uptime

the magazine for PdM & CBM professionals

jan 2006

Condition-Based Maintenance

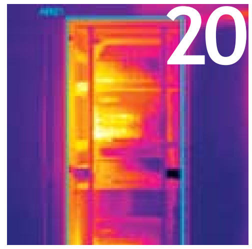
Finding The Final Piece

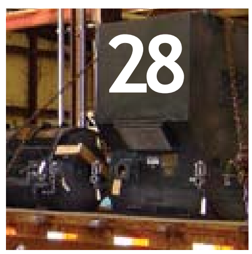
Vanquishing Varnish in Gas Turbines

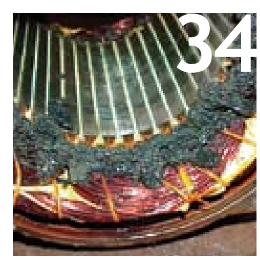
Ultrasonic Lubrication

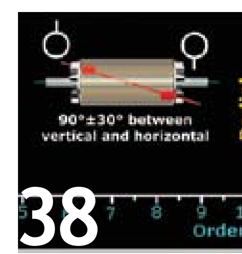
Vibration: Beyond Basic Training

uptime contents









Follow Your Own Road

Welcome to Uptime's 3rd issue. Time really flies when you're having fun.

I enjoy hearing and reading about organizations making successful journeys to improved maintenance programs like the Eastman Chemical story in our feature article. Sometimes the voyage can be long and arduous, but the final destination is always worth the trip. The extraordinary return on investment from a world class maintenance & reliability program is well documented. Many times it turns out to be the best investment a company can make.

I'm excited to announce that uptime® and Reliabilityweb.com™ have come together to bring you a powerful new educational tool we call the Reliability Roadmap (see details on facing page). The Roadmap's starting point is a series of six web workshops in 2006. But the workshops are intended to be just the start of the journey. By registering for the workshops, you will gain access into - and be able to contribute to - a web-based community of knowledge.

There are many ways to get to California from here in Florida. Not everyone chooses the same road. Some people want to get there as fast as possible, some want the most scenic route, some just have to see Graceland and others want to see Aunt Mildred.

There are also many ways to achieve world class maintenance. We will layout a map for you, the maintenance & reliability professional, so you can plan your own expedition to maintenance excellence. Our roadmap will show you how to navigate through vibration analysis, ultrasound, motor testing, infrared thermography and oil analysis programs. We hope you will join us for a voyage that you will surely find rewarding for both you and for your entire maintenance team.

I would be remiss if I didn't report errors in our first issue. The alignment case study was written exclusively for uptime® by Alan Luedeking of Ludeca - not Alan Ludeking as we printed it. The contact number was wrong as well. Ludeca can be contacted at 305-591-8935. It is rather embarrassing to have any error go to press. When the error is in the first issue and it is in the name of an author who is providing an excellent article it makes me feel that much worse. So, I am here eating crow. It's not the first time, and I guarantee you it won't be the last. My sincere apologies Alan.

All the best,

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Putting it all Together

Communication & Accountability Complete the Puzzle

by

Mark Mitchell & Steve Quillen
Forrest Pardue & Dick Hancock

Over the past 20 years, many US plants have invested heavily in condition monitoring technologies such as vibration, oil analysis, thermography, and motor circuit evaluation to provide an accurate prediction of plant equipment problems. These predictive maintenance programs use best of breed technical equipment along with trained and certified analysts, and they often produce solid technical results. Each month valid condition monitoring results are produced and distributed to plant maintenance and operations personnel. So why do critical machines that have been identified as degraded in advance continue to fail in service? Why do many predictive maintenance programs have their funding and staff cut at the first sign of a sales decline?

The problem is actually that plant management implemented condition monitoring without laying the groundwork for Condition-Based Maintenance. What's the difference? Condition monitoring is largely a technology and training issue while Condition-Based Maintenance requires the existence of a reliability culture involving both operations and maintenance. Innovative plants such as Eastman Chemicals in Kingsport, Tennessee have found that a consistent program of communication and accountability have helped them to instill and sustain that type of Condition-Based Maintenance culture.

Condition-Based Maintenance is far more than conducting condition monitoring activities and developing technical proficiency with the tools.

Creating a Condition-Based Maintenance Plant Culture

Typically, top management sets a Condition-Based Maintenance vision:

"Our plant will…

- Eliminate in-service failures on critical equipment,
- Eliminate costly preventive (scheduled) maintenance work when condition analysis shows no need for the work,
- Eliminate basic machinery problems so that less total maintenance is required,
- Extend the life (reliability) of plant equipment while achieving the lowest total lifecycle cost, and
- Measure program results and adjust resources and focus as needed.

The plant then proceeds to either buy monitoring equipment and train personnel, or hire predictive maintenance contractors. So the plant must be doing Condition-Based Maintenance… Right?

Not really – Condition-Based Maintenance is far more than conducting condition monitoring activities and developing technical proficiency with the tools. Those steps are necessary, but so is the need for the organization as a whole to incorporate a mindset that equipment reliability is the shared responsibility of operations and maintenance. Until that shared attitude is made an integral part of plant culture, the reliability improvement initiative is fragile and prone to cutbacks, inattention, and failure. Therefore, top management must buy in to the concept of condition-based maintenance. Someone within the organization must act as a 'champion' of the cause to get the necessary buy-in. The champion can come from any level within the organization. It doesn't have to be one individual, it could be a group of people. The key is for the champion to effectively communicate the benefits of condition-based maintenance – and to do it in a language top management understands. Typically, that language will be more economic than technical. Buy-in at the top is critical, because, ultimately, top management's responsibility must go beyond 'setting the vision' and 'acquiring monitoring technology' to include:

- Creating an effective system for communicating machinery health status, and
- Holding plant employees accountable for follow-up actions & results

Eastman Chemical Facility   Kingsport, TN

Effectively Communicating Machinery Health Status

In too many plants poor communication leads to wasted effort by the condition monitoring teams. Condition monitoring results are produced by multiple monitoring technologies, each using a different database and analysis software. This is inevitable as the plant strives to match the best system for a specific technology with the plant's needs, or to select the best PdM contractor for certain technologies. Unfortunately, different technicians using dissimilar systems create reports with different formats and terminologies. These are usually dispersed among a variety of people in different departments based on the technology, and quickly secluded in report binders and long e-mail lists. This piecemeal communication makes it difficult for a broad audience of maintenance and operations personnel to be aware of all known information about a specific asset's health.

For example, Eastman Chemical's Kingsport, Tennessee plant is a large, multi-product chemical facility with over 20,000 rotating machinery trains. The Kingsport plant began performing predictive maintenance in the mid-1980's and developed a predictive maintenance group using multiple technologies such as:

- Vibration Monitoring (Route and Online)
- Infrared Thermography
- Lubrication Analysis
- Ultrasonic Monitoring
- Motor Analysis

By the mid 1990's, this predictive maintenance group was well respected for its technical proficiency, and was credited with preventing a significant number of production interruptions by catching equipment problems prior to failure. However, several people within Eastman's management felt there was room to improve.

First, they realized that the organization was handling condition information as shown in Figure 1. Individual condition reports from different technologies were going to different maintenance contacts for an operations area. These contacts would usually have to negotiate with their operations counterpart over the need for and scheduling of repair activity before being able to forward a request to the maintenance planner. This resulted in delays and "dropped balls" in handling equipment problems in a Condition-Based Maintenance manner. The key issues leading to this result were:

- Few people, if anyone, had a complete picture of all known condition issues on a piece of equipment,

- Operations had very little 'buy-in' to the concept of Condition-Based Maintenance,

- The first notice maintenance managers had about 'dropped balls' was usually a call from operations, after the fact.

In the late 1990's Eastman decided to modify organizational structure and information flow to improve use of equipment condition information and better support a Condition-Based Maintenance mindset.

