

# uptime

the magazine for PdM & CBM professionals

oct 2006

## *Paint* a better *Picture*

The Art of the PdM Report

**Infrared: Combating Corona's  
Corrosive Effects**

**Listening for the Signature  
Sounds of Electrical Problems**

**Making the Most of Vibration  
& Other CBM Tools**

# Reliability — it's great when you get it



Ivara's Reliability Workshops are the best way to learn how to improve the reliability of your capital assets, your company's bottom line & your quality of life. They are also the best way to make you (& your boss) deliriously happy. So register for a course today & prepare yourself (& your boss) for a possible mood swing.

## **NEW!** Reliability as a Corporate Strategy — 1 Day Overview for Plant Management

Interact with executives and reliability experts, learn how to make your plant(s) more reliable and achieve breakthrough performance. 1-day workshop, \$399

- December 13, San Francisco, CA

## **NEW!** Planning in a Proactive World — Getting to the Right Work

Learn the proactive elements of planning and scheduling; roles and responsibilities in a proactive, reliability focused environment; and the basics of RCM to get to the right work. 2-day workshop, \$795

- October 24 — 25, Cleveland, OH
- December 6 — 7, Las Vegas, NV

## Reliability — Preparing for Tomorrow's Maintenance World

Take a leadership role in reliability by implementing a reliability strategy in your company. 2-day workshop, \$795

- November 15 — 16, Jersey City, NJ

## Lean Maintenance

Improve your understanding of Lean Maintenance and learn how to implement Lean, step by step. 2-day workshop, \$795

- October 12 — 13, Ft. McMurray, Alberta
- November 7 — 8, Houston, TX
- November 15 — 16, Pittsburgh, PA

## Best Practices in Maintenance & Reliability

Learn a new and comprehensive approach you can use today to evaluate how your organization's maintenance and reliability practices and culture compared to recognized world-class standards. 2-day workshop, \$795

- October 17 — 18, Detroit, MI

## KPIs — Developing Leading & Lagging Maintenance & Reliability Indicators

Learn how to develop both leading and lagging performance indicators for maintenance and reliability. 2-day workshop, \$795

- to be announced soon!

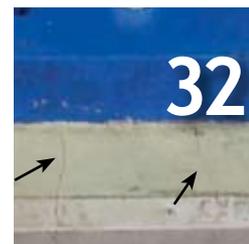
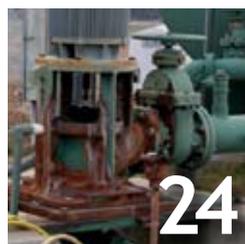
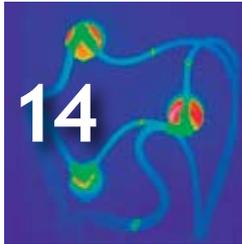
**2007 dates for all workshops will be announced soon!**



## Hold a custom workshop at your Location!

Get everyone in your organization on-board with reliability—book a workshop at your location where you can benefit from customized content delivered by world-renowned reliability leaders, while accommodating larger numbers of participants. Custom Ivara reliability workshops are the most cost-effective way to educate your workforce on asset reliability. Cost: \$3000/day, up to 20 participants.

For more information on any workshop, visit [www.ivara.com](http://www.ivara.com), phone 1-877-746-3787 ext.312 or email [askivara@ivara.com](mailto:askivara@ivara.com).



2 **upfront**

4 **upclose** how to create a masterpiece

## upload

14 infrared **catching and cleaning corona**

18 lubrication **calculations for the correct lubricant**

22 motor testing **fault finding for cables**

24 precision maintenance **standby policy adds to bottom line**

28 ultrasound **snap, crackle and pop explained**

32 vibration **taking the tools further**

44 **upgrade** the pristine pour, every time

# Communication Is Key

In the PdM/CBM industry, we are charged with increasing the MTBF as much as possible while keeping the MTTR to a minimum, so we can reduce the LLC of the equipment. We accomplish this by doing an FMEA (or FMECA) on our equipment, and report our progress through KPI's under a guiding philosophy of RCM, TPM, Six Sigma, Lean, etc. And, of course, when there is a failure, we do RCA to identify, and do our best to eliminate, the Failure Mode so we can further increase the MTBF.

If you understand all of the preceding paragraph, you are in pretty good shape. For every person that does understand all of it, there are probably 1000 in the maintenance industry who don't.

There is at least one basic component that must be in place for any society or culture to make great strides. They must be able to communicate effectively. A vocabulary that everyone understands is the foundation for all effective communication.

Joel Levitt's contribution this month (pg 38) brings this issue to the forefront. If at times you feel like you're not speaking the same language within your facility or organization, be sure to read the article. Hopefully, it will start a conversation that could lead to establishing more of a common language, which will help your program move forward.

The feature article this month by Howard Penrose is also about communication. Dr. Penrose provides some sage advice on how to tailor your reports so they speak to the overall goals and objectives of the organization. If you can show that fulfilling the needs of your maintenance program will also contribute directly to what the decision makers are trying to accomplish - the corporate goals for production and profitability - then you're one step closer to receiving the support you need for your PdM program.

Thank you for reading. Please feel free to contact me with any questions, comments or suggestions that you think will make Uptime more useful for you.

My lines of communication are always open.



All the best,

Jeff Shuler  
Editor In Chief

[jshuler@uptimemagazine.com](mailto:jshuler@uptimemagazine.com)

# uptime

volume 2, issue 12

PUBLISHER  
Terrence O'Hanlon

EDITOR IN CHIEF  
Jeffrey C Shuler

EDITORIAL ADVISORS/  
CONTRIBUTING EDITORS

Ron Eschleman	James Hall
Joseph Petersen	Alan Johnston
Greg Stockton	Jay Lee, PhD
Ray Thibault	John Mitchell
Jack Nicholas, Jr.	Jason Tranter
Howard Penrose, PhD	

ADVERTISING SALES

Bill Partipilo  
888-575-1245 x 114  
[sales@uptimemagazine.com](mailto: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 07190  
Ft. Myers, FL 33919  
888-575-1245 x 116  
[jshuler@uptimemagazine.com](mailto:jshuler@uptimemagazine.com)

SUBSCRIPTIONS

to subscribe to Uptime, log on

[www.uptimemagazine.com](http://www.uptimemagazine.com)

Uptime® (ISSN 1557-0193) is published monthly by NetexpressUSA, Inc., PO Box 07070, Ft. Myers, FL 33919, 888-575-1245. In the U.S. Uptime is a registered trademark of NetexpressUSA, Inc. No part of Uptime may be reproduced in any form by any means without prior written consent from NetexpressUSA, Inc.

Uptime is an independently produced publication of NetexpressUSA, Inc. The opinions expressed herein are not necessarily those of NetexpressUSA, Inc.

Copyright© 2006 by NetexpressUSA, Inc. All rights reserved.

POSTMASTER: Send address changes to: Uptime Magazine PO Box 07070, Ft. Myers, FL 33919.

# Need help finding the road to maintenance success?



## Use Our Roadmap.

The Reliability Roadmap™ - a series of free web workshops hosted by Uptime® Magazine and Reliabilityweb.com™ has been a big hit. By going beyond the typical “webinar”, participants have been able to continue their learning beyond the hour that each workshop runs. With two of the six web workshops in the books, you shouldn't pass on the opportunity to attend the next one.

Visit the link below to hear the last four presentations.

[http://www.reliabilityweb.com/rroadmap/playback\\_reg.htm](http://www.reliabilityweb.com/rroadmap/playback_reg.htm)



Once you listen, we think you will agree with the other 95% of attendees that responded that they learned at least one thing that will improve their work.

Each workshop features two presentations - one covering management aspects and one covering technical aspects. Each presentation will be followed by a Q & A session, and you can choose to continue the discussion with other participants via the web for days, weeks or months. Our goal is to create a community of shared knowledge that will lead maintenance & reliability professionals to a better understanding of reliability principles.

### Web Workshop #5

October 20th 11 am – noon EST

**6 Steps to an Effective Infrared Thermography Program by James Taylor  
plus Infrared Thermography Basics by Gregory Stockton**

Space is limited so enroll in this FREE workshop today!

[www.reliabilityweb.com/roadmap.htm](http://www.reliabilityweb.com/roadmap.htm)



uptime®

Your learning experience with The Reliability Roadmap is sponsored by





# The Art of the Predictive Maintenance Report

by Howard W. Penrose, PhD, CMRP

In 1878, Frederick Taylor began his work in developing a process that he published in 1911, known as Scientific Management. This work, along with a century's worth of production work that started with John Hall of Harpers Ferry Armory in 1824, prompted Henry Ford's Highland Park manufacturing line in 1913. Through this period it was assumed that workers only worked for financial gain and would produce at whatever level in whatever position, as long as their income needs were met. In effect, management philosophy was to achieve machine-like standards of speed and reliability with money as the incentive. Also, during this time, 20% of the workforce was comprised of children aged 10 through 15 with a life expectancy of 46.3 years for men and 48.3 years for women. Additionally, with a large influx of immigrants at the time, unemployment remained at about 15%. If working conditions were dirty, dangerous or otherwise unsatisfactory, the worker did not have a choice as others were always waiting for their position. This fear of unemployment - combined with the fact that it was a time when there was no safety net like unemployment benefits, social security, welfare or OSHA - re-inforced the thought that money was the only incentive.

A series of studies performed by Western Electric in Cicero, Illinois, known as the Hawthorne Studies (1923 to 1933) identified how work groups provided mutual support and resistance concerning management to unreasonably increased output. These studies were implemented as a straightforward attempt to determine the relationship between the work environment and productivity. The studies identified that the work environment is not one of formal organization but is, instead, more of a social system. They were also able to determine that early managers were aware that most workers had a tendency to limit their personal efforts in order to maintain their membership in this informal

social structure. With the exception of the individual 'rate busters,' the desire for communication, companionship and associations on the job was determined to be more important than the little bit of extra money that might be earned. These studies initiated the concept of Human Resources, which is meant to support and determine the requirements of this structure and how to increase morale amongst employees in order to increase production. Basically, it became important to determine the 'What's In It For Me' (WIIFM) of the employees as individuals and as a group.

Modern Reliability and Maintenance (R&M) training has been focusing on management with the same narrow view. Reports, budget requests, recommendations and other tasks are usually justified with such numbers as cost avoidance and cost savings. In reality, as was found in the Maintenance and Management Communication Study performed by SUCCESS by DESIGN in the Spring of 2006, these numbers have very little impact in the R&M decision-making process. Instead, it takes an understanding of the WIIFM of individual managers or groups of managers.

## Business WIIFM

While it is all well and good that R&M personnel should expect management to understand the importance of the maintenance function, it is not always realistic. Most managers and executives have had little to no exposure to the realm of R&M, other than home and auto maintenance. Formal management training often leaves out the importance of the maintenance and reliability function with the only understanding of it as an expense column in the budget. Instead, the manager is focused outside the company, towards stockholders in publicly traded companies and the owners and customer pressures in all companies.



Figure 1 - Unplanned Failures Can Be Avoided Through Proper Reporting

The challenge is to determine the best ways to get management action on R&M related issues. It is important to understand that the financial portion of the recommendation is of relatively little importance, instead, the quality of presentation, how it is presented and the ability to present choices are more important. It is equally important to understand or recognize the existing goals of maintenance. For instance, if the company is focused on 'Lean Business,' or 'Lean Maintenance,' how will your recommendation help management accomplish this focus while minimizing the risks involved. In effect, you have to take the step beyond just presenting a finding or recommendation, but you also have to identify the WIIFM factor(s) and address it (or them). Will your recommendation help achieve the objectives that the decision maker has set for him/her-self?

### Example

#### Management Perspective

Operations has a goal to produce 1,000 units of widgets in two shifts of five days (80 hours), which is a rate of 12.5 units per hour.

The production line can produce 15 units per hour which equates to 1,200 widget capacity per 80 hour week. The cost for the production line is \$650 per widget at full capacity and \$800 per widget at 1,000 unit capacity. Both instances maintain a \$10,000 per hour cost for the production line which is operating at 83% capacity. In the last fiscal year the sales cost for the factory has been \$1,000 per widget, which results in a profit margin of \$200 per widget, or 20%. Overtime will obviously increase the throughput costs. With the present environment, it is expected that labor, healthcare, materials and energy costs will increase the cost per hour of production to \$11,000 per hour while new overseas competition is reducing the price to \$950 per widget. This has resulted in a new fiscal year projection of \$880 per widget and a potential profit margin of \$70 per widget or 7.3%. The fiscal year report has caused shares in the company to drop significantly, reducing the ability to generate more capital investment. In order to counter this problem, management has tasked the sales force to increase sales in order to bring the production line to full capacity and has implemented a lean process in order to control costs while negotiating with labor through human relations to absorb some of the associated costs, such as changes to the health care benefit. If production can be increased up to 1,100 units per week (92% capacity) while maintaining costs at the \$11,000 per hour level, the cost per unit will return to \$800 per widget, resulting in a profit margin of 15.8%. If production cost can also be decreased to \$10,500 per hour, then the cost per unit will drop to \$764, resulting in a 19.6% profit margin. In this case, management has the task to reduce costs, prevent overtime and increase throughput by 9%, with the assumption that availability will be maintained at 80 hours per week. The operations manager has final say on maintenance access to the production line and knows that he has only 7 hours per week to work with for unexpected downtime and his incentive is that if he can maintain production at 1,100 units per week he will receive a bonus of 10% of his/her annual salary. If he/she falls below 1,100 widgets per week consistently either production will be moved to another location or he/she will be replaced.

#### R&M Perspective

A full infrared, vibration analysis and ultrasonics program has been implemented as part of the management objective to maintain equipment availability. Management has reviewed enough material and vendor presentations to know that such a program has had great results in other companies. During the first survey of equipment three findings are produced including: Air leaks to critical parts of the production line that have a combined impact of \$5,000 per week (\$250,000 per year) and will take 8 hours to repair; A noisy bearing on the main drive motor for the production line which will require six hours to repair (\$66,000 cost avoidance if it fails during production); and, a hot connection on the B-phase secondary connection of the production transformer which would take five hours to repair but a total production downtime of ten hours if performed during the normal 80 hour work week. Standard greasing and other preventive maintenance tasks require four hours planned downtime per week at the same time the machinery is prepared for the week's work on the Monday morning startup.

Now, what happens, in the above example, when findings are reported to the operations



Figure 2 - Generator Removed From Mission-Critical Application Three Months After Fault Detected As Recommended

**Timken  
Condition Monitoring.  
The big brother  
your equipment has  
always wanted.**



This is the one time in life you want somebody looking over your shoulder, 24/7. Because Timken's condition monitoring solutions are designed with a simple purpose: to reduce downtime and unplanned maintenance costs – and keep you running. Our condition monitoring solutions do exactly what it sounds like they should do: they help monitor your equipment and help provide warnings before unexpected downtime can occur,

enabling you to anticipate operational concerns before they truly become issues. From hand-held instruments to continuous monitoring devices, to customized real-time monitoring systems and premium route-based services, Timken provides you with a one-stop shop for all of your condition monitoring needs. For more than a century, Timken has been a friction management solutions<sup>SM</sup> provider. Our condition monitoring products and services are another example of how Timken can bring even more value to your manufacturing operations. To find out more about how our condition monitoring solutions can help, please contact your Timken sales representative or visit [www.timken.com/conditionmonitoring](http://www.timken.com/conditionmonitoring).



**TIMKEN**  
Where You Turn

# OIL MONITORING SYSTEMS

**internormen**  
*electronics*

**Oil monitoring and diagnoses pays off!**

**Benefit from our dependable oil monitoring systems:  
Improve your system's availability and efficiency!  
Reduce machine downtimes and maintenance costs!**

## CCM 01

- The new, inexpensive inline particle counter
- Dependable determination of contamination classes according to ISO 4406 and NAS 1638
- Based on the successful CCS 2
- For stationary and permanent applications
- Applicable in new or existing systems



**NEW**



## MPM 01

- The new metal particle sensor MPS 01 with control unit
- Dependable detection of metal particles > 200 µm
- Inexpensive inline measuring system
- For stationary and permanent applications
- Applicable in new or existing systems

## WSTM 01

- Reliable inline measurement of the saturation level of a hydraulic or lubricating fluid with water
- For stationary and permanent water-in-oil monitoring
- Also measuring temperature
- Results can be displayed as theoretic ppm values



## WSH 01

- Reliable offline measurements of the saturation level of a hydraulic or lubricating fluid with water
- For simple and mobile water-in-oil monitoring
- User-friendly handheld measurement device with LED display



**Request your free copy of our new brochures!**

### **INTERNORMEN** *Technology Inc.*

900 Air Park Drive • Zanesville, Ohio 43701 - USA  
Phone: +1 - 740-452-7775 • Fax: +1 - 740-454-0075  
Internet: [www.internormen.com](http://www.internormen.com)  
e-mail: [sales@atico-internormen.com](mailto:sales@atico-internormen.com)

*Competence through Experience*

manager as follows:

- Repair Air Leaks, 8 hours, \$250,000 per year
- Repair bearing, 6 hours, \$66,000 cost avoidance
- Repair connection on transformer, 10 hours, \$110,000

What appears to the operations manager is that the production line is still in operation and those components have not failed. If there is enough manpower, the work can be done during the Monday startup meaning that there are only 70 hours for production which leaves a capacity for 1,050 widgets with an associated cost of \$800 and a resulting loss of 3.8% profit (\$36/widget).

How do you think the operations manager would consider the maintenance recommendations given the above scenario? How could you adjust your recommendation presentation in such a way to convince management to make the improvements? What happens as the recommendations and findings begin to increase? What happens if you have limited maintenance manpower to perform the corrections? What is the WIIFM for the decision maker? For management? How can your program be used to the advantage of the goals for the company?

Once the WIIFM for the managers and corporation are determined, recommendations and presentations can be developed in such a way as to meet the requirements of management. So, what can be done with the above situation?

First, the objectives of the company must be identified. In this case, the objective is to return profitability back to the 20% realized in the past. Management has identified that an increase in throughput, resulting from sales, and a decrease in operating costs through lean management/maintenance and labor cost improvements, can meet this objective. As part of this, the application of planned maintenance was brought into play due to internal/external recommendations and publicity with little understanding of the needs of the program. Sales needs to meet the commitment of 1,100 units and the operations manager needs to maintain levels for his/her annual bonus.

First, you must consider the risks associated with not performing maintenance on each of the items identified. Which are safety/regulatory? Which are Production-Related? Which are related to expensive equipment? Which can be run to failure? Can they be prioritized? Can overtime be authorized and have

a cost benefit?

### Considerations for Recommendations

1. Make recommendations for which should be performed on overtime;
2. How important is each recommendation

### Maintenance and Engineering Opportunities

In a challenging environment where success or failure rests on your decisions... you excel beyond expectations!

