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june/july 11

the magazine for maintenance reliability professionals

Q&A with South Carolina Senator Paul Campbell

Clean, Green & Reliable

How equipment reliability delivers low-cost, energy-efficient assets at plants around the world!

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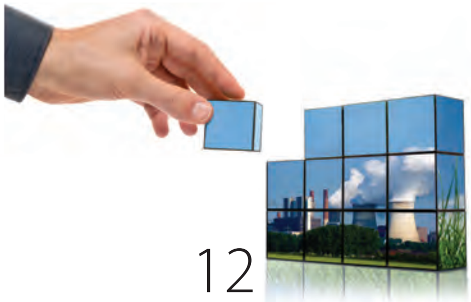

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Continuous Improvement

The team at *Uptime* is really lucky. We get to read articles and listen to presentations from some of the smartest and most innovative people in maintenance reliability. The information they share is golden if you are receptive to listening, understanding, and applying it.

Although there is some specific knowledge related to best-in-class maintenance reliability, much of what is needed is a clearly stated mission and vision, fundamental business processes, team empowerment, metrics and measurements, and leadership common to almost any business.

Now in our 12th year, we are re-examining *Uptime Magazine's* mission and vision, business processes, team empowerment, metrics and measurements, and leadership.

There are many instances where I think back to a presentation I attended or an *Uptime* article I read that relates as much to improvements at *Uptime* and Reliabilityweb.com as it does to your maintenance reliability program.

So even if your job is highly technical or you do not have much influence over the business you work in, I suggest that you pay special attention to the articles and presentations that you think may not apply to you. There is so much wisdom being shared that you can find nuggets of gold in some very unexpected places.

We are also preparing for the IMC-2011 26th International Maintenance Conference (Solutions 2.0) being held December 5-8, 2011 at the Hyatt Regency Coconut Point Resort in Bonita Springs, Florida. The event has attracted some fantastic practitioner presentations that provide a look into over 50 "real-world" maintenance reliability programs. Many attendees report that they value IMC as a great place to reflect on the year just passed and to firm up strategies and improvements for the coming year. I hope you can make it this year to find new ideas for your program!

If you have not done so, please download the *Uptime* App on your iPad, iPhone, or iTouch so you can get special editions of *Uptime* and e-Publications such as the new "Things to Think About (and Do) in 2011," a collection of maintenance reliability wisdom from some great contributors.

Even if the economic signals are mixed, there is one thing for sure: keep moving ahead and improving or you run the risk of allowing laggard performance to threaten your organization's very existence. The law of the jungle is alive and well, so make sure your program contributes to making your company one of the strong that will survive!

Best regards,
Terrence O'Hanlon

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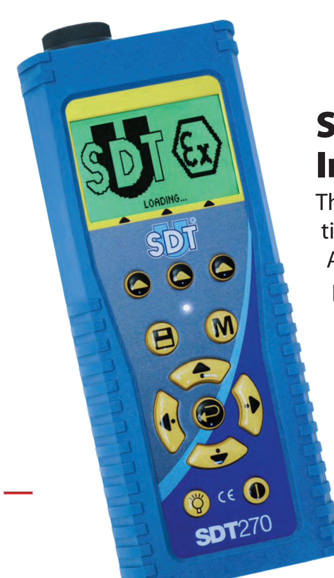

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Clean, Green & Reliable

How equipment reliability delivers low-cost, energy-efficient assets at plants around the world!

Douglas Plucknette and Chris Colson

I first became interested in manufacturing reliability nearly twenty years ago working as a maintenance mechanic who had a personal interest in improving the reliability of individual assets by searching through our maintenance history for areas where we were spending the most time and money with regard to emergency/demand work orders. Using the history we had in our database, we used the 80/20 approach to identify the 20% of our assets where we spent nearly 80% of our maintenance budget. Once we identified a system or asset to work on, we would use a cause-map or root-cause analysis to identify the potential causes of our equipment failures. Understanding these causes, we would then look to identify potential redesigns to eliminate or reduce the frequency of equipment failures.

Clean, Green & Reliable

In working on these problems and identifying solutions as a group, we also began to understand the power behind understanding the relationship between cause and effect, noting that a single cause could have several effects and that any given effect could also have several causes. We also noticed, in finding solutions to causes of many equipment failures, that the impact of these solutions reached far beyond the measures of equipment reliability.

While the benefits of equipment reliability are most noted for reducing the cost of maintenance, the benefits of reliable assets reach far beyond the cost of eliminating emergency and demand maintenance. In wrapping up each project, we highlighted the benefits and savings derived to drive home the point that equipment reliability would deliver more than a reduction in maintenance costs. For each project, we would report the following information.

- Overall equipment effectiveness (OEE) in the months before the project and following implementation.
- Number of maintenance man-hours dedicated to maintaining the asset 12 months prior to the start of the project and again in the months following implementation.
- Parts costs before and after the project.
- Energy usage/costs in the 12 months prior to the start of the project and usage in the months following implementation.

Nearly every time our teams reported this information in meetings to management I found it interesting that someone would comment that the savings and increase in productivity were significant but that the energy savings were insignificant. "As a company we generate our own utilities, so the 25% reduction in energy usage for this asset will not result in a cost savings to the company. Unless the savings were significant enough to warrant the shutdown of one of our boilers or turbines it would have no impact on the company bottom line."

"Thanks for the effort, but next time leave the energy piece out of the equation!"

Fast-forward fifteen years and things are a little different. Most of the MBAs I used to work for had to go find employment someplace else. It would seem that for most, all they learned in graduate school was to nod their head yes after our former CEO demanded they do something stupid.

Simon says nod your head yes!

I believe one would now get a totally different response should they be able to reduce energy consumption at any manufacturing facility. Regardless of one's beliefs with regard to global warming, reducing energy consumption is the right thing to do, especially when we can show that this reduction in energy consumption is a byproduct of improved equipment/manufacturing reliability.

As reliability engineers and consultants, we find it exciting that nearly every major company in the world includes pages regarding energy efficiency and environmental responsibility on their corporate websites. We're excited because we know that reliable systems, reliable processes, and reliable assets are both energy efficient and environmentally responsible.

The idea to write a book on this topic, *Clean, Green, & Reliable*, came out of some discussions I had with Terry O'Hanlon regarding my purchase of the domain name Reliabilityisgreen.com, an idea I had while writing the *RCM Blitz* book. Terry and I have both experienced how improved reliability can have a positive impact on energy efficiency, and it was Terry who had the idea for this book. While we both have experienced this relationship between manufacturing reliability and energy efficiency, the true experts who can answer the questions of what we need to do, why it works, and the results we should expect are key contributors to the book. With this information, and a few real-life case studies on how equipment reliability improved energy efficiency, we hope to enlighten the masses on how reliability delivers energy efficiency.

> ***Using the history we had in our database, we used the 80/20 approach to identify the 20% of our assets where we spent nearly 80% of our maintenance budget. Once we identified a system or asset to work on, we would use a cause-map or root-cause analysis to identify the potential causes of our equipment failures.***

Chris and I started researching and reading about the various reliability tools and methods that made general claims regarding energy savings. While some of these claims have been substantiated, there are others where the claims are still in question. The most popular claim regarding energy savings is up to 20%. If you read that some device can deliver up to a 20% reduction in energy costs or a 20% improvement in energy efficiency, use a bit of common sense and ask for a case study or client testimonial. We're not saying it is impossible; we are simply saying validate the claims with data. If there is one thing I know about manufacturing managers, they will not release fudged numbers to the public.

We wanted this book to be different than the other books aimed at business regarding energy savings. I bet I can find at least 20 books that talk

This steam leak is clearly suffering from improper insulation, as well as improper design. This leak is not only a waste of energy; it sooner or later will result in unscheduled equipment downtime and is an obvious safety hazard.

about reducing energy usage through upgrades to the building lighting, windows, and office thermostats. With plenty of this information available, we wanted to write about some common systems and technologies where, if they focused some time and effort, they would see a quick return on investment and an improvement in reliability.

Clean, Green, & Reliable focuses on ten of the most common industrial systems and the equipment utilized in these systems to address specific reliability tasks and technologies that yield improved reliability and "bottom-line" energy savings. We take an in-depth look at systems, such as electrical power distribution, air handling, compressed air, steam systems, hydraulic systems, air/gas conveyance systems, and refrigeration systems, to name a few. While this effort has taken nearly two years to complete, we are pleased with the results and believe you will be as well.

There are certainly some big hitters on the systems we chose to write about, and a few of them may be well known, such as steam systems. Although we knew this topic had the possibility like no other to be huge and overdone, we made the decision to set clear boundaries on this topic by sticking to the theme and explaining how reliable steam and condensate systems are more energy efficient, along with some simple operating and maintenance tasks that we can do to maintain reliable and efficient steam and condensate systems.

In the world of manufacturing, we tend to use steam for an unlimited number of uses, from turning turbines to create steam to heating our buildings for comfort. Steam is often the choice because it is relatively simple and can be a somewhat reliable source of energy. If the words relatively simple and somewhat reliable seem cautious, it's because many of us tend to take steam for granted. There seems to be a mentality that concludes, "We have steam readily available in the area for use in our process, so why not take advantage of it being there and use it for as many things as possible."

This is where the trouble begins. In designing the steam header for your process equipment, one would hope that your engineers performed the proper calculations for the steam and condensate loop that included temperature, pressure, density, volume, heat, work, and energy. Performed properly, the calculation ensures we have the right amount of steam and energy available for manufacturing. Any additions to this system that demand steam will impact this system and may have an impact on its original intent. While this all would seem to be common sense, those of us who have worked with manufacturing companies around the world can all share stories of unreliable and inefficient steam systems.

The steam leak pictured on this page is just one example of the thousands of steam leaks we see at plants around the word. It is quite clear that this system is suffering from at least a few of the common mistakes we see with steam and condensate systems. It is clearly suffering from im-

How Energy Efficiency Declines As Excess Oil Builds

Percent Oil in Evaporator	Energy Efficiency Loss
• 1 Percent to 2 Percent	• 2 Percent to 4 Percent
• 3 Percent to 4 Percent	• 5.5 Percent to 8 Percent
• 5 Percent to 6 Percent	• 9.5 Percent to 11 Percent
• 7 Percent to 8 Percent	• 13.5 Percent to 15 Percent

Table 1. Because oil usually accumulates gradually in refrigerant through migration, the attendant loss in efficiency usually is diagnosed to be some other cause. It isn't until performance has significantly degraded that oil is suspected.

proper insulation, as well as improper design. This leak is not only a waste of energy; it sooner or later will result in unscheduled equipment downtime and is an obvious safety hazard.

We also took a look at some other, not so publicized, systems, such as refrigeration systems. Refrigeration systems are very similar to Heating, Ventilating, and Air Conditioning (HVAC) systems, in that most cases are ripe for changes in design and maintenance practices that will have a direct impact on the reliability and energy efficiency of the asset. Likely because refrigeration systems are a key element in most HVAC systems, they are seen as a utility, and people as a rule want comfort and functionality over efficiency. We simply want utilities to work, and when they do we forget about them. Refrigeration systems are comprised of some form of combination of condensers, compressors, evaporators, valves, absorbers, pumps, and chillers, which presents many opportunities to optimize the efficiency of these components.

Contamination is one of the major defects of refrigeration systems. When a chiller operates with contaminated refrigerant, performance will decline, power use increases, and operating costs have the potential to increase exponentially. Contamination can be air, oil, moisture, dirt, or acid. If contamination is not detected and addressed, catastrophic damage can result.

The most common contaminant in refrigerants is oil. A recent ASHRAE research project (601-TRP) sampled refrigerant from 10 randomly selected chillers and concluded that most contained excess oil, even though three of them had recently had their refrigerant recycled. Of the ones that were recycled, the study showed oil content of 3% to 7% in the refrigerant. The other seven samples showed contamination levels ranging from 9% to more than 20%. The table above, presented in the article, *Process Heating for Manufacturing Engineers*, by Mark Key of Redi Controls, Inc., shows approximately how energy efficiency declines as excess oil builds within refrigerants.

Typically, little is done to identify and remove excess oil from chillers until it becomes a major problem. Why is this? Well, it is because oil on the refrigerant side typically does no damage to the system, gives little indication of its presence, and generally has significant costs associated with detection. It typically isn't until performance has significantly degraded that oil is suspected.

We hold a core belief that if doing something doesn't provide a return on investment then it is likely not worth doing and certainly will not be sustainable. Everyone knows the old management adage that says, "You can't manage what you don't measure." In other words, unless you measure something you will never know if it is getting better or worse. Savings can occur in the form of either repetitive, reoccurring savings or one-time savings. Recorded before and after measurements are critical to eliminate the possibility of misrepresented or even unnoticed savings.

Measurement systems should be put into place to collect data and express results as standard key performance indicator (KPI) metrics. These metrics will be compared to benchmark data to help the organization evaluate and measure progress toward its defined goals.

It is important to communicate these metrics and the success of the program both up and down the organization. People want to know how things are progressing and certainly like hearing the good news and how they are helping the organization become more efficient and environmentally responsible. With energy management metrics in place, your organization will begin to recognize the directly proportional relationship between equipment reliability and energy efficiency.

Clean, Green, & Reliable focuses on ten of the most common industrial systems and the equipment utilized in these systems to address specific reliability tasks and technologies that yield improved reliability and "bottom-line" energy savings.

A great place to start selecting KPIs for your energy management should be from a scorecard that is used by your company to track energy costs (an example scorecard is shown on the next page). These types of scorecards should not only exist for the entire facility but also have the ability to drive down to specific areas, systems, and even the equipment level. Initially the thought might be that this information is hard to gather and requires substantial time. In reality, it couldn't be easier utilizing the technology readily available today. In fact, in most cases you probably already have most if not all of the data needed, and it would take little additional time for the few additional data points to be collected.

We understand the key elements in sustaining positive results. The major elements we have discovered over the years involve impacting the entire organization's beliefs and behaviors related to energy management.

Energy Management Scorecard

Month/Period	Electricity				Oil				Natural Gas				Other (Coal, Wood, Purchased Steam, etc.)				Total Energy Cost
	Quantity kWh	Cost (dollars)			Quantity Gallons	Cost (dollars)			Quantity mcf	Cost (dollars)			Quantity (unit)	Cost (dollars)			
		Total $	$ / kWh	$ / MMBtu		Total $	$ / Gal.	$ / MMBtu		Total $	$ / mcf	$ / MMBtu		Total $	$ / (unit)	$ / MMBtu	
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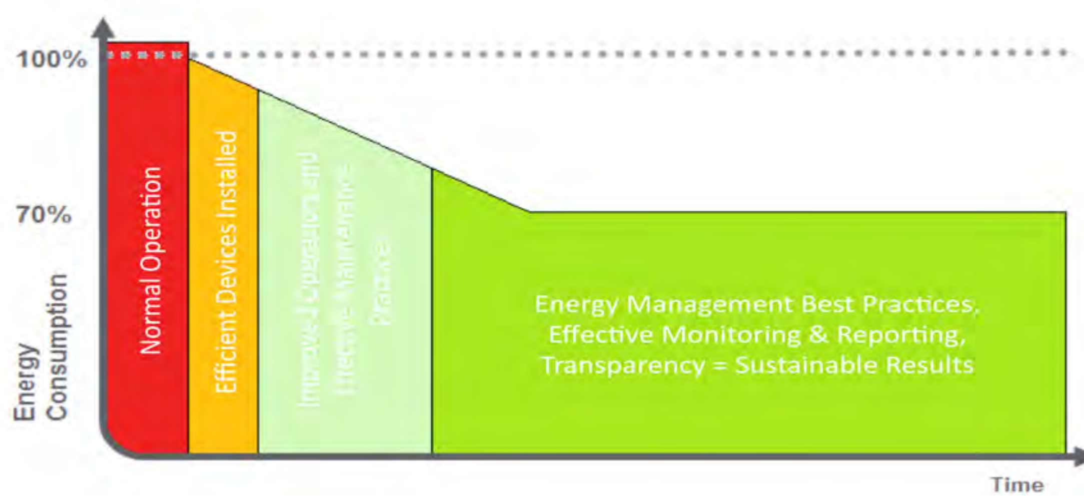


To maximize sustainable results, it is imperative that your organization assume ownership of any improvement initiative, process, or program. Like many initiatives, energy management isn't any different; behavioral changes are required, which leads to culture change. To sustain this change, everyone must be an active participant in development and implementation.

Beliefs are vital to the ability to change and must be modified prior to any behavior change. Education and knowledge transfer are keys to changing beliefs. The most effective way to sustain change in your organization is to impact each and every level of the organization.

The moment you stop looking to improve is the moment you open yourself up to competitors making inroads as they find ways to improve quality or reduce costs. Perfection will never be achieved, and thus improvement is always possible.

The continuous improvement cycle is an effective team-involvement tool and forms the basis for a "lessons learned" database and best practices, which are continually reinforced at the leadership level and reflected in changed KPIs, updated business processes, and continual modeling and monitoring. Rigorous application of the continuous improvement cycle often realizes step change, while sharing lessons learned through a knowledge management system ensures that change is sustained, despite leadership changes or staff turnover issues.

Clean, Green, & Reliable is a book about common sense. It's about doing the right things for all the right reasons. It's about making more with less and each of us doing our part to make our manufacturing companies more reliable, energy efficient, cost effective, and competitive.

It is also about being a steward to God's earth, knowing what we leave behind we leave to our children and to their children. Let's forget all the politics and all the people who get paid to stir the pot and fog the issues. Let's be smart, responsible, and successful. *Douglas Plucknette*

Doug Plucknette is the World-Wide RCM Discipline leader for GPAllied, creator of the RCM Blitz(TM) Methodology, author of the book Reliability Centered Maintenance using the RCM Blitz Method*, and co-Author of the book* Clean, Green & Reliable*. Doug has been a featured speaker at conferences around the world and enjoys training and mentoring peoople in reliability tools and methods. www.rcmblitz.com*

Chris Colson is the Director of Electrical Services for Allied Reliability and co-Author of Clean, Green & Reliable*. Chris is a member of the Association of Energy Engineers and is a Certified Energy Manager. He also is an active member of SMRP and currently serves as a Pillar Lead for the M&RK committee. Chris is passionate about improving operational capacity through equipment reliability and has written and spoken widely in the reliability engineering field. You can follow Chris on twitter: colsonchris and learn more about the services Allied Reliability provides by visiting www.alliedreliability.com.*

Chad Wilcox

Balancing Out the Root Cause

As anyone who has practiced vibration analysis knows, vibration signatures obtained on routes are often far from the wall chart examples. The reason for this is that the vibration signatures collected and analyzed represent the response of a system due to a variety of different forces that act simultaneously to produce one signature. Unfortunately, vibration analysts are actually interested in determining the individual forces that cause the response. Once the forces are accurately identified, only then can they be reduced or eliminated.

Take for example the force of unbalance. Wall charts and texts on vibration analysis represent mass unbalance as a running speed peak in the spectrum that dominates all other content. Also, these theoretical, or textbook, examples indicate the vibration amplitudes will be equal in the horizontal and vertical planes. However, experienced vibration analysts know this is often not the signature we see. This is due to the fact there are multiple forces acting on the system, and it may have asymmetric stiffness resulting in highly directional vibration. In these situations, following the wall chart examples without additional phase analysis may send an analyst down the wrong path.

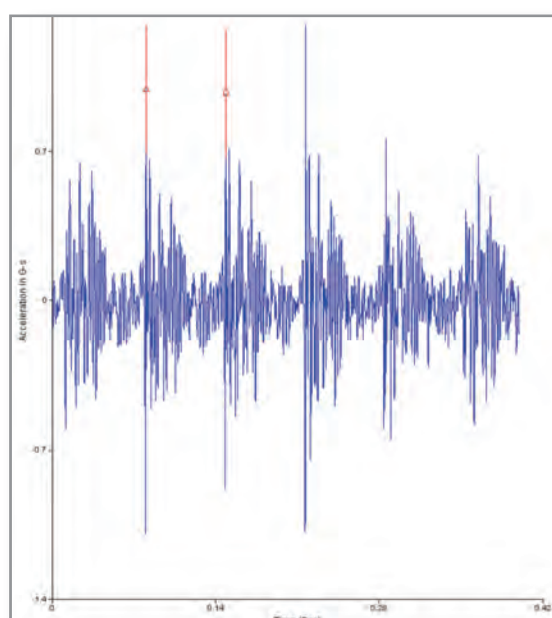


Figure 1. Time waveform taken at outboard fan bearing showing impacts once per revolution.

In order to be effective in vibration analysis, it is necessary to first resolve the most dominant problem and then reanalyze the machine to determine if there are any further forces that need to be minimized. Properly

In order to be effective in vibration analysis, it is necessary to first resolve the most dominant problem and then reanalyze the machine to determine if there are any further forces that need to be minimized.

identifying the most dominant problem can be difficult, so make sure to use all tools available. This case history illustrates a situation in which the vibration signature was far from being textbook due to multiple sources simultaneously acting on the system to produce one non-textbook signature. Getting to the root causes of the problem took multiple iterations.

Loose Bearing in the Housing

A 6-foot-diameter, double-suction centrifugal fan that is driven by a 250 hp electric motor shut down as a result of high vibration on the outboard fan bearing. Additional data was collected with a portable analyzer that showed low overall amplitudes of vibration of 0.12 ips (pk). Since the overall vibration switch was part of an old monitoring system, the integrity of the switch was tested and was found to be working properly. Plant personnel suspected the passing of a nearby train could be causing the high vibration, so it was investigated and ruled out as a possibility. Spectra and time waveforms analyzed showed multiple harmonics within the spectrum and an elevated noise floor, indicating a loose condition at the outboard bearing location. No problems were found in the bolted and welded connections, so it was suspected the bearing was loose in the housing due to wear. The bearing housing cap was removed, and inspection revealed skid marks on the outer diameter of the outer bearing race, indicating the bearing had indeed spun inside the housing and was loose. Both the bearing and housing were replaced, and the motor was realigned.