The organization structure was modified as

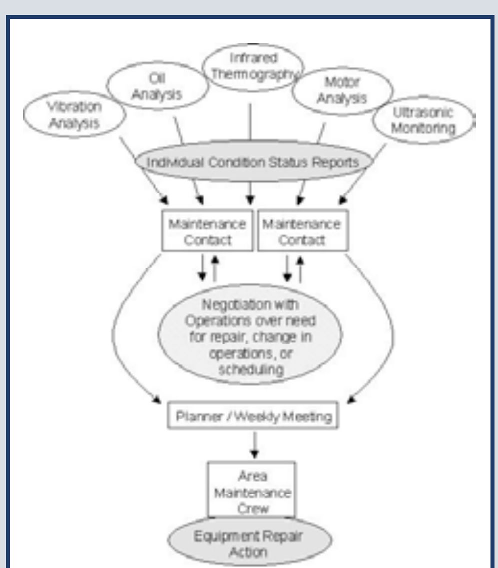

Figure 1 - Old flow of condition based work at Eastman Chemicals

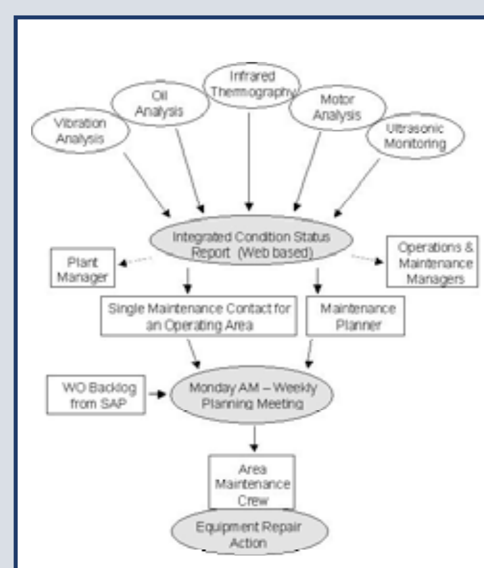

Figure 2 - Modified flow of condition based work at Eastman Chemicals

shown in Figure 2. The key change was assigning a single maintenance contact to each operating area; this contact is the liaison between the predictive maintenance group and operations. They work with operations to evaluate potential equipment problems and scheduling options for maintenance action, and are ultimately responsible for ensuring that timely maintenance action takes place.

Following the organization change, it was also decided that an integrated condition status report was needed to merge findings and recommendations from each of the technologies being used to monitor a problem machine. High priority was put on making the integrated condition results easily available to a wide audience of operations, maintenance, and executive managers. The report had to be asset based rather than monitoring technology based, and it also needed to be accessible without requiring installation of special software by users. That lead to the creation of a web-based Integrated Condition Status Report system.

With the new organization and Integrated Condition Status Report in place, the weekly planning meeting became a focal point for joint responsibility of equipment reliability. Everyone involved, including predictive maintenance analysts, planners, and area operations and maintenance managers, now have access to the same equipment health status information before and while in the meeting. Issues can't be swept under the table or ignored, and the group is able to spend their time focusing on operations scheduling and work order priorities for maintenance action.

High Priority:

Making the integrated condition results easily available to a wide audience of operations, maintenance, and executive managers.

There were several communications issues that had to be tackled in the evolution from technology focused reporting to asset-centered communication of condition monitoring results. The biggest of which were:

1) Integration of health status information from multiple technologies

2) Standardization of reporting format and terminology

3) Distribution of findings, recommendations, and work status to a broad base of plant personnel

Integrating Condition Status in a Web-hosted database

The piecemeal communication described in Eastman's old organization was technology-centered, both in report generation and in who received the reports. Integrating condition results from all technologies under each specific machine location is the first step toward asset-centered communication of health status. Web-hosted database technology offers a solution for asset centered integration. Condition results can be collected in a single web-hosted database, independent from the proprietary databases housing the technical data. In-plant technicians and outside PdM contractors enter plain language findings and recommendations into this web-hosted database via the Internet, bypassing any issues about outside vendors having to cross security firewalls in the plant network. Authorized plant users login via a web browser to retrieve a health report for their area of the plant, without having to install and maintain any special software. Machines with severe health problems are marked with a red light at the top of the list. Eastman Chemicals, Kingsport, uses an asset-centered health status report (as seen in Figure 3) to graphically communicate which machines have significant health issues based on all the monitoring technologies being applied to that machine.

Planners, supervisors, and plant managers can see what may affect operations, then drill down for more detail to support their daily decisions (Figure 4). If they are interested in the technical data behind the analyst's recommendations, they can open linked documents to view the supporting information.

Once planners have generated a work order, they can enter a reference number to the condition entry, so anyone who wants to

Issues can't be swept under the table...

the group is able to spend their time focusing on operations scheduling and work order priorities for maintenance action.

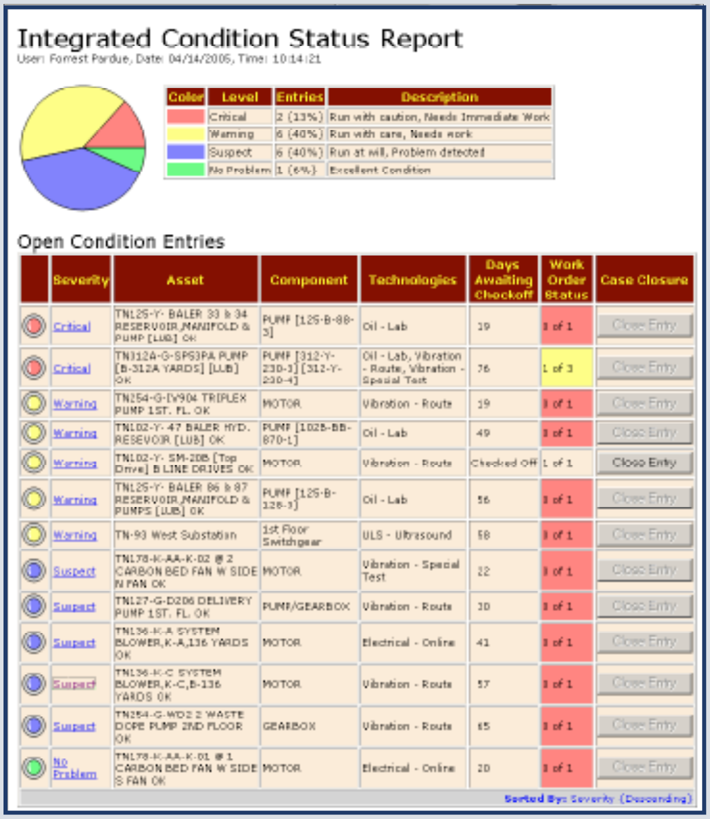

Figure 3 - Multiple technology results integrated for each asset location

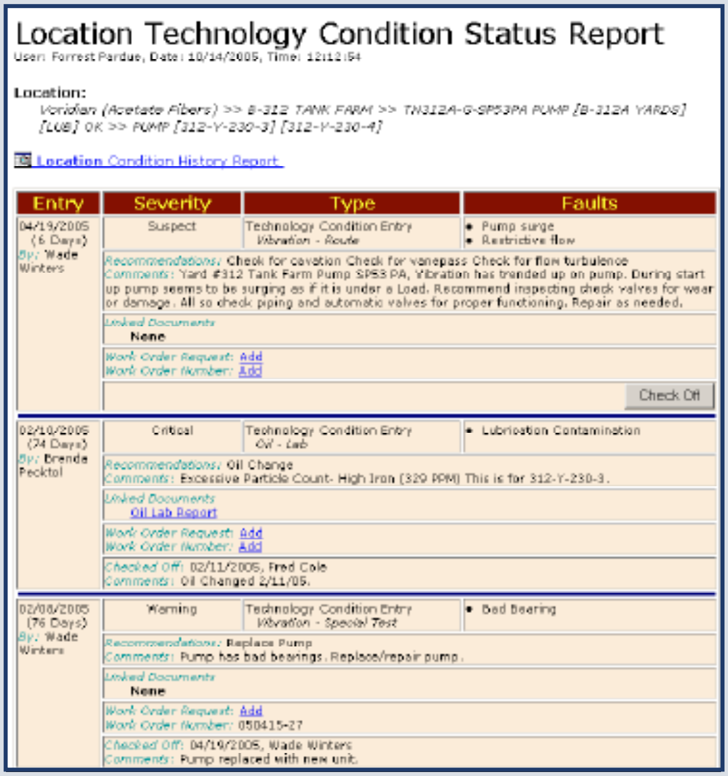

Figure 4 - Drilling down to detailed recommendations & supporting documents

check into work order progress knows where to look it up in the plant's SAP system. Once a work order reference has been entered, the Integrated Condition Status Report also shows how many days the oldest work order for an asset has been open. When the work is complete, the planner can also notify others by 'Checking Off' the condition entry. When that is done, then the Integrated status report also shows a 'Close Entry' button for that condition case, as seen in Figure 3. Eastman's predictive maintenance technician responsible for that entry can then close the case and remove it from the report, in many cases after a follow-up monitoring session to confirm that the problem has been resolved.

Therefore, participants in the weekly planning meeting not only see condition status for problem machines, but they also get a snapshot of response and work status for those health issues. That keeps all departments informed on progress; such broad exposure of Condition-Based Maintenance status also makes it a lot harder to hide shortcomings.

Standardization to Improve Understanding of Information

Just as in human medicine, it is very important that all parties use common terminology when describing machinery health issues. Standardization of condition results means that everyone inputting findings and recommendations uses common equipment location names, faults, and severity levels, and that the output information has a standard look and content regardless of technology, analyst, or whether they're plant employees or an outside contractor.

