uptime

may 2007

the magazine for PdM & CBM professionals

Transformation

Fostering Metamorphosis Key to Sustaining Organizational Change

Expand Your Infrared

Change Management for Lube Program

The Surprise of Balancing Instruments

Hazards of Hidden Hydrogen

www.uptimemagazine.com

Once you get reliability, you can get off the crazy ride!

IVARA
WORK SMART

You arrive at work & fight fires. One day you're a hero and the next, you're taking the heat for unexpected failures. Sounds like you're on a crazy roller coaster ride! Want to get off? Ivara can help.

As a leader in Asset Reliability Solutions, Ivara offers a proven, multi-faceted solution to move your organization from repair-based equipment maintenance to proactive asset care.

Our reliability experts are well-known and -respected. They provide insight into the processes and practices you need to improve and sustain equipment reliability.

And our unique WorkSmart implementation methodology and unparalleled reliability software Ivara EXP, have helped many capital intensive companies to:

- increase production throughput by 14%
- increase machine efficiency by 5%
- extend asset life by more than 60%
- capture the knowledge of their aging workforce
- reduce environmental & safety risk

Attend Ivara's Reliability Leadership Summit, Sept. 17 - 20, 2007, Las Vegas

Whether you're new to reliability or well on your way to operational excellence, Ivara's Summit will provide you with the tools you need to accelerate your journey.

Attend the Summit to meet reliability experts and leaders, hear dynamic keynote speakers and listen to exciting case studies that prove reliability delivers breakthrough performance and measurable results.

This year's Summit offers:

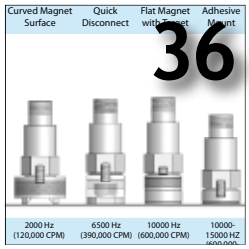
- Dynamic keynote speakers including Terry O'Hanlon, publisher of reliabilityweb.com and Stephen Thomas, author of Improving Maintenance & Reliability through Cultural Change.
- Unique plant simulation tours that offer all the great value of a plant tour without the long drive to the plant.
- Reliability workshops delivered by renowned experts including Ricky Smith, Stephen Thomas, Al Weber and others.

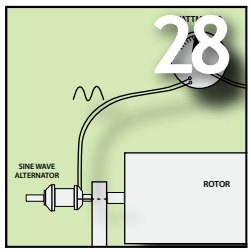
Register Today! Call 1-877-746-3787 ext. 312

Complete details at http://summit.ivara.com

contents

uptime





Time Is Running Out

Where would we be without maintenance? Everything from the simplest implement, like a knife, to the most complex industrial facility needs to be maintained or it dies a premature death. Maintenance professionals literally keep the world running; without them everything grinds to a halt.

The analogy has been made between facility health and personal health time and time again. For good reason, the health of our bodies provides an excellent illustrative example of machinery health because there are many parallels. So I am going to use the comparison again.

Let's think of our industrial facility as a patient. The maintenance professionals are the health care professionals that take care of the patient. Simple enough so far.

If the facility is operating in a reactive maintenance mode, they are visiting the emergency room all the time. Maintenance pros in these facilities are like ER doctors, patching the patient up to keep him alive. Now think about all the bills for those repeated ER visits. Ouch.

Facilities that are operating proactively with a mature PdM program are visiting nutritionists and personal trainers. Here, maintenance pros spend their time keeping the patient healthy and productive instead of patching him up.

The problem with moving to proactive maintenance is that the ER doctors get much more glory than nutritionists and personal trainers. But I ask you, as a patient, who would you rather be spending your time with?

The fact is that PdM professionals deserve much more credit than they receive. For that reason, Uptime created the PdM Program of the Year Awards. The deadline for entering the 2007 edition of these awards is June 1st. Time is running out, so I encourage you to enter your program today. There is no cost to enter. For more information or to download an application, visit our website - www.uptimemagazine.com

Rarely do we take the time to step back and take a look at the overall picture of our program. Simply filling out the application allows you to do this and is a worthwhile exercise in and of itself.

If you win, you'll receive two complimentary passes to attend the PdM-2007 conference in September where the awards ceremony will be held, a handsome trophy, and - the best prize of all - the knowledge that your PdM program is among the very best in the industry.

Thank you for reading. We hope you find something of value within these pages. If you have any questions, comments or suggestions that will make Uptime more useful to you, please let us know.

All the best,

Jeff Shuler
Editor In Chief
jshuler@uptimemagazine.com

uptime
volume 2, issue 19

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

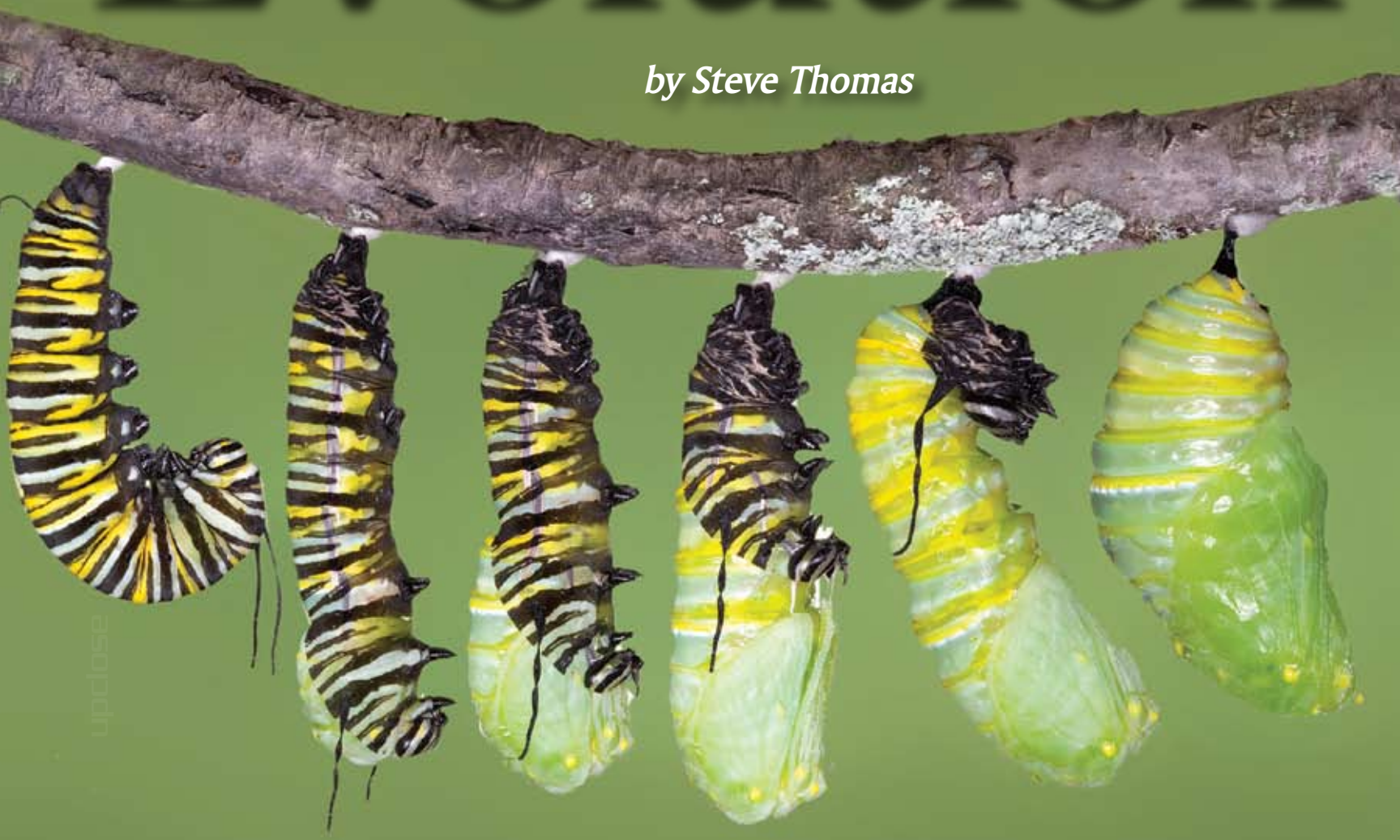
www.uptimemagazine.com

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. No part of Uptime may be reproduced in any form by any means without prior written consent from Reliabilityweb.com.
Uptime is an independently produced publication of Reliabilityweb.com. The opinions expressed herein are not necessarily those of Reliabilityweb.com.

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

You Say You Want An Evolution

by Steve Thomas



Imagine that after months of hard work you and your change team are ready to begin deployment of a revised maintenance work process that has been designed to vastly improve your plant's reliability. In fact the work that the team has accomplished is expected to propel your site onto the list of the most reliable plants in your industry.

The process that the team has followed to get to this point was text book. You built a team which included experts from all functional areas within the plant and the team conducted extensive interviews and determined the current or "as is" state. They then spent a considerable amount of time redesigning the work tasks to focus on reliability based repairs and sound planning and scheduling practices. The team even convinced management to give them enough time to do it right and they did do it right.

Initially there was great excitement and commitment by the organization to follow the process and the results were excellent; even better than expected. However in the last several months you have noticed that the process has started to fall apart. Work processes that people had been following religiously were not being completed and, in some cases, simply ignored. In some areas of the plant it even appeared

Initiatives to implement large changes often fail because they neglect the human element. A productive, lasting organizational change requires many people to transform their thoughts and habits. To be successful, the change needs to first be embraced and reflected in the values of the organizational culture.

that there were more of the former processes being practiced than what you and your team had deployed only a few short months ago. The metrics which once looked so good have taken a turn for the worse and management is very unhappy with the state of the effort.

Something is causing the change initiative to fail, but as hard as you try, you can't seem to put your finger on the reason.

To save the change initiative described, some form of corrective action is needed since failure is on the door step. With this objective in mind, you reconvene the team to begin the analysis hoping to be able to save the day.

The team in our example above didn't miss anything at the task or "hard skill" level as they conducted the redesign. In fact, they did everything required to identify their vision of the future and then design a set of work tasks to get them there. Their problem is much deeper than that and it's a problem that plagues most change initiatives that fail to deliver on expectations or simply fail outright.

The root cause is that there are two other levels that must be addressed if successful change is the desired result. The first of these two levels is the level of "soft skills." These are not tasks but rather elements that support the successful implementation of a new set of tasks within an organization. This level is composed of eight distinct elements called the Eight Elements of Change. They include:

- Leadership – Direction and guidance for the organization
- Work Process – The method or process by which work is conducted
- Structure – The organizational framework supporting the process
- Group Learning – The ability of the organization to learn and adapt
- Technology – The software supporting Reliability / Maintenance efforts
- Communication – Dissemination of information
- Interrelationships – Effective and efficient working relationships
- Rewards – Reinforcement for performance (not always money)

Each of these elements is important for a successful change initiative on their own, but they are even more important when considered as a collective whole. Recognizing the critical importance and the role that these elements play, both individually and collectively, in the process of change is very important to a successful outcome. This is shown in figure 1.

At the foundation, is Group Learning. Without the ability to critically examine what you do, to learn from the experience and to continuously improve, an organization is doomed. They will do the same old thing the same old way and always get the same results. The real problem is that they may never know why they failed until it is too late.

At the next level are the enablers. These elements, Leadership and Technology, build on the foundation of learning. They enable the group to change successfully. I have seen many thoughtful change initiatives fail because the leadership either didn't understand them, didn't want change to happen, or were comfortable with the status quo. I have also seen changes take place because the leadership strongly believed in and led the change.

Technology is also an enabler. In today's world we have vast amounts of information at our finger tips and the ability to process it. Reliability and maintenance software, if employed correctly, provides the tools needed to enable and support successful change. These enablers—good leadership and sound technology-based solutions—support the other components of the change process.

The next level includes Structure and Work Process. These are core elements. Structure defines how you are organized to accomplish the work, whereas work process defines how the work actually gets accomplished. When you develop your change initiative, these two elements are essentially what you are going to change.

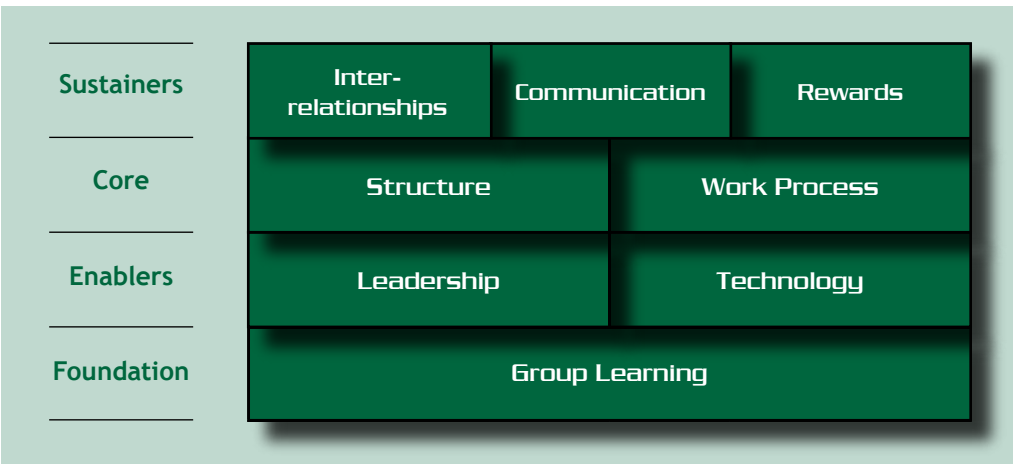


Figure 1 - The Interrelationship of the Eight Elements of Change

Once you have worked through the core elements, the remaining elements are the sustainers. The long-term success rate of any change is dependent on solid Communication, sound Interrelationships, and a Reward process that reinforces the change across the organization. Communication focuses on how information is transmitted from those who have it to those who need it. Interrelationships determine how well people within the company get along and work cooperatively toward a common goal. Good relations cannot by themselves overcome other problems and deficiencies. However, bad relations can undermine or ruin even the best of plans. The reward system is the last of the sustainers. In many cases, the reward systems of the past will not sustain change. We need to create new reward systems based on a work team approach if we wish to sustain the change we have created.

There is one more level below the level of soft skills. It is the foundation of every successful change initiative and the ultimate root cause of every change initiative that fails to achieve its desired end in either short or long term. This is the level of Organizational Culture. Without carefully addressing this foundational level, the roots of the change initiative will never take hold and long term success is unlikely.

The three tiered model showing hard and soft skills and the Organizational Culture level is shown in figure 2.

The foundational level of Organizational Culture must be addressed in every change effort. Failure to make the necessary changes at this level will cause any initiative to fail over the long term, or, at the minimum, prevent your change initiative from ever delivering the expected value.

The foundational level of change - the Organizational Culture - is composed of four elements which we will refer to as the Four Elements of Culture. These elements include:

- Organizational Values
- Role Models
- Rites and Rituals
- Cultural Infrastructure

Organizational Values are those basic beliefs

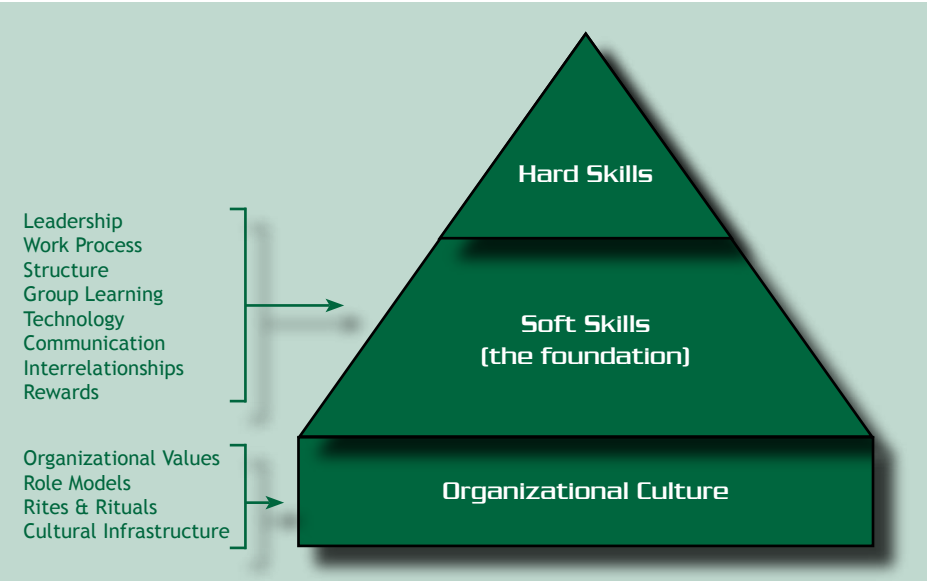


Figure 2 - The Three Levels of Change

that an organization has tested over time and collectively holds to be true. As a result when issues arise that require decisions that will dictate performance, the organizational values are the governing force that directly influences the ultimate outcome. Consider a change initiative that deployed a sophisticated preventive maintenance (PM) program with dedicated PM planners and a PM crew. After deployment the crew was consistently pulled from their designated duties to handle plant emergencies. If the organizational values were truly reliability focused this would never happen.