Data collected after the bearing and housing were replaced showed the vibration amplitudes had increased slightly to 0.15 ips (pk). This was not a surprise since the new bearing and housing now had a proper fit, which resulted in a solid transmission path of forces from the fan to the case-mounted accelerometer. Additionally, if the bearing housing became worn enough for the bearing to spin in the housing, an excessive force had to be present to cause the wear to occur.

In all situations where the diagnosis is looseness, there must be an underlying cause for the looseness to occur. Looseness is only an aggravating condition and therefore must have an underlying cause that leads to the looseness. In most cases, looseness develops over time as a result of excessive force acting on the system components.

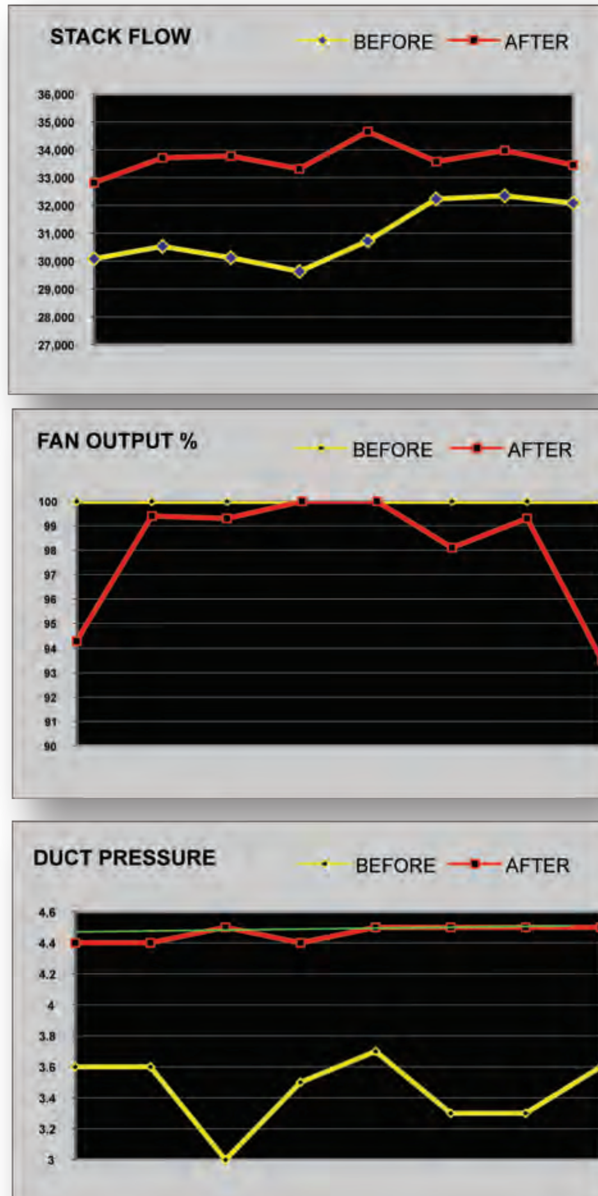


Figure 2. Fan performance metrics before and after inlet cones were replaced to provide the proper overlap.

Interference and Poor Performance

Figure 1 depicts time waveform readings taken after the new bearing housing and bearing were installed. They reveal an impact occurring once per revolution.

It was suspected that there was interference between stationary and rotating parts within the fan. After opening up the fan, the interference problem between the fan wheel and the inlet cone was apparent. There was excessive overlap between the fan wheel and the inlet cone, which resulted in very tight clearances. Corrosion of the inlet cone over time caused it to distort, resulting in contact between the fan wheel and inlet cone. Additionally, it was noticed that repairs over the many years of service to the opposite inlet cone had led to the opposite problem. There was a substantial gap between the inlet cone and the fan wheel, which can significantly decrease performance of the fan.

An immediate fix to the interference was implemented, and it was recommended that the plant have both inlet cones cut out and replaced to provide the proper overlap. The work was scheduled at a later opportunity to have the old inlet cones that were corroded and distorted cut out and replaced with completely new sections on either side. This work was performed by the fan OEM. The new inlet cones provided the proper clearance between the wheel and the stationary inlet cone section, which eliminated the interference problem, as well as substantially increased the performance of the fan. Prior to putting in the new inlet cones, operators were continuously running the fan at 100% output and still not achieving the desired pressure set point. After the fan inlet cones were replaced, operators only occasionally were required to run the fan at 94% output to achieve the desired set point, as is shown in Figure 2. The increase in performance achieved was a 12% increase in stack flow and over a 20% increase in duct pressure. As shown in the duct pressure plot in Figure 2, the desired duct pressure set point (green line) was able to be held, given the increase in fan performance.

Dynamic Balancing

The follow-up phase analysis showed the dominant force was a rotating force and more specifically was a static unbalance. However, the spectral and time waveform data did not sup-

Initial Balance Quality Grade (per ISO 1940/1)	**G77.8**
Initial Amplitude (at 1X)	**1.188 mils (Pk-Pk), 0.055 ips (Pk)**
Initial Residual Unbalance Force	**3336 N (750 lbf)**
Final Balance Quality Grade (per ISO 1940/1)	**G2.6**
Final Amplitude (at 1X)	**0.078 mils (Pk-Pk), 0.004 ips (Pk)**
Residual Unbalance Force	**196 N (43 lbf)**
Influence Coefficient (Single Plane)	**21.8 oz / mil**

Table 1. Single-plane dynamic field balancing results.

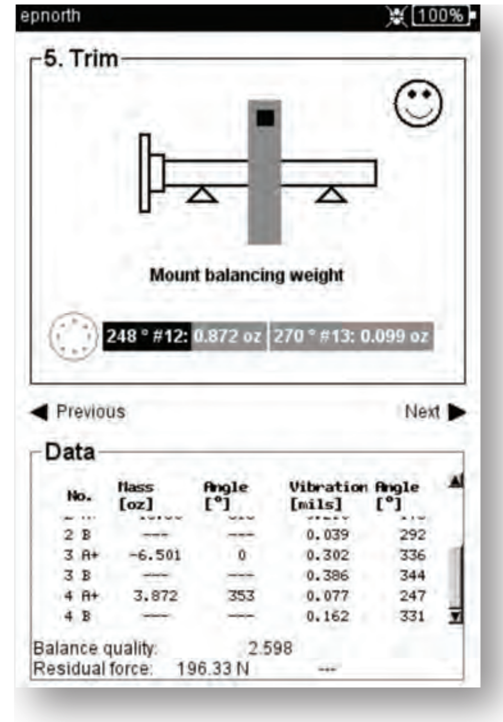


Figure 3.
By providing the rotor weight, rpm, and correction radius the LUDECA VibXpert will automatically calculate the balance quality grade and residual unbalance force during balancing.

Equation 1

$$F = 1.77 \times R \times CW \times \left(\frac{N}{1000}\right)^2$$

Where:

- F = force of unbalance in pounds force
- R = radius of correction weight in inches
- CW = correction weight in ounces
- N = shaft turning speed in revolutions per minute

Equation 2

$$U_{per}\ (oz - in) = 6.015 \times G \times \frac{W}{N}$$

Where:

- U_{per} = the permissible residual unbalance in ounce-inches
- G = ISO balance quality grade
- W = rotor weight in pounds
- N = maximum service speed e_{per} in revolutions per minute

port this per wall chart/textbook criteria. The spectra had low amplitudes of vibration at the 1X running speed and did not dominate other content in the spectrum. Additionally, the horizontal and vertical amplitudes were not similar as analysts are taught to expect. Knowing that spectral data and amplitudes can be misleading, the decision to balance the fan was made using the phase analysis alone. Relative motion analysis using phase information is usually more accurate than spectral amplitudes in the diagnosis of the dominant force acting on the system. Using relative motion phase analysis to determine whether the dominant force is rotating or stationary helps to pinpoint the possible problems.

Since phase analysis showed the relative motion of the rotor to be "in-phase" end-to-end, the dominant unbalance condition was determined to be static. Therefore, a single plane balancing procedure was performed. The fan wheel was thoroughly cleaned before balancing was performed, and it was noted that a significant amount of balancing weight was already present on the wheel. Three corrections were performed, which resulted in the removal of previous correction weights totaling 24.17 ounces. It is always a best practice when balancing to have the least amount of additional weight on the rotor as possible. This can be accomplished by removing or modifying old correction weights if they are mounted close to the proper location for weight removal. Modern portable analyzers, such as the VibXpert used in this case, often have the capability to toggle between weight addition and removal. Another way to minimize the amount of weight is to combine multiple weights into one. A combination of two weights at different angles will always combine to make one with less total weight.

Analyzing only vibration response spectra is difficult since they often don't clearly match wall chart and textbook examples.

The balancing results are summarized in Table 1.

The force due to the unbalance mass that was removed equaled 707.5 lbf at the running speed of 884 rpm. This was calculated using Equation 1 (listed above) with a correction radius of 33 inches and the vector combination of weight of 15.5 ounces.

Even though the amplitudes of vibration were low, and the spectral data did not indicate a dominant unbalance problem, there clearly was an excessive force due to unbalance. The reason for the lack of 1X running speed frequency response in the spectrum is a result of the system on which the forces were acting. This is apparent when reviewing the influence coefficient in Table 1. It took a significant amount of mass to cause a change in the response amplitude. In this case, this is because both the motor and fan have a very robust support structure and are securely attached to a large inertia base, which does a very good job of resisting vibration. In the process of properly balancing the fan, the root cause of the looseness in the bearing housing was identified and solved.

When balancing a rotor, it is very important to balance to balance quality grades and not simply response amplitudes. If only amplitudes were considered in this case, balancing would have not been performed, due to the very low amplitudes of vibration. The ISO 1940/1 standard outlines the balance quality requirements for rigid rotors. Industrial fans need to be balanced to within an ISO G6.3 balance quality grade or better. Since the balance quality grade is directly proportional to the amount of residual unbalance, achieving a better balance quality will decrease the force due to unbalance on the bearings and significantly increase the overall bearing life. The ISO 1940/1 standard includes a chart to determine the balance quality grade, or it can be calculated using Equation 2 (listed on the left). Again, the modern portable analyzers make balancing much easier for users, and some will calculate the balance quality grade as well as the residual unbalance force (Figure 3).

Conclusion

Analyzing only vibration response spectra is difficult since they often don't clearly match wall chart and textbook examples. This requires vibration analysts to utilize multiple vibration analysis techniques to get the whole picture, which may lead to solving multiple problems. The end result should solve the root cause of the problem, which leads to increased reliability. Here are a few things to consider for this type of difficult problem:

- Utilize advanced techniques, such as phase and time waveform analysis, to ensure that the system's response does not mask the true root cause.
- Consider the system analyzed and ask a few questions:
  - What kind of response would this system exhibit given how it is supported, adjacent equipment that is running, current operating state, etc.?
  - Could there be an aggravating condition such as looseness, resonance, or beating that is masking the real problem?
- Identify aggravating conditions first, fix the aggravating condition, and then reanalyze the system and repeat until all issues have been resolved.
  - Do not attempt to solve fundamental problems such as unbalance and misalignment with aggravating conditions present. Such attempts may immediately result in excessive vibration, or the vibration will return in the future, causing additional problems.
- Multiple faults may be present. Identify and resolve the most dominant problems first. Then reanalyze the system and repeat until all issues have been resolved.
- Balancing is performed to reduce the amount of residual unbalance force in the rotor. It is not sufficient to balance to a given amplitude without knowing the influence of unbalance mass to the particular machine.
  - Always balance to ISO, MIL-STD, or API balance tolerances.

Chad Wilcox, B.S.M.E., has been a consultant for seven years, providing vibration analysis solutions and training for clients across the United States and overseas. He is certified Category III by The Vibration Institute. Mr. Wilcox is currently the Director of Engineering Services for Pioneer Engineering, located in Fort Collins, Colorado. www.pioneer-engineering.com

Operator Maintenance or Autonomous Maintenance

Malcolm Jones

When Productivity, Inc. came across the work of the Japan Institute of Plant Maintenance (JIPM), developers of total productive maintenance (TPM), as part of our research into Japanese manufacturing practices in the 1980's, we encountered the same problem as with other systems: how do we teach this to people in the West?

When we first published the work of Shigeo Shingo on single-minute exchange of die (SMED), we came across the same issue: manufacturers saying, "That's fine in theory, but how do we do it in practice?" This led to our development of practical SMED workshops: a little theory and then extensive application on a pilot project. We then applied the same approach to lean flow – developing the Kaizen Blitz with Mr. Iwata and his group of ex-Toyota supplier development engineers.

TPM has two fundamental additions to our current approaches to maintenance management: OEE analysis and autonomous maintenance (AM). Our approach was therefore to take OEE and AM and develop a Kaizen event, which we rather grandiosely called "A Maintenance Miracle." More than twenty years on, we are still running these events as a way of learning about TPM.

Over those twenty years we have seen autonomous maintenance anglicised as "operator maintenance," but there is an important difference. Operator maintenance is largely the transfer of basic maintenance tasks to operators; autonomous maintenance is the improvement process we take people through on the "Maintenance Miracle," a process of restoring, improving, and maintaining equipment. If all we do is the third step, maintaining, then we have lost a major part of the process.

Operator maintenance is largely the transfer of basic maintenance tasks to operators; autonomous maintenance is the improvement process we take people through on the "Maintenance Miracle," a process of restoring, improving, and maintaining equipment.

The AM process is also important for learning. Once a team have inspected a piece of equipment in exhaustive detail, restored all its functions, and improved some further, they develop an understanding of the machine's functions, which enables them to operate and maintain it at its optimum condition. Personally, I am a great admirer of Professor Fujimoto's analysis of the Toyota Production System, which focuses on TPS as a "learning system." TPM, and AM in particular, can also be seen as learning systems, and learning generates improvement.

So what is the AM process? In the original translation from the Japanese, the first three steps are given as:

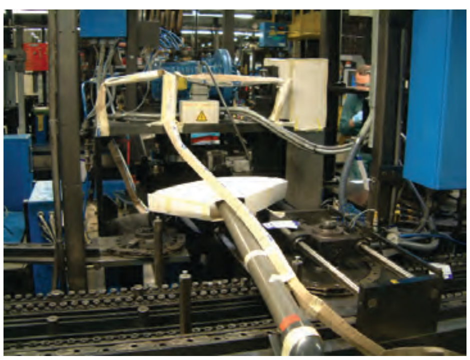
1. **Initial cleaning and inspection**
2. **Elimination of contamination and inaccessible areas**
3. **Establishment of provisional maintenance standards**

I prefer to call these restore, improve, and maintain. There are of course seven steps of AM in all the textbooks, but the first three are the fundamental processes, to which we might want to add visual management of maintenance standards, both on the equipment and on activity boards.

Step One – Restore. This step involves a team from production, maintenance, and engineering, most definitely including the equipment operators, in a comprehensive "deep clean," inspection, and restoration of a piece of equipment. The key to this activity is the recording and correction of every single abnormality with the equipment: every loose fastener, bent guard, damaged piece of insulation, leaking connector, and instance of dirt or grease. Often this is done by "tagging" the machine, giving the well-known "Christmas Tree" effect of a machine covered in tags. Personally, I am not an ardent advocator of tags, except during training exercises, as they themselves deteriorate quickly and are only an outward sign of the process. The important point is that abnormalities enter the work list and are corrected in a timely manner. For minor defects this means during the exercise and for more major work, or work that requires new parts or special skills, I tend to use an eight-week plan as a goal for completion.

Step Two – Improve. In this step we look for areas that are the source of the contamination that we spent step one removing from the equipment, and we try to prevent them from causing more contamination. We do this by developing guards and devices to contain and remove the contamination from the machine. We also look for areas where we had problems gaining access to clean, or areas where operating the equipment involves awkward movement by the operators. We then try to make modifications to eliminate these problems.

Step Three – Maintain. In this step we develop a provisional standard based partly on the current maintenance plan, but mainly on our experience in restoring the equipment. The question to ask is, "What maintenance activities would have prevented all this deterioration from happening in the first place?" It is a provisional standard because, as with all



The first three steps of the AM process:
Step 1 - Initial cleaning and inspection (top)
Step 2 - Elimination of contamination and inaccessible areas. "Cardboard engineering" (far left)
Step 3 - Establishment of provisional maintenance standards. Visual lubrication (left)

Kaizen activities, we go through a plan, do, check, act cycle where we not only make improvements, but also check how well they are working and modify as required.

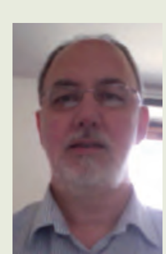
We will then use visual management to secure this maintenance standard. My favorite method is having a numbered inspection route around the equipment, with each inspection point being visualised in terms of max/min levels on sight glasses, gauge markings, valve markings, and even match marks on critical fasteners and thermal labels on bearings.

There is an important link between OEE and AM. OEE measures and analyses the availability, performance, and quality of equipment. Availability losses are due to changeovers or breakdowns. Performance losses are due to reduced speed or minor stoppages. Although TPM analyses show 6, 7, 8 or even 16 losses, depending on which model is used, another categorization of breakdowns and performance losses is more useful for AM.

The majority of breakdowns (around 70%) can be seen as caused by deterioration in equipment functions. The AM concept of accelerated deterioration regards this deterioration as not inevitable–in fact, accelerated deterioration points out that deterioration is normally happening faster than it should because of inadequate maintenance practices. AM aims to eliminate this accelerated deterioration through the restore, improve, and maintain process. Similarly, the majority of performance losses can be traced back to contamination issues, and AM aims to eliminate this contamination, particularly during step two improvements.

My problem with some of the operator maintenance programs I see in my work around the world (North America, Europe, Asia, and Africa) is that they are maintaining equipment in a deteriorated condition, because they have not gone through the hard work of restoring and improving the equipment before establishing the maintenance standard. When this is combined with a lack of proper OEE measurement, we really are working in the dark, utilizing equipment with no true idea of its real capacity and performance.

AM will not solve all your equipment problems, but it can be used to eliminate the deterioration and contamination that is the source of many of them. We can then use all our maintenance technologies to tackle the remaining more complex issues of equipment condition and performance. In this respect, AM is like 5S – it is providing a foundation for more complex improvement activities, and there is no point in performing complex analysis on equipment that is subject to extensive deterioration and contamination. First, we must remove the deterioration and contamination and then assess our baseline performance.



Malcolm Jones founded Productivity Europe Ltd. in partnership with Productivity Inc., USA in 1989. He provides facilitation in lean and TPM for global clients and was involved in the development of TPM programs in a number of large organizations, including Unilever and Diageo. He is currently working on a five-year lean transformation with a global manufacturer with plants in Eastern Europe and the Far East, alongside other smaller projects in the UK and Europe.

The Maintenance Miracle - An Autonomous Maintenance Kaizen Event, November 8-11, 2011.
www.productivityinc.com

decision support

cMms computerized maintenance management system

Computer Maintenance Management System

Mark Brunner

Your computer maintenance management system (CMMS) is your maintenance management database, and like any database, if the input is bad the output will also be bad. A well-utilized and well-managed CMMS is an invaluable tool that should be in close alignment with a work management system. What does a good CMMS look like?

In a great step forward from management, an experienced reliability engineer was hired to help improve plant reliability. The first task for this engineer was to determine the equipment that causing the biggest losses for the business. Having had a CMMS in use for a number of years, this was the obvious place to start. The first place to look was the breakdown data, and this was easy to locate, as all breakdown work requests had been tagged in the CMMS. The breakdown crew had been trained well in the use of the CMMS, and each breakdown had been coded appropriately, which made it easy work to identify chronic losses.

The next place to look was in high-cost areas, so a work order cost report was run that spilt the costs against the equipment hierarchy. Because the equipment hierarchy had been structured well and all relevant hours and materials had been booked against the correct area most of the time, a picture of high-cost items was developed quickly. Matching the chronic losses and costly repairs over the last 12 months, it was easy to find where the effort needed to be applied, so task briefs were raised so maintenance planners could begin planning some critical repairs and engineering could prepare some capital submissions.

The planners developed a plan in the CMMS for the repairs by estimating hours and purchasing materials, which were easy to find as they had all be catalogued and put in bills of materials. In a few instances the planning had already been done, as the work had been done before and the job had been saved as a task list in the CMMS. When all materials were available for the task, the scheduler reviewed his list of work orders from within the CMMS, checked his labor availability through the automated connection to the HR module, and then matched the labor to the task that would be completed in the following week. In the following week, all tasks were completed as they had been planned so well, the planner closed off all the tasks in the CMMS, and this data was now captured for reporting. At the end of the week, a PM compliance measure of 100% was reported, and planning accuracy was spot on. The capital work was still in the approval stage, but at least all the maintenance work was completed on time and to budget.

Is this how it works at your workplace?

Mark Brunner has been working for over 30 years in the steel industry in Australia. Currently he is responsible for plant reliability and production data mangement systems the CMMS in his business unit. www.thereliability-roadmap.com

Enhance Asset Performance with Effective Labels and Visuals

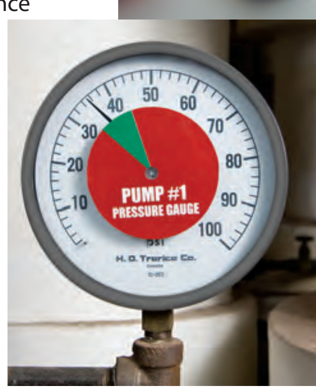
Chris Rutter

Visual Systems Improve Maintenance

Visual devices are widely used in 5S, Standard Work, Quick Changeover, Kanban, and other lean techniques, but they should also be an important component of your proactive maintenance strategy.