Again, a single web-hosted database can provide a results entry form (Figure 5) that uses pull down lists to enforce standardized terminology. This screen utilizes a standard pull down list for the selection of faults, recommendations and severity. The pull down lists also enforce brevity to make the information easier to understand; but, an analyst can also write a more comprehensive problem description if needed. Such standardization allows a common look and language between condition technologies, and it also facilitates future mining of the information for common patterns. This simple mechanism for standardizing basic findings and recommendation content does not exclude technical reporting, as supporting data images and documents can be linked to the condition entry, for

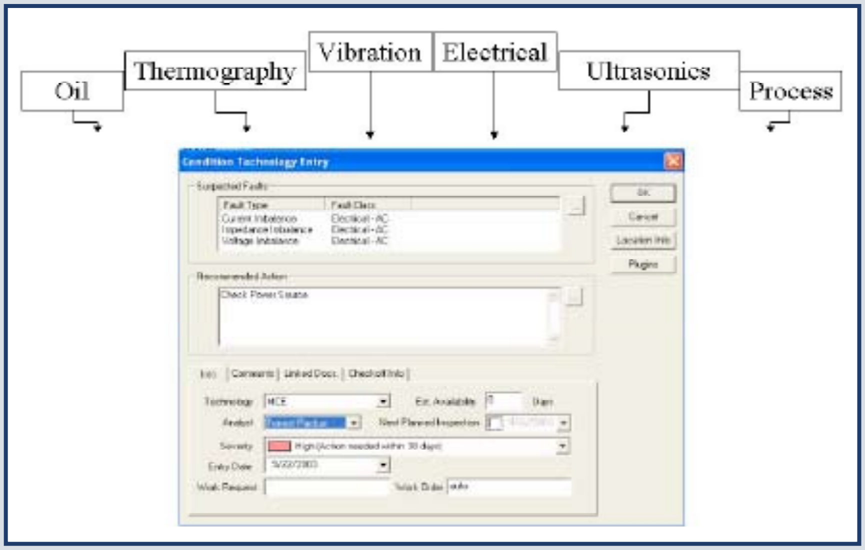

Figure 5 - Standard condition results form

retrieval by interested users.

Distribution to a Broad Plant Audience via Web-browser

Something amazing happens in human organizations when people know that information about their area of responsibility is widely available to others. They tend to care more about what's happening and focus their energy on doing a better job. This applies to executives as well as managers, engineers, and craftsmen.

Web-browser technology is well suited for allowing a broad base of users to access equipment health information with minimum effort, while still providing some control over what information each individual user can view or interact with. Practically all computers have an Internet browser installed, so there's no need to install and maintain specialized software. They only need the correct URL for their web-hosted database, along with an authorized user name and password, to access the current health status of equipment in their area of concern.

One of the Reliability Engineers at Eastman's Kingsport facility credits the wide and persistent visibility of condition results as one of the keys in making operations and maintenance joint owners of equipment reliability. He says that "prompt response to resolve condition-based maintenance issues" has become the way of life because everyone knows that "the bosses care".

Accountability for Results

Good communication of condition status may be essential for guiding work prioritization, but that alone does not mean that the best Condition-Based Maintenance results are being delivered to the plant business.

Personnel must be held accountable for using the information to produce increased reliability results. Two important execution measurements for Condition-Based Maintenance are:

1) If equipment does show health issues, are timely maintenance responses happening?

2) Is condition history being kept and analyzed to spot & address chronic reliability issues?

As has been said many times - "What gets measured gets done!"

In addition to the work response measures available in the Integrated Condition Status Report, Eastman Chemicals has taken advantage of a single database with integrated condition results and work follow-up status to generate several custom reports. One of these trends the timeframe in which condition-based work orders are resolved; the report can be set to cover all condition-based activity or a single technology in a specific operations area. Figure 6 shows that over 90% of work requests generated by vibration monitoring during the first nine months of

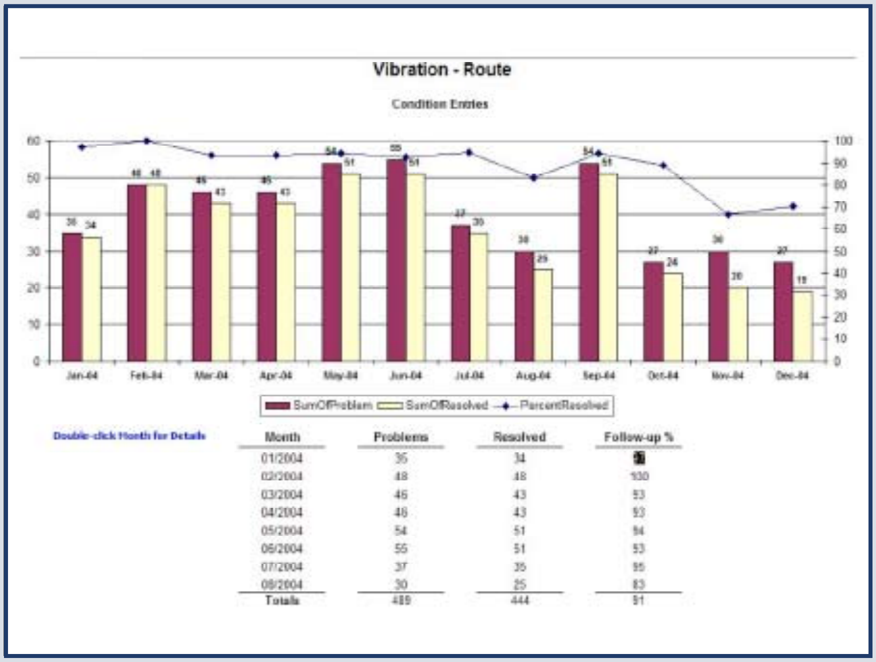

Figure 6 - Customized maintenance follow-up report for condition-based work orders

2004 had been addressed and resolved.

Eastman's Reliability Technology Report (RTP) for vibration monitoring is shown in Figure 7. It tracks resolution of condition-based work requests and is available to area managers for more detail on how well their crews are utilizing information from a specific predictive technology. It shows area operations and maintenance managers how condition generated work orders were handled during the month, and how their area compared to others. Area managers typically focus on the Year To Date '% Corrected' table at the bottom and ask 'what do we have to do to get better?" Predictive maintenance technicians also review these reports to understand which areas may need additional help in using their information.

Reliability Technology Department

Vibration Monitoring - Monthly Report

User Name G K   Thursday, May 12, 2005

Area CE&SP   Month April   Year 2005

Vibration Index this month 0.14   Vibration Index All TED 0.101

449 Machines in Database
241 Machines Monitored This Month
4 Problems Documented This Month   29 Documented YTD
4 Problems Known Corrected This Month   13 Corrected YTD
3 Problems Outstanding This Month   20 Outstanding YTD

Job Sheet Data   *** May Include Prior Year Jobs**

CE&SP	Reported This Month	Reported Y. T. D.	Corrected This Month *	Corrected Y. T. D. *	Corrected This Year
	1	1			0
B- 51 CR. 4210	0	1	0	1	0
D- 65 CR. 4227	1	1			0
B- 81 CR. 4204	0	4	0	1	1
B- 81 CR. 4211	2	7	0	1	1
B-120 CR. 4207	0	2	0	1	1
B-120 CR. 4208	0	10	4	9	3
B-190 CR. 4228	0	3	0	0	0

Year To Date Percentages   *** May Include Prior Year Jobs**

Unit Name	Finds	Follow ups *	Percent *
CE (Acid Con)	8	2	25.0%
CE (CPE-EST)	12	10	83.3%
CE (Film)	4	1	25.0%
CE (Plastics)	5	0	0.0%
Totals	29	13	44.8%

Figure 7 - Customized maintenance follow-up report by individual monitoring technology

Use of Historical Condition Information

Eastman's condition monitoring analysts and reliability engineers are also able to receive custom reports that help them identify chronic failure issues. In Eastman's 'Faults by Component' report, the user selects plant areas, time frame, and monitoring technologies; the example shown in Figure 8 covers all technologies being used across several operating areas for 2005 YTD (through June 2005). Reduction gearboxes quickly stand out with the highest number of faults. Drilling into the report would uncover filter design and lubrication issues that are the greatest common denominators behind the gearbox faults; providing important information for targeting reliability improvement initiatives. For example, over the last several years Eastman has significantly reduced chronic equipment problems such as imbalance, misalignment, lubrication, and installation issues by using historical failure

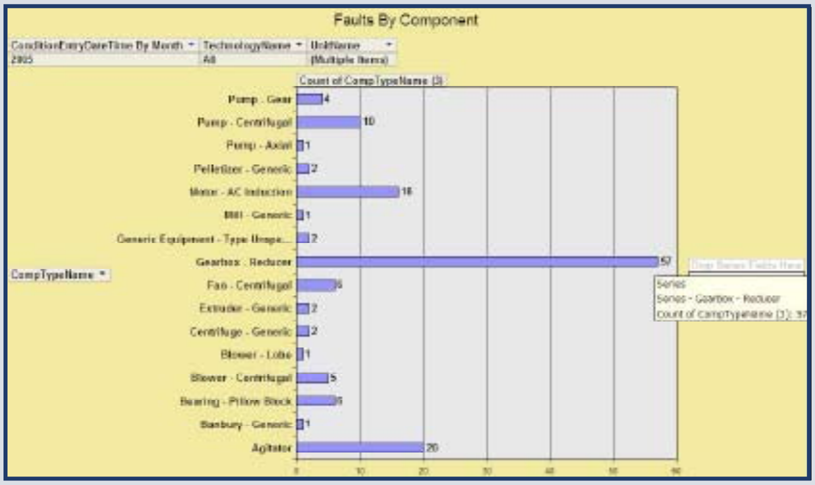

Figure 8 - Customized report for number of faults by equipment type, 2005 YTD

mode information to change procedures and justify special training and tools.

