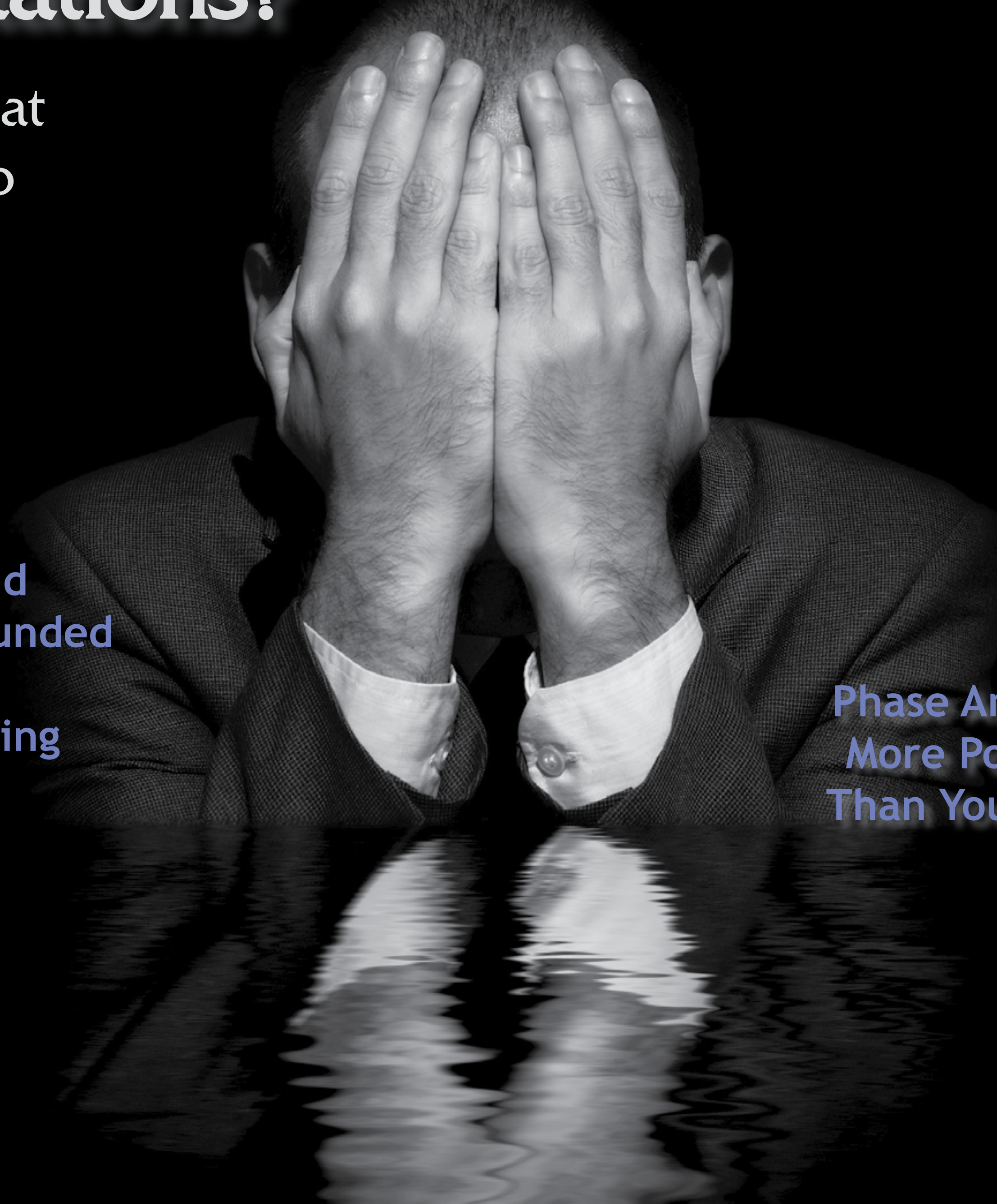
uptime

the magazine for PdM & CBM professionals

feb 2007

PdM Results Not Meeting Expectations?

Why & What You Can Do



Motors: Avoid Getting Grounded

Field Balancing Revealed

Phase Analysis: More Powerful Than You Think

Reliability–Get it and Get Off the Crazy Ride

What happens when you arrive at work? You fight fires, running from one equipment failure to another, as if you're on a wild roller coaster ride! Improving reliability can ease your work life, but implementing reliability can feel just as out-of-control if it's not sustainable.

Get off the crazy ride. Take an Ivara workshop, taught by reliability experts, and get the skills you need to improve plant performance through sustainable, equipment reliability improvements.

IVARA RELIABILITY WORKSHOPS

Reliability – Preparing for Tomorrow's Maintenance World

Take a leadership role in reliability, learning the fundamentals of reliability improvement.

2-day workshop, $795

Lean Maintenance

Improve your understanding of Lean Maintenance and learn how to implement Lean, step by step.

2-day workshop, $795

Best Practices in Maintenance & Reliability

Learn a new and comprehensive approach you can use today to evaluate how your organization's maintenance and reliability practices and culture compared to recognized world-class standards.

2-day workshop, $795

On-site Reliability Workshops

Get everyone in your organization on-board with reliability–book a workshop at your location where you can benefit from customized content delivered by world-renowned reliability leaders, while accommodating larger numbers of participants. On-site Reliability Workshops are the most cost-effective way to educate your workforce on asset reliability.

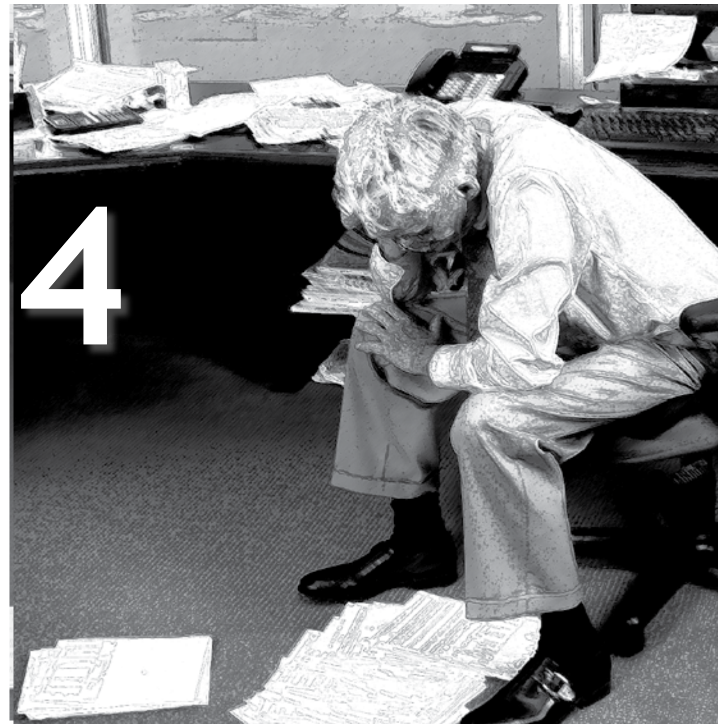
Cost: $3000/day, up to 20 participants.

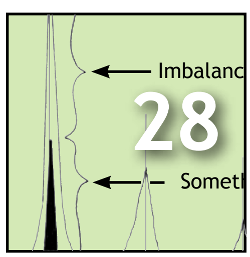
IVARA
WORK SMART

For more information, visit www.ivara.com, phone 1-877-746-3787 ext.312, or email askivara@ivara.com.

uptime

contents





upfront

Working with Magic

Predictive Maintenance works. There is absolutely no doubt that it can and does lower maintenance costs, increase uptime, increase throughput and improve organizations' bottom lines. For the companies that have embraced predictive technology and forged a high quality PdM program, it produces these results day in and day out. I find it remarkable that, with so many powerful tools available, there are many facilities that have not adopted a maintenance strategy that includes a heavy dose of predictive technologies.

However, as you will read in our feature article by Ricky Smith this month, predictive maintenance does fail at many companies. Why? The problem with predictive maintenance lies not in the technologies, but in the expectations and implementation of those technologies. You are not assured of success just because you buy the latest vibration analysis gizmo or infrared camera.

Predictive maintenance is hard work, but is smarter hard work than reactive maintenance. You have to establish proper goals and objectives, organize the installation of the technology to optimize results, set up good data collection, put the data to good use by planning and scheduling the proper work and continuously evaluate the results of the program. Only by working diligently on each of these steps will the predictive technologies perform their magic.

Yes, I think that the results from predictive maintenance can be magical, but the magic only happens when the hard work is invested.

If companies want to be competitive in today's marketplace, they need to use all of the tools available to them. But the tools will never be what makes them successful. You, the maintenance professionals, are the only ones who can do that.

I would like to apologize for the omission of a chart in the article entitled "Gearing Up for Energy Savings" in last month's issue. We have included it on page 48 this month. It is also available within the context of the story on-line in our January digital edition.

Thank you for reading. Please don't hesitate to contact me with any questions, comments or suggestions that will help Uptime be more useful to you.

All the best,

Jeff Shuler
Editor In Chief
jshuler@uptimemagazine.com

uptime
volume 2, issue 16

PUBLISHER
Terrence O'Hanlon

EDITOR IN CHIEF
Jeffrey C Shuler

ADVERTISING SALES
Bill Partipilo
888-575-1245 x 114
sales@uptimemagazine.com

EDITORIAL INFORMATION
Please address submissions of case studies, procedures, practical tips and other correspondence to

Jeff Shuler, Editor In Chief
Uptime Magazine
PO Box 60075
Ft. Myers, FL 33906
888-575-1245 x 116
jshuler@uptimemagazine.com

SUBSCRIPTIONS
to subscribe to Uptime, log on

www.uptimemagazine.com

Uptime® (ISSN 1557-0193) is published monthly by Reliabilityweb.com, PO Box 60075, Ft. Myers, FL 33906, 888-575-1245. In the U.S. Uptime is a registered trademark of Reliabilityweb.com.

POSTMASTER: Send address changes to: Uptime Magazine PO Box 60075, Ft. Myers, FL 33906.

The Top 4 Reasons

Predictive Maintenance Fails

& What To Do About Them

by Ricky Smith, CMRP

Many companies adopt some form of Predictive Maintenance (PdM) technology as the first step in the path to improved plant reliability. However, the returns from these initial PdM investments often fail to meet the expectations of management. Many of you have seen the ineffective use of predictive maintenance where failures occur even though you are using some type of PdM monitoring. I lived in this world as a maintenance supervisor and it frustrated me that I could not define the use of PdM more effectively. I wrote this article in order to share my experiences with you based on my successes and failures. So let's look at the top 4 reasons why PdM has failed to meet management's expectations as I have seen.

In order to define why Predictive Maintenance fails let's first understand the definitions of "Predictive Maintenance" and "Predictive Maintenance Technologies" or PdM Technologies.

Predictive Maintenance is the monitoring of an asset's health in order to anticipate the opportunities to proactively perform maintenance to preserve an asset from failure or to protect it in some way. PdM Technologies are the instruments or technologies used to collect asset health data.

The purpose of Predictive Maintenance is to maximize, at optimal cost, the likelihood that a given asset will deliver the performance necessary to support the plant's business goals. By "optimal cost" we imply that if it is feasible, and economically sensible to perform a task that detects a failure far enough in advance to make intervention practical, then we will have avoided the far greater costs of equipment downtime, secondary damage, human injury, environmental impact, production quality and others.

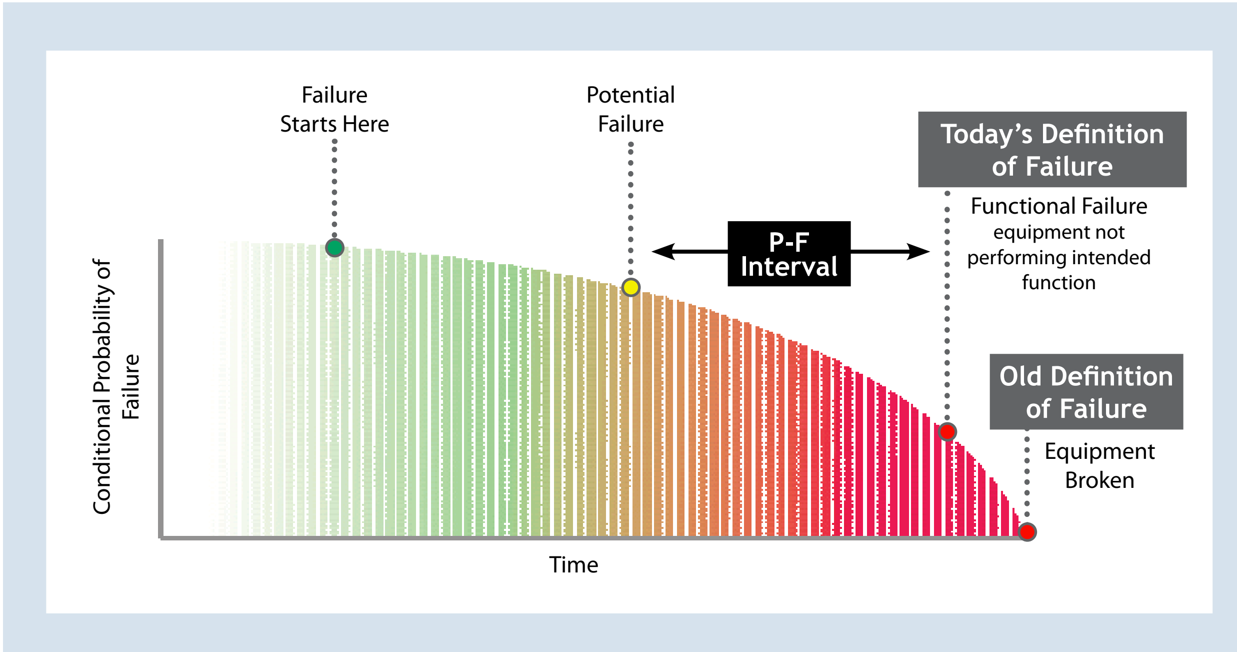


Figure 1 - P-F Curve

In order to use PdM technology effectively one must understand how equipment fails. Through studies we know that no more than 20 % of failures are time based and no less than 80% of failures are random in nature and cannot be effectively correlated to time or operating hours. PdM provides one of the major tools to predict failure of an asset. PdM use for random failures must focus on the health of the asset (through monitoring indicators such as temperature, ultrasonic sound waves, vibration, etc.) in order to determine where an asset is on the degradation or PF Curve. Point "P" is the first point at which we can detect degradation. Point "F", the true definition of failure, is the point at which the asset fails to perform at the required functional level. In the past, we defined "Failure" as the point at which the equipment broke down. You can see points P and F and the two different definitions of failure in Figure 1.

The amount of time that elapses between the detection of a potential failure (P) and its deterioration to functional failure (F) is known as the P-F interval. A maintenance organization needs to know the PF Curve on critical equipment in order to maintain reliability at the level required to meet the needs of the plant. Without this knowledge how can one truly understand how to manage the reliability of the asset?

PdM should be used to define where the health of the asset is on the PF interval. PdM can define the point of failure in the PF interval far enough in advance so that the asset can have planned and scheduled maintenance performed to restore it. Costly equipment failures, and more importantly, the larger costs of unscheduled downtime can thus be avoided. As you can now see, understanding failures is very important in understanding how to use PdM technologies to their fullest potential.

Let's now look at the 4 main reasons that PdM has failed to deliver expected value.

Reason 1: The collection of PdM data is not viewed as part of the total maintenance process.

Many organizations, at least initially, view PdM as a separate activity from the core role of the maintenance function, and so it is not covered in the maintenance process. Some organizations start down the PdM path by "trying it out" on a contract basis. The contractor's role is to e-mail or snail-mail the resulting predictive data to the plant. In other companies, a PdM resource (often seen as the Reliability Technician) is assigned the predictive role, or a PdM Team is formed. When these individuals or teams are not seen as an integral part of the maintenance department, their value is unlikely to be realized. Also, quite often the predictive data will be supplied to the maintenance organization, but the technician who collected the data is not consulted on the results, so the potential for well-informed data-driven decisions is limited. If PdM is disconnected from the maintenance process, the PdM program will likely fail because the value cannot be identified.

For example, have you ever seen a case where a maintenance employee becomes the new PdM technician? He may be the lucky one picked to operate the brand new $50,000 thermography equipment. In an immature reliability environment, the new role usually comes with a title that includes the word "Reliability". This new Reliability Technician goes out and starts snapping pictures of assets that show interesting heat profiles (when your only tool is a hammer, everything looks like a nail). But for most of these assets, a reasonably sound failure analysis, if performed, would not identify excessive over heating as the best predictor of failure. Or, potentially even worse, after the failure of a particular asset is determined to be “overheating”, the Reliability Technician is assigned to produce thermographic profiles of every similar asset in the plant, regardless of probability of failure, frequency of failure, failure consequence etc. Is it any wonder that production and maintenance personnel see limited value in the Reliability Technician’s data?

To get the most out of PdM, I recommend that you make it an essential part of the Work Identification and Work Execution elements in your maintenance process (see Figure 2). The steps in the Work Identification should clearly identify failure modes, and the best techniques for predicting those failures. PdM tasks are identified as part of a complete asset maintenance program, so we understand why we are doing the work and we are not doing unnecessary work. Work Execution conducts the work specified in the asset maintenance program in the most efficient manner possible. Tasks should be grouped in routes and handheld devices used

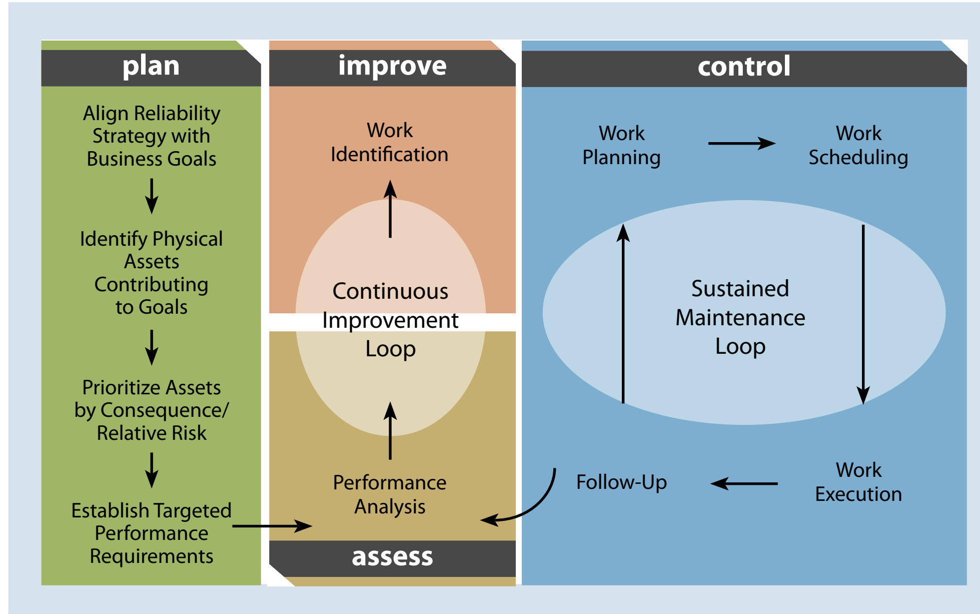


Figure 2 - Established Proactive Maintenance Process

where the PdM technology requires human intervention.