Role Models are those people at various levels within the organization who people emulate when it comes to work performance. These are the people who have proven successful in the existing organizational culture and provide visible examples of how work is conducted that leads to success both for the organization and on a personal level. Think about the level of difficulty associated with making reliability based change if the plant role models do not model a reliability behavior. For change to be successful it is imperative that the new way of working is modeled by those who fill this role. It is also imperative that if they can't make the change they need to be changed. Training or coaching often can help the role models make this transition.

Rites and Rituals include the work processes (rituals) and how we reinforce their behavior (rites). Rituals are what we do as part of our day-to-day work. In fact they are often so ingrained that we do them with little thought as to why. In essence they are "how things are done around here" if one wants to have a successful career. Rites are the reinforcing part of rituals.

An example of rituals and their reinforcing rites, would be maintenance's reactive response to the demands of the Production department for immediate equipment repair and interruption of the scheduled work. This form of reactive response is most often followed by immediate praise for a job well done. The response is the ritual and the reinforcement the rite. In our PM example above, if the foreman and the PM crew had successfully worked in the reactive maintenance and immediate praise mode they would not object to being pulled off of the PM assignment. In the PM process, the rituals would have been new and uncomfortable and the rites far different than their prior experience in reactive maintenance. Consequently a return to their comfort zone would have been appreciated.

The Cultural Infrastructure is the hidden organization within the organization. It is the unofficial manner in which information (valid or invalid) flows throughout the organization. It is also the way that people are influenced to behave within the context of the orga-

GE
Energy

Lug Less

Tired of lugging so much data acquisition gear? With the all-new Bently Nevada™ ADRE® System, we've packed the power of oscilloscope, spectrum analyzer, signal conditioners, amp racks, and even a fully digital recorder into one very small yet very powerful box — without any sacrifice in functionality.

Find out what all the buzz is about and why multichannel machinery data acquisition just took a quantum leap forward. Visit us online at www.ge-energy.com/ADRE or call us at +1 (775) 782-3611.

imagination at work

1631 Bently Parkway South
Minden, NV 89423
+1 (775) 782-3611

nization's culture. Change can take place without addressing the cultural infrastructure however doing so ignores the significant influence that the cultural infrastructure has within the organization. The seven elements of the Cultural Infrastructure are as follows:

- Story Tellers are individuals who promote the existing culture by telling work related stories. While on the surface these stories often appear to be a waste of time and off topic, they are clearly informing those listening how the culture expects people to act.
- Keepers of the Faith are the people who serve as mentors for the organization. By mentoring new employees they serve to protect the culture by showing everyone how things are expected to be handled.
- Whisperers are passers of information behind the scenes most often to those in position of power. Whisperers have the ability to pass information that you or your work team may not want passed. While the whisperers feel a sense of power by having this unique access they can cause great disruption if not controlled.
- Gossips make up the hidden day-to-day communication system. While it is an unofficial means of communication a great deal of information is passed throughout a company in this manner. The problem is that in a change process this information could be wrong or incomplete leading to speculation and disruption of the effort.
- Spies are passers of sensitive information to those who may or may not need to know. Having a spy in your midst that is passing information to those who should not have it can cause many problems. Information passed in this manner often leads the receiver to the wrong conclusion and the change team to a great deal of unnecessary work to address issues that would not have to be addressed otherwise.
- Symbols and language are mechanisms for conveying what and who is important. Both of these cultural infrastructure elements dictate who is a part of the group, and who is not. Symbols convey importance and set one person apart from another. Consider companies that establish the size of an individual's office based on job grade. Language can also be a problem. At a meeting where a team uses acronyms and terminology only understood by the team when other non-team members are present, it is immediately clear who is part of the group. These two elements are barriers that must be addressed since they tend to break down organizations into definitive groups.

If you consider the different components of the cultural infrastructure, you can see how they can play an important role and have enormous impact on change. If they are not addressed they can work to severely undermine or destroy the change initiative. On the other hand, if addressed proactively, they can be employed to support and sustain it.

What needs to be recognized in any change effort is that all three levels of the change model must be addressed for success. Simply altering or improving tasks won't solve the problem. The change initiative must also address the "soft skills" and the organization's culture or the outcome of all of the hard work will ultimately will fall short of the organization's expectations.

Recognizing the importance of the "soft skills" and the organization's culture as key parts of any change initiative is really only the beginning. It does however open the door to a very important question. If you work on altering the hard and soft skills and take the time to address the organization's culture within your change initiative, how do you know how you are doing? What measurement tool can you use that can bring all of these elements together on a single chart so that you can see your areas of strength as well as areas that need improvement? The answer to this question is The Cultural Web of Change®.

The Cultural Web of Change® is a radar diagram with eight radial spokes. Each of these spokes is one of the elements of change.

To be able to show cultural impacts on each of the elements, the web survey lists sixteen questions for each of the eight elements. These questions are divided up into four

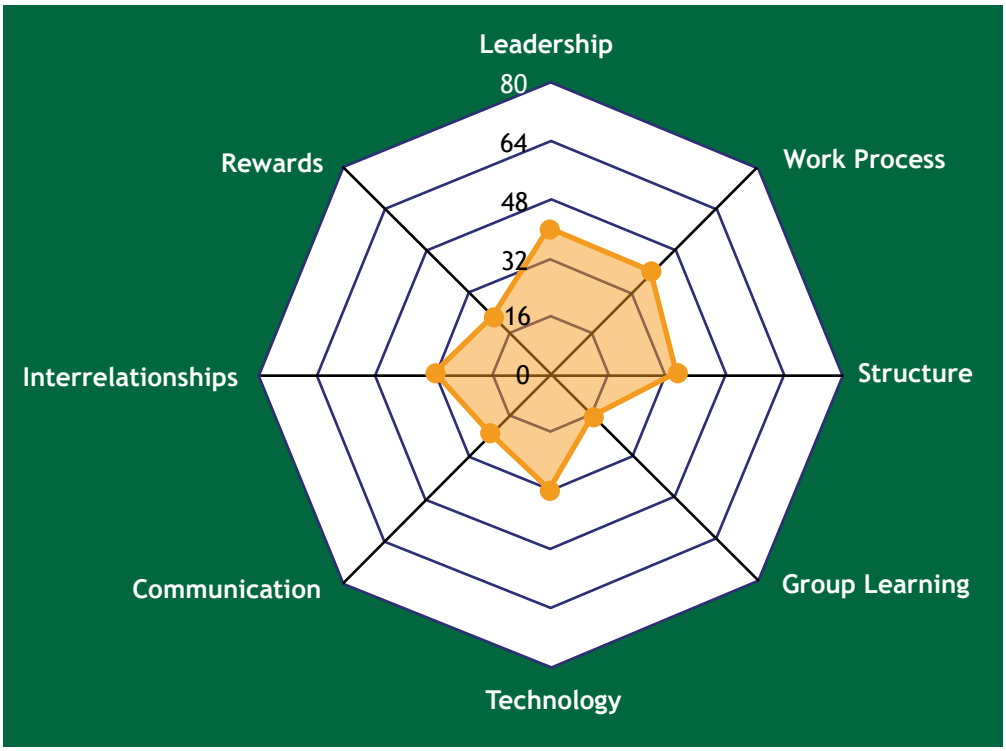


Figure 3 - The Cultural Web of Change®

sets, one set for each of the four elements of culture. The first four questions relate to Organizational Values, the second four to Role Models, the next to Rites and Rituals and the last set of four to the Cultural Infrastructure. In this manner by looking at any group of four across the eight elements we can create a web diagram for just one element of culture related to the eight elements of change. A sub web for organizational values, questions one through four, in each of the elements provides you with additional value and identifies more specific areas of improvement as shown in figure 4 for organizational values.

I would like to tell you that having this information is the end of the road but that is far from the case. Figure 3 shows Leadership as a strength while Figure 4 shows that Interrelationships and Communication relating to Organizational Values are strengths. Any strengths will need to be reinforced, while also addressing the areas that need improving (low scores on the web diagram).

Remember Root Cause Failure Analysis?

Well it works just as well to determine the root causes of problems with a change initiative as it does for a pump bearing failure. All you need to do is select one of the elements that scored the lowest and ask yourselves successive "why" questions until you drill

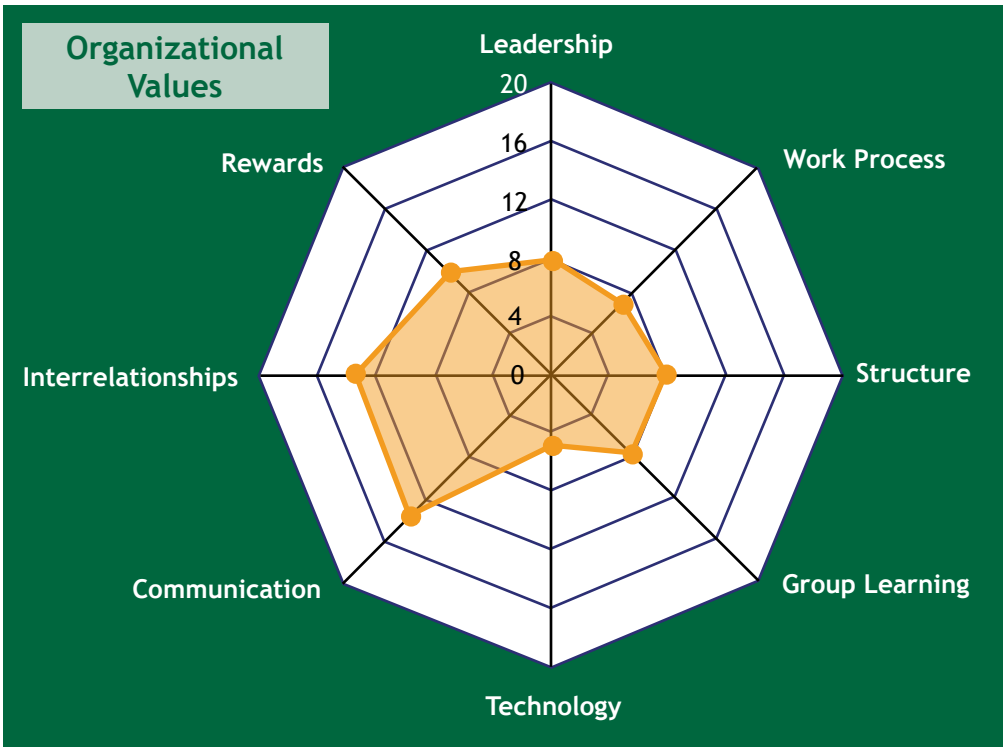


Figure 4 - A Sub Web – Questions 1 to 4 in Each Element

down to the root of the problem. Then, by taking corrective action on the root of the problem, you can make strides to get your change initiative back on track.

At this juncture you may be thinking that you would like to take the Cultural Web of Change survey for your plant and see how you score. You then may even conduct a Change – Root cause Failure Analysis to determine how you can get your change initiative back on track. I can accommodate this and have posted a free download of this web and an even more basic Web of Change for your use on my web site – changemgt.net. Take the survey and see how you do. From there, reinforce your strengths and take corrective action for the areas needing improvement. This will go a long way in support of your change initiative.

The important thing to remember is that "hard skills" are only one of three important parts of a successful change effort. Addressing the "soft skills" and the organization's culture are equally critical to delivering the value sought when you began your journey down the road of change.

Steve Thomas has more than 35 years of experience working in the petrochemical industry. During this time, through personal involvement at all levels of the work process, he has gained extensive experience in all phases of strategic development and implementation of organizational change. Together with a B. S. in Electrical Engineering (Drexel University) and two M. S. degrees in Systems Engineering and Organizational Dynamics (University of Pennsylvania), this broad range of experience has enabled Thomas to contribute significant value to the many projects he's worked on over the years. He has also presented workshops on successfully conducting organizational change for clients throughout the United States and Canada. In addition, Thomas has presented his change management workshop at many industry conferences that address improving reliability and maintenance – one prominent example being the annual International Maintenance Conference. While doing all this, he nonetheless has found the time and energy to write three books which constitute the Web of Change Series.

A Once In A Lifetime Maintenance Conference

by Terrence O'Hanlon. CMRP

Waikiki Beach Honolulu? Maintenance Managers wearing flower Lei's? Steak and Lobster dinner? Samoan Fire Knife and Hula dances? This cannot be a maintenance conference – it must be a dream.

I pinched myself and sure enough – I was wide awake. Over 350 maintenance and reliability professionals, many of them at the Director level; from around the world traveled to Honolulu for the Reliability Centered Maintenance Managers' Forum and the Enterprise Asset Management Summit.

The conference kicked off with "Asset Management from an Insurance Perspective" by Ian Bernard of American International Group (AIG) not only the world's largest physical asset insurer but the 7th largest company in the world. He took the mystery right out of calculating the value of Physical Asset Management and I am sure more than one attendee will be much better prepared for the next "Macro" audit from their insurance company.

Even though most corporate bosses have been to Hawaii on a business trip, most think that if they send you – you would skip the conference and attend a beach party instead. This event was boondoggle free! With over 60 workshops, case studies and technical presentations on Reliability Centered Maintenance and Enterprise Asset Management, attendees spent most of the 4 days willingly inside the Sheraton Waikiki hotel, learning and sharing their own experiences. RCM and EAM implementations have a very high failure rate and the learning sessions at this event shared important information from those who have run the gauntlet and achieved various levels of successful programs.

Maintenance expert and noted Author, Joel Levitt bent everyone's mind as he presented his keynote "20 Steps to World Class Maintenance" which turned out to be more of a "Change Management" lesson. Joel explained that we can change the way we do maintenance by the way we think about the people who are involved in maintenance, and how we treat each other. In the spirit of lean Joel states that the less maintenance inputs to your company's product the better.

The final keynote was presented by Bob DiStefano of MRG who demonstrated "How to Turn Reliability Improvements Into Real Earnings Per Share (EPS)" – one of the best business oriented presentations related to the efforts of maintenance and MRO improvements I have ever heard and seen.

Other RCM/EAM-2007 highlights included:

- GE Energy presenting Reliability Services on a Global scale
- Aladon (RCM2) Worldwide Licensee meeting
- Authors Mac Smith, Neil Bloom and Phillip Slater on hand
- First dedicated SAP-PM Track was very successful and will be expanded
- ARMS Reliability/Isograph/Oniqua marketing partner ship announced

Although the conference was one of the best we have produced to date – we heard your message loud and clear – no more tropical island locations. We fully appreciate the difficulty the location presented for many

companies and we plan to make it much easier for you to attend RCM-2008 and EAM-2008 with a return to the Orleans Hotel in Las Vegas March 18-20, 2008. This event sold-out the last time it was in Las Vegas and we expect a repeat in 2008 so make plans to attend now.

For those who were able to attend and participate in Hawaii – thank you for your support. Be sure and hang on to your memories as RCM-2007 and EAM-2007 in Hawaii were once in a lifetime events.

ReliabilityShopper

Top 10 Reliability Solution Providers

Excellence in Maintenance & Reliability Services

1

Reliability Solutions, Inc. • Continuous Improvement

Leading the World in RCM
585-349-7245
www.reliabilitysolution.com

2

Allied Inspired Reliability

Maximizing the Return on Asset Reliability
918-382-9400
www.alliedreliability.com

3

LCE Life Cycle ENGINEERING
Redefining Maintenance • Delivering Reliability

Redefining Maintenance, Delivering Reliability
843-744-7110
www.LCE.com

4

IVARA WORK SMART

Experts in Making Reliability Work
1-877-746-3787
www.ivara.com

5

ARMS RELIABILITY ENGINEERS

Reliability Software, Training & Engineering Services
509.928.5083 / 5084
www.reliabilityusa.com

6

Reliability Center Inc.

Root Cause Analysis
804-458-0645
www.reliability.com

7

RMG

Masters of Reliability Process Implementation
952-882-8122
www.rmgmpls.com

8

wyle laboratories

RCM, Lean, Six Sigma, Asset Management
904-264-8570
www.wylelabs.com/products/vrcm.html

9

PCA

Improving People, Process & Technology Performance
770-717-2737
www.pcaconsulting.com

10

IRISS® IR Infra Red Inspection Support Solutions

Infrared Inspection Windows and Installation Services
941-373-1528
www.iriss.com

To learn more about these
Top 10 Maintenance & Reliability Solution Providers please visit

www.reliabilityshopper.com

A Golden Opportunity

Finding Other Applications for Thermography

by Jeffrey L. Gadd

Most of us would agree that infrared inspection of electrical distribution and other critical electrical equipment is money well spent. But it's important to remember that infrared thermography is a very diverse technology with many uses other than electrical inspections. On your next electrical infrared inspection, why don't you spend a little extra time and take a look at your critical mechanical systems such as: motors, bearings, boilers, steam traps and tanks. Problems are nothing more than failures that surprise us. So, what we are looking for are the golden opportunities to prevent surprises, to actually prevent problems from occurring.