When implemented correctly, visuals can provide a number of benefits to your reliability program, including:

- Simplified preventive maintenance
- Optimized predictive maintenance
- Faster troubleshooting and repairs
- Improved quality, with fewer errors and defects



Simplify Preventive Maintenance

Signs and labels can be used to identify preventive maintenance (PM) points and provide basic cleaning, inspection, and lubrication instructions.

These visuals are especially important if your company has implemented an autonomous maintenance program. When responsibilities for routine care and inspection are transferred to equipment operators instead of trained maintenance professionals, it becomes critical to clearly define their tasks and checkpoints.

For example, improper lubrication – too little or too much – is a major cause of equipment failure. A simple **lube label** can save your company significant costs in motor repair and replacement.

In addition, **color-coded markings** can be applied to zerk fittings and grease guns to guard against using the wrong type of lubrication.

Oil level indicators can also be applied to sight tubes to simplify oil management. The use of green and red striped labels placed behind the sight tube lets the operator easily detect when oil levels are too high or too low.

Preventive maintenance schedules and check sheets are other valuable visuals to have on your shop floor. These schedules show who needs to perform what task and when the task should be completed.

A schedule should simply highlight the task to be performed; it should not list the steps taken to accomplish it. If step-by-step instructions are required for the task, those details should be made available on a separate procedure.

Signs and labels can be used to identify preventive maintenance (PM) points and provide basic cleaning, inspection, and lubrication instriations.

Optimize Predictive Maintenance

As baby boomers retire – about 78 million in the next 10 to 15 years – there will be a growing number of new and relatively inexperienced technicians in the workforce. One large, well-known manufacturer recently forecasted that by 2014, approximately 70 percent of its maintenance staff will have less than five years of relevant job experience.

This will greatly increase the risk of errors and omissions in maintenance activities.

In addition, maintenance workers must learn how to use a growing number of sophisticated predictive maintenance technologies, such as vibration analysis, ultrasound, and thermal imaging. When performing predictive maintenance, it's critical to take measurements at the same exact place each time. To ensure that the location for readings remains consistent – regardless of who conducts the inspection – you can apply **predictive maintenance targets**.

When implementing predictive maintenance programs, reliability technicians often use inspection routes to streamline the process and maximize efficiency. The drawback to this approach, however, is that the technician may not be familiar with each and every piece of equipment, and the proper readouts may vary across different machines.

Visual controls like **gauge labels** make it clear to anyone at a glance whether the temperature or pressure is within the normal operating range. In fact, these visuals make it so easy to detect abnormalities that anyone walking by becomes a potential inspector, facilitating early detection of potential problems.

Visuals can also be used to detect when **chain tension** is too loose, or advise when to replace the chain. When tension slackens, links from the chain should be removed, and the adjustment block can be shifted to restore proper tension with the shorter chain. Once a specified number of links have been removed, the edge of the block extends outside of the green area, clearly indicating that the chain should be replaced.

Faster Troubleshooting and Repair

Visuals can also speed **troubleshooting and repairs**. Including "to" and "from" information on equipment ID labels makes it easier to trace lines in electrical systems and pipe networks. As a result, you can perform repairs faster and reduce the risk of errors and potential injury.

Maintenance stores are perhaps the biggest contributor to maintenance inefficiencies, and your storeroom may offer plenty of opportunities for improvement through visual management. You can make repairs even more efficient by ensuring that the proper replacement part and its storage location are clearly identified, ideally by putting the information right at the point of need as shown.

To reduce search time, and ultimately reduce downtime, clearly **label shelves and bins** in stock rooms and tool cribs. Where possible, use graphics and/or photos on your labels for faster recognition and to avoid pulling the wrong part.

To enhance safety and reduce hazards, many companies are posting graphical lockout procedures right on or next to their equipment. These procedures provide the detailed steps included in accomplishing a task, including photos, diagrams, and instructions.

All procedures should include the content, or what you do; the sequence, or the order in which you do it; the time, or the time it takes to do it or how frequently it should be done; and the objective, or the desired outcome.

Be sure to keep your procedures simple. For example, don't mix operator tasks with maintenance technician tasks. The most effective procedures are designed specifically for one type of user.

Posting hazard warnings and procedures with safe work instructions right at the point of need is the most effective way to reduce accidents and injuries at your plant. These procedures are as important (if not more so) than classroom or computer-based safety training.

Promote Error-Free Setup

When restoring equipment to operation, how can you ensure efficient and error-free setup? Visuals such as the **operator control panel labels and alignment aids** shown below help to simplify machine settings and positioning.

In addition, labeling the **rotational direction on gears and shafts** can help you avoid costly setup errors that can damage or destroy motors and drive systems.

Make Your Own Visuals

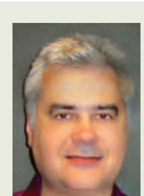
All of the visuals referenced in this article can be created right from your facility using a lean tools software system and industrial lean label printers. With a versatile in-house labeling system, you can create your own industrial-grade visuals on site and on demand, at a fraction of the cost of having them printed by an outside vendor.

Today's lean software uses template wizards to speed and simplify the design and layout of custom visuals. The software includes thousands of safety and industrial pictograms, and it even lets you import your own logos or photos. You can also import data from spreadsheets and databases to include on your labels.

Industrial printers are available that can print multiple colors without manual ribbon changes and can even print photographic images. These printers output to a wide variety of media, including permanent and repositionable adhesive labels, tags and Kanban cards, magnets, and more.

If you purchase a printer with a built-in plotter cutter, you can easily create cut-letter door signs and paint stencils. All these capabilities are available in a make-it-yourself visual workplace printing system for use in lean and world-class manufacturing environments.

As you look to improve equipment performance and reliability, it pays to keep your eyes open for new ways in which visual systems can benefit your overall lean initiatives.



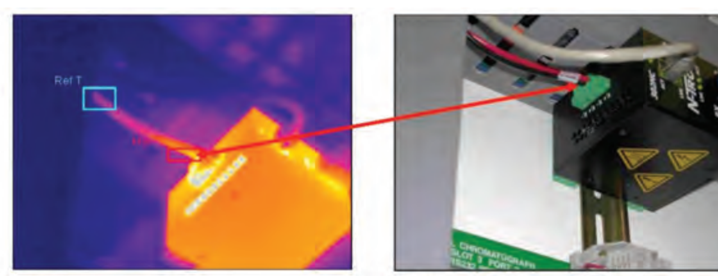
Chris Rutter is a Senior Marketing Manager for the lean manufacturing and maintenance markets of Brady North America. Chris delivers training on visual workplace techniques and has presented at numerous conferences, seminars, and webcasts.
www.bradycorp.com or
www.BradyID.com/visualworkplace

DO Sweat the Small Stuff:

The Benefit of Inspecting "Small" Equipment With Infrared Thermography

Dave Sirmans and Roy Huff

The field of Infrared Thermography (IRT) has seen quite a few changes over the years. Camera innovation would be chief among those. Thermography was once upon a time a much more tedious and cumbersome endeavor than it is today.



Label	Value
Max T. : max	89.5°F
Ref T : max	77.3°F

IR information	Value
Date of creation	5/6/2008
Time of creation	1:08:22 PM

Figure 2

Figure 1

As an instructor of IRT, I often have students in Level One courses who complain about the size and weight of their cameras. That all ceases after I show photos of older equipment, such as this Inframetrics 740 rig from back in the early 80's (Figure 1). Believe it or not, this was once considered man-portable.

Well thank goodness for technology. Today's cameras are smaller, are less expensive, and have increased portability compared to what we lugged around in the "old days." Almost every camera on the market today has onboard memory, which is a far cry from the Polaroid camera attachment days, and even a huge improvement over carrying a video recorder attached to your imager. As these technological advancements help us get more done in less time, and at a reduced cost, are we taking full advantage of these improvements? As a service provider, my personal experience has been that as inspection costs decrease, the savings aren't passed on to increase the number of assets within the scope or the frequency of inspection. The opposite is often true, with the scope of an inspection *decreasing*, leaving "small" equipment out in the cold while switchgear equipment and large distribution devices remain on inspection lists.

Obviously facility switchgear equipment is quite critical; it's the heart of the electrical distribution system. Industrial equipment requires its operating voltage in order to perform, hence the inspection of distribution devices that feed process equipment. But why leave off the circuits feeding the process control or Human-Machine Interface (HMI) devices like touch screens and control panels? If the switchboard feeder breaker for your conveyor line never goes down, but the Programmable Logic Controller (PLC, seen in Figure 2) controlling it fails catastrophically due to a heat-related failure in *its* distribution path, what has been saved?

Almost anyone with knowledge of IRT as applicable to electrical apparatus inspections understands how we find anomalies. Increased contact resistance in an electrical connection causes heating that increases at the square of the applied current. For this reason, the NFPA-70B (*Recommended Practice for Electrical Equipment Maintenance)* suggests a minimum of 40% load on a circuit at the time of IRT inspection for optimum results. One common misconception is that the resistance within the connection point has to be very high in order to cause heating. In the example in Figure 3, the electrical resistance

Figure 3

between the failed component and the new replacement component is 2.2 *micro*-ohms. Not exactly what we would normally consider "high," but significant nonetheless.

Another common misconception is that lower-power devices don't carry enough current to be susceptible to heat-related failure. While abnormal heating is a product of current *squared* times the resistance (I^2R), and electrical devices are rated according to their ability to accommodate the flow of current, lower-current-rated devices can also experience heat related failure. Notice the following example in Figure 4.

We're looking at what appears to be 14AWG control wire, which is rated for between 25 and 35 amps, depending upon the particular application. In the thermal image you will notice that the conductor is only showing abnormal heat at the connection point, not on the entire conductor, which would appear to indicate that the conductor itself is not overloaded, and that the heat present is due only to the high resistance connection point. Note the apparent temperature of the anomaly by comparing the color to the temperature scale. An apparent load of significantly less than 30 amps is producing nearly 300 °F. Also important to note is that the control circuit was for an industrial boiler, and if it had failed the boiler would shut down, halting the process of this facility. Another example appears in Figure 5.

The white tape on the large conductor in the center of the image indicates that this is a neutral. We expect that a neutral conductor in a panel should carry some amount of current. If operating correctly, though, this amount of current should be a fraction of what is being carried by the phase conductors. Notice the temperature scale on the thermal image. The point of saturation is on the wire insulation (which has a high emissivity and therefore should give a relatively accurate temperature) and indicates an apparent temperature of greater than 200°F. THHN wire is rated at 90°C (194°F), so we're looking at the potential for thermal damage here.

Notice the wire colors on the breakers. This is a 208VAC panel, which is often overlooked in the inspection process. You might also notice that the panel components are completely exposed. Surface scanning is an excellent *pre*-inspection process, but it isn't a substitute for fully exposing a panel. If this panel had not been completely exposed, this anomaly wouldn't have been revealed until catastrophic failure occurred. Let's assume for a moment that this panel feeds an office space in a manufacturing facility, and within this office space is the computer that monitors a critical process. What happens in the event of a failure in this panel? Assigning criticality of an asset based on nothing more than its voltage or current rating might have led to the panel in this example having *never* been inspected.

What about voltage levels? Among the common criteria used to determine criticality of electrical apparatus for inspection is the voltage class or rating of the device. Again, abnormal heating in an electrical connection is a product of *current*, not voltage. The voltage level of the device has no bearing on the potential for a heat-related failure. Take a look at Figure 6.

These images are from a 24 volt power supply. The temperature scale beside the thermal image indicates an apparent temperature of approximately 40.5°C (105°F), compared to an apparent 37°C (98°F) on an adjacent connection point. Had this particular device not been deemed critical due to other factors, and its importance gauged solely on the voltage level, this anomaly might not have been found until it failed.

As technological advancements help us get more done in less time, and at a reduced cost, are we taking full advantage of these improvements?

Control panels offer an excellent opportunity to maximize the benefit of thermography as a predictive technology, but sadly they are often overlooked. Contained within a typical control panel are transformers, fuse blocks, circuit breakers, and a host of other electrical devices that are inspected in their larger forms inside of larger apparatus. The control transformer inside

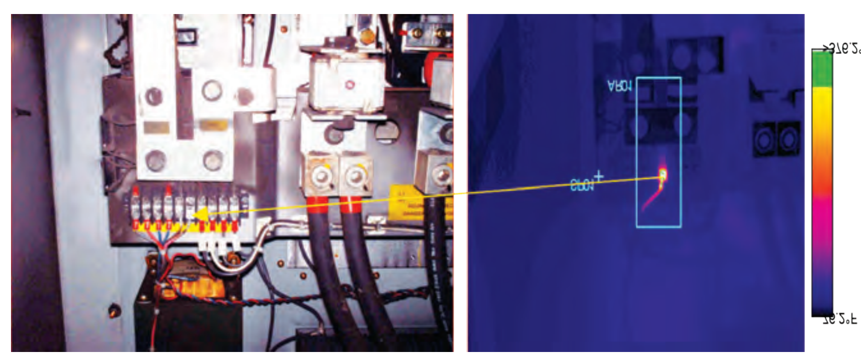


Figure 4

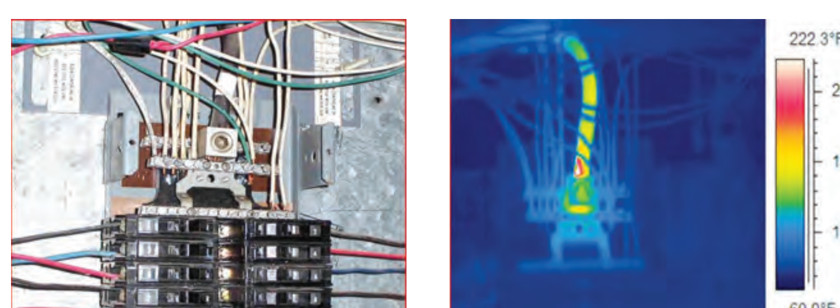


Figure 5

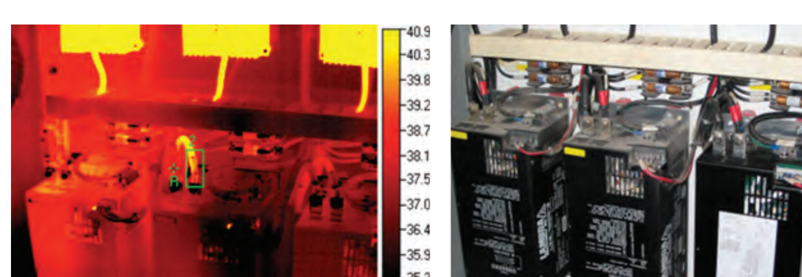


Figure 6

a control panel operates exactly the same as the larger ones we inspect as part of the utility equipment. Just because they are smaller versions of what we normally would consider critical devices doesn't mean they should be inspected at a reduced frequency. In Figure 7 you will note that even "small" components like those mounted on DIN rail can have sufficient I^2R in their connection points to experience heat-related failures.

One common misconception is that the resistance within the connection point has to be very high in order to cause heating.

The 20 amp circuit breakers inside a control panel have the same potential for failure as the 400 amp ones in a distribution switchboard. Does the 20 amp circuit breaker cost less to replace? Sure it does, but what impact on the overall process of the facility does it have? Can we expect that a circuit breaker couldn't experience the same degree of abnormal heating because it's in a 120VAC panel as opposed to a 480VAC distribution board? See Figure 8. We have what appears to be a 20 amp circuit breaker in a 208Y/120VAC panel with a high temperature anomaly. What if this circuit breaker is the one feeding the production server in an office space? Sweating the small stuff yet?

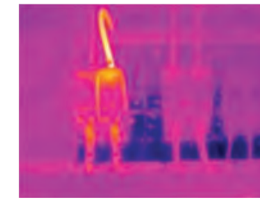


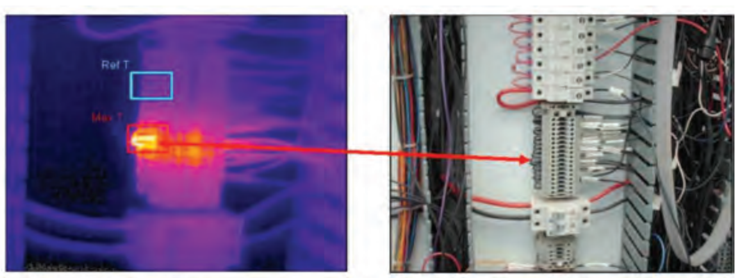
Figure 10

Service main switches are routinely inspected, but what about the 20 amp service disconnect for the control panel (as shown in Figure 9)? Downtime is downtime, no matter the cause.

The anomaly in Figure 10 was found inside a control panel at a textile facility in Alabama. As my escort walked me past this control panel on our way to another device, I asked if we were going to inspect it. The answer I received was "if we have time after the important stuff." Upon the discovery of this item, my escort decided to take time to look at the other 19 control panels identical to this one, each one of which was responsible for the operation of finishing machines at the end of their process. Had this control panel failed, one half of the finishing process would have ground to a halt. Subsequent inspection of the remaining control panels in this production area yielded two additional discoveries. They're sweating the small stuff now!

As reliability professionals within a facility, your input to the routes and frequencies of asset inspections is crucial in bringing about a change. The assessment of criticality for any asset within a particular route needs to consider the impact of failure of devices previously believed to be unimportant due to its voltage class or current rating.

As a service provider for client companies, your task is to educate your customers on the importance of including these "small" devices in their inspection. Often a service provider only sees their customers once or twice a year, and they're almost always pushed to get as much out of their annual visit as they can and to cut time out of the inspection process to stay competitive in their pricing. It's often an uphill battle to make changes; we know that from the history of IR thermography itself. But it can happen, and ***you*** can make it happen if you start sweating the small stuff.



Label	Value
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Ref T : max	92.2°F

IR information	Value
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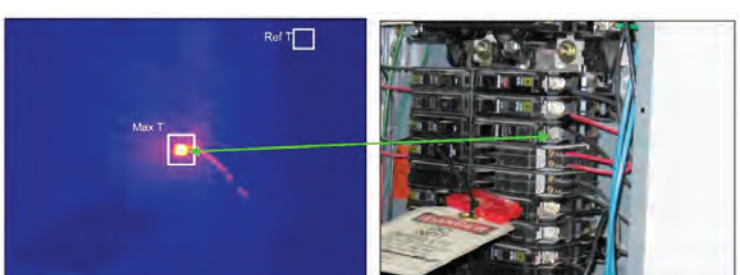
Time of creation	1:01:47 PM

Figure 7



Label	Value
Max T. : max	398.7°F
Ref T : max	75.3°F

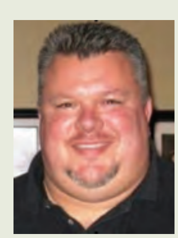
IR information	Value
Date of creation	6/21/2004
Time of creation	10:37:31 AM

Figure 8

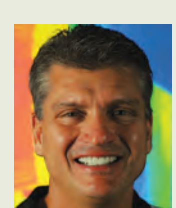
Label	Value
Max T. : max	117.1°F
Ref T : max	97.2°F

IR information	Value
Date of creation	5/6/2008
Time of creation	10:44:51 AM

Figure 9



Dave Sirmans joined The Snell Group in the fall of 2008 as Operations Manager for the company. Here he is responsible for managing and coordinating The Snell Group's field service operations and overseeing the company's team of technicians that offer infrared thermography, motor circuit analysis, and ultrasound testing services at various locations throughout the United States. Prior to joining The Snell Group, Dave worked in reliability as lead engineer in an electrical testing company. www.thesnellgroup.com



Roy Huff, SMRP, CMRP, is New Product Development Manager and Instructor with The Snell Group and partner in the inspections services company specializing in auditing, mentoring, and consulting services for a broad range of industries. With a professional background in reliability engineering, Roy's strengths in management and program development have been a tremendous asset to The Snell Group. Before that, Roy spent twelve years as an Equipment Reliability Engineer with Allied Signal Aerospace. www.thesnellgroup.com

precision maintenance
Lu lubrication

Automatic Lubrication Systems - Don't Work!?!

David Piangerelli

Companies seeking ways to gain operational efficiency and increase reliability often turn to technology. Increasing productivity with reducing operating costs has become a mandate for managers. Maintenance plays an important role in increasing equipment reliability through condition monitoring of critical assets, using tools such as oil analysis, vibration analysis, thermography, etc. Each concept or tool must often be sold to the management team, who is looking for a return on the investment.

Although the technology for automatic lubrication systems has been available for many years, there is a relatively large number of people who remain unconvinced, simply rejecting the use of these systems altogether for a variety of reasons, or perhaps waiting for more data to support their use and the impact they could have on their operations.

Skilled craftspeople, like their manager partners, are generally overwhelmed with tasks and responsibilities that continue to increase as companies reduce personnel and seek lean strategies. Yet, when labor-saving devices like centralized lubrication systems are proposed, objections and observations are often put forth that contradict the proven reliability and relatively simple technology automatic lubrication systems provide. A lack of awareness of the actual return on investment system installations provide is prevalent. Even more telling is that those that have systems don't understand why anyone would resist their use.

In my opinion, the resistance to the use of lubrication systems stems from a basic lack of understanding of how these systems work. In fact, the many comments we receive as marketers, designers, and installers of automatic lubrication systems, as well as premium lubricants, suggests there are a number of objections that have no merit. While there are those that have a catastrophic story to tell, there is invariably a sound reason or set of circumstances that contributed to the failure that in almost every case could have been avoided.