Involve production, maintenance and PdM personnel in failure analyses and the resulting work execution. In this way, we ensure that the prescription for failure management applies our PdM capabilities where they are most valuable. The involvement of these groups also ensures that the predictive data will be welcomed and seen as valuable as it arrives.

Reason 2: The collected PdM data arrives too late to prevent equipment failures.

In this scenario, maintenance and operations management ask "Why did we not see this equipment failure coming?" Yet the PdM technician can often point to a chart or spreadsheet logged days ago and say "I told you so". Management's perception is that the information was received too late. Yet, in reality, the data was there, but was not visible when it would be most valuable. Predictive maintenance activities generate massive amounts of data related to the health of the equipment. To be of real value to maintenance and operations, the data must be visible to maintenance, effectively analyzed while it's still current, compared against states that are defined as "normal" and the analysis communicated in a real-time manner.

> **...degradation in equipment performance can be seen well in advance of failure...**

We know from a reliability standpoint you cannot see or predict all equipment failures. However, most degradation in equipment performance can be observed well in advance of failure with the integration of PdM technologies and techniques. Using handheld data collectors, operators and trades people can record real-time and time-stamped health indicators and feed that data into a computerized reliability system. The amount of data collected in any 8 hour shift is likely to be overwhelming if it was to be managed manually. And yet with appropriate computerization, the normal and non-normal state information creates the opportunity to selectively focus on only the handful of data points that are relevant each shift– where the asset health degradation is evident in the data. This form of data management can lead to the ultimate use of PdM capability, where management can easily make critical maintenance intervention decisions – driven by real-time data, before it is too late.

Reason 3: Many companies fail to take advantage of data from PLCs (Programmable Logic Controllers) and DCSs (Distributive Control Systems).

PLC's and DCS's can provide important production data such as pressure, flow and temperature that can also be useful for assessing asset health. Most of us think of PdM in the traditional sense; that is, vibration analysis, oil analysis, thermography, etc. Yet the production data available in many companies is quite extensive. We need to selectively tap into this valuable resource.

A cautionary word about production data; like other forms of PdM information, it's only valuable if used in the context of a failure analysis. Most thorough failure analyses will point to production data as appropriate for understanding indicators of only certain failure modes, while the majority of failure modes will rely on the collection of data through human senses. So hooking up a data-rich production database to a CMMS/EAM will only result in increasing the amount of useless data in making the right decision at the right time and help capture equipment historical data which is typically not accurate in most plants.

The more advanced PdM programs recognize where production data can add value, and they take advantage of the fact that it's readily accessible electronically (for production use). Using this data, maintenance can better predict the degradation of equipment performance to determine the most opportune time to intervene with proactive maintenance activities.

For example, as a maintenance supervisor in a previous job, we had a DCS (Distributive Control System) which was supposed to monitor the parameters of our production process and production equipment as its main function. We managed our production process using Statistical Process Control. Our DCS managed a lot of data and did a great job of it for production. What we missed was using specific data in this system to help maintenance make asset reliability decisions. I will use our rotary press as an example; the rotary press (calendar system) pressed two 300 CM rolls to form a matted product from woven fibers through a drum type press at speeds of over 500 meters per minute. The pressure of this rotary press had to stay constant in order to make the desired product. A complex hydraulic servo system was used to maintain the pressure required on this press in order to deliver the product required. Our DCS monitored the hydraulic servo valve milliamp output as part of its process control measures. Daily we checked (visual inspection by an electrician) the milliamp signals from all servos. But we did not plot the data and relate the data to the PF Curve, and thus the decisions we made on this system were either made too early or most the time too late. Reliability software now allows for continuous monitoring of the milliamp signals coming from these servos. This data could have been collected real time, plotted and used to help in determining where on the PF Curve we needed to make a decision to change out a servo valve (based on the values from one servo valve controller) or the change out of the hydraulic pump (based on the values from numerous servo valves controllers) using reliability technology and methodology. With this new technology available, a milliamp signal can be connected from the DCS to the Reliability Software where a decision can be made based on data with an alarm to the maintenance planner who plans and schedules a change out of a servo valve or pump far enough in advance to completely avert, or at least minimize, failures. This reliability software can be connected directly to the CMMS/EAM so that planning and scheduling of the work is seamless and allows accurate history to be documented on the equipment.

Reason 4: Most PdM data is dispersed in too many non–integrated databases.

Separate software systems are usually employed to manage the many specialized sources of PdM data: contractors have their data; the PdM team has several separate databases for each PdM technology, and the production PLC's and DCS's also store required data. In addition, reliability engineers collect condition and state data from a variety of sources (typically as a result of a formal work identification process like RCM) and apply rules and calculations manually (day-after-day). Maintenance and operations personnel, themselves, are collecting and managing an increasing number of condition based proactive tasks in their own databases or often still on paper checksheets. It becomes impossible to realize significant value because it is so difficult to act in a meaningful way based on this disjointed information that comes from such a variety of sources.

So what should you do about it?

With today's technologies, all of these data sources can be integrated to enable timely maintenance decisions. Quite often, the

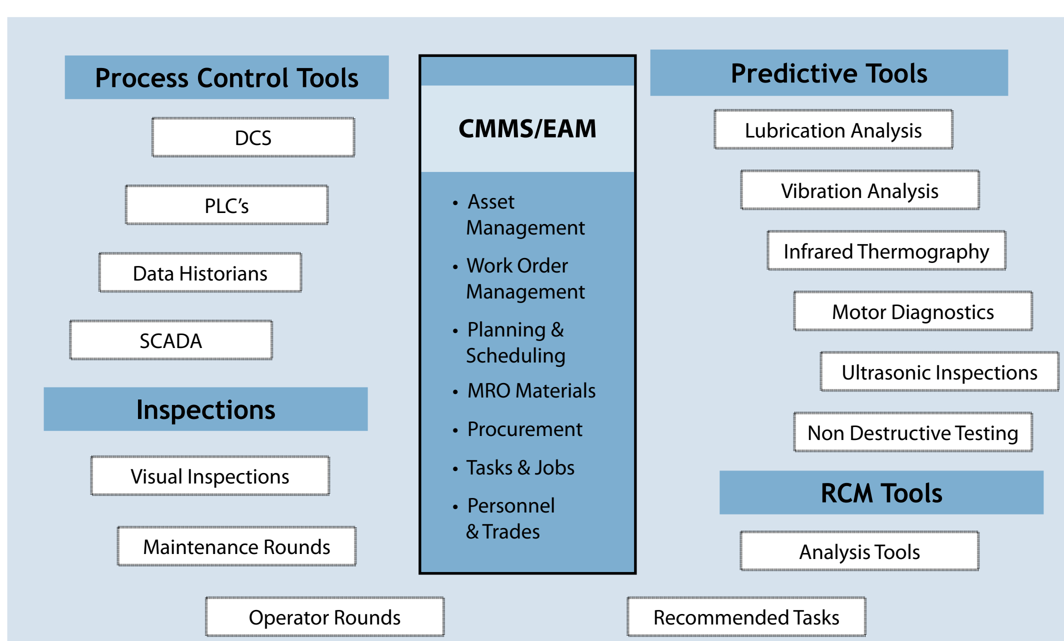


Figure 3 - Tools that can provide input to maximize the value of a CMMS/EAM System

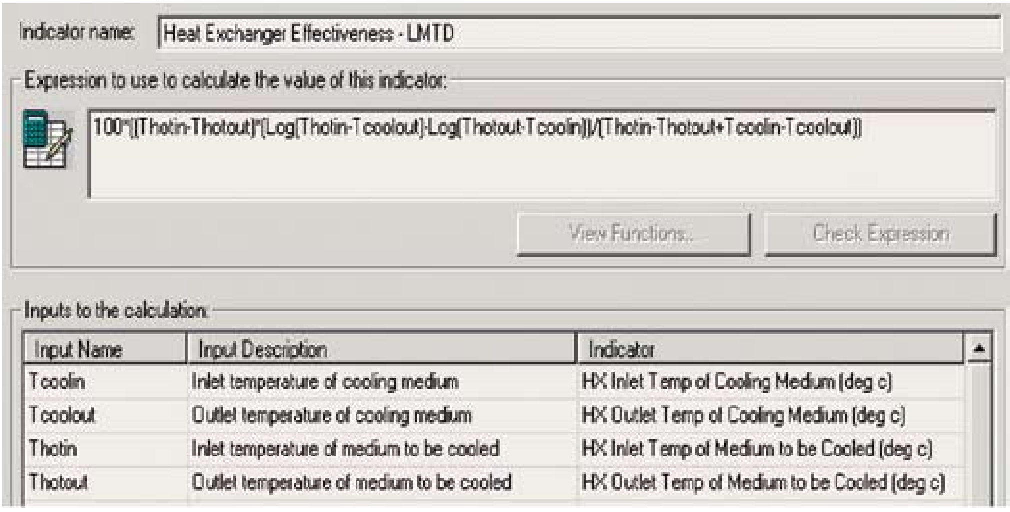


Figure 4 - Use software that eliminates day-to-day manual calculations and captures the knowledge of your experts.

best indicator of health is built using rules or calculations that combine data from multiple sources.

With a well integrated solution, maintenance can use real-time data to focus on defining the right proactive work to be performed at the right time.

To maximize the value of the data, it is important to utilize systems that sort through normal and non-normal data, and display the results in ways that are easy to understand, and utilize.

Figures 4 and 5 are examples of a system that eliminates the need to sift through piles of data. The plant, all of its assets and failure-mode-specific health indicators are displayed in a Health Indicator Panel, a two-panel screen showing the entire plant hierarchy and all assets on the left side, and relevant health indicators on the right side. This panel allows you to monitor asset condition and, at a glance, see any indications of impending failures – before the failures occur. As non-normal values are recorded, alarms are triggered and displayed, drawing attention to only the few data points that currently signal the potential for equipment failure. These flashing alarms are displayed when assets are moving closer to functional failure and alarm severities are readily understood based on the type of icon displayed. Here corrective maintenance decisions can be made based on asset health and risk to production and the business.

Some simple guidelines will help get you moving in the right direction:

1) Do not stop what you are currently doing in Predictive Maintenance, but evolve your PdM strategy into your maintenance program trading the ad hoc wrong work at the wrong time to the "right work at the right time". Do this by aligning your PdM work with the maintenance process required to keep your equipment reliable.

2) Identify the most critical assets (those which pose the highest risk to your plant) and focus on putting a PdM strategy in place within the context of a complete maintenance program for these assets. If you want to make your PdM more effective, you need to know which assets are most important to monitor. Your PdM program will then make an impact within the plant as quickly as possible and be a true contributor to asset reliability. When this new strategy is implemented you want "rapid results" which will immediately get people excited about what you are doing.

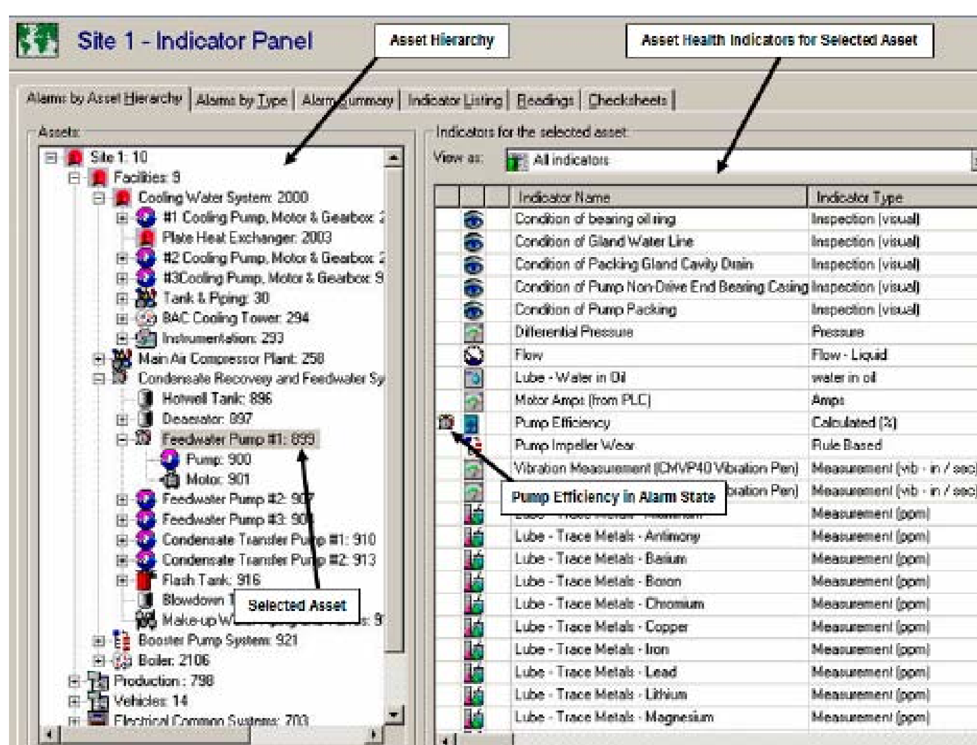


Figure 5 - Utilize systems that sort through normal and non-normal data, and display the results in ways that are easy to understand.


Take Your Maintenance Performance to a Higher Level
High Performance Asset Management and Reliability Forum
featuring the
Reliability Centered Maintenance Managers' Forum 2007
&
Enterprise Asset Management Summit 2007
April 3-6, 2007
Sheraton Waikiki
Honolulu, Hawaii
Learn from top experts how to build and develop high performance operational excellence through enterprise asset management and reliability centered maintenance.
Reliability Strategies
Reliability Centered Maintenance
PM Optimization
Value Driven Maintenance
Enterprise Asset Management
Asset Management Innovation
Enterprise Analytics
Asset Management from an Insurance Perspective
Zero Breakdown Strategy
for more info, to request a brochure or to register, call
888-575-1245 (US/Canada) 305-735-3746 (Intl) or visit
www.maintenanceconference.com
presented by
RELIABILITY WEB.COM

3) Establish performance targets for these highest risk assets (focus on just one asset at a time) and measure the success of your new strategy. Performance targets must be in production terms: increased capacity, decreased downtime, etc. and in maintenance terms such as increased Mean Time Between Failure (MTBF).

4) Work with operators, maintainers, and PdM technicians to assist in identifying known and likely failure modes on the highest priority assets. Develop a complete asset maintenance program of which PdM is an integral element.

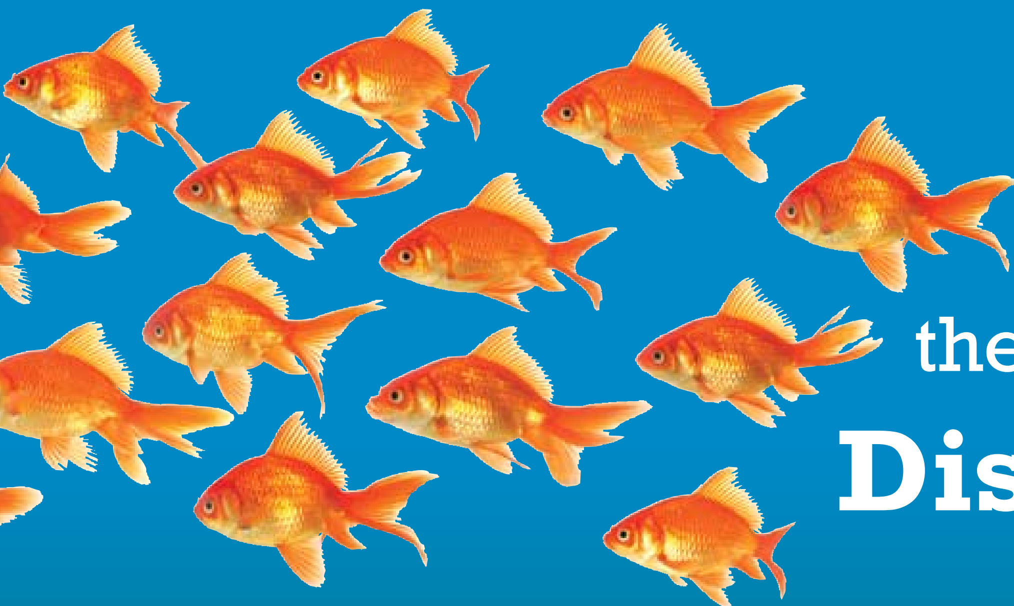
5) Implement this new PdM strategy within the context of a complete maintenance program on one asset at a time and monitor the results. If this process has been followed properly you should see results in a short period of time.

Summary

An effective PdM program must be integrated into a company's asset reliability process so that the right decisions can be made at the right time, utilizing accurate data which is fed into a reliability software which is, in turn, seamlessly linked to an effective CMMS/EAM. Being able to make reliability decisions far enough in advance to plan and schedule maintenance work will drive an organization from being reactive to proactive quickly, thus allowing the company to meet it's maintenance and production goals 100% of the time.

The time has come for change. The best time to begin this new journey is now.