Trending Electric Motors

The best option for critical motors would be to trend them over time (Figure 1). Sure a quick look when comparing similarly operating motors will give you some instantaneous information, but trending critical motors will provide more valuable information as to their reliability. Whether you gather this information quarterly, semiannually or annually, you will get the big picture once you have established a baseline. The "quick look" method without documentation, will be less effective. In fact, chances are you will not be able to recall that motor "A" was 172°F and now this year the motor is 194°F (given the same load & ambient conditions). Once a motor starts to fail, it's only a matter of time versus temperature until failure. If you see a trend like the one in Figure 1, you may want to plan to change this motor before it fails in the middle of the night during a production run.

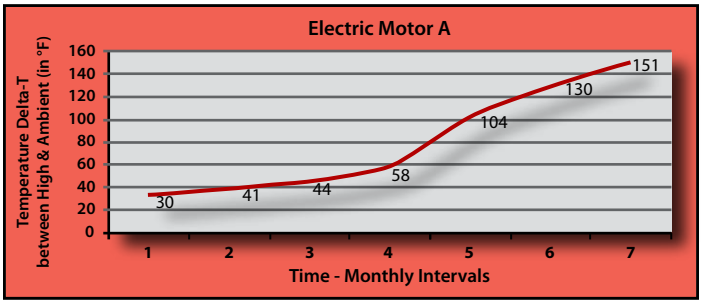


Figure 1- Trend of motor monitored monthly

Bearings

Trending critical bearings is also a useful way to catch issues before the bearings fail. In my experience, the quick look method often does provide very useful information. In many instances, a facility has many similar bearings, which makes it easy to compare the good performers to the bad performers. This works very well when bearings are used in pairs, like pillow block bearings on a shaft. Once, while performing a demonstration, I was walking by the bearing shown in Figure 2 and decided to check it out. I showed the customer the image and he said, "That's not good, is it?" Of course, I replied that it didn't look too good to me. He then asked me if I could perform a full inspection the next day.

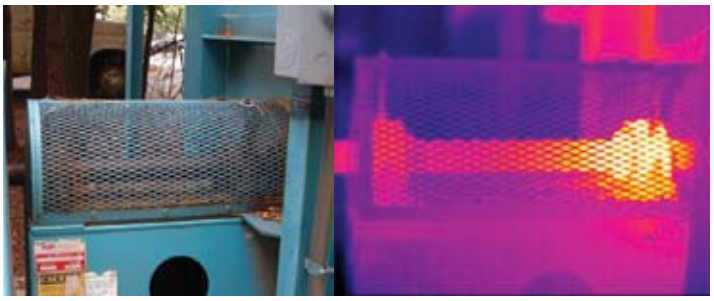


Figure 2 - Visual and Infrared images of a bearing taken using the "quick look" method while walking past it.

Boilers

Another excellent opportunity is to use infrared thermography to check the insulating properties of boilers. Inefficiencies in boilers can be a costly undetected utility expense because insulation or refractory breakdown can go unnoticed for quite some time. Checking the shell and the doors for thermal anomalies can be very quick and easy. While failure is eminent, many of these detectable problems can be identified and scheduled for correction before a loss occurs. The example shown in Figure 3 was discovered in the later stages of failure, and to anyone paying attention, a visual inspection would have been sufficient. But with IR, it is now a documented problem with two graphic images.

STOP BUYING INFRARED CAMERAS!

BUY A THERMOGRAPHY SYSTEM INSTEAD.

Integrated Route-based Infrared Survey Software Simplifies Inspections

Cost-effective, Arc Flash Compliant Wide Angle Lens/IR Window Packages

CMMS Data Import – Easily Import Data Into RouteIR Database

Automatic Multi-page Reports – 30-page Reports in Less Than 3 Minutes!

New IR Inspection Software Suite!

RouteIR™

- Equipment Database
- Route Management
- CMMS Data Import
- Automatic Multi-page Reports

New Resource Center
Complimentary Online Downloads!

WHITE PAPERS on Best Practices Available:

- **Route Based Infrared Inspection Best Practices:** www.electrophysics.com/rir
- **NFPA 70 Thermography Best Practices:** www.electrophysics.com/nfpa

Electrophysics®
973-882-0211 or 800-759-9577
www.electrophysics.com

Steam Traps

Steam traps failing in the open position is not just a problem, but a huge utility expense. Many companies take for granted that their steam traps are working properly, which is often an incorrect assumption. Without a PdM program, steam traps can seriously bleed a company's profits (see Figure 4). For example, if your facility has 100 steam traps (3/16" orifice) and 10% of them are stuck open, then $70,200 is literally going down the drain in one year. If there is no PdM program in place for your steam traps, the failure rate will most likely be higher than 10%, which can equate to astronomical numbers. Infrared inspection in conjunction with ultrasound can provide a big savings to the bottom line.

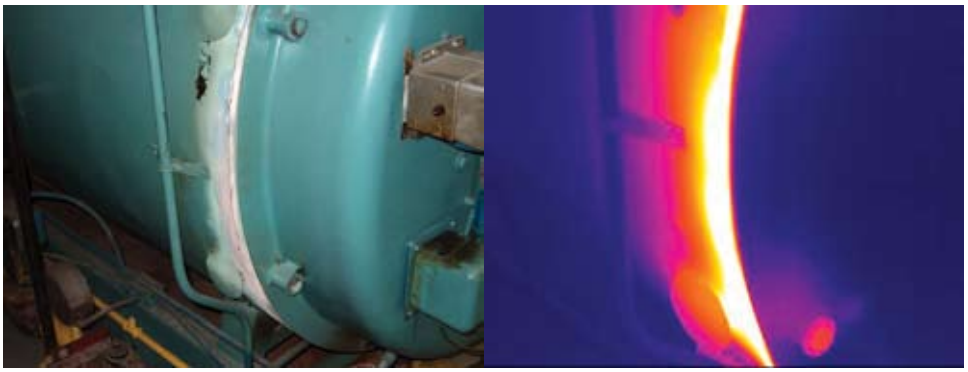


Figure 3 - Visual and Infrared image of boiler with a problem brewing.

Cost of Various Sized Steam Leaks at 100 PSI (Assuming steam costs $5.00/1000 lbs			
Size of Orifice	Lbs. of Steam Wasted per month	Total Cost per Month, $	Total Cost per Year, $
1/2"	835,000	4,175	50,100
7/16"	837,000	3,185	38,220
3/8"	470,000	2,350	28,200
5/16"	325,000	1,625	19,500
1/4"	210,000	1,050	12,600
3/16"	117,000	585	7,020

Figure 4 - Costs of Steam Leaks[1]

Tank Inspection

Using IR for tank inspection can provide valuable information regarding levels of various liquids and the level of any sludge in the bottom. Air, liquids, and solids all have a different thermal capacitance, which enables us to distinguish one from the other. Most

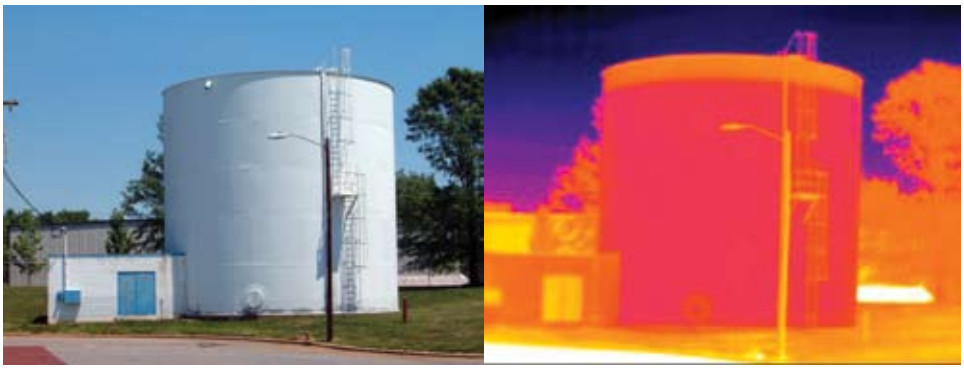


Figure 5 - Visual and IR images of from tank inspection. Liquid levels are easily identified with IR thermography.

tanks have a level sensor or a sight glass to determine levels, but sensors sometimes fail and sight glasses can become blocked, giving false readings. The images seen in Figure 5 were taken around noon and tank level is clearly visible. The liquid in the tank is cooler and, having much more mass, changes only a tiny bit over a 24-hour period. Adversely, the air in the top of the tank changes much more over the day and night, and here it is warmer than the liquid because the Sun has heated it. This inspection could be completed at night as well, which would eliminate any effects of solar loading. An inspection at night would show the inverse as the air in the top would appear cooler and the liquid warmer.

Conclusions

During your next electrical inspection, try adding a few of the aforementioned mechanical applications to the inspection list. ROI for adding equipment-especially critical machinery is almost guaranteed. Processes (especially heat processes) can be a great place to find a new opportunity whether you are looking at soda crackers on a conveyor or parts coming out of a plastic injection-molding machine. With infrared, the sky is the limit, and you are only limited by your imagination. We have this powerful technology so use it, or you might just miss a Golden Opportunity.

1. Source: Armstrong Steam and Condensate Group - http://www.energysolutionscenter.org/boilerburner/Eff_Improve/Images/Steam_Leak_Cost_Table.jpg -- The steam loss values assume clean, dry steam flowing through a sharp-edged orifice to atmospheric pressure with no condensate present. Condensate would normally reduce these losses due to the flashing effect when a pressure drop is experienced.

Jeffrey L. Gadd is owner of Vision Infrared Services (www.visioninfrared.com) in Cleveland, OH. He is a Level II Infrared Thermographer and has an AAS in Industrial Electricity along with 10 years experience as an electrician and maintenance technician. Contact Jeff with questions at 440-554-3620 or e-mail to: jeff@visioninfrared.com

Sweat Equity

Implementing an Automated Lubrication Program

by Paul Defresne

A few years ago while working for a large paper company, I was asked to optimize our lubrication program. Our facility was experiencing major lubrication failures and it seemed that no one had - or wanted - ownership of this beast. The goal given to me was to implement an automated lubrication program, and failure was not an option. I was coming to the paper mill straight from the U.S. Army with a strong desire to succeed in my new career. Like most new engineers, I set out to change the world by moving our current lubrication program from the Stone Age directly to the Space Age.

In the Army, we had a saying in the form of a question. The question was, "Would you trust your life on the status of your equipment at this moment?" The answer to this question was very revealing. What this question did was make the soldier think hard about whether he had taken care of all the preventive maintenance checks for his vehicle, weapon, and ancillary equipment, as well as follow up maintenance, to know the exact status of his equipment.

Every Monday was our command maintenance day. It was on one of these Monday's that I learned an important lesson early in my military career. Every soldier (including the officers), regardless of their individual job, was in the motor pool performing command maintenance (PM's) on their vehicles for that day. I witnessed first hand people "pencil whipping" the PM sheet so that they could get out of the motor pool and onto other things. The "pencil whipping" came to an abrupt end one Monday when at the end of the day, my Commander issued an order for all vehicles to roll out of the motor pool and complete a twenty kilometer road march. He had in his hands all of the PM sheets completed for every vehicle that day. When vehicles could not make it out of the gate and there was nothing annotated on the PM sheet addressing any maintenance issues, you can only imagine the one sided conversation that followed. Preventive maintenance can be the difference between life and death on the battlefield.

In making the transition from the military to private industry, I first started out by evaluating the work practices of the oilers that I would be leading (not just supervising) on our new endeavor. I was appalled by what I found. Let's just say that I found the true meaning of the phrase "proficiency of bad practices". For example, the oilers would dispense oil into open metal containers before they would go out and service a piece of rotating equipment. If the residual oil in the can was of a lighter viscosity and they needed a different grade, they would simply fill up with a different viscosity oil. Not once did I see them flush the container or even look to see if it was dirty to begin with. This was shocking, so I decided to at least find some documentation on the lubricants used in our facility. What I found was even more shocking, a beat up three-ring binder with a lube survey that had been conducted 17 years earlier. Of course, since that time there had been numerous new installations of equipment and several pieces of equipment taken out of service. It was clear no one had any idea of what was taking place on a daily basis for lubrication.

The next phase of our journey was to contact our lubricant supplier and regional lubricant engineer. I put our lubrication supplier on notice with our purchasing department, letting them know that if their performance and customer support did not improve, we would start the process of changing suppliers. We were spending well into the 6 figures on an annual basis for lubricants, and we could get no more support than the delivery truck making a bulk delivery, and the oil company taking a couple of guys to lunch and giving them hats and pens. In the meantime, our equipment was failing due to lack of correct lubrication.

So the question remained, how do we eat the proverbial elephant? Yes, I know, one bite at a time, but where were we supposed to start? We started by analyzing our downtime due to lubrication failures using a Pareto chart (Figure 1) and began with our worst area first. I wanted our lubrication company to conduct a lube survey under my direction. The first thing that they wanted to do was to bring in a bus load of lube engineers and blitz the mill. Understanding that this was going to be a long journey, I pulled the plug on that idea. I decided that we would platoon our efforts and only focus on one area at a time. I assigned one lube engineer to handle grease and one to handle oils. We set out and identified all of the equipment in the

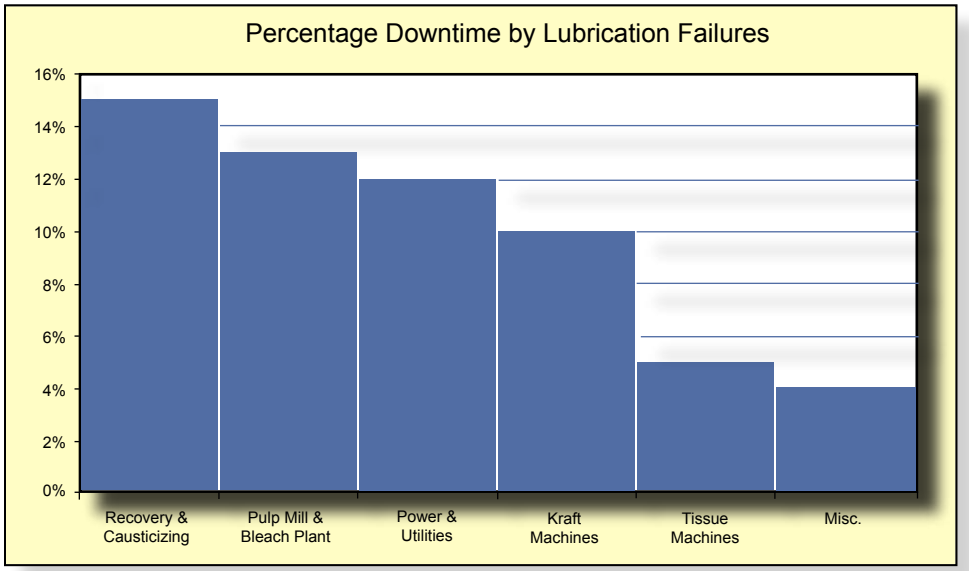


Figure 1 - Downtime Due to Lubrication Failures

specified area that used oil or grease. We identified the following:

- Equipment Name
- Equipment Number
- Type of Lubricant (OEM recommendation)
- Correct amount
- Frequency for re-lubrication
- Oil Analysis candidate

What we found was the information in our CMMS was incomplete. By verifying the data in the field we were able to do two things. The first was to identify and correct deficiencies within our CMMS and the second was to identify critical equipment that was missing from our vibration database. I simply could not believe that we had critical equipment that was not being monitored. This cannot be emphasized enough - You must take the time to verify that your equipment information is correct. If you do not, then you will be setting yourself up for failure before you even start.

The next step was establishing priorities of work. What does the daily tour of work consist of? One of the big differences between military service and industry is the mentality that something is owed to the worker for doing his job right. In the military, before you even think about eating, personal hygiene, or even sleeping, your equipment comes first. It doesn't matter where the hands on the clock fall. So, while in the military the question is, "Would you trust your life with the state of your equipment?", in industry the question should be, "Would you trust your paycheck to the state of your equipment that YOU are responsible for maintaining?"

Unfortunately for many of the oilers at the time I came on board, the answer would have to be a resounding "NO!" Prior to implementing any changes, we were getting roughly 20-30% productivity from each employee. Responsibility and accountability were missing, and it showed in missed goals, low production numbers, and high maintenance costs. Our daily tour of work had to change drastically. After changing our priorities of work, and re-educating the oilers through a hands on training program, our initial productivity increased by 50%. I will show you later how we were able to accomplish this. What was surprising is that all of our lubrication related failures started to reduce dramatically.

