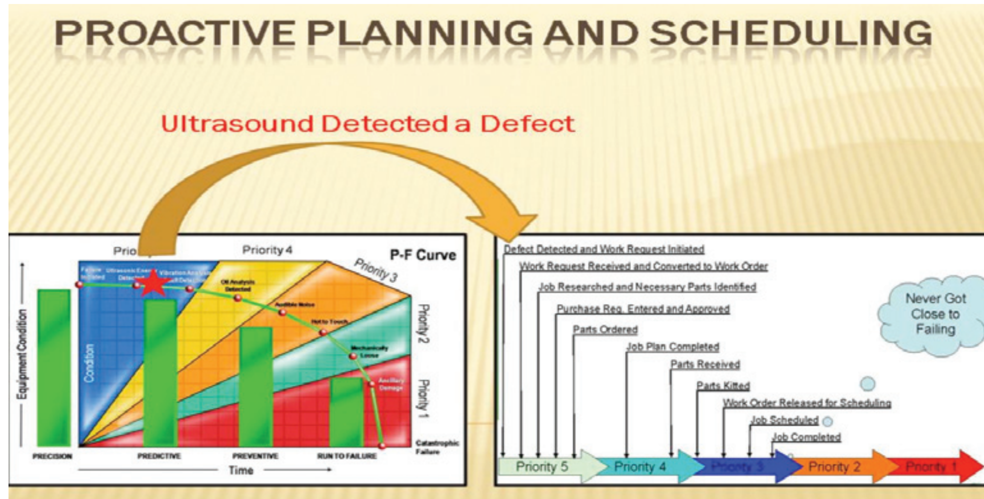
A Functional Failure (High or Critical Defect Severity – very little, if any, time to plan and schedule proactive work) is the inability of an item (or the equipment containing it) to meet a specified performance standard, and is usually identified by an operator.

Condition Monitoring Execution: 15% of Work
Results from Condition Monitoring: 35% of Work
(Typically identify Potential Failures)

A Potential Failure (Low Defect Severity - time to plan and schedule proactive work) is an identifiable physical condition that indicates a functional failure is imminent and is usually identified by a maintenance technician using condition monitoring or quantitative prevention maintenance.



PM Vs CBM



Notice that the planner has not had any involvement in work that is underway, and almost all of the planner's activities have been directed toward work that will leverage his/her time.

Prior to the Beginning of the Maintenance Day Shift:

The maintenance planner's day starts before the regular maintenance day shift in order to review the work orders that came in overnight. The planner will make an estimate of the man-hours, number of personnel, and craft types needed for any emergency work orders that must be started that day, then move those work orders directly to the maintenance crew, followed by a quick phone call to notify the maintenance supervisor responsible for that area of the plant. The planner will also code these jobs as emergency work orders so the level of this type work can be tracked over time. Well-disciplined proactive maintenance strategies (PM/CBM) coupled with effective planning and scheduling will make these emergency jobs fewer and fewer over time.

The planner should also use good planning and scheduling techniques on his/her own responsibilities. Once any emergency work has been estimated and sent to the maintenance crew, the maintenance planner will plug new work requests into his/her field inspection schedule. Some jobs may need to be worked into the current day's field inspection schedule in order to be put on the next day's maintenance schedule. Other new requests can be scheduled for field inspection and planning later in the week. It is important for a proactive planner to schedule all of his/her jobs (other than emergency work) for field inspections on a particular day to be most effective. The planner will also set the planning status for these new requests to "Planning," to show planning is underway.

Early Morning:

Field inspections: Armed with an inspection schedule, job inspection forms, and a camera, the planner will begin making his/her inspection of all of the job sites. The planner has established a logical route to minimize travel time and will make notes of the specific needs of the requests, any ancillary work that should be completed by the mechanics while at the job site, and all of the other applicable information required for a well-planned job. The planner will make note of the complexity and predictability of the various issues relative to a particular job in order to create an effective job plan suited to the particular job. Also, the planner will pay particular attention to job issues where significant delays were identified in the wrench time study. Understanding and watching for complexity, predictability, and likely wrench time losses will enhance the likelihood of creating a job plan that will minimize delays during execution and result in a high-performing work force. More on these topics can be found in the 3rd edition of *Planning and Scheduling Made Simple*, by Smith and Wilson.

Immediately after completing field inspections is a good time to start ordering parts, or at least creating a list of parts to order, depending on the time available before meeting with the supervisor, scheduler, and maintenance coordinator. At this point in the process, it is not known when the job will actually be scheduled, so any parts not on site should be ordered on the same day they are identified as a need. In particular, identifying the parts that will require more than 24 hours to obtain will be important. These parts should also be ordered that day, and the status should be changed to "Waiting for Parts." Parts that are available from the storeroom should be put on reserve so they will be available for ordering the day before the job is scheduled for execution. The planner will also need to review the status of parts previously ordered and update the status to "Ready to Schedule" on the work requests where all parts have arrived and storeroom parts are all on reserve. Some organizations go ahead and have storeroom parts delivered and placed in parts kit boxes for each job. This process can work fine, but when jobs get pushed to the future for execution, you can end up with a lot of parts kits to keep track of, or you can end up sending some parts back to the storeroom if jobs get canceled. If you have a firm parts reservation system, it will be best if the parts are put on reserve so they can't be brought out for a different job, yet if a job gets cancelled, they don't have to be returned. Less handling and better inventory accuracy provided by the reservation approach will reduce costs.

Working from the job inspection form, the planner will identify the various needs required by the jobs and will start documenting the job plan. First and foremost is the job summary page, which will contain the basic information that a fully qualified mechanic who is very familiar with this type of job would need. The job summary would provide reference numbers to the detailed information for the job that would follow in the job plan. This type of job plan format will allow those familiar with the task to quickly review the job using only the summary sheet. Anyone less familiar or skilled would have references on each item on the job summary sheet to the specific section of the job plan to access the specific information

All of the planner's free time should be spent refining and permanently documenting job plans.

they need. This provides maintenance personnel with quick access to the information they need without having to read through information they don't need. See more on this in *Planning and Scheduling Made Simple*, 3rd edition, by Smith and Wilson.

All of the planner's free time should be spent refining and permanently documenting job plans. As the planner's job plan database grows, he/she will have more plans that can be used on future jobs with only minor refinements. This will allow the planner to plan for a greater number of field maintenance personnel. As job plans are completed, the planner should update his/her backlog status to "Planning Complete." When all parts not available through stores have been received and the storeroom parts are on reserve, the status should be changed to "Ready to Schedule," assuming the job plan has been completed. The scheduler will initiate the delivery of storeroom parts on reserve the day before the job is scheduled for execution.

Late Morning:

Now armed with the information gathered during the field inspection route, processing parts needs, and updated status reports on jobs that have received some or all of the parts ordered, the planner should meet with the maintenance supervisor, scheduler and coordinator. The planner should bring a copy of the updated planning backlog. This meeting should be short, 30 minutes or less, and its purpose is two–fold: 1) provide preliminary info to those who will be building/amending the maintenance schedule, and 2) ensure that the planner has scheduled the various jobs in his/her queue in a manner consistent with the needs of maintenance and production. The planner should share parts issue updates and the schedule for his/her planning activities. Any other major restraints, such as boom truck, crane needs, or other special needs for particular jobs, will need to be communicated. This will provide maintenance and operations with important information that will allow them to start planning for when particular jobs will be ready for placement in the maintenance schedule. This meeting will also allow maintenance and operations to provide feedback to the planner on any changes that need to be made to the planning schedule. For example, the planner may have a particular job on schedule for planning to be complete and have "Ready to Schedule" status by next Tuesday, when, in fact, production needs it earlier or later.

Early Afternoon:

Immediately after lunch, the planner will continue writing job plans, researching technical issues for particular jobs, obtaining approval for jobs meeting specific criteria, referring other jobs to engineering for redesigns as applicable, and updating the status of the requests as appropriate.

Each day, the planner should designate a small amount of time for reviewing the feedback from mechanics on jobs recently completed. This is an important step for the planner to be able to improve the effectiveness of the plans he/she creates.

Late Afternoon:

An hour or so before the daily scheduling meeting, the planner should review his/her email account and phone messages to see if there have been any late changes to the general plan that has been forming for the next day's schedule. This information may have impact on the job summary sheets the planner takes to the scheduling meeting.

The daily scheduling meeting is not a meeting where the planning backlog will be reviewed and jobs will be selected for scheduling. Because the planner meticulously keeps the status of all jobs updated, and because of the late morning meeting between the planner, scheduler, maintenance coordinator, and the maintenance supervisor, the schedule has inherently been forming on its own. The daily scheduling meeting is where the weekly schedule will be either confirmed for the next day or slightly amended to respond to higher priority needs that presented themselves after the weekly schedule was made. Also, changes may be made to other days, depending on needs and planning status of the jobs. This meeting should take 30 minutes or less if each role has prepared in advance and communicated effectively with the other players as needed. The meeting's purpose is only to finalize what they have already been discussing and working toward since the previous day's daily planning meeting.

After the daily scheduling meeting, the scheduler will change status of any work orders that are to be added to the maintenance schedule and will order all parts that are on reserve in the storeroom. Following the daily planning meeting, the planner will amend the field inspection schedule and make any adjustments necessary to the overall planning schedule.

The planner will need to update any measures the organization tracks relative to planning, such as man-hours planned and emergency man-hours per day.

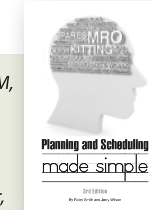
End of the Day:

The planner will make a quick review of the entire Planning Backlog:

- Is the job status up to date on all jobs?
- Is the field inspection schedule for the next day ready?
- Have all parts coming from off-site been ordered, and have parts available from the storeroom been placed on reserve for jobs that have been inspected?