Ricky Smith has more than 30 years of experience working in over 400 plants world wide providing increased reliability and maintainability in asset management. Ricky has worked for such companies as Exxon, Hercules Chemical, and Alumax Mt Holly (recognized for over 18 years as the best maintained plant in the world) in all levels of maintenance and maintenance management. Ricky holds designations as a Certified Maintenance and Reliability Professional from the Society for Maintenance and Reliability Professionals (SMRP) and a Certified Plant Maintenance Manager from the Association of Facilities Engineering (AFE). Well-known on the speaking and lecture circuits, Ricky is also a well-respected author with his books, "Lean Maintenance" and "Industrial Repair, Best Maintenance Repair Practices". His most recent books, "Rules of Thumb in Reliability Engineering" and "Best Practices in Maintenance and Reliability" are due out in mid year 2007. He also regularly writes for various publications including Plant Services Magazine, Maintenance Journal, Uptime Magazine, Reliabilityweb.com and others. Ricky can be contacted at ricky-smith@comcast.net



Avoiding the Disconnect

Reliability Centered Maintenance meets Enterprise Asset Management

by Terence O'Hanlon, CMRP, Publisher

Ever wonder why there is such a huge disconnect between your CMMS/EAM Software vendor and the reliability and maintenance work that actually takes place on the plant floor?

Recently I was fortunate enough to be invited to a major Enterprise Asset Management vendor event. The event included product managers, programmers, implementation specialists, marketing staff and trainers. They were seeking answers to what the future held for maintaining physical assets and I guessed that is why they invited me. There were no clients or users at this meeting.

After two days of meetings – some interesting presentations and some not – they turned to me and asked if I had anything I would like to present to the group? Not one to ever turn down a chance to address a captive audience or to influence the thinking of 75 people who supply a large percentage of the software that accounts for maintenance – I quickly accepted.

I asked for a show of hands of those who had heard of Reliability Centered Maintenance. Most of the people in the room raised their hands so I continued. I asked how many could quote at least one of the seven questions posed by a Reliability Centered Maintenance analysis and not one of the 75 people in the room raised their hand.

Remember – these are folks whose livelihoods depend upon making, installing and training for software that automates the maintenance process.

There was not one single representative that had ever worked directly in the maintenance and reliability community that was part of that team! I have been involved with numerous other asset management software vendors, big and small; who were no better in terms of resident knowledge of maintenance. It is just business as usual. Is it any wonder that 57% of EAM implementations fail to generate the expected results or return? Or that only 20% of CMMS/EAM implementation are characterized as successful?

I have also been to companies where extensive Reliability Centered Maintenance analysis has been performed. The RCM analysis lays out a complete roadmap to ensuring reliable plant operation, yet it sits dormant in a spreadsheet or in 3 ring binders and has never been implemented or entered into the EAM/CMMS system. Our studies show that 71% of Reliability Centered Maintenance programs fail to generate the expected results or returns.

Reliability Centered Maintenance (RCM) or PM Optimization (PMO) are the processes that will define the maintenance tasks to be performed to ensure reliability. The Enterprise Asset Management (EAM) Software is the system that will manage, store, trend, report and archive the work processes, procedures, materials, labor and paperwork. They need to fit hand in glove.

With both RCM and EAM implementations experiencing such high failure rates, perhaps we should throw both methods out the door. Processes that fail more often than they work would seem to be counter intuitive and should be avoided. However, in this case – the answer is not so simple.

Reliability Centered Maintenance has been around for over 30 years and when implemented properly – it has proven itself time and again. When adding PM Optimization into this category, there is simply no better way to determine the proper maintenance work to ensure reliable machinery or system function. If you have not performed RCM/PMO you should ask yourself what the foundation or basis for all of the work orders in your facility is, and the likely answers are one or more of the following:

- We have always done them this way
- If a little PM is good then a lot of PM is great
- The OEM recommended these PM's
- I go by gut feeling and I am right most of the time
- Or worse – I do not know why we are doing this work!

The 7 Questions of Reliability Centered Maintenance*

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

* Section 5 of SAE Standard JA1011 Evaluation Criteria for Reliability-Centered Maintenance (RCM) Processes

Major studies show that only 11%-17% of failures are time related. If you are spending more than 20% of your effort and budget on time based PM's, much of that work is not adding value or preventing failure. In fact, your PM's might actually be creating failures!

You need a method to direct value added maintenance work that prevents failure and you need an information management system to direct and track the history, the labor and the material. You need RCM/PMO to define the tasks and you need an EAM to manage them.

That is why we have collocated RCM-2007 – The Reliability Centered Maintenance Managers' Forum with EAM-2007 – The Enterprise Asset Management Summit April 3-6, 2007, held at the beautiful Sheraton Waikiki in Honolulu, Hawaii. This event includes learning and networking for both beginning and advanced practitioners. Participants will hear real world case studies of how companies made RCM and EAM work. We have also assembled the leading RCM/EAM subject matter experts from around the world to lead a series of half day workshops.

Unlike software user conferences, this event is independently produced and managed by Reliabilityweb.com. Being independent means we can design an event that revolves around you – the maintenance and reliability professional.

I am sure some of you reading this are thinking you wouldn't dare to ask permission for a maintenance and reliability conference in Hawaii. Why is it OK to go to Cincinnati but not Honolulu? We are quite confident that it is perfectly fine for maintenance professionals to look good and to feel good about what they do. If you can bring back a strategy to achieve operational excellence through reliability and asset management – you should be able to go to the tip of Mount Everest or Timbuktu if you need to. If you are seeking reliability solutions, then we encourage you to test the enlightened nature of your management, heck why not even invite your manager to attend (this conference is your best shot at getting him/her to a reliability event) – and book a ticket to RCM-2007/EAM-2007 today!

See for yourself why 90% of our past participants report taking back information that created immediate improvements in their organizations. For more program details, please visit

www.maintenanceconference.com

Hear case studies describing how leading companies are achieving operational excellence with reliability and enterprise asset management including:

- Agrium
- Holcim
- AGY
- Bavaria Brewery
- Lone Star Steel
- Catalyst Paper
- Ternium Centro
- US Postal Service
- Barrick Goldstrike
- Cargill
- Chevron
- Nucor Steel
- USS POSCO
- WCI Steel
- DuPont
- US Navy
- US Army
- US Air Force
- Newmont Mining
- Century Aluminum
- Koch Mineral Service
- Pearl Harbor Naval Shipyard
- East Bay Municipal Utility
- Arnold Engineering Development Center
- Much more...

NFPA 70E & Infrared Thermography

Staying Alive is a Good Thing

by Terrence O'Hanlon, CMRP

Right off the bat, I would like to state that I am not an expert at either Infrared Thermography or NFPA 70E. I am, however, an expert at eating, drinking and breathing – in other words – living. That is what I am writing about here now– of living – a long and healthy life as an infrared (IR) thermographer.

I was deeply impacted after viewing an Arc Flash DVD featuring Lowrey Eads, a retired safety and infrared expert from DuPont. Face it…as maintenance professionals we work in some very hazardous environments.

In our litigious society, it is clear that the value of your life has already been determined, at least on a monetary basis. Your life is worth between $450,000 - $1,000,000, plus whatever amount your attorney can get for pain and suffering. Not an amount I would consider trading my life for – so my living strategy includes reducing risk and unsafe behavior.

We promote the same strategy for all of our family, friends, the people who visit Reliabilityweb.com and those who read Uptime Magazine.

NFPA 70E is a standard for safe electrical work practices produced by the National Fire Protection Association.

What are Infrared Thermographers doing about NFPA 70E?

That is what we wanted to know. We have heard stories of PPE gear being too bulky, or too hot and too restrictive (See Figure 1). We have heard of one day infrared inspections turning into three day affairs as a result of meeting safety requirements. We also heard stories of contract infrared thermographers who follow NFPA 70E, but were conducting inspections at companies that have not completed an Arc Flash study nor have the required updated drawings.

One of our goals was to find out who is responsible for NFPA 70E compliance. I reached out to Greg Stockton of Stockton Infrared Thermographic Services, Inc. (and more recently ConnectIR™, the e-Bay of electrical infrared service jobs), to discuss this issue and develop an on-line survey that would shed some light on the issues, which would give us an idea of what percentage of users, thermographers and managers understand NFPA 70E and its ramifications.

The Results of the Reliabilityweb.com Survey on NFPA 70E

Reliabilityweb.com is an on-line community of over 50,000 maintenance and reliability professionals. Most members have some connection with infrared, either through direct employees who are in-house thermographers (50%) or by contracting inspections through professional thermographers (46%) or insurance companies

Figure 1 - Infrared thermographer wearing PPE

(4%). Most thermographers were certified to either Level 1 (43%) or Level 2 (42%). 161 companies of different sizes and activities participated in the study, providing data that we think is representative of the behaviors in the real world.

Only 22% of the study participants currently use infrared windows or viewports. However many expressed a great deal of interest. (We did not ask how many use or plan to use continuous temperature or infrared sensors.) IR windows and viewports seem to be a great solution in the current context of safe infrared inspections, but there seems to be a wide misunderstanding of these devices and how/where they apply. Confusing matters further is that there are no published standards for their installation or use…but we will save that for a future study.

There does seem to be a broad awareness, if not understanding, of NFPA 70E as 86% of the thermographers surveyed said that they were aware of it. Only 70% said that NFPA 70E had created new "policies" for their inspections – which either means they were already in compliance (doubtful) or their awareness of the standard has not caused a change in behavior (probable). Only 47% perform work at a facility where a formal Arc Flash survey has been performed. This indicates that the majority of companies do not comply with NFPA 70E because:

As it stands now, in order to perform a proper electrical IR survey, one must...

1) Open live electrical panels.

   In order to open a live electrical panel, one must...

2) Be in compliance with NFPA 70E.

   In order be in compliance with NFPA 70E, one must...

3) Wear the proper PPE.

   In order to wear the proper PPE, one must…

4) See a label on the panel stating the Arc Flash rating.

   In order to see a label on the panel stating the Arc Flash rating, one must…

5) Have an Arc Flash survey,

   In order to have an Arc Flash survey, one must…

6) Have updated line drawings of the electrical switchgear.

   In order to have updated line drawings of the electrical switchgear, one must…

7) Have conducted an engineering study to assess the electrical switchgear and loading.

The survey told us much about the low level of knowledge and compliance. So, when we asked the question "Are you in compliance with NFPA 70E" and they answered yes, but later stated that they had not conducted an Arc Flash survey, we knew that they did not understand NFPA 70E and were not in compliance. Several study participants indicated the need for infrared thermographers to be better represented or have a stronger voice in revisions to NFPA 70E as they feel no other group is as exposed to the affects of the standard than thermographers. Actually, IR is a small part of the overall electrical maintenance industry and an even smaller part of the larger "safety in the workplace" issue.

Questions to ask yourself if you work in electrical infrared:

1) Has an ARC Flash survey been performed by a qualified surveyor?
2) Does management enforce PPE requirements, even when a production line is down?
3) Has the time required to perform a survey with PPE been increased to compensate?
4) Has everyone been trained on NFPA 70E?

Who is responsible for NFPA 70E compliance?

The asset owner is responsible. So is the insurer, the independent infrared thermographer, the operations manager, the risk manager and plant manager. In fact, EVERYONE is responsible for safety in the workplace. It is imperative that you understand NFPA 70E and you ensure the environments that you work in are as safe as possible. Shortcuts with safety are never a good idea. Do not cash in on the $450,000 - $1,000,000 as you will not be around to enjoy it!

Terrence O'Hanlon, CMRP is the Publisher of Reliabilityweb.com, Uptime Magazine and co-Publisher of Reliability® Magazine. He is a Certified Maintenance & Reliability Professional and is the Director of Strategic Alliances for the Society for Maintenance & Reliability Professionals (SMRP). Terry is also a member of the American Society of Mechanical Engineers, The Association of Facilities Engineers and the Society of Tribologists and Lubrication Engineers. Terry can be contacted at tohanlon@reliabilityweb.com



Figure 2 - Various inspections being conducted with the proper levels of PPE. Everyone is responsible for safety in the workplace.

All photos courtesy of Snell Infrared.

The Black Gold Mine

Oil Analysis A Wealth of Information If Mined Properly

by Jack Poley

The Oil Analysis industry has burgeoned over the last four decades, adapting information technology to its processes on a steady, ongoing basis; and with noteworthy success. However, many organizations do not attempt to document their savings with this long-established condition monitoring tool. In most cases, it seems intuitively obvious that savings are being garnered, even if not fully quantified. So, even if the results aren't fully documented, it is mostly 'right' to embark on an oil analysis program with the reasonable expectation that something 'good' will happen immediately, and continue to happen in the future.

Maximizing An Oil Analysis Program's Performance

It is also most likely that users of oil analysis are leaving money on the table by not availing themselves of all the information and savings potential to be had. Some of the reasons for this include:

Minimum Diligence on the Customer's Part – There's no way to prove this, but this author's opinion is that this is the number one reason why full program value is often unrealized. Many samples are submitted without sufficient information on the container label, or its accompanying information chit. Such missing information includes lube or component time/distance, feedback as to on-site observations such as noise, vibration, heat or smoke, failure to note unusually high makeup oil addition. Or unreported pertinent repairs, whether advised via the oil analysis service or not. Most egregiously, (even though the industry consistently distributes information on proper sampling procedures) a grossly non-representative sample may have been submitted.

Nevertheless… if you're responsible for the caretaking and sampling of equipment and you're not willing to ensure that quality samples and information are furnished to the analyzing facility and/or evaluator, the remainder of the points herein will be of no value to you.

Lack of Understanding in Terms of Expectations – Most laboratories providing oil analysis services do a workmanlike job of testing, evaluating, reporting and, in some cases, periodically furnishing sliced-and-diced test data summaries and comparisons under the general heading of 'management reports'. If that laboratory is in-house, so much the better because critical units can usually be more precisely targeted.

But how does the maintenance supervisor (or his financial manager) know that a near-maximum savings has been gleaned in terms of downtime avoidance, safe extension of lube life, spare parts inventory management or, simply, highest quality evaluation of the test data for best decision-making? Well, he/she likely doesn't. Unless one has a reasonably complex spreadsheet infused with meaningful information and events, including estimated financial impact, such omissions are never identified, and, therefore, never realized.

Lack of Motivation to Explore the Previous Bullet Item - Again, the notion that savings via oil analysis is intuitive often leads to program initiation while blunting any initiative to fully investigate such potential.

Lack of Personnel to Maximize Program Potential – Cost controls mean less people and more automation. Sometimes this is for the better, sometimes not. It is not reasonable to expect a maintenance manager, who is multi-tasking at several levels these days, to be able to thoroughly sift through all the test data from the program. Further there is no reason to anticipate that such expertise exists on site in the first place. This stems from the previous point that installing an oil analysis program is often accomplished with the audacious premise that it will 'manage itself' or 'the lab' will take care of things. In many cases, time and resources don't get assigned to the program in the needed amounts. The consequence? Money left on the table, many times far more than enough to pay for the program resources that were not allocated.

There are more points to list, but they are primarily subsets of the above. Addressing them will allow progressive-thinking maintenance and financial managers to pick all the low-hanging fruit, as well as most of the higher fruit, resulting in maximized programs. Here are some basic ideas:

- Establish the fact that the program is not only going to be implemented, but will also be implemented as a fully resourced tool in the maintenance management scheme, including financials.
- Demand good and timely sampling, testing, evaluation (data interpretation) and follow-up (feedback). If any of these breaks down, value is compromised
- Institute follow-up data analysis to calculate savings; this is always the primary metric for program effectiveness
- Provide your operations' proper share of the information and personnel needs to ensure that expectations from your side can be fully met. It's a two-way street.
- Don't assume the lab will 'handle' things, or that matters will settle themselves. Get the responsibilities, parameters, expectations and personnel assignments out on the table (into the Program document language). PUT IT IN WRITING!
- Hold all participants accountable for program performance. Programs need to be periodically reviewed and tweaked, or revamped, based on management's findings.
- Consider engaging a qualified consultant or company to guide this process, or even be on board to help manage the process, perhaps even the program itself.

Scope of the Oil Analysis Program

This can be straightforward, but many times important aspects are missing from the Program at the outset. It can't hurt to have an experienced advocate review this important parameter set.

Data Evaluation

Most recipients of oil analysis reports do not know the name of the person who evaluated the data for the component under review. Sometimes this person's name is printed on the report for callback consideration when the recipient has questions.

Still, this is tantamount to receiving a medical diagnosis without ever talking to, let alone meeting, the doctor diagnosing you. Not enough attention has been given to this critical aspect of oil analysis. Labs provide data and sometimes a serviceable comment, sometimes not. Most labs have limits set for test results; some perform trending, as well.

There is more to data analysis than limits and trending… and, there is the question of how limits and trending themselves are determined. There are ASTM and de facto (industry) standards for testing; but there are no standards for data evaluation. Sadly the label "Oil Analysis" has curtailed more emphasis on the latter.

Savings Documentation

We have the capability to mathematically sift through data in extremely sophisticated fashion. Availing this capability properly can result in an accurate assessment of the program savings, provided all pertinent parameters are considered, properly assessed and placed in the savings calculation scheme.

Data Interpretation and Commentary (Maintenance Advisories)

An oil analysis report consists of data and, perhaps, a comment. It is interesting to note that, for practically all commercial oil analysis programs, fees are based by the tests performed. The comment is thrown in as part of the package. Most labs will entertain calls that ask for report clarification and not charge for the time consumed or further opinion that may be offered. Comments are, in other words, 'free'. Sometimes, unfortunately, that's what they're worth. Other times, thoughtful and insightful comments are included (see Figure 1).

There are two primary aspects to data evaluation: Data Rating and Maintenance Advisories.

Sample Data - Diesel engine, copper-lead bearings

Iron	Chromium	Lead	Copper	Silicon	Sodium	Potassium
46	0	7	12	7	20	12
54	1	8	17	6	21	14
50	1	8	14	9	35	19
58	2	6	19	6	39	60
89	4	8	198	8	190	234

Example 1 - A comment with words, but says nothing

Copper is HIGH
Sodium is HIGH
Potassium is HIGH
Iron is MODERATE, but INCREASING

Example 2 - Comments that is informative and prioritized effectively

Recommend inspection for coolant leakage, beginning with the oil cooler

Sodium and Potassium are SEVERE; Likely source: coolant chemicals

Copper is HIGH; Likely source: oil cooler

Iron is MODERATE but INCREASING; Likely source, cylinder region wear from coolant contamination. Wear will likely decrease once repairs are effected

Flush engine after repairs; Resample at half interval to check repair efficacy

Figure 1 - Even though the data may be the same, varying levels of comments can be given by different labs or different technicians in the same lab.

Data Rating is the process of categorizing a test result as Normal, Notable, Abnormal, High and Severe (you can substitute other terms or numerical ratings, if preferred). For each test datum the data range for each of these ratings is typically expressed using standard statistical analysis. Aspects of Data

Rating that should be considered:

- At a minimum the component must be known (gear box, hydraulic, gas turbine).