When it's decision time, you never hesitate to make the right call. Your competence and confidence not only inspires others, but also reassures upper management that as long as you're around, the plant will run optimally.

**GAF Materials Corporation**, North America's largest roofing manufacturer, with 27 plants nationwide, is expanding.

We're looking for professionals who can demonstrate exceptional skills in:

- communication, problem-solving and leadership
- failure analysis (i.e. FMEA, FTA, KT)
- practical knowledge of predictive technologies including vibration analysis, thermal imaging, oil analysis, laser alignment and non-destructive testing.

### Regional Maintenance Reliability Engineers

You'll lead reliability improvements in multiple plants; develop and drive GAF's high performance maintenance plans; and define strategies and implement predictive technologies to improve uptime, availability and reliability. A BS in Engineering and 8+ years' in maintenance improving reliability in a high speed, continuous manufacturing process environment are required.

### Maintenance Managers

You'll manage the plant's maintenance budget and performance objectives; develop and sustaining a system that identifies work, plans, schedules, and that executes jobs and audits work quality. You will also develop and implement a training system for associates. To qualify, you will need a BS in Engineering, plus 5 years' maintenance and 2 years' supervisory experience.

### Maintenance Supervisors

You will supervise internal and external personnel to ensure maintenance standards. A BS in Engineering is required, plus 4 years' maintenance and 2 years' supervisory experience. Ability to develop and prioritize performance plans is preferred.

### Maintenance Reliability Engineers

You will develop and refine equipment maintenance plans and repair procedures; analyze equipment failures and initiate corrective actions; incorporate predictive technologies; and drive development and implementation of standards and specifications for equipment, facilities, and plant systems including parts standardization. A BS in Engineering plus 4-6 years' manufacturing experience in MRE are required.

We offer comprehensive benefits including relocation assistance.

Please e-mail your resume, indicating desired position, to:

**GAF@ConfidentialReply.com**. (Word documents preferred).

EOE M/F/D/V

[www.gaf.com](http://www.gaf.com)



# ReliabilityShopper Top 10 Reliability Solution Providers

## Excellence in Maintenance & Reliability Services

1



Leading the World in RCM  
585-349-7245  
[www.reliabilitysolution.com](http://www.reliabilitysolution.com)

2



Maximizing the Return on Asset Reliability  
918-382-9400  
[www.alliedreliability.com](http://www.alliedreliability.com)

3



Redefining Maintenance, Delivering Reliability  
843-744-7110  
[www.LCE.com](http://www.LCE.com)

4



Experts in Making Reliability Work  
1-877-746-3787  
[www.ivara.com](http://www.ivara.com)

5



Reliability Software, Training & Engineering Services  
509.928.5083 / 5084  
[www.reliabilityusa.com](http://www.reliabilityusa.com)

6



Reliability  
Center  
Inc.  
Root Cause Analysis  
804-458-0645  
[www.reliability.com](http://www.reliability.com)

7



Masters of Reliability Process Implementation  
952-882-8122  
[www.rmgmpls.com](http://www.rmgmpls.com)

8



RCM, Lean, Six Sigma, Asset Management  
904-264-8570  
[www.wylelabs.com/products/vrcm.html](http://www.wylelabs.com/products/vrcm.html)

9



Oil Analysis Services  
813-621-6463  
[www.pdma.com](http://www.pdma.com)

10



POLARIS  
Laboratories, LLC  
Fluid Analysis, Data Management, Field Services  
877-808-3750  
[www.polarislabs1.com/training.htm](http://www.polarislabs1.com/training.htm)

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

[www.reliabilityshopper.com](http://www.reliabilityshopper.com)

- for the corporate goal;
3. How can the recommendations be presented in such a way to show impact on profitability; and,
  4. How can the recommendations be presented in such a way to ensure the operations manager meets his goal.

As time moves forward, additional issues will arise that will have to be addressed. This needs to be considered when developing the recommendations and incomplete recommendations will need to be assessed each time new findings are brought to light.

For instance, if the Saturday rate for overtime is \$200 per hour for multiple maintenance personnel who can correct the issues, then a ten hour overtime shift on Saturday to take care of maintenance actions would cost \$2,000 per week. Corrections to the compressed air system will yield \$5,000 per week, which results in an immediate return on investment. In the meantime, the overtime recommendation results in the maintenance of the three hour buffer that existed in availability. The cost avoidance for all repairs can be measured as \$426,000 per year, which seems impressive. However, given the company's objectives, the concept of maintaining production capacity and reducing production costs of each widget by \$2.73 per widget in compressed air costs alone, will have more of an impact. This benefit can be directly measured in a relatively short time as an improvement. Therefore, that should be the focus of the report, then the soft findings of \$176,000 and the benefit of avoiding lost production and meeting capacity needs should be presented in such a way to add support to the report.

Development of such a report, and its presentation, should be considered important along with the ability to prioritize recommendations. A common issue that causes a communication challenge with maintenance reports is that all of the problems are lumped into one. However, if recommendations are ordered based upon severity and impact on the WIIFM, then at least a few of them should be followed once it is presented.

Repair priority should be given in the following order:

1. Safety and Regulatory Impact
2. Production Impact and Severity of the Impact
3. Expensive Equipment to Repair or Replace

Each of these should be weighted by the severity of the defect detected. For instance, the connection on the transformer would be considered a potential safety and production impact with a relatively high risk of failure, so would be rated as a first priority. The drive motor bearing would have an impact on production with a medium risk of failure, so would be the second priority; and, the compressed air system may impact production, has a low risk of failure but has a high associated expense, so would be the last priority.

By combining a report, and presenting it, in such a way that you are identifying an impending failure, making thoughtful recommendations (ie: out of the box) that relate to the WIIFM of the company and decision-maker and prioritizing the recommendations, it is more likely that those recommendations will be followed.

### Areas to Focus On

As the term 'cost avoidance' represents 'imaginary money,' it does not fit into any budget column. Playing with magic numbers in your recommendations will not normally obtain the results you want. Instead, the areas that management may consider could include the following, and additional, issues:

- Profitability
- Throughput
- On-time Delivery
- Just-In-Time Capability
- Bottleneck Reduction
- Improved Workforce Effectiveness
- Reduced Overtime
- Reduced Risk

It is also important to note that people are visual. A picture really is worth a thousand words. The more graphic your presentation the better. In addition, you will want to focus on the part of the graphic that emphasizes what you are trying to convey. For instance, if you are showing an FFT of a bearing problem, if you show the whole FFT, the peaks may be relatively small compared to the lower frequency (or other) peaks (Fig Figure 3). The result is a visual reduction in the severity of the problem. Therefore, focus in on just the peaks that are of concern and adjust the scale so that they seem large on the image that you put into the report (Figure 4). We often forget, management does not understand the technology that we are using. Remember, they are probably thinking, "The

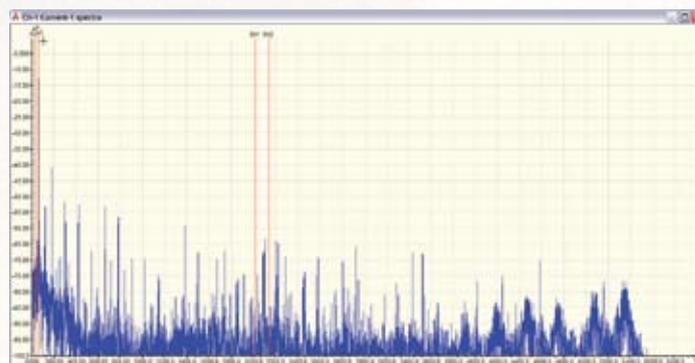


Figure 3 - A Full Spectra Can Be Confusing

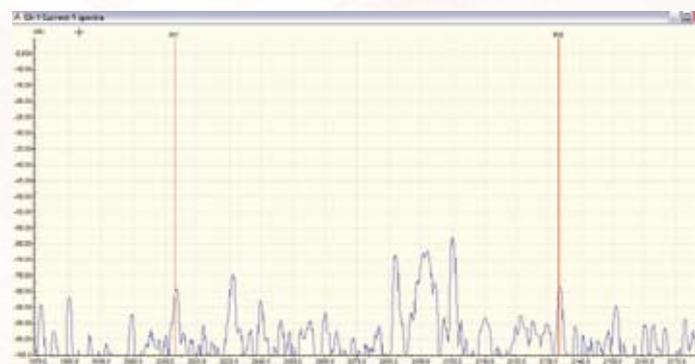


Figure 4 - A Closer View Can Remove Confusion While Conveying the Message

equipment is still running, so why should I be that concerned.”

### Outline of the Report

Most Condition Based Maintenance findings reports will have the following components:

1. List of what was in the route;
2. Statements of what was detected such as ‘high temperature connection’ and a value or high vibration and a value;
3. Graphics supporting statements; and,
4. Sometimes the cost avoidance.

A report that will have an impact will have the following components:

1. List of findings with priorities. You can still include the list of what was in the route, but place the findings at the top of the list in order of priority;
2. A description of what was detected and what it means;
3. Supporting graphics with emphasis on the problem;
4. Risk of impact on business if not addressed and a time limit. For instance: “There is a 50:50 chance that the windings will fail within two weeks and an 85% chance that they will fail within the next four weeks. When this motor fails, it will reduce production capacity by 20% on this line.” Use definitive statements! You can add such things as throughput, on time delivery, etc.;
5. State the actions that need to be taken! For instance: “During shutdown next week, remove the motor and replace it with the spare. Send the motor in to the rewind shop for repair.”; and,
6. Follow up with a reminder card or report (tickler) a few days after submitting your report.

Figure 5 shows an example of an effective report. It is important to remember that you usually will have only one chance to get the decision maker’s attention. They will pick up the report, look at it, act and then put it down, not to pick it up again. So, SELL your recommendations!

### Conclusion

In order to develop a successful condition-based maintenance report, modern R&M professionals will have to understand the WIIFM of the decision makers within their organization. In order to do this, the professional will have to have a deeper understanding of the business impact of the machines that they are responsible for. The basic design of the reports should de-emphasize such imaginary

numbers as cost avoidance and, instead, focus on the impact of those areas that are most important to the organization and associated managers.

*Howard W. Penrose, Ph.D., CMRP, is the President of SUCCESS by DESIGN, a reliability services and consulting firm based in Old Saybrook, CT. Dr. Penrose can be contacted at howard@motordoc.net or by phone at 860- 575-3087.*

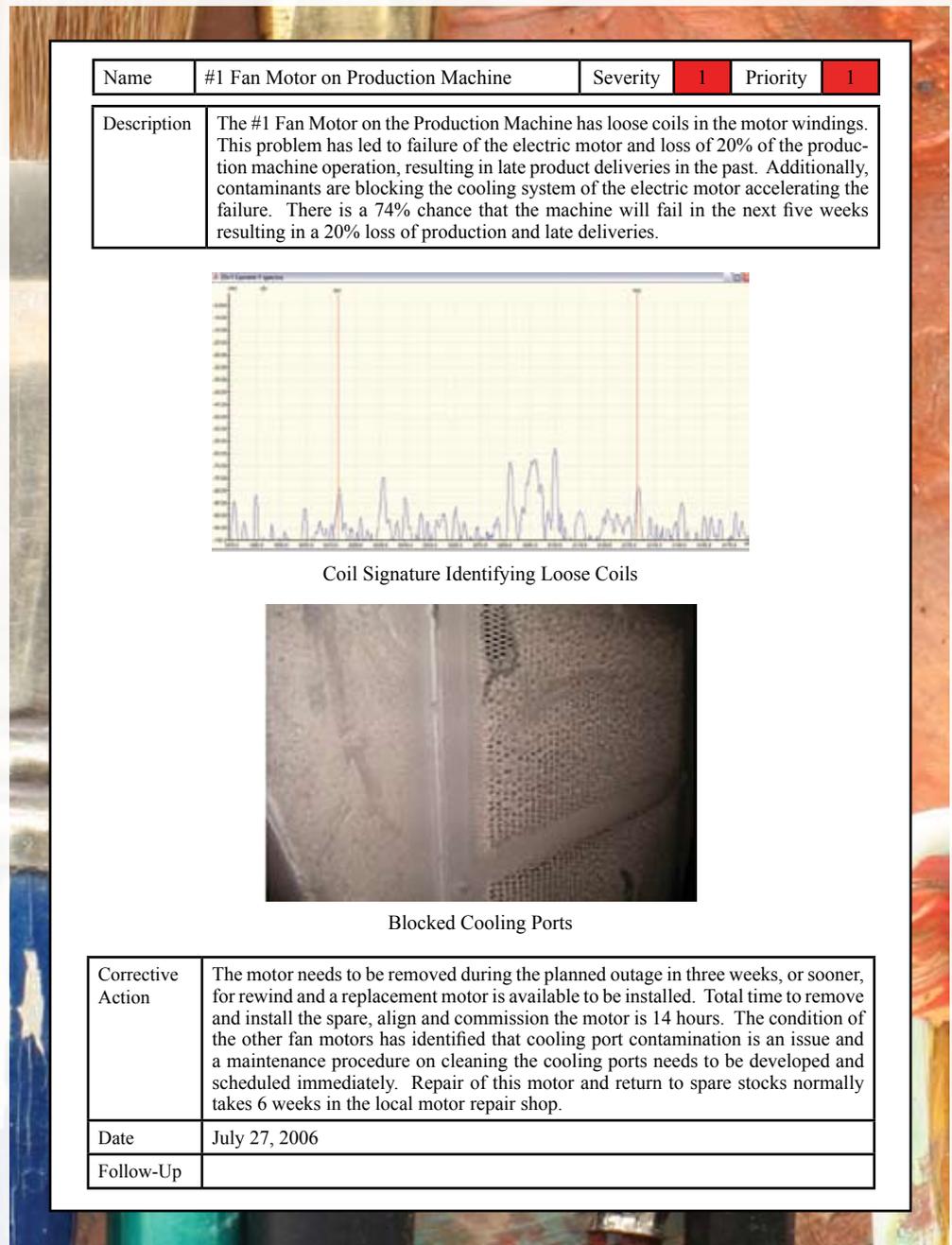


Figure 5 - Sample of a Successful Report Format

# get proactive

## Make the shift...

Your organization wants to stop putting out fires. You want your guys to take charge before things become costly. Making the shift from reactive to proactive is not straight forward but it needs to start somewhere. So why not start with the basics...Asset Basic Care?

Asset Basic Care records the condition (sight, smell, touch, sound) of your assets using an electronic checklist on a handheld computer. It's an excellent way to start recording what's going on with your machinery and changing the mind-set from reactive to proactive. In a very short time, your equipment database becomes populated with information that can prevent failures before they happen—putting you in control AND saving money.

Built on a multi-tiered pyramid approach to reliability, **MAINTelligence™** provides a simple start toward becoming proactive with a solid foundation in Asset Basic Care, (operator inspections and total lubrication management). Then when you are ready to expand your reliability program, **MAINTelligence™** will support you each step of the way at a rate that suits your organization.

Talk to a DMSI reliability specialist to ask how we can assist you in meeting your reliability goals.

**MAINTelligence** > helping you become proactive!



**Design Maintenance Systems Inc.**

+1.604.984.3674  
info@desmaint.com  
www.desmaint.com

# Avoiding Flashover

## Tracking Down Corona Discharge in 5kv & 15kv Metal Clad Switchgear

by Chuck Humphrey

**C**orona is a serious issue in metal clad switchgear because of its highly destructive nature. It also happens to be the cause of most flashovers in medium voltage metal clad electrical equipment. The fundamental cause of this symptom is an electrical breakdown of air brought on by electrical stress and poor air quality within the switchgear. If not rectified a flashover is imminent, possibly causing enormous damage and injury to personnel.

Tests have proven that when a flashover occurs the temperature is in excess of 20,000 degrees, with the bulk of damage being caused by secondary explosions from a build up of compressed unburned gases within the enclosure. Dealing with corona discharge in the case of metal clad switchgear is very unpredictable and caution must be used at all times.

With today's instruments used for condition monitoring and predictive maintenance, we are able to help combat and verify this problem and do it successfully.

We always take extra precautions to prevent serious potential hazards such as electrical shock and severe burns which are the two main safety issues in the business. The other serious issue is making sure we are part of the solution and not part of the problem. Most of our customers have up to a million dollar price tag if their plant goes off line. Of course, we are there to prevent a power outage, not be the cause of one.

All experienced electrical maintenance personnel are familiar with the various surprises when entering any electrical equipment. Always expect the unexpected. So prior to opening any equipment a visual inspection, ultrasound detection and sometimes IR imaging are necessary.

Corona damage is one of the problems that we find on a regular basis. Because of the by-products, nitric acid and carbon, produced from the corona discharge a continuous decay of insulation is taking place, which makes the situation highly unpredictable. With corona being the cause of most flashovers in metal clad switchgear you can predict that flashover is imminent in all cases. There are various signs that identify corona. In some cases, there is no indication of corona using non-destructive testing. However, with closer visual inspection we find that corona discharge had been present, but is not active as shown in Figures 1 and 2.

In both of these images, flashover was imminent if the problem was not rectified. Even though the corona was dormant at the time of inspection, it would have started discharging again with the appropriate relative air density, temperature, moisture and lack of air movement. Fig. 1 shows insulation decay phase to phase on a 5kv feeder. Fig. 2 shows actual air flow in the dust during corona activity on a 4160v conductor. In this case the deterioration is on the conductor insulation and corrosion on the metal clad.

In other cases we find the corona discharge extremely active. This is when extra caution is taken because a flashover could occur at any time. Corona also produces airborne ultrasound, ultraviolet light and, if advanced into arcing, it will sometimes show a thermal signature. This is a perfect opportunity for Ultrasonic detection, UV/Corona Imaging, and IR/Thermal Imaging to find out where and why the corona is discharging as shown in Fig. 3.