Conclusions

Notice that the planner has not had any involvement in work that is underway, and almost all of the planner's activities have been directed toward work that will leverage his/her time. The only exception to this should be the small amount of time it took the planner to make a quick labor estimate on emergency work. A planner that follows this type of rigor can be assured that he/she is leveraging the entire maintenance crew by his/her efforts and helping to propel the organization to a more proactive state where emergency work and unexpected failures are the exception. This job requires discipline and patience as the transition from reactive maintenance to proactive maintenance occurs.



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Quantifying Financial Benefits from an Asset Performance Initiative

Asset performance improvement initiatives that are based on an increase in asset reliability are an excellent way to maximize financial return from your assets. These initiatives provide significant and sustainable benefits for relatively low financial investments compared to their capital expenditure alternatives. This white paper describes how to quantify these financial benefits, as well as the possible metrics to use in managing the initiative. The paper includes a number of examples where such benefits have been achieved and provides a normalized compilation of results from work performed over the past 10 years.

Reliability Improvement Initiatives: Proven, Rapid, and Sustainable Results

Paul Lanthier

Introduction

Industry is forever searching for ways to maximize financial return from its physical assets while responding to ongoing market changes and social requirements. As a result, the average system undergoes 30 to 50 physical and operational changes per year. This represents significant capital expenditures for most organizations. Unfortunately, most organizations do not achieve a measurable improvement in their asset performance from year to year despite these efforts.

"Insanity is doing the same thing over and over again and expecting different results."
Einstein

There is an alternative: asset performance enhancement through a reliability initiative. Comparatively, reliability initiatives are much less expensive than capital projects and drive the culture change that is more apt to ensure sustainability, as they include improvements to systems and processes. They also provide a continuous improvement stream that leads to an increase in benefits beyond the project phase.

As with all projects and initiatives, reliability improvement initiatives need to be managed and therefore measured. The measures and expected results should be defined up front and used to scope out the initiative and track success. Asset reliability strategies can help increase asset performance and asset life, reduce safety and environmental incidences, and reduce costs. For example, ArcelorMittal Mine Mont-Wright was able to reduce the operating cost of its haul truck fleet by 8.6%, more than double the fleet's useful life, reduce the number of safety related incidences, and cut costs by over $7,000,000 per year.

"Your systems (and processes) are perfectly designed for the results you are getting."
Deming

When embarking on a reliability improvement initiative it is essential to quantify the potential benefits; define and apply a suitable strategy that incorporates process improvements, best practices, and technology; and establish, measure, and communicate the success metrics. This document defines the typical measurable financial benefits, gives a guideline to establishing KPIs, and provides a compilation of ten successful reliability projects, as well as specific details on five unique reliability initiatives. Examples are described throughout the paper, but care has been taken to scrub out confidential information.

"To mange you must be able to control and to control you must be able to measure."
Drucker

Quantifying the Anticipated Benefits

We've grouped the benefits derived from reliability-focused asset performance improvement initiatives into four categories: increase in Overall Equipment Efficiency (OEE), Conversion Loss Reductions (CLR), Maintenance Cost Reductions (MCR), and Indirect Cost Reductions. Following are definitions of each with examples:

- The **Overall Equipment Efficiency (OEE)** equates to availability x quality x machine speed. Increases in asset management efficiency and effectiveness translate into increased asset availability, better quality results, and the possibility of increasing machine speed without penalizing the first two. The result is an increase in production throughput.

  In this example, the anticipated benefits were based on the paper machine's current OEE results, failure history, benchmark data, and technical limit. Market and operational losses were factored out. A 3.7% increase in OEE was anticipated and deemed to be well within the possible. This represented a $3.3M/year operational gain.

Paper Machine #5	Last 12 Months	Benchmark	% Attributable to Equipment Condition	% Gains Targeted by this Initiative	Gain Targeted by this Initiative
OEE (Technical Limit: 95.2%)	**81.6%**	**92.3%**			85.3%
Uptime	89.3%				
Scheduled Maintenance	1.0%	1.4%		100%	2.5%
Unscheduled Maintenance	3.1%	0.7%		60%	-0.4%
Pulp Supply Shortage	0.1%		70%	60%	1.4%
Steam/Air Shortage	0.0%		100%	60%	0.0%
Downtime due to Electricity Shortage	0.6%		0%	60%	0.0%
Couch Breaks	0.0%		100%	60%	0.0%
Press Breaks	3.0%		50%	60%	0.9%
Dryer Breaks	0.1%		50%	60%	0.0%
Calender Breaks	0.7%		60%	60%	0.3%
Reel Breaks	0.3%		100%	60%	0.2%
Ropes	0.2%		70%	60%	0.1%
Quality	91.9%				1.5%
Cull Losses	2.2%		50%	60%	0.7%
Slab Losses	1.7%		50%	60%	0.5%
Unaccounted Losses	1.1%		50%	60%	0.3%
Speed	99.4%				0.1%
Speed Losses	0.6%		50%	25%	0.1%

- **Conversion Loss Reductions (CLRs)** include the excess use of energy, water, and consumables due to inefficiencies in the process caused by poorly functioning equipment and/or consumed while the equipment was not used. CLRs also include the quality loss component of OEE (the benefits must not be counted twice). Quality losses include both the scrapping of the product and, when applicable, the cost to rework the product. In this example we anticipated reducing scrap levels (shrinkage) from 4.2% to 2% for an annual saving of $300K. In this mining site, the ball mill continues to turn and uses energy during line stoppages.

  We were able to calculate the amount of hours where the line was stopped due to failures of some line equipment. A 70% reduction was considered plausible and represented a $30K/year saving in energy.

  Lime is used in the production of kraft pulp. When the kiln is down for whatever reason, lime needs to be purchased. At this particular site, the company purchases $150K of lime per year, and 100% of this is due to kiln failure. At an improvement target of 60% this represented $90K/year.

Reduction in Quality Losses for Bottling Line 2

	Value	Unit
Total Units Produced	1,200,000	hectoliters
% Shrinkage	4.20%	%
Total Units Scrapped	50,400	hectoliters
Cost per Unit	$12	$
Shrinkage Targeted	2%	%
Gain Targeted ($)	**$316,800**	

When embarking on a reliability improvement initiative it is essential to quantify the potential benefits.

Reduction in Energy Usage per Year
UPG Ball Mill

	Value	Unit
Amount of Energy Used	$4,215,649	$
% Used due to Equipment Failure	1%	%
Total Opportunity per Year	$42,156	$
Gain Targeted (%)	70%	%
Gain Targeted ($)	**$29,510**	

Reduction in Purchased Lime per Year

	Value	Unit
Amount Purchased	$150,000	$
% Purchased due to Equipment Failure	100%	%
Total Opportunity per Year	$150,000	$
Gain Targeted (%)	60%	%
Gain Targeted ($)	**$90,000**	

An effective asset care program translates knowledge into actionable information.

- **Maintenance Cost Reductions** are the maintenance labor and spare part consumption benefits achievable from an increase in maintenance efficiency and effectiveness.
  - ◊ Labor effectiveness is a result of how pertinent the tasks are to maintaining the asset operating at the required level of performance. An effective asset care program translates knowledge into actionable information and is comprised of activities that reduce the amount of "firefighting" needed to maintain the equipment. This is often referred to as proactive work and is made up of predictive, scheduled restoration; scheduled discard; and state monitoring tasks. This same program must also minimize the amount of non-value-added work that is performed. The organization maximizes effectiveness by ensuring that it performs "the right work at the right time." In a world-class environment 85% of asset care activities are proactive with no more than 5% being non-value-added work. The labor impact of moving from reactive to proactive work is based on the estimate that reactive work takes three times longer to accomplish compared to proactive work. As it takes effort to be more proactive, a shift from reactive to proactive usually translates into a 20% to 25% reduction in maintenance effort.

    In this area of a metal refining plant, we targeted a shift from 30% proactive to 60% proactive, for a reduction in the maintenance effort of 4600 hours per year.

    Material usage on work converted from reactive to proactive will also drop by a factor of 2 to 4. In this case we anticipated a savings of $140K/year in consumed parts.

    In this site we moved from 35% to 25% PM; world class is 20%. This represented an annual saving of 23,000 hours.

    Combined with the rest of the effectiveness gains, the plant can move to a ratio of 25% PM, 50% proactive corrective work, and 25% reactive corrective work.
  - ◊ Labor efficiency of the reliability process is a result of how well we plan, schedule, and support the execution of the asset care activities. This can be related to the percentage of work planned and scheduled and the percentage of available time that is wrench time. Efficiencies come from adherence to the reliability process, the implementation of easy to use systems, access to enterprise-wide information, and standardization of repetitive tasks. The identification and reduction of work inefficiencies translates into more available manpower and less equipment downtime due to maintenance activities. World-class objectives are 85% planned and scheduled and 60% wrench time.

    In this plant a shift from 40% to 70% planned and 35% to 45% wrench time represented a 6,000-hour reduction in maintenance effort.