We rolled out our first pilot project with a lubrication technician running a route with a PDA. I instructed the tech to run his old route just as before we changed. The results were staggering. What we found was that when the new lubrication tech ran his old oiler route, he was looking at only about 23% of the equipment in any given area. Now that we had built a complete lube route and it was in the PDA, the inspection had to be triggered by the piece of equipment in the field. The equipment was now getting inspected properly and the correct work was starting to take place. Another point of contention with management was that when we started these new routes, our maintenance costs began to increase because the years of neglect had taken a heavy toll on the equipment. As we continued to roll this effort out across the plant, we found the same to be true in almost all of the areas.

It took roughly one year to implement this program across the facility. The main reason for the lengthy process was that I wanted all of the equipment identified and one functional area to be completely up and running before we moved on to the next. We followed the information on our Pareto chart and continued the implementation. By the time we finished, our lubrication technicians had moved from doing lube routes, to conducting an "equipment essential care program" which consisted of visual inspections of the equipment, lubrication checks, and temperature readings. In the eighteen months that followed after our implementation, our maintenance costs were steadily on the decline, and machine uptime and plant availability had increased dramatically.

Summary

After implementing this program we increased our oil analysis sampling by over 400%. Our route compliance moved from 23% to an average of 92%. Our machinery failure was reduced by over 70% in an eighteen month period. These numbers are indicative of the new program, but remember that when implementing an automated lubrication program, it requires much more than plugging in new tools and software and expecting results. You must do the grunt work in the field to ensure you have collected all of the right information to build your program on a solid foundation. You must develop a thorough training program to ensure that all of the technicians understand not only what is expected of them, but why they are doing the work. If everyone understands why doing things differently will work better, then they will be much more likely to perform

their new function. Finally, you must inspect what you expect. You can easily teach an old dog new tricks. The real trick is finding the proper motivation.

Paul Dufresne is a Senior Reliability Consultant with Trico Corporation. Prior to working for Trico, Paul worked for Georgia- Pacific Corporation as a Reliability Supervisor in their Pulp & Paper Division. Paul served 10 years in the United States Army as an Armor Officer for an M1A1 Abrams Main Battle Tank Company and is a Distinguished Military Graduate from the University of Central Florida. Paul can be reached at (414) 418-6992 or pdufresne@tricocorp.com.

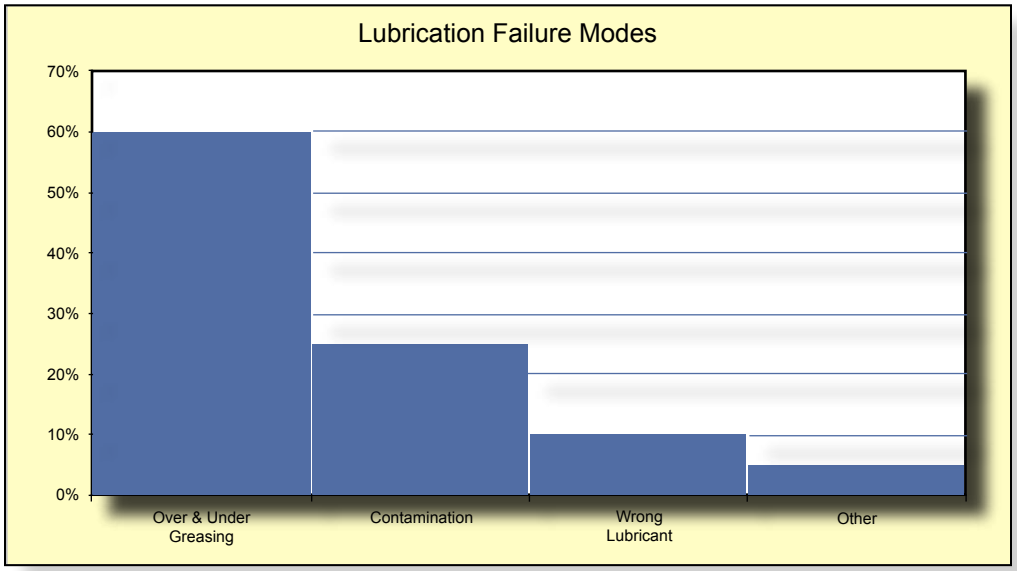


Figure 2 - Downtime by Lubrication Failures Mode

ReliabilityShopper

Top 10 Reliability Software Providers

Excellence in Maintenance Software

1

Capturing Workplace Expertise to Improve Equipment Performance
1-877-746-3787 www.ivara.com

2

Maintenance Development Strategy and Spares Optimization
USA: 508-359-1966 Asia/Pacific: +61 3 9455 2211
www.strategicorp.com

3

Large Enough to Lead. Smart Enough to Listen.
864-458-3333
www.assetpoint.com

4

Reliability Center Inc.

PROACT. Eliminating Problems. Eliminating Stress.
804-458-0645
www.reliability.com /proact/proact.htm

5

The Sensible Approach to Maintenance Management
Malaysia +603 8656 9041 US 1-716-631-4750
www.cworks.com.my

6

Asset Intelligence At Your Fingertips
1-888-AVANTIS or 905-632-6015
www.avantis.net

7

RCM Software & Training Video
408-365-1975
www.jmssoft.com

8

A Simpler CMMS
360-678-8358
www.benchmate.com

9

Mtelligence
Greater Visibility, Greater Return

MIMOSA-based Maintenance Intelligence Software
866-247-2122
www.mtelligence.net

10

CHAMPS - The Original CMMS Solution
(352) 795-2362
www.champsinc.com

To learn more about these
Top 10 Maintenance & Reliability Software Providers please visit

www.reliabilityshopper.com

Modern Motor Testing

Evaluating Motor Condition with Advanced Diagnostics

by Howard W. Penrose, PhD, CMRP

In the first part of this two-part series, we discussed the components of low voltage testing and how ALL-TEST Pro, LLC and PdMA Corp utilize these methods in order to identify and trend faults in motor windings. In this article, we will discuss surge comparison testing as a high voltage testing method used to detect weakened insulation between conductors. We will then compare the application for each of the testing methodologies.

Surge Comparison Testing

The concept of high voltage testing for turn insulation faults has been around for over 80 years, but only put into practical application over the past fifty plus years. In modern times, if a motor repair shop or motor manufacturer is not using surge comparison technology to confirm the quality of their turn insulation system, they cannot meet modern motor repair or manufacturing standards or specifications. These include the ANSI/EASA AR-100 motor repair standard by the Electrical Apparatus and Service Association, Inc., NEMA MG-1 standard by the National Electrical Manufacturers Association and Institute of Electrical and Electronics Engineers, Inc. (IEEE) standards.

Surge comparison test instruments operate by sending out a high voltage, fast rise-time impulse. When the impulse is introduced to a coil, the peak of the impulse resonates based upon the impedance of the coil and a 'ringing' effect will appear at the peak of the impulse. If impulses are applied to two or more identical coils, and the peaks are viewed on an oscilloscope, the ringing should be exactly the same. If any of them deviate, it represents a difference between coils.

This technology operates via Paschen's Law. The basic definition is that this guides the voltage required to ionize the space (gas or material) and then draws an electrical arc between two conductive surfaces. Jacob's ladder is an example of Paschen's Law at work and was often used in old horror and science fiction movies to show an arc forming between two antennae then climb to the top and repeat. When breakdown occurs between two conductors, how the energy reacts will depend on the type of breakdown or failure. When dealing with two points in atmosphere (air), a point of partial discharge will occur at a voltage below the point where an arc would be drawn. If there is weakness between two points in insulation, the fault may react with some level of partial discharge, or may not and go directly to an arc. The amount of voltage required depends on the distance across the fault point, the material across the fault and the depth into the coil.

In smaller machines, there are a larger number of turns per coil and per phase. As the high energy impulse is applied to the winding, it dampens quickly across the first two to four turns of up to hundreds of turns per phase. In larger machines, the depth of penetration of the high energy impulse will vary by the design and size of the coil. This means that when the new winding or used winding voltage is applied, the surge may not detect weakness further than a few turns into the winding. Both found conditions or missed faults are frequent enough that those that support the technology and those who object to the technology in field applications can identify numerous examples. The user should understand that both situations are very possible.

When a breakdown does occur, it will happen at a specific voltage that relates to the severity of the fault. Typically, the minimum voltage to pass can be found in Formulae 1 and 2.

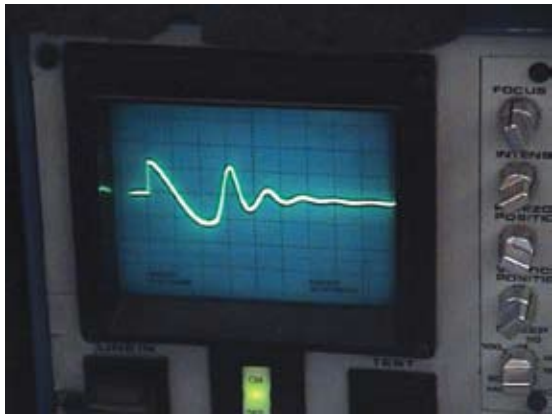


Figure 1 - Surge Waveform Phase to Phase Comparison

Formula 1 - New Winding Surge Voltage

$$Eapp = 2E + 1{,}000V$$

Where Eapp is the Surge Voltage and E is the motor nameplate rating.

Formula 2 - Used Winding Surge Voltage

$$Eapp = 0.75(2E + 1{,}000V)$$

When an electric machine has a rotor, the position of the rotor has a direct impact on the shape of the waveform and will be different for each phase. With a standard surge comparison tester, the position of the rotor must be adjusted whenever comparing two coils in an assembled machine. Newer technology surge comparison testers, used in field applications, electronically compensate for rotor position.

The size and voltage rating of the surge comparison tester will vary based upon the size of machine to be tested. Commonly if there are a number of medium voltage motors that will be tested, up to 6,000 Vac, a surge tester with

Figure 2 - Standard Surge Testing With Arc

a voltage limit of 12,000 V is used. If all of the motors to be tested are rated under 600 Vac, new testers are available with an upper limit of 2,000 V.

Winding Analysis with Surge Comparison Testing

When a winding is evaluated, and is in new and good condition, the waveforms associated with the condition of the machine will be identical between phases when electronically compensated. In fact, a new winding can often have voltages applied many times the maximum values calculated by either formula 1 or 2 without degrading the insulation system. It is not until energy crosses between conductors that any latent damage, or accelerated degradation, may occur.

As a result of the potential damage that may occur when weakness is found, the newer digital surge testers monitor for the point where partial discharge occurs, which, by eyesight, would be an unstable surge waveform. This is very important as previous testers relied upon user operation, as shown in Figure 3, which illustrates a human operator using a surge comparison tester on a failed insulation system. The fault point is shown in Figure 2 which

(cont. on Pg 26)

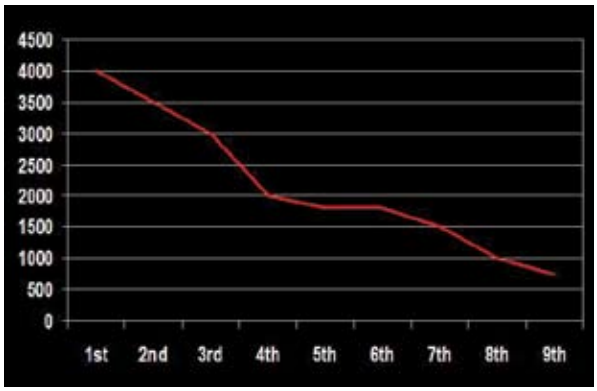


Figure 3 - Repeated Surge Impact Human Control

vb7™

$$V = \frac{f}{C^5}$$

There is a new equation in vibration analysis

Everyone defines **value** differently, our goal is to provide the best value in the industry. We define value as **features** divided by the **5-year** total **cost** of ownership. Support for life, no recurring update and support fees, robust hardware and the best software. **Contact us to experience first - hand, the latest in vibration analysis from Commtest.**

commtest
The Revolution

Call us on 865 588 2946
or toll free 877 582 2946
www.commtest.com

SPECIFICATIONS	vb7	REMARKS

ITEMS IN RED INDICATE A SIGNIFICANT CHANGE FROM THE VB3000 INSTRUMENT.

ALL SPECIFICATIONS ARE SUBJECT TO CHANGE WITHOUT NOTICE PENDING FINAL ENGINEERING APPROVAL **14 March 2007**

Sensor Input	2 channels	Simultaneous sampling
Sensors	Accelerometer, velocity, displacement, current	
AC coupled range	16 V peak-peak	Allows for ± 8 V sensor output swing (± 80 g)
DC coupled ranges	0 V to 20 V, -10 V to 10 V, -20 V to 0 V	E.g. for reading prox-probe gap
Connectors	BNC	Safety feature: break-free inline connector
Analog to digital conversion	24-bit ADC	
Sensor excitation current	0 mA or 2.2 mA (configurable), 24 V maximum	2.2 mA required for ICP® - type accelerometer
Sensor detection	Warns if short circuit or not connected	
Tachometer		
Sensor	Laser sensor with reflective tape included in kit	Sensor triggers when the tape reflects its beam
Laser sensor range	10 cm to 2 m nominal	Dependent on size of reflective tape
Other sensor types supported	Contact, TTL pulse, Keyphasor®	Instrument has optically isolated input
TTL pulse rating	3.5 V (4 mA) min, 28 V (6 mA) max, off-state 0.8 V	
Power supply to sensor	6 V to 8 V, 50 mA	Battery voltage with current limit
Keyphasor® threshold	13 V ± 1 V	
Speed range	30 RPM to 300 000 RPM (0.5 Hz to 5 kHz)	
Parameter Indication		
Maximum levels	>1000 g (10 000 m/s2), >1000 in/s (25 000 mm/s), 100 in (2500 mm), >10 000 amps	Effective limit is sensor sensitivity and output voltage
Dynamic signal range	> 95 dB (typical at 400 line resolution)	Acceleration and velocity
Harmonic distortion	Less than -70 dB typical	Other distortions and noise are lower
Units	g or m/s2, in/s or mm/s, mil or mm or µm	0-peak, peak-peak or RMS. Auto-scale by 1000x when required
AdB, VdB, amps	US and SI options for both adB and vdB	
Magnitude and cursors	Overall RMS value, dual cursors, harmonics	Digital readouts on chart
Accuracy	± 1% (0.1 dB)	For DC level (%F.S.) and AC measured at 100 Hz
Frequency response	± 0.1 dB from 10 Hz to 15 kHz; ± 3 dB from 1 Hz to 40 kHz	Acceleration and velocity. From value measured at 100 Hz High freq response also applies to DC ranges
Spectrum Display		
Fmax possible ranges	25, 50, 100, 125, 150, 200, 300, 400, 500, 600, 800 Hz 1, 1.2, 1.6, 2, 2.5, 3, 4, 5, 6, 8, 10, 15, 20, 30, 40 kHz	Or equivalent CPM values Or orders-based from 1X to 999X
Fmin possible range	0 to Fmax	Instrument zeroes all spectral lines below Fmin
Resolution	400, 800, 1600, 3200, 6400 lines	3200 lines max for dual channel measurements
Frequency scale	Hz, CPM, orders	Linear scale with zooming
Amplitude scale	Acceleration, velocity, displacement or current	Linear or log scales, auto or manual scaling.
Window shapes	Hanning, rectangular	
Overlap	(0, 12.5, 25, 37.5, 50, 62.5, 75, 87.5) %	Dependent on Fmax and number of lines
Number of averages	1, 2, 4, 8, 16, 32, 64, 128	Increases sampling time proportionally
Averaging types	Linear, exponential, peak hold, synchronous	
Demodulation bandwidths	20 bandwidth options	From 125 Hz to 1250 Hz up to 16 kHz to 20 kHz
Waveform Display		
Number of samples	1024, 2048, 4096, 8192, 16 384	
Time scale	10 ms to 256 seconds	Or orders based from 1 to 999 revs
Time synchronous averages	1, 2, 4, 8, 16, 32, 64, 128	Only available when tachometer triggered
Long time waveform	Up to 10 kHz Fmax	
Logging Features		
Output formats	LCD screen, transfer to Ascent PC-based software	
Data storage	1 GB non-volatile flash memory	Virtually unlimited recording storage
Data storage structure	Folders / machines / points / locations / routes	No limits are applied, 50 character names
Max folder size	10 000 measurement locations	
Keypad entry value range	± 999 999.999 999	50 character prompt string
Balancing	Planes 1, 2	
Speed range	30 RPM to 60 000 RPM	
Measurement type	Acceleration, velocity, displacement	
Weight modes	Angle 0° to 360°, fixed position, circumference arc	E.g. weights on fan blades, linear dist around circumference
Manual data entry	Yes	Allows re-entry of previous balance jobs
Storage	Against machines in data structure	No limits are applied
Display and Communication	Graphic grayscale LCD	
Resolution	480 x 320 pixels (HVGA)	
Viewing area	4.6" x 3.1" (117 x 79) mm	
Backlight	White LED, 4 V, 100 CD/m²	
Communications with PC	USB and Ethernet	PROFLASH allows instrument software to be upgraded
Battery and Charger		
Battery type	Custom Lithium Ion pack, 7.4 V, 4500 mAh	
Operating time	10 hours	Backlight on (60 second timeout)
Charger type	Internal charging, automatic control	External power pack 12 V DC, 3 A output, included in kit
Charge rate	3 A nominal	3 hours for complete charge
Mechanical		
Size	9.9" W x 5.8" L x 2.4" H (252 x 148 x 60) mm	
Weight	2.6 lb (1.2 kg)	Including strap
Environmental		
Operating temp	14 °F to 122 °F (-10 to 50) °C	
Storage temp and humidity	-4 °F to 140 °F (-20 to 60) °C, 95% RH	
EMC	EN61326	
Ruggedness	MIL-STD-810F-IV, 4' (1.2 m) drop onto concrete	Procedure: MIL-STD-810F-IV

was a deep-winding phase to phase short that was observable to the operator prior to surge application. The surge was applied repeatedly to the winding and stopped as soon as there was any deviation to the waveform which, to the human eye, only occurred when the arc was drawn.