  Even then, 'hydraulic' may not be sufficient because of the many different numbers of pump sub-types: gear, axial-radial, vanes, etc. Without this minimal knowledge no sensible evaluation can be rendered.

- Components should be identified by manufacturer and model where possible.

- Application (Plant, Off-Highway, On-Highway, Marine, Oil & Gas, etc.) should be separately considered. The same component will perform differently, thus yielding significantly different test results, from application to application.

- The population of results statistically analyzed has to be sufficient to render the statistics valid.

- Trending, especially beneath preset limits, is common in large numbers of situations; however, simple percent changes without any consideration for the test result's statistical ranking, can be an issue.

Cautionary Note about Trending

Using spectrometric metals analysis as an example, single-digit parts-per-million values will generally repeat at plus/minus 1ppm. A change in a value for 'x', from 2ppm to 3ppm for consecutive samples, represents a fifty percent increase, but the spectrometer, upon retesting another set of sample aliquots, might have actually provided values exactly reversed from those above, i.e., 3ppm and 2ppm, respectively. This pattern now represents a thirty-three percent decrease. As well, both values might be identical upon a third set of tests, resulting in 'no change'.

Such uncertainty is surely unacceptable and, moreover, would result in wrong conclusions as often as not. The solution is to have a variable percentage change trending algorithm that compensates for inherent data drift as well as the overall scale of the values under scrutiny.

- Normalization (allowance for lube and component time/distance) of data should ideally be performed; however, this is contingent upon consistent and valid time and distance information on every sample in the Normalization sequence, without which the process breaks down.

Maintenance Advisories are the really main purpose for submitting samples.

Data anomalies are indicators of potential problems within a given piece of machinery or its components. The end purpose of sampling, however, is not data, but an accurate assessment of the component's condition. A side goal may be to assess the suitability of the lubricant for continued use, but this still points to the need for an evaluation of the test results in terms of machinery condition, simply because machinery health equals increased cost savings. It is here that many oil analysis purveyors fall short.

When the conclusions are straightforward, or where only one conclusion is plausible, most facilities fare well in the evaluation process. But there are many complex data scenarios in which some labs either fail to deliver analysis or do so in a marginalized way. For instance, perhaps rating contaminant severity, then informing report recipients that “x is high” or “y is very low”, providing no suggestions as to the possible source, or the reason(s) for such findings, let alone what reasonable action might be taken to further investigate or to mitigate the situation. (See example 1 in Figure 1.)

Most oil analysis users are neither schooled nor particularly skilled at data evaluation in terms of translating it to practical action on the shop floor. That’s perfectly fine as long as the user knows where to go to get more detailed analysis. Complex data scenarios represent the crux of maximizing value from oil analysis programs because such scenarios often represent situations where maximum exposure and risk are occurring. They are also the scenarios that are most highly exposed in the evaluation process, in terms of an optimal evaluation.

It isn’t reasonable to expect that one person, or even a group of highly trained and experienced personnel, would be able to assess every possible scenario that might develop for each sample analyzed; yet this is what is ultimately being asked by the simple submission of an oil sample to a laboratory. Intelligent software, as might be expected nowadays, is a big part of the solution to this conundrum, but it must be such that it can ‘learn’ and grow, handling increasingly complex data patterns as such patterns arise. While some facilities possess software programs with ‘expertise’, these programs are usually fed by the knowledge of a single individual, or a small group at best. This works well when situations repeat themselves, but poses issues when new patterns emerge. With as many as eighty variables in a test package suite, one is assured that new patterns will continually crop up, and need to be assessed and deciphered.

New capabilities originally developed for the national intelligence community have been applied to the oil analysis problem. Intelligent analysis agents used are based on associative memories that use a proprietary analytical engine. First envisioned in the late 1940’s (oddly coincidental with the birth of “Oil Analysis”), associative memories provide machine learning and pattern recognition functions that are analogous to human capabilities, but more consistent. Associative memories “learn” by storing data – and the relationships between data elements – in a compressed format that facilitates pattern recognition. Unlike older technologies such as neural nets, associative memories are designed to handle extremely large data sets. This, in turn, allows the power of pattern recognition to be wielded to full effect.

The complexity and potential of oil analysis demands more than just a “computerized approach”. The combination of a sophisticated system for data rating, coupled with expert system and associative memory applications, provides a new echelon of incisiveness and dependability in the evaluation of oil analysis test data. Vibration results and other Condition Monitoring data can also be integrated, where appropriate.

Provided the oil analysis user does his/her part to supply good samples and necessary information, and inject the willingness and resources to properly support the oil analysis program, the collected data can be fully mined to yield reliable after-test management reports that include savings, isolation of poorly performing components, lube and filter evaluations, spares inventories; and on-and-on. When properly implemented oil analysis programs are, indeed, a black gold mine of savings.

Jack Poley is founder and Managing Partner of CMI (Condition Monitoring International), a condition monitoring consulting and products company, and is a 47-year veteran of the Oil Analysis industry, having managed several commercial entities, and having founded Lubricon, a commercial oil analysis firm acquired by Cummins Engine Co. in1988. He can be contacted at jpoley@cmiglobal.biz; telephone 305.669.5181.

Keeping Up Resistance

Electric Motor Insulation to Ground Testing

by Howard W. Penrose, PhD, CMRP

So far, in this series of articles for Uptime, we have covered Volt meters, Ammeters and Resistance testing. This month, we are going to discuss insulation to ground testing using an insulation tester commonly called a 'Megger®.' The insulation to ground tester, or Meg-Ohm meter, is also one of the earliest instruments used by technicians in evaluating and troubleshooting insulation systems, including electric motor insulation systems. In this article, we will concentrate on the testing method as outlined in IEEE Standard 43-2000 (R2006), "The Recommended Practice for Testing Insulation Resistance of Rotating Machinery," (IEEE 43) and a few additional methods for evaluating findings, we will also refer to the testing method as Insulation Resistance (IR) testing.

The standard that we generally reference within industry is the IEEE 43, which went through a major revision in May, 2000. It was updated because post 1970 insulation systems went through a series of changes in their chemical makeup. Newer insulation systems are very different from the older systems, including how they react through testing methodologies. The revised standard drastically changed a number of traditional testing programs for insulation resistance that had been in place for over 50 years, including the Polarization Index (PI), insulation to ground tests and AC vs DC testing of insulation systems.

The purpose of the IR reading is to evaluate the condition of the insulation between the conductors in the stator slots and ground. This is done by applying a direct voltage between the conductors (windings) and the casing of the electric motor (machine) and measuring current leakage across the insulation system. The measurement of current and voltage, applied, provide a finding measured as resistance (Ohm's Law: R = V/I). In the case of an insulation system, the leakage current may be measured in milli- or micro-Amps, with the lower the current reading, the higher the insulation resistance value. These IR readings change over time because of 'insulation polarization.' In effect, the insulation system consists of polarized atoms that 'line up,' or polarize, with the applied DC voltage. As they polarize, the insulation resistance will increase.

The Basic Insulation Resistance Test

Straight insulation resistance testing has been used to troubleshoot and evaluate the condition of machines for over a century, often with disastrous results, in the hands of an inexperienced user. There are very clear limitations on the ability of insulation resistance testing, alone, to evaluate the condition of an electric motor for operation. For one thing, there has to be a clear path between the insulation system and the casing of the machine. Air, mica, or any other non-conducting material between the winding and ground will provide a high insulation resistance. Faults on the end-turns of motor windings will also not provide a clear path to ground, with most winding faults starting as internal winding shorts that might graduate to insulation faults. So, care must be taken when using IR as a troubleshooting tool.

In performing IR, the proper method is to connect all leads together, test with the IR meter for a period of one minute, ensuring that the red test lead (negative) is on the leads and the black lead is on the housing. Once the IR measurement is obtained, it is then adjusted for temperature while the leads are grounded for four, or more, minutes. The values for IR applied voltage and minimum test values can be found in Tables 1 and 2.

Winding Voltage	IR DC Voltage Applied
<1000	500
1001 – 2500	500-1000
2501 – 5000	1000-2500
5001 – 12000	2500-5000
>12001	5000-10000

Table 1 - Insulation Resistance Test Voltage

There are a few things that have to be considered when performing insulation resistance from a Motor Control Center (MCC) or disconnect that is some distance from the motor under test. For one thing, if you tie all of the cable leads together and test, because of the surface area under test, it is possible that the readings may be only a few MegOhms. This does not necessarily mean

Min Insulation Resistance at 1 Min	Winding Being Tested
kV + 1MegOhms	Most windings made before 1970
100 MegOhms	Form wound stators after 1970
5 MegOhms	Random wound stators under 1,000 Volts after 1970

Table 2 - Insulation Resistance Minimum Values

that the system is bad, and a few tricks can be used to evaluate the condition of the cable. Additionally, any capacitors or lightning arrestors should be disconnected from the circuit and variable frequency drives or amplifiers must be disconnected from the motor.

First, take each conductor and test between the conductor and ground. If the reading is greater by an order of magnitude then chances are that no problem exists. Next, disconnect the other end of the cable and separate the conductors from each other and ground. At the other end, perform the insulation resistance test between conductors. If the readings are above the minimum, then the insulation resistance of the cable is OK (however, it does not definitively clear the cable of any potential faults).

The same process can be used on some motors, with the exception of a phase to phase test, unless the internal connections of the motor can be broken, such as in a wye-delta motor or all twelve leads are brought out of the machine. If the phases can be separated, then an insulation resistance measurement can be taken between phases. The results should be above the minimum values shown in Table 2.

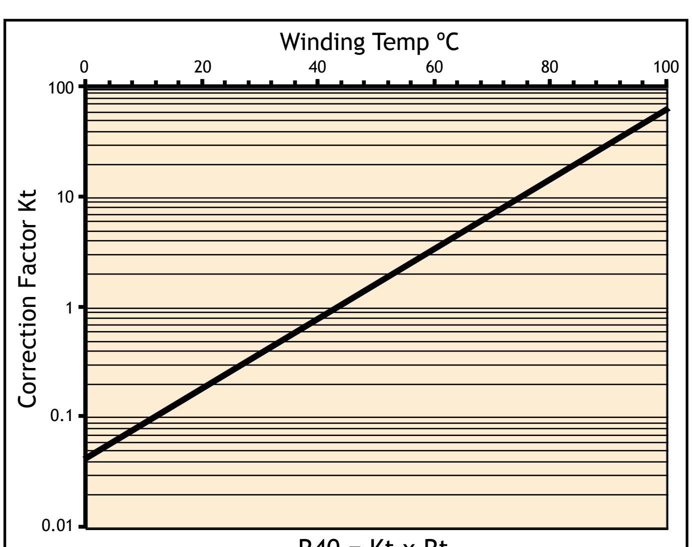


Figure 1 - Insulation Resistance Temperature Correction

During these tests, if you are using an analog IR meter, if the needle is not steady, or the digits 'dance' around in a digital IR meter, then there is the strong possibility that moisture or contaminants have gotten into the windings. The bouncing is the result of 'capacitive discharge,' or the build up of the DC energy within the winding that suddenly discharges and then starts to re-charge.

Figure 1 represents the insulation resistance temperature correction chart for correcting to 40°C. Using this chart, if the winding temperature is 60°C and the insulation resistance was 200 MegOhms, the correction factor (Kt) would be '4,' and the result would be 4 times 200 MegOhms which would be a corrected insulation resistance of 800 MegOhms.

Dielectric Absorption

The dielectric absorption test, or 'DA,' is a ratio of the sixty second IR reading to the 30 second IR reading. As shown in Figure 2, the value at position A is divided by the value at position B. In a good insulation system, the IR will increase as a curve which will start fairly steep then will plateau, depending upon how fast the insulation system polarizes. Pass/Fail criteria can be found in Table 3. However, in insulation systems manufactured after 1970, it is not uncommon for insulation systems to polarize rapidly and insulation systems with a temperature corrected one minute reading greater than 5,000 MegOhms may show a low value. In these instances, the test results should be used for trending only, and in the new IEEE 43, the test results must be corrected for temperature.

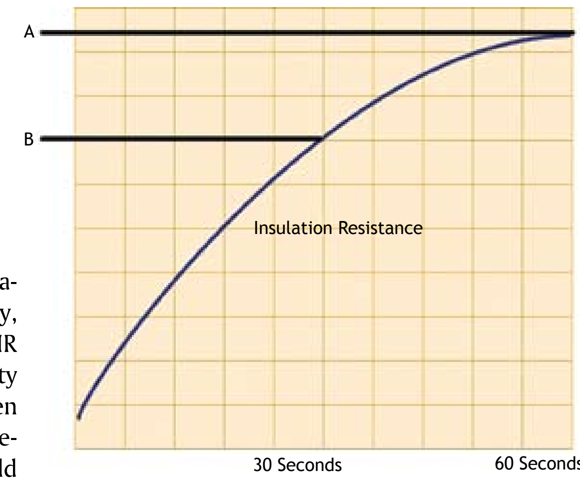


Figure 2- Dialectric Absorption

Insulation Condition	Dialectric Absorption Ratio
Dangerous	< 1
Questionable	1.0 - 1.4
Good	1.4 - 1.6
Excellent	> 1.6

Table 3 - Dialectic Absorption Chart

Polarization Index

The Polarization Index, or PI, is the ratio of the 10 minute to 1 minute insulation resistance test. As shown in Figure 3 (pg 26), the result is the value at position A divided by position B. In a good insulation system, the IR will increase as a curve which will start fairly steep then will plateau, depending upon how fast the insulation system polarizes. Pass/Fail criteria can be found in Table 4. However, in insulation systems manufactured after 1970, it is not uncommon for insulation systems to polarize rapidly and insulation systems with a temperature corrected one minute reading greater than 5,000 MegOhms may show a low value. In these instances, the test results should be used for trending only, and in the new IEEE 43, the test results must be corrected for temperature.

Using the PI, the user should watch the needle if the meter is analog. If the needle bounces as it increases, then it represents capacitive discharge and an impending insulation problem such as contamination. If the meter graphs the PI as a chart, the user should review the data

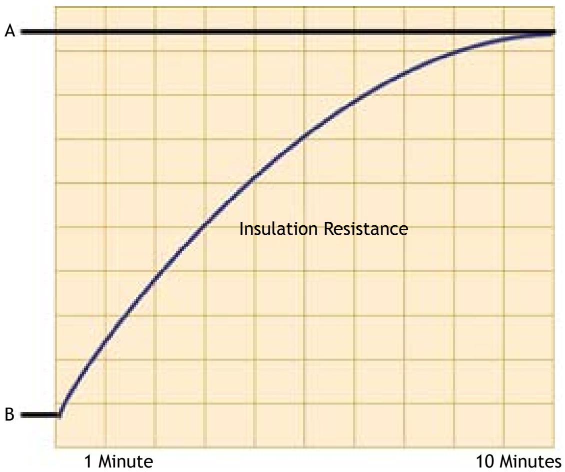


Figure 3- Polarization Index

Insulation Condition	Polarization Index
Dangerous	< 1
Questionable	1.0 - 2.0
Good	2.0 - 4.0
Excellent	> 4.0

Table 4 - Polarization Index Chart

to see if there are any downward spikes or the graph shows a decreasing value across the ten minutes. This would also indicate insulation resistance defects.

Conclusion

A common method for evaluating the condition of electric motors is insulation resistance testing. The most common methods of IR testing are outlined in the IEEE Standard 43-2000 (R2006) and include the 60 second test, the dielectric absorption and the polarization index test. Each of these tests are used to evaluate only the portion of the insulation system between the motor winding and the frame of the electric motor.

In post 1970 machines, insulation systems tend to polarize rapidly and systems with values over 5,000 MegOhms should only be trended when using DA and PI. However, the insulation charging can be viewed to see if capacitive discharges, which indicate winding contamination or insulation degradation, are occurring. However, the insulation resistance test is a powerful tool when used in conjunction with other testing methods.

Howard W. Penrose, Ph.D., CMRP, is the President of SUCCESS by DESIGN, a reliability and maintenance services consultant and publisher. He has over 20 years in the reliability and maintenance industry with experience from the shop floor to academia and manufacturing to military. Dr. Penrose is a past Chair of the Chicago Section of the Institute of Electrical and Electronic Engineers, Inc. and is presently the Founding Executive Director of the Institute of Electrical Motor Diagnostics. For more information, or questions, related to this article or SUCCESS by DESIGN services, please contact Dr. Penrose at howard@motordoc.net.

Field Balancing Revealed

Sometimes it's Simply a Game of Chance

by Victor Wowk, P.E.

As I teach balancing seminars, I notice one common problem that balancers with some experience have. The problem is, and I quote, "balancing doesn't always work." A more accurate description of their grievance is that the results are variable. There may be a partial improvement, but insufficient to be acceptable. In extreme cases, there is no convergence to a smooth-running machine, and the vibration at operating speed becomes worse with each weight placement. If this sounds familiar, read on. There are valid reasons for variable balance results which have nothing to do with faulty instruments or inexperience. The reasons can be classified into two broad categories:

1. The Physical System
2. Chosen Methods

I will assume, for the remainder of this discussion, that the balancing instruments are functioning well, and the balancer is following procedures properly.

The Physical System

Shop balancing on a balancing machine usually has more consistent results. This is because it is a much more controlled situation. The rotor alone produces the measured motion, unmodified by the surrounding structure (i.e., housing and bearing supports), and the response of the balancing machine to unbalances on the rotor are known and calibrated. These stable and known conditions do not exist in field balancing, where each rotating machine is a different configuration, with different bearings, different support stiffness, and perhaps, some pre-existing defects in the rest of the machine. These pre-existing defects could be any number of the following:

- Worn bearing
- Bent shaft, or some other distortion
- Looseness
- Misalignment
- Eccentricity
- Reciprocating forces
- Resonance
- Instability

Worn rolling-element bearings are characterized by unstable amplitude and phase readings, because the bearings cannot repeat the shaft position each rotation. In addition, the bearings will be noisy. Gross unbalances can be corrected to some extent, but we cannot balance any finer than the precision in the bearings. A lift test with a dial indicator can measure the radial clearance and gauge the amount of wear. The way to deal with worn bearings is to advise the machine owner, letting him/her decide how to proceed, which could be:

1. Do the best you can today.
2. Replace the bearings and call you back when ready to continue balancing.
3. Ask you to replace the bearings.