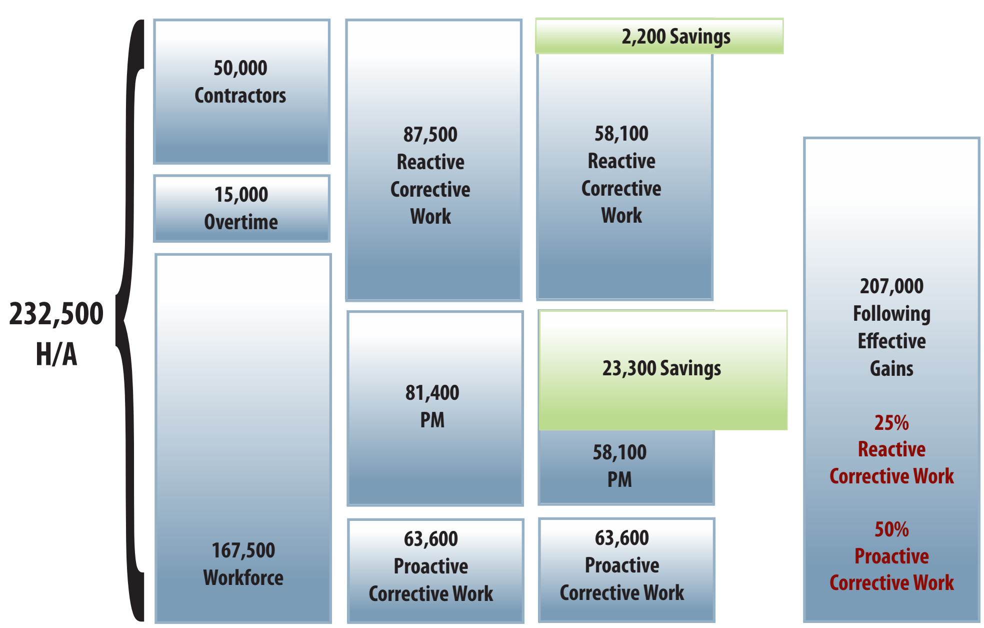
Efficiency and effectiveness are closely linked, as effectiveness is about doing the right work while efficiency is about doing the work right. Therefore, a more effective organization will be more efficient, while a more efficient organization is better positioned to take advantage of the effectiveness strategies.

Reductions in Manpower Due to Improved Effectiveness

	% Proactive Work		Reactive Work	Potential Savings	
	Current	Target	Number of Reactive Hours (Current)	Hours Reduced When Target is Achieved	Manpower Reductions
Target	30%	60%	53,609	4,595	2.6
World Class		85%		8,424	4.8

Reductions in Parts Usage Due to Improved Effectiveness

	% Proactive Work		Reactive Work	Potential Savings
	Current	Target	Cost of Parts Used for Reactive Work	Reduction in Material Usage Once Target is Achieved
Target	30%	60%	$655,200	$140,400
World Class		85%		$257,400



Reductions in Manpower Due to Improved Effectiveness

	% Planned		% Wrenchtime		Potential Savings	
	% Hours that are Planned and Executed as planned (Current)	% Hours that are Planned and Executed as planned (Target)	% Wrenchtime (Current)	% Wrench-time (Target)	Hours Reduced When Target is Achieved	Manpower Reductions
Target	40%	70%	35%	45%	45%	2.6
World Class		85%		60%	60%	4.8

- The final benefits category is **Indirect Cost Reductions**. Indirect costs include such things as operator overtime, excessive spare parts inventory, demurrage charges and penalties, work in progress, excessive finished goods inventory levels, and capital expenditures. Some of these are directly impacted, but most require additional steps to achieve the benefits.
  - ◊ Reliability-related operator overtime reductions apply to operations that are market limited. That is, where the equipment is not used 24/7. A market limited production has spare capacity and staffs its operations according to demand. Equipment availability issues often require the organization to compensate by running the equipment during the scheduled non-production periods. This in turn creates a requirement for extra operators.

    In this example we projected a reduction of 420 hours/year in the number of operator overtime hours.
  - ◊ Spare parts inventory reductions require a spares optimization exercise before the benefits are achieved. This said, to be sustainable an inventory reduction exercise requires an efficient and effective maintenance organization, as this will increase part requirement visibility and provide proper part identification. World-class organizations have a parts inventory to replacement asset value ratio of 1 to 2%. At this site, we estimated that the inventory level will be reduced by $2M, for an annual saving of $340K.
  - ◊ Demurrage charges and penalties include penalties for late delivery or poor quality, penalties for not respecting government regulations such as environmental discharges, and penalties for breaching safety regulations. The latter two may also have a significant impact on people's lives. Reliability initiatives focus on mitigating the consequences of failure and have less probability of leading to transgressions.
  - ◊ Work in progress (WIP) and finish goods inventory are a significant source of cost for organizations, and initiatives, such as supply chain management and JIT, are used to minimize these levels. The strategy is to determine the right balance between carrying costs and the risk of not meeting customer demands. Improving asset performance through improved reliability increases the organization's confidence in its ability to meet demands. This in turn is a key factor in reducing WIP and finish goods.
  - ◊ Capital expenditures savings from a reliability initiative relate to improvements in the asset's performance through more efficient and effective maintenance. If the performance gains are sufficient to meet demands, the purchase of new equipment can be deferred or even eliminated. For example, ArcelorMittal Mines was able to extend the life of its 190T haul trucks from 50,000 to over 100,000 running hours.

Reduction in Purchased Lime per Year

	Value	Unit
Unscheduled Downtime	500	Hour
Excess Scheduled Downtime	200	Hour
Total Recoverable Downtime	**700**	**Hour**
Operator Overtime Cost per Hour	$125	$
Total Opportunity per Year	$87,500	$
Gain Targeted (%)	60%	%
Gain Targeted ($)	**$52,500**	

Inventory Reduction Savings

Current Parts Inventory to Replacement Asset Value Ratio	2.11%
Inventory Level Exceeding 1% of the Ratio	$3,900,000
Inventory Reduction Selected	$2,000,000
Carrying Cost	17%
Future Parts Inventory to Replacement Asset Value Ratio	1.54%
Savings	**$340,000**

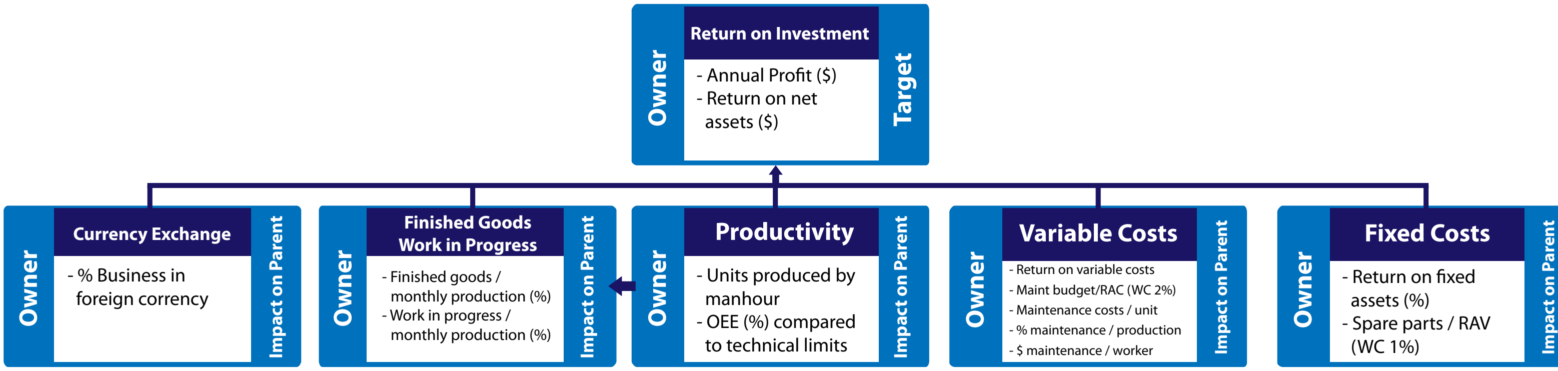
Using Key Performance Indicators

Key Performance Indicators (KPIs) are very popular. Most say they are a must, but unfortunately many organizations do not adequately benefit from their use. KPIs exist as a means of positively affecting results by affecting individual and group behavior. For KPIs to be effective, the results we are targeting must be in line with the corporate objectives, the targets selected have to be attainable, and a communication strategy must be in place to create awareness of the KPI with those whose behavior we are attempting to influence.

The six basic rules of KPI development are:

1. There must be an owner.
2. You must establish an aggressive, meaningful, and attainable target.
3. Impact on the parent KPI needs to be clearly defined.
4. The measuring method needs to be identified and should be as automatic as possible.
5. An action plan must be defined and agreed upon in the event that the target is not met.
6. There needs to be a communication plan in place prior to launching the KPI. The plan needs to include a regular review of the KPI.

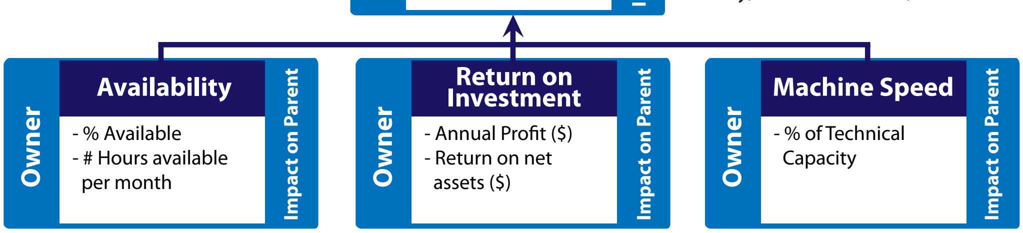
We've grouped the benefits derived from reliability-focused asset performance improvement initiatives into four categories: increase in Overall Equipment Efficiency (OEE), Conversion Loss Reductions (CLR), Maintenance Cost Reductions (MCR), and Indirect Cost Reductions.



The leading KPIs measure the process that will lead to the results. These can and should be managed.

KPIs are used to manage the process to ensure successful results. KPIs such as Return On Investment measure results of the process and in themselves cannot be managed. These are called lagging KPIs. The leading KPIs measure the process that will lead to the results. These can and should be managed. The relationship between the leading and lagging KPIs can be clearly defined, as shown in the following graphs.

As shown in the top graph, Return On Investment is impacted by Currency Exchange, Finished Goods, Work in Progress, Productivity, Variable Costs, and Fixed Costs. These in turn are impacted by lower order KPIs. Examples of possible KPIs for each grouping are listed in the boxes. Please note that the Finished Goods and Work in Progress levels are indirectly impacted by a reliability initiative and have a dotted line from Productivity. As the organization develops more confidence in its ability to meet market demands through higher, more stable Productivity levels, these can be reduced.