The newer digital technology surge testers are designed to avoid this type of situation by identifying the variation in the waveform prior to the arc being drawn. This reduces the instances where the detection of insulation weakness causes immediate faults.

Baker AWA Tester

Two of the primary digital surge comparison instruments are the Electrom TIG instruments and the Baker Instruments Advanced Winding Analyzer (AWA). With the AWA providing a trendable phase to phase value, we will cover that instrument in this article.

There are two primary models, the AWA IV which has a 12,000 Volt limit and includes a built-in surge comparison tester, polarization index, DC Hi-Pot, insulation resistance and winding resistance testing. This unit weighs 42 pounds and requires a power outlet. The AWA II is a solution for users of smaller electric motors and includes the same tests with a 2150 Volt limit. This one weighs 18 pounds and also requires a power outlet. Both contain a software for trending, record keeping and troubleshooting.

Test	AWA II	AWA IV
Surge	0-2150 V, 200 Amp	0-12,000 V, 400 Amp
DC HiPot	0-2150 Volts	0-12,000 Volts
Insulation Resistance	Up to 50 Gig-Ohms	Up to 50 Gig-Ohms
Resistance	0.001 to 50 Ohms	0.001 to 50 Ohms

Table 1 - AWA II and AWA IV

Figure 4 - The AWA II

Comparison of Technologies

There has been a long battle of articles and papers by the manufacturers of both low and high voltage winding analyzers. To be quite blunt, the verbiage is presented in such a way that claims one or the other is either not effective or unable to live up to the manufacturer's claims. These discussions are, quite simply, market speak - as the users of each of the technologies will attest.

Following is a short summary of the strengths of each of the primary technologies' capabilities (in alphabetical order):

- ALL-TEST Pro, LLC: Manufacture the ALL-TEST IV PRO 2000 and ALL-TEST PRO 31 analyzers. Both are hand-held instruments that are focused on evaluating insulation degradation, contamination, insulation troubleshooting and rotor testing. While they each include an insulation to ground tester, this is not their primary focus. The ALL-TEST IV PRO 2000 instrument saves data in memory that can be uploaded and down loaded to software that provides data analysis and trending. Requires a minimal level of training for successful use.

- Baker Instruments: Manufacturer of surge comparison test instruments including the AWA II and AWA IV. The built-in software provides trending capabilities with a focus on insulation weakness due to insulation defects and wear. The insulation resistance test capabilities also test for insulation to ground weakness and built in limits provide an increased level of automatic protection which are designed to reduce the chance of damage and will stop testing if a fault is detected early enough.

- PdMA Corp: Manufacturer of the MCE instrument which is portable and includes a laptop. The focus of this instrument includes insulation to ground testing, winding contamination and rotor testing with the ability to detect later stage turn insulation faults. This instrument requires a medium level of training and experience for successful use.

All have the capability of testing AC induction motors from the motor control center, disconnect or right at the motor. Each will detect cable faults as well as motor winding faults and each will detect insulation faults in advance of failure.

Conclusion

Advanced winding analysis troubleshooting and trending techniques for electrical machine insulation testing are extremely important for improved reliability of industrial, commercial, utility and manufacturing firms. At the present time, there are three primary off-line motor diagnostic technologies including: ALL-TEST Pro, LLC, Baker Instruments and PdMA. Each of the technologies has specific strengths and capabilities which should be selected based upon the particular site's needs.

The purpose of these last two articles has been to outline the basic concepts of each technology and their specific strengths and concerns.

Howard W Penrose, Ph.D., CMRP, is the President of SUCCESS by DESIGN Reliability Services. SUCCESS by DESIGN specializes in corporate maintenance program development, motor management programs and maintenance and motor diagnostics training. For more information, or questions, see http://www.motordoc.net, contact info@motordoc.net or call 800 392-9025 (USA) or 860 577-8537 (World-Wide).

Balancing The Options

A Guide to Instrumentation for Balancing

by Victor Wowk

The majority of dynamic balancing instruments measure the vibration, or oscillation, of a stationary structure like a bearing housing. So theoretically, any vibration measuring instrument can be used for mass balancing, with the appropriate choice of method to match the capabilities of the instrument. The non-uniform mass distribution around the rotating center creates the centrifugal force that transfers to the stationary structure. The bearing gets "beat up" in the process. If the mass distribution was perfect, then there would be no centrifugal force, hence no vibration. Perfect balance is undetectable because there would be no vibration to measure. That's a little theory to stimulate your philosophical neurons.

However, the real purpose of this article is to provide some knowledge to help you make intelligent purchase decisions. Some instruments work better than others, and there is a wide range in cost. There appears to be no correlation between cost and performance. Low-cost instruments achieve just as good balance results as much more expensive ones. Low-cost instruments tend to be easier to learn and easier to use by not introducing confusion with added features.

Before introducing electronic balancing instruments, it is worthwhile to discuss the default option. It is possible to mass balance with no instruments.

No Instruments

Static balancing, whether on a stand or in-place in the machine's own bearings, is a method that requires no measuring instruments at all. It is a trial-and-error method that corrects for single-plane only, but it works.

Timed oscillation is another method closely akin to static balancing. It requires only a stopwatch and a weighing scale. It has been used to successfully balance large and heavy rotors weighing up to 20 tons[1].

The pencil-marking method only requires a pencil (or other marker) to identify the "high spot" on a rotating shaft. It was used successfully for decades prior to electronic vibration-measuring instruments, and is still described in some current manuals for equipment installation.

Generic Electronic Instruments

To measure unbalance vibration, without contamination from other sources, I need a filtered amplitude at rotating speed. Modern electronic instruments begin with a transducer that converts physical motion into an electronic voltage variation. The transducer can be an accelerometer, velocity sensor, or proximity probe. Proximity probes are only used where they come installed by the equipment manufacturer. They are never used in portable field-balancing instruments, or on balancing machines. Velocity sensors are the most sensitive, and are the preferred transducer for balancing because of their natural amplification of low-frequency motion below 61 Hz (3,660 rpm). Accelerometers have advantages of smaller size and lighter weight, to get into tight places. Both velocity transducers and accelerometers can be used for balancing with equivalent results.

The varying voltage signal from the transducer is filtered to the rotating speed. This can be done with an analog box or a digital box. The analog instruments are an older technology. They are easier to learn, less costly, easier to use, and faster. However, beware that the amplitude reading can be in error when the battery voltage drops below a lower limit.

Digital boxes maintain the correct accuracy until they blink off due to low battery voltage. The digital boxes generally cost more, but have more useful features, like averaging and memories. A low-frequency spectrum analyzer makes an excellent balancing instrument and has the added benefit of doing vibration analysis on the spot by seeing all vibrations simultaneously. It is, however, a complicated instrument to learn, and difficult to use with confidence.

If the influence-coefficient method is being used to balance, then I also need a phase measurement. This can be acquired with a strobe light or a photosensor observing reflective tape on the rotor. The strobe light requires line-of-sight access to the rotor and can be difficult to see in strong outdoor light conditions,

like cooling-tower fans. The strobe light is faster to use, and typically comes with analog instruments. The photosensor requires some extra time to set and string cables. It also requires stopping the machine to attach photo tape, then restarting, before the first phase measurement can be acquired. All these extra steps with the photosensor make it slower to balance.

A weighing scale is desirable to accurately weigh test weights and correction weights. It is, however, possible to mass balance without a scale. In that case, the correction weights are a ratio of the test weights, and the balancer then has to figure out how to come up with *x* times the test weight. All professional balancers carry a portable weighing scale.

The last generic instrument is something that simply provides a means to calculate the correction weight amount and location from the vibration measurements. This could be:

a. A protractor, compass, and handheld arithmetic calculator when using the 4-run method.

b. Vector graph paper, a protractor, and handheld calculator for the single-plane influence-coefficient method of balancing.

c. A programmable calculator or laptop computer when doing 2-plane balancing.

d. The calculator capability can be on-board the balancing instrument. The balancer presses a button when he/she is satisfied with the stability of the vibration measurements. The instrument loads the new data into a matrix, then automatically calculates the correction-weight amount and location when the matrix is full.

Shop-balancing instruments are basically the same as field-balancing instruments. In fact, when purchasing a balancing machine, it is wise to only consider those machines with detachable instruments if field balancing is a possibility in your future.

Minimum Instrumentation

The minimum instrumentation to mass balance could be zero if one of the methods above under "No Instruments" is used. If I wanted to balance using a vibration measurement, then the minimum could be a velocity sensor and an AC voltmeter. This could cost as little as $ 200. With this simple amplitude measurement, I could balance very successfully single plane using the 4-run method without phase. Any overall vibration meter could do the same thing.

To refine the measurement to unbalance only, I could use a tunable-filter instrument to obtain the filtered amplitude at rotating speed. There are many older analog instruments on the used market and they work very well. If the tunable-filter instrument also had a strobe light, then I could obtain amplitude and phase measurements, and have the capability to do 2-plane or multi-plane balancing using the influence-coefficient method. The calculation capability for matrix calculations using the influence-coefficient method is now public domain software and downloadable over the internet.

Honestly, we at Machine Dynamics prefer not to use phase measurements for balancing unless it becomes necessary. Phase is the more difficult measurement to take and is the least accurate. Phase is only necessary for 2-plane balancing using the influence-coefficient method. Two-plane balancing is only required to correct for couple unbalance when serious cross effect is present. We prefer to keep things simple and single plane, which is about 70 percent of all balancing in the field.

There are also times when phase measurements are not wanted. That is when the phase is not stable (i.e., it varies 10 degrees or more). It is also prudent to abandon phase measurements when the first correction weight does not make at least a 50-percent improvement in vibration. The matrix could be ill-conditioned and the influence-coefficient method may not converge at all. All modern balancing instruments have phase-measurement capability and focus on the influence-coefficient method, sometimes exclusively. This is a warning about modern instruments.

There is another method to do 2-plane balancing without phase measurements, that compensates for cross effect and couple unbalance simultaneously[2]. The static-couple method can also be used for 2- or 3-plane balancing using single-plane calculations without phase measurements.

Maximum Instrumentation

There have been no significant improvements in balancing instruments for over 30 years. The recent introductions have been stylistic changes, with colorful displays and report-generation capability. The most significant improvement came in the 1970's with the tracking filter. This is a bandpass filter that stays centered on the rotational speed. It is usually implemented in digital instruments with a photosensor phase measurement (which provides a tach signal to measure speed). This stabilizes the amplitude and phase measurement as the machine speed changes. It also improves the stability of measurements near resonances, which have been the bane of balancing. The tracking filter came from radio technology.

I would not purchase any modern balancing instrument unless it had a tracking filter. The

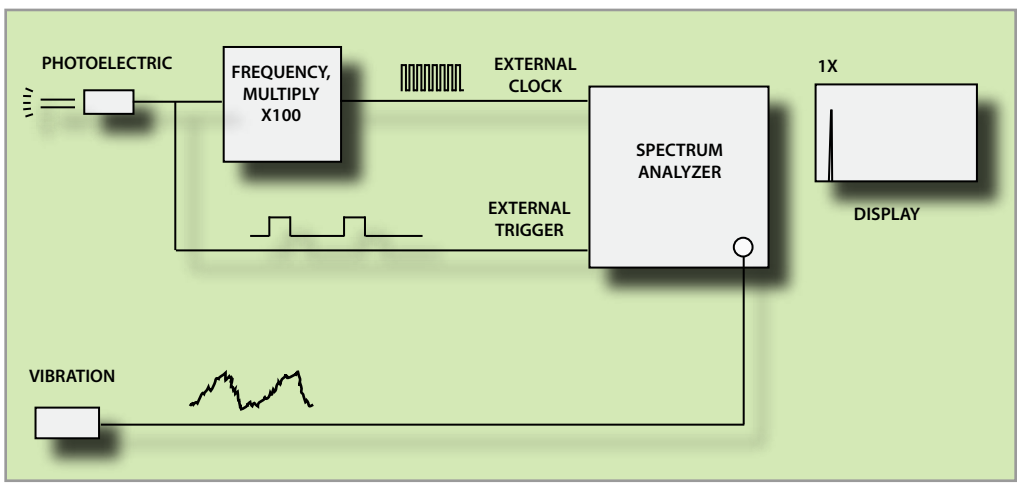


Figure 1 - Simulated tracking filter with a spectrum analyzer and a frequency multiplier.

way to test for this is to vary the machine speed and observe how much the amplitude, and especially phase, changed. A good tracking filter will show gradual amplitude changes as the centrifugal force grows or declines with speed, but negligible phase change unless a resonance is encountered. A simulated tracking filter has been incorporated into modern FFT based spectrum analyzers with a frequency multiplier and a phase locked loop, Fig 1.

Another technique to enhance the balance measurement is the wattmeter. This is illustrated in Figure 2.

A wattmeter receives voltage at one input, and current at a second input. The two are multiplied together to display power in watts. For balancing purposes, the voltage input can be from a velocity sensor and the current input from a generator, or alternator, being driven by the rotor to be balanced. The sine wave from the alternator, when applied to the complex vibration voltage, greatly emphasizes the amplitude at rotating speed. This technique, using an oscillator whose frequency is adjusted by the tach-speed signal, is still used in some balancing instruments, even though it is an old technique dating from the 1920's. It improves the signal-to-noise ratio on hard-bearing balancing machines, but is usually not necessary elsewhere.

The maximum-cost balancing instruments will have the capability for multiple sensors to do multi-plane balancing. They will also have the capability to build a larger matrix from multiple speeds and to average the data for a best-fit solution. This is useful for flexible-rotor balancing.

The best instruments will also have memories to store sensitivity vectors for one-run balancing on the same machine again in the future.

Conclusion

The instrument that measures vibration is the least significant factor determining balance results. Almost any instrument will do with the proper method. The person taking the measurements, selecting methods, and recognizing when things are not going well, is the most significant factor in obtaining good balance.

Vibration-measuring instruments are mature for balance purposes. Even 50-year-old instruments can easily measure to low enough levels to achieve excellent balance. In my opinion, no further improvements in sensitivity are required for balance instruments. There is room, however, for improvements in the methods.

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 every year in Phoenix. Schedules are posted at www.machinedyn.com.*

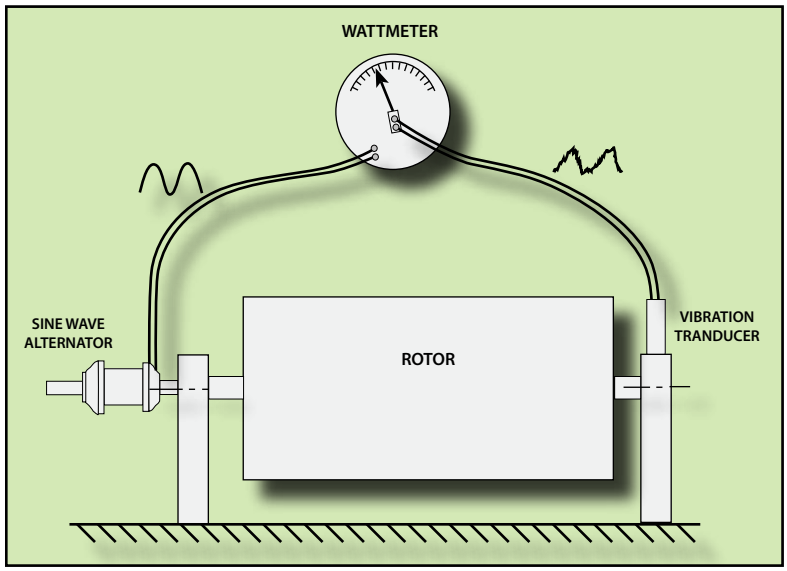


Figure 2 - The wattmeter method of measuring vibration heavily weighted to the rotating speed.