Eastman has also been able to use historical condition information to fine-tune its condition monitoring activities. When a condition monitoring 'find' is defined as leading to a maintenance or repair action, it is generally accepted that condition monitoring programs at industrial plants typically progress according to the trend shown in Figure 9.

A Reliability Engineer at Eastman used the historical information to calculate their 'find %' and found that they were at the 4% level in the mid-90's and reached 2 ½% around 2003. It's probably not a coincidence that the improvement in reliability culture was occurring at the same time. Management's confidence in Condition-Based Maintenance execution contributed to the decision to reduce vibration monitoring frequency for less critical equipment from monthly to every other month or even quarterly. They were then able to shift some manpower from routine monitoring to higher value added root cause analysis activities. It's also probably not a coincidence that over the same time period Eastman's wrench-turning maintenance force has decreased from approximately 1200 employees to around 800, while production capacity has slightly increased.

Summary

At Eastman Chemicals in Kingsport, Tennessee the management vision for Condition Based-Maintenance and equipment reliability has really been embedded in most of the plant's

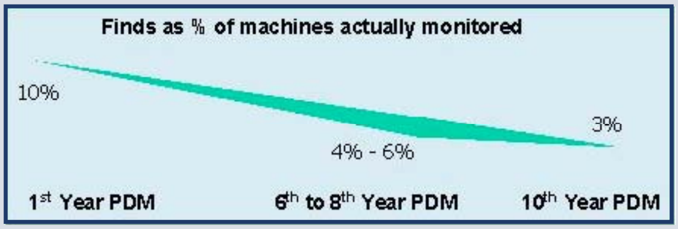

Figure 9 - Typical 'Find %' as PDM Program Matures

culture in the following ways:

- Operating area 'bosses' know and care about what's happening with equipment reliability because they can view current Integrated Condition Status and worker response via their web-browsers.
- A weekly planning meeting is the focal point where operations and maintenance work together to prioritize work based on condition status - to the point that condition surveys conducted on Friday are expected to be entered and responded to in time for the Monday am planning session! Now that's culture change!
- Accountability is consistently based on condition status and work execution rather than informal complaints from operations.
- Condition history is being used to spot chronic equipment problems and focus reliability improvement resources, as well as fine-tune the monitoring activity.

One of the significant contributors to Eastman's Condition-Based Maintenance success is their single database for housing all equipment condition status and web-based distribution of information from that database.

Dick Hancock has over 30 years experience related to industrial machinery and maintenance. In the 1990's he helped CSI grow into the largest manufacturer and marketer of predictive maintenance systems, and following Emerson Electric's acquisition of CSI he served as VP of Marketing. Currently, Dick is a sales and marketing consultant working with 24/7 Systems, Inc. to introduce web-based equipment lifecycle management services.

E. Forrest Pardue is the president of 24/7 systems, a company focused on the development of strategic equipment management software and services. n 1998 Forrest co-founded 24/7 Systems with his partner, Paul Wolfensberger. 24/7 Systems' founders realized that the biggest needs facing industrial maintenance had shifted to the measurement, management, and improvement of plant machinery reliability.
Forrest has worked in the field of vibration analysis and production maintenance for the last 25 years. Forrest was one of the founding members of CSI and has been very actively involved in the technical and market development of predictive condition monitoring technologies. Forrest received his BS in Electrical Engineering from North Carolina State, and his MBA from Lynchburg College

Steve C. Quillen is the Senior Technician in the Rotating Equipment Group of the Reliability Technology Department. He has been with Eastman Chemical Company 28 years and has worked in various roles including Operations, General Mechanic Apprentice General Mechanic, Training Instructor and Relief Supervisor.

Mark Mitchell, P.E., is the Rotating Equipment Group Leader, Reliability Technologies Department.

Enterprise Asset Management Users Generate Better Odds at EAM-2006

by Terrence O'Hanlon, CMRP

EAM-2006 brings the intelligence, innovation and leadership of the maintenance and reliability industry together in one place at place at one time. Asset Management challenges and best practices are discussed in a format designed to facilitate knowledge exchange.

A Computerized Maintenance Management System (CMMS) or Enterprise Asset Management (EAM) System is designed to manage maintenance transactions the same way an Accounting Information Management System manages financial transactions. In the case of maintenance, the transactions are work orders instead of invoices. Inventory is the maintenance work backlog and spare parts instead of the raw material used in manufacturing.

Accurate information is critical to making decisions that ensure the reliable operation of equipment. Developing strategies and tactics for ensuring equipment function can be made easier with accurate failure data and maintenance transaction history details. Summary reports allow maintenance managers to spot "bad actors"; the "critical few" trouble spots that are causing the greatest problems. Typically 80% of your critical problems come from just 20% of your systems. Planning and scheduling jobs can also be more effective with a fully functional CMMS/EAM. Although creating a proactive maintenance culture is possible without a functional CMMS/EAM, it is very rare.

Over 300 people came together for EAM-2005 (CMMS-2005) in Indianapolis last July to explore the problem in greater detail and to suggest solutions. Now it is time to bring a new group of people who are interested in Enterprise Asset Management together again for EAM-2006, a focused 3 day "community of practice" event held March 8-10, 2006 in Las Vegas, Nevada. The audience will include some of the world's leading EAM experts along with people who are just beginning to explore the subject.

CMMS/EAM Return on Investment (ROI)

Our research indicates that 57% of members reported that the CMMS/EAM implementation failed to generate the anticipated return on investment (ROI). Only 20% characterized their CMMS/EAM implementation as successful.

Many companies have been sorely disappointed with the results of their CMMS/EAM implementations. In some instances, the complex system capabilities and functions that can assist maintenance management are rarely used. The advantages of leveraging maintenance transaction information are often reduced by poor CMMS/EAM work practices.

The learning program at EAM-2006 has been designed

to increase the odds of successful implementation and use of enterprise asset management information systems (EAM/CMMS). The workshop leaders, short course instructors and learning zone presenters each bring unique knowledge and experience to EAM-2006.

We are very proud to offer a chance for participants to experience the Manufacturing Game (facilitated by the originators at Ledet Enterprises). We can think of no better way to shape the learning that will follow. The Manufacturing Game is a proven tool for engaging the workforce in defect elimination. It gives participants a bird's eye view of a manufacturing facility. They experience in a short time what could take years to experience in the "real world." Actions launched as part of a workshop have typically resulted in 40% fewer failures and a third lower costs. Engaging the majority of the workforce in eliminating small defects before they become performance-limiting problems is a hallmark of delivering world-class performance. The Manufacturing Game® inspires front-line workers to take action to eliminate defects, product rework and waste and the reactive work that these defects create.

The Manufacturing Game has been used by over 175 companies worldwide and 29,000 people. DuPont, BP, Honda, Whirlpool and ExxonMobil are a few of the companies that have used The Manufacturing Game to reduce failures and lower costs.

This EAM-2006 workshop is designed for maintenance managers, mechanics, operations managers, supervisors, operators, planners, schedulers, inspectors, reliability managers, reliability specialists, materials procurement personnel, trainers and IT providers who need a better understanding of how maintenance and operations work in the plant. Seating is limited and is expected to sell out - so book early if you wish to participate.

For those more focused on MRO Spares, EAM-2006 offers an "MRO Inventory Optimization" workshop led by Gene Moncrief, co-author of PRODUCTION SPARE PARTS. Gene is a leading authority worldwide on setting part stocking levels for safety stocks to support the production process. His work has shown that between 25 and 50 percent of the inventory investment is not necessary. Thus the overall objective of this workshop is to instruct participants in how to optimize their company's spare parts asset. This compilation of the best techniques and practices for optimizing MRO inventory offers numerous case studies showing both the best ways to improve plant inventory performance and some well-intentioned, but misguided approaches. Based on practical solutions to everyday inventory problems, it uses simple, but useful metrics for setting and monitoring goals.