In the case of Fig. 3, a thermograph was able to show a temperature rise on the 15kv buss insulators, verified by the ultraviolet corona images. The



Fig 1 - Insulation Decay due to Corona on 5kV Feeder



Fig 2 - Residue from Corona on 4160v Conductor

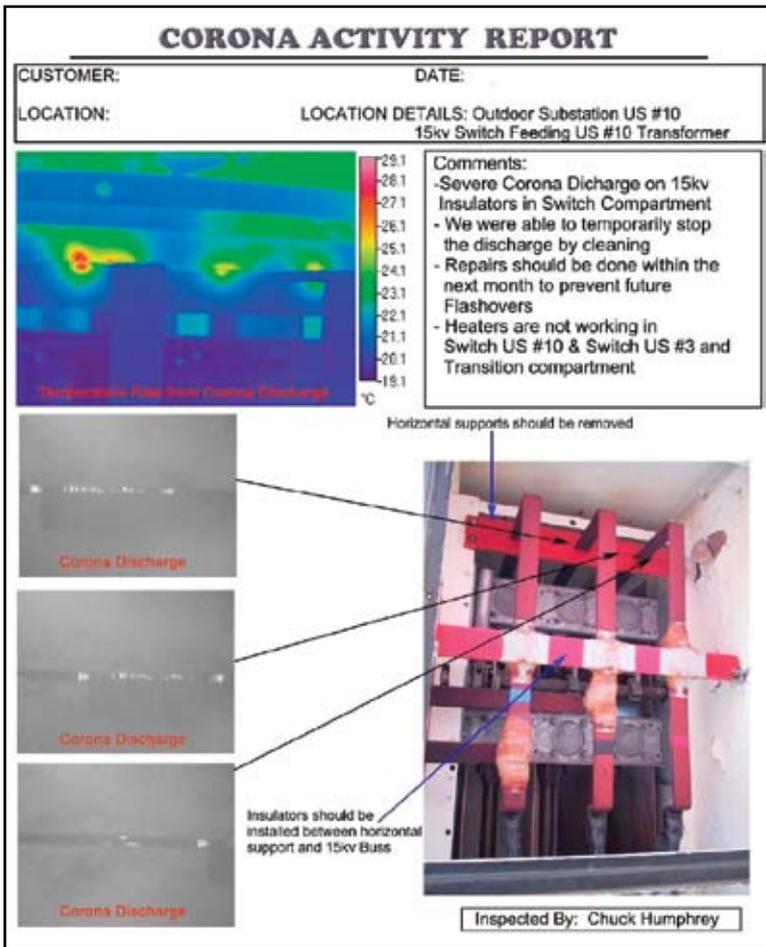


Fig 3 - Corona Activity Report on 15kV Buss Insulators

problem in this case is decay in the horizontal insulators causing electrical stress to initiate the corona. This all started with contamination entering the switchgear, trapping moisture and then, under the right conditions, started producing corona. Then with nitric acid, ultraviolet light, ozone and carbon deteriorating the insulation the corona eventually spreads on its own.

Corona at anytime is extremely serious and should be dealt with and eliminated as soon



Fig 4 - 5kV Shielded Cable with Stress Cone

different cases of defective stress cones. Fig 4 shows a 5kv shielded cable with a stress cone and Fig 5 shows a 15kv shielded cable with stress cone. The temperature rise is minimal, but the problems are very serious. Both stress cones were developing corona underneath the insulation and would have eventually flashed to ground. I have talked to different electrical thermographers and some believe that if the temperature rise is less than 10 degrees, there is nothing to worry about. However, as you

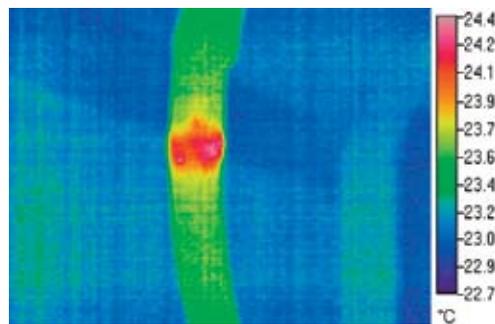


Fig 5 - 15kV Shielded Cable with Stress Cone

as possible. In our case we can stop the corona with our cleaning equipment. Sometimes permanently and sometimes temporarily, depending on the situation.

At times when entering equipment the environment changes inside the metal clad compartment when you open a door or remove a cover. This, on occasion stops the corona discharge which makes it a little tougher to verify. Another by-product of corona is ozone and the odor can be identified. Also there may be a chance of a thermal signature as shown in Figures 4 & 5.

These thermographs represent two dif-

ferent cases of defective stress cones. can see from the images in Figures 4 and 5, the temperature rise was less than 2° C, and there is definitely reason for concern.

During the course of our duties we have found that some corona discharge events sometime show up well in a thermal image as shown in Figures 6 and 7.

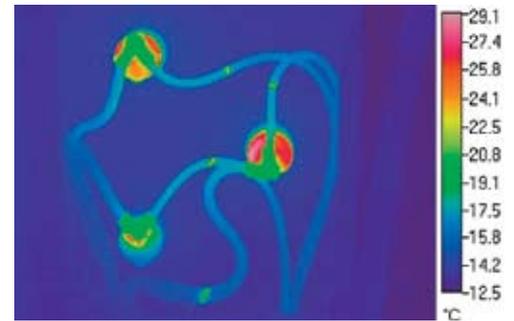


Fig 6 - Active Corona in 4,160V Junction Box

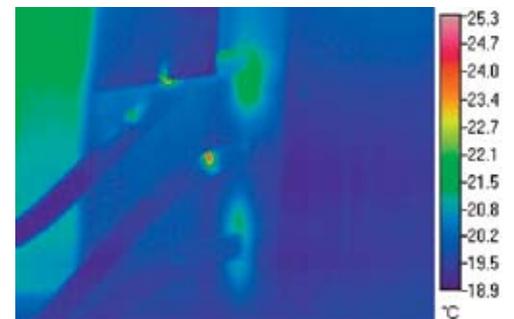


Fig 7 - Rising Temp Due to Corona Discharge in 13,800V Conductors/Insulators

Active corona in Fig. 6 shows a 4,160v junction box which is very close to flashover on three phases and had to be rebuilt because the corona damage was too extensive. We were able to temporarily stop the activity with cleaning, which kept it energized until they had a scheduled shutdown. Fig. 7 shows 13,800v conductors and insulators developing a temperature rise from corona discharge.

Corona discharge is always caused by a deficiency which in turn creates electrical stress on the components (i.e. - contamination, design defect, or poor installation). Corona is not always easy to find, but with the use of UV/Corona Imaging, IR/Thermal Imaging, Ultrasonic detection and visual inspection to verify your findings, it is getting easier.

The corona camera that we use is an excellent tool to find, verify and know exactly where the discharge is and what the corona discharge is doing. When our customers are burdened with high costs for downtime, it is necessary to be as accurate as possible with our findings.

Fig. 8 shows a 5kv main feeder for an underground mine. No outage was needed for this corona problem. After we cleaned the junction box and separated the leads, a heater was installed to keep the moisture out.

Corona is an electrical breakdown of air phenomenon that results from the ionizing of gasses due to a high electrical stress. This stress is often caused by the reasons mentioned earlier, such as contamination and poor insulation values.

After continually working in live metal clad electrical equipment, our company has grown to take the corona situation very seriously. By wearing fire retardant clothing, knowing your surroundings and exits at all times and using proper tools, we have been able to extinguish a lot of corona problems, enhancing employees safety and insuring the integrity of the equipment to prevent costly outages.

There are times when corona is quite obvious even without using any test equipment. Again we use extreme caution to investigate issues like the one shown in Fig 9.

Fig. 9 shows severe corona in a 15kv interrupter switch. The green material on the

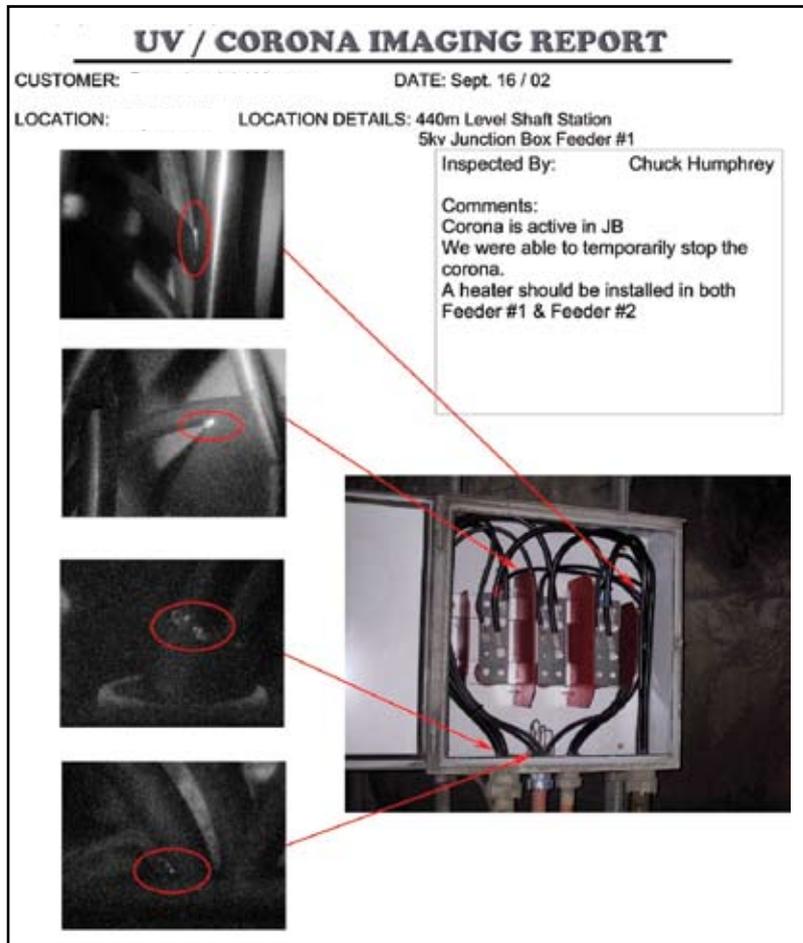


Fig 8 - Ultraviolet/Corona Imaging Report on 5kV Main Feeder for an Underground Mine.

buss bar is corrosion from active corona and the black material on the bakelite insulation is carbon residue from active corona and arcing. This particular switch was very close to flashover.



Fig 9 - Effects of Severe Corona on 15kV Interrupter Switch



Fig 10 - Same 15kV Interrupter Switch After Cleaning

Fig. 10 shows what Fig. 9 looked like after it was cleaned. We were able to stop the corona activity temporarily, to buy time for a scheduled power outage. The problem in this case was the red bakelite divider was tight against the 15kv buss and was starting to short out. The problem was resolved by cutting the insulating divider a couple of inches back from the buss.

There is no single tool that will verify all corona problems every time because the corona discharge is erratic and unpredictable, especially in the early stages. Ultrasound detection is used to verify if airborne ultrasound is present from the corona discharge. The IR camera is used to verify if there is any temperature rise from corona discharge. The UV/corona camera is the ultimate tool for verifying corona discharge. If the discharge is dormant, then none of this equipment will indicate or verify anything. That's when a visual inspection may indicate there was discharge previously as shown in Figures 1 & 2 earlier. Which will tell you, it will return.

When tracking down corona we have found that it does not always leave a thermal signature. Corona by nature creates little or

no heat, but as it progresses into arcing and tracking a thermal signature can sometimes be found. Corona is most intense in the 300 nanometer to 400 nanometer range in the ultraviolet spectrum. When it exceeds the 400nm range, corona can be seen in the visual spectrum if there is no interference from

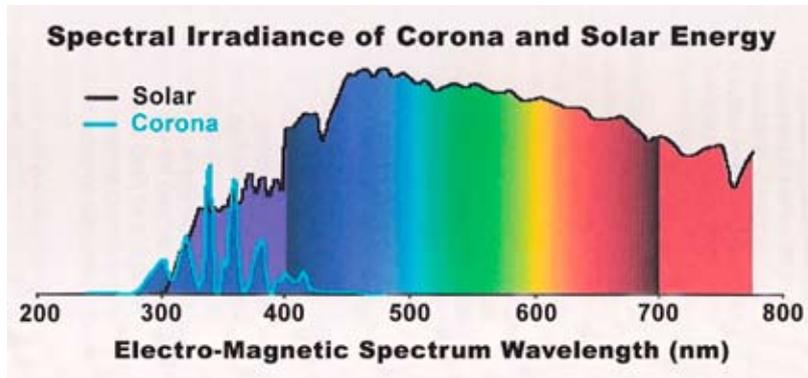


Fig 11 - Where Corona Falls on the Electromagnetic Spectrum

background light. This is similar to heat coming into the visual spectrum at approximately 585°C. at the 700nm level, as shown in Fig. 11.

**Summary**

Corona is a serious and dangerous phenomenon. Over the years Highvec has gone through an enormous learning curve to improve safety

for ourselves and others, while performing on-line electrical cleaning and maintenance up to 230kv. With the use of infrared imaging, corona imaging and ultrasound detection, we are able to find problem areas before they become either a health and safety risk or a serious financial burden to our customers. To clean and maintain electrical equipment under live conditions has proven to be very beneficial to everyone.

*Chuck Humphrey is the president of Highvec Canada, Inc, an electrical company specializing in a unique, environmentally friendly cleaning system for medium & high voltage switchgear under live conditions. Chuck has over 38 years experience in the electrical industry, forming Highvec Canada in 1992. Highvec has extensive experience in on-line cleaning of metal clad switchgear, substation, plant/mill switch rooms, electric motors, etc. Highvec has customers in many sectors of industry, including Mining, Smelting, Refineries, Steel Plants, Pulp & Paper, OSB Plants, and Manufacturing.*

*Chuck has been married to his wife Cindy for 35 years and they have one child, Brianna, who is in college. Highvec Canada is located in Timmins, Ontario, Canada, home to country singer Shania Twain and a city with a "Heart of Gold." Chuck can be contacted at 705-268-6011 or at highvec@highvec.com*



**14<sup>th</sup> Annual Conference**  
**Sheraton Birmingham Hotel**  
**October 22-25**



SMRP is the only independent, non-profit society specifically serving the Maintenance & Reliability profession that offers a conference by practitioners, for practitioners.

**Get Your License to**  
**learn • share • network**

**Over 40 managerial and technical sessions focused on Reliability:**

- Business Management
- Equipment Management
- Manufacturing Processes
- People Skills
- Work Management

**Workshops:**

- Four Secrets To A Successful Reliability Program
- Issues in PM Improvement
- Overview of RCM
- The Application of Six Sigma, Lean Tools and Theory Of Constraints to Maintenance and Reliability
- The Manufacturing Game
- The OZ Principle

**Plant Tours:**

- CMC Steel Group Alabama
- Honda Manufacturing of Alabama
- Southern Company Headquarters
- Motion Industries

**Special Events:**

- Sunday, October 22 | Annual Golf Tournament
- Monday, October 23 & Tuesday, October 24 | Spouse Programs
- Wednesday, October 25 | Barber Motorsports Museum Reception  
*sponsored by BE&K Reliability Solutions and Motion Industries*

**For more information visit [www.smrp.org](http://www.smrp.org) or call 800.950.7354.**

# Making The Right Call

## An Analysis of Large Journal Bearing Lubricant Selection

by Mike Johnson, CMRP

**L**ubricant selection for large journal bearings is a relatively straightforward process if one has a working knowledge of calculus, and/or has and can operate a machine design program that incorporates visco-metric calculations. For those that don't do 'the math thing' or have the software with which to cheat, there are workable alternatives if one knows the right questions to ask, and is willing to dig for the needed details.

Within this two part case study, the author will present a multi-step process that may be used to assess journal bearing lubricant selection fitness, without the complicated mathematical calculations. (Some math is required, but the individual calculations are easy to understand). While the outcome for this approach provides a 'subjective' rather than 'objective' answer, it is hoped that with a better understanding of the process, everyday practitioners will have a better feel for when an existing lubricant selection should be questioned.

This portion of the case study will explain the steps needed to identify the current operating condition and compare that state to the required condition. The second part, to be provided in the next issue, will address the options for reliability-centered improvements.

### A 3-Way See-saw

Plain bearings run in a hydrodynamic condition. The rotating surface is floating on an oil film created through a balance of oil that is just thick enough that it resists being pushed out of the way by the moving surface. There are a few simple ways to change the degree of 'push back' provided by the lubricant. When the amount of 'push' is adjusted, the depth of the oil film between the two surfaces is also adjusted. Increased resistance (increased pushing power) translates to a thicker or deeper oil film between the machine surfaces, which is desirable to a large degree. Increased resistance comes from increased viscosity.

After the machine is installed, the machine maintainer could change the amount of push back by picking a higher initial viscosity (higher viscosity = higher resistance = more 'push back'), which translates to better lifting ability and a deeper oil film.

Before the machine is built, the machine designer could change the machine's lubricated surface area to increase oil film depth. When the surface area increases the available fluid resistance ('push' power) increases; when the surface area decreases then the available fluid resistance decreases.

Machine speed can also influence the oil film depth, but machine speed is selected during original design considerations, and rarely subject to enough change to make a difference.

This is a 3-way see-saw that can be manipulated to arrive at lubricated surfaces that don't bump and rub during operation. Changes in either surface speed, load or viscosity will influence the balance between having an oil film that is either too thick or too thin.

### Is it Safe Yet?

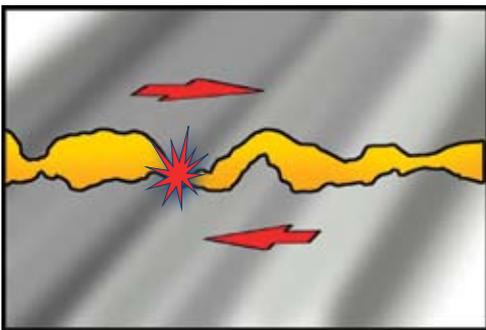
How will the machine owner know when it is time to review the lubricant selection? That is also relatively straightforward. Components operating in a hydrodynamic condition do not interact. If there is any sign of wear debris being produced by the component, mostly in the form of Copper, Lead, Tin and/or Iron, then the likely causes are two and three body abrasive wear, cavitation or corrosion. One should not discount that misalignment, imbalance, and bent shafts are also potential culprits for surface interaction, but at this point the assumption is that the 'normalized' operating state is one of precision balance, alignment and mechanical condition.

Debris analysis (Analytical Ferrography) will help the technician identify corrosive wear, and to some extent differentiate between the other wear modes. The owner can control 3-body abrasive wear (shown in Fig 1) by removing particles that are at or larger than the oil film depth (in the 3 to 10 micron range).



**Fig 1 - Three body wear occurs when the oil film is not thick enough to provide clearance for solid particles in the lubricant.**

A useful cleanliness level would be in the ISO 17/16/13 range. In fact, this should probably be the first priority for a variety of reasons, but that story can wait for another day.



**Fig 2 - Two body wear occurs when the oil film is not thick enough to separate surfaces, leading to prolonged surface interaction.**

If the oil is clean, and there is wear metal present, even to a slight degree, then one may suspect the other wear modes. This is known as 2-body wear and is shown in Fig. 2.

### Double-Check the Operating Viscosity

A wholesale collapse of the oil film in a plain bearing will lead to rapid machine failure. Some machines can operate for years with a marginally adequate oil film. With the change in seasons, and/or changes in oil temperature, the depth of the film increases and decreases. Hot weather, and hot oil sumps, can cause the film depth to fall to a degree that intermittent (or wholesale) contact occurs, generating wear debris. As the weather and the sump temperature cools the oil film depth increases and the rotating shaft floats safely above the stationary

surface. Obviously, wear rate increases with the speed of rotation.

All of this begs the question: is the depth of the oil film adequate to overcome incremental changes in machine speed and oil temperature? Without delving into the attributes of the Sommerfield equation (the mathematical formula used to calculate the theoretical film thickness), how might one go about estimating film adequacy with sufficient accuracy to have confidence in the results from the review?