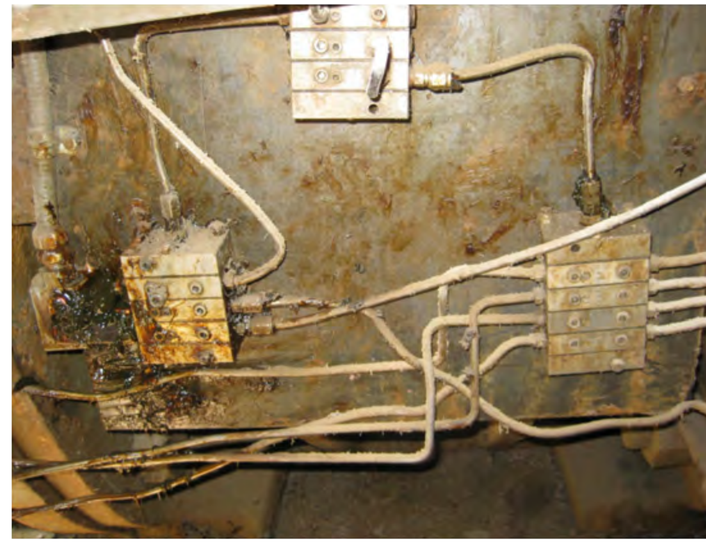
Why we don't want one!

Following is a litany of what we often hear from those that resist the concept of an automatic lubrication system.

- We used to have one on that machine, we took it off.
- Systems are not reliable.
- What happens when a line plugs?

Top: Leakage should not be tolerated. Tubing runs allowed to fly freely will not last

Bottom: Components are properly mounted: two pressure gauges, one at the pump discharge and one at the furthest run from the pump.



- Lube systems are for lazy people!
- They're too complicated; we like to keep things simple.
- If we put one on, no one will look at it!
- If a line breaks, the reservoir will empty.
- If a line breaks, all of the lube will go to the path of least resistance and nothing will get greased.
- They're too expensive; we would never even consider that.
- We've never needed it before, why do we need it now?

Although these comments represent only a sampling of our own experiences in the New England states we serve, it is safe to say that many equipment caretakers hold similar opinions or thoughts regarding the use of automatic systems. In fact, I offer here a few examples that stretch credibility:

1. A major corporation has spent $25,000 this year to date on replacing bearings in an application that is extremely wet, hot, and dirty. Several types of lubricants have been evaluated, as well as bearing types. A proposal was made for an automatic lubrication system that would serve 48 bearings, for a cost of $10,000 (not installed). The maintenance team states that management does not believe that the system will address the issue.
2. 12 lubrication systems were installed on new Kenworth trucks. The systems worked reliably for 6 years, at which time the company was sold. The new owners experienced a failure on a universal joint on the steering box input shaft. They declared that the presence of the systems caused the mechanics to ignore this lube point, resulting in all 12 systems being removed from the trucks and discarded.
3. A wheel loader system was proposed for a challenging environment. ROI was calculated at 17 weeks. This did not include the projected extended component life, reduced lubricant usage, or personnel safety enhancement. The cost of $6,500 was rejected by the company management, a waste hauler with over 120 trucks and several recycling facilities. Two years later the machine was line bored and rebushed at a cost of $10,000. A system was installed then. This company implemented a policy of installing systems on every piece of equipment they procure. After installing 18 systems, the company hired an outside consultant to review the maintenance of their equipment. The consultant declared that the purchase of lubrication systems should cease. His reasoning was that the systems cause the mechanics to believe that since everything is being greased automatically, they have no need to inspect the components they would typically see when being greased manually. A suggestion was made that if the mechanic was directed to inspect all of the components when the unit is in for service that this concern would be addressed, was rejected.

Education is critical

In order to install auto lube systems, they must first be sold, so many of the objections and observations listed must be overcome in order to do so. Our task becomes one of an educator. Our mission is sharing knowledge as to the actions one must take to minimize the notion that systems are not reliable or cannot be justified economically.

Owners and potential purchasers of any lubrication system, regardless of type, can benefit by being aware of the following list of areas of concern we often see as being ***causative factors in poor system reliability.***

Method of refilling - Some grease system designs expect the user to remove a reservoir cover and refill it with their hands or a paddle or board. System refilling should not be an afterthought but rather a part of the system itself. A manually operated pail pump with a hose and QD coupler or a Fluid Safe™ container or similar vessel should be provided.

Pressure gauges - These allow personnel to confirm the pump is creating pressure and are used as a convenient diagnostic tool. Yet, many systems, particularly on heavy equipment, lack this simple and valuable component. *Any system moving grease or oil through progressive divider valves, injectors, or flow meters (Single Line Resistance) should have a pressure gauge on it.*

Filters / strainers - Rarely seen on grease systems, filters and

Right: Allowing the reservoir to be refilled by removing a spin-off lid, is a sure recipe for system contamination.

Below: A grease and oil system serving a rotary dryer in a paper mill. It utilizes QD couplers to properly fill the reservoirs, pressure gauges, oil and grease filters, proximity switches on divider valves, and redundant controls, allowing the machine it serves to start up only after the system is energized and a lube cycle has been completed. It also provides visual confirmation of a failure to complete a lube cycle, as well as a signal to the mills' DSC.

Right: Lacking a pressure gauge, it is not possible to verify operation.

strainers provide basic protection of the components downstream from contaminants that may have entered the reservoir, ensuring longer, more reliable service from the system itself.

Lubricant selection - Ignorance of the appropriate type of lubricant suitable for a specific system is one factor leading to condemnation of systems in general. If system hardware mandates the use of an NLGI # 0 grade grease or softer, it will not perform properly when an NLGI # 2 grade lubricant is used. Systems using and/or calling for an NLGI # 2 grade grease, particularly parallel injector systems, have a vent valve that relies on the grease's venting characteristics to ensure proper repriming of the injectors in a timely manner. Inability to vent in a timely manner results in injectors that do not cycle properly, causing the resultant failure of the bearing the injector feeds. Greases that may be susceptible to separation of the oil and thickener can cause piston seizure in progressive divider valves, leading to system failure.

Quality of lubricant - Some believe that since a lubrication system meters lubricant so frequently, the quality of lubricant used is insignificant, giving license to use a cheap lubricant. Some lubricants may not possess the load carrying properties, or have the resistance to oil/thickener separation, that a superior lubricant will have. Oil/thickener separation results in the oft-cited complaint of blocked lines. Especially prevalent in progressive divider systems where residual pressure exists, separation can stop the system cold. Hence, the system malfunctions and bearings may be lost, all because of an inappropriate lubricant, not a poorly designed system or hardware failure.

The lubricant must be capable of carrying the load and reducing or eliminating metal-to-metal contact. We have serviced systems that were using inferior lubricants that operated as designed yet experienced unacceptable component life simply because the lubricant was unable to maintain an adequate film while in the contact zone. It didn't matter if the lubricant was being replenished every minute; if it was incapable of carrying the load, wear occurred.

Lacking a fundamental understanding of how the system operates and what must be done to properly maintain it is at the root of many failures.

Lack of caretakers - In my opinion, this is the most unacceptable reason why a negative opinion is formed. The initial purchaser believed there was a return on the investment and that the system would be expected to work as desired. By caring for the system and ensuring it functions correctly, one can easily ensure years of trouble-free performance and the resultant benefits lubrication systems provide. For those that may not be familiar with these benefits, I list them here for your review:

- Enhanced personnel safety
- Reduced lubricant consumption
- Dramatically extended component life
- Increased machine productivity
- Reduced product spoilage
- Reduced man hours
- Improved operating efficiency

The caretakers' responsibility comes down to a few basics:

Pump operation - When the lubrication system controller initiates a lube cycle, the pump will create pressure. A means to verify or confirm the pressure rise should be available, and doing so should be a routine task. When the system is energized, one can check for proper operation. ***Confirming the ability of the pump to build pressure and pump lubricant should be done on a routine basis,*** be it daily, weekly, or monthly, depending on the system and application.

Lubricant use - We have received calls from those who suddenly realized the pins were squeaking on their wheel loader, or that a bearing failed, yet no one can remember the last time the reservoir was refilled. ***Properly operating systems will use lubricant, so the reservoir will require periodic refilling.***

Visual inspection - The person charged with the responsibility for ensuring the system operates properly should have a checklist. On that checklist should be a general inspection of the tubing/hose runs, as well as the system distribution components, and of course the bearings or lube points. ***A "collar" of lubricant should be visible at the lubrication points; tubing, hoses, and components should be properly attached; and there should be no signs of leakage anywhere within the distribution system.*** In short, we like to say…

- the reservoir will go down
- lubricant will appear at the bearing points
- nothing should leak
- the pump should build pressure

System knowledge - ***Lacking a fundamental understanding of how the system operates and what must be done to properly maintain it is at the root of many failures.*** A progressive divider type system is not designed to allow elimination of a discharge port one no longer wants to use. Doing so results in a no lubricant condition; as this is one of the benefits of a progressive divider design, a blocked lube point will alert personnel to that condition. Yet the system will be non-operational because of personnel intervention, and of course a negative opinion will be formed.

Vendor support - Providing proper support to our clients to ensure reliable system operation is a mandate. ***The lubrication system vendor has the responsibility to the owner and purchaser to educate and share information freely to ensure that the system performs as expected for many years with minimal maintenance cost.***

Summary - A properly designed and installed system will provide years of reliable service. It cannot, however, do so without proper care. Like any other machine or asset, it requires care and understanding of system functionality and a partner vested in their success.

About the author:

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Key Performance Indicators for Stores and MRO

Key Performance Indicators (KPI) are used to measure and monitor daily, weekly, and monthly activities in MRO and Stores. Management uses them as tools to analyze past performance and make decisions as they move forward. KPIs are objective measurements, and taking these measurements is a key activity for the maintenance manager to oversee.

Daniel DeWald

Learning point takeaways are listed below:

1. Learn what a key performance is
2. Learn the formulas and the priority for each KPI for MRO and Stores
3. Apply the knowledge to individual companies

Also discussed are a criticality matrix, benchmarking activities, and expected outcomes when implementing Key Performance measurements.

Introduction

A Key Performance Indicator (KPI) is defined as a method to measure quantifying objectives to enable the measurement of performance. Some examples of this include the measuring of inventory turns, inventory accuracy, the dollar amount spent on emergency purchases compared to the overall purchases of the company, internal and external quality defects, stock outs, service levels (customer satisfaction), and others listed in the KPIs matrix. Management then takes these measurements, that are done on a periodic basis (daily, weekly, and/or monthly), and analyzes them through trend analysis, benchmarking, and critical path analysis (PERT). These numbers are posted at work centers, strategic operations areas, and other areas where they can be readily viewed.

Many companies use only a few KPIs to measure outcomes. Stores and MRO are not always measured for their performance. However, the old adage that if you do not measure, you cannot know where you have been or where you are headed is often true.

KPIs play a major role in gauging the success or failure of MRO and Stores. They provide a simple and concise method for comparing actual performance from one period to another. They can even be used to compare performance to industry best standards, plants within a corporation, and other storerooms. It is important to have most of the information required to calculate KPIs in the computer system or CMMS program. That way the manual effort is removed and replaced with an automated one. The accuracy of these calculations is directly dependent on the accuracy of the data in the database and the documentation of material movement.

Quantitative Measurements Matrix Chart

Cut out for fast reference

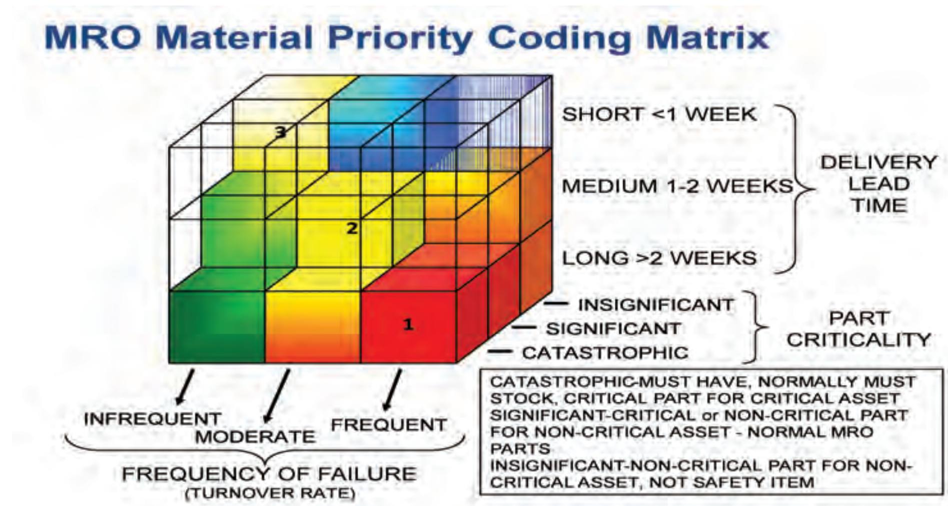
Listed are the required formulas and descriptions of each KPI for Stores and MRO. The maintenance manager must rank the importance of each KPI to his or her needs. They are ranked in four categories: **C-Critical need, H-High importance, M-Moderate need, and L-Low importance.** Performance can then be benchmarked and compared.

Description	Acceptable Range	Formula	When Due	CHML
Inventory Turnover	Greater than 12.0	Cost of Goods Sold / Average Inventory	Weekly/ Monthly	C
Inventory Accuracy	Greater than 95%	Actual Count / Computer on Hand Balance	Weekly	C
Total Inventory Valuation	Actual Dollars	Graph Inventory Valuation	Weekly	C
Total Dollars Used	Actual Dollars	Graph Dollars Used	Weekly	C
Stock Outs	Less than 1%	# of Occurrences / Total Pieces Picked	Daily/ Weekly	C
Emergency Purchases	Less than 2%	Emergency Dollars / Total Purchases	Monthly	C
Days Inventory On Hand	Less than 30 days on hand	Inventory Valuation / Average Daily Dollars Used	Monthly	C
Quality Defects Received vs. Overall Receipts	50 PPM or less external defects	# of Parts Defective / Total Parts Received = X / 1,000,000	Monthly	C
Required Delivery Dates Met	98%	Receipt Date / PO Date	Monthly	C
Warehouse Space Utilization	85% or less	Cubic Feet Used / Cubic Feet Available	Monthly	H
Slow Moving Parts	Less than 5% of total SKU	Parts Identified as Slow Moving / Total # of Parts in Inventory	Monthly	H
Equipment Bills of Materials	100% critical equipment; 95% and greater for all	Equipment Parts Entered / Total Equipment Parts	Monthly	H
Service Level	Greater than 95%	Parts Filled / Parts Ordered	Weekly/ Monthly	H
Receipt Lines Received Daily	Actual number	Graph--Trending	Daily/ Weekly	M
Target Ship Dates Met	95%	# Shipments on Time / Total # Shipments	Monthly	M
Backorders and Vendor Performance	98%	Items Delivered / Items Ordered	Monthly	M
Daily Order Picking Productivity	Actual lines picked daily (per employee)	Graph	Daily/ Weekly	M
Productivity of Receiving Personnel	Actual lines picked daily	Graph	Daily/ Weekly	M
Warehouse Capacity Measurement	Measured capacity	Total Floor Space Available In Cu Ft (Aggregate Of All Warehouses) *Should Be Posted*	Monthly	L
Price Variance	+ or - 2%	Price on Invoice / Price on Purchase Order	Monthly	L
Warranty Claims	Less than 2% of total inventory $	Dollars of Warranty Costs / Total Dollars of Inventory Value	Monthly	L
Freight Claims	Less than 2% of all freight dollars	Dollars in Freight Claims / Freight Dollars Expensed	Monthly	L
Kit Delivery Dates Met	Greater than 98%	Kits Filled / Kits Due	Daily/ Weekly	H
Delivery Route Effectiveness	Greater than 98%	# Delivered on Time / # of Stops Scheduled	Daily/ Weekly	H

There are two types of measurements. The first type consists of qualitative measurements. These include Pareto charts, milestone charts, critical analysis, and project plans. The second type consists of quantitative measurements, which are formulas.

Qualitative Measurements

A qualitative measurement is one that has no numerical value. Nonetheless, qualitative measurements are important KPIs that should be utilized. As noted previously, there are a number of qualitative measurements that can be used. Following are descriptions of a few of these measurements that are most often used. A milestone chart is a preliminary timeline on a chart that depicts major time intervals and events for a project. This gives management and project members an overall look at an upcoming project. These charts are used in construction, industry, government, retail, and other situations to visually and quickly show the overall progress and upcoming major events. A second measurement involves a project plan itself, showing all the events related to a project with start and finish dates, the percent of completion, and the resources and costs needed to complete the project. A critical analysis shows the path to meet the end goal. Some call this the determination of the critical path. Finally, there is a Gantt chart, which shows the events and the dates graphically, as well as the completions.



The quantitative measurements matrix chart (on the previous page) presents the required formulas and gives a description of each KPI for Stores and MRO. The maintenance manager must rank the importance of each KPI to his needs. They are ranked in four categories: C—Critical need, H—High importance, M—Moderate need, and L—Low importance. Performance can then be benchmarked and compared.

Benefit Tracking – Having KPIs Work for You

These are potential benefits, gained by measuring through the KPIs that are shown in the quantitative measurement matrix. In addition, there are other benefits gained from KPIs in the storeroom. These include salvage operations

Benefit	Reason for the Benefit
Reduction in inventory	For every increment decrease, the benefit to the company is the carrying cost reduction (percentage carrying cost times the inventory dollar decrease). Tracked over time, this amounts to a significant dollar savings.
Reduction in staffing dollars	Tracking productivity and measuring improvements leads to reduction and/or reallocation of staff and a cost benefit over time.
Reduction in downtime	Improvements in kitting and inventory accuracy cause downtime reduction as parts are more readily available. Planned work is able to be performed, and the scheduled due dates are met.
Reduction in maintenance overtime	On-time delivery of parts; accurate equipment bills of materials; coordinated planning and scheduling; and improvements in reliability engineering at predicting failures through conditional monitoring techniques, preventive maintenance, and operator care all lead to reduced maintenance overtime.
Reduction in paperwork	With the use of bar coding, there is less need for administrative functions of support.
Reduction in warranty claims	Tracking warranty costs over time, and better working relationships with vendors in the design of equipment, lead to a reduction in warranty costs.
Reduction in freight claims	Through carrier evaluations, selection of top carriers, and improvements in the supply chain materials, freight claims are reduced.
Reduction in quality defects	Evaluating and certifying suppliers improves the quality of products received, which reduces quality defects.
Reduction in emergency purchases	There are fewer emergencies when suppliers ship on time.

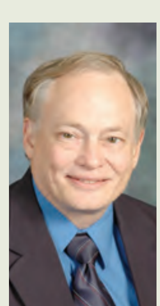
and scrapping obsolete parts, vendor buyback programs, sale of equipment, reduction in freight expediting dollars, improvement in collections from past due invoices, improvements in service after the sale, and others.

Criticality Matrix

Critical parts are very important in the calculation of KPIs. This matrix shows the criticality index cubed. The most critical item is in the red first row and in the first square. The failure is imminent, and the lead time is catastrophic or long. The middle row (yellow) is moderately critical. The last row is green and is the least critical. Critical parts always have priority.

In summary, if you do not measure, you cannot determine where you have been, or objectively analyze where you are going. It is important to establish the KPIs for the storeroom and MRO to measure their performance, evaluate suppliers, and measure productivity.

"Success equals goals; all else is commentary."
– Brian Tracy



Daniel DeWald, CMRP, CPIM, CPMM, has spent the last seven years in project management affiliated with Life Cycle Engineering, NFI industries, and DMD Solutions. He is currently working as a consultant for GP Allied as an SME in materials management. He has over 30 years of experience in warehousing and distribution, production control, materials management, logistics, supply chain management, and purchasing.

What Is Risk Management?

R. Keith Mobley

Risk management is simply the identification, assessment, and prioritization of risks, followed by a coordinated and economical application of resources to minimize or control the probability of occurrence and the impact of negative events, as well as to maximize the realization of opportunities. What is considered a risk? Risks can come from uncertainty in financial markets, project failures, legal actions, regulatory liabilities, accidents, and natural disasters, as well as simple human error.

The definition of risk is generally compartmentalized based upon whether the risk is in the context of business continuity, project management, security, engineering, industrial processes, financial portfolios, actuarial assessments, or public health and safety. The potential list is finite, but is certainly overwhelming. Within the context of reliability excellence and effective continuous improvement, risk management can be limited to two major categories: business risk and asset risk.

Risk Management and Business Continuity

All risks can never be fully avoided or mitigated simply because of financial and practical limitations. Therefore, all organizations have to accept some level of residual risks, but it is imperative that all risks are isolated and clearly defined and managed within financial and practical constraints.

Business risk management must include all financial, market loss, and business continuity risks, as well as well-planned emergency response plans to catastrophic events that could affect the health and safety of the workforce or the public. These risks must also include product-related liabilities.

Risk management tends to be preemptive and must be augmented with business continuity planning (BCP) to deal with the consequences of realized residual risks. The necessity of BCP arises because even very unlikely events will occur if given enough time. Risk management and BCP are often mistakenly seen as rivals or overlapping practices. In fact, these processes are so tightly tied together that such separation seems artificial.

Asset Risk Management

The physical assets that comprise the installed capacity of plants have inherent risks or the potential for failure. In addition, they have the potential for off-specification operation that could result in poor product quality, lower output, or increased production costs. These risks must also be clearly understood and managed to assure cost-effective business continuation.

In addition to the inherent risks of catastrophic failure, risk management must also consider the relative importance (e.g., criticality) of each asset to the plant's ability to meet delivery commitments and the business plan. This type of risk cannot be resolved solely by applying preventive or predictive maintenance technologies. Too many of the risks are the result of inherent design deficiencies, mode of operation, and operating practices. Therefore, risk management must address all forcing functions and triggers that would result in risk.

Risk Management Plan

Ideal risk management follows a prioritization process whereby the risks with the greatest loss and the greatest probability of occurring are handled first, then risks with lower probability of occurrence and lower loss are handled in descending order. In practice, the process can be very difficult, and balancing between risks with a high probability of occurrence but lower loss and risks with high loss but lower probability of occurrence can often be mishandled. In addition to those risks that can be easily identified, an effective risk management plan must address:

Intangible risk: Intangible risk management identifies a new type of a risk that has a 100% probability of occurring but is ignored by the organization due to a lack of identification ability. For example, when deficient knowledge is applied to a situation, a knowledge risk materializes. Intangible risk management allows risk management to create immediate value from the identification and reduction of risks that reduce productivity.