There are also workshops designed specifically for SAP PM™ (EAM) users and Maximo® users. The first workshop titled "Leadership and the SAP Plant Maintenance Tool" is led by John Hoke, CMRP and Lorri Craig, of Reliability Solutions, Inc.

Engaged leadership by most any measure, is the key success characteristic in any successful SAP Plant Maintenance Implementation. As a leader, the organization will respond to what your values are and participation in the SAP PM implementation. As the saying goes "We tend to respect what the boss inspects". Understanding the basic SAP PM tool set and providing leadership support for the organization is the foundation required to develop reliable maintenance practices and, ultimately, achieving your goal of increased reliability and lower cost to achieve that reliability.

This workshop is designed to educate leadership within a manufacturing environment on the functionality of the SAP Plant Maintenance Module and its interdependencies with the other SAP Enterprise Modules. It is this collective synergy of manufacturing subsystems that present the largest value to the company as a whole. The maintenance organization is asked to standardize their reliability processes across an entire manufacturing environment, which in turn will both globalize many facilities while at the same time creating agility and small company flexibility to multi-facility organizations. Leadership's role of champion of the SAP Plant Maintenance reliability effort is to demonstrate and lead the value proposition. The workshop will conclude with a leadership evaluation of key skills and action items to benchmark success.

Note: This workshop is offered independently of and has no connection with SAP AG or its affiliate companies. SAP is a trademark of SAP AG.

The other software specific workshop is "Be Brilliant with the Basics: Making Maximo Work" by Steve Richmond, Projetech Inc. Participants of this workshop will learn basic (but important) tips and tricks to get the most out of their investment. We'll discuss ways to enhance navigation and querying skills, better understand sites and locations, and correctly classify assets (equipment, rotables and inventory.) We'll also cover the importance of keeping value lists simple, mapping business processes, and choosing the appropriate reporting tools (SQR, Actuate or Crystal.) If you are new to MAXIMO, or just eager to save time by making it more user friendly, you will find the "best practice" resources in this session very useful.

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- Unleashing the Power of the EAM as a Reliability Improvement Tool by Bill Keeter, BK Reliability Engineers
- MRO Excellence – Equipment Available to Meet Customer's Expectations by Kevin Lewton, MET DEMAND LLC
- Connecting Reliability to EAM by Ricky Smith, CMRP, IVARA
- What I Wish I Had Realized at Go Live – Learning's from SAP PM Renewal Efforts by John W. Hoke and Lorri A. Craig, Reliability Solutions
- Accelerating Implementation & Use of Maximo by Steve Richmond
- MP2 Tips and Tricks by Leanne Joseph, CMMS Data Group

Short courses are designed to provide a more in depth learning experience and are scheduled at the beginning and end of each learning day. A series of Enterprise Asset Management case studies are also included as part of the learning zone sessions including:

- Basic Asset Care by Steve Reilly Design Maintenance Systems Inc. (DMSI)
- Look Before You Leap: Effective Planning Yields Optimal Change by Miguel Giles, Signum Group
- Rising to the Occasion - How Gonnella Frozen Products Uses CMMS to Optimize its Inventory Management Practices by Ruth Olszewski CMMS Data Group and Dennis Marcucci Gonnella Frozen Products
- ROI, Phones and The Tucker by Dave Loesch, Oracle
- The Keys to a Successful Mobile EAM/CMMS Solution by Jeff Gibson, Datasplice
- Getting More Than Data Processing Out Of A CMMS James Huzdovich-Project Manager, Raven Services Corporation
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Five Nines

Data Centers Maximize Uptime with Infrared Thermography

by Gregory R. Stockton

99.999% uptime…five nines. That is what Information Technology (IT) customers are looking for. Uptime or "availability" at data centers is an absolutely necessity. A loss in power to a data center can cost the owner millions, literally. The power, cooling and support systems are vital to the continuous flow of information in these "mission critical" facilities. Infrared predictive maintenance (IR/PM) is a must. The electrical switchgear, uninterruptible power supply (UPS), automatic transfer switches (ATS), server systems and cooling systems must be checked with infrared thermography and other testing means on a regular basis to insure super-high reliability.

Mission Critical

Mission critical facilities are like other facilities in that they have electro-mechanical equipment that must be maintained. The difference is that the operators of mission critical facilities, owing to the extremely high availability requirements from management, have to pay much more attention to the equipment so that it will not fail. This requires dual-path power supply systems (for redundancy) and regular testing of the systems.

FIG 1 – Typical PDU in a data center with load bank test being run.

Systems

Dual-power technology requires two completely independent electrical systems tied together with switchgear. When the normal source of power fails, these dual-path power supply systems quickly switch to a back-up source. A UPS system keeps the power flowing until the normal source is restored or another source is brought on-line and synchronized. Usually, the UPS, through a power distribution unit, or PDU (see FIG 1 & 2), takes AC power, converts it to DC where a bank of batteries is tied in and then inverts it back to AC to feed the computer hardware. Since the systems often cannot be tested on-line, they must be tested during "maintenance windows", planned outages or times when the impact of testing is low, so that simulations can be run. By pulling power from a load bank, resistive load testing is used to fully simulate and test all equipment on the floor. Any problems that are encountered during an infrared survey are repaired immedi-

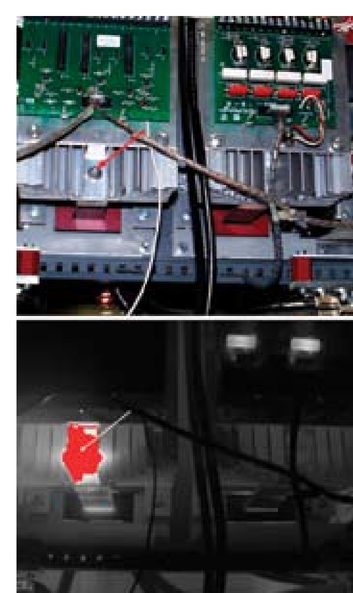

FIG 2 – SCR connection on an inverter assembly at over 550° F.

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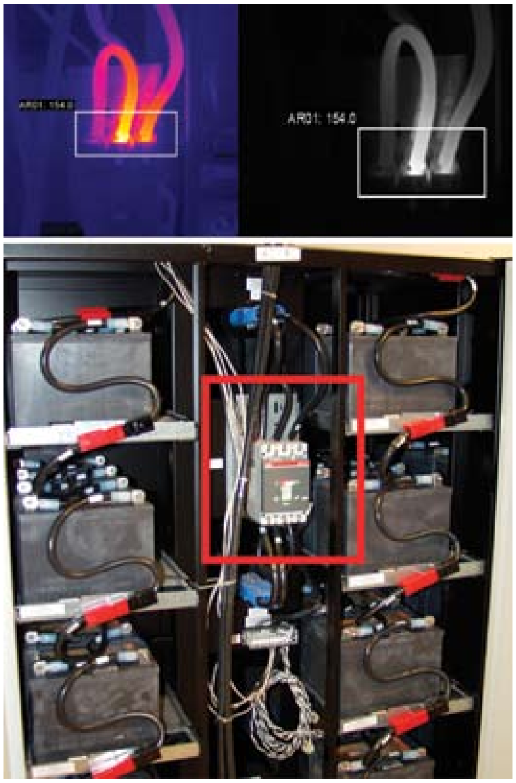


FIG 3 – Small battery bank with loose lug connection on the main breaker.

ately and the system is rechecked before putting the equipment back on-line.

Battery back-up systems (see FIG 3) must be checked in a real-time battery discharge situation to fully simulate an actual loss of the normal source of power. The batteries, connections, cables, switches and charging systems are checked for unwanted heating conditions.

Uniform cooling of all data center server, storage, and computer equipment is essential for proper operation. The design objective of the cooling system is to provide a clear path from the source of the cooled air to the equipment and back to the cooling unit. This issue has received much attention lately as miniaturization of the equipment and economic pressures have increased the amount of heat that is generated per cubic foot of floor space and per cubic foot of rack space in the server rack panels. This hardware is sensitive to heat and humidity and some new designs are being tested so that failures do not occur solely because of environmental conditions (see FIG 4). How perfect an application for IR!

Utility main power supplies are typically owned by the local power company but are sometimes owned by the user. A looped system feeds power from two different power company substations and can be "back fed" if the power is out on the primary. No matter who the technical owner of the utility equipment is, it must be checked with IR like all other components. (See FIG 5).

Mechanical Systems have the same stringent requirements as the electrical system. Again, this is achieved by redundancy and failure prevention engineering.