Be advised that the 1x-rpm amplitude and phase can also wander if the inner ring has non-uniform thickness, the outer ring rotates in the housing, or a nearby machine at close to the same speed contributes some vibratory energy.

A bent shaft looks just like an unbalance with a high 1x-rpm amplitude of vibration. Unfortunately, this condition usually cannot be corrected by weights. It can be corrected if weights are placed in the axial plane where the bend is the largest. This usually requires an unusually large correction weight and it works well only at a single speed. The way to deal with a bent shaft is first to recognize that balancing is not producing good results fast enough. Then stop the machine and measure the shaft runout with a dial indicator at several places. Acceptable runout is less than 0.001 inch total indicator reading (T.I.R.). When a bent shaft is confirmed, then advise the owner so they can order a new shaft. In the meantime, the bent shaft will beat up the bearings.

Looseness is assumed to be nonexistent at the start of the balancing procedures. Everything should be tight that is supposed to be tight. If not, get out the wrenches. Looseness will manifest itself as high amplitude vibration at ½ rpm, 1x rpm, 1½ rpm, 2x rpm, 2½ rpm, etc. It is a string of harmonics and half harmonics that is easily discernible with a spectrum analyzer. Misalignment of shafts creates a string of harmonics, in addition to some component amplitude at 1x rpm.

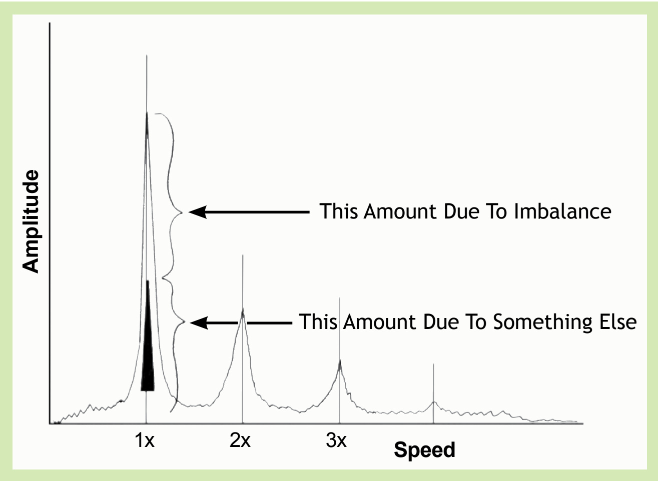


Figure 1 - All vector balancing algorithms assume that the full amplitude of the 1x-rpm vibration is due to unbalance and nothing else. The full amplitude is used in calculations.

This component due to misalignment cannot be removed by mass balancing, but even worse, it will make the 1x-rpm amplitude measurement inaccurate. This will make the calculation of the balancing weights incorrect because the input readings are wrong. We are off to a bad start, and it gets worse from there. The only way to verify good shaft alignment is to swing a set of readings with a fixture attached to the shafts. If balancing is not working well, and the shaft alignment is questionable, then the proper thing to do is to stop the futile balancing, align the shafts, then proceed with balancing afterwards.

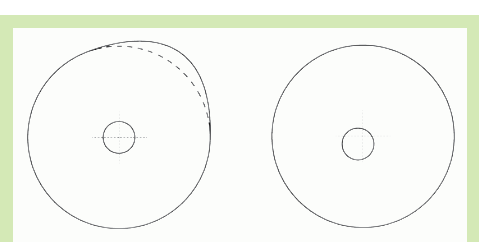


Figure 2 - Electronic Pulleys

Eccentric pulleys, gears, sprockets, and wheels will produce a strong 1x-rpm pulse every time torque is transmitted over the high spot. This looks just like unbalance, but has no hope of correction with weights. This again, is best diagnosed with dial indicators and corrected by replacing the defective part. For the balancer, his/her responsibility ends when this condition is recognized and reported to the machine owner. We should stop burning up balancing dollars as soon as we smell the smoke.

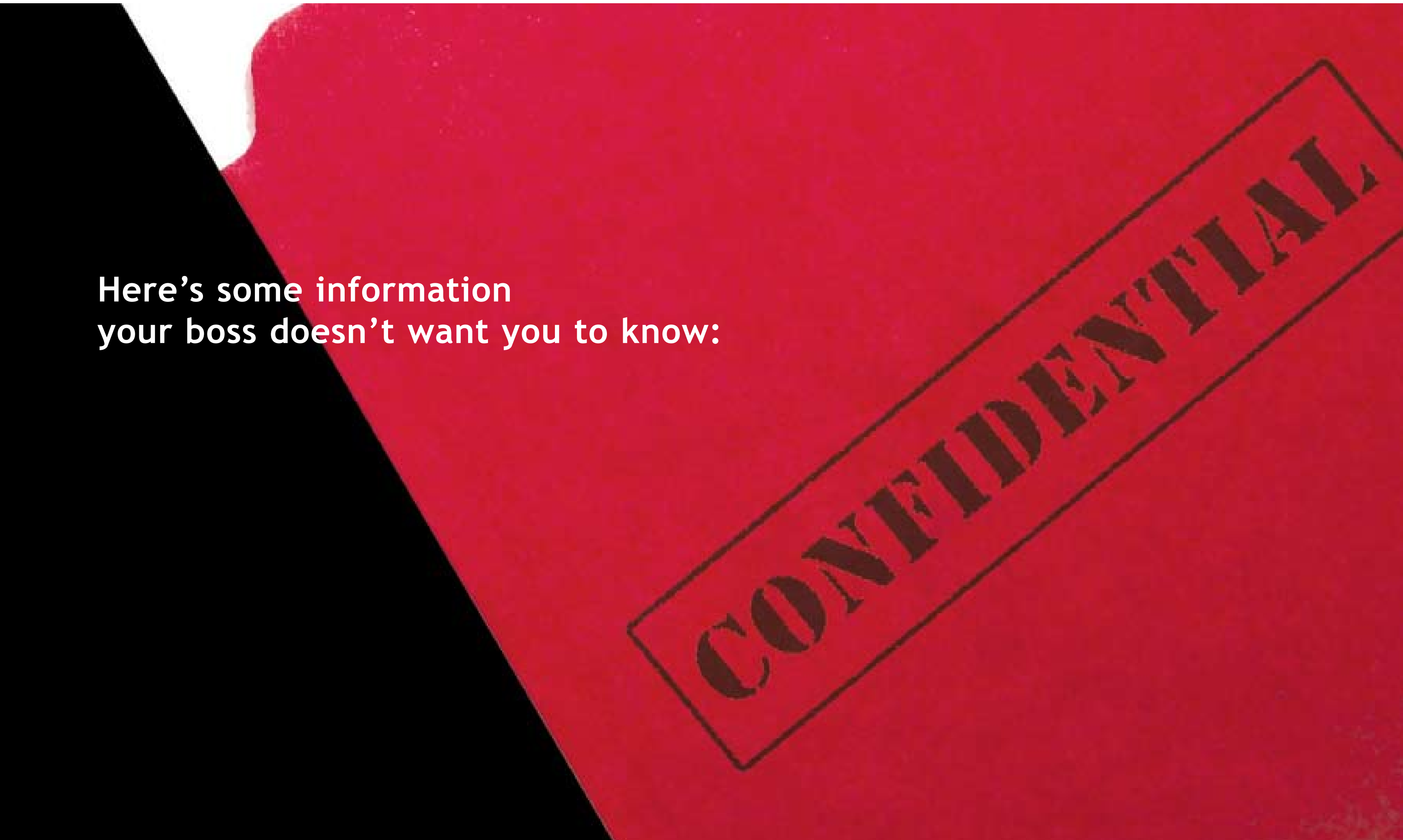
All reciprocating machines produce a strong pulse at 1x rpm from gas pressure forces, that can only be partially compensated by crankshaft balance weights. Even so, multi-cylinder reciprocating machines (engines, compressors, and pumps) can be mass balanced to less than 1.0-mil peak-to-peak amplitude if no other operational defects exist, like poor fuel flow, sticky valves, incomplete combustion, or leaking rings. Since reciprocating machines do not always maintain a constant speed, a tracking filter must be used to acquire valid phase data, or use the no-phase balancing method.

Resonance is a dynamic structural weakness that really confounds the balancing task for two reasons—the amplitude response is nonlinear and the phase response is highly variable near a natural frequency. It is a structural defect and the appropriate fix is to modify the structure. Any nearby part can be resonating—the rotor itself (it is then called a critical speed), the bearing supports, a panel, the base or foundation, the housing, or an attached pipe. It is a cloaked defect that the balancer is unaware of until the balancing process goes amiss—it diverges with many weights all around the wheel with little improvement. The subject of resonance could consume an entire book itself, and how it affects balance could be a 50-page chapter. The fixes for resonance could be another book. For the balancer, it is important to recognize that resonance is speed sensitive, so one strategy is to pick another speed at which to balance. Another strategy is to use the 4-run method without phase, which is one of the few methods that works at or near a resonance. Another strategy is to stop the machine and do some impact testing to find the resonating part and stiffen it. Most balancing instruments can be used for this natural-frequency testing, if configured properly and a systematic test method is used. The important point is to recognize the creature, stop balancing as usual, and do something different.

Method	Instrument Requirements	Planes	Advantages	Disadvantages
Trial & Error	Minimum, None or Simple Filtered Amplitude	As many as Desired	Potential for Producing Fine Levels of Balance	Time Consuming
Four Run without Phase	Filtured Amplitude	One at a Time	Quickly Converges, Always Works, Simple Graphical Calculations	Requires Four Starts and Stops
Seven Run without Phase	Filtered Amplitude, Computer	Two	Compensates for Cross-effect, Quickly Converges	Requires Seven Starts and Stops
Single Plane	Filtered Amplitude plus Phase	One at a Time	Fast Balancing when it works, Best for Thin Disks, Applicable when Phase is Nearly the Same at Both Bearings, Graphical Calculations	Cannot Compensate for Cross-effect, Doesn't Work Well Near Resonances, Faulty Foundations, Instabilities, Non-linearities or when Other Root Cause Exists
Two Plane	Filtered Amplitude plus Phase, Computer	Two	Compensates for Cross-effect, Applicable when Phase is more than 30° Different at Both Bearings	Same Difficulties as Above for Single Plane when Phase is not Reliable, Requires Computer to Calculate Correction Weights
Static Couple	Filtered Amplitude plus Phase	Three	Graphical Calculations using Single-Plane Vectors, Useful when Three Planes are Available	Requires More Runs than Two-Plane Method on Rigid Rotors, Limited to 1st and 2nd Flexural Modes on Flexible Rotors
Modal	Filtered Amplitude plus Phase	As Many as Necessary	For Flexible Rotors	Requires Knowledge of Bending Modes
Multiplane Multispeed	Filtered Amplitude plus Phase, Computer	Many	For Flexible Rotors, No Previous Knowledge of Bending Modes Needed	Many Runs, It's a Mechanical Method - Physical Insight is Lost
Manufacturing Tolerance Control	Precision Metrology Tools	Many	Potentially Smoothest Machines, Can Make Field Balancing Unnecessary	Most Costly
Cleaning	None	All	Fast, Cheap	None - A Cleaning is Always Recommended for a Dirty Rotor

Table 1 - Pros and Cons of Balancing Methods

Instability is almost as elusive as resonance, and like resonance, makes for a bad balancing day. It displays itself as a step change in vibration. The machine could be balanced down to 1.5 mils, then abruptly jump up to 7.5 mils as you drive away. The instability could be a cracked foundation, a crowned bearing pedestal, or a thermal-induced expansion. The machine has two stable conditions that it can flip-flop between, usually against some physical stops, and insufficient friction to hold it in any intermediate position. The only solution is to find the defect and fix it. One clue though; it usually has something to do with the bearings, and



a bearing inspection, or bearing replacement may be in order.

Chosen Methods

There are ten known methods of mass balancing, listed in Table 1. Of those, the single-plane and two-plane influence coefficient methods are the ones that most all balancing instruments come pre-programmed with. Balancing classes focus on these two methods, which are actually only one method with different-size matrices in the calculation. The balancer is prompted at the start, on which subroutine to follow—single- or two-plane. The balancing world is really bigger and there are more choices, with others that work better than the influence coefficient method (I.C.M.).

The influence coefficient method is flawed in several respects when applied to field-balance situations. It works best on a balancing machine with soft supports, a rigid rotor, and at slow speeds, i.e., less than 1,000 rpm. In the field, with a machine in its own bearings and powered by a driver machine, on a foundation and support system of unknown response, and at high speed, anything goes. The first flaw with the influence coefficient method is that it assumes linearity, for both amplitude and phase response. This is implied by the matrix calculation and is a required precondition for the math to produce a valid correction weight. We know that the world is not linear near natural frequencies, and phase response goes wild. There can also be subtle situations with a hardening or softening bearing support system that make the system respond in a non-linear manner. There is no big flashing neon sign on the machine that says, "Balancers beware of non-linear dog." What to do about this? Leave the balance weights on that made an improvement and start over with new original data.

The second major flaw with the influence coefficient method is that it is sensitive to the test-weight location. It shouldn't be, theoretically, but it is (See Ref. 1). Placing the test weight is like placing a bet on a roulette wheel. Any place is just as good as any other, supposedly. It is a guess on where to place the test weight (without prior knowledge of the machine behavior), so you may as well satisfy your gambling urge at this balance step. You will come out richer in the end than if

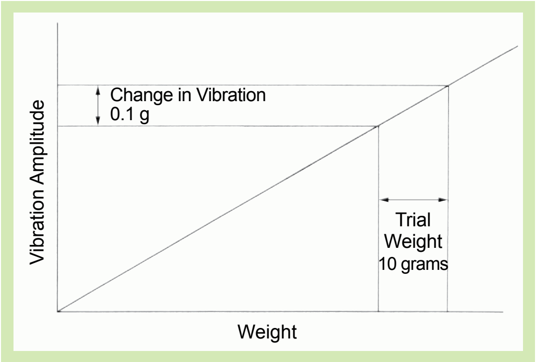


Figure 3 - Linear relationship between weight and vibration.

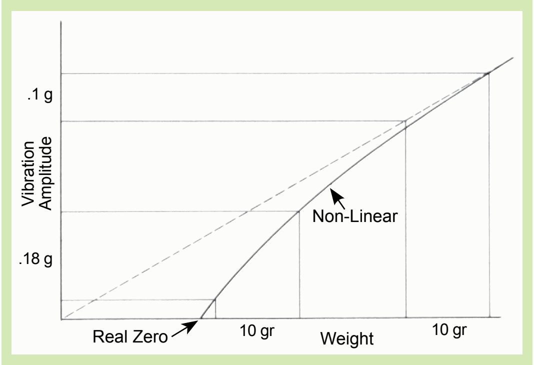


Figure 4 - Nonlinear relationship between weight and vibration.

you sought your satisfaction at a casino. If your bet was a bad one, you can always remove it, put it somewhere else, and spin the wheel again, with the loss of only a little time.

The third major flaw with the influence coefficient method is that it requires expensive phase-measurement instruments and a computer to do the matrix math. Single-plane calculations can still be done with vector graphs, but few people are still alive that can do two-plane vector calculations on graph paper. Who would want to anyway, when laptops and programmable calculators do it so easily? The main point here is that all of these instruments must be properly connected, configured, and working as intended. The balancing process moves to the inside of an electronic box, and the balancer loses "touch" with what is happening. He/she is flying (balancing) on instruments and their heads are in the clouds. The vibration measuring instrument will take the readings, good or bad, and the computer will spit out a correction-weight calculation based on the input data. Whether it is a good weight that reduces vibration depends on the input data, various assumptions made earlier, and the condition of the matrix. An ill-conditioned matrix is more likely in field balancing with non-linearities, than on a balancing machine in the shop.

What to do about this? There are eight other methods of balancing. Give another method a try. In my business we are quick to abandon the influence coefficient method if it does not produce at least 50-percent reduction in vibration with the first correction weight. In fact, my balancers prefer to just start with the 4-run method without phase on all balance jobs, and transition to the 2-plane influence coefficient method if it looks like there is a strong couple unbalance with cross-effect. The reason, we have found from experience, is that the 4-run method without phase works consistently more often than any other method in the field, besides cleaning. If any reduction in vibration can be had with weight placement, the 4-run method will find it.

An added benefit with the 4-run method is that it requires minimal instrumentation—just a filtered amplitude reading (no phase required). In fact, in the classroom in Dallas, students have balanced very successfully with an AC voltmeter and a velocity sensor. A student pulled out a multi meter from his tool bag, we made up a quick cable to connect an IRD 544 velocity sensor, and with the 4-run method, he had the machine balanced down just as well as an IRD 245, and just as fast. Granted, this is an overall AC RMS voltage, not a filtered reading at 1x rpm, but the method works.

So why don't balancing courses taught by instrument manufacturers show these simple methods with simple instruments? The answer is obvious. You would not purchase their expensive instruments with phase measurements that do the influence coefficient calculations. We have those expensive instruments, and use them when necessary, which is about 15-percent of the time. The remaining 85-percent of balance jobs can be done single plane. In the field, the 4-run method without phase has the highest success rate.

A common problem in all balancing is not knowing, in advance, where to place weights along the axial length of the machine. This is illustrated in Fig 5. It would be nice to have an imaging system, like a mass density camera (which does not exist), that we could view the rotating assembly with and see the location of the imaginary heavy spot. Then, at least, we could place the test weight in the correct axial plane. As it stands, we usually place the test weight where it is most convenient to place it. This, then, also defines the correction plane (unless I do plane transposition, which is never done in field work). If it was a good day, and the test weight was not too far away from the heavy-spot plane, then balancing should work O.K. If my test weight missed the heavy-spot plane by a significant amount, then the test weight and heavy spot create a couple unbalance. This would require two-plane balancing to fix on a rigid rotor. On a flexible rotor, the world gets considerably more complicated. The point with this discussion is that we have no way of knowing where the true heavy spot is on a long rotor. We can guess, based on what we see, that it is probably in a plane that has more mass, but if there are several mass-loaded planes, then which one? After balancing is complete, and it being successful, then we can look at the correction weights and see where they are distributed to come up with an "after the fact" estimate of the heavy-spot plane. The problem with all balancing is that we are not entitled to this knowledge beforehand, and this could be a reason why balancing is not working.