Relationship risk: Relationship risk appears when ineffective collaboration occurs. Coordination between engineering, procurement, production, and maintenance is the primary source of these relationship risks.

Process-engagement risk: Process-engagement risk may be an issue when ineffective operational procedures are applied. These risks directly reduce the productivity of knowledge workers and decrease cost-effectiveness, profitability, service, quality, reputation, brand value, and earnings quality. Risk management also faces difficulties with allocating resources. This is the idea of opportunity cost. Resources spent on risk management could have been spent on more profitable activities. Again, ideal risk management both minimizes spending and minimizes the negative effects of risks.

The *International Organization for Standardization* (ISO), in ISO 31000, identifies the following principles of risk management:

Risk management should:

- Create value
- Be an integral part of organizational processes
- Be part of decision making
- Explicitly address uncertainty
- Be systematic and structured
- Be based on the best available information
- Be tailored
- Take into account human factors
- Be transparent and inclusive
- Be dynamic, iterative, and responsive to change
- Be capable of continual improvement and enhancement.

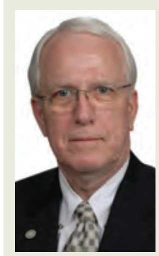
To create an effective risk management plan, select appropriate controls or countermeasures to measure each risk. Risk mitigation needs to be approved by the appropriate level of management. For example, a risk concerning the image of the organization should have top management decision behind it, whereas information technology management would have the authority to decide on computer virus risks.

The risk management plan should propose applicable and effective security controls for managing the risks. For example, an observed high risk of computer viruses could be mitigated by acquiring and implementing antivirus software. A good risk management plan should contain a schedule for control implementation and persons responsible for those actions.

Finally, risk management is multi-dimensional and requires the direct support of most business and plant functions, as well as the entire workforce. The most effective approach to risk management is to integrate all facets into a single, manageable process in which roles, responsibilities, expectations, and single-point accountability are clearly defined. For example, Environmental, Health, and Safety may retain the responsibility for regulatory compliance, occupational health and safety, etc., but a central function, usually reliability engineering, has single-point accountability for the overall risk management process.

In addition to the inherent risks of catastrophic failure, risk management must also consider the relative importance (e.g., criticality) of each asset to the plant's ability to meet delivery commitments and the business plan.

Risk management is not limited to catastrophic failures of assets or processes. To be effective, risk management must acknowledge that risk takes many forms and that all must be clearly understood and effectively managed. Do not become fixated on asset-related risks—they are important, but they have much less impact on overall performance than less spectacular failures in the business and work processes that dictate your ability to meet market, financial, and overall business goals. Business success and continuation depends on your ability to recognize and manage these less-visible risks.



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Integrated Oil Analysis

the Key to Early Detection

Mark Barnes

When it comes to oil analysis, there are a number of options, from simple inspections to onsite instruments, and from basic test packages to full blown "forensic" lab analysis. But which one's the best? Which one will provide the earliest detection and the most information to successfully diagnose a failure? The answer is all of them!

Those running world-class oil analysis programs don't rely on a single level of diagnostic measurement, but rather use a variety of strategies to ensure that lubrication related failures aren't missed. Just like a car mechanic has a variety of tools at his or her disposal depending on the issue at hand, the oil analysis toolkit needs an integrated series of options that work together to achieve the desired result.

In Figure 1, we show an integrated oil analysis scheme for a gearbox that combines four different levels of diagnosis: basic inspections, onsite oil analysis, lab analysis, and expert diagnostic testing. Used in conjunction with other predictive maintenance technologies such as vibration analysis, thermography, and ultrasonic measurements, this scheme provides maximum coverage with the lowest total cost. Here's how it works:

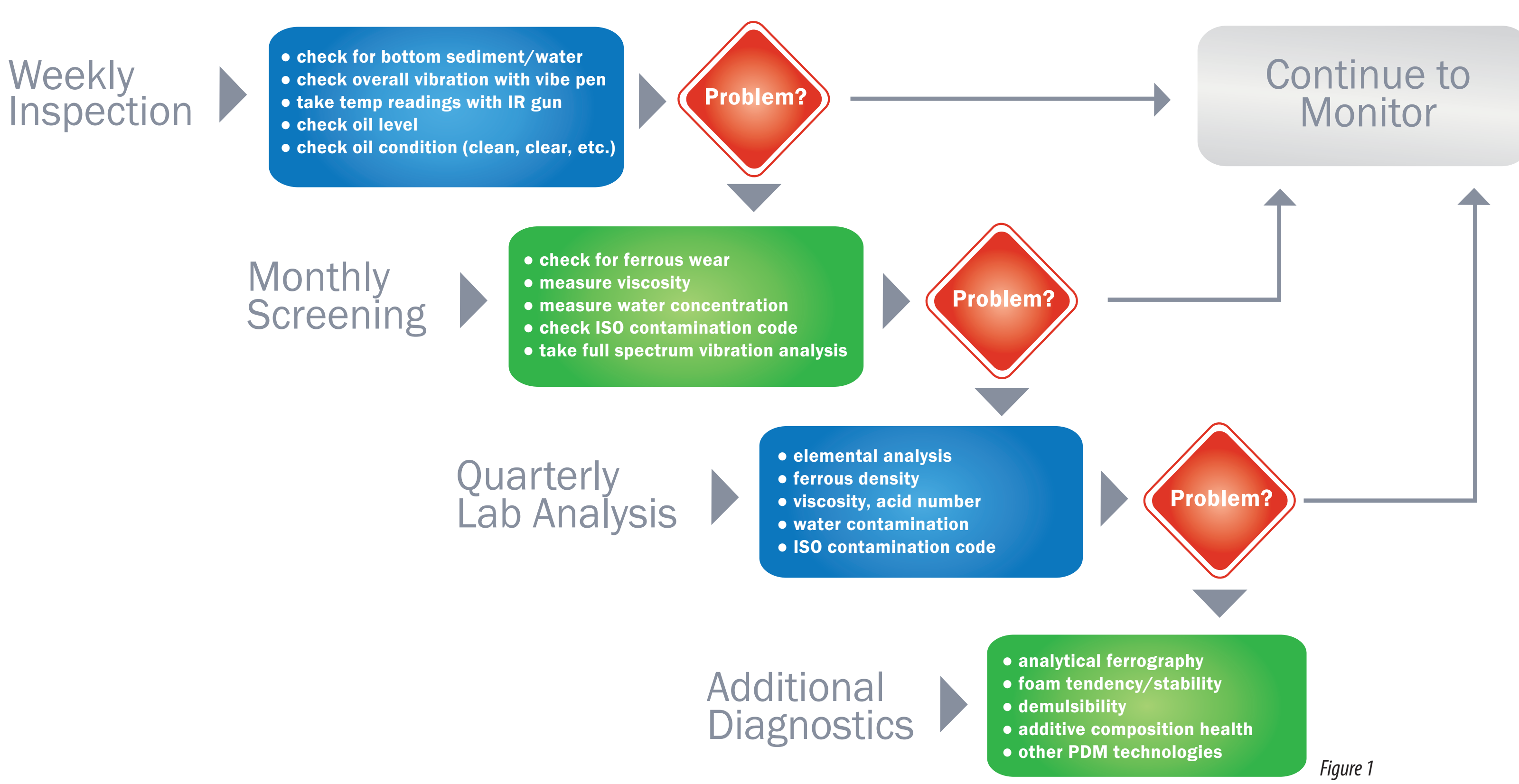


Figure 1

Basic Inspections

It's been estimated that 80-90% of emergent maintenance problems can be identified through basic mechanical integrity inspections. When it comes to lubrication, checks should include looking for evidence of water or sediment on the bottom of the sump, checking oil level, or inspecting the oil in the site glass to look for changes in the oil's color or clarity. In addition, other checks, such as taking temperature readings using an infra-red temperature gun, or taking an overall vibration reading with a vibration pen can, all help to highlight an emergent problem. Lubrication problems identified through basic inspections should prompt immediate further diagnosis using the other "tools" in our oil analysis toolkit.

Onsite Oil Analysis

Periodically, all critical oil-lubricated assets should be tested more rigorously. For plants that are large enough to justify the time and costs involved, onsite instruments capable of evaluating the condition of the lubricant, the level of contamination in the machine, and any active machine wear are an excellent way to isolate problems. Done on a periodic basis or in response to problems observed through basic inspections, onsite oil analysis is an important piece of the puzzle. For plants that are too small or are unable or unwilling to spend the money on onsite instrumentation, onsite analysis can be replaced with offsite lab analysis, but the frequency of sampling must be increased to make up for the "loss" of onsite oil analysis data.

Additional Diagnostic Testing

Good oil analysis labs offer a range of oil analysis tests from basic tests, such as viscosity and elemental analysis, to high-end testing, such as analytical ferrography, x-ray fluorescence, or other ASTM tests that take a detailed looked at lubricant health. Any problem that is identified through inspections, onsite or lab-based analysis, or any other PdM inspection should be fully investigated. With several hundred relevant tests that can be run on lubricating oils, there is always a way to dig deeper using oil analysis.

Integrated Model

Using an integrated approach to oil analysis requires careful pre-planning. It's not good enough to simply buy a box of oil sample kits from your preferred lab and expect them to tell you what's failing, how long until the problem becomes terminal, and what corrective action to take. Oil analysis is an integrated effort requiring input from difference sources.

The key to oil analysis is to sample from the right place and at the right interval. Depending on the machine, failures can go from incipient to catastrophic in just a few days in the case of high-speed turbo machinery to several months for slower equipment such as industrial gear reducers. While the scheme and measurement frequencies shown in Figure 1 are appropriate for a gearbox, for other equipment such as compressors or hydraulics the periodicity should be shortened perhaps to daily inspections, bi-weekly onsite testing, and monthly lab analysis. But the same concepts apply: use simple techniques onsite, integrated with quality offsite analysis, to truly reap the benefits that oil analysis can provide.

Periodically, all critical oil-lubricated assets should be tested more rigorously.

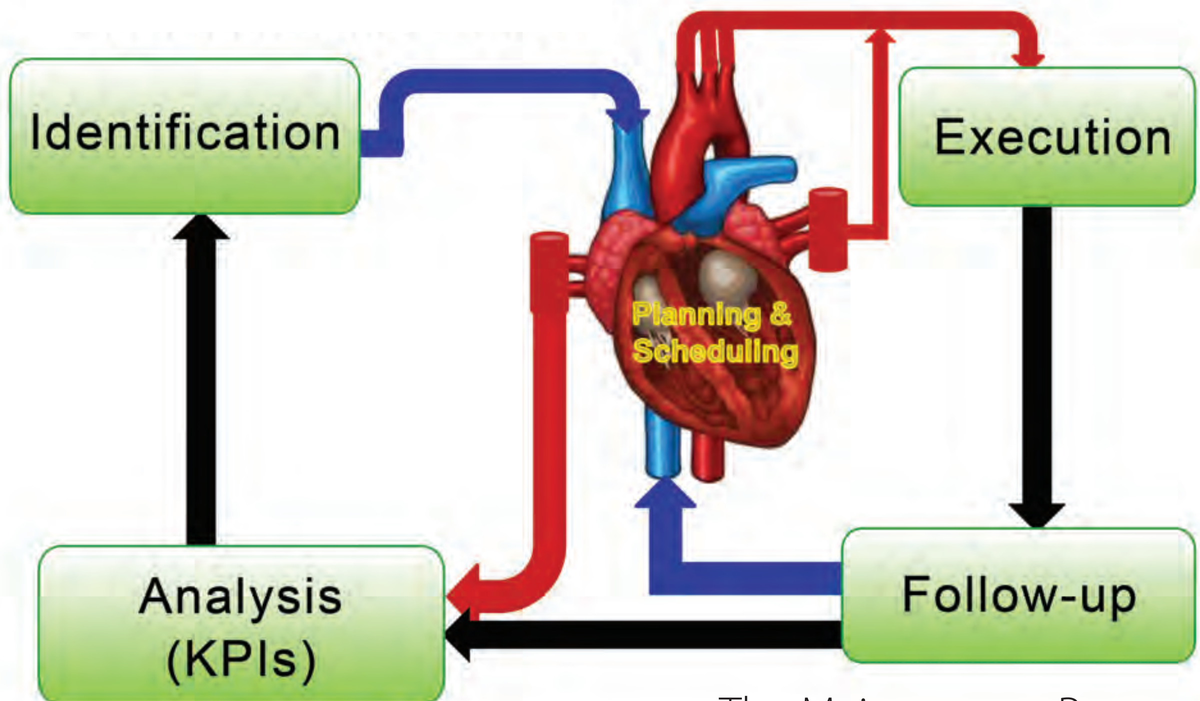
Full Lab Analysis

Even those plants that have great inspection routes and great onsite capabilities need to do offsite oil analysis with a commercial lab. Short of investing the same amount of money it takes to set-up a fully functioning commercial oil analysis lab, onsite analysis cannot and does not provide the same amount of diagnostic horsepower that a well-equipped commercial lab possesses. Lab analysis should include checking for evidence of wear, looking at the overall health of the base oil and additives, and trending particle and moisture contamination to ensure the oil is fit for continued use. Any problem identified with routine lab analysis where the route cause is not immediately obvious should prompt an expanded set of oil analysis tests to try to pinpoint the root cause of the problem.

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

management

Ps planning and scheduling



The Maintenance Process

The Planner: The Heart of the Maintenance Process

Imagine your body without a heart

Tarek Atout

Most of the maintenance organizations use the planner role as part of the configuration for the planning and scheduling process. Planner involvement in the process is demonstrated as an added value. The impact of having a planner within the group is not limited to improving the efficiency and optimizing the costs and resources usage, but it will extend to the whole maintenance process and work to cure the symptoms of maintenance process illness.

The planner is proven to be the heart of the planning and scheduling process and one of the arms that supports the whole maintenance process. As in a human being, a strong heart is an indication of good general health; a good planner is an indication of a streamlined planning process. The heart is responsible for blood circulation within the body, while a planner is responsible for smooth workflow within the maintenance body. Have you imagined your body without a heart?

How do you get those expected benefits from the planner? It is how you select, develop, and use the planner in the organization. The planner in this article means the person who performs planning and scheduling functions (Planner / Scheduler). In the following paragraphs, I will try to explore the reliable planner profile in simple and practical words.

1. Selection of the planner:

The right person at the right place

Planner is not the job to be assigned to just any one of the crew. You will need to develop selection criteria that assure that the right people are chosen. The criteria are both technical and personal and may include:

- A good maintenance background, such as one of the maintenance crew of the plant would have, regarding specific crafts, mainly, mechanical, instrument, and electrical. The advantage of this is will be that the planner will be familiar with the plant hierarchy structure, equipment history, execution constraints, and special needs. Such a person also will be aware of the maintenance policies and procedures that are implemented by the company. Specialization in a specific craft is a core skill, but as a support skill the planner will need to have knowledge of multiple crafts. ***Promoting a maintenance foreman to a planner is recommended over hiring a planner from the outside.***
- Good communication and teamwork skills. As one of the maintenance crew, the planner will have open communication channels with other parties of the process (e.g., operations and maintenance teams). This will ease building partnerships with other stakeholders.
- Computer literacy. This is a support skill and will add more quality to the planner's deliverables.

Introducing planning concepts and philosophy to such a person will be much easier, and getting immersed in the planning and scheduling process will be effortless and handy.

2. Development of the planner:

A few exercises are necessary to keep your heart fit

Now, as you have the person who is ready to serve as a planner, it is vital to start developing his or her skills to get maximum efficiency and quality product. Developing the planner's skills will go in two parallel directions: one will focus on technical competencies, and the other will improve interpersonal skills. Both types of training are critical for the planner to do the job in an effective manner.

- **Technical competencies development:**
  - ◊ The planner must be aware of the expectations for planning and scheduling, which are the return on investment for that job.
  - ◊ Planning and scheduling best practices are the core of the job, so the planner must have a comprehensive knowledge of the best practices on how to perform the job. This training should be linked to the implemented processes and work flow within the organization.
  - ◊ CMMS training: CMMS is the main tool used to support implementation of the processes. The planner must have advanced training on that software and be aware of the system functions, features, and capabilities. The planner should not only know how to enter data on the system but also how to enter useful, accurate, and complete data. Much more important than data entry is how to get information from the system: how to tailor and produce reports that give a clear picture on current work status and bottlenecks in the process. Data reporting and analysis are vital in maintenance planning.
- **Interpersonal skills development:**

  The work environment and job description of the planner dictates some essential interpersonal skills that will help the planner to perform the job effectively. The planner's job is a technical job that requires coordination between different teams, starting from receiving operation's request for a specific job; through planning, scheduling, and follow-up execution with maintenance; then final reporting and feedback. This scope requires the following skills to be developed and sustained:
  - ◊ Communication skills: the planner should be able to communicate clearly with all parties, sending and receiving messages with visible contents and objectives.
  - ◊ Teamwork / coordination skills: the planner will work with operations, maintenance, warehouse, engineering, safety, and other departments that may be involved in a specific job; this will require a high caliber of teamwork and coordination.
  - ◊ Meeting management skills: in preparing and conducting weekly and monthly scheduling meetings, these skills will be of high value to the business.
  - ◊ Conflict resolution skills: in many situations, where clashes between operations and maintenance occur, the planner should be able to intervene within a specific authority level to resolve those conflicts in a way that makes the work run smoothly without affecting the production and maintenance targets.
  - ◊ Time management skills: working between site visits and the office, planning

multiple jobs with different priorities, and handling some coordination issues require good time utilization and management.

3. Using the planner:

- **Use the planner only to plan** ***(Your heart doesn't digest food)***

  If you have a problem with your stomach, would the doctor recommend using your heart for food digestion? Of course not! The same goes for the planner, whose duties should be limited to those in the planner's job description. I recommend that each planner write a reminder on his or her office board or hang a sign on the office door, to remind everyone in the maintenance organization:

  ◊ I am a **planner**
  ◊ I am **NOT** a maintenance foreman
  ◊ I am **NOT** a maintenance supervisor
  ◊ I am **NOT** a secretary
  ◊ I **DON'T** run after a rush job

  Efficient utilization of the planner's time is fundamental. The advantage of having a planner within your team will be smashed by utilizing the planner in other jobs that take his or her focus out of planning. Using the planner in other jobs rather than planning and scheduling is a short, effective message that you can live without a planner. Planning is a full-time job for the planner; if it turns to "let the planner do planning when the planner has time," expect a collapse of the maintenance planning function.

- **Get the benefit of the planner's craft skills** ***(Your heart can't circulate blood to a neighbor's body)***

  When it comes to the planner's assignment, the question that rises is, "shall we assign planners by area or assign planners by craft?" Or, if we have group of planners with different craft skills (e.g., mechanical, electrical, instruments) working in a plant with different functional areas:

  ◊ Would you assign each planner to a different area to plan mechanical, electrical, and instrument jobs irrespective of the planner's technical background?

  ◊ Or would you assign each planner to multiple areas to plan only jobs that match with that planner's technical experience?

  To answer, let's think back to what I mentioned in the introduction of the interpersonal skills section: the planner's job is a technical job that requires coordination between different teams. A maintenance planning job requires experience with performing maintenance, so we recommend selecting a planner with a maintenance execution background. To get benefit of the planner's past field experience, the second option seems more practical and efficient.

  In the first option, if it is not a simple job, the planner will need to consult many partners to reach the final perfect job plan. This will mean interruption to his other craft planner colleagues and to maintenance performers who are expecting the job to be planned and ready for execution without deep involvements as they are focusing only on performing jobs at site. Jobs will consume more time and effort to be planned than expected, and accuracy also is not completely guaranteed.

  In the second option (recommended), the planner will use his or her own work experience to plan the job with minimal interruption to others. We all concur that a planner should be skilled in multiple crafts but be an expert in a specific technical field, and the planner would use this additional knowledge for minor or simple jobs that are different from the planner's main background.

  We try to employ the planner in the best effective way that makes the job expectations visible and achievable. Simply, it is the same as with a general practitioner doctor and a specialist doctor; normally a general practitioner doesn't do surgery but can give first aid until the patient is seen by the specialist.

4. The planner's role within the maintenance organization:

The heart is integrated with other body functions

It is very important to recognize the value of the planner in the process and give more attention to the planner's role, starting from selection through development to employment. More important is to realize that planner is not working alone but is part of the maintenance organization. Any defect in the organization will have negative impacts on the planner's deliverables. Expectations from planners are achieved with the following:

- **A solid planning and scheduling process:**

  Developing a clear, firm, and solid maintenance planning and scheduling process and related procedures is essential to the planner's job. Although most parties may say the rules are clear, documentation is extremely valuable. This process must focus on achieving the maintenance planning objectives, ensuring proper function performance, monitoring, and reporting. The processes must have clear assigned responsibilities for all participants to ensure that maintenance activities are correctly initiated, planned, executed, and reported.

Developing a RACI matrix as part of this process is advantageous, in addition to job flow charts. Management must show support and commitment to the process and enforce the adherence of all maintenance workforces.

> ***Promoting a maintenance foreman to a planner is recommended over hiring a planner from the outside.***

- **A proper work load for the planner:**

  It is very important to assign the proper number of planners in your maintenance organization. Your heart can effectively serve only your body, so maintaining the proper ratio of planners to maintenance workers (planners control span) is crucial to the process. This ratio is governed by many factors. The level of planning details required and the skill levels of planners' maintenance personnel are two key factors. The structure and strength of the planning process, applied maintenance strategy, CMMS implementation and utilization, the nature and criticality of the industry, and your targets of planning and scheduling performance are other important factors. Normally the ratio ranges between 15-20 craftspeople for each planner.