Accountability

There must be a total accountability of all infrared survey results, especially all of the equipment associated with the UPS, computer and server systems. This can be accomplished by recording the entire survey on digital videotape and/or capturing fully-radiometric images of all equipment, whether problems exist or not. In either case, a data log of all equipment surveyed must be created including a time/date stamp reference for all equipment. Detailed documentation is very important to the project's success

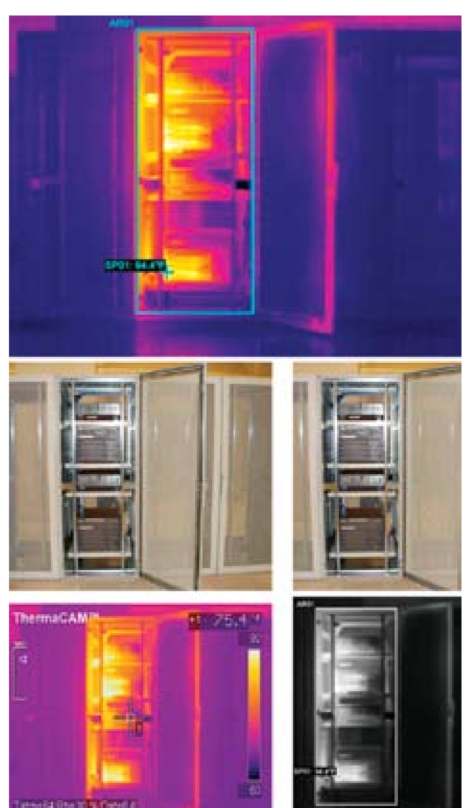


FIG 4 - Server rack designs being tested for heat dissipation.

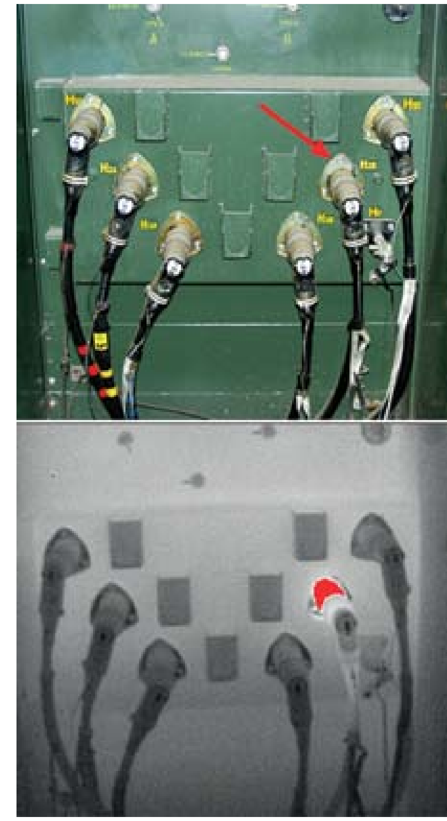


FIG 5 – Pad-mounted transformer with loose connection on line side.

Summary

To achieve five nines availability, it is essential that competent IR testing be performed on all electrical and mechanical systems in conjunction with other testing, and in cooperation with management and maintenance personnel.

If you maintain an office building, manufacturing facility or any other type of facility where uptime is important, you should take time to follow what is happening with data centers, as they are among the most mission critical of all operations.

Gregory R. Stockton is president of Stockton Infrared Thermographic Services, Inc. The North Carolina-based Corporation operates seven application-specific divisions performing many different infrared services in the US, Canada, Central and South America. Greg has been an infrared thermographer since 1989, and has published numerous white papers and articles on infrared thermography. He can be reached at 336-498-4734 or by e-mail at gregsits@northstate.net

Vanquishing Varnish

Successfully Removing Submicron Contaminants From Gas Turbines

by Gerald Munson

A power station using seven GE F7FA combustion turbines as primary firing and generating capacity utilizes the waste heat in a combined cycle to power old, but serviceable, steam turbines. The first three F7FA's were brought on line during the spring of 2003, in a base load capacity. Plant management had concerns about varnish buildup in close clearances causing stuck servos and actuators. It was expected that the frequency and severity of these varnish related issues would increase over time. Other F7FA users had reported the appearance of varnish as early as 8,000 hours, and therefore it was presumed that the level of pre-varnish material was near saturation in the lubricating system and would eventually cause problems. As a result, management decided to move forward with the implementation of lubricating oil purification and varnish reduction/removal technology.

After considerable study and review, the plant elected to install ISOPur's Balanced Charge Agglomeration (BCA™) technology on all seven F7FA Combustion Turbines (CT). One ISOPur MR Series (10 gpm) was installed on each of the gas turbines. The CT installations started simultaneously in January 2005 as the Series 1 CT's were approaching 10,000 hours. The systems have been running continuously since that point. The lube oil condition was monitored, first daily, then weekly, then bi-weekly.

This case study demonstrates the process of the Balanced Charge Agglomeration technology. Oil analysis and results are detailed after 10 weeks of ISOPur operation.

Chevron GST-32 Turbine lube oil, made from group II base stock (ISO VG 32), used in the GE Frame 7FA Combustion Gas Turbines was analyzed before ISOPur use and at sequential intervals after ISOPur startup.

Independent lab tested oil analysis was conducted throughout the trial. Samples were taken at 0 hours, 48 hours, 1 week, 3 weeks, 5 weeks, 8 weeks, and 10 weeks. The results can be found in Figures 1 & 2.

As the oil was aggressively cleaned, the filters' performance, with regard to particulate removal, provided a significant reduction in sub-micron particulate within hours. As you can see in Figures 1 & 2, following the initial cleanup period, there was an increase in particle count as the agglomeration of particles began.

The seven gas turbines are listed in the legend from Unit 1A to unit 2D and accompanied by the average number of particles in all of the seven combined. The average reduction in submicron particulate is impressive because this particulate would have otherwise passed through standard filtration. Also, note that the same particle trend took place on each of the seven turbines. Without the use of the BCA technology, this level of oil cleanliness would not have been be achieved.

Note the drastic drop in particulate from extremely high counts to low counts, then followed by the sporadic levels during the cleaning process within the system. As shown by the graphs, the lube oil is undergoing conditioning after only 10 weeks of BCA operation. The average reduction in 2 to 5m*μ* particulate is over 80%.

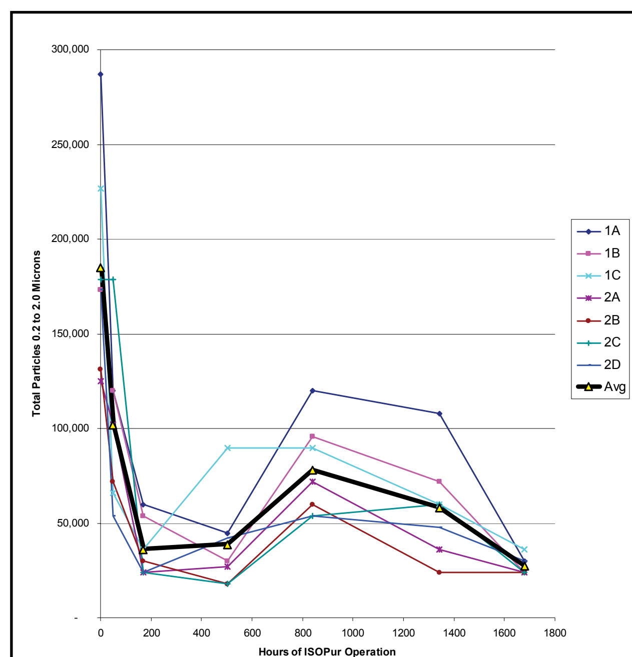


Figure 1 - Turbine Lube Oil Particle Analysis
0.2 to 2mμ/100 ml[2]

The Varnish Potential Rating (0-100 scale) is based

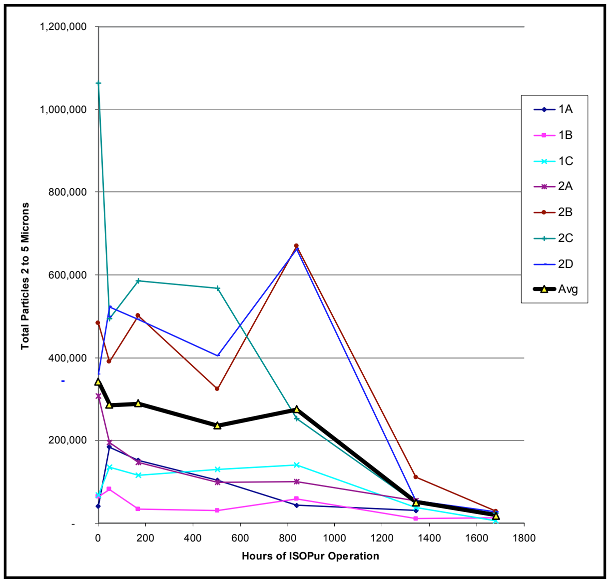
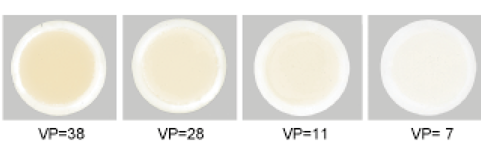


Figure 2 - Turbine Lube Oil Particle Analysis
2 to 5mµ/100ml²

on the harmful, varnish producing deposits found in the oil. The higher the rating, the more deposits found. The ISOPur systems reduced varnish producing deposits from an average rating of 38 to 26 on the 7 gas turbines (Figure 3). The rate of varnish potential has followed the same process as the particle counts; an initial dramatic drop, scattered cleaning, and continual drop.