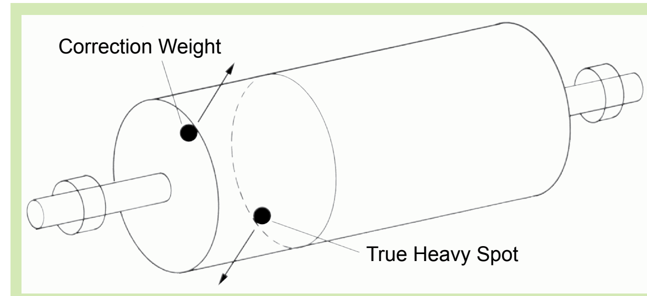


Figure 5 - A couple is created when the correction weight misses the plane of the true heavy spot.

So with all of these obstacles to field balancing, why do we even try? The answer is that it does work well more than 50-percent of the time. Balancing is a joy for me because it provides immediate job satisfaction. I enjoy balancing more than any other process in correcting vibration on machines. It takes me to interesting places. This article is intended to provide you with knowledge to handle those occasional troublemakers. Keep an array of balance methods in your toolbox and pick an appropriate method based on what you observe. Don't be afraid to admit failure with one initial method, abandon it, and proceed on with another approach. We sometimes need to switch 2 or 3 times until we find a method that works on that day, on that machine.

Victor Wowk, P.E. is the president of Machine Dynamics, Inc., based in Albuquerque. He is the author of Machine Vibration: Balancing, published in 1995 by McGraw-Hill. He teaches a two-day balancing seminar in March every year in Phoenix. Schedules are posted at www.machinedyn.com.

Ref. 1 "What's Wrong With My Balancing Instrument?" by Victor Wowk, P/PM Technology, August 1997

Ref. 2 "A Management Guild to Balancing," by Victor Wowk, Maintenance Technology, June 1998

Ref. 3 "The Trouble With Balancing," by Victor Wowk, Energy Tech, June 2005 (Part 1) and August 2005 (Part 2)

RTF - Just Don't Do It

Run-to-Failure a Company Killing Maintenance Strategy

by Jim Hall

Recently, I toured a plant in which the technicians did not even have a "multi-meter". No infrared pyrometer, no vibration pencil, not even a doctor's stethoscope. All they had was a bunch of drawers full of wrenches. This is a classic example of "Run-To-Failure", or RTF, maintenance. There, when a motor fails it is simply replaced. This particular plant has several motors on the assembly line that can be replaced at a relatively low-cost and in a short time. These motors have "sealed for life" bearings installed (no greasing required). No vibration readings, no infrared inspection and no ultrasound inspections are performed. This plant is the exception to the rule, because most plants practicing RTF have at least some sort of inspections, whether they be visual, lubrication, alignment adjustments, etc.

True Run-to-Failure is straightforward. When a piece of equipment breaks, fix it or replace it. There is no attempt to predict or anticipate a failure. There is no attempt to realign a motor or adjust tolerances. Sealed for life bearings are preferred, and there is no vibration analysis, and no infrared or ultrasound survey performed. RTF is, without a doubt, the most costly form of maintenance you can employ.

A friend of mine is head of maintenance at an Atlanta, Georgia area plant that also follows a Run-To-Failure policy. But, this plant is not a "true" Run-to-Failure plant. This company periodically lubricates the bearings, visually inspects the motors, gear boxes and annually has an outside vendor provide an infrared inspection of motor control panels and other switchgear. Other than these rudimentary precautions, no other predictive or preventative maintenance is performed. He confided in me that his plant is barely meeting their production levels. Costs are through the roof for repairs and production line stoppage is at an all time high. He explained to me about the many resources that have to be available 24 hours a day - spare parts (motors & major parts), a labor force (on-site or on-call). This kind of reactive maintenance creates extensive downtime and loss of production.

You know the saying, "friends don't let friends drive drunk"? Well, friends don't let friends Run-to-Failure. Especially when a simple and relatively inexpensive tool, airborne ultrasound, can dramatically improve plant performance.

Figure 1 - Using the SDT 170 MD to trend bearing readings. Can store several routes and three readings per point.

For those plants that are practicing Run-to-Failure, airborne ultrasound can be the start to lowering costs and downtime. Many plants have started their PdM program with airborne ultrasound. Having sold ultrasound instruments for years, I would make it my business to ask the question, "What does your predictive maintenance program include?" Many times I heard, "we have no formal predictive maintenance program, we have no predictive maintenance equipment", or, "we outsource our vibration and infrared duties".

I have been known to use the term "Fortune 500 Companies" to describe the companies with enough money to buy equipment and train technicians to implement a predictive maintenance (PdM) program and everyone else as a run-to-failure company.

If your facility is not a true Run-to-Failure plant, that is, one that lubricates bearings periodically, one that performs some inspections, or if you work at a facility that would like to upgrade some of its run-to-failure methods, then airborne ultrasound is for you.

Versatile

Airborne ultrasound is the most versatile of the predictive technologies. Many people think of it primarily as a leak detector. Although an ultrasonic instrument can pay for itself by finding one large leak in a compressed air system, and go on to save thousands, tens of thousands even hundreds of thousands of dollars in utility bills over its useful life, calling it a leak detector simply doesn't do the technology justice. Try to listen to slow speed bearings with your vibration analyzer, try to find corona with your infrared camera, how about trying to hear that clicking sound of a bad gearbox among 5-6 other gearboxes with your own ears in a noisy environment. It just can't be done.

Don't get me wrong. The other technologies all have their strong points, and facilities would be wise to incorporate them all into their maintenance program because the cost savings from a well rounded PdM program can be staggering. But the sheer versatility of ultrasound makes it the ideal technology with which to start a predictive maintenance program.

Figure 2 - Ultrasound used on bearing on pumps and to locate cryogenic gas leaks of bottled gas and storage tank system.

Why Ultrasound?

Airborne ultrasound is the earliest indication of wear prior to a rise in temperature and/or before an increase in the low frequency or vibration levels. Ultrasound is:

- Lightweight
- Versatile
- Cost Effective
- Easy to understand & learn
- Works well in a noisy environment

Applications for which ultrasound can be used include:

- Bearing Wear
- Steam Trap Troubleshooting
- Acoustic Lubrication
- Leak Detection (pressure or vacuum)
- Electrical Scanning
- Switchgear
- Substations

Ultrasound should be the Alpha and Omega of your predictive maintenance program.

It should be the Alpha because you can use airborne ultrasound to build a predictive maintenance program. The skill sets learned when using airborne ultrasound will better equip your technicians as they move forward to other predictive maintenance programs.

It should be the Omega because the skills learned in using ultrasound can then be integrated with other technologies, such as using the airborne ultrasound interfaced with your vibration analyzer for waveform analysis. Or, interface the technology with your infrared imaging program. Ultrasound can hear corona under 240 kV, whereas infrared cannot.

If you are at a plant operating in a Run-to-Failure mode you should, at the very least, have an airborne ultrasound instrument on every shift to perform routine scanning and inspections of your equipment.

One maintenance supervisor told me that while they have mechanics and technicians, none are formerly trained in predictive or preventative maintenance. That situation is quite common in facilities. The beauty of ultrasound is that it has a very small learning curve. Within just a few days someone can become a user, within a few months, a journeyman level (Level I) can be achieved and after a year or two, the technology (Level II) can be mastered.

Very few companies that practice RTF are true Run-To-Failure plants. However, as one article I read recently mentioned, "Traditional mainte-

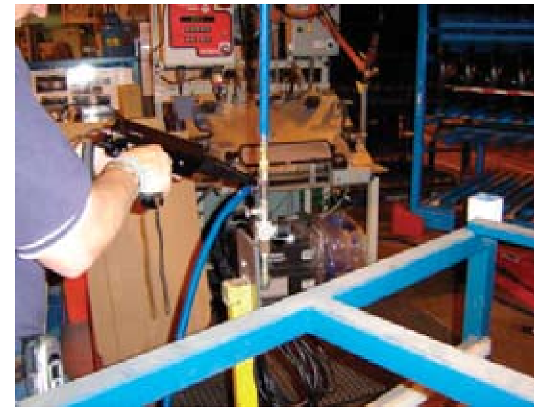


Figure 3 - Using an Ultraprobe 2000™ to locate air leaks in compressed air supply system.

nance costs (i.e. labor and material) in the U. S. have escalated at a tremendous rate over the past 10 years. In 1981, domestic plants spent more than $600 billion to maintain their critical plant systems. By 1991, the costs had increased to more than $800 billion and topped $1.2 trillion in 2000. These evaluations indicate that between one third and one half of these maintenance dollars are wasted through ineffective maintenance management methods. American industry can no longer absorb this incredible level of inefficiency and hope to compete in the world market".[1]

And, in fact, they haven't. There have been far too many plant closings in the U.S. since 2000. So how can any plant today justify a Run-to-Failure mode of maintenance? The answer is that they can't.

The good news about airborne ultrasound is that it's the best Return-On-Investment (ROI) that a small company or any company that currently practices any form of RTF could possibly have.

Implementing an ultrasound program for bearings is as simple as taking a comparison of similar motors and comparing the decibel levels. A baseline reading is best to have but if one cannot be established, use the lowest reading as the baseline. Comparing drive-end to drive-end, etc. and non-drive end to non-drive end. Consult your manufacturer's handbook

Figure 4 - Using a CSi Sonic Scan 7000™ on this motor, both an ultrasonic bearing reading and a temperature reading were taken for trending purposes.

Photos Courtesy of Pete Marquardt of Predictive Maintenance & Consulting

or manual as to what readings are considered incipient wear, failure or a catastrophic failure.

When I am training a company on how to implement an airborne ultrasound program I like to emphasize the importance of multiple ultrasonic resources. I believe the best practice is to have, at a minimum, one ultrasound instrument available on every shift.

Ultrasound - Why Not?

Take a hard look at your maintenance program. What premise is it based upon... Run-to-Failure, Preventative or Predictive? Do you have an airborne ultrasound instrument? If not, why not? If you do, do your technicians know how to use it properly? Are you using the technology to its fullest capacity? Can you define the applications within your plant for which airborne ultrasound could be useful?

The cost savings of establishing a predictive maintenance program are well documented today and proof is readily available. So if you are interested in reducing maintenance costs and increasing uptime in your facility, predictive maintenance is the answer. Because you can provide quick results and establish immediate credibility, starting your predictive maintenance journey with ultrasound is the smartest choice.

Reference:

1. January 2007, http://www.capetronics.com/predictive_preventive_maintenance.htm

Jim Hall is the president of Ultra-Sound Technologies, a "Vendor-Neutral" company providing on-site predictive maintenance consultation and training. UST provides an Associate Level, Level I & II Airborne Ultrasound Certification. Jim is also a regular provider of on-line presentations at ReliabilityWeb.com and is a contributing editor for Uptime Magazine. Jim has provided airborne ultrasound training for several Fortune 500 Companies in electrical generation, pulp & paper, petro-chemical and transportation (marine, automotive, aerospace). A 17-year civil service veteran, Jim served as an aerospace engineering technician for Naval Aviation Engineering Service Unit (NAESU) and with the Naval Aviation Depot Jacksonville Florida (NADEP). Jim is also president of All Leak Detection, LLC an underground leak detection company. Jim can be reached at 770-517-8747 or at jim.hall@ultra-soundtech.com

Phase Analysis

The Missing Weapon in the Fight Against Machine Downtime

By Jason Tranter

For so many vibration analysts, life revolves around the spectrum. If the fault is not obvious in the spectrum then the fault may not be detected. And in some cases, the fault condition is misdiagnosed because a number of conditions present themselves in very similar ways. The use of phase readings can help you to differentiate between these conditions. If you master phase analysis, your ability to diagnose faults correctly will be enhanced greatly.

Phase analysis is a very powerful tool. The perception may be that phase measurements are difficult to collect or possibly that the readings are difficult to understand or interpret. Some may even believe that phase measurements do not offer any useful information. They are wrong.

The purpose of this article is to show that phase measurements are neither difficult to collect nor difficult to understand.

We will start by reviewing the fundamentals of phase, and then look at how you can measure phase with a single-channel data collector, a dual-channel data collector, and with a strobe.

In part two of this article, we will look at how these readings can be used to diagnose a wide range of fault conditions: unbalance, misalignment, looseness, bent shaft, cocked bearing, eccentricity and resonance. We will review how comparing phase readings can reveal so much about the machine, and we will take a quick look at Operating Deflection Shape (ODS) and modal analysis.

What is Phase?

First, let's do a quick review of phase. We have placed a phase simulator on our Web site to help you better understand phase relationships:
http://www.ilearninteractive.com/phase.

Phase is All About Timing

Phase is all about the relative timing of related events. Here are a few examples:

1. When balancing we are interested in the timing between the heavy spot on the rotor and a reference point on the shaft. We need to determine where that heavy spot is located, and the amount of weight required to counteract the rotational forces.
2. When we look at fault conditions such as unbalance, misalignment, eccentricity, and foundation problems, we are interested in the dynamic forces inside the machine, and as a result, the movement of one point in relation to another point.
3. We can use phase to understand the motion of the machine or structure when we suspect a machine of structural resonance, where the whole machine may be swaying from side to side, twisting or bouncing up and down.

So, phase is very helpful when balancing, and when trying to understand the motion of a machine or structure. But phase is also very useful when trying to diagnose machine fault conditions. If your attitude is "the vibration levels are high – it needs to be overhauled", then you probably don't care about phase. But if you want to make an accurate diagnosis, and correctly distinguish between faults such as unbalance, misalignment and bent shaft, then phase is an essential tool.

Phase Fundamentals

If you measure the vibration from a machine and filter out all sources of vibration leaving only the vibration at the frequency corresponding to the running speed (i.e. 1X vibration) then the time waveform is a sine wave. The vibration level will be dictated by a number of factors, but let's just focus on the forces due to unbalance.

Let's use a simple fan as our reference machine. There is a gold coin attached to one of the blades which generates the unbalance force. We see a sine wave with the corresponding angles of rotation as illustrated in Figure 1.

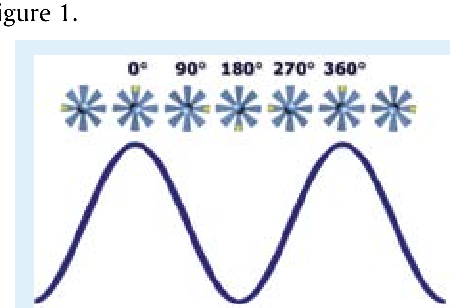


Figure 1 - A Sign Wave with the corresponding angles of rotation.

But this information by itself does not tell us very much. Phase is a relative measure, so we need to compare one source of vibration to either another source of vibration or a reference of some kind.

First we'll try to understand phase by comparing two sources of vibration. If we had two identical fans, each with coins on a blade (to generate an unbalance force), we would expect to see sine waves from each fan as shown in Figure 2. If the fans were perfectly synchronized such that the coins were both at the 12:00 position at the same time, they would be said to be "in-phase".

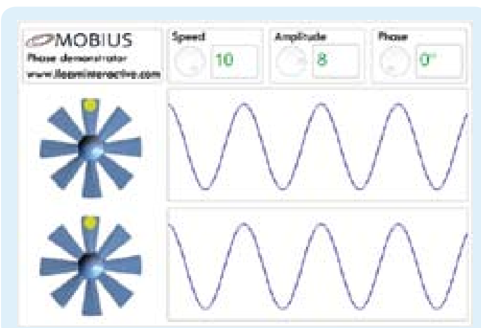


Figure 2 - The Two Fans are In-Phase.

However, if one coin was at the top (12:00) when the other was at the bottom (6:00), they would be "180° out-of-phase", as shown in Figure 3. Why 180°? Because one rotation is 360°, so half a rotation is 180°.

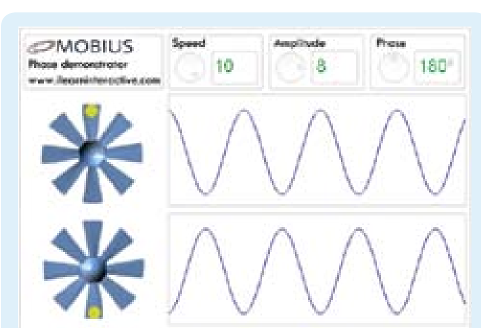


Figure 3 - The Two Fans 180° Out of Phase.

And if one coin was at the top, and the other was a quarter of a rotation around, they would be 90° (or 270°) out of phase, as shown in Figure 4.

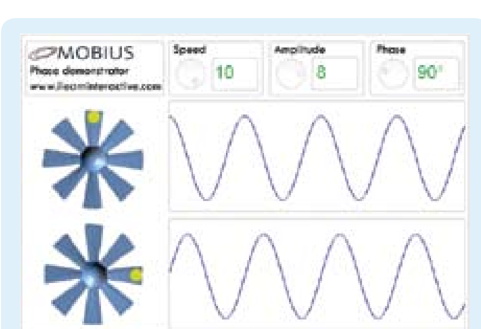


Figure 4 - The Two Fans 90° Out of Phase.

Comparing Two Waveforms

If you look at the previous examples you can see two waveforms with the same frequency (the fans are running at exactly the same speed). By comparing the two time waveforms we can see the time difference between them. In our example the waveforms have come from two different fans. We are normally interested in two sources of vibration from the same machine. We can determine the phase difference by first measuring the period (i.e. time) of one complete cycle (remember, one cycle is 360°) and comparing that to the difference in time between the waves, as illustrated in Figure 5.

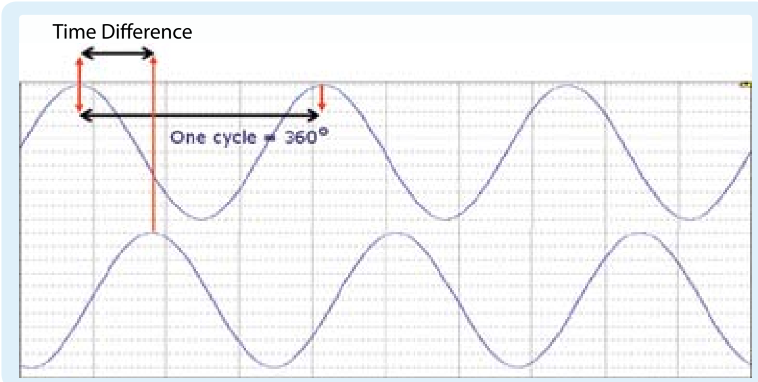


Figure 5 - Time Delay between Two Waveforms

Using A Reference

Instead of measuring phase as a time difference between two sources of vibration, it can be measured as a time difference between a source of vibration and a "reference". The two most common references are to place a piece of reflective tape on the shaft and then use a photo cell or laser to generate a pulse each time the shaft rotates, or to use a displacement probe opposite a keyway. Each time the keyway passes the tip of the displacement transducer, the measured displacement changes dramatically so the signal will have a step change. We discuss these measurement setups in greater detail later in this article.