- **The planner's role in the organization structure:**

  The planner must fit within the maintenance organization in a way that allows the planner to do his or her job in effective way. The planner must report to the maintenance manager or the maintenance engineering manager, or a planning engineer layer may be introduced

  The planner's position must be given high rank to send the message to staff that planning is an important function. The planner should not report to maintenance performers; the planner has to work freely away from the influence of performer authority in order to avoid using the planner in jobs other than planning and in order to prevent using performer authority for data manipulation to show that maintenance performance is in good shape.

  Ideally, the planner should be equal in rank to the maintenance supervisor in order to create authority balance and maintain work stability.

As a final tip, the planner is an important role in the maintenance organization. The planner must be selected, developed, and utilized in the best effective way to secure the expected output from the job. Management is requested to support the whole planning process and assure that the planner is recognized within the organization.

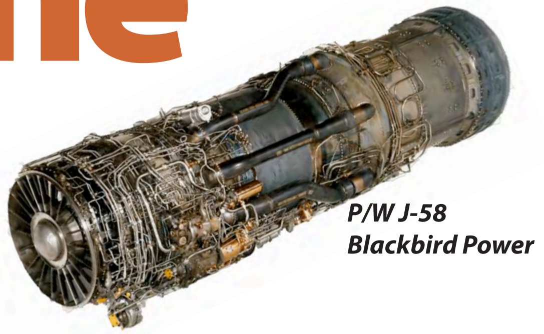
Tarek Atout, CMRP, is currently a maintenance planning engineer in Qatar Gas in their new expansion project. He has 20 years of experience in maintenance planning and scheduling in oil and gas industries. Tarek has worked with many international organizations as a consultant in maintenance planning, work management, and inventory control, and he has worked in many countries in the Middle East.

Improving the Reliability of a Turbofan Jet Engine

Larry Tyson

by Using the Weibull Distribution for Failure Mode Analysis (WFMA)

NOTE: FM = FAILURE MODE, MAL CODE = MALFUNCTION CODE, they are the same



P/W J-58 Blackbird Power

Our team is directly involved in the reliability, availability, and maintainability (RAM) of a turbo fan jet engine. The engine fuel controller (FC) is one of the main components on the engine. Its purpose is to control the flow of fuel based on pilot demand from the throttle levers in the aircraft cockpit. If the FC does not operate properly, the engine does not receive fuel in accordance with pilot demand and may shut down. As can be imagined, shutting down an engine is not a good situation in flight.

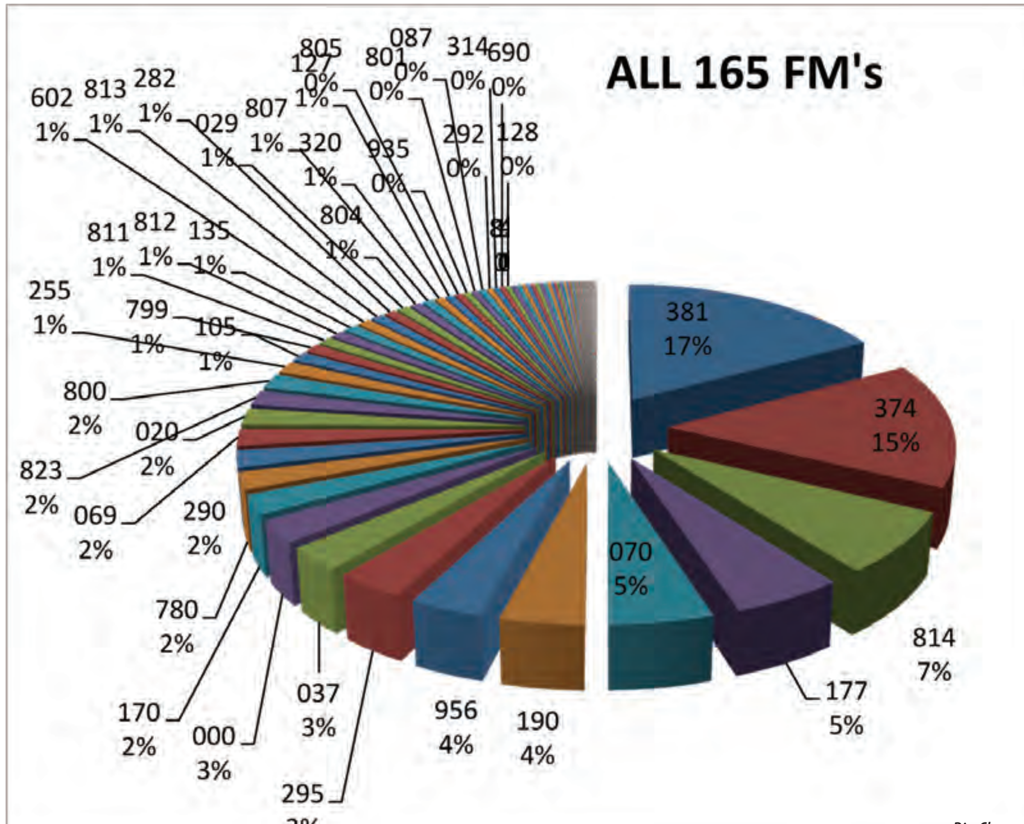
In recent years, our FC has had in-flight shutdowns due to flameouts and other problems. A flameout refers to the failure of a jet engine caused by the extinction of the flame in the combustion chamber. It can be caused by a number of factors, including fuel exhaustion, compressor stall, insufficient oxygen supply, foreign object damage (such as birds or hail), severe inclement weather, mechanical failure, and many other failures.

One root cause of these shutdowns and flameouts was the FC. In-flight-shutdowns result in in-flight aborts (IFAs). An IFA is a dangerous condition that puts the pilot, aircraft, and property at risk of damage. This flameout situation requires the pilot to defer quickly to emergency procedures and can lead to loss of aircraft; it is therefore a potentially costly failure that must be corrected. Between calendar years (CYs) 1999 and 2006, our team developed and published five technical directives (TDs) to correct the flameout problem. In late 2007, with most of the TDs completed, we used reliability growth analysis (RGA), part of the IEC-61164, to monitor the effect of the TDs, and we noticed a real change in the failure mode (FM). Instead of IFAs, we were starting to see a change to another FM. This additional FM was not previously known. This is because the flameouts took precedence due to their safety impact. This condition is called a "hidden failure." A hidden failure is where one failure (such as In-Flight Shutdowns (IFS)), hides another FM, which in this case was leaks. This is a continual story in fielded systems: when one problem is corrected, another problem will arise. Analysis of the maintenance data illustrated that we had many FMs (in aviation these are called malfunction (MAL) codes). Previously, we did know about the leaks problem, but safety due to IFSs had a higher priority. These leaks were occurring more frequently, however, and no IFAs were involved. The lead engineer requested assistance in determining if the FMs were related. The Weibull process was used to determine interdependence of the various leaks. While accomplishing this engineering investigation, we developed a series of five pie charts that show the actual analysis progression. Information on Dr. Weibull and Weibull analysis may be obtained by searching for the term "Weibull" at google.com; there is a vast amount of information on this process.

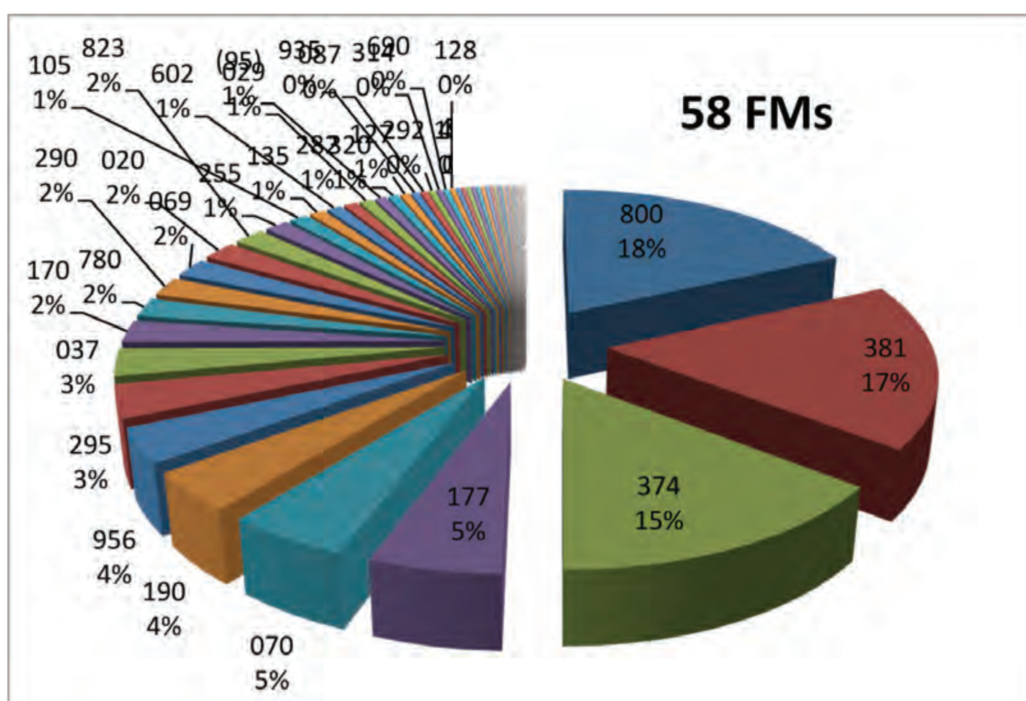
In November 2007, Dr. Robert B. Abernethy ("Dr. Bob") taught a 4-day Weibull Life Data Analysis class in Jacksonville, Florida. The instruction involved Weibull analysis and reliability growth management and analysis. Both of these are part of the International Electrotechnical Commission (IEC) publications. Outside of his reliability of life limited data analysis, Dr. Bob may not be known; however, Dr. Bob's 11 patents

This flameout situation requires the pilot to defer quickly to emergency procedures and can lead to loss of aircraft; it is therefore a potentially costly failure that must be corrected.

are very well known and were obtained when he was employed by Pratt & Whitney (P&W) as an engine designer. In the mid 1950's, the US Air Force and CIA approached Mr. Kelly Johnson (Lockheed Skunk Works), desiring a new aircraft that could fly very high and fast. This aircraft became known as the SR-71 Blackbird, and its power plant is the P&W J-58 that Dr. Bob and

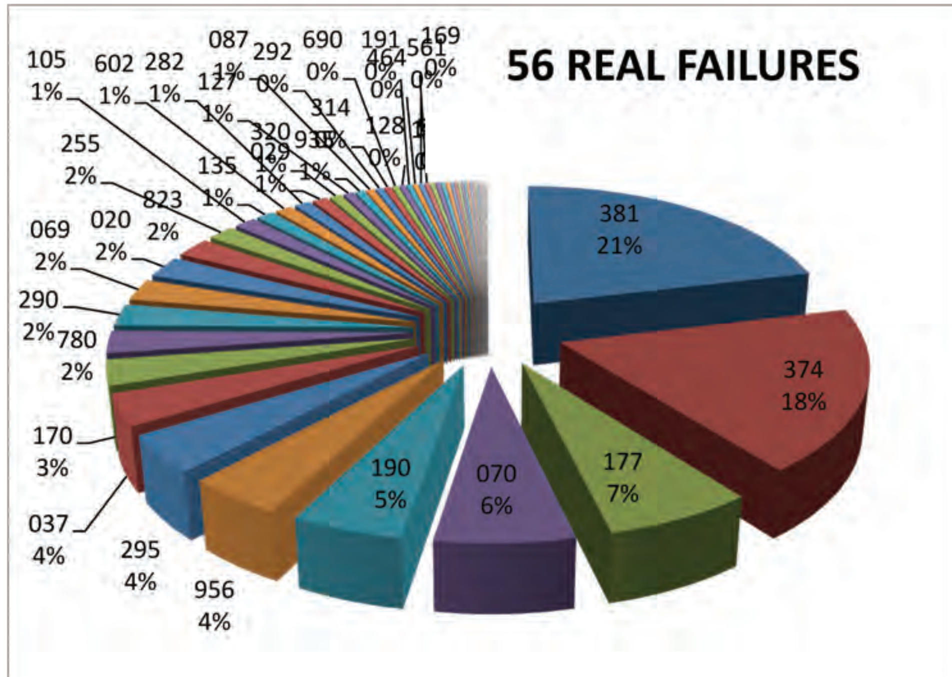


Pie Chart 1



Pie Chart 2

We were able to take a complex situation, perform the analysis, filter or reduce those failures down to the most critical, and do a detailed analysis of those root cause failures.



Pie Chart 3

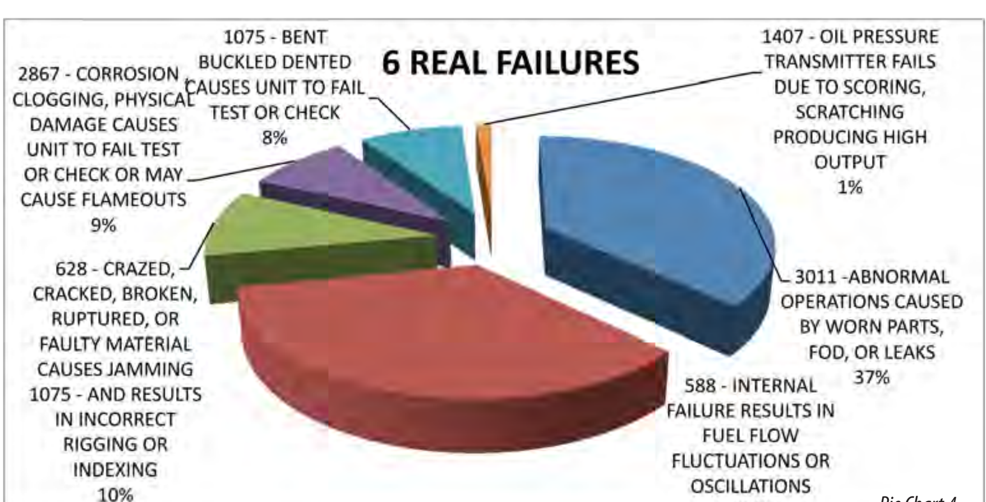
his team of engine designers and technicians developed. The SR-71 still holds all altitude and speed records for jet engines, and it has been 54+ years since the very first SR-71 flew.

So, how did Dr. Bob help us with our jet engine problems? He helped us to take 165 FMs we had observed and reduce them to a very manageable and defined set of failures. By utilizing Weibull distributions, we were able to make sense out of this large number of failures. This was accomplished by using the likelihood contour plot (LCP). If the contours intersected, then the FMs were from the ***same*** Weibull Family and their data was merged. This process continues until there are no more LCP intersections. To visualize the process and to see the reduction of FMs, we will use pie charts. Before we get to these charts, in the first iteration of this paper, we used the FM descriptions, and this proved to be complicated. Here we will use a 3-digit number, or an alpha character followed by 2 numbers that is associated with the description, to reduce the clutter.

We will look at a series of pie charts that show the results of using the Weibull distribution for failure mode analysis. The first chart is an eyesore, because it has all 165 FMs.

In Pie Chart 2, the 95 FMs that had fewer than 3 data points were combined to form mal code (95), which makes up 1% of the data. Please keep in mind that 3 data points is the minimum required for distribution analysis. This chart also combines those FMs that fall in the cannibalizations, administrative, and no trouble found categories; these will carry the number 800 and make up 18% of total data points.

Pie Chart 3 strips the mal code (95) and 800 series of FMs that are not real failures. We also have removed all cannibalization, administrative, and no trouble found FMs. This leaves us with 56 true failures. Our failure mode analysis starts here.



Pie Chart 4

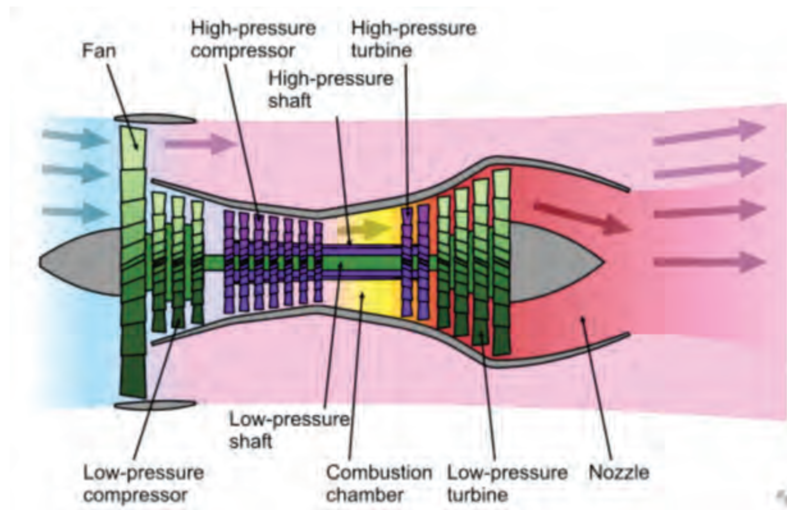
From the above 56 FMs, the detailed statistical and mathematical process of the Weibull distribution analysis begins. Some of these FMs will fail the outlier test, some will fail the distribution analysis and not be the required Weibull rank regression (Wrr) or Log normal rank regression (Lrr), and others will be the Weibull 3 parameter (W3P), which cannot be used.

Pie Chart 4 is the "bottom line." It is the very reason to perform the Weibull Failure Mode Analysis (WFMA). The final 6 FMs started out of the original 165 FMs. The numbers associated with the FMs on the pie chart originated from the original FMs. That is, this FM is arrived at by adding the FMs that make up the below FM (e.g., FM 588 is derived from the following FMs : 037 - Fluctuates/Oscillates, 177 - Fuel Flow Incorrect, 374 - Internal Failure).

At this point, our lead FC engineer had a clear understanding of the problems. This enabled him to write a local engineering specification (LES) to require the replacement of a group of internal seals during depot-level maintenance. Previously, these seals were subjectively changed based on condition. Due to the results of this LES, we now have slightly over 735 (as of 12/2010) FCs with new seals (40%+ of total FC's). A formal technical directive (TD) would take another 2 years to complete, but by this time the FCs will be 85%+ incorporated using the LES. This saves a great deal of time and money for the military. Another benefit we saw was the 1% reduction in cannibalizations that occurred as a direct result of this analysis. This makes the FC "stay on wing" longer. In other words, the FC is not failing as often, which results in it staying on the aircraft longer. This is called time-on-wing (TOW).

In closing, we think the Weibull analysis really helps a great deal on doing engineering analyses when numerous failure points are involved. We were able to take a complex situation, perform the analysis, filter or reduce those failures down to the most critical, and do a detailed analysis of those root cause failures. The Weibull analysis provides a powerful and useful tool for the engineering community that deserves more attention and use for these types of complex analysis.

This document may be used to follow the PowerPoint presentation by the same subject title. The presentation (35 pages) is a detailed step-by-step instruction and includes technical details of WFMA.



Larry Tyson, retired, has spent 24 years in the US Naval Service. Currently working for government service, his tasks include: support equipment specialist, involved in LIFE-CYCLE-COST (LCC), and reliability and maintainability (R&M) for avionics, support equipment, airframes, hydraulics, and power plants, both propeller and jets. Larry is involved in the TURBOFAN Community with a concentration on R&M analysis, RCM, and RCA.

Useful websites:
www.iec.org • *Dr. Bob:* www.bobabernethy.com
Wes Fulton: www.weibullnews.com
Paul Barringer: www.barringer1.com

Acknowledgment: Wes Fulton and Dr. Bob assisted with this article and the power point presentation; I thank them very much. Mr. James Young, Naval Surface Warfare Division, Crane, IN: his help was greatly appreciated in the formulation of this document.

condition monitoring

A Day In the Life of a Proactive PdM Technician

Ricky Smith and Carey Repasz

Beginning of the Maintenance Shift and Unplanned Work:

The day begins with the PdM technician reviewing any equipment that has been repaired or replaced in the past 24 hours. If any equipment has been changed or repaired, the PdM technician will identify specific failure modes for the work completed and conduct follow-up inspections of repairs for the purposes of QA/QC, confirming that the defect has indeed been removed and that no new defects have been introduced as a result of maintenance activity.

If a defect is identified, a new work request to make the repair is written by the PdM technician. On the work request, it is important for the PdM technician to identify the cause of the potential failure. Many times the cause will be "human-induced failures," due either to current maintenance technicians not having effective procedures with accurate specifications, or to a rebuild vendor not having or following procedures and specifications. Identifying the cause of the potential failure is critical to the continuous improvement of the maintenance processes and establishing buy-in of the PdM program.

When repairing, replacing, or installing anything on a critical or important asset, it is imperative that the PdM technician conduct a baseline survey and communicate to management whether or not the equipment is free of defects after the work is completed.

Planned and Scheduled Work:

The PdM technician has a planned and scheduled route to conduct his/her inspections and to conduct baseline readings on repaired or replaced equipment during the day. This is a busy job when done correctly.

From a PdM technician's standpoint, his/her time needs to be scheduled to validate that a defect has been eliminated and establish a baseline anytime a repair is made. If you do not conduct this validation, expect that unexpected failures will occur, which will result in people believing PdM is not effective.

The table on the left shows an example of a daily schedule for a proactive PdM technician.

Key Learning Point: If your maintenance process is reactive, then your PdM Technicians will be reacting to urgent and emergency work and their true value will be diminished.