Each of the groupings can be subdivided many times, as shown in the two following graphs. The impact of each lower order KPIs on their parent KPI can be defined.

One of the factors that impacts availability is Maintenance-Related Outages, and this is impacted by Maintenance Efficiency and Maintenance Effectiveness. The latter is impacted by staffing, program quality and the proper use of technology.

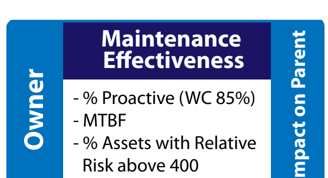
Further children groupings can be defined. In some cases the leading KPI may affect more than one parent.

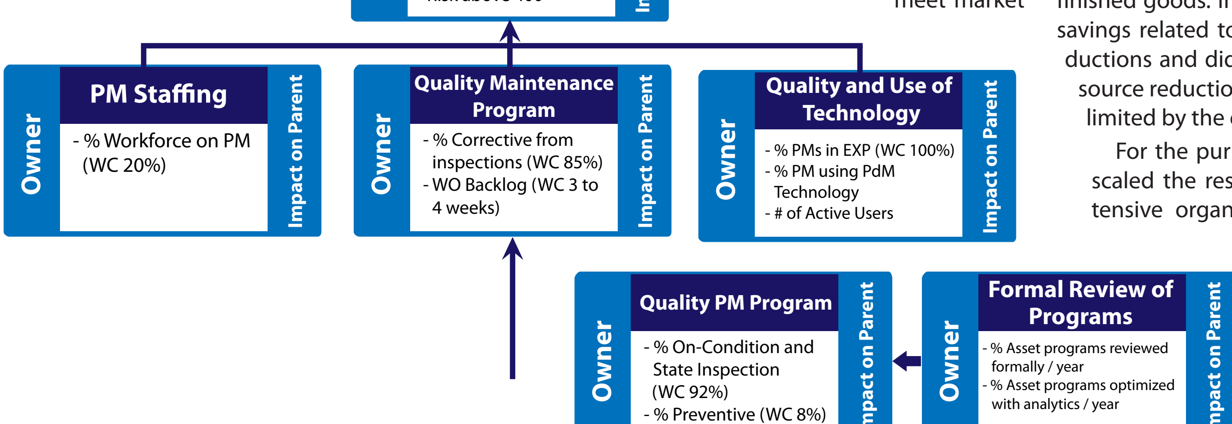
We should only define KPIs that impact the results we are trying to achieve and limit the number of KPIs to that which we can properly manage and communicate. A deluge of KPIs will only confuse people and reduce the overall effectiveness of the metrics. A progressive introduction of KPIs is always preferred.

Compiled Results

Unfortunately, few organizations will publish detailed information concerning their results, as this could help their competitors. Nonetheless, working closely with these companies we were able to quantify the benefits while ensuring anonymity through a normalization exercise. In turn, this provides an ideal model that can be scaled to fit your specific situation and organization. The following data does not include reduction in spares inventory, work in progress, or finished goods. In all cases, we only used labor savings related to contractor and overtime reductions and did not consider the internal resource reduction savings, as the latter is often limited by the existing union agreement.

For the purpose of this exercise we have scaled the results to represent an asset intensive organization with an annual production rate of $100M, a maintenance budget of $15M, and 90 tradesmen. This organization has 4 Planners, 6 Supervisors, 2 Maintenance Engineers, and 1 Maintenance Manager.





The cumulative benefits of an average 3-year reliability improvement initiative (normalized) are $8.6M by the end of year 3, and the cumulative costs (internal, external, and technology) are $2.6M, for a benefit to cost ratio of 3.3. An interesting fact of reliability improvement initiatives is that they start paying dividends early in deployment rather than once the project phase is completed.

The average breakeven on these initiatives was 18 months, and the initiatives continued to generate benefits once the project phase was complete. Post-project-phase annual gains/savings are $6.8M, with an annual cost of $200K. As a result, the organizations achieve a recurring benefit equivalent to 44% of the maintenance budget and 6.8% of the annual production rate. This data is a compilation of 10 sites, with extrapolations made where necessary.

These results do not take into account reductions in spares inventory, work in progress, finished goods, and internal resources through attrition. As well, reliability initiatives usually reduce the number of safety incidences, environmental regulation issues, and the overall risk. In two cases the organization was able to renegotiate its insurance policy based on a better asset management record.

Conclusion

Asset performance initiatives based on asset reliability improvements have helped many organizations maximize financial return from their assets. Benefits start early in the project phase, the cost is relatively low, and, when properly conducted, the results are sustainable. Quantifying these financial benefits before starting the initiative serves as a rallying point to ensure commitment from all levels of the organization and can be used to develop success metrics and KPIs. These in turn help to properly define and manage the initiative, ensuring the desired results.

But the benefits are much more than monetary. A reliability-driven initiative positively impacts safety and the environment and helps organizations manage their assets. On the latter point, Guy Boisé, Superintendent of Mobile Fleet, ArcelorMittal Mine, said it best: "Up to one and a half years ago I used to be called at home every night. In the last year and a half I have received zero calls. That's what reliability means to me."

Specific examples of four of our plants are available online at ***http://reliability.9nl.com/up3_ex/***

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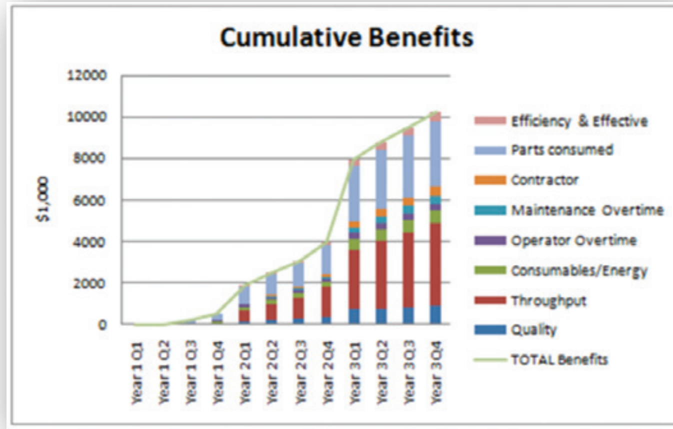
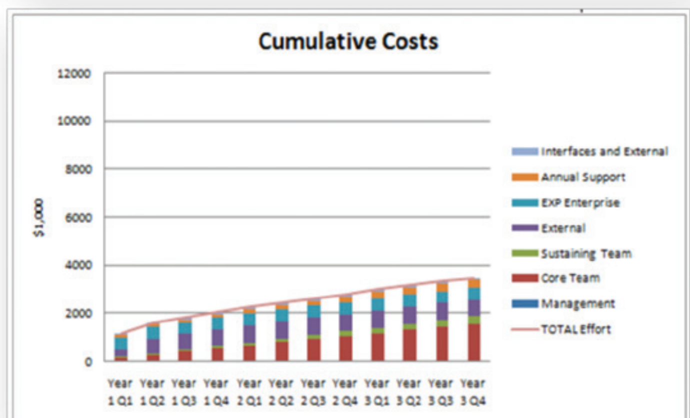
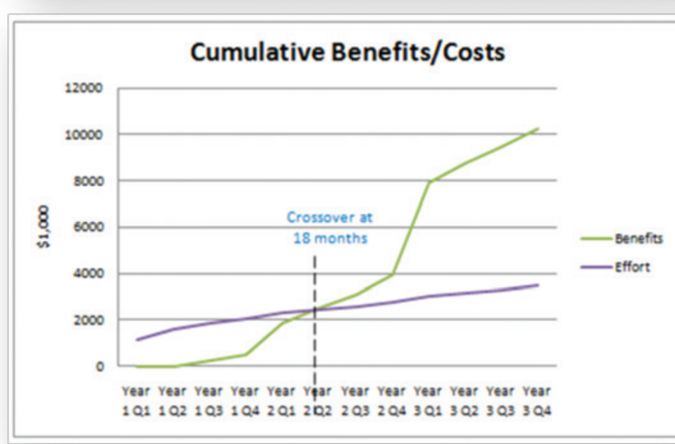
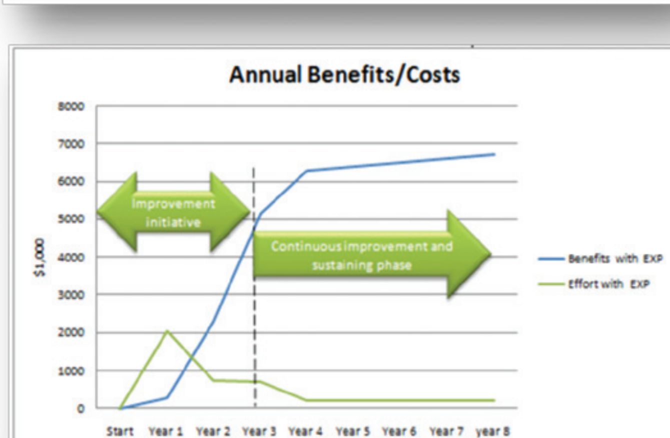








The benefits are much more than monetary. A reliability-driven initiative positively impacts safety and the environment and helps organizations manage their assets.

management

RL reliability leadership

Ron Moore

Lean Manufacturing – Are You Ready?

Innumerable books have been written about Toyota and their lean manufacturing practices. Literally thousands of companies have tried to emulate these practices, some with some short-term success, but most with little or no long-term success. Jeff Liker, author of The Toyota Way, ***at one point estimated that only about one percent of US companies are truly effective at applying lean manufacturing practices. Few achieve the high level of sustained performance embodied in lean manufacturing principles. Why is this?***

There are a multitude of reasons, but one need look no further than the Toyota House, which is a visual model depicting lean manufacturing principles. A simplified version of the model proposed by Jeff Liker in his book, *The Toyota Way*, is shown in Figure 1.