There are a few available resources that may be used to arrive at the degree of desired detail. The chart in Fig 3 is provided by Michael Neal in the highly useful textbook 'The Tribology Handbook'<sup>1</sup>. This chart provides the user with a dynamic viscosity reference (centipoise, which equals centistokes x lubricant specific gravity) for a known surface speed and mean load. Surface speed and unit loads are calculated based on inputs from the machine and operating parameters. The required surface speed parameter is meters per second, and the load parameter is Kilo-newtons per square meter. Neither unit is necessarily convenient, but both are manageable. (For help with unit conversions try [www.convert-me.com](http://www.convert-me.com).)

The Surface Speed, in meters per second, represents the speed at which a given point on the surface of the journal is traveling in its rotation. This value is calculated by measuring the circumference of the journal (Circumference =  $\pi \times$  Shaft Diameter (in meters)), and multiplying this value by the shaft speed (RPM).

The unit load, in Kilo-newtons per square meter, represents the Mean Pressure on the

loaded surface. This value is estimated by dividing the total load divided by the product of bearing width times shaft diameter (Mean load = Total load / (Bearing Width \* Shaft Diameter)). The total load must include the load of any process weight added to the machine (such as a large rod or ball mill).

To evaluate the viscosity there are several pieces of information that must be collected. For example, consider the following scenario in the table below.

Machine Type	Ball Mill
Lubricant Type	ISO 220 Circulating Oil w/ 0.855 typical specific gravity
Size	13.5' x 32'
Shell Static Weight	110.25 Tons/220,500 lbs (two heads and shell - bare)
Liner & Ball Charge	141.5 Tons 483,085 lbs
Material Feed Rate	77.11 Tons/hr 154,233 lbs/hr
Total Weight	429 Tons / 857,816.6 lbs / 3,139.89 Kilo-newtons
Bearings Type	Oil Lubricated (Hydrodynamic) Journal Bearings - 2 ea
Bearing Width	30 inches
Shaft Diameter	72 Inches
Shaft Speed	16.2 RPM

From these details we calculate the bearing surface area and the total load distributed into the surface area, and arrive at a unit loading, as seen below.

Linear Surface Speed	1.5512 meters/second
Mean Pressure	1,126.58 Kn/m <sup>2</sup>

Once the unit mean pressure is known, one can verify the required viscosity at operating speed and operating temperature.

# TOTAL *Lubrication Management* SOLUTIONS

## SERVICES

## ASSESSMENTS • AUDITS • CONSULTING



Trico's consulting services will identify existing lubrication and work management system problems, then develop custom solutions for improving your facility's equipment reliability and reducing your maintenance costs.

- Lubrication Program Assessments
- Critical Equipment & Lubrication Program Audits
- PM Work Task & Route Generation Development
- Base Signatures – Root Cause Analysis
- CMMS/EAM Integration & Implementation

## TRAINING

## PUBLIC • PRIVATE • CUSTOMIZED



Trico's training services provide practical, hands-on instruction to help you achieve industry "Best Practices" with your lubrication management program. Only Trico offers progressive lubrication management training seminars – with three tiers of certification available.

- Public & Private Lubrication Management Seminars
- Customized Training Programs – from 1 to 100 Days
- Multiple Industry Organizations Certifications – ICML & STLE
- Progressive Lubrication Management Training – Three Levels Available!

## PRODUCTS

## PREVENTION • DETECTION • CORRECTION



• CONSTANT LEVEL LUBRICATION



• OIL SAMPLING



• GREASE LUBRICATORS



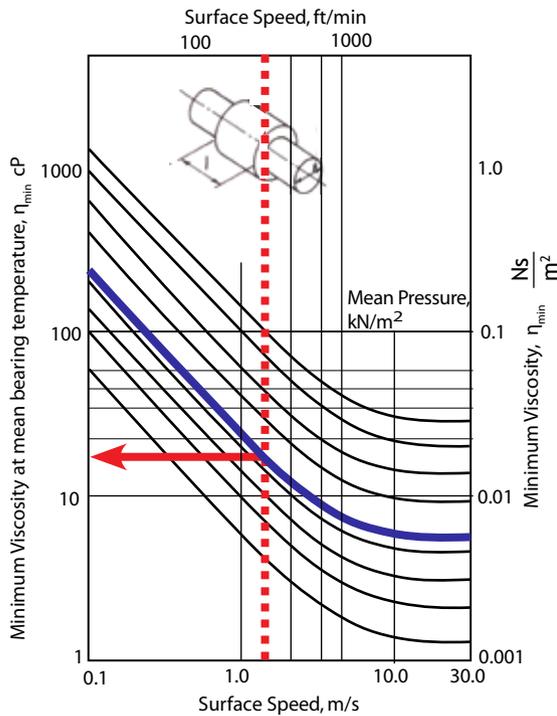
• DESICCANT BREATHERS

**TRICO. Your Company for TOTAL Lubrication Management SOLUTIONS.**

Maximizing your machine productivity. Optimizing your operations. Never compromising your standards.  
That's TRICO. That's our way of doing business.

Call us at 800.558.7008 or visit our website at [www.tricocorp.com](http://www.tricocorp.com) for more information.

**TRICO**  
MAXIMIZE, OPTIMIZE, NEVER COMPROMISE.



**Fig 3 - This chart illustrates how to identify the minimum acceptable viscosity for a given plain bearing condition.**

(Courtesy of M. Neale, "The Tribology Handbook", 2nd Edition.)

The next step is to determine the actual dynamic viscosity. The Centipoise measurement unit represents the thickness of the lubricant within a system in operation, where the oil is literally pushed around by lubricated components. Centipoise is calculated by multiplying the lubricant's viscosity rating in centistokes by the lubricant's specific gravity. The specific gravity can be either measured or taken from the 'typical value' shown on the product data sheet. The typical value is adequate unless, in the final synopsis, the actual viscosity is lower than the minimum allowable limit. The closer the actual value is to the minimum allowable limit the more important it is to know the exact number. In the example case, the typical value is adequate.

The second step itself has a few different requirements. Step 2.a requires that one determine the lubricant's viscosity at operating temperature. Step 2.b requires one to convert this value to a centipoise unit, and 2.c requires one to compare the actual value to the stated limit. Hopefully, the actual value is around 3 times greater than the observed minimum value.

Stay tuned for the second and final part of this analysis in next month's issue of Uptime.

*Mike Johnson is the founder of Advanced Machine Reliability Resources Inc., a firm that provides precision lubrication program development, consulting and training. He has written and presented numerous technical papers at symposia and conferences throughout North America about how to use machine lubrication to drive machine reliability. Mike is happily married, plays and coaches soccer, and has 3 young children that consume his remaining time and attention. He can be reached at [mjohnson@amrri.com](mailto:mjohnson@amrri.com) or 615-771-6030.*

1. Neal, M.J. 'The Tribology Handbook', 2nd Edition. 1999. Page C7. Published by: Butterworth - Heinemann, Div. of Elsevier PLC Group.

This is a two step process. First, plot the linear surface speed (bottom axis, the bold red dotted line), and then plot the load (side axis, solid blue line) as closely as possible. Remember the spacing is logarithmic. Wherever the two lines intersect represents the minimum allowable Dynamic viscosity. Dynamic viscosity is provided in Centipoise. In the example, the absolute minimum appears to be around 18 centipoise. Keep in mind, there are generally two bearings, so the surface area must be combined to determine the mean loading value. This completes the first step.

The next step is to determine the actual

## WHY ARE WORLD LEADING COMPANIES CHOOSING ALL-TEST PRO™?



**NEW**

**AT**  
**PRO**

### Is It Because Of:

- **USER FRIENDLINESS?** Average operator learning time 2 hours for on-line + 2 hours for off-line.
- **SAFETY OF OPERATION?** Off-line testing = no requirements for safety gear; on-line testing can be done through laptop at 15 ft of distance from starter.
- **NON-DESTRUCTIVE TEST?** Off-line = low voltage. No deterioration to insulation guaranteed.
- **FAST AND ACCURATE?** Each motor is tested in a few minutes, including set-up. Repeatable Results.
- **PRICE?** Lowest cost on the market. Fast ROI.
- ✓ **OR - ALL OF THE ABOVE?**

### TOTAL PREDICTIVE MAINTENANCE PROGRAM

The ALL-TEST PRO™ MD kit offers you on and off-line testing and trending with motor current analysis, motor current signature and power quality management. Tests are conducted safely and quickly from the starter. Powerful software analyzes and writes reports and work-orders. ALL TEST PRO™ units are hand-held and lightweight.

### QUALITY ASSURANCE PROGRAM

Test all incoming or outgoing motors, new or repaired.

### TROUBLE SHOOTING

Know immediately if your problem is mechanical or electrical.

### POWER QUALITY CONTROL

A must for controlling the cost of energy and for evaluating equipment performance.

**Please visit our website or email, phone or fax us today for more information!**

**GSA** Schedule

Proud to Serve Our Federal Customers

**ALL-TEST Pro, LLC**

Phone: 860-395-2988 • 800-952-8776

Fax: 860-399-3180

E-mail: [info@alltestpro.com](mailto:info@alltestpro.com)

Web: [www.alltestpro.com](http://www.alltestpro.com)

# Finding Faults and Failings

Using Motor Diagnostics to Detect Cable Faults

by Richard Borge

**P**erformance Evaluations provides motor testing services for industrial sites and commercial buildings throughout the United States. The primary tools we use for predictive maintenance and evaluation are the ALL-TEST IV PRO 2000 motor circuit analyzer and the ATPOL electrical signature analyzer. Two of the most common findings that we have identified in many of the commercial building applications are cable and connection faults both in the motor control and in the motor connection box.

## Field Testing

During a routine predictive maintenance route in a New York City commercial building, we identified unusual Motor Circuit Analysis (MCA) test results on a 600 horsepower, 1150 RPM, 4160 Vac electric motor driving a pump. This motor is shown in Figure 1.



Figure 1 - 600 HP, 4160 Vac, 1150 RPM Motor

The phase angle and current/frequency response (I/F) test results should be +/- 1 digit between phases if there are no problems. As shown in Table 1, the phase angle and I/F were significantly off on one phase. The instrument software identified it as a "Shorted Winding; Recommend check at motor if tested from MCC."

	T1-T2	T1-T3	T2-T3
Resistance	0.6554	0.6563	0.6544
Impedance	252	232	235
Inductance	100	92	93
Phase Angle	85	86	80
I/F	-47	-46	-50

Table 1 - Initial Findings with Motor Current Analysis

The reason for the requirement to check at the motor connection box, in these cases, is that MCA can detect cable problems when testing from the Motor Control Center. If the test results are good at the connection box, then the cable is bad, if the test results are the same, then the motor, if it is still operating, has a developing winding short.

## Discovery

Before testing at the motor, we recognized that the cable from the motor control to the motor was excessively long. As a result, it was forced into the cabinet and up against one of the sides. We decided to inspect the cable prior to going through the difficulty of taking apart the connection box and connections. During the inspection, the electrician pulled the cable away from the side of the cabinet.

	T1-T2	T1-T3	T2-T3
Resistance	0.6549	0.6547	0.6541
Impedance	255	233	236
Inductance	101	92	93
Phase Angle	85	85	85
I/F	-47	-47	-47

**Table 2 - Final Findings with Motor Current Analysis**



**Figure 2 - Cable in Motor Control Center**

Discoloration (shown in Figures 2, 3 and 4) was identified as partial discharge between the cable and cabinet, which would have led to a catastrophic cable to ground failure at some point in the future.

After moving the cable away from the side of the cabinet, MCA tests were performed which identified good test results, which are shown in Table 2. Tests were repeated to confirm the discovery.

The cable was shortened and repaired by wrapping a high voltage tape around the affected area. By shortening the cables, they were no longer forced against the side of the cabinet, removing the danger of cable to ground failure.

### Conclusion

Cable faults are far more common in commercial and industrial applications than many realize. The use of MCA diagnostic tools allow the field service technician and electrician to identify insulation issues in both the electric motor and cabling that feeds the motor. Outside of the motor, MCA has allowed us to detect connection problems and cable faults. Within the electric motor, we have been able to trend winding degradation, winding contamination issues, and identify broken conductors and rotor faults well in advance of the motor ultimately failing.

*Richard Borge is president of Performance Evaluation Inc., a company that has developed a unique method of testing AC/DC electric motors, cables and transformers that is known as "Time Domain Reflectometry". Performance Evaluation has been testing electrical equipment for the past 22 years with an assortment of test equipment. Performance has used both static and dynamic tests to help prevent unscheduled downtime. The testing includes AC/DC motors of all sizes and transformers. You can reach Richard Borge at 888-484-7564, perfeval@aol.com and 973-661-4281 (fax). The website is www.performancetdr.com*



**Figure 3 - Partial Discharge Between Cable and Cabinet**



**Figure 4 - Partial Discharge Location On Cabinet**

# Big Return on Little Investment

## Changing Standby Equipment Procedure Could Lead to Large Payoff

by V. Narayan

**S**tandby equipment is installed in order to ensure the availability of process systems or sub-systems at a high level. The configuration may be 2x100%, 3x50%, 2x75%, 4x50%, 4x33% or similar. The common operating practice is to run standby equipment intermittently with the duty equipment, so that in most cases the running hours are equalized.

This practice has several benefits from the operational point of view. For instance:

- Equipment changeover is often linked to the shift changeover, allowing some measure of ownership.
- The operators 'know' that both the duty and standby equipment work, because this has been demonstrated.
- The equipment accumulate equal running hours, and operating experience.
- In some cases, startup procedures are difficult and time consuming. So once the standby has been started up, it is convenient to leave it running.
- In other cases, the equipment has to accumulate running hours in a predetermined fashion, as in the case of gas turbine drivers. The policy will be set by this requirement.

However, running duty equipment intermittently with standby equipment is somewhat different from the maintenance point of view, and the relevant points are set out in this article.

### Historical Background

In the days before the introduction of mechanical seals, the shaft sealing arrangement for reciprocating and rotating machinery involved packed glands. These packings needed regular lubrication or they would dry up and harden, rendering them useless. In the majority of cases, the only way to lubricate these packings effectively was to run the equipment, allowing controlled leakage of the process fluid to provide lubrication. The practice of running duty and standby equipment probably started to meet this requirement, and has continued long after the demise of the packed gland in reciprocating and rotating equipment.

### Functional Differences

Let's consider the case of a 2x100% product export pumping situation, where we have a designated duty and standby pump.

The consequence of failure of the two pumps differ, as will be readily observed. If the duty pump fails in service, the other cuts in, and in most cases, there is no impact on production. Of course, in the case of large pumps, the cost of repairs after a breakdown can be much higher than corrective work done as a result of condition monitoring. For the same reason, some limited preventive maintenance work can be justified. When we consider the consequence of failure, in the majority of cases, it is difficult to justify any significant maintenance work.

As far as the standby pump is concerned, the most important failure mode is the failure to start on demand. Depending on historical failure-to-start rates, a test start can be organized at a suitable frequency, to ensure its desired availability. The next failure mode to consider is the inability to deliver the required flow at the operating pressure. The solution is to run the 'test' for a reasonable length of time, say 8-24 hours, with the duty equipment shut down. A spin off benefit from running long duration full load tests is that it will then be possible to take condition monitoring readings for the standby equipment regularly.

Let's consider the situation when we run the pumps alternately - either pump, if running at the time may fail while running, and if on standby, may not perform the duty satisfactorily. Thus both pumps need to be maintained on a preventive basis, often with poor condition monitoring data (since the collection of data is a hit or miss affair). The wear out rate is about equal, and the conservative policy would be to carry out time-based overhauls. This is certainly costly and inefficient. However, there is one small benefit - test starts are no longer required, as alternate running is in itself a load test.

# Shaft alignment in a Flash®



Fig 1 - Pump, piping, valves at an industrial waste treatment facility.

## Impact on Failure Rates

Seal failures have a significant impact on overall failure rates. Their failure rate is influenced by the number of starts, rather than the duration in operation. This is because seals that are running are well lubricated, and generally show low wear rates. The worst time for a seal is during start-up. At start, the seal faces are dry, and it takes a short while to build up the fluid film between the faces. Therefore, frequent starts are a major cause of wear in seals, and by reducing the number of starts, we can reduce the seal failure rate, and hence the pump failure rate.

Intermittent operation results in many starts, which tends to increase failure rates, while in the case of duty/standby operation, the test frequencies will generally be quite low, and hence fewer startups will be required.

## Discussion

There are two issues to consider, one relating to uptime and the second relating to costs.

In the case where both pumps are run alternately, both have to be taken out of service from time to time to carry out maintenance. The work may be initiated by condition monitoring trends, or on the basis of running hours

or time. In the duty/standby case, little or no maintenance is required on the duty pump, until it exhibits performance problems. Work on the standby pump will only be initiated if the test run fails.

Thus it is apparent that the total downtime will be much higher in the first case. While system availability may be kept up to requirements by strictly controlling repair times, there is a cost penalty associated with this policy. Due to the higher seal failure rate, in absolute terms the workload will be higher. Further, the longer the downtime on one pump, the greater the chances that the other will fail while running, hence overall, the system availability will tend to fall.

In general, the system availability will be higher when designated duty and standby services are identified and the operating policy suitably aligned.

The volume of maintenance work is reduced considerably by following such a policy. As discussed earlier, little or no work is required on the duty pump, and the only work required on the standby pump is to perform the test runs, followed by any corrective maintenance resulting from the test. Any overhaul of the duty pump will be based on performance. Secondly, seal failure rates will fall, resulting in fewer interventions and effort.

This has an immediate favorable impact on maintenance costs.

Alternatively, a biased unequal running policy may be adopted. In this case, the duty equipment runs for say 7 weeks, and the standby equipment runs for 1 week. The advantage of this policy is that it produces a lower total number of starts, while allowing a long duration test run (of 1 week), and a test frequency in this case of 7 weeks.

## Conclusion

The duty/standby operating policy should be



## Introducing the Fixturlaser XA.

The XA, Fixturlaser's next generation system for laser alignment of horizontal shafts, is designed to get alignments done fast, really fast. The system incorporates on-screen Flash® animations that actually walk the user through the alignment process! Other innovations include large 30-millimeter detectors, line laser beams, and wireless connectivity.

# VibrAlign

www.vibralign.com

800-379-2250

Flash is a registered trademark of Adobe Systems Incorporated.