1. R.S. Beebe, MCM Consultants, Machine Condition Monitoring, 2001 reprint. ISBN 0646250884.

2. Louis J. Everett, "Two-Plane Balancing of a Rotor System Without Phase Response Measurements," Transactions of the ASME Journal of Vibration, Acoustics, Stress and Reliability in Design, April 1987, Vol. 109, pages 162-167.

Shine a Spolight on Your PdM Program

Categories

Best Infrared Thermal Imaging

Best Lubrication/Oil Analysis

Best Motor Testing

Best Precision Maintenance
(Alignment/Balancing)

Best Ultrasound Inspection

Best Vibration Analysis

Best Total PdM Program

Enter the 2nd Annual Uptime

PdM Program of the Year

Awards

Uptime Magazine is devoted to Predictive Maintenance and Machinery Condition Monitoring. Part of our mission is to promote and acknowledge best practices. We have created the Uptime PdM Awards to provide positive exposure and acknowledgement for predictive maintenance professionals from around the world.

Any company with an active PdM program can enter. We expect that you have been performing some sort of PdM for at least one year. If you are just getting started – you should consider entering at this time next year!

There is no cost to enter. This is not a commercial activity – it fulfills our mission to promote excellence in predictive maintenance. International entries are encouraged.

Each winning company will get a handsome award trophy, two free passes to PdM-2007 The Predictive Maintenance Technology Conference, acknowledgement in front of peers at the award presentation (Sept 12) and an exclusive invitation to a special winners award dinner.

Entry due date June 1st

For more details and for an application to enter go to

www.uptimemagazine.com

Hazardous Hydrogen

Find Leaks Safely with Ultrasound & Low Surface Tension Liquids

by Jim Hall

For years I have been entering plants to sell airborne ultrasound instruments for predictive and preventative maintenance. But, it doesn't seem too long ago that I was a young U.S. Navy sailor, an Airdale - not a Black Shoe and proud of it. As an aviation mechanic specializing in egress, my job was to work around ejection seats (explosive charges) and produce liquid oxygen and nitrogen. Both of these processes can kill you quicker than a New York minute.

As a young man, I learned early on to have a healthy sense of fear and respect for the things around me. Today, especially in a power plant, I find myself looking over my shoulder, well ahead of where I am walking and all around my feet. That is, visually looking for signs of problems. Unfortunately, problems are not always visible. Hydrogen gas is frequently the choice of most generating plants to help cool the turbine during the generation of electricity (Figure 1). To help extend the life of associated equipment and the generators themselves, hydrogen is used to help dissipate the heat, a by-product of producing electricity. Hydrogen has a high heat capacity and therefore removes the heat quite effectively. Hydrogen needs to be kept free of moisture. The presence of moisture means the gas will not remove the heat as efficiently. Moisture also increases the danger of arcing. The voltage within this area can be as high as 12,000 volts (12kV). So, an arc may not only damage the generator, but could possibly ignite the hydrogen gas and cause a serious explosion.

Airborne Ultrasound Instruments

Airborne ultrasound is known by most as a leak detector first, and a predictive and/or preventative maintenance instrument second. So why not use this instrument effectively in your power plant?

In order to use an ultrasonic instrument in your plant, I would highly recommend that you first acquire an intrinsically safe or IS rated ultrasonic receiver. That is, an instrument that will not create a spark. Preferably, one rated Factory Mutual or the equivalent, Class I, Division

Hydrogen-gas leak causes fire at power plant

Friday, February 9, 2001 - Hydrogen gas leaked into an electrical panel causing a fire yesterday at Toledo Edison's Bayshore power plant in Oregon, Richard Wilkins, an Edison spokesman, said.

Plant workers said they heard a loud noise about 5 p.m. They found that hydrogen used to cool turbines at the plant had ignited inside a circuit panel.

That caused a fire that the plant spokesman described as "a little smaller than a bushel basket." It was extinguished by the plant's fire brigade about 5:20 p.m. There were no injuries, and Edison and local fire officials had no damage estimate last night.

One of the plant's four turbines was shut down because of the fire, but a plant spokesman said the closing had no effect on Edison's power generation. Firefighters were called to back up the plant's fire brigade, but they did not participate in extinguishing the fire, local Fire Chief said.[1]

One Dead, 45 Hurt from Hydrogen gas explosion

Thursday, April 8, 1999 - Early Thursday morning around 7:15 am, an explosion blew the outside shell of the turbine off. "One person has died after the outside shell collapsed upon him," a spokesman said. "The cause of the fire appears to be a generator they were testing, a possible hydrogen gas leak."

The fire was brought under control within 15 minutes after the explosion occurred, a rescue worker said. Forty-five people were hurt, 33 of them taken to area hospitals for treatment. Several suffered serious to severe burns.

Note: Several weeks later another newspaper published a report that the explosion had been caused by a worker who forcibly removed a cap on the generator that had been shut-down for scheduled maintenance. The turbine/compressor building still had hydrogen stored in it. A total of three people died from this accident.[2]

Figure 1 - Hydrogen Gas is used within the compressor housing.

I, Groups A, B, C & D. These instruments are readily available, so ask the manufacturer of your instrument if, in fact, your instrument is IS rated.

WARNING: *Only use an Intrinsically Safe Rated (IS) instrument for hydrogen leak detection. Check with your safety team leaders to see if the instrument you use meets the Intrinsically Safe Rating for hydrogen-gas leak detection.* Most of today's airborne ultrasound instruments are digital, they have a large digital display, bright lights and internal data-loggers - all of which require a large battery source to power the unit. These units are not IS rated. If your ultrasound instrument does not say IS rated, then it is not safe to use for this application.

Figure 2 - Access plate/door, inspected and found 6 hydrogen leaks around bolts.

Low-Surface Tension Surfactant

A low-surface tension surfactant or wetting solution can be used for hydrogen leaks in areas outside of the enclosed areas of the turbine housing. For instance, the access plates, shown in Figure 2, are notorious for leaks. Many of the leaks in these types of plates are caused by bolts with improper torque. The areas around the bolts are exposed to ambient air, and can be leak checked using a low-surface tension liquid wetting solution by simply spraying the liquid on the bolts and visually inspecting for bubbles. It's important, however, not to be fooled by the size of the bubbles.

Most low-surface tension surfactants leave very tiny bubbles that often resemble a line of very small white spider eggs or a piece of white thread under and around the bolt's head. If you have trouble seeing any bubbles, that doesn't mean there is no leak present. You should then use the airborne ultrasound instrument to listen for the bubbles.

When using an ultrasonic receiver the bubbles will sound something like a bowl of Rice Krispies, you know, "snap, crackle and pop", but, a thousand times over.

On a recent inspection of an access plate (shown in Figures 3 and 4), I had no trouble seeing the bubbles after the liquid had been applied. Since it has such a low-surface tension, this liquid does not typically fall off or dissipate from the leak site quickly. The bubbles can usually be seen and/or heard for several minutes. For more information about low-surface tension surfactants, review the April issue of Uptime Magazine and/or consult with the manufacturer of your ultrasound instrument for information as to where you can purchase and/or receive a copy of the Material Safety Data Sheet (MSDS) report. Always keep a copy with you and always provide a copy of the product's MSDS to your Plant's Safety Director or safety personnel contacts for approval to use within your plant.

Figure 3 - Note the tiny white bubbles on bolt head. These bubbles could also be heard with the ultrasound receiver.

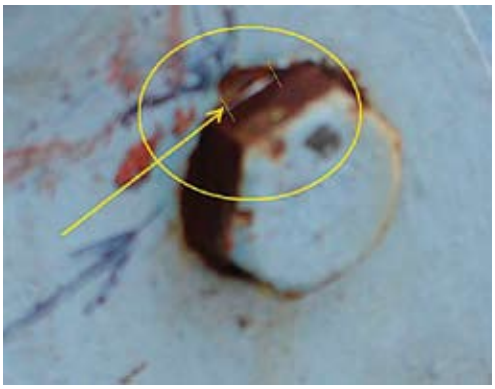


Figure 4 - Note the tiny white bubbles on bolt head. These bubbles could also be heard with the ultrasound receiver. Between the two yellow marks.

Hydrogen Sniffer

Although a gas specific detector (in this case a detector built specifically to detect hydrogen gas) is always best to use, the ultrasound receiver and low-surface tension liquid can also be very effective. Sometimes the hydrogen gas specific detector will not pick up the trace gas, especially when scanning outside the turbine/compressor housing. The trace gas can easily be blown away before the leak is identified.

As shown in Figure 5, I used the rubber cone from my ultrasonic detector's kit and adapted it to my gas specific detector to enable me to surround the bolt head to detect the presence of the hydrogen gas.

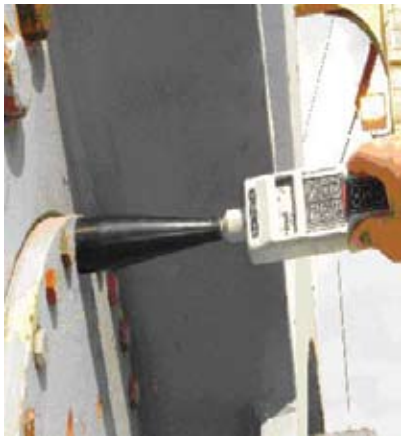


Figure 5 - Using a gas specific detector to locate hydrogen leaks around access plates.

Where Is Your Ultrasound Instrument?

The fact is most of you reading this article probably have an ultrasound instrument within your plant. Where is it? Have you checked lately? Have you become familiar with how to use that instrument?

Safety Note:
Always keep a copy of the Material Safety Data Sheet (MSDS) for any product you would like to use and always provide to your Plant's Safety Director or safety personnel contact for approval to use within your plant.

Get familiar with how to use an airborne ultrasound receiver. These instruments are easy to use and are relatively inexpensive. Remember, your airborne ultrasound instrument is a high frequency receiver, therefore sounds above the human hearing range can be heard relatively easily. In a plant environment, and most compressor/turbine areas, airborne ultrasound has been proven repeatedly to be very effective in locating hydrogen leaks, bleed air leaks, condenser water box leaks, heat exchanger leaks (on-line & off-line), expansion joint leaks, steam leaks, cryogenic gas leaks, and pressure/vacuum or in-leakage leaks.

1. The Toledo Blade - http://www.toledoblade.com/apps/pbcs.dll/artikkel?Avis=TO&Dato=20010209&Kategori=NEWS17&Lopenr=209002&Ref=AR

2. Reuters, April 8, 1997.

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 the new 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.

All photos provided courtesy of Ultra-Sound Technologies, Woodstock, GA.

Restrained by Resonance

Frequency Limitations Resulting from Mounted Resonance of an Accelerometer

By Jack Peters

Accelerometers are some of the best diagnostic sensors available today to measure machine vibrations and assist the trained analyst in the diagnosis of a potential problem developing with the machine. Faults such as imbalance, misalignment, bearing failure, gear failure, flow disturbances, or blade passing disturbances are just some of the many problems that can be detected with an accelerometer. All of these faults are sensed by the accelerometer through surface to surface contact with the machine.

Transmission of vibration from the machine to the accelerometer is only as good as the mounting of the accelerometer allows. Poor mounting methods can severely limit the ability of the accelerometer to measure those vibrations that it was designed for. Typical industrial accelerometers have usable frequency ranges as high as 15 kHz (15,000 cycles/second) or 900,000 CPM (cycles/minute). To achieve the full use of this upper frequency limit, the mounting must be very good to avoid a characteristic known as "Mounting Resonance".

Mounting resonance is a direct result of lowering the accelerometers natural frequency and occurs as the result of reduced stiffness or increased mass. This is probably best described by viewing the formula where the stiffness is expressed in the numerator, and the mass is expressed in the denominator:

$$f_n = [1/(2\pi)] \sqrt{k/m}$$

Where: fn = natural frequency
k = stiffness
m = mass

Accelerometer Natural Frequency

Initial design and construction of the accelerometer involves a much higher natural frequency than the usable range. This allows for tolerances to be placed on the usable range of +/- 5%, +/-10%, or +/- 3dB. Stiffness is accomplished by the rigid mounting of a piezoelectric element inside of the accelerometer. The size of the mechanical mass used to exert a force on the piezoelectric element, and provide the source of excitation, is based on the desired frequency output of the accelerometer. A lighter mass will produce a higher natural frequency, and a heavier mass will produce a lower natural frequency. Of course, a lighter mass will produce less force, and a heavier mass will produce more force, so the size of the mass is carefully balanced for frequency and amplitude characteristics.

Figure 1 is typical of a natural frequency response for an accelerometer. The regions of transmission, amplification due to resonance, and isolation have been marked for clarity.

Functionality

The transmission region is the functional region for the accelerometer. The degree of accuracy within this region is described by the amplitude tolerances of +/- 5%, +/- 10%, and +/- 3dB. Although +/- 5% has the best amplitude tolerance, it will also have the smallest transmission region. The largest transmission region will occur at the +/- 3dB amplitude tolerance, but put into linear units this is approximately -29.3% or +41.3% in amplitude tolerance.

Initially the +/- 3dB tolerance would seem to be excessive, but it is used consistently in the industry with a

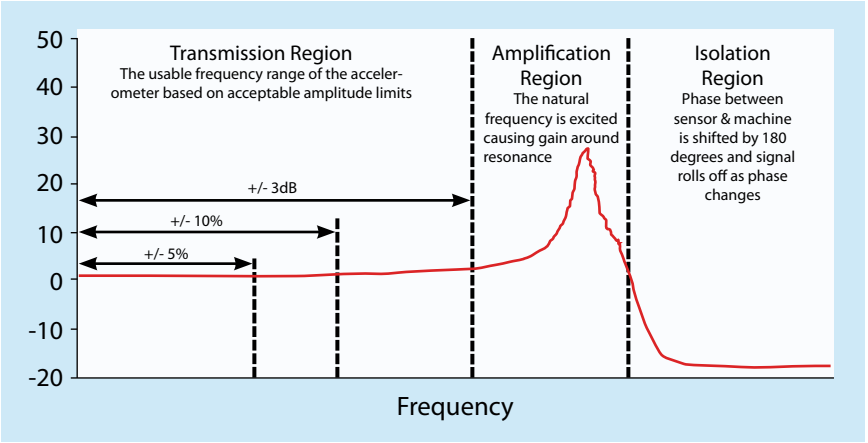


Figure 1 - Typical Natural Frequency Response of Accelerometer

great deal of success. These tolerances are produced during the manufacturing of the accelerometer, and are essentially fixed for the life of the accelerometer provided it does not get damaged. Since most programs are based on trended history, and not absolute amplitude, the application of a +/- 3dB tolerance is acceptable.

The amplification region is the direct result of excitation of the natural frequency and occurrence of resonance. This region is capable of producing very large gains in the vibration signal, which can cause the vibration levels to appear much higher than they actually are.

Typically, the data in the amplification region is not used because it is not repeatable. There are some techniques that do use the amplification region to achieve early warning of mechanical faults through high frequency detection, but they will not be discussed at this time, and are best left to various manufacturers of vibration instrumentation that are applying them in several different application programs.

The isolation region is an area of phase shift and signal loss. A phase shift of 180 degrees occurs after passing through resonance. Errors in the vibration amplitude and phase will occur when operating above the natural frequency.

Mounted Resonance

Under ideal circumstances, the accelerometer mounting should provide total use of the transmission region. Although this is an excellent goal for any analyst to have, it is totally dependent on the mounting method used. Remember, the natural frequency of an accelerometer is based on its stiffness and mass, and anything that modifies these characteristics during the mounting of the sensor will shift this natural frequency. Unfortunately, this shift in resonance always reduces the usable range of the accelerometer. The accelerometer is not broken, or any less worthy than it was designed, it is just altered during the mounting process.

There are several different mounting methods available. Figure 2 is a manufacturer's chart indicating some of these methods, and the expected usable frequency ranges for the transmission of machine vibrations to the accelerometer.

Relative to Figure 2, there are a couple of methods that are used much more than the others, and this investigation will look at the resulting changes in mounted resonance for each of them.