Proactive PdM Technician Daily Schedule Example

Work Order Number/Schedule	Scheduled Work	Conduct Baseline	Take Readings	Write Work Requests
0630: XXX-111	PdM Route	Overnight Repairs	No Defect Detected	Not Required
0700: XYZ-123a	PdM Route		No Defect Detected	Not Required
0730: XYZ-123b	PdM Route		Defect Detected	Yes
0830: XTZ-123c	PdM Route		No Defect Detected	Not Required
0900: Emergency WO		AC Induction Motor Replaced	Defect Detected – Vendor Called	Use Maint Techs WO Number for Emergency
1300: XYZ-123d			Defect Detected	Yes
1400: Urgent WO		New Gearbox Installed by Construction	No Defect Detected; Baseline Taken; Oil Analysis Sent Out	Yes for Oil Analysis
1500: Work Closeout	End of Shift			
Available for EM Callout if required				

Common Questions a PdM Technician Will Be Asked:

Q: What value does a PdM technician provide to a proactive organization?

A: The ability to identify a defect or unacceptable condition that will lead to equipment failure and unexpected downtime.

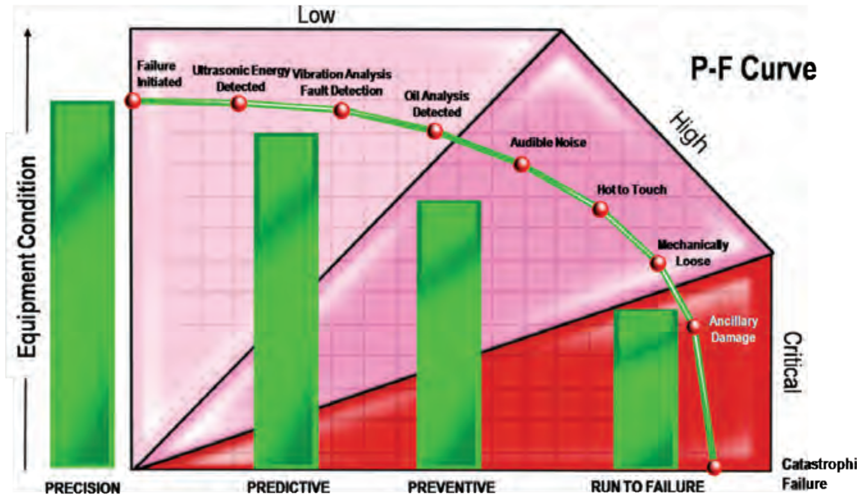
The purpose of early defect identification is that work can be planned, scheduled, and executed without getting close to a failure on critical assets. The PF curve on the next page clearly demonstrates this value.

Early defect identification affords the ability to schedule maintenance work during the windows of opportunity that operations/productions offers us, therefore creating the ability to run as much production as possible without an upset.

Q: What is a PdM technician unable to provide to a proactive organization?

A: A PdM technician is unable to estimate when the failure will occur.

The focus of a PdM technician is detection of defects that are random in nature. To attempt to trend the propagation of a defect and forecast the actual time of functional failure is a dif-



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ficult proposition, as well as a very poor use of the technician's time. The defect will never be cheaper to address than directly before failure, and the PdM *work execution processes* must be utilized to address the timing of repairs as opposed to the PdM team. This one issue causes more pain to an organization than any other. Management always wants to know: "How much longer will it run?" To this question, the only appropriate answer is: "How much risk are you willing to accept?"

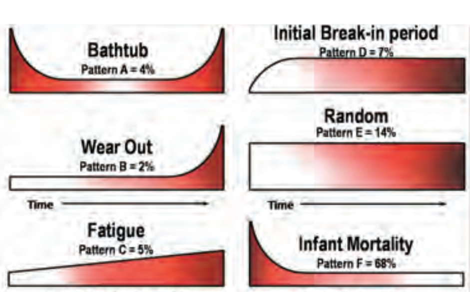
Sometimes, people lose confidence in PdM technologies. Listed below are some common arguments:

"Predictive maintenance is not a true term."

This has some truth to it. Condition monitoring is the true definition of PdM, because we are measuring the condition of specific failure modes at a specified time. It may be 30-90 days before a reading is taken again.

"If you really want to know what the most effective method for addressing failure modes is, you must begin by determining what the most dominant failure pattern is at your organization."

Less than 2% of organizations can identify a failure pattern statistically, because they do not have the data from their maintenance software to support a decision. As it turns out, identifying the dominant failure pattern is useless anyway. A study conducted in the 1960s by Nowlan and Heap proved that the majority of failures are random.



Failure Patterns from a Nowlan and Heap Study, 1960s

Q: From where does proactive work come?

A: Here is how PM and PdM work should break out:

PM Execution: 15% of Work

Results from PM: 15% of Work

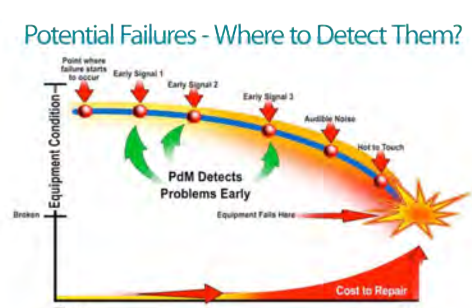
Condition Monitoring Execution: 15% of Work

Results from Condition Monitoring: 35% of Work (planned and scheduled work; emergencies not included)

Q: Does a PdM technician focus on the present or the future?

A: A PdM technician's focus is on the future, not today's problems.

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 PdM or quantitative PM.



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As a PdM Technician, You Know You Are Still In Reactive Maintenance Mode When:

- An organization is using only vibration analysis and infrared technologies, so technicians can identify potential failures only on specific failure modes addressed by the two technologies. What about the failure modes that can be addressed only by ultrasound, UT, MCA, etc.?
- A technician makes a repair after a defect, but the equipment is not inspected to ensure it is free of defects after the repair. For example, if a loose electrical connection was repaired after an outage, and infrared is not employed to confirm the defect has been fixed, how do you know that the repair has been made properly?

Outage complete - but has the defect been eliminated?

- Ultrasound is used only for compressed air leaks.
- PdM technicians do not know each other and never work together as a unit.
- The PdM program is not focused on specific failure modes, which causes "too much PM" to be conducted.
- Infrared technology is not employed for low-voltage applications and is instead used only for high-voltage applications.
- Maintenance technicians do not use repeatable, effective work procedures.
- Your main source of failure mode identification is when something fails.

A PdM technician performs a vital role in making sure that a company's needed repairs are identified, made, and done correctly. A PdM functions best and is of the most value when allowed to take a proactive role in identifying and solving problems rather than being left to respond to emergencies. A proactive PdM technician can be an invaluable asset.

Ricky Smith and Carey Repasz wrote this article based on their combined 45 years of maintenance supervision experience and work in the field.

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

Carey Repasz, CMRP, has spent the last fifteen years in maintenance. Today, he serves as the Program Manager for Cargill Corn Milling in Eddyville, Iowa. He is one of Allied's Senior Instructors for the PM/PdM Best Practices Training & Tools Series. www.alliedreliability.com

ULTRASOUND... Worth Its Weight in Gold

Jim Hall and Roger Collard

Photos are courtesy of Jim Hall, Ultra-Sound Technologies.

Recently, I traveled to Lihir Gold PNG, Ltd. (now Newcrest Gold), a mining operation on Lihir Island, to deliver my Ultrasound for Predictive Maintenance Level I Certification Class.

Figure 1 (top): Entrance gate to Newcrest Gold. Technical Training Center, Lihir Island.
Figure 2 (left): Newcrest Gold (formerly Lihir Gold, Ltd.).

The Lihir Gold operation is located on Lihir Island, in the New Ireland Province of Papua New Guinea (PNG) (Figures 1 and 2). Gold deposits are located in an inactive volcanic crater known as the Luise Caldera on the east coast of Lihir Island. The mine produces over (800,000) ounces of gold per year.

Upon arrival I met several of the Lihir Gold (now Newcrest Mining, Ltd-Lihir) technicians. Three of the key personnel were Mr. Trevor Black, Coordinator Condition Monitoring/NDT; Mr. Dominic Kalua, Field Training Officer-Maintenance; and Mr. Jimmy Romalus, Coordinator Process Plant Maintenance. All were attendees in the Ultra-Sound Technologies Level I Training Class. During the ultrasound training session walk-around of the plant I was told of a poorly performing GEHO slurry pump (Figure 3).

Instinctively, I used an ultrasound instrument (a CSI 7100) to listen to the cylinder walls (Figures 4A and 4B) while listening for an abnormal sound or condition that might help identify a problem. One cylinder when compared to the others sounded distinctly abnormal (see Figure 5).

Figure 3. GEHO Pump: ZPM-800, Gold Ore Slurry. Min: 62.5 cubic/hr, Norm: 176 cubic/hr, Max: 270 cubic/hr. High pressure is built from the piston moving back and forth on the eccentric flywheel, which moves the piston back and forth horizontally.

Figure 4A. Technicians using the ultrasound instrument on the external cylinder walls from beside and between the bolted diaphragm housing.

Figure 4B. A CSI 7100 being used to monitor cylinder walls of the GEHO Pump and showing a normal signature.

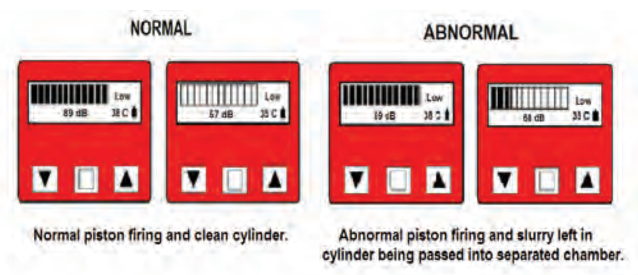

Figure 5. The results of utilizing a CSI 7100 ultrasonic receiver to listen to cylinder PU801 of the GEHO Pump.

I needed to know more about GEHO pumps, so I contacted Roger Collard, Chief RCM Engineer of Wyle Laboratories, who I knew had previous relevant mining experience. I believed that, together, my recent experience at Lihir and Roger's 18 years of mining experience on similar equipment could me offer a more complete view of this unique situation.

Roger explained to me that GEHO pumps of this series are powerful piston diaphragm pumps that allow slurry material to be conveyed with much lower water content. Through timing of the diaphragms and piston movement, extremely dense material can be conveyed. The design is very dependent on product density, system pressure, and temperature. Diaphragm leakage is a concern as mixing can occur. If this is the case, any or all three of the previously mentioned parameters can be affected.

Listening to each valve and diaphragm at the end of the piston stroke, a bad ring or piston problem would have a distinct signature. The trick is that the diaphragms, valves, and pistons are all in the same area, so leaking valves, leaking diaphragms, leaking rings, and broken pistons may all sound alike. Slurry passing through a good valve can sound like a leak. You have to time the component's "noise" signature with the pump timing to know if the valve is operating correctly or leaking. Monitoring for an energy change, either up or down, may indicate cavitation, leakage, or regurgitation.

Ultrasonic technology offers the ability to detect these potential failure conditions before extensive damage has occurred.

Mr. Trevor Black from Lihir explained that what we were listening to at Cylinder PU801 with the CSI 7100 ultrasound device was the sound of fluid passing into the other chamber via the damage on the roof-shaped seals worn area (Figure 6A) from chamber 3 to chamber 4. This was confirmed via the instrument panel monitoring the inlet filling times on chamber 3 and outlet times on chamber 4. A possible explanation for the phenomena is a previous chamber 3 diaphragm rupture. The slurry that entered into the chamber may not have been cleared out completely. More evidence of damage was seen in the cylinder liner (sleeve) from the 6 to 9 o'clock position of the sleeve (Figure 6B).

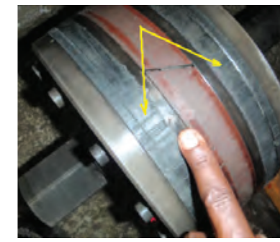

Figure 6A. Damaged piston roof-shaped seals set (front & back) from chambers 3 & 4 (9 o'clock position when removed).

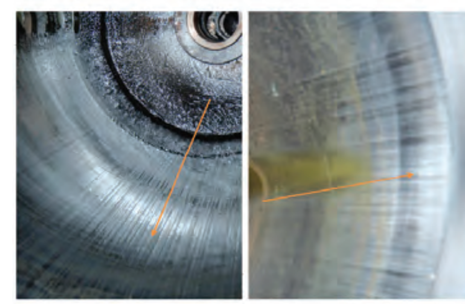

Figure 6B. Evidence of damage to the cylinder sleeve, seen from the 6 to 9 o'clock position of the sleeve.

Most ultrasonic instruments today have an intensity meter and/or read in decibels, so this inspection can be accomplished using most ultrasound instruments (Figure 7).

An illustration in the many uses of this technology is to measure and trend the ultrasound from the discharge and suction valves of the GEHO pumps on the autoclaves.

The potential cost savings from the early detection of these valves passing (being able to plan and prepare) is as follows:

Approximately 5 hours reduction in turnaround time @ $7k/hour deferred production + a valve body @ $10,400 = $45,500.

The average ultrasound instrument in the marketplace weighs roughly 2 pounds. That's approximately $41k in gold. Most plants can easily show a return-on-investment of $41k or more just in air and steam.

Ultrasound can be worth its weight in gold.

Figure 7. The new SDT North America, SDT-270 instrument with intensity meter and the new U.E. Systems, Inc., UE15000 with intensity meter.

Inactive ancient volcano

Drilling Platform

Geothermal

Overview of plant

Roger Collard, CMRP, has 20 years of maintenance experience based in reliability centered maintenance. His background is strongly suited in manufacturing, heavy industrial applications, and mining, with a focus on stationary and mobile equipment. Roger Collard is the Chief RCM Engineer at Wyle Laboratory (Jacksonville, FL). He graduated from the University of Utah with a Bachelor of Science degree in Mining Engineering.

Jim Hall is the president of Ultra-Sound Technologies (UST), a "vendor-neutral" company providing on-site predictive maintenance consultation and training. UST provides Associate Level, Level I, and Level II Airborne Ultrasound certification. Jim is also the author of Ultrasonic War Stories, *a free bi-weekly newsletter. www.Ultra-SoundTech.com*

Balancing of an FD Fan at a Refinery

Troy Feese

This article provides a case history of a forced draft (FD) fan that experienced high vibration due to unbalance and an impeller resonance near the operating speed. The common balancing method of influence coefficients was unsuccessful due to varying phase data. However, vibration was reduced to an acceptable level using the four-run method without phase data.

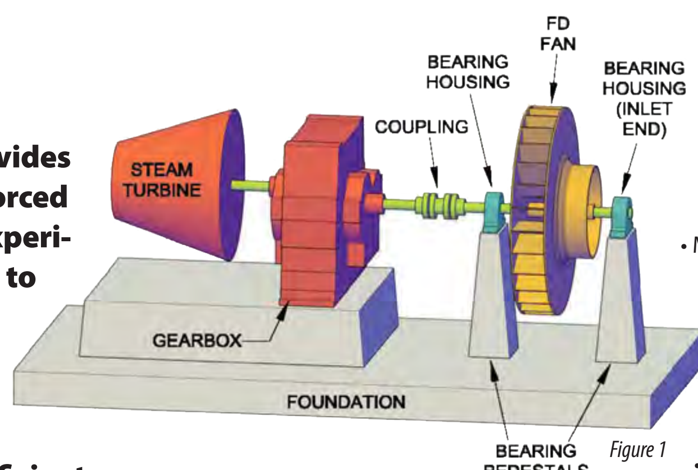

Figure 1

Background

The FD fan supplied air for a boiler and was driven by a steam turbine through a speed-reducing gearbox as shown Figure 1. Refinery personnel reported high vibration several days after replacing the fan roller bearings. In an attempt to reduce the vibration, a second set of replacement bearings was installed; however, the vibration remained high. Initial vibration data were acquired with a hand-held analyzer. The predominant vibration was in the horizontal direction and occurred at 1× running speed of 1745 RPM (29 Hz) of the fan.

Test Procedure

High vibration at 1× running speed is a typical indication of unbalance. However, other factors can cause vibration problems, as described in the reference paper[1]. Therefore, the refinery requested that more detailed testing be performed before attempting to field balance the FD fan.The test procedure included the following steps:

- Measured operating deflection shape (ODS) while running at 1745 RPM with load.
- Monitored bearing housing vibration while reducing air flow to boiler.
- Inspected the fan while it was down.
- Performed impact tests of bearing pedestals and fan rotor.
- Created vibration waterfall and Bode plots during coastdown.
- Balanced the fan using the four-run balance method to reduce vibration.
- Performed a final check of fan vibration with maximum air flow.

Operating Deflection Shape (ODS)

There are several commercially available software packages, such as SMS Star and ME'Scope, that can be used to perform operating deflection shape (ODS) measurements. First, a simple wire-frame model was created from basic dimensions of the FD fan. The undeformed representation of the bearing housings, bearing pedestals, and concrete foundation is shown in Figure 2 as dashed lines.

While operating the unit at constant speed and load, a tri-axial accelerometer was moved to 18 different locations to measure vibration in three orthogonal directions. Phase angles were determined from a stationary reference accelerometer. The software was then used to animate the measured vibration (amplitude and phase) at 1× running speed.

The highest vibration occurred at the top of the bearing housings in the horizontal direction. Figure 2 shows the rocking motion in which both ends (air inlet and coupling) were moving in-phase. The maximum vibration was approximately 6 mils p-p at 1× running speed (29 Hz). Vibration on the concrete foundation was 3 - 4 mils p-p, which was also considered excessive. However, no significant separation was found between bearing housings, pedestals, and concrete foundation. Therefore, looseness was ruled out as a possible cause of the high vibration.

There are several commercially available software packages, such as SMS Star and ME'Scope, that can be used to perform operating deflection shape (ODS) measurements.

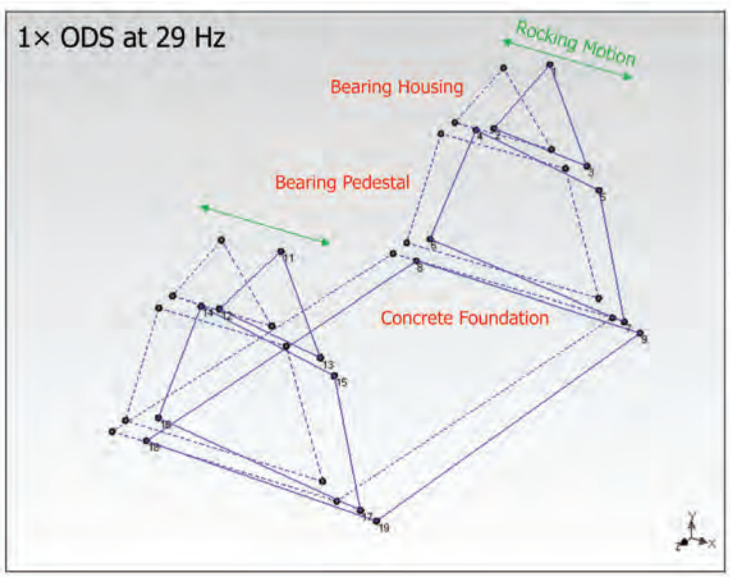

Figure 2

Reduced Air Flow to Boiler

As the fan was unloaded, the air flow reduced from 70,000 lb/hr to zero with the louvers closed, which caused the speed to increase from 1745 to 1760 RPM. During this time, the vibration levels of the fan bearings were monitored, and no change in 1× vibration was observed. This demonstrated that the vibration was not caused by aerodynamic forces. Both bearings still had approximately the same level of vibration, which pointed to a static unbalance condition of the fan impeller and not coupling unbalance.

Fan Inspection

During the inspection, five balance weights of various sizes were found already welded around the periphery of the fan impeller. This indicates previous trouble balancing the fan. The fan impeller was covered with a thin layer of dirt, so it was difficult to tell if a balance weight had possibly come loose.

No obvious signs of damage were found, and no foreign objects were found inside the fan housing. The amount of dirt would have been similar before and after the bearing replacements. Therefore, the inspection did not explain the change in vibration after installation of the new roller bearings. Other items to verify included: the speed rating of the roller bearings, bearing clearances, and proper lubrication.

Impact Tests

With the fan shut down, impact tests were performed using an instrumented hammer containing a load cell. The results showed that the bearing housings did not have any natural frequencies near running speed.

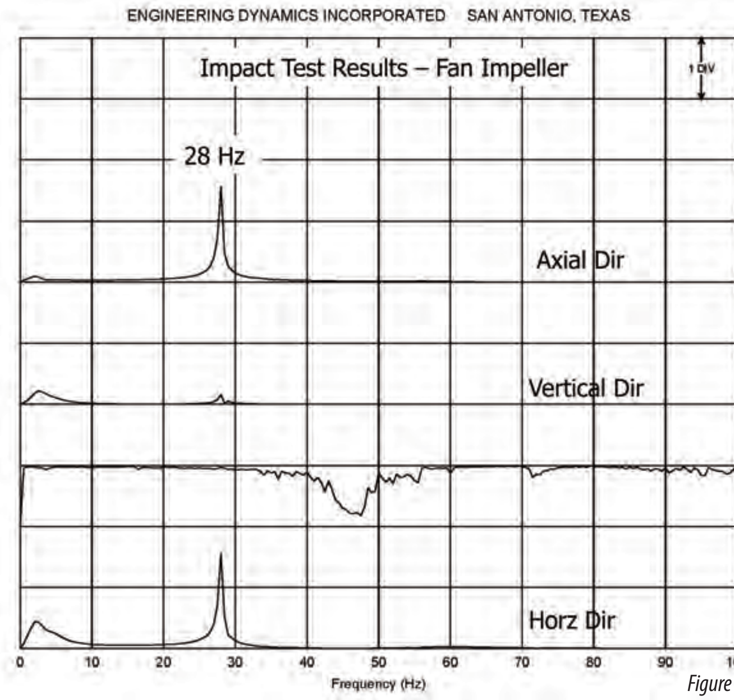

Figure 3

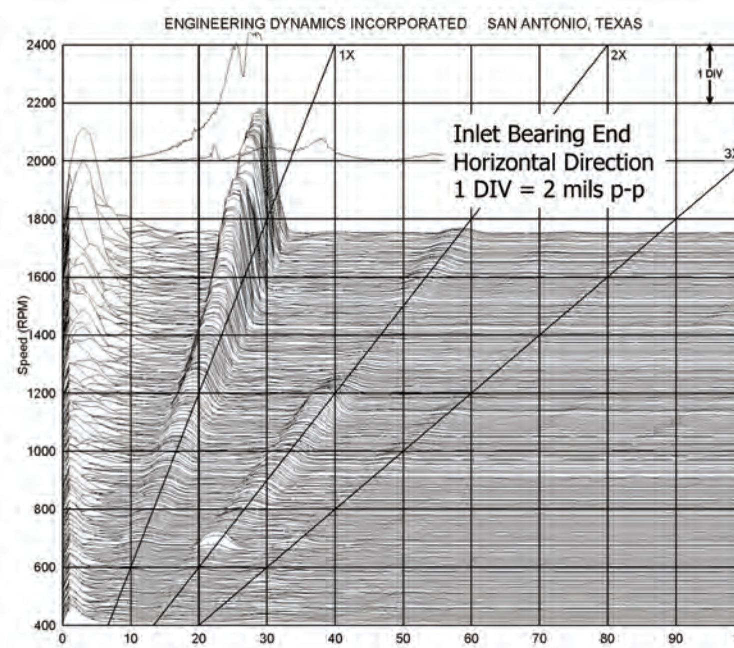

Figure 4

However, a natural frequency of the fan impeller was measured at 28 Hz and appeared to be more sensitive in the axial direction, as shown in Figure 3. This natural frequency could be a wobble mode of the impeller and could increase in frequency during operation due to gyroscopic effects. The EPRI paper by Smith[2] gives an example of a wobble mode.