Varnish Potential Patches

The varnish potential patches are a visual representation resulting from spectrophotometric analysis of oil samples taken from one of the 7 GE Frame 7FA Gas Turbines with the ISOPur system in operation. The varnish potential rating of 38 has a much higher concentration of contamination than the VP of 7 in the last patch, illustrating just how efficient the BCA technology performed in reducing the varnish producing deposits.

The photographs in Figures 4 and 5 were taken after three months of operating the BCA technology. The reservoirs were drained for inspection during overhaul.

In Figure 4, there is no varnish present in the BCA treated reservoir. In Figure 5, the

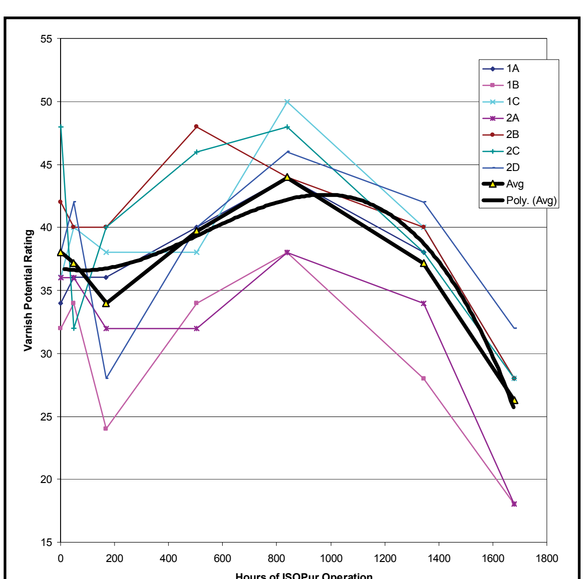


Figure 3 - Turbine Lube Oil Varnish Potential Rating

oil splash from the return line has created varnish that remains as it is above the oil treated with the BCA technology.

Balanced Charge Agglomeration

Balanced Charge Agglomeration was designed and patented to enable fine filters to remove submicron particulates from lubricating and hydraulic fluids. The postulation is that by removing a large portion of the contamination not previously removed by filtration, the function and life of machinery and lubricating oil would be maximized. Fluids circulating through close clearances are known to create static electricity, causing contaminants in the oil to become electrically charged and electrostatically suspended within the solution. This electrical charge will cause these particles to “electro-deposit” on grounded, metallic surfaces inside the machine and reservoirs. These deposits can reduce critical clearances.

Balanced Charge Agglomeration automatically counteracts this uncontrolled electrical charging. Electrical charges are transferred from electrodes to particles of contamination in sufficient numbers to arrive at the filters within the system. The unbalanced charge is then neutralized, permitting the filter media to become effective in accordance with the original machine and filter design.

Figure 4 GE Frame 7FA reservoir after BCA operation

Figure 5 Varnish remnants found above the oil level treated with ISOPur.

How BCA Works

1. BCA is created by forcing oil through two equal paths where oppositely charged electrodes are located. The fluid contains particles with an unbalanced average electrical charge.
2. The particles in each path are charged preferentially and to a high degree in accordance with the polarity of the electrodes in each path. The charging is designed to create a result equal to a potential of 0.0 volts DC when exiting the charging assembly.
3. These two liquid streams are now mixed together to force the charged particles into close proximity.
4. The electrostatic forces between oppositely charged bodies now pull the particles together forming agglomerates. Once discharged electrically, these particles are held together by VanderWaals forces.
5. The agglomerates continue to combine

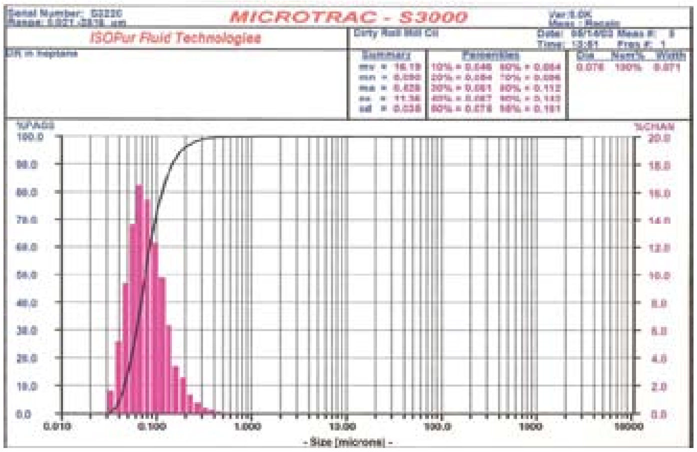


Figure 6 - Oil sample before BCA process

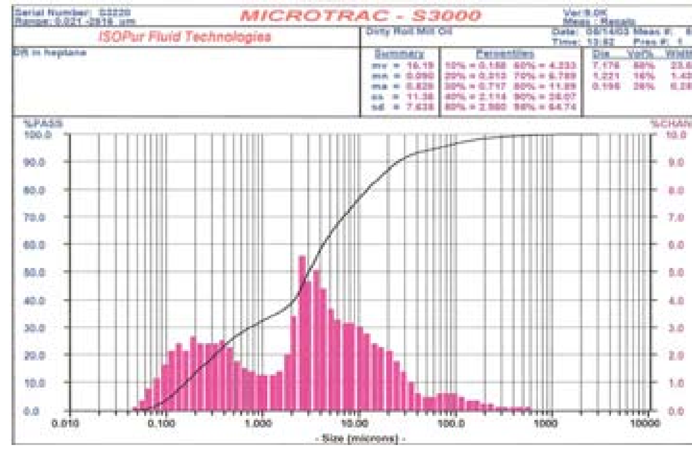


Figure 7 - Oil sample after one pass through BCA technology

with other charged bodies with in the local area. Electrostatic forces overpower the gravitational forces of the submicron particles by a factor of 10 to 1000 depending on the size of the particle and the physical separation.

Particle Agglomeration

A sample of lubricating oil contaminated with metal fines with a diameter centered near 0.08 micrometer (as determined with proton correlation spectroscopy) is passed through the BCA technology once and the effect is recorded in a similar fashion. Figure 6 shows a concentration of particulate less than 1 micron. In Figure 7, after just one subsequent pass through the BCA™ technology there is notable shift in particles to a much larger diameter, providing a clear example of particle agglomeration.

The count mean of this new distribution is just under 3 microns in size. This will enable a 3 micron filter to capture nearly 50% of this fine contamination. Each successive pass will produce another series of enlargements until the filter or other particulate removal scheme has pulled the material from the fluid.

BCA not only eliminates the net electrostatic charge on the contaminants within the lubricant, it also effectively removes the fines caused by wear, micro dieseling, and soft particles. These elements can represent up to 90% of the contamination within the oil.

The Benefits of BCA

In addition to eliminating the impact of net static charge found in standard filtration systems and conditioning the oil, BCA offers the following benefits:

- Micro-organisms are quickly killed by the BCA process. Elimination of microbial growth in lubrication, hydraulic or industrial systems reduces sticky servo valves, eliminates sludge formation, and blocks odor formation.
- Maintain physical properties of oil hundreds of times longer than standard filtration. Because standard filters do not eli minate small particles, they tend to accumulate to enormous levels, compromising the physical properties of oil. BCA gathers this submicron material and conditions oil to a cleaner standard. Lubricity, film strength solvent action, and viscosity are maintained in BCA equipped systems.
- Super clean oil tends to shed water and the BCA process eliminates most emulsions by removing the small particles which trap water.
- Reduced wear rates occur as ALL sizes of particles are removed.
- Varnish and sludge formation is blocked and pre-existing varnish purged from internal surfaces.

BCA removes products of oxidation. Standard filters tend to cause static charge on particles, which accumulates and damages both oil and filters. In addition, particles that are trapped in filters tend to repel incoming particles of like charge, which can steer larger particles through the filter. These filters lose their efficiency as debris accumulates. The BCA collection cartridge depth media filter encourages growth of particles based on charge attraction, removing submicron particles and products of oxidation from the oil.

Conclusion

After just 10 weeks of ISOPur oil conditioning with Balanced Charge Agglomeration, the plant management was impressed with the drop in particle counts, varnish potential rating and the appearance of the reservoirs. After trying other technologies, the plant engineer found that the BCA technology reduced particle contamination to previously unattainable levels. This includes particle sizes at or below 0.1 microns, which contribute significantly to reliability issues and may lead to catastrophic failures. BCA technology also demonstrated the ability to remove the precursors of varnish to extremely low contamination levels consistent with minimal threat to machinery. In addition, this technology has shown to be an effective tool for the removal of both hard and soft varnish deposits, which existed in the oil prior to the application of this technology.