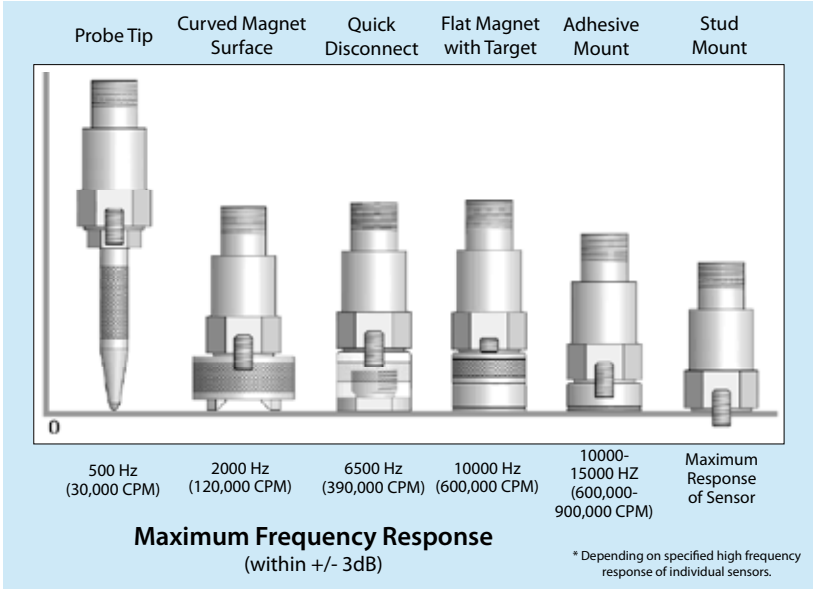


Figure 2 – Mounting Methods and Usable Frequency Range

The curved surface magnet, sometimes referred to as a two bar or two pole magnet, is probably the most popular method of mounting for portable vibration measurements. It fits well on curved surfaces like bearing housings, and quickly lets the vibration analyst mount it in the vertical, horizontal, or axial locations of each bearing. Typically the curved surface magnet will offer usable transmission of vibration up to 2000 Hz. Stud mounting requires a smooth machined surface with a drilled and tapped hole. This type of mounting is best suited to permanent vibration monitoring where an accelerometer will be installed and left on the machine for each and every location that vibration will be measured. This is often referred to as the reference mounting because it will typically provide a usable transmission of vibration up to the limits of the accelerometer.

Analysis of the Two Mounting Methods

In order to analyze these two methods of accelerometer mounting, there will need to be some vibration instrumentation and techniques employed to simulate a vibrating machine.

- A vibration shaker, with a calibrated standard reference accelerometer built into it, will be used to simulate the machine vibration. It will provide a controlled vibration disturbance across the entire frequency range of the test. The reference accelerometer will be considered as the input, and compared to the accelerometer under test (output). The shaker used for this application note was limited to 10,000 Hz.
- A function generator will be used to drive the shaker with random noise and simulate the multitude of vibration disturbances common to industrial machines. It would be very rare to have a machine that generates only one vibration or frequency disturbance, and the application of random noise will provide a better simulation of industrial machinery vibration.
- An accelerometer to test using the desired mounting method on the shaker.
- A dynamic signal analyzer will be used to capture the data, and display the results of the test in five different formats.

1) The power spectrum (FFT) of the reference accelerometer indicating amplitude vs. frequency. (Input)
2) The power spectrum (FFT) of the test accelerometer indicating amplitude vs. frequency. (Output)
3) The frequency response generated by dividing the output of the test accelerometer by the input of the reference accelerometer. The ideal response in amplitude would be a value of one (unity gain), but it will also indicate the gain produced at resonance.
4) The coherence indicating the percentage

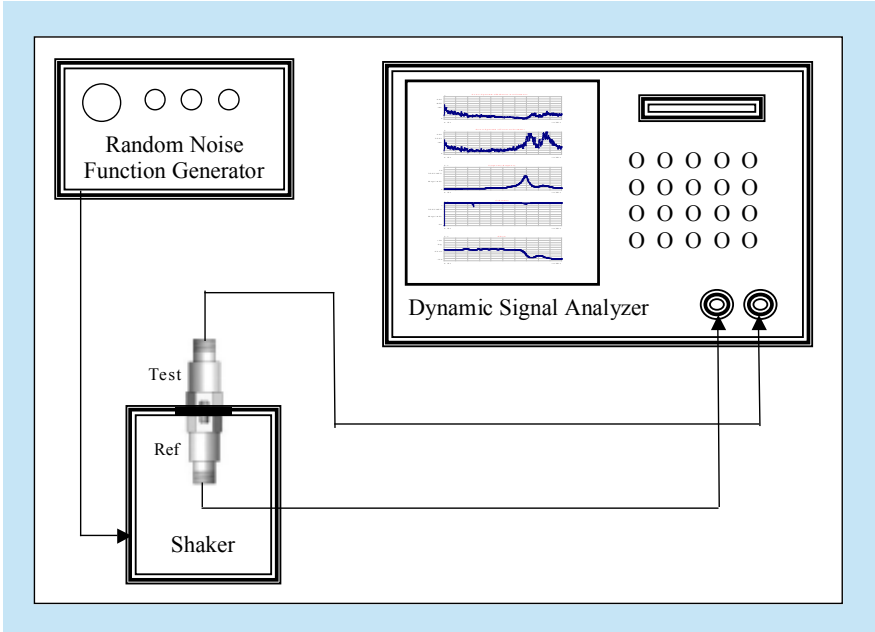


Figure 3 – Test Set-up

of output of the test accelerometer that is related to the input of the reference accelerometer. This is often referred to as Linear Causality.

5) The phase between the two accelerometers. The reference accelerometer and test accelerometer should be in phase with each other in the transmission region and prior to resonance. After resonance, these two sensors will be out of phase with each other.

As shown in Figure 3, the random noise function generator supplies the electrical signal to drive the shaker. The reference accelerometer is built into the shaker and the test accelerometer is mounted on top of the shaker. The signal for the reference accelerometer is applied to channel one of the dynamic signal analyzer, and the signal for the test accelerometer is applied to channel two of the dynamic signal analyzer. Channel one and the reference accelerometer will be considered the input for testing purposes. Channel two and the test accelerometer will be considered the output for testing purposes. The mounting method under test will be applied between these two accelerometers and the output compared to the input.

Stud Mounting

Stud mounting is accomplished with a drilled and tapped hole using a threaded fastener between the accelerometer and the machine. During testing and calibration, this is often referred to as "back to back" mounting. The accelerometers are essentially bolted together on the shaker, with the shaker table in the middle between them. Figure 4 is an illustration of the back to back mounting technique.

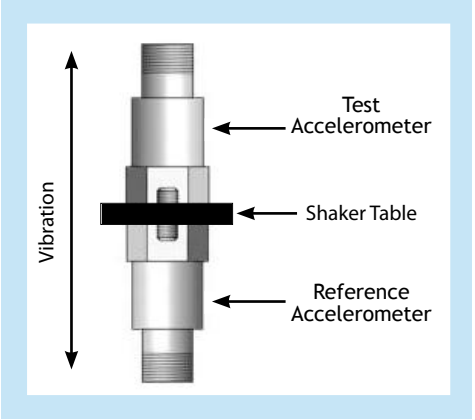


Figure 4 – Back to Back Accelerometer Mounting on Shaker Table

The application of random noise from 0-10,000 Hz will cause the shaker to oscillate (vibrate) both sensors simultaneously. In this manner the two sensors can be compared to each other with the dynamic signal analyzer. Figure 5 represents the results obtained with the back to back mounting method.

Analysis of the data measured in Figure 5 indicates that the power spectrums for the reference accelerometer and test accelerom-

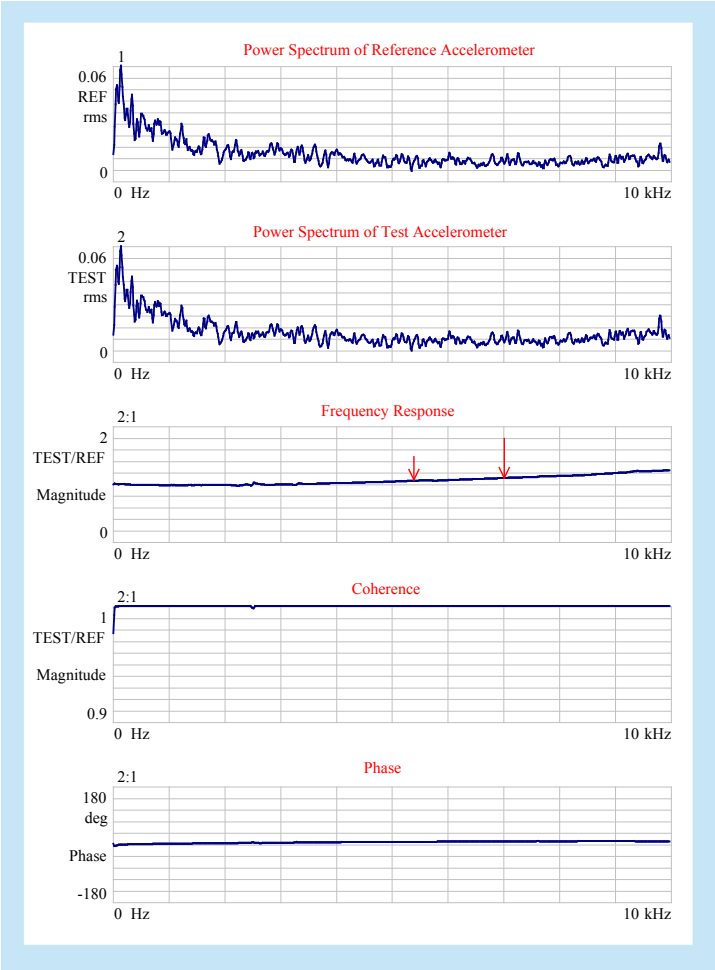


Figure 5 - Back to Back Mounting Results

eter are almost identical. Frequencies and amplitudes are well matched in both power spectrums.

The frequency response approximates a gain of one, with the +5% limit at 5,402 Hz, and the +10% limit at 7,037 Hz. The +3dB limit was never exceeded. This would provide a transmission range, within the 3dB limit, up to at least 10,000 Hz and probably higher if it had been within the scope of the measurement and shakers capability.

The coherence is very good and provides an indication that 100% of the vibration measured by the test accelerometer was caused by the shaker and reference accelerometer.

The two sensors are in phase with each other, and indicate that they are operating below resonance.

Magnet Mounting

The curved surface magnet has the accelerometer attached to it by a threaded stud. However, when the assembly is placed on the machine to measure vibration, the attachment to the machine is accomplished by two magnetic bars. Transmission through the magnet is accomplished by two lines of contact and the pull force of the magnet. This provides limited surface area and stiff-

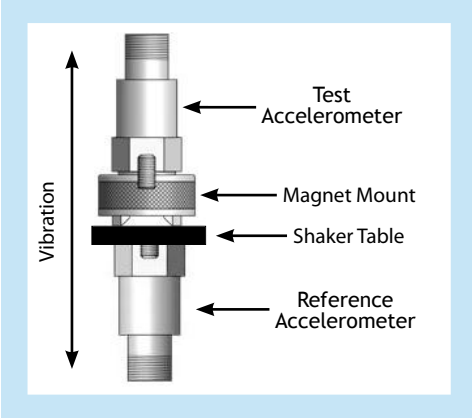


Figure 6 - Magnet Mounting Accelerometer on Shaker Table

ness for the assembly. The magnet itself adds significant mass to the accelerometer. The loss of stiffness and the increase in mass will reduce the resonant frequency of the sensor and magnet combination. This mounted resonance will be much lower than the capabilities of the accelerometer without the magnet. Figure 6 illustrates the magnet mount and reference accelerometer for testing purposes.

The application of random noise was again applied to the shaker over the frequency range of 0–10,000 Hz. The same measurements were made on the magnet mounting that had been previously made on the stud mounting. Figure 7 represents the results obtained with the magnet mounting method.

Analysis of the data measured in Figure 7 indicates that the power spectrums for the reference accelerometer and test accelerometer are very different. Amplitudes are significantly higher in the test accelerometer above 5000 Hz.

The frequency response is limited to a transmission range below the resonant frequency of 6,937 Hz. The +5% limit is 1,537 Hz, the +10% limit is 1,875 Hz, and the +3dB limit is 3,487 Hz. The resonant frequency at 6,937 Hz has a gain of 12.32. If an amplitude of 1 inch/second were applied to the shaker at 6,937 Hz, the mounting resonance would cause a vibration measurement of approximately 12.32 inches/second on the output of the test accelerometer.

The coherence is very good and provides an indication that 98% of the vibration measured by the test accelerometer was caused by the shaker and reference accelerometer. Keep in mind that the amplitude of the signal is displayed in the frequency response, and that the coherence is a measure of causality.

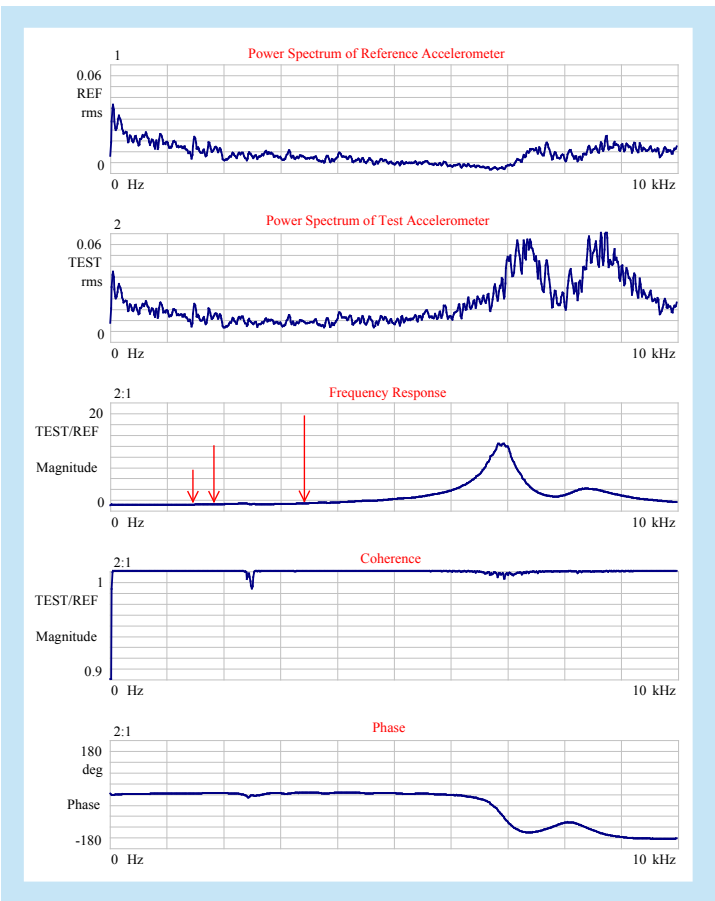


Figure 7 - Magnet Mounting Results

The two sensors are in phase with each other below 6,937 Hz, and out of phase with each other above 6,937 Hz. Above resonance, if the test accelerometer is measuring a positive going signal, then the reference accelerometer is measuring a negative going signal. Essentially, above resonance they are out of phase.

Summary

It is difficult to match the typical performance in Figure 1 with the actual results in Figure 7. Small

inconsistencies in the mounting methods, system performance, and broad frequency response at resonance in the actual measurement prevent ideal correlation to the typical performance characteristics. These small inconsistencies are faced on a daily basis by the vibration analyst. It does not take away from the testing though, and, in actuality, the typical performance is well represented by the outcome of the testing.

Back to back mounting of the two sensors provided a very wide transmission range, and even at 10,000 Hz, the +3dB limit was not exceeded. This clearly indicates that stud mounting the accelerometer to the machine would give the best possible frequency response, and is an ideal method for permanently mounted accelerometers. A flat prepared machine surface with a drilled and tapped hole, to mount the accelerometer stud, should provide the full frequency range of the accelerometer's design specification.

Recommendations for curved surface magnet mounting are typically limited to a maximum of 2,000 Hz. Testing for this investigation actually yielded a +3 dB limit of 3,487 Hz. This improved result is probably caused by the flat surface of the shaker table. The two bars in the magnet had significantly more surface area and better stiffness on a flat surface than the lines of contact that would be experienced on an actual curved bearing housing. The mounting resonance was identified, and the reduced transmission range was apparent. Although the curved surface magnet is very useful and convenient for portable vibration measurements, the user needs to be aware that the frequency response is limited, and amplitudes at mounted resonance will be higher than expected, and amplitudes above resonance will be lower than expected and out of phase.

There are other portable mounting methods that will provide increased transmission ranges, A quick disconnect or flat surface magnet are excellent examples. However, each of these designs requires surface preparation and the mounting of a permanent target to achieve as much surface to surface contact and stiffness as possible. If portable data collection requires the measurement of vibration above 2,000 Hz, then one of these alternatives should be considered.