There is an insufficient separation margin between the 28 Hz natural frequency of the impeller and the operating speed of 29 Hz. For reliable operation, a separation margin of at least 10% is recommended. Therefore, the fan vibration could be amplified due to the resonant condition, and the fan would be sensitive to even small amounts in unbalance. A change in unbalance condition could be caused by dirt build-up, a lost balance weight, or insufficient press fit of the impeller on the shaft allowing the impeller to shift slightly.

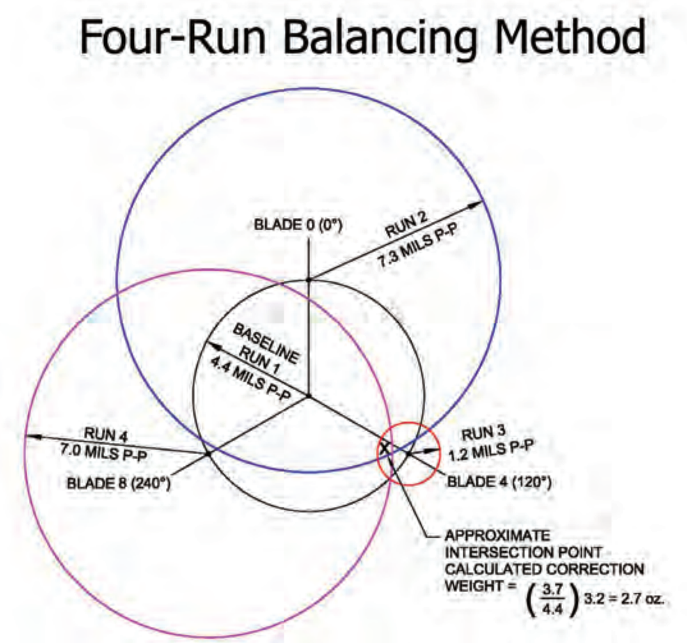

Figure 6

If the fan would have continued operation with high vibration, the new roller bearings could have been damaged due to the excessive unbalanced forces.

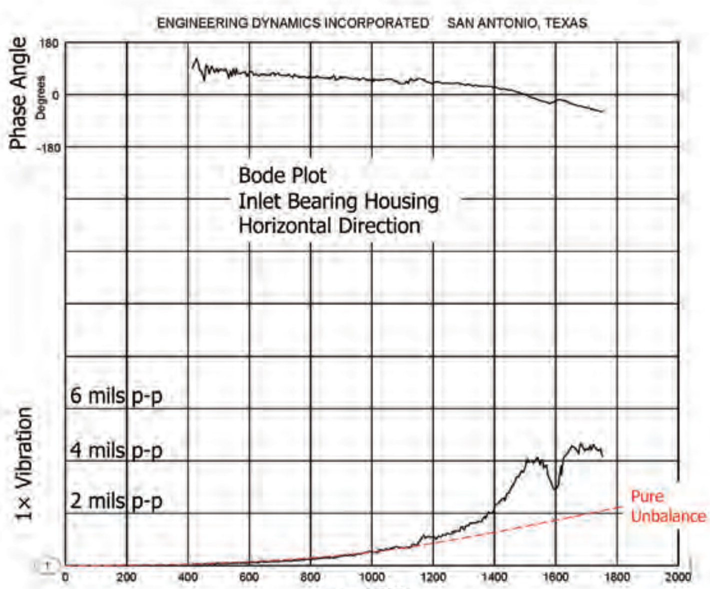

Figure 5

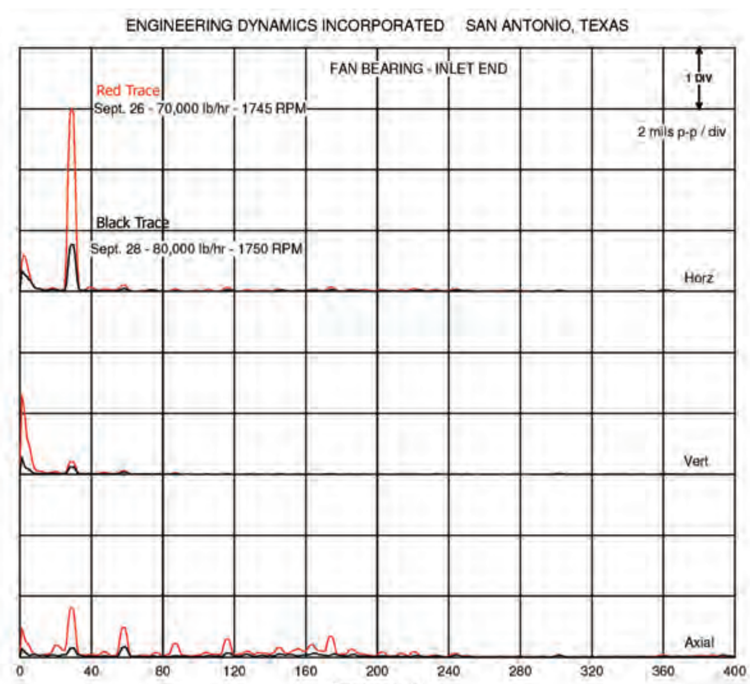

Figure 7

Vibration Plots Taken During Coastdown

Vibration waterfall (Figure 4) and Bode (Figure 5) plots showed that two peaks occurred during the coastdown. It was unknown if the second peak was caused by a sudden change in speed as the steam was cut off to the turbine or if this might be a critical speed of the fan. The phase shift confirmed a resonance. In addition, the vibration is amplified above the expected speed squared relationship due to pure unbalance.

Balancing

During the inspection, previous balancing locations were found all around the fan impeller. This indicated trouble balancing the fan using the typical influence coefficient method. Because the fan was running near a resonance, the phase angles could vary significantly at slightly different operating speeds. The speed of the steam turbine could not be held absolutely constant as would a motor.

The refinery was willing to start and stop the fan multiple times, so it was decided to try the four-run balance method. The four-run method is best for balancing near a resonance because it does not rely on phase data. Dennis Shreve discussed this simple balancing procedure in the

	Inlet End	Coupling End
Run 1: Baseline (As Found)	4.4 mils p-p	3.9 mils p-p
Run 2: 3.2 oz at Blade 0	7.3 mils p-p	6.2 mils p-p
Run 3: 3.2 oz at Blade 4	1.2 mils p-p	1.0 mils p-p
Run 4: 3.2 oz at Blade 8	7.0 mils p-p	6.4 mils p-p
Calc. Correction Wt: 2.7 oz at Blade 4	1.5 mils p-p	1.3 mils p-p
Final Correction Wt: 4.0 oz at Blade 4	1.2 mils p-p	1.0 mils p-p

Table 1: Horizontal Vibration with Fan Operating at 1745 RPM

previous issue of *Uptime Magazine*[3], and it is also detailed in the reference paper.[1] Therefore, the four-run procedure will not be repeated here.

To prepare for the four-run balance, the fan blades were numbered 0 to 11 (opposite direction of rotation). An optical tach and strobe light were used to ensure that all balance runs were performed at approximately the same speed of 1745 RPM. For the trial weight, a washer weighing 3.2 ounces was selected. A general rule of thumb for determining an appropriate trial weight is that the resulting unbalanced force should not exceed 10% of the rotor weight.

Table 1 summarizes the vibration data. Since the vibration readings were slightly higher on the inlet end, these values were used to construct the diagram shown in Figure 6.

The four-run balancing method uses circles to represent vibration amplitudes from each run. The approximate intersection point of the circles indicates the final balance weight location, which was near blade 4. The calculated amount was 2.7 ounces, which was slightly less than the trial weight of 3.2 ounces. The trial weight was removed, and the 2.7-oz correction weight was installed. As shown in Table 1, the vibration was higher than Run 3.

In an effort to further reduce the vibration, a larger weight of 4.0 ounces was tried at blade 4. As shown in Table 1, the vibration readings with the 4-oz weight were similar to Run 3. Therefore, it was decided to leave the 4-oz weight installed and to stop balancing. All of the vibration levels shown in Table 1 were for no-load conditions. Figure 7 compares the "before and after" vibration readings while operating the fan at 1745-1750 RPM with air flow.

Conclusions

This case history demonstrates how the four-run balance method was used in a real-world application. If the fan would have continued operation with high vibration, the new roller bearings could have been damaged due to the excessive unbalanced forces. At the time of the field study, the fan was scheduled to be replaced in approximately one year. Therefore, the manager of the refinery was satisfied with the short-term solution of field balancing to reduce the fan vibration to an acceptable level.

With one or two natural frequencies near the operating speed, the fan was still very sensitive to small amounts of unbalance due to dirt build-up, etc. For long-term reliability, natural frequencies of the fan rotor, impeller, and foundation should have a separation margin of at least 10% from the operating speed range. The refinery maintenance department reports that this fan was always difficult to balance and has now been replaced with a new one, which is more reliable.

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Troy Feese is a Senior Project Engineer at Engineering Dynamics Incorporated (EDI) in San Antonio, Texas. He has 20 years of experience performing torsional vibration, lateral critical speed, and stability analyses, as well as evaluating structures using finite element methods. He conducts field studies of rotating and reciprocating equipment. He is a lecturer at the annual EDI seminar and has written technical papers on torsional vibration, lateral critical speeds, and balancing. He is a member of ASME, Vibration Institute, and is a licensed Professional Engineer in Texas. www.engdyn.com

Q&A

Uptime Magazine Publisher and Editor **Terrence O'Hanlon** recently caught up with **South Carolina Senator Paul Campbell** on the topics of reliability and sustainability and their impact on keeping America competitive.

Q Senator Campbell, as Past Regional President of Alcoa, you have that rare combination of industrial leadership experience combined with experience as a Senator. Can you tell us if you find any similarities between the two positions or are they worlds apart?

A The two positions are actually complimentary to each other, or should be. My background in industry gives me a business perspective when making decisions, and I believe government should run more like a business. Some people will say that government is not a business and that it shouldn't run like one. However, I will tell you that is one of the biggest problems we have in society today. Government decisions impact lives and drive the economy, and if government is not run like a business, political decisions will be made, not necessarily the best decisions. We in South Carolina have a requirement to have a balanced budget (I wish we had that at the Federal level), so just like a business, we have to make the hard decisions to match expenses with revenue. We create jobs and have to stretch capital to get the best bang for our buck when providing services. Reliability and sustainability have to be built into roads, bridges, buildings, environmental issues, and in all we do. Doesn't this sound like a business?

Q You wrote the forward for the newly published *Clean, Green & Reliable*, by Plucknette and Colson. What do you see as the connection between reliability and sustainability?

A Reliability and sustainability are congruent. In fact, you cannot have sustainability unless you have reliability. Reliability allows you to optimize both personnel and materials so that sustainability works as it is defined. Sustainability by itself can only go so far. You have to put the foundation under it for it to be successful, and that base has to be reliability. Unless these ideas are connected, they just don't work. As you read *Clean, Green & Reliable*, the connections become obvious. In today's world, with competition not just around the corner but global, limited capital to invest, currency fluctuations, and government interferences/incentives, we have to have sustainability, and the only way this is possible is with reliability initiatives and the discipline to stay the course. The alternative is to lose competitive advantage and market share and put your business at risk.

Q We have had the good fortune to have known you and your work for a number of years and appreciate your experience using reliability to drive superior business results in your past career. In your current work to make South Carolina and other U.S. manufacturing companies more competitive, what are you telling today's industrial leaders to get them to see the benefits of becoming more reliable?

A As I see it, what we have to do to become more competitive within South Carolina and U.S. manufacturing is to get more throughput with the same hardware and the same processes so that our unit costs can compete with China, India, Brazil, and other countries. This will also allow us to better utilize human capacity (productivity), scarce capital, and resources. We have to make our products of superior quality and reduce our unit costs so that we can compete within our own industries on a global basis. We are losing manufacturing jobs because of our high production costs. If we can work together to drive reliability and sustainability throughout the manufacturing industry, and drive our unit costs down, then we can be competitive with any country in the world. The markets are here, the technologies and the ability to apply the technologies are here, and the stability of our country for continued investments is here. We have what we need to be competitive and win; we just have to do it – and do it through reliability and sustainability. Reliability and sustainability are not what we do but *how* we should be doing what we do.

Q Are the industrial leaders you meet receptive to your enthusiasm about reliability and sustainability?

A I think most industry leaders see "the last frontier" as reliability and sustainability. The problem for some of these leaders is that they expect results to happen overnight. Reliability and sustainability are journeys that require continuous improvement, hopefully with step changes that push you along at a faster pace and let you see the desired results sooner. Reliability and sustainability never stop; they must continue to truly be successful. Many leaders are receptive but impatient, which is why I try to continually remind them that you have to stay

Reliability and sustainability are congruent. In fact, you cannot have sustainability unless you have reliability. Reliability allows you to optimize both personnel and materials so that sustainability works as it is defined. Sustainability by itself can only go so far. You have to put the foundation under it for it to be successful, and that base has to be reliability.

South Carolina Senator
Paul Campbell

behind the reliability and sustainability initiatives no matter what. Whether the economy is up or down, you don't back off of your reliability initiative. I continue to tell people that reliability does in fact produce a product, and that product is capacity.

Q What do we have to do as a nation to make places like South Carolina more attractive than overseas locations for global manufacturers and service companies?

A To make South Carolina and the United States more attractive, we have to have government support our business initiatives, specifically, by looking at things like taxes, environmental requirements, and permitting as they pertain to manufacturing; having the ability to be innovative and creative; and supporting things like research and development. In doing this, we have to look at our competition and be at least on same playing field as they are. If we're not, we will fall further behind. Capital and jobs will flow where the returns are best, where jobs are wanted, and where profits are seen as a good thing. Our challenge is to make this a business, investment, and job friendly environment.

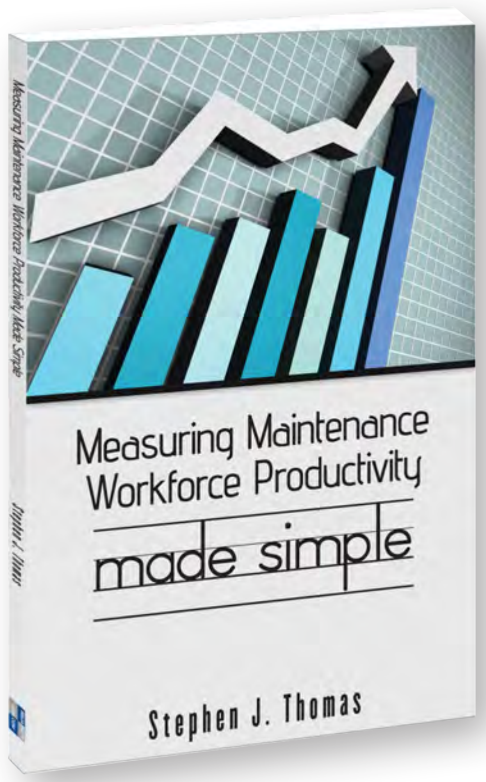
Additionally, one of my biggest concerns about South Carolina, and the United States as a whole, involves competitive power and rates for the future. If we do not improve these, we could have serious problems. With the way China is building power generation, they will essentially have a new portfolio of plants while ours is aging. I am talking about both renewable and base load. We are not doing enough on base-load plants.

Q What is in store for the next 5-10 years in terms of maintenance reliability and sustainability for the companies you know in South Carolina?

A Those companies that continue to push excellence in manufacturing, which means using reliability and sustainability and applying all of the tools that Plucknette and Colson refer to in *Clean, Green & Reliable*, will continue to drive costs down and become more competitive while growing market share. Those companies that are not willing to put resources into reliability could very well fall further behind. To survive in a global economy, you have to get better every day just to stay even with the competition. Reliability and sustainability are the true competitive advantage and maybe, as Captain Kirk once said, "the Last Frontier." Following these initiatives will produce winners.

"Measuring Maintenance Workforce Productivity Made Simple"

Author: Stephen J. Thomas
Reviewed by: Robert S. DiStefano



When I was asked by *Uptime Magazine* to review this book, I was reluctant because of my busy schedule, but I agreed to do it because I am an avid reader of *Uptime* and a supporter of its mission. I am happy I agreed to do it. As it turned out, the book was a very fast and easy read.

Beyond that, I had considered myself quite well-informed about the subject of work sampling and worker productivity measurement, having been involved in countless such exercises during my career. I didn't expect to learn much from this book. I was wrong. The book illuminated the subject, brought some very well-designed practical tools to bear, and debunked some myths about the subject. All in all, I was impressed and think this book is a must read for those struggling with measuring maintenance workforce productivity.

Many companies have a history – long-ago history in many cases – of work sampling or worker productivity measurement activities that were negative experiences. Years ago many companies intentionally or unintentionally misused the measurement activities to find and punish unproductive workers. Many organized labor groups, including unions, negotiated prohibitions of work sampling in their contracts, and some of those limitations still exist today. However, more modern and enlightened use of work sampling and workforce productivity measurement has been put to good effect both for company management and workers and is of late coming back into favor. These efforts are being used to identify and eliminate company-imposed roadblocks that are not allowing workers to be as productive as they could be, and by-and-large want to be, in my opinion. I encourage my clients to give strong and careful consideration to reintroducing these tools in the context of the larger goal of improving asset performance and lowering costs to appropriate levels. Mr. Thomas fully recognizes this checkered history and directly addresses it throughout his book. One example that comes to mind is his intentional use of worker anonymity in the design of his tool-set. Since Mr. Thomas has written extensively on the subject of culture and cultural change, he is fully aware of the resistance to the use of worker productivity measurement techniques, and he addresses the cultural aspects head-on. This I think is essential for adoption and successful use of the tools presented in the book.

As the title implies, Mr. Thomas has made it very simple to deploy a practical application of maintenance workforce productivity measurement. The tools he has designed and presents in the book are easily available and adaptable to the readers' circumstances. Templates and forms, calculation formulae, tables and charts, sampling instructions, and even statistical analysis for non-statisticians, are all made available in clear black and white terms. The book also includes a host of hints that are obviously based on Mr. Thomas' personal experiences with pitfalls that he admits he has fallen into during his career, but which are entirely avoidable.

As is typical in books by Mr. Thomas, the organization and flow of the content in the book is well done. There are only six chapters, including the first chapter, which makes a case for improving productivity through work sampling and also includes discussion on breaking down management's resistance. The remaining chapters deal with planning, execution, reporting results, continuous improvement, and what Mr. Thomas calls "spot sampling," which I might call a mini-sampling after the initial baseline is established. In addition, the appendices include forms and sample charts that can be readily adapted and used immediately by the reader.

As Mr. Thomas explains in the introduction, he sets out to provide the reader with a process that is easy to use, easy to understand, easy to implement, engages the workforce, can be done with little to no cost, can be replicated over time to track continuous improvement, and, with slight modification, can be applied to any size organization. I think Mr. Thomas has accomplished those goals with this book, and I highly recommend reading it and putting it to use!

Reviewer:
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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.

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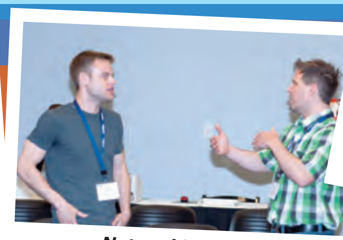
Networking at CMMS

CMMS Conference in Session at RPI



Networking at CBM

Attendees visiting with UE Systems at CBM

MRO bookstore at CBM

Sunil Kamerkar at CMMS

CMMS Evening Event - Beach Dinner

Carey Repasz at CBM

Mike Early, iPad winner at CMMS

CBM Conference in Session at RPI

Saul Cizek at CBM

Networking at CMMS

This was one of the most informative conferences that I have been to. This conference will aid me in improving CBM and convincing my company to head in the right direction.

CBM

Marcus Thomas
Instrumentation & Electrical Technician
Jamaica Energy Partners

The presenters brought a wealth of knowledge in their fields that demonstrated the strengths and weaknesses of each technology. I have several take-aways that I can immediately apply to improve our CBM process.

CBM

Chris Tindell
Engineering Technician
Alcoa

Highly recommended! A great mix of "common-sense" approach coupled with the use of leading-edge tools.

CMMS

Tim Nevins
Project Manager
Facility Asset Mgmt System
Greater Toronto Airports Authority

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