**Solution Oriented Asset Reliability**

Toll Free: 888.575.1245

Phone:305.735.3746 Fax:309.423.7234

www.reliabilityweb.com

**RELIABILITY**<sup>TM</sup>

**WEB.COM**

**Benchmarking Surveys**

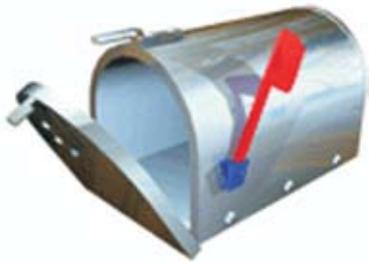
**White Papers**

**Exclusive Articles**

**Web Based Seminars**

**Reliability E-Mail Discussion List**

**Maintenance & Reliability Best Practices**



*Delivered Weekly To  
Your E-Mail Inbox*

**Stay up to date on:**

- ▲ RCM
- ▲ TPM
- ▲ PMO
- ▲ Root Cause Analysis
- ▲ Maintenance Planning
- ▲ Vibration Analysis
- ▲ Infrared Thermography
- ▲ Motor Testing
- ▲ Oil Analysis
- ▲ Ultrasound

**Subscribe now at:**

**FREE**

[www.reliabilityweb.com/newsletter.htm](http://www.reliabilityweb.com/newsletter.htm)

adopted as the standard mode of operation. Duty and standby equipment should be designated wherever redundancy exists. As an alternative, a biased unequal running policy may be adopted. Reliability Centered Maintenance logic should be used to determine the maintenance requirements of such equipment.

In specific cases, where other considerations dictate operating policy, exceptions can be made to suit the circumstances.

### Benefits

I have seen results within 6 months of implementing a duty/standby policy that were truly amazing:

- 10-12% rise in MTBFs
- 10-12% fall in maintenance costs
- 1-2% rise in sub-system availability

An additional benefit that we achieved, and

you could too, was that our condition monitoring data quality improved dramatically, with all of our data points entered, not just those of the items that happened to be running when the technician came around. Of course, that is because we could now plan when they would come and it was no longer a hit or miss affair. Many of our gains came from having a better handle on our Condition Monitoring program, not just the reduction in seal failures.

Our implementation was not unique though. The savings listed earlier are very achievable by any number of companies across many industries. Those are the kinds of gains that you would normally pay consultants a lot of money to achieve, and you would spend an awful lot of effort to implement.

Implementing the duty/standby alternative costs close to nothing, can be achieved

quickly and will generate a monetary return in months, not years.

*V. (Vee) Narayan, is the author of Effective Maintenance Management: Risk and Reliability Strategies for Optimizing Performance. Mr. Narayan is a mechanical engineer with over 38 years experience in Petroleum Refining, Pharmaceutical, Liquefied Natural Gas Production, Oil & Gas Exploration and Production and in the Engineering Industries. He led the Maintenance Strategy group in Shell UK Exploration and Production, Aberdeen until his retirement in March 2002. He also managed the Royal Dutch Shell Group's Centre of Excellence (CoE) in Maintenance and Reliability Engineering. Within Shell, Mr. Narayan has been teaching Reliability Centred Maintenance, Root Cause Analysis and Maintenance Management for about 12 years.*

## **NO MATTER WHOSE ULTRASOUND YOU ARE USING, WE CAN TRAIN YOU!**

ONSITE

ONE & TWO DAY

WORKSHOPS

LEVELS I & II

- ◆ Leak Detection
  - ◆ Compressed Air
  - ◆ Cryogenics
  - ◆ Wind/Water Leaks (Aviation, Automotive)
- ◆ Bearing Analysis

- ◆ Acoustic Lubrication
- ◆ Steam Trap T/S
- ◆ Electrical Scanning (Arcing, Tracking & Corona)
- ◆ Switchgear
- ◆ Substations

SPECIALIZING IN

**ONE & TWO DAY AIRBORNE  
ULTRASOUND WORKSHOPS**

**Call Today to Schedule Your Training!**

**“REAL WORLD ULTRASOUND”**

**“VENDOR-NEUTRAL TRAINING”**

**WE DO NOT SELL EQUIPMENT!**



Contact: Jim Hall  
(770) 517-8747

[jim.hall@ultra-soundtech.com](mailto:jim.hall@ultra-soundtech.com)  
Co-editor of UPTIME Magazine  
Author of: Ultrasonic War Stories

**(770) 517-8747**

**www.Ultra-SoundTech.com**

# A Real Life Saver

## Scanning Electrical Switchgear with Ultrasound Increases Safety

by Jim Hall

**“***n religion and politics people’s beliefs and convictions are in almost every case gotten at second-hand, and without examination, from authorities who have not themselves examined the questions at issue but have taken them at second-hand from other non-examiners, whose opinions about them were not worth a brass farthing.”*  
 -- Autobiography of Mark Twain by Samuel Clemens

Could Samuel Clemens have also been referring to ultrasonic scanning for electrical switchgear?

Have you received your information about scanning electrical switchgear with airborne ultrasound second-hand from so-called authorities? Have you put a lot of thought into that information? Do you trust that those authorities have examined the questions about ultrasonic scanning, or could they have taken what they know, second-hand from non-users of ultrasound?

For those of you who have never used ultrasound for leak detection or for electrical scanning of switchgear, I urge you to borrow a unit right now and start scanning and listening. All of the technicians now using airborne ultrasound to scan electrical switchgear first had to become familiar with the sound of arcing, tracking, corona discharge and destructive corona discharge. This knowledge can only be gained by proactively using the instrument in the field.

### Know the Warning Signs

There was one southern utilities engineer who had taken the time to familiarize himself with his ultrasound equipment - as well as what corona, arcing and tracking sounded like through an ultrasonic receiver.

One day this engineer had a call from a customer complaining about power interruption, so he decided to scan the area using his ultrasound receiver. He drove out to the plant and parked near a metal clad switchgear cabinet. He rolled down the window of his truck and scanned from about 20 feet away using a long range parabolic dish. To his surprise he heard what sounded like destructive corona. Using his infrared (IR) camera he scanned but did not see any obvious IR signatures for concern. He then got out of his truck and dressed himself in the proper personal protective equipment (PPE).

Now, this engineer knew the possibility of what could hap-

pen when he opened the door to the switchgear but, he was now prepared both mentally and physically. A hot summer day, high humidity, and possible carbon



Figure 1 - Scanning a substation for problems using SDT 170 and Parabolic.

build-up from the active arcing. Everything was present for a potential flash-over. As he slowly opened the door to the cabinet, sure enough he experienced the dreaded flash-over. After picking himself up off the ground he examined the switchgear to find that the Bakelite boards had “L” shaped holes in them and that the paint was discolored on the inside.

Within just a few hours a major problem had been discovered and a replacement cabinet had been ordered to divert a possible shut-down.

I have spent many hours talking with infrared thermographers and electrical technicians. Yet most of the doubting Thomases - those who don’t see the validity or value in using airborne ultrasound for electrical inspection - are the

ones who have not actually used the technology themselves. Unfortunately, it seems many of these people are still living in the past, when the fact that ultrasound was subjective was somehow interpreted to mean it is not valid. Don't confuse subjective with inaccurate or invalid. They are not the same.

## Audioception

**Audioception:** *a: to take an audio signal (wave file) into one's mind <conceive a prejudice> b: to form a conception of: Imagine.*

Think of this word as you familiarize yourself with the sounds that are described in Figure 2. Form a conception in your mind, perhaps a mental picture of the inside of an electrical cabinet you are scanning. Then while using a little mental dexterity as you scan think of the sound you are hearing and relate it to the situation at hand. Ask yourself, is it corona, tracking or arcing?

Of course "audioception" is not limited to electrical scanning. Audioception can also be used when listening, for instance, to a bearing on a motor. What is the sound you are hearing - outer race, inner race, flat spots, brinelling or lubrication? Concentrate and try to form a visual image.

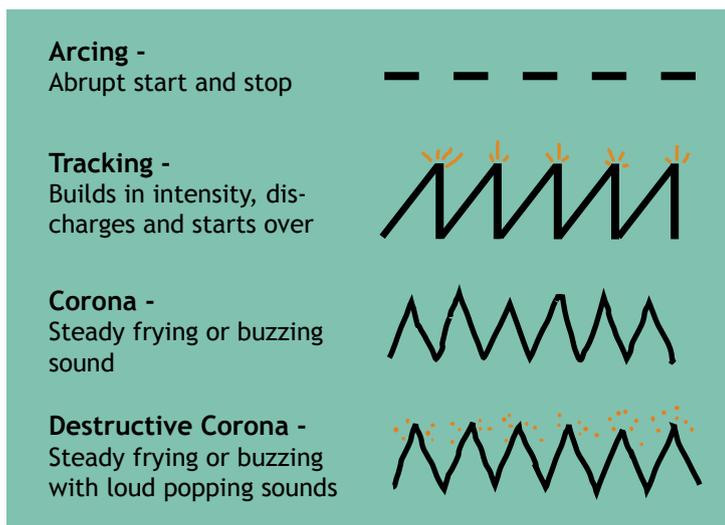


Figure 2 - Visual representations of the sounds formed by electrical problems.

As with all airborne ultrasound applications, ultrasound readings can be very subjective. However, it is not so much the readings that should compel you to take action, it is the familiar sound that may precede the opening of an electrical panel or door or the sounds discovered before entering a vault or substation.

## Corona

Corona is a faint glow adjacent to the surface of an electrical conductor at high voltage as a result of the ionization of gases due to the high electrical stress.

Corona is really just air. With no ground there is no heat build up. No ground, no heat, no IR signature. In detecting corona, listen for a steady frying or buzzing sound, some say an egg frying sound.

## Destructive Corona

Just like corona, destructive corona also is a faint glow adjacent to the surface of an electrical conductor at high voltage as a result of ionization of gases due to the high electrical stress.

As with corona, Destructive Corona is also air. With no ground there is no heat build up and, as a result, no IR signature. The signature sound for destructive corona is a steady frying or buzzing sound with intermittent popping sounds. The popping sound is typical of an advanced condition. Take action immediately.

## Tracking

"Baby arcing" is a phrase sometimes used to describe tracking. Damaged insulation provides a path for tracking to occur. As with corona, contaminants like moisture, dust, dirt or fiber particles



Figure 3 - Ultrasonic inspection of a 480v panel using an SDT 170.

must be present to provide a path for tracking. Again, heat is not present until the problem is very advanced and failure is certain. If tracking is occurring, you will hear the sound build in intensity, discharge and then the process starts over again.

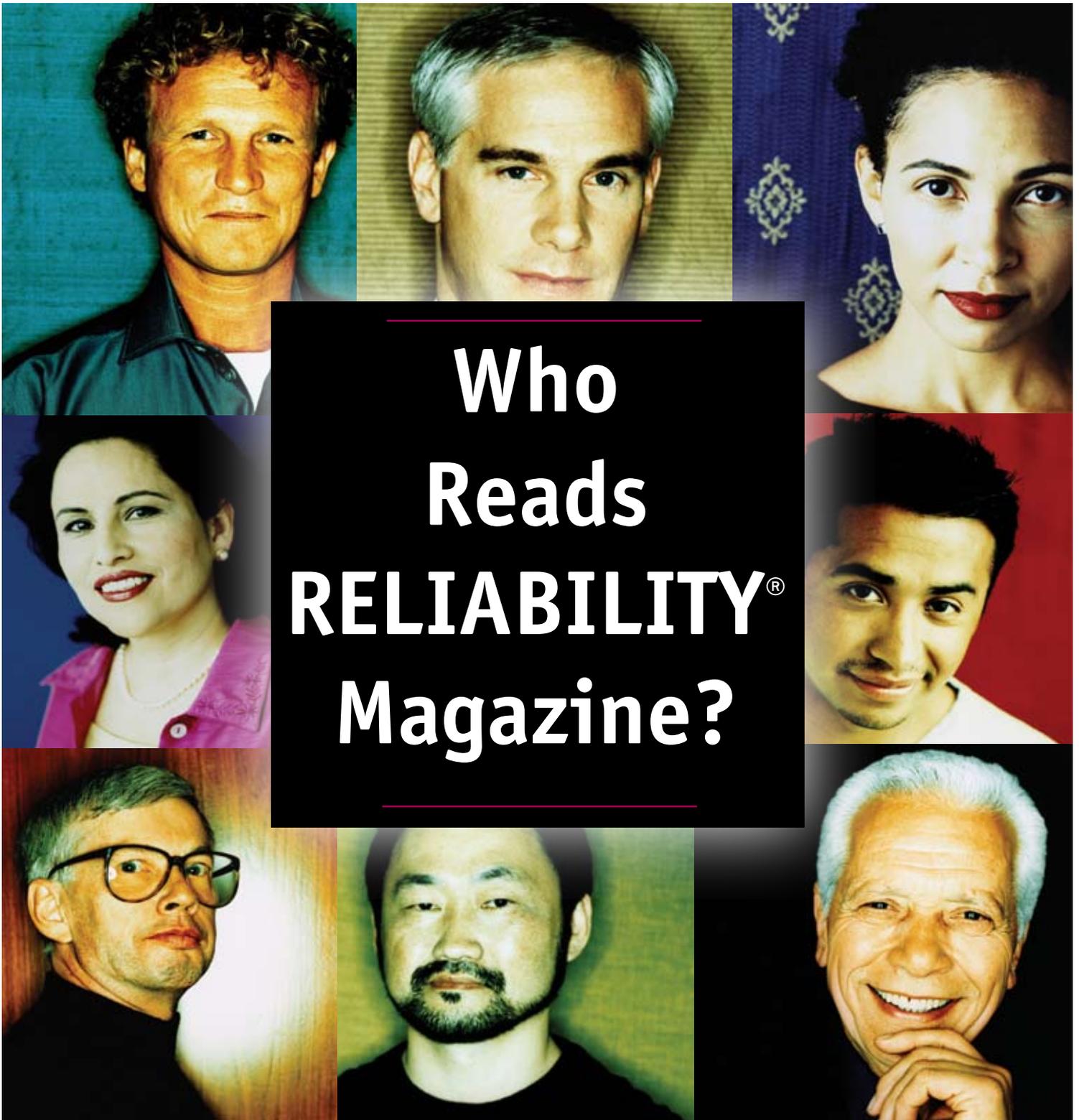
## Arcing

**Arc:** *A sustained luminous discharge of electricity across a gap in a circuit or electrodes (or conductors)*<sup>1</sup>

Arcing is the flow of electricity through the air from one conductor to another. Arcing can produce visible flashes and flames along with a crackling sound. It is generally caused by overloaded electrical equipment, and requires immediate attention. To detect arcing, listen for a sound with an abrupt start and stop.

When scanning electrical equipment, do not rely solely on either the lack of volume or increased decibel levels to identify a problem. As a technician, you should also rely on your instincts. Again, the more ultrasound scanning you do, the better you will get at it. Remember to take each situation you experience as a separate, and potentially dangerous, case.

Here is an example of audioception. You are scanning a panel and you unexpectedly hear a steady frying or buzzing sound as you scan the



# Who Reads RELIABILITY® Magazine?

**O**ver 10,000 maintenance & reliability decision makers from some of the largest companies in the world! Our subscription base is expanding rapidly with help from our new partners at Reliabilityweb.com.

Our readers tell us they are seeking "solutions" that they don't find in traditional free trade magazines... but they do find them in RELIABILITY® Magazine, featuring how-to articles and solution oriented case studies.

Providing bonus distribution at over 20 major maintenance & reliability related events throughout the year, RELIABILITY® Magazine is the premier publication to reach professionals in the maintenance and reliability market.

*To learn more about advertising options please contact Bill Partipilo at 239-985-0317, ext 114 or email [bp@reliability-magazine.com](mailto:bp@reliability-magazine.com).*



**RELIABILITY®**  
THE MAGAZINE FOR IMPROVED PLANT PRODUCTIVITY



**Figure 4 - Electrical cabinet inspection with appropriate personal protective equipment (PPE).**

front lower right-hand corner of a 13.8kv rectifier panel. This particular panel has a vacuum breaker in the lower right hand corner. What is it? What do you do? Are you properly attired? This particular panel was scanned just days before with IR, and no IR signature was seen. Yet, ultrasonically it could be a screamer that sends chills down your back.

Most importantly, get familiar with the sounds of arcing, tracking, corona discharge and destructive corona discharge.

Wave files of these sounds are posted at [www.Ultra-SoundTech.com](http://www.Ultra-SoundTech.com). Feel free to visit and listen to get familiar with the ultrasonic sounds of electrical scanning.

*NFPA 70E – Standard for Electrical Safety in the Workplace* covers the full range of electrical safety issues from safety-related work practices to maintenance, special equipment requirements, and installation. If you are responsible in any way for inspecting electrical systems, you should get a copy. Read it and get familiar with Personal Protective Equipment and how to perform an electrical panel safe boundary survey. This is one area where you should not depend on information from other people. It's your life.

Although you may have the PPE on, you should scan electrical panels, switchgear and substations with airborne ultrasound before you open them. You shouldn't ever let your guard down just because you don't hear anything. However, if ultrasound does allow you to hear arcing, tracking or corona discharge, you will certainly be better prepared, both mentally and physically, to handle the situation.

*Jim Hall is the president of Ultra-Sound Technologies (UST), a 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 contributor at both ReliabilityWeb.com and Uptime Magazine. Jim has provided airborne ultrasound training for many Fortune 500 Companies in*

*electrical generation, pulp & paper, petro-chemical and transportation. 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).*

1. Webster's Ninth New Collegiate Dictionary, published by Merriam Webster Inc.

## ONE-Stop Shopping for Your Condition Monitoring Needs



**Prescient<sup>sm</sup>**  
Intelligent Oil  
Analysis Diagnostics

Sensors - Oil and  
Vibration Monitoring



Laboratory Instruments  
and Installations



Training

**STLE**

Education Partner

Condition Monitoring International, LLC  
(A Kittiwake and ifm efector Octavis Distributor)  
515 E. Crossville Rd, Suite 110, Roswell GA 30075  
**Tel:** 678.942.3582 / 514.953.7034 **Fax:** 678.483.3505  
**Email:** [sales@cmiglobal.biz](mailto:sales@cmiglobal.biz)  
**[www.cmiglobal.biz](http://www.cmiglobal.biz)**



# The Bigger Picture

Making Vibration & Other Condition Monitoring Tools Go Further

By Thomas J. Murphy

**C**ondition monitoring works. It is a well-proven technique which helps keep planes flying, power stations generating, paper machines making paper and presses printing. The concept of vibration monitoring using a portable digital vibration analyzer is roughly the same age as the PC. We all know that if our PC fails to perform we re-boot and carry on. However, if vibration monitoring fails to perform, many people think it is because the technique “doesn’t work”.

The common perception of condition monitoring, and vibration analysis in particular, is one of the trouble-shooter called out to solve the acute problem. However, the large majority of the money lost in the operation of any plant is not from the acute problems. It is lost in the chronic, everyday problems. These are the problems that everyone has become accustomed to solving through the “quick fix” in order to just “keep things going”.

The tools involved have become more complex over the years, and today we basically have two significantly different streams:

1. Those organizations prepared to throw tens of thousands of dollars into condition monitoring
2. Those organizations who still have fitters listening to screwdrivers.

Which way moves you forward?