Now let's ask the question, "Are you ready to apply lean manufacturing?"

Before we continue, let's note that Just-in-Time has to do with having the right part, at the right time, in the right amount, while running the plant steady according to a particular pace or rate, and having continuous flow, where you use a pull system to make to demand. It also incorporates quick changeover for minimizing inventory requirements, while managing the use of equipment and integrated logistics. In-station quality has to do with things like making problems visible, stopping the process for any problems with quality, error proofing, and solving problems to root cause using simple techniques like 5 Whys.

I. The Foundation – Long-Term Thinking, Employee Engagement, and Process Mapping.

Of course any good strategy is built on a solid foundation. So, let's begin there, and ask some additional questions:

1. **Long-Term Thinking.** Is your company one that is characterized by long-term thinking, even at times at the risk of short-term profit? Or, alternatively, are you almost totally focused on short-term profit, even at the risk of your future?

Granted, you must cash flow the business in the short term. And, if you're publicly traded, meeting your quarterly goals and analyst's expectations are really critical to your share price. But is your company willing to occasionally miss a given quarterly forecast if it means longer-term growth and profit? Of course you wouldn't want to do this, and you may not have to do this, but would you be willing to do it? Just for argument's sake, let's give ourselves a score, with a 10 being that we're very willing and have, though rarely, actually sacrificed short-term profit for long-term gain and have actually realized the anticipated gain by making that decision. A zero means we'd never do that and are almost exclusively focused on this week, month, or quarter. Yes, we have one-year and five-year plans, but those are hopes and dreams, and we don't pay them much attention when we run into a slight bind in meeting quarterly estimates. Most companies, I think, will be somewhere in between. Give yourself a score.

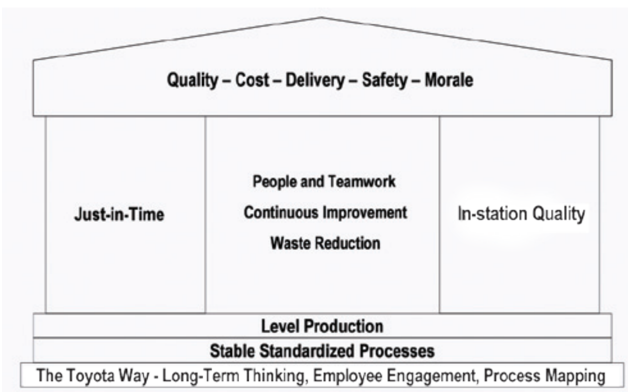


Figure 1: The Toyota production system

Do you routinely map your processes (production, engineering, maintenance, marketing and sales, procurement, accounting, etc.) to understand how things happen in your company, where you're incurring waste, and where you're adding value?

2. **Process Mapping.** Do you routinely map your processes (production, engineering, maintenance, marketing and sales, procurement, accounting, etc.) to understand how things happen in your company, where you're incurring waste, and where you're adding value? Are you encouraged to think at a systems level regarding the impact a decision in one area has on another area and on the entire business? Let's give a 10 to those who do this well and do it routinely, and a zero to those who don't do it at all. Most will be in the middle somewhere.
3. **Employee Engagement.** Do you have various processes for engaging your employees? For example, do you have routine structured improvement time, using the appropriate tools for that improvement (tools like kaizen, 5S, 5 Whys, RCM, TPM, and so on)? Are people fully trained in these improvement processes and tools? Are your employees fully trained in their jobs, including requiring specific demonstration of the skill to do each task before going to the next level of skill? Is there a personal development program for each employee? Has it become a routine expectation that they will be called upon to do problem solving? As I've always said, if you want to know where the problems are with the work being done, ask the people doing the work, and get them to help you improve the work, and you'll get ownership and so-called engagement. Let's give a 10 to those who are doing all these things exceptionally well, and a zero to those who aren't doing any of these things. Give yourself a score.

II. The Next Level – Stable, Standardized Processes.

To apply the principles of just-in-time, having the right part, at the right time, in the right amount, you must have stable, standardized processes. Stability of course would include equipment reliability. Otherwise, you'll need lots of inventory and other counter measures to compensate for the instability in your system. Figure 2 provides a model that we'll use to describe various issues around stability.

In this model, production flow is going to the right, while demand flow is coming from the left. Balancing precisely the variability of production flow with the volatility of demand flow is difficult at best. A lack of product to deliver in a timely way can result in lost sales and profits and/or unhappy customers who seek other suppliers. Too much product represents waste in the form of excess inventory, working capital not working, and that same inventory incurs additional inherent costs for storage, potential damage, hidden defects and scrap, deterioration with time, and so on.

In between processes we often have delay times for one reason or another. For example, it may be that upstream supply has been disrupted because a process has unexpectedly failed, or an operator didn't show up for work, or there are raw material problems related to quality or quantity. For many of the same reasons, it's also likely that we have inherent variability in each individual process in terms of daily quality output from that process. Note the variation in daily output for each step in the process shown. Top all that off with several different products, or so-called stock keeping units (SKUs), and it results in lots of complexity to manage and still meet a typically volatile customer demand. We manage all these delays and variability by keeping buffer stocks: extra raw material, work-in-process (WIP) between processes, and finished goods, along with extra spare parts, overtime, extra people, and so on. The greater the variability, induced by lack of stability and equipment unreliability, the more counter measures that are needed, and the less likely it is that you will be able to use the just-in-time approach. Indeed most folks are in the "just-in-case" mode, because they don't have stability.

Some have decided to expose these problems by reducing inventory, to "expose the rocks" so to speak, only to then run squarely over the rocks and nearly sink the boat. It's important that we take a balanced view on the reduction of inventory. Some problems are known to us without having to reduce inventory. For example, if production planning changes the production schedule daily, or even shiftly, to suit sales demands, or if equipment and process failures occur frequently, we should not reduce inventory before addressing those problems. We also need level flow in production, a key lean principle. As we address those problems, we will get better stability and can confidently reduce inventory and still meet demand.

So, how stable are you? How ready are you to support level flow and making to demand, and thus able to support lean principles? Let's score ourselves on this one as well.

1. **Production Planning.** How often do you change the production schedule in a significant way, such that you require significant changes to raw material, equipment set ups, or inventory planning? Granted, this may vary with industry. For example, I would expect that discrete parts manufacturers would have more inherent changes because of their complexity in product mix. For argument's sake, let's give a 10 to those who have only one change per month, and a zero to those who have daily changes. Give yourself a score.
2. **Variation in the Daily Production.** What is your variation in daily production output? While there's considerable variation in industries, for argument's sake, let's compare plan to actual. If your statistical standard deviation is greater than 10%, it would seem to me at first glance that you've got a serious problem and deserve a zero. If it's less than 1%, you're really quite good. Give yourself a score.
3. **Quality.** What is your quality rate? Once again this will vary from industry to industry, but for argument's sake, let's give a 10 to those who have six sigma quality (less than three defects per million units produced), and a zero to those who have more than 30,000 defects per million.
4. **On-Time Delivery.** What is your on-time delivery performance? Let's say that anything less than or equal to 80% deserves a zero, and that 100% deserves at 10. Give yourself a score.

5. **Inventory Turns**. What is your inventory turns ratio? If you don't know what this means, that's a different kind of problem. Ask accounting, and ask them why it's so important. The more inventory you keep (a lower ratio), generally the more unstable your production system. The higher the ratio, the more stable your system. So, again for argument's sake, let's give a zero to those whose inventory turns are two to three, and a 10 to those whose are over 50. This too will vary from industry to industry, so adjust this as you see fit. Give yourself a score.
6. **Unplanned Equipment Downtime**. How much unplanned equipment downtime do you have? Anything around 1% or less is really good, indicating high equipment reliability, and deserves a 10 (or a nine anyway), and anything over 10% deserves a zero. Give yourself a score.
7. **Reactive Maintenance**. Related to unplanned equipment downtime is reactive maintenance. Reactive maintenance is defined as work you did today that you didn't plan to do at least a week ago. Schedule break-ins would be another measure of reactive maintenance – how often do you change your scheduled work in a given week? What percentage of your maintenance is reactive? Anything less than 10% is really good and deserves a high score. Anything more than 50% is really bad and deserves a very low score. By the way, another measure here might be emergency maintenance, where anything less than 1-2% is quite good, and anything more than 10% is quite bad. Give yourself a score.

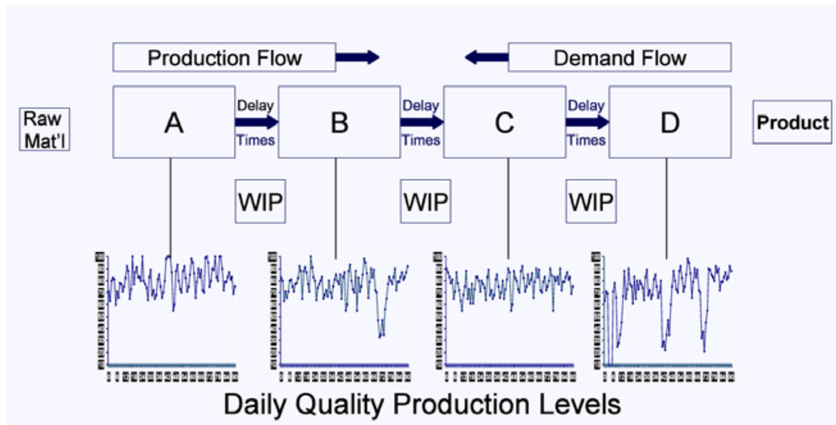


Figure 2: Stability is essential for lean manufacturing.