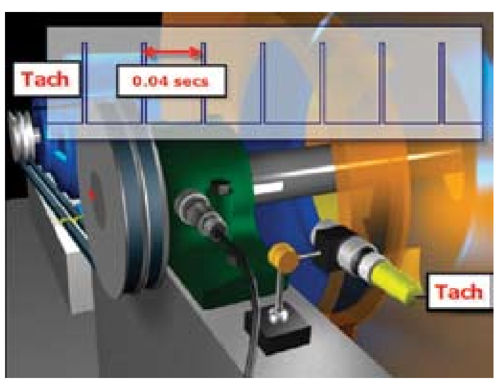


Figure 6 - Tachometer signal from a fan.

The result is a voltage signal that provides a "TTL" pulse once-per-revolution as shown in Figure 6. The time between pulses is the period of the machine speed. To keep the numbers simple, let's assume the fan was rotating at 1500 RPM, or 25 Hz. Therefore the time between the pulses would be 0.04 seconds (1/25 = 0.04).

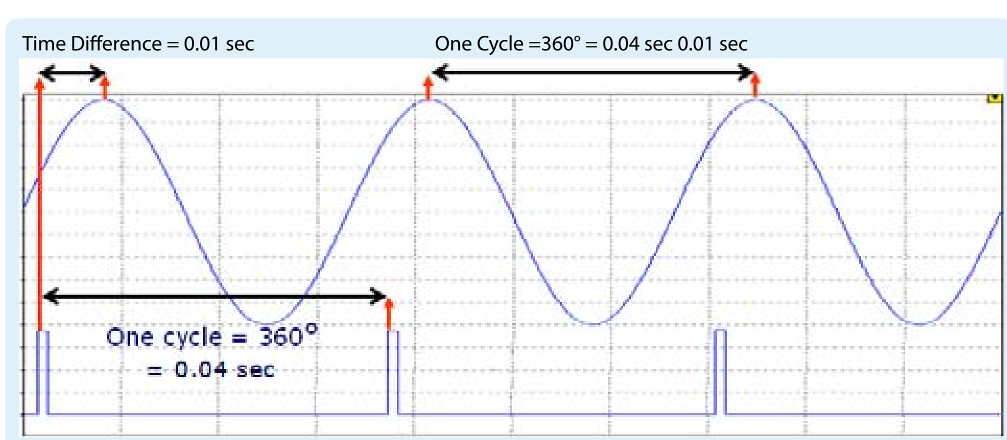


Figure 7 - Sine wave and tachometer signal showing the time and phase difference.

As before, we can compare the vibration from the machine to the reference signal as illustrated in Figure 7. The time between pulses is 0.04 seconds, and the time between the peaks of the wave would be 0.04 seconds. If there is 0.01 seconds between the pulse and the peak of the wave, then the phase difference would be 90°. (Note: ¼ of 0.04 seconds is 0.01 seconds. ¼ of 360° is 90°.)

Fortunately the data collector has the electronics and software necessary to utilize tachometer signals or signals from accelerometers in order to determine the phase angle, so these calculations are performed automatically.

Collecting phase readings

Let's take a closer look at how we measure phase. In the previous section we described two basic methods: using a tachometer reference, and using the vibration from another sensor. There is a third method that utilizes a strobe, but we'll get to that later.

Using a Tachometer

There are a number of ways to obtain a once-per-revolution tachometer signal. The most common involves the use of reflective tape and an optical (or laser) tachometer as illustrated in Figure 8.

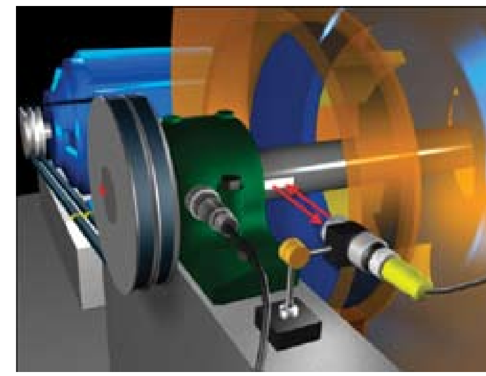


Figure 8 - Accelerometer and laser tachometer installed on a fan.

There are a number of products available that can use reflected light, including laser light, to generate the tachometer signal. Some will work without reflective tape, as long as there is an area of high contrast – for example, a paint spot.

The photocell shines a light (visible or laser) onto the shaft. Due to the surface texture and color, the light does not normally reflect. When the tape passes underneath, the light reflects. The tachometer generates a "TTL" signal that is fed into the data collector.

Another way to generate a once-per-revolution signal is to use a displacement (proximity) probe which is aimed at a keyway or setscrew. The change in displacement provides the step in voltage which is used as the reference. This is commercially known as a "keyphasor" (by Bently Nevada).

The output from the tachometer is fed into the tachometer input of the data collector; it may be labelled "EXT" or "TACH" or "TRIG" or by some other label. You will need to refer to the operating manual of your data collector to understand where to connect the tachometer signal and how to use it to collect phase readings. Figure 9 is an example of one such data collector, used by DI, SKF, DLI and Rockwell (Entek).

Figure 9 - Trigger (tachometer) input of a typical data collector.

The data collector is then able to use the tachometer signal to determine the speed of the machine, and as a reference to compare the vibration at the running speed (1X) from an accelerometer, as illustrated in Figure 10. It will then provide a phase angle of between 0° and 360° (in some cases the data collector may provide a reading of -180° to +180°).

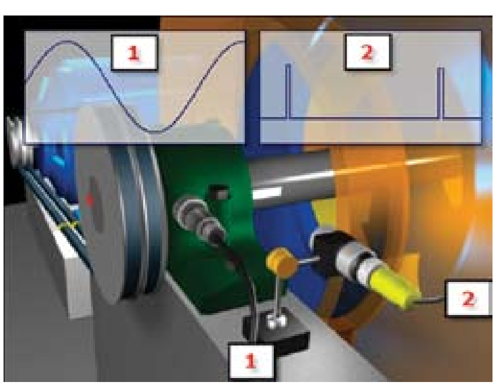


Figure 10 - Filtered 1X vibration signal and tachometer signal.

The data collector can determine the phase angle in a number of different ways. It can apply the two-channel method that will be discussed next, or it can use the tachometer to trigger the data acquisition process and acquire the phase angle from the FFT process.

Using a Two-Channel Data Collector

Did you know that when your data collector takes a measurement on a machine and computes the FFT (spectrum), it actually computes the magnitude (amplitude) spectrum and "phase spectrum"? But because you do not have a reference signal (the data collector starts sampling when you press the button, not according to any pre-defined reference on the shaft) the phase data does not have a lot of value. So it is discarded and we only keep the magnitude spectrum.

However, there are two possibilities available to us. If the data collection was synchronised to the tachometer reference, the phase data would be relevant. We could look at the phase at the running speed and use that information. This is one of the ways that data collectors measure phase when using the tachometer. But there is another way.

If we connect one accelerometer to one channel of a two channel data collector, and we connect another accelerometer to the second channel, the data collector can sample them simultaneously (this is essential) and compare the phase spectra. We would place one sensor at a reference location, and the second sensor at the point of interest, as shown in Figure 11. We can also move that sensor around to different locations to see how the phase angle changes (while leaving the reference sensor in the same location the whole time). In Figure 11 we are measuring the difference in phase between the vertical and horizontal axis.

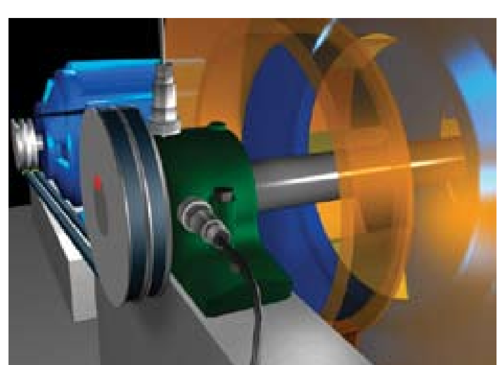


Figure 11- Two accelerometers attached to the bearing so that we may measure the phase difference between the vertical and horizontal axes

As you can see, two-channel phase readings (or "cross-channel phase" as it is widely known) is easy to collect. A great many analysts own two-channel data collectors, but do not utilize them to their fullest potential.

Using a Strobe

Stroboscopes can be used to collect phase readings in two ways.

Strobe as a Tachometer - If we tune the strobe to the running speed of the machine (so that the shaft or coupling appears to have stopped rotating), the output of the strobe can be connected to the tachometer input of the data collector. The data collector would treat the signal from the strobe as if it were a normal tachometer input.

However, if the machine speed varies slightly, the signal from the strobe will no longer represent the exact speed of the machine – the phase reading will be inaccurate. If you set up the strobe so as to freeze a keyway, setscrew or some other point on the shaft or coupling, then you should use that as your reference before you record the amplitude and phase reading. If the speed varies then you will see the keyway/setscrew begin to rotate forward or backwards. You can then adjust the flash rate so that it again freezes.

Data collector driving the strobe or visa versa
There is another way to use a strobe that is very effective, however not all strobes or data collectors have this capability.

The vibration sensor is connected to the strobe and it is placed in "EXT" mode. You control the flash rate of the strobe until you freeze the motion of the shaft. Switch to "LOCK/TRACK" and the strobe will now use its internal circuitry to filter the vibration signal and extract the vibration at the running speed. The strobe can now track any changes in speed. The strobe will typically have a TTL output signal that can be connected to the tachometer input of the data collector. A sample strobe is shown in Figure 12 on the following page.

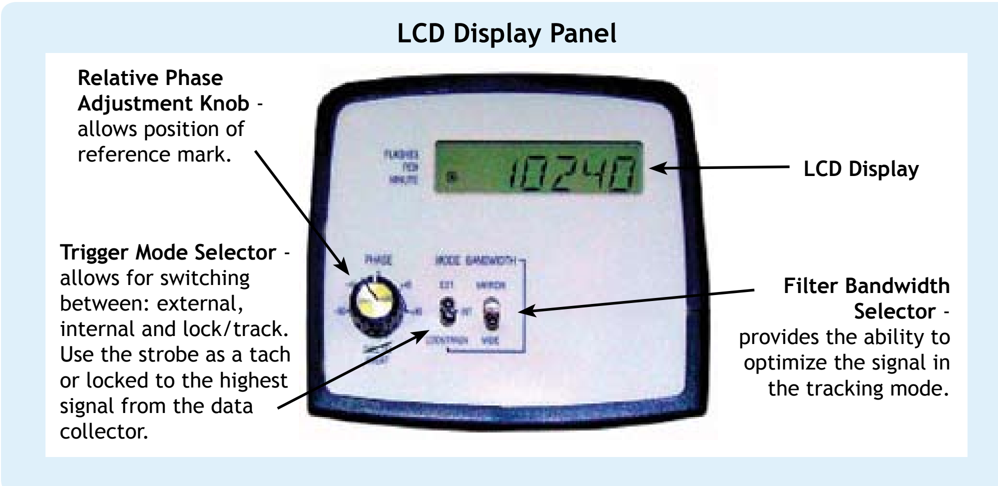


Figure 12 - A strobe from Monarch Instrument
www.monarchinstrument.com

Alternatively, certain data collector models can be used to track the dominant 1X vibration and drive the strobe. The data collector can either track the 1X speed automatically, or you can move the cursor on a spectrum to set the speed. A cable is connected from the output of the data collector to the input of the strobe. The flash rate of the strobe is now under the control of the data collector. If the machine speed varies slightly, the flash rate of the strobe, and the trigger signal, will be automatically corrected.

When the strobe or data collector is set to track the running speed you can perform "visual phase measurements". The strobe will flash at the running speed of the machine, thus the shaft (or coupling) will appear to freeze. (Of course, you must be very careful – the shaft has not stopped and you must be careful not to touch it.) You should then set a visual reference, like a keyway or setscrew, and use the "Relative Phase" knob on the strobe to adjust the keyway/setscrew so that it is at the 12:00 position.

If you watch the shaft/coupling while you move the accelerometer, it will appear as if the shaft/coupling rotates. The amount of rotation is dictated by the phase difference between the original sensor position and the new position. For example, if the machine was out of balance and you move the accelerometer 90º, the shaft/coupling will appear to rotate 90º (a quarter turn), as demonstrated in Figure 13.

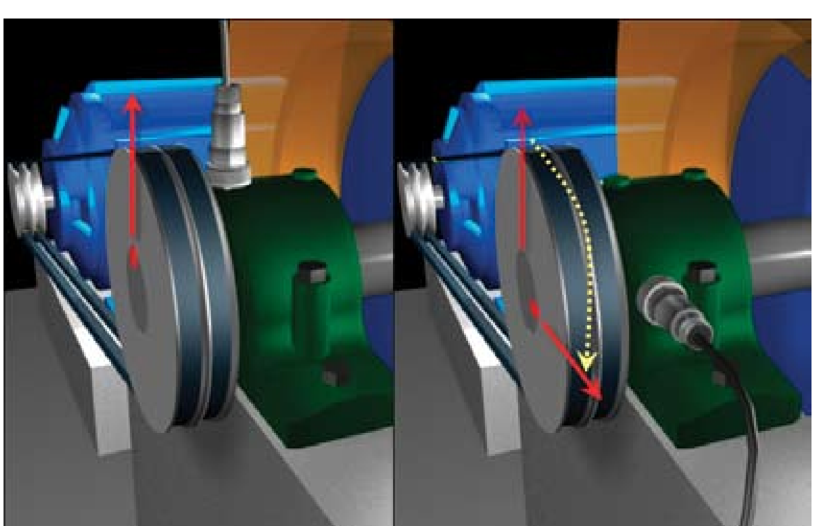


Figure 13: The pulley has rotated a quarter-turn when the accelerometer was moved 90°.

This is a very effective phase analysis method. As you move the sensor around the machine you can see how the phase changes without even looking at actual phase values. It is best if you can use a setscrew, keyway, paint spot, or reflective tape as your visual reference. You should start by adjusting the strobe so that the reference is at the top of the shaft. As you move the sensor it is very easy to note the change in phase.

Using the Phase Readings to Diagnose Fault Conditions

Next month, in part 2 of this article, we will investigate how to utilize the phase readings to diagnose fault conditions. We can do this in a very simple way, by comparing the readings between two axes or two points on the machine (utilizing a bubble diagram to make it easier to keep track of the readings), or we can utilize more sophisticated software to animate the movement of the machine and supporting structure.

Suffice it to say that the phase readings allow us to understand the relative motion of the machine. We investigate whether two points are in-phase, 90° out-of-phase, 180° out-of-phase, or some other relationship. The two points being compared may be two points on either side of the coupling, two points at either end of a component, or between two axes (e.g. horizontal and vertical) at the same location.

Phase is a great diagnostic tool, and if you have a dual-channel data collector or a strobe it is very easy to acquire and interpret the readings.

Jason Tranter is the founder of Mobius, the iLearn company, and the founder of The Mobius Institute. Jason is the author of iLearnVibration, iLearnAlignment, and the analysis tool, Interpreter. Jason began his career in vibration analysis in 1986 in Australia. After selling his business to DLI 1990, he spent six years working for the consulting and product development company near Seattle. Jason has written articles, given papers, and delivered training courses in many countries around the world. Mobius has offices in Seattle, Knoxville and Melbourne, Australia, and has customers in over 80 countries.

RELIABILITY®
THE MAGAZINE FOR IMPROVED PLANT PRODUCTIVITY

RELIABILITY®MAGAZINE ***presents***

INTERACTIVE LEARNING EVENT 1
Root Cause Analysis

February 21–22 • Omni Hotel • Charlotte, North Carolina

LEARNING IS A TWO-WAY STREET!

The typical method of transferring information to the Reliability Community has been a one-way street – speaker to participant with very little input from you, the customer. RELIABILITY®Magazine offers a new, more interesting, meaningful and significant method of learning:

- **You determine conference content.** Extensive pre-conference surveying of Root Cause Analysis presets the conference agenda.
- **Benchmark your Program/Process.** Benchmark your current Root Cause Analysis with other participants via on-site surveying using audience response technology – participants provide data in complete confidentiality but view group benchmarking data instantaneously!
- **On-site data interpretation.** Pre-conference and on-site Root Cause Analysis survey results will be presented and discussed as a "team" – participants, moderators and plant commentators will comment, ask and answer questions.
- **A customized plan for the future.** New technology will offer attendees the opportunity to develop a process map defining and/or refining their own Root Cause Analysis efforts.
- **Achieve management buy-in.** A comprehensive report based on preliminary and on-site Root Cause Analysis surveying justifies to management what changes need to be made at your facility.
- **Ongoing support.** Our learning process doesn't stop once the conference ends! Attendees will be provided with exclusive web based tools for on-going support and communication with other Root Cause Analysis conference attendees including private message boards.

RESEARCH SHOWS*

More than 60% of manufacturing organizations have doubts regarding their root cause analysis efforts in terms of:

- Root Cause Analysis triggers
- Recommendation, implementation & follow-up
- Program structure
- Metrics correlating RCA to KPIs
- Communication of results
- Management buy-in

**Research conducted by Reliabilityweb.com and The Reliability Center, Inc.*

If you, like so many others, seem immobilized in the pros, cons, obstacles and concerns surrounding your Root Cause Analysis effort, we invite you to interact with a "small" group of other "A+" Reliability professionals to develop a clear vision for your Root Cause Analysis initiative resulting in:

- Lower costs
- Increased availability
- Increased production
- Higher profits

MAKE HOTEL RESERVATIONS ***Today!*** Limited Rooms Available

Room Rate: $131 (available only through 1/30)
Reservations: On-line at www.reliability-magazine.com or call 1.800.THE.OMNI

HOW TO REGISTER

Due to the highly interactive nature of our Learning Events, the number of participants must be restricted, allowing us to provide participants with the highest level of attention possible. Early registration is highly recommended. To register, visit www.reliability-magazine.com, call 888.575.1245, ext. 6.