## Moving Forward

One of the key benefits of predictive maintenance is the ability to predict failures and trap them before they occur. Another must be to learn from your mistakes. When reviewing the effectiveness of operating condition monitoring regimes, one is often brought face-to-face with what can best be described as the “saw-tooth” trend i.e. a historical trend where an increase has been identified, maintenance performed, trend drops, trend increases, maintenance is performed, trend drops, etc.

Technically, it is predictive and it is certainly maintenance, but is it moving forward? Of course the answer has to be “no”. Such a system has reached its asymptote, there is no room for further expansion, nor for further improvement.

This is a classic case for the need to move from daily to diagnostic – to use the data collected not only via the data collector but also via the fitter, mechanic, greaser, operator and floor cleaner to piece together a bigger picture. The three letters RCM have come to be well recognized as Reliability Centered Maintenance. Another, and arguably more powerful, use of those three

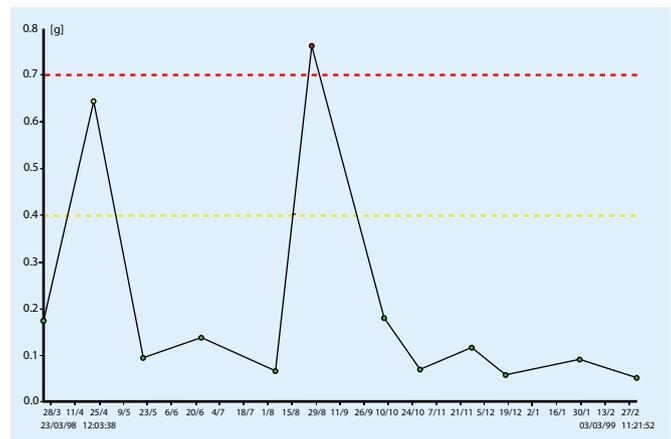


Figure 1 - Trend of Vibration Levels for Bearing

letters would be Root Cause Maintenance. Look at the trend in Figure 1. Initial greasing of this bearing reduced the vibration level. When the vibration level increased again a strip down of the bearing was ordered and the old grease removed and cleaned out thoroughly. Since then, the same bearing has been fine and the vibration levels have remained down. Without the stripdown, this case could have easily developed into the sawtooth trend, making for more repetitive work without finding the real solution.

## Never Assume

One of the golden rules in safety is “Never Assume”. This same rule has very powerful benefits in mainte-

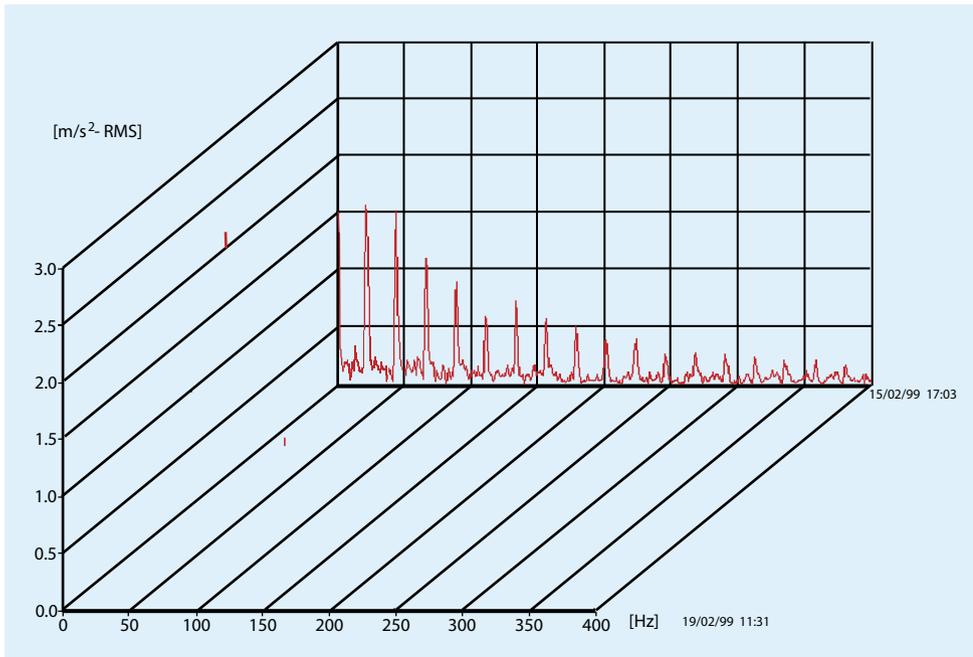


Figure 2 - Vibration Levels of Bearing on Fan Shaft

nance. Just because it is new or just because it has recently returned from overhaul does not justify the assumption that it is perfect.

The spectrum in Figure 2 shows looseness of a bearing on a fan shaft. Damage had occurred within 2 weeks of fitting new bearings to an old shaft. The smudge on the axis in the foreground is the “properly” repaired condition.

### Hand-held vs. Continuous On-line Monitoring

The primary reason that most organizations fail to develop the correct regime of monitoring is due to a fundamental lack of understanding of the problems and the costs at the board level. There is understanding regarding photocopiers and company cars but not maintenance.

In the final analysis the choice is not an either or, it is both. There will be some parts of a press, paper machine or other piece of equipment where continuous monitoring will be the only way to provide the depth of operating condition information necessary to make an informed judgement about incipi-

ent failure. At the other extreme, monthly checks on some pumps or fans using a portable instrument will probably be more than sufficient.

One of the biggest problems with portable monitoring is the frequency of measurement. Once again price becomes an issue and companies fall into a false economy of quarterly or twice-a-year surveys. Condition monitoring measures the condition now. If the condition is good and the prognosis is good then all is apparently well. However, two months from now – maybe even two weeks from now - the story may be different, and that change may result in a failure before the next scheduled visit. If that happens, the conclusion will be that the technique does not work!

A simple car analogy would be checking tire condition. Routine checks will reveal wear problems and some prediction about the onset of poor handling may be made. But, even daily checks cannot predict a puncture. There will always be mechanisms for potentially catastrophic machine failures – like blockages in a shared lubrication system - which, if overlooked or not present at the

time of the routine survey, will inevitably lead to premature machine failure.

It is for these reasons - as well as the need to gather and process significantly more data than can sensibly be collected by hand - that on-line systems have their place in the toolkit. The most important aspect must be the integration between the two. It is essential that the on-line and off-line should use the same database and present the same user interface. This keeps all data accessible to all people and in a universally understandable format.

### Benefits of Multiple Approaches

I often hear “we use thermography” or “we use oil analysis” as if that is the only technique which works, and is used to the total exclusion of all others. In fact, most of the techniques are complementary rather than mutually exclusive.

Oil analysis is fantastic for identifying wear and trapping damage due to incorrect lubrication. I would be tempted to say “only” except for the fact that wear and inadequate lubrication are two of the biggest killers in industry.

Thermography works by detecting infrared radiation. If you have a defect which generates heat (or the lack of it) and that heat conducts or convects to a surface which you can see, then you can use thermography. It is a quick, easy method of identifying many of the common problems found in manufacturing industry. Apart from the common electrical surveys, thermography can be used to investigate mechanical problems, lubrication problems and product quality issues.

Oil analysis can tell you if a gear is wearing, thermography can tell you if the bearings are warm or if the oil is warm. However, only vibration can tell you if a gear is eccentric, how significant the wear is, if there is a bearing defect or if there is an internal misalignment of a meshing pair.

Thermography can tell you if you have a

# ReliabilityShopper Top 10 Reliability Software Providers

## Excellence in Maintenance Software Services

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.strategiccorp.com

3



Large Enough to Lead. Small Enough to Listen.  
864-297-9290  
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.jmsssoft.com

8



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

9



Gold Standard in Asset Management  
813-621-6463  
www.pdma.com

10



Powerful CMMS starting at \$495  
1-800-922-4336  
www.mapcon.com

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

[www.reliabilityshopper.com](http://www.reliabilityshopper.com)

phase imbalance on a large motor. Vibration can show the influence of this imbalance in the dynamic behavior of the motor.

### Advanced Diagnostic Methods

The same tools we use for routine monitoring can also be used to perform a variety of more complex diagnostic and remedial techniques. With the addition of nothing more than a laser tachometer and the appropriate software, a mundane vibration data collection system can be transformed into a powerful diagnostic tool for operating deflection shape testing, phase analysis and in-situ balancing.

Many companies still pay large amounts of money to have fans and motors balanced externally by manufacturers. In fact all of this work could be performed in-house for a fraction of the cost using the existing vibration equipment.

All of the vibration analysis we use is dedicated to the micro level: looking inside the

machine and deducing the condition of a motor, gear or bearing. ODS looks at the macro level: it is a very powerful technique for visualizing defects associated with how a machine or structure moves in operation.

Trying to increase the operating speed of a paper machine by merely changing belts or gearboxes is one of the most common problems solved by ODS. Another common one is a badly-designed, or installed, pump. The following examples are pump problems.

The first is a new pump. It was noted during the commissioning phase that there were cracks appearing in the concrete bases of three new pumps. "Not unusual" was the cry from the commissioning team. What was unusual was that all three pumps showed similar cracking and that the crack-



Figure 3 - Cracks in concrete base of new pump

ing showed some symmetry. An operating deflection shape test was performed on one of the pumps.

Using almost any decent FFT-based data collector, the right software and practice, it is possible for any vibration engineer to carry out such a test.



just one of our strengths

Not only do we make strong, rugged and reliable products, we are committed to making vibration analysis accessible to you. This includes user-friendly software, affordable prices, and exceptional customer service.  
[www.commtest.com](http://www.commtest.com)



Commtest, Inc.  
 6700 Baum Drive, Suite 12  
 Knoxville, TN. 37919  
 Phone 865-588-2946  
 Fax 865-588-2949

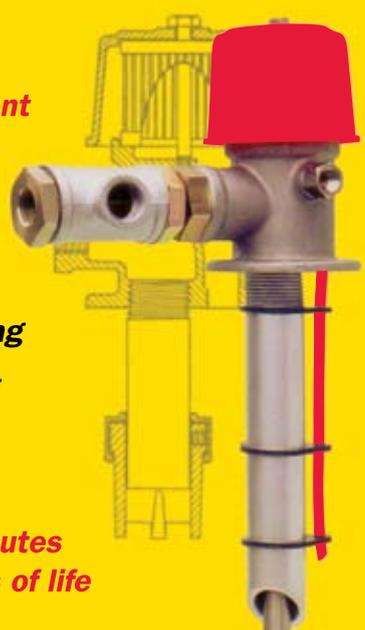
CT19768E

The **OILMISER™**  
**FILLorDRAIN™**  
 by JLM Systems Limited

Meet all your oil management needs:

- Off-Line Filtration
- Fluid Handling
- Oil Sampling
- Air Quality

Installs in minutes  
 Can add years of life



For more information visit our website [www.oilmiser.com](http://www.oilmiser.com) or telephone toll free: 1-888-RENU OIL (1-888-736-8645)

A good animation software will not only allow you to show individual frequency behavior but it will also be able to superimpose multiple frequencies in order to produce a motion which is more representative of real life.

In this case, the main excitation frequencies were the vane passing frequency of the pump, the running speed of the motor/pump and a 100Hz signal coming from an electrical supply defect to all three motors.

The entire test took less than a day from start to finish. The animation clearly shows:

1. The holding-down bolts are moving and are thus ineffective
2. The frame under the motor is twisting
3. The frame is lifting under the pump

This is one of three new machines which, purely by providence, was not passed off by the commissioning engineers and handed over to the maintenance department to

become a long-term problem.

This electric motor pump set produced very high vibration levels on the motor. All of the normal "micro" methods such as balance, alignment, hot alignment, changing coupling, etc. had been tried and failed. Operating deflection shapes was then employed to assist.

The motor was bolted to lands which were part of a skid mounting arrangement with a concrete infill represented in Figure 4. The dots are the measurement locations - in this case 83 points.

A laser tachometer was positioned in front of the motor fan and a trigger was taken from a white paint marker on one of the blades.

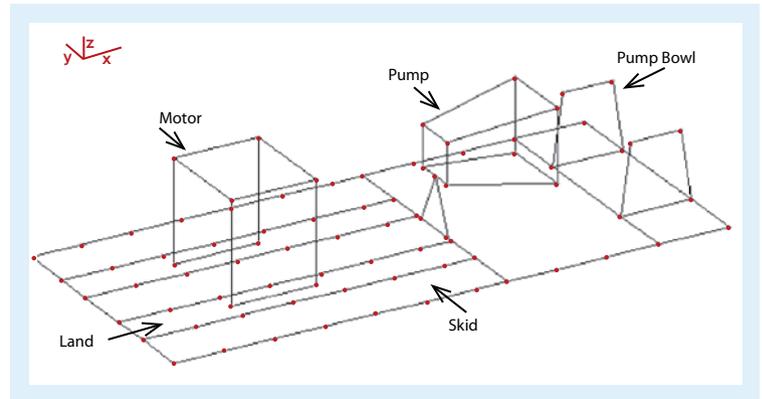


Figure 4 - Setup of Electric Motor Pump Set

The total time to acquire all the data was roughly 4 hours.

Running speed was the largest of the modes of vibration. Figure 5 shows the locus of all points of motion. This shows the motor rocking front to back on the bed plate.

### After Modification

In response to the operating deflection shape

## Do you BALANCE ROTATING MACHINERY ?

*CDI is your balancing correction weight specialist!*



Serving the predictive maintenance community for over 16 years with:

- **Balancing Correction Weights**
  - Over 5 million weights in stock
  - 100 sizes in 15 styles
- **Custom metal stampings**
  - Quotes from print or sample
- **Alignment Shims**
- **No order too small! Same day shipping**



**NOW SERVING EUROPE!**



**CD International, Inc.**  
**United States • Canada • Europe**

[www.balancingweights.com](http://www.balancingweights.com)

U.S. 1.716.741.8851

Canada 1.905.845.3630

Europe +33(0)4.90.37.64.22

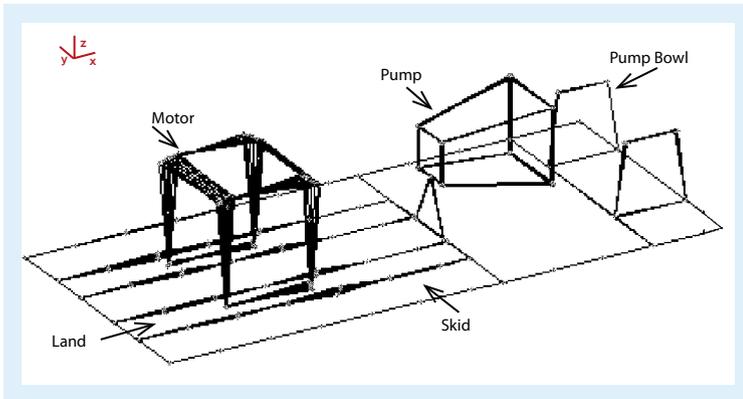


Figure 5 - Readings at Running Speed

test, structural modifications were made. A series of clamps were bolted in place on bolts which had been set in the concrete of the bed-plate. These clamps were bolted securely onto the lands at 10 positions along the length of the land. This action effectively coupled the lands directly to the seismic mass of the bed-plate.

To check the efficacy of these modifications and to provide an “after” set of results for comparison, a repeat of this test was performed. The after results showed that the fundamental mode shape which is causing the motor vibration remained unchanged. What we succeeded in achieving is a reduction in amplitudes of vibration of significant proportions. The peak amplitudes on the four corners of the motor, both before and

Data Point #	Vibration in mm/s	
	Before	After
50	26	4.2
52	34	4.6
54	30	4.3
56	35	4.2

after modification, are shown below: Paper industry applications for the use of phase analysis are vast. Frequently, companies are sold the idea that by simply changing the belts, gears or motors of a drive system, the paper machine can be operated at higher speeds. This is simply not true. Such a simplistic approach takes no account whatsoever of the dynamics of the machine and therefore, more often than, not leads to vibration and/or process problems which ultimately limit the speed increase. The following example is taken from the archives of operation problems solved using operating deflection shapes.

## A Doctor Beam

This doctor, on a coater, was causing quality problems. A test was performed which confirmed that the beam was operating with virtually no constraints at either end (free-free motion) and this lack

of constraint produced vibration patterns consistent with the coating thickness variations observed.

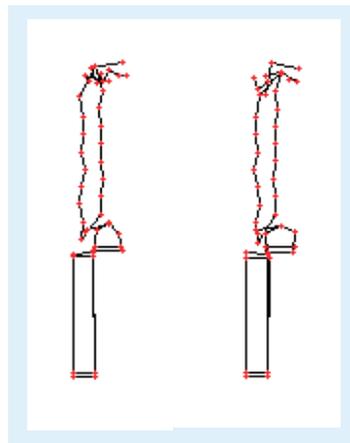


Figure 6 - Free Moving Doctor Beam

Presentation of this data to the machine manufacturer produced a simple solution. The manufacturer’s drawing showed the back-side mounting dowelled into position, but this had not happened during the installation.

Correcting this oversight resulted in the vibration on the doctor beam being reduced by a factor of 6 in amplitude and cleaning up the shape of the vibration sufficiently to remove the problem.

## Conclusion

Most organizations are aware of the benefits of condition monitoring, though for many there is still room for expansion of the techniques and the benefits.

Vibration measurement of machines is generally considered to be in quite an advanced stage of evolution. Considerable work has been performed over the last 15 years to spread the knowledge that vibration technology can be used as a diagnostic tool to provide insight into machine condition.

The majority of this work could be described as having taken place at the micro level of the machine - that is looking inside the machine to find out what is happening inside. Sometimes it is more important to look at the macro level - that is, how the machine is performing in its environment and what interactions are taking place there. Unfortunately, comparatively little effort has been put into this area.

There are numerous anecdotes concerning the persistent machine problem: frequent coupling failures, impossible to align, high noise levels, buildings shaking, etc. Frequently these problems are either “lived with”, handed over to consultants or thrown back to the machine supplier. Normally the problem cycles between these three until the machine fails catastrophically or additional protective systems are installed to deal with the disastrous consequence.

Techniques and software tools are available to give the plant vibration engineer the information to solve such problems.

*Tom Murphy is an Acoustics graduate from Salford University and has 25 years experience in the world of industrial vibration measurement – 15 of those years have been involved with the use of ODS techniques in the paper, printing, petrochemical, power generation, pharmaceutical and food industries. Tom is the Managing Director of Adash 3TP Limited, based in Manchester England, a Company specialising in the application of vibration, infrared and ultrasonic technologies to improve maintenance. More info can be found at [www.reliabilityteam.com](http://www.reliabilityteam.com) and Tom can be contacted at +044 161 788 9927 or at [tom@adash3tp.co.uk](mailto:tom@adash3tp.co.uk)*

*All illustrations used in this article are ©1995 by Adash.*

# What's In A Word?

## The Importance of a Standardized Maintenance Vocabulary

by Joel Levitt

In medical school the students struggle to learn the formal (Latin) names for all the common body parts and hundreds of smaller parts (most of which that they probably never knew existed). This language exercise allows doctors to describe conditions very accurately to other doctors. In law school young aspiring lawyers learn the legal definitions of common and also Latin words to more precisely write contracts and briefs.