Finally, as noted, you should feel free to modify the criteria I've suggested to suit your particular circumstance, even adding additional criteria. So, with your scores and your overall review of this, what do you think? Are you ready for a lean manufacturing initiative? Or should you get back to basics, focusing on getting stability in your processes and equipment and engaging your employees in problem solving and process mapping, all the while thinking a little more long term?

Are you ready for lean manufacturing?

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

Part 1

Allan Rienstra and Thomas Murphy

Establishing **Ultrasound Testing** as a CBM Pillar

Looking beyond the acronyms and buzz words may be our best and only chance at discovering the true meaning of our Condition-Based Maintenance journey.

This may seem too philosophical a beginning for an article on Condition-Based Maintenance (CBM), but read on. For what is the goal of any journey, but to arrive at a destination? The goal of starting down the path of CBM should be well defined before taking the first step.

Is it to save money? Increase reliability? Increase productivity? Reduce stress? Improve quality? How about all of the above? Certainly they are all important to us. So where do we rank each one? What is the priority? Is it to improve reliability, productivity, and quality in order to reduce stress and make money? Surely the last one, "make more money," is the key. It is very easy to get too engaged in the process, such that we completely lose sight of the goal.

Condition-Based Maintenance represents a change in the way maintenance tasks are driven. No longer do work orders get pushed out just because an approved amount of time has lapsed since the last maintenance task. By the very definition of the acronym, call to action in a CBM environment dictates that we manage maintenance in response to changes observed from condition-based indicators. If this is indeed fact, then in order to observe a change in condition we must have a reference to measure condition against, and technologies that compare similar machines to each other in order to identify their differences. This is the point along our CBM journey where we meet the Condition Monitoring (CM) of CBM.

Implementing CM into your CBM strategy is not a task to be taken without careful and thoughtful planning. Like your CBM journey, that first perilous step must not be reckless. **Here is a quick list of things NOT to do first:**

1. Buy stuff because there is budget available
2. Take it all out of the box
3. Don't worry about training – the salesman said it was simple
4. Install the software
5. Create some database
6. Take readings
7. Wonder what they mean

This scattergun approach is commonly taken and more often than not winds up being a death sentence for the program. It lacks focus, direction, planning, and education. Success requires a plan, it requires focus, it requires clarity, and most important of all, it requires managerial support – and support is more than just money.

A better starting place is to draw a list of the small day-to-day problems that continually erode productivity and profitability. There are things that bite you hard every hour of every day and cost you more money in the long run. The problem is that most of those problems are now almost invisible to the business – they are just considered the cost of living.

Some examples:

- Compressed air leaks
- Steam leaks
- Defective steam traps
- Over-lubricated bearings

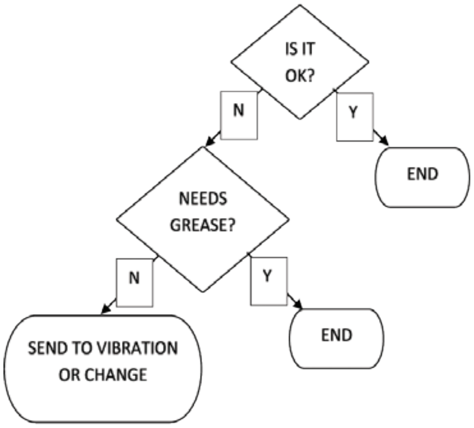
This list represents four huge daily drains on resources. Targeting each of these will yield almost immediate justification for an investment in CM. Are they difficult to do? No, not really. Do they need a long history and a lot of technology? No again. Do they require a huge investment in labor and technology? Once again, "No."

We anticipate hearing some readers shouting, "But this is not what CBM is about!"

Really? These four attacks save a fortune, reduce maintenance cost, and improve plant efficiency, which is a pillar of any productivity calculation. So, yes, this really is what CBM should be about.

Expand the list of four examples above to include monitoring all your rotating machinery and electrical systems. Then add the one technology that can provide effective surveillance of all six: ultrasound detection. Jumping on the ultrasound testing bandwagon is not the point of this article. It's not enough to simply say "You need ultrasound." You need to understand WHY you need ultrasound, and more importantly, HOW you are going to implement it as a supporting pillar of your CBM.

Consider the following simple logic tree:



"Is it okay?" must be at the heart of your CBM program. Answering this question is what your first-line data collection should be about. There are many cases in a plant, both in terms of rotating and non-rotating assets, where ultrasound does answer this question better than most other tools.

Using the quick and simple ultrasound test tool in either troubleshooting or structured (survey-based) modes will allow you to quickly answer this question. **Here are some examples:**

- Bearing condition
- Slow speed bearings
- Belts
- Couplings
- Chains
- Gearboxes
- LV and HV electrical systems
- Hydraulic systems

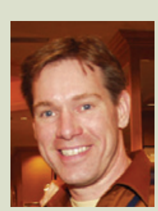
Ultrasound, faster and simpler than other technologies, is capable of providing the simple answer to the simple question "Is it okay?" There are other technologies that allow you to dig deeper into the problem and maybe allow you to look at the problem in a different way. But if the answer is "YES," why make it more complicated?

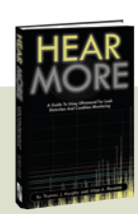
Establishing the need for CM and understanding why ultrasound is a pillar technology for CBM takes us to the next stage of our journey: Ultrasound Program Implementation. The "why to do" and the "what to do" are important first steps, but getting past the "how to do" will either make or break the effort. The space allocated to this article does not allow us to cover the next step in depth. Don't dismay, there will be a Part Two follow up in a future issue of *Uptime Magazine*, as well as a complete short course covering Part One and Part Two at CBM2011, on May 2-6, in Fort Myers, FL. Here is what we will tackle in Part Two.

With so much to do you need to be able to define your resources and your assets. Resources refers to your CBM team members, and assets refers to all of your problem areas. Split up your assets into non-trendable and trendable defects. Already you may see conflicts develop. With so many inspection tasks, they must be split into small manageable "bite-size" chunks. Making the tasks too onerous guarantees they won't get done. Keeping surveys to one-hour and two-hour tours ensures successful data collection. Plan for tasks to be performed two, three, or four times each year. Each inspection will generate work. After each survey, track how much repair work is generated. This will serve as a useful KPI as work orders per survey should decrease over time.

By non-trendable, we mean tasks that need to be done but don't require database set-up or trending. Compressed air leak management is a prime example. Steam system surveys are another, as are electrical inspections. General trouble shooting on couplings, hydraulic cylinders, belts, and tightness testing are other non-trendable applications. Applications that are trendable and require database setup include valves, some steam traps and electrical inspection, machine lubrication, and bearing condition monitoring.

In Part Two of this paper we will turn our focus to proper database setup, data collection, processing, and analysis of ultrasonic data. A considerable amount of thought must go into the structure of your database, and time spent at the beginning considering what sort of information you will want to mine from your database in the future will help decide the structure now. How you structure the reporting process to get the results your CBM program needs will prove a fundamental step. Communicating outcomes to your team will lead to timely intervention to attack identified problems in an incisive manner, resulting in massive cost reduction.





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

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

Part 2

Detecting Bearing Faults

Jason Tranter

This article is the second in a series of four. The first article provided a summary of how the vibration patterns change as the bearing fails. After very briefly recapping the basics, this article will discuss the detection and analysis tools that can be used to determine the nature and severity of the bearing fault: ultrasound, Shock Pulse, PeakVue, enveloping, and spectrum and time waveform analysis.

How Much of a Risk Are You Willing to Take?

What are your goals? Do you want to know that a bearing may fail just days before it is likely to fail, with no prior warning? Or would you like to know that a bearing has been poorly lubricated, or has a minor defect that will develop into a major fault? With the techniques described in this article you could learn these things months (certainly weeks) before the bearing is likely to fail. With that extra time you could change the lubrication, order parts, organize the labor, and look for the best opportunity to perform the bearing replacement. The result is a safer plant with less downtime, less stress, and higher profits.

Brief Recap

In the previous article, a few important points were made that are pertinent to this article:

1. As bearings begin to fail, the vibration is very low in amplitude, and the frequency is very high (beyond your ability to hear, even with the best screw driver).
2. Simple spectrum analysis will not reveal the fault until it has developed to stage three, unless you take special precautions (listed later in the article).
3. To measure high frequency vibration you ***must*** mount the sensor correctly.

Beyond Your Hearing: Ultrasound

The ultrasound technique is very easy to implement. The measurement tool listens for very high frequency vibration and provides an indication of amplitude. It also amplifies the vibration and shifts (heterodynes) the frequency so that you can hear it through headphones. Therefore, you can listen for the telltale sounds of poor lubrication and bearing distress. When used correctly and appropriately, ultrasound instruments can be very complimentary to the other techniques described in this article.

What Are "Stress Waves," and Why Should I Care?

Before describing the next two techniques it is important to briefly introduce the concept of the *stress wave* (also known as shock pulse). Metal-to-metal contact sets off a ripple effect: a stress wave races through the metal components, causing the components to vibrate due to resonance. The stress wave is a very short-duration, low-amplitude, high-frequency wave. Every time the rolling elements roll over the damaged area on the inner and/or outer race (or as the damaged areas on the rolling elements contact the raceways), a stress wave will be generated. We can seek to detect that wave with techniques such as Shock Pulse, PeakVue, and SWAN (Stress Wave ANalysis, not discussed further in this brief article). The vibration that results can also be detected via the envelope method, and as the fault develops further, via the time waveform and spectrum.

Metal-to-metal contact sets off a ripple effect: a stress wave races through the metal components, causing the components to vibrate due to resonance.