Bibliography

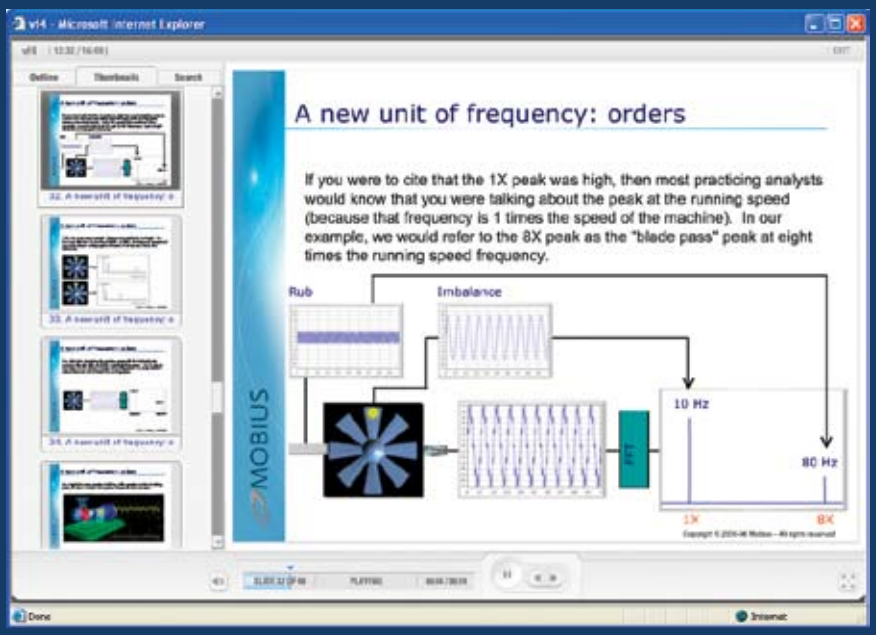
- *Effective Machinery Measurements using Dynamic Signal Analyzers*, Application Note 243-1, Agilent Technologies
- *Piezoelectric Accelerometers and Vibration Preamplifiers Theory and Application Handbook*, Bruel & Kjaer
- *Shock and Vibration Handbook*, Cyril M. Harris

Jack D. Peters is a Regional Sales Manager for Connection Technology Center, Inc. (CTC) His regional responsibilities include Asia/Pacific, Canada, and South Africa. He has more than 25 years of experience in measuring, monitoring, and analyzing vibration problems on process manufacturing machines for photographic films and papers. He currently provides technology leadership, training for distribution partners, engineering support, and applications engineering for customers at CTC. Jack is an Instructor for the National Vibration Institute, Past Chairman of the Central New York Chapter of the Vibration Institute, and certified as a Vibration Analyst Category IV in accordance with ISO 18436-2. Jack can be reached at 585-924-5900 x834 or jpeters@ctconline.com

Vibration made easy? Not possible you say. You might think differently after looking at

iLearnVibration & Mobius

Learning vibration used to be drudgery. For many people, trying to learn not only the myriad of concepts, rules and procedures, but also trying to diagnose fault conditions by looking at spectra and waveforms was just a mind-numbing experience. Not anymore. iLearn Vibration makes a complex technology much easier to understand. Its animations and simulations allow you to not only see the concepts, problems, fault conditions and solutions as they are explained, but more importantly, to visualize them and understand the *why* behind all of them. We tracked down 24-year vibration veteran Jason Tranter, the founder of Mobius and creator of the iLearn training products, to get a better understanding of vibration training and his remarkable training tools. Here are Jason's answers to a few of our questions...



iLearn's unique software simulations and animations make it easier to understand and grasp the concepts as they are being explained.

First it's a fact that there are many vibration analysis programs in place that aren't producing the returns that were expected when they were started. Why do you think that this happens?

Unfortunately you are quite right… It is relatively easy to set up a vibration program and collect vibration spectra. Sadly, it is difficult to do it correctly. Measurements must be taken correctly, and the skills required to accurately and confidently diagnose faults take time to develop.

The free training offered with the purchase of most systems is a great place to start, but far more training is required to build the knowledge required to correctly run a vibration program. It takes a special breed of person, lots of great training and experience, to become a successful vibration analyst.

From what I've seen, iLearn is a completely different, and highly effective, form of training. Why don't you explain what makes the iLearn system such a powerful learning tool.

We offer two forms of training: iLearnVibration for self-paced learning on your PC, and the Mobius Institute training classes. Both feature the unique software simulations and animations that are totally unique in our industry.

The fact is that it is difficult to master vibration analysis. There are so many concepts, procedures and rules to understand and remember. Our animations and software simulators make it far easier to master vibration analysis. We love hearing from our customers when they tell us: "I have taken other training courses, but after your course I actually understand these topics". Of course, we also commonly hear: "I sure wish I had iLearnVibration when I got started in vibration analysis!"

Please explain the various types of training courses that you offer.

We offer three ways to learn about vibration analysis:

1. Computer-based training: You can purchase iLearnVibration to own forever. Not only do you have access to the training system, but you also get the case study library of 50 "virtual machines"; the "virtual fault demonstrator"; the "virtual signal generator"; and the "machine modeler". You can learn so much from the training, and the additional modules allow you to put the training into practice.

2. Distance learning: You can attend a "distance learning" course. To save all the travel and other costs, you can learn with iLearnVibration but gain assistance from our instructors (and take an on-line exam).

3. Public and on-site training: You can attend a public course, or we can deliver a tailored on-site course. We offer three levels of training that follow the ISO and ASNT standards – and we offer certification examinations. People who attend our courses have access to the iLearnVibration training system before and after the course to get even more out of the training experience.

The Interpreter is a unique piece of software that sets the iLearn system part. Explain what the Interpreter does.

Most people can't believe their eyes when they see Interpreter in action! Interpreter actually looks at the pixels on your computer screen to find the spectrum, then it overlays colorful markers to highlight the harmonic and sideband patterns. It provides a list of possible fault conditions indicated by those patterns (with quick tips on what they mean). And to learn more, a single click opens iLearnVibration at the appropriate topic. Interpreter helps analysts to diagnose faults, and in turn, to become better analysts.

What are the three top reasons a company should consider investing in iLearn training?

Training is essential – there are just so many benefits! But the unique benefits of our training are:

1. Passionate instructors: Our instructors are all hand picked because of their experience and passion for training new, and seasoned, vibration analysts. In the US, Bill Kilbey and Tony DeMatteo will take you under their wing and ensure that you leave a better, happier and more confident analyst that when you arrived.

2. Unbelievable training tools: Our unique animations and simulators help people to understand vibration analysis like never before. You really have to see them to believe them...just check out our Web site to see for yourself.

3. Training available 24/7: iLearnVibration provides self-paced training that can be accessed at any time. No matter when a question arises, and no matter when the need for refresher training comes up, iLearnVibration is ready to serve.

What is the time frame that a company can expect for a return on their investment in iLearn training?

There are three ways that I can answer that question.

1. Reduced training costs: Some people purchase iLearnVibration to save on the costs of public training (travel, accommodation, meals, training fees and time away from the plant). These cost savings are immediate.

2. Recover the value of the vibration monitoring system: iLearn training will ensure that you get the greatest return from the vibration monitoring system.

3. Reduced maintenance costs: When you consider the high cost associated with the failure of just one machine, the $1400 cost of iLearnVibration and our course is minimal in comparison. Our training will improve an analyst's ability to detect and diagnose faults in rotating machinery, so the payback can potentially be measured in days.

Give us a success story or two from companies that have used the iLearn system of training.

We have been very fortunate to get feedback from our customers all over the world with stories about how much they use iLearnVibration and how they have benefited from the training. We received this e-mail from a customer just a few days ago (unfortunately we are not allowed to use his company's name):

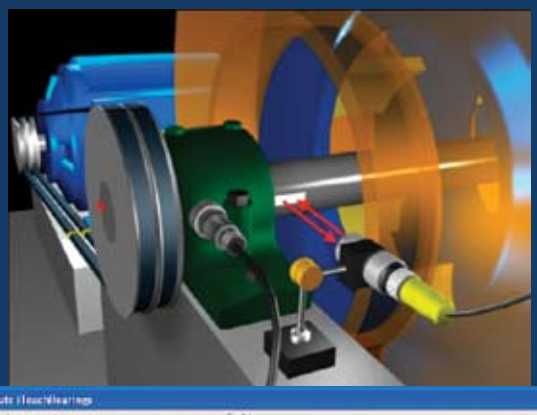
"I have utilized the Mobius iLearn computer based training at two different plants. I found it so useful at the first plant that I set up a similar training program at the second plant. I would use the system to teach an Introduction to Vibration class to all of our maintenance technicians, both mechanical and electrical. Then they would access the computer iLearnVibration class when time permitted and go through at their own pace. It was very useful at both locations as we operate 24 hours a day, usually 7 days a week, and the training was available at all times. It provided the mechanics a great understanding of vibration, which also aided them in troubleshooting and repair.

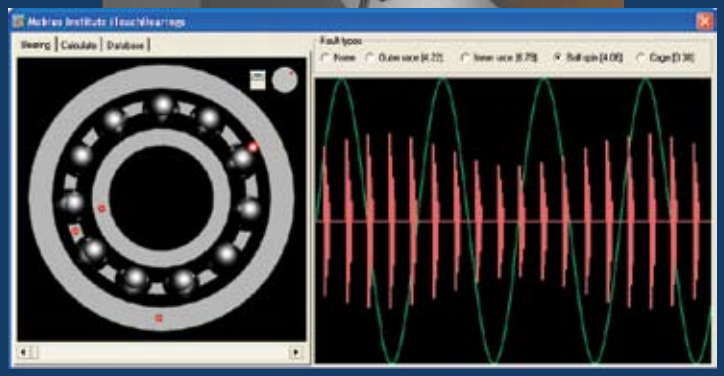
The electrician that was doing the motor current analysis also found that the vibration training helped him in diagnosing motor faults. When I was transferred from the first plant, the two technicians that had utilized the iLearnVibration program the most were given the responsibility for the plant vibration program.

I have attended several vibration classes from other companies, yet I still received better understanding through the iLearnVibration course. The constant availability allowed me to revisit the training and review certain topics to help me solve vibration problems in the plant."

How can interested people get more information about iLearn training?

The best way to learn more is to visit our Web site: www.ilearninteractive.com You will see Web pages and presentations about our products and courses, and you will see examples of the animations and simulators. If you like what you see on our site you will love our products and courses! Or better yet, you can contact Gary Peterson in our Seattle office and talk to him about your specific training requirements: gary@ilearninteractive.com or by phone toll free at 1-877-550-3400.





Simulations in the iLearnVibration software allow you to see the problems happening and visualize solutions.

CTC, a leading supplier of industrial vibration analysis hardware, announced that it has obtained Class I, Division 2, Groups A, B, C, D; Class II, Division 2, Groups F & G; Class III certification on its AC920 Series of accelerometers and LP822 and LP922 Series of 4 –20 mA, transducers; permitting the use these accelerometers in a hazardous environment without a barrier.

These certifications have made the AC920 and LP Series "CSA approved" in North America for use in hazardous areas containing volatile flammable liquids, gases or vapors. The Class I, Division 2 certification will allow these sensors to be installed in hazardous environments common to the petrochemical, chemical, gas and mining industries.

www.ctconline.com

CALL FOR PAPERS **CALL FOR PAPERS** CALL FOR PAPERS

Thermal Solutions®

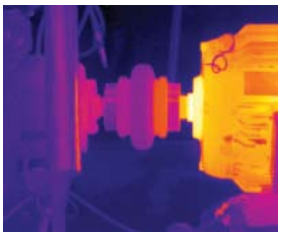
A Conference for Professional Thermographers

Sarasota, Florida – January 21-24, 2008

The Snell Group is looking for anyone interested in presenting a paper at next year's conference. Please write a brief abstract (100-200 words) and submit it for review by the Conference Steering Committee.

Abstracts sought on the following subjects:

- Electrical Applications
- Mechanical Equipment
- Building Diagnostics
- Moisture Intrusion
- Mold Detection
- Roof Moisture Surveys
- Program Management
- Case Studies in Thermography



E-mail: abstracts@thermalsolutions.org • **Fax:** 802-223-0460
Mail: Thermal Solutions *Call for Papers 2008,*
P.O. Box 6, Montpelier, VT 05601 USA

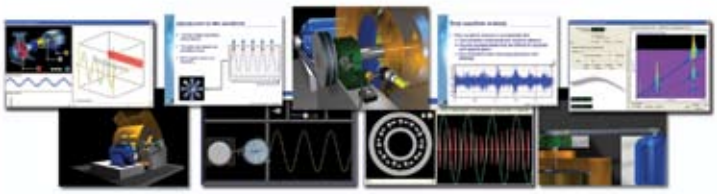
www.thermalsolutions.org • 1-800-636-9820

www.micromotion.com

Emerson Process Management announces a change in the brand name of the company's densitometers product line from Solartron® to Micro Motion®. Emerson acquired the densitom eters product line in 2005 and added it to the Micro Motion offering, giving customers a complete single-source solution for flow, density and viscosity measurement. Emerson's measurement knowledge and expertise are expanded with the leading Micro Motion technology to deliver measurement problem solving and innovative solutions. Micro Motion products provide a complete range of leading technologies for applications where both flow and density or density measurement alone are required.

"Unforgettable vibration training"

The leaders in computer based training are now the leaders in live training. The combination of experienced instructors - Bill Kilbey and Tony DeMatteo - and the amazing, new iTeachVibration simulators & 3D animations guarantee the best vibration training experience.



Think iLearnVibration was cool? Wait 'till you see iTeachVibration!
Used only by Mobius Institute instructors. Certification follows ISO and ASNT.

MOBIUS**iLearn**
www.ilearninteractive.com

Offices in Melbourne, Seattle, and Knoxville. Training centers all over the world.
Check our Web site for course schedule and product prices.
Toll free: 877 550 3400 Tel: 206 842 8721 e-mail: info@ilearninteractive.com

Simplified displacement monitoring with the iT230

The new iT230 Intelligent Transmitter is a vibration transmitter with displacement output. The displacement 4-20 mA output signal has a maximum full scale available of 100 mils (0.100 inches).

Using a velocity sensor and Intelligent Transmitter to obtain machine vibration information in terms of displacement saves money and greatly simplifies installation, compared to a proximity probe, and provides useful bearing cap displacement measurements.

The iT230 has 4-20 mA output proportional to overall case vibrations and can be used with your existing PLC or DCS network. Raw velocity vibration data is also available from a BNC connector on the front of the DIN-rail mounted module, to diagnose problems with portable vibration analyzers.

Wilcoxon Research

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

Want Fast and Reliable Solutions?

Introducing Reliability Shopper

the newest way to find what exactly you need

How It Works

Use ReliabilityShopper.com to request information about maintenance and reliability products, software, services and training for a fast response from leading edge solution providers.

You can use the ReliabilityShopper.com online shopper form to request information or bids from multiple vendors who will compete with each other to earn your business by offering the best prices, best service, best support and best training with a simple click of your mouse.

You can also use the toll free ReliabilityShopper.com E-Voice System 1-800 789 9037 to speed your request to our list of preferred solution providers. The system offers a simple to use 3 step process:

Step 1) Find Solution Providers in Uptime® Magazine, RELIABILITY® Magazine, MaintenanceConference.com Expo listing or in the ReliabilityShopper.com Directory

Step 2) Dial 1- 800 789 9037 toll free and the extension listed for the maintenance and reliability solution provider

Step 3) Record a message and leave your contact details including call back number, postal address and email address.

Your voice mail will be sent with high priority to the select solution provider immediately after your leave it.

Try It Now! Dial1-800-789-9037 and use the extensions below

Company	Page	Extention
Allied Reliability Services	pg 38	200
ARMS	pg 23	253
Commtest	pg 24,25, 39	203
Des Case	pg 49	232
Easy Laser	pg 35	232
Electrophysics	pg 15	225
GE Energy	pg 8	283
Hy-Pro Filtration	pg 42	208
iLearn/Mobius	pg 10	224
IMI Sensors	pg 17	233
IRISS	pg 26	271
Ivara	Inside Cover	222
IVC	pg 26	276

Company	Page	Extention
Leak Detection	pg 16	277
Maintenanceconference.com	pg 40	212
Manufacturing Game	pg 27	272
Mastering Maintenance	pg 5	211
Mikron	Back Cover	204
RELIABILITY® Magazine	pg 34	214
Reliabilityweb.com	pg 27	215
SDT	pg 35	230
Timken	pg 41	246
Trico	pg 7, 9, 11	236
Ultrasound Technologies	pg 43	216
Vectron	pg 16	282
Vibralign	pg 31	247

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 need to re-focus for different cabinet depths
- Attaches to Mikron's models 7600-PRO, M7800 series, and M7500 cameras
- ViewPorts are UL- and CSA-approved
- A better value for your inspection budget...

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

MIKRON INFRARED

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