In the maintenance field there is no agreed upon language. You don't go to maintenance school and learn the specific language of maintenance, and every company has its own language. This makes for a sometimes difficult challenge when people from different companies, and even different plants within the same company, try to communicate.

However, the tide seems like it is just beginning to come in for the maintenance world. Helpfully, the largest institutions (like the U.S. Army and Exxon-Mobil) and the big software packages (SAP and Maximo) are starting to drive language in a consistent direction. This is good since the language is portable and allows you to communicate more productively with people in other companies and, perhaps, even within your own company.

I hate to say it but "Call a Meeting!" At the meeting, put forward the words and definitions below and vote them up or down or amend them. Once you have completed it, publish your vocabulary to all your maintenance, operations, purchasing, engineering folks, and anyone else you can think of, in all of your plants. Let the communications begin.

**Autonomous Maintenance:** Routine maintenance and PM's are carried out by operators in independent groups. These groups solve problems without management intervention. The maintenance department is called for bigger problems that require more resources, technology or downtime.

**Asset:** Either a machine, building or a system. It could be a machine, piece of equipment, area (floor in a building), product production line, or even a major component. It is the basic unit of maintenance and the driver of the PM and computerized maintenance systems.

**Backlog:** All work for the maintenance department that has been formally identified with a work order. While in Backlog identified work is approved, parts are either stocked or bought, and (in ready backlog) everything is ready to go.

**BNF equipment:** Equipment left off of the PM system, left in the Bust 'N Fix mode (it busts and you fix- no PM at all). BNF is a choice used when PM is not advantageous.

**CBM (Condition Based Maintenance):** a maintenance strategy based on measuring the condition of equipment, usually with a predictive technology. Based on the data collected, an assessment of future equipment

failure is made, and then actions are taken to avoid that failure. Many people use CBM and PdM interchangeably.

**Capital spares:** Usually large, expensive, long lead-time parts that are capitalized (not expensed) on the books and depreciated. They are kept for protection from excessive downtime.

**Call back:** Job where maintenance person is called back because the asset broke again or the job wasn't finished the first time. See rework.

**Cause:** (Special to FMECA) A Cause is the means by which a particular element of the design or process results in a Failure Mode.

**Charge-back:** Maintenance work that is charged to the user. All work orders should be costed and billed back to the user's department. The maintenance budget is then included within the user budgets. Also called "rebilling".

**Charge rate:** This is the rate that you charge for a mechanic's time. In addition to the direct wages you add benefits and overhead (such as supervision, clerical support, shop tools, truck expenses, and supplies). You might pay a tradesperson \$25.00/hr and use a \$65/hr or greater, charge rate. Important to compare your cost

of doing a large maintenance job or using a contractor.

**Continuous Improvement (in maintenance):** Reduction to the inputs (hours, materials, management time) to maintenance to provide a given level of maintenance service. Increases in the number of assets, or use of assets with fixed or decreasing inputs.

**Core damage:** When a normally rebuildable component is damaged so badly that it cannot be repaired.

**Corrective maintenance (CM):** Maintenance activity that restores an asset to a preserved condition. CM is normally initiated as a result of a scheduled PM or PdM inspection. See planned work also.

**Criticality (Special to FMECA):** The Criticality rating is the mathematical product of the Severity and Occurrence ratings. Criticality = (S) \* (O). This number is used to place priority on items that require additional quality planning.

**Customer:** Customers are internal and exter-

nal departments, people, and processes that will be adversely affected by product failure.

**Deferred maintenance:** This is all of the work you know needs to be done that you choose not to do. You put it off, usually in hope of retiring the asset or getting authorization to do a major job that will include the deferred items. You worry the asset will fail before you get to it.

**Detection (Special to FMECA):** Detection is an assessment of the likelihood that the Current Controls (design and process) will detect the Cause of the Failure Mode or the Failure Mode itself, thus preventing it from reaching the Customer.

**DIN work:** 'Do It Now' is non-emergency work that you have to do now. An example would be moving furniture in the executive wing.

**Effect Cause: (Special to FMECA)** A Cause is the means by which a particular element of the design or process results in a Failure Mode. An Effect is an adverse consequence that the Customer might experience. The

Customer could be the next operation, subsequent operations, or the end user.

**Emergency work or emergent work:** Maintenance work requiring immediate response from the maintenance staff. Emergent work also refers to work that emerges after you open up an asset (pump, vessel, etc). Emergency work is usually associated with some kind of danger, safety, damage, downtime or major production problems.

**FMEA Element:** FMEA elements are identified or analyzed in the FMEA process. Common examples are Functions, Failure Modes, Causes, Effects, Controls, and Actions. FMEA elements appear as column headings in the output form.

**Failure Mode:** Failure Modes are sometimes described as categories of failure. A potential Failure Mode describes the way in which a product or process could fail to perform its desired function (design intent or performance requirements) as described by the needs, wants, and expectations of the internal and external Customers.

# NEW! PREVENTIVE AND PREDICTIVE MAINTENANCE TRAINING & TOOLS SERIES

Finally, PM and PdM Training with the TOOLS you need to implement a successful PdM program at your facility

No more excuses not to have a good PdM Program because it's all right here. And not just theory. You get the tools you need to build your program.

However, achieving these results is not easy. For starters, you need to have a common vision, a basic implementation strategy and a clear understanding of what's required for success.

That's why Allied Reliability presents this series: To provide the framework you need to reach best practices in PM and PdM, in the shortest possible time, at the lowest overall cost.

Sign up for a FREE e-course at [www.pdm-training.com](http://www.pdm-training.com)

Please stop by our Booth #N801 at IMC-2006 in Daytona Beach, Florida  
December 5th-8th



## PM / PdM

Best Practices Training & Tools

**Allied**

Inspired Reliability  
918-382-9400

[training@alliedreliability.com](mailto:training@alliedreliability.com) • [www.alliedreliability.com](http://www.alliedreliability.com)

**Feedback:** (When used in the maintenance PM sense) Information from your individual failure history is accounted for in the task list. The list is increased in depth or frequency when failure history is high and decreased when it is low.

**FMECA:** Failure Mode Effects and Criticality Analysis

**Frequency of Inspection:** How often do you do the inspections? What criteria do you use to initiate the inspection? See PM clock.

**Function:** A Function could be any intended purpose of a product or process. FMEA or RCM functions are best described in verb-noun format with engineering specifications.

**Future Benefit PM:** PM task lists that are

initiated by a breakdown rather than a usual schedule. The PM is done on a whole machine, assembly line, or process after a section or sub-section breaks down. This is a popular method with manufacturing cells where the individual machines are closely coupled. When one machine breaks then the whole cell is PM'ed.

**GLO (Generalized Learning Objective):** Are the general items necessary to know to be successful in a job. Each job description would be made up of a series of GLO's. by your service person.

**In-box:** Maintenance jobs not ready to release to the mechanic. You haven't approved, received money, parts are on order but not received, or other problem. In-box jobs are the first step of the maintenance work order process before the job is reviewed and entered into backlog.

**Inspectors:** The special crew or special role that has primary responsibility for PMs and PdMs. Inspectors can be members of the maintenance department or can be members of any related department (machine operators, calibration, drivers, security officers, custodians, etc.)

**Interruptive (task):** Any PM task, which interrupts the normal operation of a machine, system or asset and required maintenance to take custody of the asset.

**Labor:** Physical effort a person has to expend to repair, inspect, or correct a problem. Expressed in hours and can be divided by crafts or skills.

**Life Cycle:** This denotes the stage in life of the asset. Three life cycles or stages are recognized by the author: start-up, wealth, and breakdown.

**LCC (Life cycle cost):** A total of all costs through all of the life cycles. Costs should include PM, repair (labor & parts & supplies), downtime, energy, ownership, overhead. An adjustment can be made for the time value of money.

**MTBF (Mean Time Between Failures):** Important calculation to help set-up PCR schedules and to determine reliability of a system.

**MTTR (Mean Time to Repair):** This calcula-

# Do Your Filters Perform True to Rating?



**DFE Filter Development and Validation Testing Ensures That Ours Do Even in the Toughest Hydraulic and Lube Applications!**

- Complete range of filter element performance upgrades
- High-pressure, in-tank return, Spin-on and Main lube filter assemblies
- DFE rated filter element technology pioneer
- Beta ratios  $B_{x[c]} \geq 1,000$ ,  $B_x \geq 200$
- Basic and advanced hydraulic and lube filtration training for distributor or mill maintenance teams (preventive maintenance focus)
- Element upgrades to replace all Pall, Schroeder, Hydac, PTI, Parker and more
- Visit us at IMC 2006, December 5-8, Daytona Beach, FL

## HY-PRO

## HY-PRO FILTRATION

12955 Ford Dr. • Fishers, IN 46038  
 Tel: 317-849-3535 • Fax: 317-849-9201  
 E-mail: [INFO@hyprofiltration.com](mailto:INFO@hyprofiltration.com)  
 Web site: [www.filterelement.com](http://www.filterelement.com)

tion helps determine the cost of a typical failure. It also can be used to track skill level, training effectiveness and effectiveness of maintenance improvements.

**Maintenance:** The dictionary definition is “the act of holding or keeping in a preserved state.” The dictionary doesn’t mention repairs. It presumes that we are acting in such a way as to avoid the failure by preserving the asset.

**Maintenance Prevention:** Maintenance free designs resulting from increased effectiveness in the initial design of the equipment.

**Maintainability Improvement:** Also Maintenance Improvement. This is an activity that looks at the root cause of breakdowns and maintenance problems and designs a repair that prevents breakdowns in the future. Also includes improvements to make the equipment more easily maintained.

**Non-interruptive task:** PM task that can safely be done without interrupting production of the machine.

**Non-Scheduled work:** Work that you didn’t predict or plan for at least the day before. Falls into three categories: 1. Emergency 2. DIN 3. Routine. Also includes work that you knew about but didn’t think about in a systematic way and didn’t add to a schedule.

**Occurrence:** Occurrence is an assessment of the likelihood that a particular Cause will happen and result in the Failure Mode during the intended life and use of the product.

**OEM:** Original Equipment Manufacturer

**PCR:** Planned Component Replacement. Maintenance schedules component replacement to a schedule based on MTBF, downtime costs and other factors. Technique for ultra-high reliability favored by the aircraft industry.

**Parts:** All of the supplies, machine parts and materials to repair an asset, or a system in or around an asset.

**Planned maintenance:** Maintenance jobs for which all resources have been identified. Once the resources are written into the planned job package and backlog relief hours are available the job can be scheduled for

execution. Also see scheduled work.

**PM:** Preventive Maintenance is a series of tasks that either: extend the life of an asset or detect that an asset has had critical wear and is going to fail or break down.

**PM Clock:** The parameter that initiates the PM task list for scheduling. Usually buildings and assets in regular use days (For example, PM every 90 days) as the clock. Assets used irregularly may use other production measures such as pieces, machine hours or cycles.

**PM frequency:** How often the PM task list will be done. The frequency is driven by the PM clock. See frequency of inspection.

**Predictive Maintenance (PdM):** Maintenance techniques that inspect an asset to predict if a failure will occur. For example, an infrared survey might be performed on an electrical distribution system looking for hot spots (which would be likely to fail). In industry, predictive maintenance is usually associated with advanced technology such as infrared, oil analysis, ultrasound, vibration analysis, etc.

**Priority:** The relative importance of the job. A safety problem would come before an energy improvement job.

**Proactive:** Action before a stimulus (Antonym: reactive). A proactive maintenance department takes actions before a breakdown.

**RCM:** Reliability-centered Maintenance. A maintenance strategy designed to uncover the causes and consequences of breakdown. RCM sets up the priority by the severity of the consequences. PM tasks and redesign are directed specifically at those high consequence failure modes. RCM is a procedure for uncovering and overcoming important failures.

**RM:** Replacement/Rehabilitation/Remodel maintenance. All activity designed to bring an asset back into good shape, upgrade an asset to current technology or make an asset more efficient/productive.

**Reason for write-up (also called reason for repair):** Why the work order was initiated. Reasons could include PM activity, capital improvements, breakdown, vandalism, and any others needed in that industry.

**Rework:** All work that has to be performed again. Rework is bad and indicates a problem in materials, skills, or scope of the original job. See call back.

**Risk Priority Number:** The Risk Priority Number is a mathematical product of the numerical Severity, Occurrence, and Detection ratings.  $RPN = (S) * (O) * (D)$ . This number is used to place priority on items than require additional quality planning.

**Root cause (and Root Cause Analysis - RCA):** The root cause is the underlying cause of a problem. For example you can snake out an old cast or galvanized sewer line every month and never be confident that it will stay open. The root cause is the hardened buildup inside the pipes. Analysis would study the slow drainage problem and figure uncover the cause and also estimate the cost of leaving it in place. Some problems (not usually this type of example) should not be fixed. Root cause analysis will show this.

**Route maintenance:** Mechanic has an established route through your facility to fix all the little problems reported to them. The route mechanic is usually very well equipped so they can deal with most small problems. Route maintenance and PM activity are sometimes combined.

**Routine work:** Work that is done on a routine basis where the work and material content is well known and understood. Example is daily line start-ups.

**SLO:** Specific Learning Objective is the detailed knowledge, skill or attitude necessary to perform a specific job or task.

**SM:** Seasonal Maintenance. All maintenance activities that are related to time of year or time in business cycle. Cleaning roof drains of leaves after the autumn would be a seasonal demand. A swimming pool chemical company might have some November activities to prepare for the next season.

**SWO:** Standing Work Order, Work order for routine work. A standing work order will stay open for a week, month or more. The SWO for daily furnace inspection might stay open for a whole month.

**Scheduled work:** Work that has been planned and is written on a schedule at least a few days in advance. Many writers use the

phrase, 'planned maintenance' to refer to maintenance work that is both planned and scheduled.

**Severity:** Severity is an assessment of how serious the Effect of the potential Failure Mode is on the Customer.

**Short Repairs:** Repairs that a PM or route person can do in less than 30 minutes with the tools and materials that they carry. These are complete repairs and are distinct from temporary repairs.

**String based PM:** Usually simple PM tasks that are strung together on several machines. Examples of string PM's would include lubrication, filter change, or vibration routes.

**Survey:** A formal look at the overall condition of all assets. All of the aspects of the facility are recorded and defined. The survey will

look at every machine, room, building and around the grounds. The surveyor will note anything that looks like it needs work.

**TPM:** Total Productive Maintenance. TPM is a maintenance system set-up to eliminate all of the barriers to and losses to production. TPM identifies production losses and using teams solves the problems causing the waste. It uses autonomous maintenance teams (focusing on operators) to carry out most basic maintenance activity.

**Technical Library (Maintenance Technical Library):** The repository of all maintenance information including (but only limited by your creativity and space) maintenance manuals, drawings, old notes on the asset, repair history, vendor catalogs, MSDS, PM information, engineering books, shop manuals, etc. The maintenance technical library could be virtual (entirely computer-based).

**Task:** One line on a task list (see below) that gives the inspector specific instruction to do one thing.

**Task List:** It contains directions to the inspector about what to look for during that inspection. Tasks could be inspect, clean, tighten, adjust, lubricate, replace, etc.

**UM:** User Maintenance. This is any maintenance request primarily driven by a user. It includes breakdown, routine requests, and DIN jobs.

**Unit:** Also see asset. The unit can be a machine, a system, or even a component of a large machine. See asset.

**Work Order:** Written authorization to proceed with a repair or other activity to preserve an asset.

**Work request:** Formal request to have work done. Work requests are generally entered or filed by a maintenance user. Work requests are usually time/date stamped and are the basis of the work orders.

# Vibration Analysis



**VIBXPert®** —a most powerful data collector. Automated fault detection provides a visual indication when a fault is present.

Breakthrough technologies such as 102,400 lines of spectrum resolution, 256MB compact flash storage (up to 1 Gigabyte optional), order spectrum, phase, cepstrum, cross-channel phase, orbits, run-up and coast-down and signal post processing make the VIBXPert® a powerful tool whether in the hands of a novice or the most advanced expert.

**LUDECA, INC. • (305) 591-8935 • www.ludeca.com**

*Joel Levitt is a leading trainer of maintenance professionals. He has trained over 7000 maintenance leaders in 3000 organizations from 20 countries in over 425 sessions. Since 1980 he has been the President of Springfield Resources, a management consulting firm that services all sized clients on a wide range of maintenance issues.*

*Joel has almost 25 years experience in many facets of maintenance including, positions such as a process control designer, source equipment inspector, electrician, field service technician, merchant marine worker, manufacturing manager, and property manager. He is a frequent speaker at maintenance and engineering conferences and has written the texts: Handbook of Maintenance Management, Managing Factory Maintenance and Internet Guide for Maintenance Management. He has published over a dozen articles on the topic. Mr. Levitt has also served on the safety board of ANSI, Small Business United, National Family Business Council and is currently a member of AFE and on the board of the Miquon School. Joel can be contacted at 800-242-5656 or at JDL@maintrainer.com*

# Revving Up Reliability



Only Reliabilityweb.com brings the intelligence, innovation and leadership of the maintenance & reliability community together in one place at one time. Attendance at Reliabilityweb.com conferences is limited to foster a community setting that encourages dialogue and information exchange among all participants. Each event is a live conversation creating a focused learning community.

---

## **IMC-2006 – The 21st International Maintenance Conference**

**December 5-8, 2006      Hilton Daytona Beach/Ocean Walk Village      Daytona Beach, FL**

Reliability, Maintenance Management, Planning & Scheduling, Business & Financial Aspects of Maintenance, Root Cause Analysis, Technology Innovations

## **CMMS-2006 - The Computerized Maintenance Management Summit**

**December 5-8, 2006      Hilton Daytona Beach/Ocean Walk Village      Daytona Beach, FL**

Computerized Maintenance Management Systems for Small to Midsize Companies

---

## **RCM-2007 - The Reliability Centered Maintenance Managers' Forum**

**April 3-6, 2007      The Sheraton Waikiki      Honolulu, HI**

Reliability Centered Maintenance (RCM), Reliability Analysis, Failure Analysis, PM Optimization, Reliability Incident Management

## **EAM-2007 – The Enterprise Asset Management Summit**

**April 3-6, 2007      The Sheraton Waikiki      Honolulu, HI**

Enterprise Asset Management (EAM), Computerized Maintenance Management (CMMS), ERP Integration, MRO and Spares Inventory, Handhelds, RFID and Bar Coding

---

## **PdM-2007 - The Predictive Maintenance Technology Conference & Expo**

**September 11-13, 2007      The Orleans Hotel & Casino      Las Vegas, NV**

Vibration Monitoring and Analysis, Infrared Thermography, Motor Testing, Ultrasonics, Non-Destructive Evaluation

## **LubricationWorld**

**September 11-13, 2007      The Orleans Hotel & Casino      Las Vegas, NV**

Practical Plant Machinery Lubrication, Contamination Control, Oil and Fluid Analysis

---

Events produced by Reliabilityweb.com

Events supported by Uptime Magazine, RELIABILITY® Magazine, MRO-zone.com and the International Proactive Maintenance User Group (IPMUG).

for more info or to register

[www.maintenanceconference.com](http://www.maintenanceconference.com)

# Be In The Driver's Seat

*Looking for an Astonishingly Simple Solution to Help Clean Up Your Lubrication Practices?*

# Fast Funnel

Every industrial facility in the world uses lubricants for their machinery. That is a lot of facilities. So it stands to reason there are untold numbers of plants using questionable methods of pouring their lubricants. The old Folger's can, elaborately outfitted with a handle and spout from the machine shop, might be a more interesting relic than a Fast Funnel. However, if getting clean lubricants into your machinery is more important to you than an old, dirty reusable funnel, Fast Funnel is definitely the tool of choice. We talked to Ted Salani of S & S Concepts, the makers of Fast Funnel, about how the idea of a disposable funnel came to fruition, and how the product can help industrial facilities.