There is one very key point you must be aware of: we are talking about very high frequencies, and as such the vibration sensor *must be mounted correctly*. Unless specifically designed for the purpose (e.g., Shock Pulse), a handheld probe is horribly inadequate. Even a two-pole magnet mounted directly to the machine surface is not adequate! All of the analyzer vendors will tell you, you must properly prepare the surface and use an attachment pad (or stud mount) in order to achieve the best results.

It is also important to note that there are other defects that will generate stress waves and high-frequency vibration, including looseness, gear wear, and cavitation. That can help us to detect those conditions, but it can confuse our attempts to detect bearing and lubrication faults.

Shock Pulse

The vibration sensors provided by SPM and PRÜFTECHNIK are designed to amplify (through resonance) high-frequency vibration (at *approximately* 35 kHz). As noted earlier, lubrication and physical defects (including wear/spalls) will generate vibration around this frequency. The vibration can be displayed as an amplitude to be trended, or a spectrum can be displayed in order to better understand the specifics of the defect: inner race, outer race, etc.

Spike Energy

The Spike Energy (units of gSE) technique aims to utilize the accelerometer's mounted resonance to amplify the high frequency vibration. However, in more recent years, the accelerometers provided have not been manufactured to have a repeatable resonance characteristic. What that means is that when you change your accelerometer, the amplitudes will change.

PeakVue

The PeakVue technique, developed by Emerson Process Management (CSi Division), is also designed to detect the stress wave; however, it is performed in a different way. The signal from the accelerometer is digitally sampled (converted from analog voltages to digital numbers) at a very high rate so that the very short duration stress waves can be detected and quantified. The PeakVue waveform and spectrum provide an indication of the bearing defect. As with all of the techniques, the accelerometer must be mounted correctly, and the filter settings (used to "tune in" to the bearing vibration) must be set correctly.

Enveloping

Also known as "demodulation," the enveloping technique, which is used by a large number of vibration analyzer vendors, has been optimized to measure the low-amplitude, high-frequency bearing vibration. See Figure 1.

The envelope spectrum is then checked for signs of the fault condition. Similar to the spectrum that results in the Shock Pulse, Spike Energy, and PeakVue systems, we are looking for peaks, sidebands, and harmonics that are related to the four characteristic bearing frequencies: Ball Pass Frequency Outer race (BPFO), Ball Pass Frequency Inner race (BPFI), Ball (or roller) Spin Frequency (BSF), and Fundamental Train (or cage) Frequency (FTF). See Figure 2 for a summary of the progression we expect to see.

Spectrum Analysis

If we do not use one of these techniques and simply view a spectrum, then we may have limited success unless we take precautions:

1. Acceleration is most sensitive to high-frequency vibration, so if we view the spectrum in units of acceleration (Gs or mm/s^2) and have a high Fmax (70X or higher) and, better yet, we view the spectrum in logarithmic format, then we will achieve the best results (with a spectrum alone).
2. If we view the spectrum in units of velocity (in/sec or mm/s), then we may need to wait until the bearing is at stage three until we see positive signs of the fault. Increasing the Fmax and viewing the spectrum in logarithmic format will help significantly.

When viewing the velocity or acceleration spectrum (or any spectrum from PeakVue, enveloping, etc.) there are a few techniques that help to achieve the best results:

1. Look for peaks at frequencies that are non-integer multiples of the shaft speed (e.g., 3.09X, 4.65X, 7.89X, etc.).

FIGURE 1

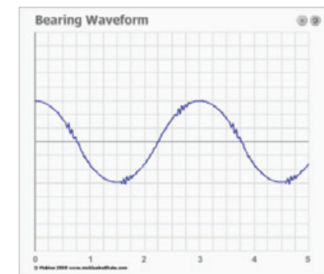
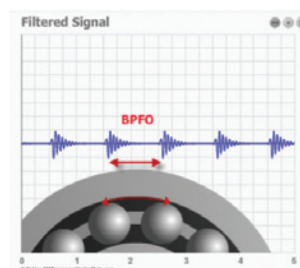
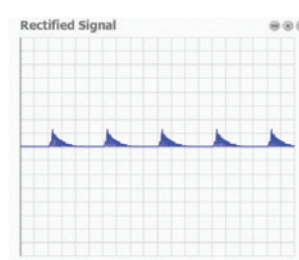
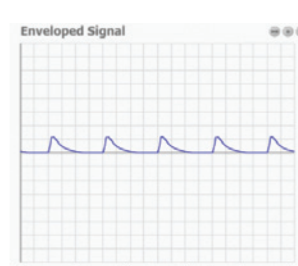
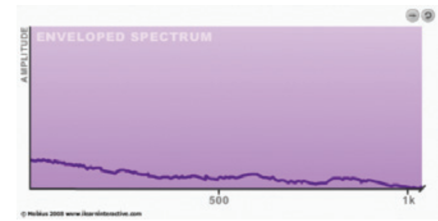
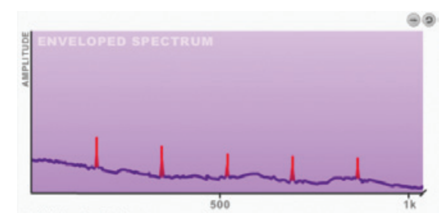
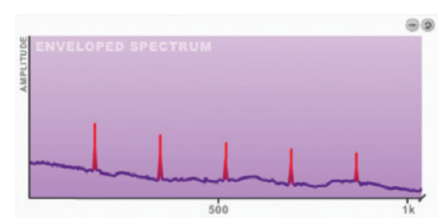
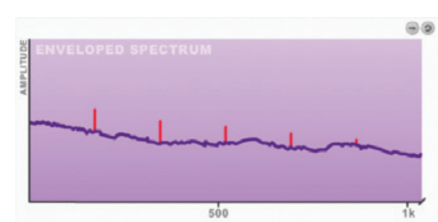
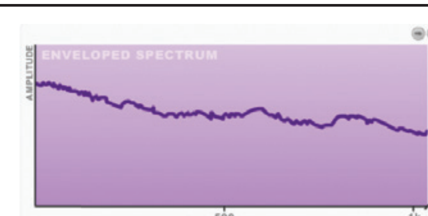
Description	Visual
In this example, we have a smooth vibration signal with the weak bearing signal overlaid. In reality, the vibration would not be as smooth, and the bearing vibration would not be visible.	
First, the relatively high-amplitude, lower-frequency vibration must be removed from the accelerometer signal. This is typically achieved with a high-pass or band-pass filter. The time between these "pulses" is equal (in this example) to the time between balls rolling past the damaged area on the outer race, which represents the "ball pass frequency" for the outer race: BPFO.	
The signal is then rectified (all of the negative-going vibration is turned into positive-going vibration).	
The signal is then "enveloped" (thus the name) via a low-pass filter. There is a lot that could be said about this process, and there are differences from one vendor to the next, but the end result is a low-frequency time waveform that, when transformed to a spectrum (FFT), will indicate that a fault exists on the outer race (in this example).	

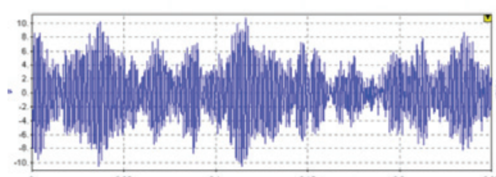
FIGURE 2

Description	Visual
If the lubrication is OK and the bearing is faultless, then the envelope spectrum will contain "noise" – no peaks to speak of.	
As a fault develops, peaks will rise up out of the noise floor at frequencies described in the spectrum analysis section.	
When the peaks are clearly above the noise floor the bearing should be replaced.	
As the fault develops further, the noise floor will begin to lift.	
When the noise floor swallows the peaks, the bearing is in late stage four and is about to fail. The surface of the bearing is severely damaged; there is no longer period vibration.	

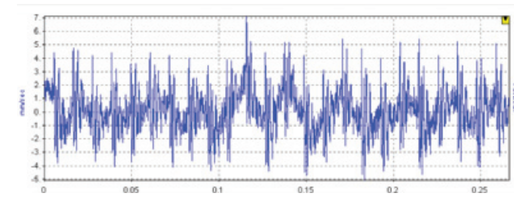
2. There should be harmonics of those frequencies (e.g., peaks at 3.09X, 6.18X, 9.27X, etc.).
3. Check for sidebands of the turning speed of the shaft. If they exist, then suspect a fault on the inner race. If there are no sidebands, suspect an outer race fault.
4. Check for sidebands of the fundamental train frequency (slightly less than half the turning speed of the shaft). If they exist, then suspect a fault on the rollers/balls.

Time waveform analysis

It is typically possible to view the time waveform from the Shock Pulse, PeakVue, and envelope process, but I'll focus on the raw waveform from the accelerometer. In the early stages of the fault condition it will be very difficult to detect the fault with a time waveform. However, as the fault develops, an acceleration waveform can reveal the fault, especially when taken from low-speed machinery. As the fault develops, the waveform will have characteristic "pulses" and patterns that indicate the condition of the bearing fault. In the later stages of the fault, a waveform in velocity units can display the defect quite clearly.



Characteristic "modulated" pattern in the acceleration waveform (often called the "angel fish" pattern).



"Spikes" in the velocity waveform indicate the presence of a severe fault.

Conclusion

I hope this article has helped to provide a basic understanding of these techniques. They have all been used for many years to successfully detect bearing faults at a very early stage. The key is to mount the sensor correctly, choose the correct settings, and analyze the data correctly.