Registration Fee: $995 (includes daily breakfast, lunch & reception)
Discounts: $100 RELIABILITY®Magazine subscriber
$100 discount registered prior to January 15, 2007

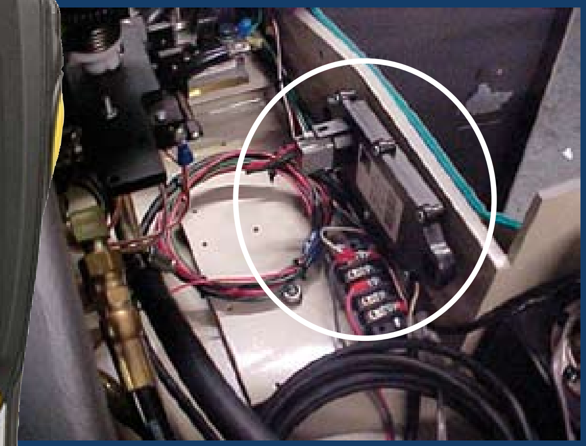
PART OF THE RELIABILITY®MAGAZINE COMMUNITY OF LEARNING™

"Where we make the Reliability Learning Journey More Interesting, Meaningful and Significant"

Taking readings, checking parts in and out, inspections and many other mundane tasks take a lot of time. Let RFID do that work so people don't have to.

RFID and mNOW!

Radio Frequency Identification (RFID) is a technology that has been around for about 20 years. The most widely known application of RFID is probably the device in cars (transponders) that automatically pays for tolls as you drive through a toll plaza. You don't have to stop if you have established an account with the tolling authority and have a transponder in your car. This saves you a great deal of time over the course of a year. And we all know that time is money. Blue Dot solutions has taken that concept into the industrial arena, and the cost-saving results can be both immediate and quite large. We talked with Gary Blohm, VP of Business Development & Marketing at Blue Dot, to learn a little more about how industrial facilities can take advantage of this time-saving technology...



With a small footprint, RFID tags can be placed easily on a wide variety of assets (above). Using a handheld active RFID reader (left), data can be automatically acquired from the asset by simply getting within 200 feet of the asset.

Let's start with a brief explanation of what RFID is and how it works.

RFID is an electronic tagging technology that allows an object, place, or person to be automatically identified at a distance without a direct line-of-sight, using an electromagnetic challenge/response exchange. An RFID system is composed of readers and tags. Readers generate signals that are dual purpose: they provide power for a tag, and they create an interrogation signal. A tag captures the energy it receives from a reader to supply its own power and then executes commands sent by the reader. The simplest command results in the tag sending back a signal containing a unique digital ID that can be looked up in a database available to the reader to determine its identity, perhaps expressed as a name, manufacturer, inventory item, preventive maintenance reading, number, or cost.

What were the first uses for RFID and when did they occur?

The first patent to be associated with the acronym RFID was granted in 1983. That said, the first "real world" deployments using RFID technology started gaining momentum in the early to mid 1990's. Initial deployments and applications ranged from transport or toll systems (electronic pay while you drive), inventory systems, to long range access control for vehicles, to fundamental product tracking. Most recently, RFID has begun to gain major media attention within the technology community with the mandate from Wal-Mart and the United States Department of Defense requiring that their vendors place RFID tags on all shipments to improve supply chain management business practices. Today, as RFID technology matures and becomes more widely adopted, maintenance organizations within asset intensive industries are exploring ways to incorporate RFID into their daily maintenance business process.

How can mNOW! help maintenance in a manufacturing or industrial environment?

RFID can help maintenance by automating manual processes associated with time-intensive equipment meter readings and related required metrics, inventory check in/out, inspections and audits, and general location tracking. Inherent capabilities of RFID enable far greater efficiencies than traditional barcode technologies and paper based processes.

What types of industries or facilities is mNOW! most suited for?

Our mNOW! product is very versatile in terms of applications. The industries that immediately come to mind are: Manufacturing, Utilities, Facilities & Maintenance, Transportation, Pulp & Paper, Automotive, Oil & Gas.

What are the 3 biggest benefits to implementing the mNOW! system in a maintenance environment?

Well, that's tough because there are a myriad of benefits, but the top three would include:

1) Increased utilization and reduced downtime for key assets that need to be operating 24/7.
2) Eliminate manual data capture of Preventive Maintenance data to increase maintenance workforce productivity and reduce operational cost.
3) Extend the life of key assets by being informed when routine maintenance task need to be scheduled and completed.

Are there any drawbacks or weaknesses in an RFID setup to think about?

In many RFID implementations, the cost of infrastructure can be very high. However, the mNOW! RFID for Preventative Maintenance requires minimal hardware investment, making the overall cost of the system affordable and straightforward to implement. The initial planning and setup of an RFID system is the most critical component. Considerations often overlooked include RFID tag placement, RFID tag installation and approach, and initial tag data association. Blue Dot's RFID experience will avoid costly mistakes in these areas through proper project planning and experienced consulting.

What is time frame for a return on the investment in an mNOW! system?

mNOW! RFID for Preventive Maintenance brings extremely quick return on investment to organizations requiring extensive preventative maintenance. Other Active RFID solutions on the market cost thousands per dollars per equipment/unit. mNOW! RFID for Preventive Maintenance is in the low hundreds; a result of combining state of the art RFID technology, a cost effective mobile framework, and streamlined approach to implementation. Return on investment is recouped within 6 months. After that it's all gravy.

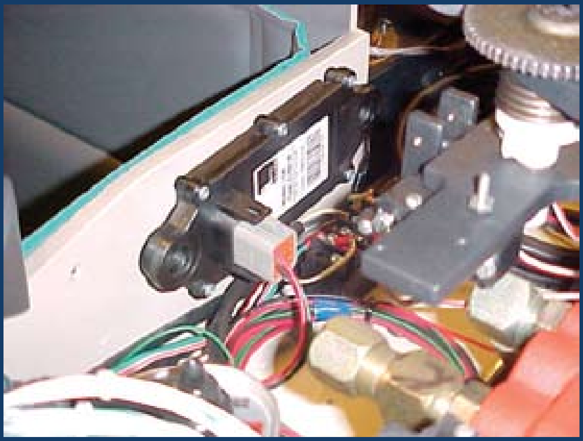
Give us a success story or two from the implementation of mNOW!

Premier Manufacturing Support Services, Inc. currently provides services to over 150 vehicle assembly and supplier plants worldwide, and their customers include most of the largest automotive manufacturers in the United States, Brazil, Canada, China, Czech Republic, England, Germany, Mexico, Netherlands, Poland, Spain, Sweden, and Thailand.

Premier will contract with Blue Dot to design and implement their mNOW! RFID for Preventive Maintenance mobile business application and solution. The fundamental RFID project goal is to greatly improve operational performance, thereby improving the utilization of assets such as fork lift operations, while decreasing cost across the enterprise. Premier will first deploy the solution to its El Paso facility, with a rollout plan to follow for all Premier supported plants worldwide. Premier Manufacturing currently provides support services to over 250 plants and 4000 fork trucks.

Blue Dot will also provide all the other "key" components of the mobile RFID solution, including mobile ruggedized devices, RFID tags and readers, application software, integration, implementation services, and solution support.

Currently a manual intensive process for Premier, the new mNOW! RFID for Preventive Maintenance solution will improve the efficiencies of initial data capture, eliminate data entry, and remove errors associated with handwritten processes.



Installation of an RFID tag

The primary function of Premier's mNOW! RFID for Preventive Maintenance solution will automate the data collection of fork lift truck engine hour readings. An Active RFID engine hour tag, wired directly to the fork truck engine, will be read from a mobile ruggedized device using Blue Dot's mNOW! Mobile Framework as the application software. The device will electronically capture the Active RFID tag ID and associate this information appropriately with a Premier Asset ID, engine hour reading, date/time, and user login information. The engine hours reading data, once collected, will be stored locally on the ruggedized mobile device and synchronized through Blue Dot's mNOW! Middleware to Premier's maintenance (EAM) system, Datastream 7i. The integration will leverage Web Services, consistent with the Service Oriented Architecture (SOA) strategy of both Datastream and Blue Dot's mNOW! Mobile Framework.

How can interested people get more information about mNOW! and Blue Dot?

To learn more about Blue Dot, their mNOW! RFID for Preventive Maintenance solutions, or their mNOW! Mobile Framework please visit www.bluedotsolutions.com, email to sales@bluedotsolutions.com, or 1.866.303.8324.

New SKF® pre-lubricated sealed linear ball bearings can save time and money typically spent on the bearing lubrication process, which can be especially significant in high-volume applications. These unique linear ball bearings are fitted with integral double-lip seals to retain the lubricant and protect against contamination. Seals consist of an inner lip that prevents lubricant from escaping within the bearing and an external lip that wipes the shaft surface as the bearing moves. The linear ball bearings incorporate plastic cages carrying hardened steel raceway segments and guiding the ball sets. Their recirculating balls reduce friction and provide unlimited stroke to promote optimized performance.

Sean M. Feyrer
SKF Linear Motion & Precision Technologies
800-541-3624 or 610-861-3741
www.linearmotion.skf.com

Learn how to achieve materials management excellence by implementing best practices in supply chain and maintenance, repair, and operations (MRO) management.

Materials Management Best Practices is a comprehensive 5 day training course developed and delivered by Life Cycle Institute, the leaders in Reliability Excellence training. The course is valuable for materials managers, maintenance managers, storeroom supervisors, storekeepers, and maintenance supervisors and maintenance planners and schedulers. Materials Management Best Practices classes begin in February 2007.

Call 800-556-9589 or visit www.LCE.com for a detailed course outline and to register.

788A Economy Accelerometer from Wilcoxon Research

The 788A general purpose accelerometer is designed for price-sensitive customers who require an excellent sensitivity tolerance (+10%) to monitor critical assets. The 788A has a sensitivity of 100 mV/g and an acceleration range of +50 g. Additional features include exceptional shielding, ground isolation, and hermetic sealing against environmental contamination.

High frequency response measurements up to 10 kHz identify faults and improper machine operation, ensuring that maintenance professionals are aware of potentially damaging conditions. Wilcoxon's 788A is perfect for Condition Based Monitoring and Predictive Maintenance programs. This general purpose accelerometer is suited to vibration monitoring of fans, motors, pumps, blowers, compressors, chillers, gearboxes, and mixers, as well as many other industrial applications, to significantly reduce failure rates in the field.

Wilcoxon Research

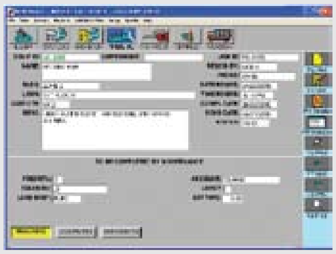
800-WILCOXON
www.wilcoxon.com
sensors@wilcoxon.com

Unotron, the leading manufacturer and worldwide marketer of high quality, washable data input and security devices, today announced the international debut of its patented SpillSeal® protected, to IP66 and NEMA 4X standards, washable, 2.4GHz wireless, 3-Button Mouse with removable Scroll Wheel (Unotron WM10 ScrollSeal Washable Optical Mouse). Unotron's patented SpillSeal® keyboards and mice feature a sealed structure that allows for washing and sterilization, providing an easy solution to the problem of bacterial infection. They can be immersed in commercial grade detergents or antibacterial solutions and rinsed under tap water, without damaging the product or impacting functionality.

Unotron 800.469.7440 www.unotron.com

Benchmate - A Simpler CMMS

Benchmate understands that more effective maintenance management begins with better organization of maintenance data. To provide maintenance department and associated users with easy access to the data they need, Benchmate is designed with six major screens — Equipment, Work Order, Preventive Maintenance, Trouble Call, Service Log, Inventory — each organized logically for simple information access.



Benchmate Systems, Inc.
www.benchmate.com
360.678.8358

E Instruments has released the NEW, LOW COST BTU 1000 Basic Portable Gas Analyzer. This portable and multifunctional unit is ideal for servicing and maintenance purposes of HVAC Professionals including boilers, heaters, and other domestic and industrial applications. The BTU 1000 provides the latest technology in flue gas analysis.

- Analyzes 1 or 2 Gases O2, CO, Calculates CO2
- Ambient CO Monitor (1 ppm Resolution)
- Draft & Differential Pressure Meter
- 7" Removable Flue Gas Probe
- Easy to Use w/ Direct Function Keys
- Large LCD, 4-Line Display
- Water Trap
- Built-in Impact Printer
- 10 Programmable Fuels

E Instruments Group, LLC
215 750 1212
info@einstrumentsgroup.com
www.einstrumentsgroup.com

NILOS® steel-disk seals for grease-lubricated roller bearings can provide superior protection against contaminants in mining equipment exposed to extreme levels of dirt, dust, and debris. They can further prevent leakage of lubricant and contribute to optimized bearing service life in a wide range of applications, including idlers, crushers, and conveyor rollers, among others. Their non-contact, grease-filled labyrinth sealing elements consist of laminated steel-seal disks and steel cores. The seals resist axial pressure and will not slip when clamped in the axial direction of both the inner and outer periphery of a roller-bearing ring.

Kody T. Fedorcha
SKF Linear Motion & Precision Technologies
800-541-3624 or 610-861-3733
www.linearmotion.skf.com

The Niagara Frontier Chapter of the Vibration Institute announces the Vibration Institute 13th Annual PdM Trade Show & Conference will be held April 26 & 27, 2007 at the Holiday Inn - Amherst in Amherst, NY.

Mike Gooding will present a concise and informative Vibration School: ½ day of Basic Vibration and a ½ day of Intermediate Vibration. The other major track of the Conference - BEARING SCHOOL - will have SKF will present two half day sessions entitled **Inspection and Analysis of Damaged Bearings** -- the analysis of the physical evidence of bearing failures, and **Use Predictive Analysis Tools to Prevent Failures** this is dedicated to catching bearing failures before they happen. Don't forget to attend one of the best vibration products trade shows in the country. On Friday, two full day classes will be offered: Course 1: Ultrasonic Technology Workshop and Course 2: Oil Analysis Course.

For more info and registration forms, visit www.nfcvi.org

PCB Piezotronics, Inc. (PCB®) has introduced a series of dynamic, ICP® pressure sensors that have been certified under ATEX and CSA for use in hazardous environments. These sensors are widely used on pumps, compressors, power generation equipment, and other machinery operating in hazardous environments. Series 102 and 121 pressure sensors are ideal for monitoring performance of compressors, pumps, and gas turbines, because they measure dynamic pressure events such as surges, pulsations, and spikes. The low-impedance signal may be transmitted over long cable distances, and the sensors may be used in dirty environments with no signal degradation.

more info available at
www.pcb.com

Scantek, Inc. announces the availability of a newly revised VibroMatrix 4-channel PC-based vibration analyzer. Using up to four sensors or one or more sensors with different filtering from the same sensor, the curves may be shifted, scaled independently. System is real time with no delay between channels. Perfect for run-up, vibration with speed, rpm, and phase curves can be displayed. Available is a balancing program.

Also available as an alternative is the pocket-sized, rugged, tri axial vibration meter from MMF. The VM-30 (shown) is a 12 oz (350 g) unit is suited for bearing vibration, whole-body-, and hand-arm-vibration.

800-224-3813 www.scantekinc.com

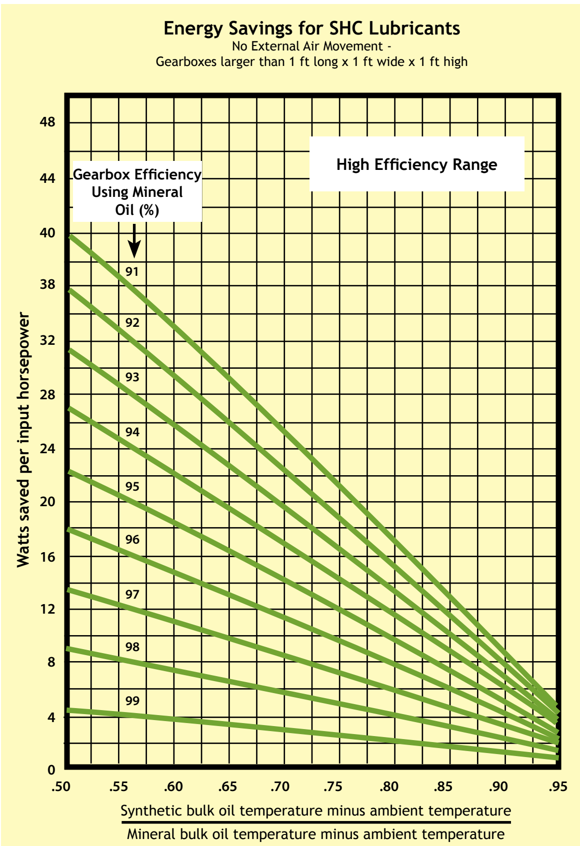
The PTM-300 Series Pulse Timing Modules solve timing issues by providing precise timing control of proximity and photo-sensor output pulses in process control, conveyor and machine applications. The PTM-300 input circuitry automatically detects and determines signal polarity from any standard 'open-collector' type sensor output, such as NPN (sinking) and PNP (sourcing). The timing module then produces a timed output with the same polarity.

Standard models operate from 10 to 30Vdc and provide 'real-time' bi-color LED indication of the input and output signals' polarities. PTM-300U models are user configurable.

Roberta - Brentek International
814-259-3333, Ext 140
800-BRENTEK.

Department of Corrections

The chart below was inadvertently left out of last month's article entitled "Gearing Up for Energy Savings" by Andy Donlan. We apologize for any inconvenience this may have caused.



Mikron SpyGlass Lens™ and ViewPorts

Increase Safety and Reduce Downtime!

Features/Benefits:

- Thermal inspections of electrical switchgear without opening the enclosure or disconnecting circuits
- Views entire scene through a .5" (13mm) hole in the cabinet. Minimum focus range 4"
- Offers 53°H x 40°V (66° Diagonal) Field of View
- Large depth of field reduces the need to re-focus for different cabinet depths
- Attaches to Mikron's models 7600-PRO, M7800 series, and M7500 cameras
- A better value for your inspection budget...

MIKRON INFRARED

Mikron Infrared, Inc. • Thermal Imaging Division
Tel: (906) 487-6060 • Fax: (906) 487-6066 • e-mail: jon@mikroninfrared.com

Call 1-888-506-3900 or visit us at *mikroninfrared.com*