*Give us a brief overview of the benefits of Fast Funnel.*

Fast Funnel® disposable funnels are the simple, convenient, and clean way to pour. This unique product is one of the most innovative approaches to assist in pouring in years, and offers several advantages over traditional funnels. These disposable funnels come folded flat in handy 3-packs so a funnel is always available where you need one...when you need one. Fast Funnel is easy to use; simply tear the top funnel from the header, pop open and they're ready. When you're finished there are no spills and no clean up to worry about... just throw the used funnel away. Made of coated, heavy grade paper stock, they can be used with virtually any liquid or powder and are designed to fit a wide variety of openings. Most importantly, since you always have a new funnel ready for use, foreign material pre-contamination and fluid cross-contamination of your lubrication system is virtually eliminated. Fast Funnels are just as useful in the field as they are in the plant, so whether you're adding oil to a company truck or a turbine pump you always get a clean pour.



*The concept is so simple. How did the idea for Fast Funnel*

*develop?*

As lifelong "gearheads" Larry and I always had a passion for tinkering and inventing. We like to joke that while other kids were out playing ball, we were usually taking things apart, putting them back together and, in the process, trying to figure out how to make them better. I think we can attribute most of our mechanical aptitude to genetics. Our father was always working on something and had his sons under the hood turning wrenches and pouring oil as long as they can remember. When we teamed up to start developing new products, it seemed natural that it would have something to do with mechanics. With our experience in auto maintenance, we recognized that no matter how many funnels you have lying around, there's never a clean one when you need it. When we designed Fast Funnel, we wanted it to be compact enough to be handy but also wanted to ensure that what you were pouring stayed clean.

*How long has Fast Funnel been around?*

Fast Funnel has been around since 2000, but has only been available commercially since 2002. Our first customer was Amsoil, who saw Fast Funnel as a perfect compliment to their line of high performance



work and specifically requested it for their job.

*What materials are Fast Funnel made of?*

Fast Funnel is made of heavy grade, cardstock paper. The properties of this material provide us with an optimum balance between the formability we need to fold down flat and the durability required to hold up while conveying fluids. Furthermore, the paper is sealed with an “aqueous” coating, a standard mill process, to bond the fibers. This coating serves both to reduce porosity and prevent paper fibers from entering the fluid stream.

*Are there Fast Funnels available for different sizes and types of machinery?*

Yes there are. We currently have three production versions of Fast Funnel. Our standard size is the general-purpose version available in stores and is around 6 in. tall. Next in line is the Fast Funnel Professional. At nine inches tall and with a 4-5 inch opening, this size will probably be most applicable to industrial applications. Finally, we have Fast Funnel extended, which at over 16 inches tall and with a ¾ inch outlet is perfect for pouring viscous fluids in hard to reach areas.

However, beyond our current inventoried product line, we’re always willing to work with businesses on custom sizes designed to fit a specific application.

*What is some of the feedback you’ve gotten from industrial users.*

Fast Funnel is fairly new to the industrial market but initial feedback has been very positive. In retail, most end users are more concerned with how their vehicles look on

the outside than how their oil looks on the inside. It takes a bit of explaining to communicate that with all they have invested in their vehicles Fast Funnel is very cheap insurance against contamination. Maintenance professionals know that it’s what’s going on inside that really counts, so when we introduce them to the product they’re immediately impressed. In fact, most of the time, they end up giving us a lesson on where the product would be most useful and why.

*Do you have Fast Funnel success stories in the industrial market to share with us?*

I think our best story comes from a nuclear plant in California - Diablo Canyon Power Plant. Diablo Canyon’s predictive maintenance group brought Fast Funnel in to eliminate the contamination potential that reusing plastic funnels presented. One unknown at the time was how the maintenance crews would receive the product. My own

engineering career started in the nuclear industry and I spent a good deal of time in the field working with the crews. As a result, I knew that changing well-established work procedures wasn’t always welcomed with open arms. When we received a re-order from the plant within the first month I was a little surprised by the quick turnaround and called in to see how things were going. It turned out that it wasn’t maintenance who had gone through the inventory that fast but requests from other

groups that wanted to start using that handy new funnel the maintenance guys had.

*How can interested readers get more information about Fast Funnel?*

They can log onto [www.fastfunnel.com](http://www.fastfunnel.com) and get information about sizes, contamination control, applications and ordering. Or if they prefer, anyone can feel free to call us at (847) 434-1560 and we’ll be happy to help them personally.

synthetic lubricants. At the time our focus was predominately on the automotive and powersports aftermarket and we had a lot to learn about selling and distributing a product on the national level. Fast Funnel is now available to consumers through a variety of retail outlets including Advance Auto Parts, Sears, and Wal-Mart to name a few.

*When I think of Fast Funnel, the first thing that comes to mind is changing oil in my car. How did Fast Funnel become involved in the industrial market?*

Well thank you, I’m glad to know the time we spent brand building on the automotive side wasn’t in vain.

We actually recognized the potential of the industrial market from the beginning. Our decision to get our start on the retail side was simply a matter of resources. With the vast number of applications and sectors Fast Funnel could serve, we realized it would be difficult for a small company such as ours to market a new product effectively. We saw more consolidation in the automotive aftermarket and therefore a better opportunity to build brand identity quickly. We were also confident that many customers using Fast Funnel to maintain their own vehicles, would help us market to industry by seeing how the product could benefit them on the job.

From what we’ve been seeing this year, I think our plan is paying off. The number of inquiries we’re getting from industry has increased tremendously. More often than not, the buyers will tell us that someone in their company saw or used Fast Funnel outside



## New Fixturlaser XA from Vibralign

VibrAlign Inc. introduces the new Fixturlaser XA, a breakthrough in laser shaft alignment designed to allow users to perform alignments more quickly.

The Fixturlaser XA is the result of an effort to completely reinvent laser shaft alignment. The system incorporates many technologies new to laser shaft alignment, along with completely redesigned software. The result is a laser shaft alignment system that is more user friendly than any previous offering. With the XA, users will be able to perform alignments significantly faster.

The touch-screen graphical user interface, first pioneered in laser alignment systems by Fixturlaser, now incorporates Flash® animated, 3-dimensional graphics. The screen graphics keep the user in touch with exactly where they are in the process, and prompts them through the correct steps to quickly complete an "express alignment".

Other new technologies incorporated in the new Fixturlaser XA include: rectangular 30-mm detectors to eliminate preliminary rough alignment, a line laser to improved target acquisition and range and CCD technology for better laser reception.

The system is PC compatible and comes with network, RS-485 and USB ports allowing options for data download and upload.

**Amy Newcomb**  
**(804) 379-2250**  
**(800) 394-3279 toll free**  
**info@vibralign.com**



Series 103B ICP® Acoustic Pressure Sensors from the Pressure Division of PCB Piezotronics, Inc. measure pulsating, transient, and turbulent acoustic phenomena on transportation vehicles and other structures. These low-profile, high-sensitivity sensors are ideal for applications such as automotive and aerospace wind tunnel testing, aerodynamic testing and analysis, aircraft cabin and cockpit noise testing, and acoustic fatigue testing on airframes.

**Pressure Division - PCB Piezotronics, Inc**  
**888-684-0011 Toll Free (U.S./Canada)**  
**716-684-0001**  
**pressure@pcb.com**  
**www.pcb.com**



## Thermography Training from Snell Infrared

### Level I

- October 23-27, Toronto
- November 6-10, San Antonio, TX

### Electrical Applications

- October 24-25, Charlotte, NC
- November 29-30, Toronto

### Level II

- October 30-November 3, Toronto
- November 6-10, Charlotte, NC

### Mechanical Equipment

- October 26-27, Charlotte, NC

For More Info or To Register Call

**1-800-636-9820**

or visit us online

<http://www.snellinfrared.com>

NILOS®-Ring "Type LSTO" steel-disk seals can provide superior protection for grease-lubricated bearings exposed to extreme levels of contamination. Applications for these specialized bearing seals include lubrication and fluid power equipment; construction, mining, paper, and agriculture machinery; and conveyor rollers, among others. Type LSTO steel-disk seals satisfy key performance requirements by minimizing bearing friction losses and heat build-up and preventing lubricant leakage and penetration of dirt.

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



Bijur Delimon International has released the SureFire automatic lubricator, a 2005 Plant Engineering Product of the Year, with an on-board programmable controller. The controller is available on all single-phase motor units, and with any of the available reservoir sizes.

The electronic controller features an LED display and a series of buttons to program the lubricator to customers' specifications. It can run in either timer mode or controller mode. The timer mode sets the controls are fairly basic. In controller mode, users have increased control over pre-lubrication cycles, run time, hold time, error alert time, etc.



**Scott Batchelor 919-465-4448 pr@bijurdelimon.com**

## Benchmate - A Simpler CMMS

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

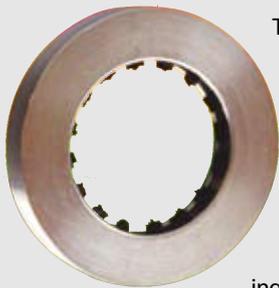
**Benchmate Systems, Inc.**  
**www.benchmate.com**  
**360.678.8358**



Klüber Lubrication announces the release of Klüberplex BM 21-322 US, a lubricating grease for aggressive environments. Designed for use in slow to moderate-speed rolling bearing applications, the Klüberplex BM 21-322 US is now available in the U.S. and Canada. This product offers extended component life, is extremely resistant to aggressive media and water wash-out and offers excellent wear and corrosion protection.

**Klüber**  
**800-447-2238 Toll Free**  
**603-647-4104**  
**www.kluber.com**





The new AEGIS SGR™ Conductive MicroFiber™ Shaft Grounding Brush from Electro Static Technology boosts reliability of AC motors controlled by variable frequency drives (VFD) in any manufacturing application. The patent pending AEGIS SGR protects motors from catastrophic failure caused by shaft current in motor bearing by channeling potentially damaging shaft currents away from the motor bearings to ground. The AEGIS SGR prevents costly motor failure, repairs and downtime. It is installed in minutes by sliding the brush over the motor shaft and locking it in place with simple screw-on brackets.

**Adam Willwerth** 866-738-1857 (207) 998-3493  
 sales@est-aegis.com www.est-aegis.com

Onset Computer Corporation has released the HOBO® U-Shuttle, a new data transport device for use with HOBO® data loggers. The new Shuttle allows users to offload HOBO U-Series and FlexSmart data loggers at multiple locations in a facility and safely, transport the data back to a PC or Mac computer for analysis. Key features include a bright LCD display that provides current sensor readings, battery and logger status, memory capable of storing data from multiple data loggers, convenient, direct USB connection to host computer and easy and fast offload with Onset's HOBOWare® software.



**Onset Computer Corp** 1-800-LOGGERS  
 sales@onsetcomp.com www.onsetcomp.com

The Mikron M7500 infrared camera is configurable for midwave or longwave imaging and four different temperature bands, for a fraction of the cost of cryogenically cooled midwave IR cameras. Longwave or midwave configurations let New Mikron M7500 image glass, steel, food, furnaces through flame, textiles, paper and many other processes with ±2°C temperature accuracy, 320x240 resolution.



**Jon Chynoweth**  
 888.506.3900  
 jon@mikroninfrared.com  
 www.mikroninfrared.com

This simple two-wire transmitter wired directly to your PLC or DCS is all that is required for early warning of impending problems and 24/7 protection against catastrophic failure. No wiring or special electronics are necessary. Just mount the transmitter on the machine case, connect the loop wiring to your PLC and read or record the vibration in units of velocity.



The ST5484E vibration transmitter features the Independent Polarity Terminal (IPT)™ circuit to eliminate sensor wiring errors.

**www.metrix1.com** 713-461-2131

### Kittiwake's New ANALEXrs Moisture Sensor

Remote online sensor technology is increasingly being recognized as the way forward in the 21st Century and Kittiwake has merged the features of their current onsite and lab based equipment to develop the ANALEXrs online moisture sensors. Water contamination in critical fluids certainly produces problems; additive depletion, oxidization, bacterial growth, component wear and corrosion to name but a few, but the ultimate issue is critical failure of your plant!

Moisture sensors can be used in Hydraulic Fluids, Lubricating Fluids, Dielectric Fluids and Fuel Oils, they need not be in the oil itself, and are of use in the headspace of a piece of machinery, for example, in a gearbox High moisture levels through a failed breather to the airspace above oil will dissolve into the oil - so this is a good place to monitor moisture - before it gets into the oil.

The intelligent Moisture Sensors are constructed from high grade stainless steel, designed to screw directly into the oil flow and are extremely robust in all conditions. The inherently stable nature of the materials and technology employed in the sensor negates the need for periodical recalibration, thus the sensor can be permanently installed, and is considered maintenance free robust in all conditions.

**Paul Froome**  
 Tel: +44 1903 731470  
 paulf@kittiwake.com  
 www.kittiwake.com



The Force/Torque Division of PCB® Piezotronics, Inc. offers a series of strain-gage reaction torque sensors for torque measurements on accessories such as Starters, Alternators, Air Conditioning Compressors, Power Steering Gearboxes, and Water Pumps. Series 2300 and 2500 reaction torque sensors feature high torsional stiffness, flange mounting, and are available in full-scale capacities from 5 to 500 k in-lb (0.56 to 56.5 k N-m).

**Force/Torque Div** 888-684-0004 force@pcb.com  
 PCB Piezotronics www.pcb.com



The Watchdog® EX Series Breathers for extreme humidity applications incorporate two check valves, one to control airflow into the protected reservoir and one to control airflow out. This prolongs the life of the desiccant by allowing the air to flow through the breather only when needed to protect integrity of the tank. Unlike system, which does not allow internally generated gases and contaminants to exit the system, the Watchdog EX Breather offers all of the advantages of breathing air in and out of the tank while removing water vapor and solid particles before they contaminate the fluid.

**Steve Southard** 262-691-9471 www.tricomfg.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 processes:

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! Dial 1-800-789-9037 and use the extensions below**

Company	Page	Extention
Allied Reliability Services	pg 39	200
All-Test Pro	pg 21	228
CD International	pg 36	206
CMI Kittiwake	pg 31	240
Commtest	pg 35	203
DMSI	pg 13	229
GAF Materials Corp	pg 9	235
Hy-Pro Filtration	pg 40	208
Internormen	pg 8	248
Ivara	Inside Cover	222
JLM Systems (Oil Miser)	pg 35	201

Company	Page	Extention
Ludeca	pg 42	202
Maintenanceconference.com	pg 43	212
Mastering Maintenance	pg 49	211
Mikron	Back Cover	204
RELIABILITY® Magazine	pg 30	214
Reliabilityweb.com	pg 26	215
SMRP	pg 17	231
Timken	pg 7	246
Trico	pg 20	236
Vibralign	pg 25	247
Ultrasound Technologies	pg 27	216



**Learn at your own pace  
in your own place.**

Now with our affordable computer based distance learning courses you are free. Free to learn when you want and where you want. Each course includes narrated slides and lectures on CD, text book, access to student/instructor message boards , quizzes and assessments online and personalized coaching through MaintenanceForums.com

**Our unique training program offers all of the training without the hassles and expense of travel.**

Courses offered include

**5 Pillars: Maintenance & Reliability  
Professional Certification Review**  
by Dave Krings, CMRP

**Achieving Total Productive  
Maintenance (TPM)**  
by Terry Wireman, CPMM

**Benchmarking Best Practices Maintenance**  
by Terry Wireman, CPMM

**Change Management For Maintenance &  
Reliability Professionals**  
by Steve Thomas

**Developing Key Performance Indicators**  
by Terry Wireman, CPMM

**Level 1: AC Induction Motor Maintenance  
& Diagnostics**  
by Howard W. Penrose, PhD, CMRP

**Time Management for  
Maintenance Professionals**  
by Joel Levitt

**20 Steps to World Class Maintenance**  
by Joel Levitt

**Lean Maintenance in a Nutshell**  
by Joel Levitt

**Reliability Centered Maintenance  
(RCM) For Everyone**  
by Neil B. Bloom

**The 3 Phases of Reliability  
Centered Maintenance (RCM)**  
by Neil B. Bloom

**Turning Maintenance into A Profit Center**  
by Kris Bagadia



# Four Times The Camera.

## Half The Cost.



*For building diagnostics, our M7815B gives you all the same features optimized to a range of -40° to 120°C for \$16,500. Just 21¢/pixel.*

**That's right!** You need four 160x120 infrared cameras to equal one M7800 camera. Our 320x240 detector gives you 76,800 temperature measuring pixels – **FOUR TIMES WHAT YOU GET WITH A 160X120 DETECTOR.**

**Our pixels cost a lot less, too.**

Just 19-25¢ each, compared to 50¢ or more for low-resolution cameras. That's a lot more temperature accuracy and imaging quality for the money. In fact, there isn't a better price-per-pixel on the infrared market today.

So don't settle for a toy when you need a tool. The M7800 gives you -40° to 500°C range with  $\pm 2^\circ\text{C}$  accuracy.

Visual camera and laser pointer. All for less than \$19,000. And it's backed by the best service in the industry. We turn it around in five business days, or you get a free loaner.

 **MIKRON**<sup>®</sup>  
I N F R A R E D

**Mikron Infrared, Inc.** • Thermal Imaging Div.  
1101 Elevation St. Suite 3 • Hancock, MI 49930  
Tel: 906.487.6060 • Fax: 906.487.6066  
email: jon@mikroninfrared.com

©copyright 2006 Mikron Infrared

**There's a free one-day PdM workshop coming to your area soon!**  
Call 1.888.506.3900 or register at [www.mikroninfrared.com](http://www.mikroninfrared.com)