Jason Tranter is the founder of Mobius Institute and author of iLearnVibration and other training materials and products. Jason has been involved in vibration analysis in the USA and his native Australia since 1984. Before starting Mobius Institute Jason was involved in vibration consulting and the development of vibration monitoring systems. www.mobiusinstitute.com management RL reliability leadership

Q&A

Uptime Magazine Publisher and Editor **Terrence O'Hanlon** recently caught up with **Joe Swan,** Maintenance Manager for Arch Coal, one of the nation's largest coal producers and **winner of the *Uptime Magazine* Predictive Maintenance Program of the Year Award for Best Overall Program Mobile/Fleet.**

Q ***Joe, congratulations on your team winning the* Uptime Magazine *Predictive Maintenance Program of the Year award for best mobile equipment maintenance reliability in 2010. Can you tell about the equipment being operated and maintained?***

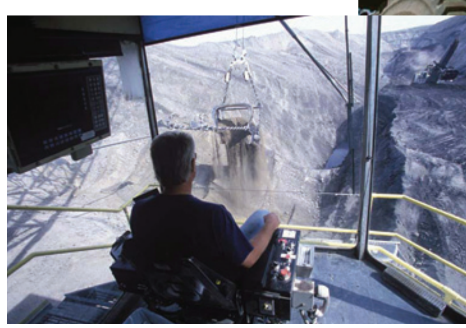
A Again, thank you Terry and *Uptime Magazine* for this award. This award is really the result of a team effort and is a direct reflection of the dedication and hard work by the men and women of Arch Coal. The mobile equipment we utilize in our mining operations can be separated into two groups: surface and underground. Our surface mines utilize a combination of draglines, shovels, drills, high-wall miners, loaders, dozers, overburden and coal trucks, motor graders, and a fleet of support equipment ranging from cranes, lube trucks, tire trucks, boom trucks, electrician trucks, fork trucks, etc. Our underground mines utilize long-walls, continuous miners, roof bolters, coal haulers (diesel, electric or battery - popular names are shuttle cars and ram cars), mobile feeder breakers, scoops, personnel carriers or mantrips, locomotives, support equipment like long-wall moving equipment, road graders, and skid steer loaders.

Q ***There are not a lot of great examples of predictive and condition-based maintenance programs on mobile equipment. How did this program get started?***

A Out of necessity and by a champion. Arch Coal's predictive and condition-based maintenance programs have been a part of our DNA for over 2 decades now and can be traced back to Bob McCreary, Arch Coal's corporate Director of Maintenance and Technical Support. Any company that has a sustained PdM program was started and led by a champion, and we have that in Bob, who has always been a forward-thinking reliability leader. He started the oil lab and predictive staff at Black Thunder when no other mining company was even thinking along those lines. From there he spread that same vision across all of Arch. He spearheaded our Arch Initiative in Maintenance (AIM) and helps guide and shepherd our current reliability efforts and the past leadership of the prior managers of predictive maintenance, Randy Fizer and Isaac Nolte. However, I cannot stress enough how the program's success would not be achieved without the assistance and collaboration of other team members like Terry Taylor, Arne Rajala, planners, clerks, mechanics, electricians, operators, supervisors, superintendents, and general managers.

Q ***What kind of business benefits are you seeing as a result of your condition-based maintenance reliability program?***

A Benefits for Arch Coal are safer mines, better system reliability, increased revenue, reduced outage costs, efficient inspections, improved and less expensive maintenance and repair costs, reduced spare parts inventory, reduced built-in defects from repaired components, and reduced operational costs. For example, our draglines will either make or break a mine. Our draglines are inspected by our UT and VIB prediction guys. Their roles are to comb those critical areas to avoid a catastrophic failure of the boom, mast, suspension, propulsion, or motor generator set. Such a failure would cause a disruption of coal production for days or weeks and impact the bottom line through significant unbudgeted CAPEX and OPEX. The benefit of having our guys out there and being around the equipment looking, listening, feeling, and smelling is invaluable as well. Another example recently was a find we had from one of our qualified electric motor repair vendors during acceptance testing of a 400 hp motor for one of our underground mines. During the acceptance testing procedure, they caught a very small defect in one plane of the spectra and wanted to know if we would accept it. We said no, dig in and find out. They found that the drive end bell (new from their supplier) was not machined correctly. The housing was out of round, and it was also tapered. This created a slight preload on the bearing, and now we don't have to live with that built-in defect.



Q ***How important has training and certification been for the maintenance reliability team?***

A For our PdM guys, the results can be directly attributed to their training with respect to PdM saves and finds. Our PdM team consists mainly of maintenance engineers and predictive engineers, each holding certificates in either or a combination of oil analysis - MLA I & II, ultrasonic flaw detection - level II, vibration – ISO Cat II & III, thermography level I & II, motor circuit analysis – online and offline, and ultrasound. The training and certifications they have are invaluable. Detecting deterioration or modes of failure as early as possible requires a deep understanding of the tools being used and how they are applied. Another way we leverage the training and certification of our prediction guys is how some have teamed with mine site electricians and mechanics to assist them in their data gathering, such as IR, oil sampling, and MCA. This strengthens their evaluation of spectra and trends since this phase can be more time consuming than data collection. Another rewarding and priceless moment comes when one of our guys uncovers a defect in a bearing and it is affirmed by the mechanics during the disassembly. Some wondered in the beginning of our journey why they were replacing a perfectly operating piece of component. Now there is coordination and cooperation.

Q ***Can you share some tips with our readers on how they can get started and what mistakes they need to avoid as they begin making maintenance reliability improvements at their organizations?***

A Start by seeking knowledge, learning, and networking with other reliability professionals. Create the PdM business case and seek out the champion from the top and ask for their support by asking those under them to support the organization's PdM efforts. Make sure your current organization is planning and scheduling even if it's done manually! Obviously, utilizing a computerized maintenance management system, or CMMS, makes asset management easier. Know what equipment and components in your mobile fleet you want to monitor, so you can prioritize your fleet by criticality. Select motivated individuals who have a passion and desire to perform predictive work and equip them for success by providing training. There are several PdM toolbox tools, but the technologies you should have deployed by preference are: oil analysis, ultrasonic flaw detection, vibration analysis, thermography, motor circuit analysis, ultrasound analysis, and x-ray. In addition to these, utilize other non-destructive testing (NDT) techniques, such as: dye penetrant testing, magnetic particle, strobe light, bore scopes, and temperature guns. Continue measuring your results and make sure your programs are producing results. The last thing to say is avoid purchasing multiple "PdM toys" all at once. This is an evolutionary path and one that requires perseverance.

For our PdM guys, the results can be directly attributed to their training with respect to PdM saves and finds.

Q ***What is in store for the next 5-10 years in terms of maintenance reliability? How will you continue to drive improvements?***

A We need to deploy technology in a sustainable way ensuring we mine profitably. This means deployment of proven smart technologies, such as online systems and remote monitoring, to determine real-time asset health. There will always be a push to get more for less, and we continue to work with our vendors and suppliers to incorporate PdM access test points on new OE equipment. Hopefully, there will be a day when the need to "retrofit" existing equipment to obtain an oil sample or vibration reading is gone and more useful equipment comes standard from the dealer.

How will we continue to drive improvements? By producing results. This is the only way these programs continue. It boils down to execution or the program will be executed! ***www.archcoal.com***

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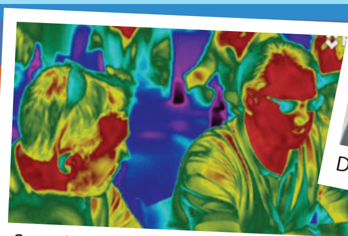

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Derek Burley and Doug Plucknette at RCM

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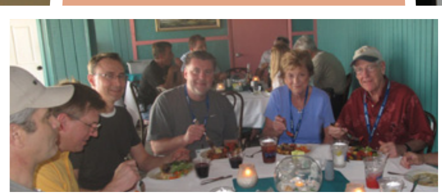
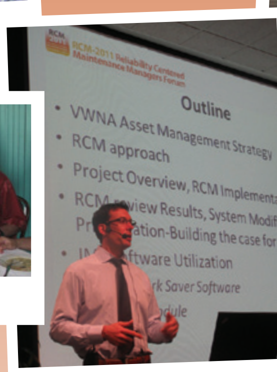


RCM Evening Event - Beach Dinner



Ryan Johnson at RCM

This conference really helped us improve our equipment strategies and our PM/PdM program. It gave me more tools and knowledge to better direct this improvement effort. Thanks!

Chris Hansen,
Suncor Energy USA
Zero2One

Wow, great experience sharing. Enjoyed hearing all the "gurus" speak. I learned a lot and have much information to draw on for the future. You put on a great seminar and went far and beyond in accomodating guests. Thanks!

Brent Hunnicutt,
Honda Manufacturing of Alabama
RCM

The session was a high-power reality-based experience by authors who have lived real world experiences. The sessions provided simple step-by-step processes to follow for continuous improvement.

Mark Pederson,
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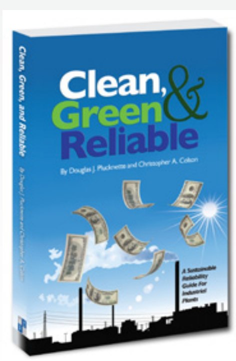

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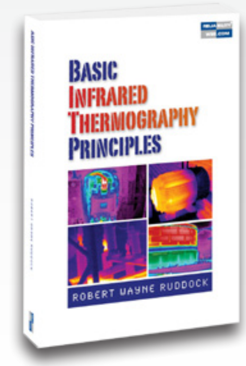

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At last, a book written by and for Infrared Thermographers.

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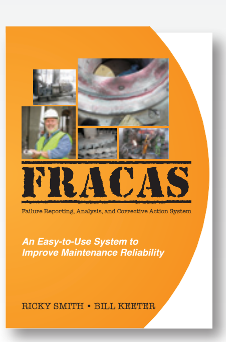

by Ricky Smith and Bill Keeter

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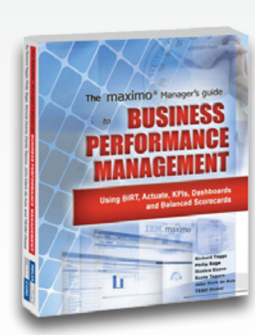

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