BCA™ is a cost effective and prompt solution for a very real threat to reliable gas turbine operation. The proper combination of documentation and the elimination of the root cause factors will permanently keep this reliability problem under control.

Gerald Munson is a co-founder of ISOPur (1995), developer and patent holder of the "Balanced Charge Agglomeration" technology. Mr. Munson was vice-president of ITP Corporation from 1990 to 1995 and instrumental in developing other solid liquid separation technologies. From 1973 to 1988 Mr. Munson served in senior engineering positions with McGraw Edison Company, Alfa Laval Company, Bird Machine Company, and Wilson Walton International Inc. During his service with the U.S. Navy as a pilot, he received 24 Air medals, numerous other awards and was awarded a navy commendation for the design/construction of a computer while serving as a student at Pensacola Naval Air Station in 1965. He can be contacted at 203 589 3396 or gmunson@fluid-assets.com

Recovering From Disaster

Saltwater Major Problem for Hundreds of Facilities

by Chuck Yung

Flooding in the aftermath of hurricanes Katrina, Rita and Wilma shut down hundreds of plants along the Gulf Coast from Florida to Texas. To get them up and running again, maintenance departments and motor repairers face the daunting task of cleaning muck and moisture from thousands upon thousands of electric motors and generators. The process took weeks for some, months for others, and some are still not fully recovered. The ordeal has required special clean-up procedures for motors contaminated by saltwater.

Although the problems are huge, affected plants can get back in production more quickly by working closely with service center professionals and following a few tips that will make the cleanup more manageable. These include prioritizing motors and generators for repair or replacement, storing contaminated machines properly, and using special procedures to flush away saltwater contamination. Constructing temporary ovens on site or at the service center can also add capacity for drying the insulation systems of flooded motors.

In the wake of the recent hurricanes, maintenance professionals and motor repairers need creative solutions to speed the removal of moisture and contamination from thousands upon thousands of swamped motors.

Understanding the Problem

The harm done to motors and generators by flooding extends beyond rusted shafts and contaminated bearings and lubricants. Even brief intrusion of moisture can compromise the electrical insulation system, making the windings vulnerable to ground failures.

Saltwater flooding poses additional problems. Unless thoroughly flushed from the equipment before it dries, the residual salt usually will rust the steel laminations of the stator and rotor cores. It also may corrode the copper windings and aluminum or copper rotor cages. The result, predictably, will be lots of motor failures.

How to proceed

Begin by prioritizing motors by size and availability. Older motors are often good candidates for replacement with more energy efficient EPAct or NEMA Premium® models. The horsepower break will vary from plant to plant, depending on the application, annual usage, energy costs, and other factors. But, considering the real possibility that your regular vendors may be backlogged with work, somewhere between 100 and 200 hp may be a reasonable place to draw the repair-replace line. By replacing those smaller motors with readily available energy-efficient models, you'll free up capacity for your service center to concentrate on the larger ones that make more sense to repair.

Two Ways to Clean

Once you decide which motors to save, ask your service center to process those with open enclosures first. In cases of freshwater contamination, have them disassemble the motor and clean the stator windings and rotor with a pressure-washer. If the insulation resistance is acceptable after the windings have been thoroughly dried, the service center should apply a fresh coat of varnish and process the motor as usual (new bearings, balance the rotor, etc.). Windings that fail the insulation resistance test should be put through another cleaning and drying cycle and tested again. Stators that fail the second insulation resistance test should be rewound.

Saltwater contamination requires a more thorough cleaning process to reduce the possibility that salt residue will rust the laminations or corrode the windings. To accomplish this, have your service center clean the stator and rotor windings and insulation systems using the "Saltwater flush procedure" described below. For best results, they should immerse stators and rotors in the freshwater tank before the saltwater dries.

For the same reason, do not disassemble contaminated TEFC or explosion-proof motors until there is room for them in the immersion tank. This will keep them full of water and prevent salt from drying on internal parts. If it will be a while before these motors can be cleaned, place them on their sides, with the lead openings up, and keep them filled with water.

Saltwater Flush Procedure

This procedure offers the best chance for removing saltwater from contaminated windings. As mentioned earlier, it works best if you do not allow the windings to dry first. The sooner the windings are immersed in the tank, the better the results.

The process is straightforward:

- Immerse stators and rotors in freshwater for 8 hours.
- Continuously agitate the water.
- Exchange water in the tank with freshwater at rate of at least 20 - 50 gallons per minute.

Tank construction. Select a dumpster or similar container that will hold enough water to completely immerse a good number of stators and rotors and drill a drain hole of at least 2" in diameter near the top. Weld a pipe nipple to the drain hole and plumb it to a storm drain or other suitable place.

Next, route a 3/4" or larger supply pipe into the top of the tank (roughly centered), down the inside wall, and across the length of the bottom. Cap the end of the pipe and then drill holes at a slight upward angle along both sides of pipe to serve as water jets. The hole size should be appropriate for the available water pressure, but no more than 1/8" in diameter. The more holes you drill, the smaller they will have to be (see Figure 1).

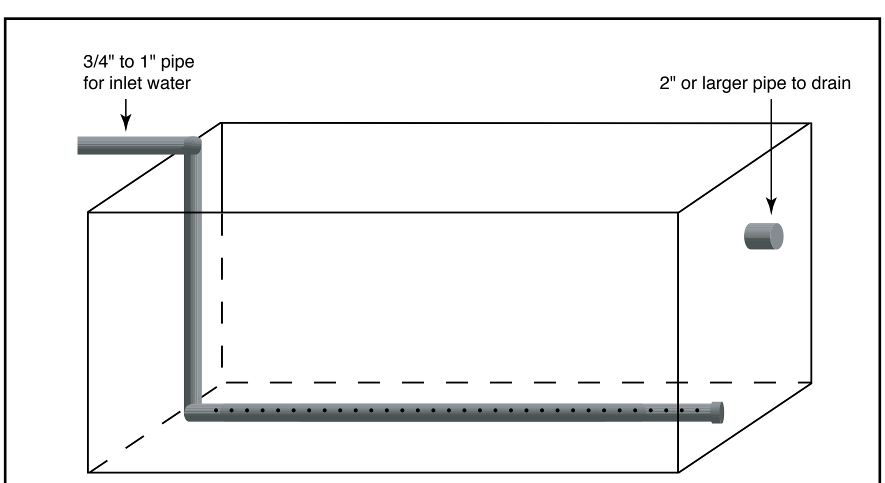


Figure 1 - Tank for flushing saltwater from windings

Flush procedure. Place the stators and rotors in the tank and fill it with freshwater. Process each batch for 8 hours, continuously exchanging the water in the tank at a rate of at least 20 - 50 gallons per minute. At the end of the cycle, remove and pressure-wash the stators and rotors, and then dry them thoroughly in a bake oven or temporary field oven (see below).

Finally, test the insulation resistance to ground. If the test results are acceptable, have the service center apply a dip-and-bake varnish treatment before reassembling the motor. If the motor fails the insulation resistance test, bake it again and repeat the insulation test. Motors that fail the insulation resistance test a second time should be rewound. Per IEEE Std. 43-2000, the minimum resistance to ground is 5 megohms for random windings, or 100 megohms for form coil windings.

The Bottleneck

For most service centers, the bake oven is the single biggest bottleneck. Even the largest oven will only hold so many motors, and the drying time for each batch can take 12 hours or longer. Imagine the backlog after a disaster, when they have hundreds of motors to process!

Of course, it's possible (but not very efficient) to dry windings by draping larger motors with tarps and applying external heat sources. Another way is to dry the windings is to energize them with a welder or other DC power source. The drawback here is that someone has to monitor the current and winding temperature and periodically move the welder leads to heat all three phases evenly. Welding machines also have a duty cycle that's a lot shorter than the two or three days it might take to dry out a large motor.

A better way to increase baking capacity is to build one or more temporary ovens that can dry motor and generator windings safely and efficiently. This approach is especially useful for drying large stators, which take a long time to heat to the required temperature, occupy the entire oven, and delay the processing of other motors. If necessary, temporary ovens can even be constructed on site. This can save the time and labor required to remove the motor from service, transport it, and later reinstall it.

Materials. Energy-shield (the hard-sided foam insulation that home builders install between the exterior frame and siding/brick) and aluminum duct tape are ideal for building temporary ovens–no matter what size or shape you might need. A stock item at most construction-supply super stores, energy-shield has a layer of aluminum foil on both sides and exceptionally good insulating value (R-29) for its thickness. The 4' x 8' sheets are lightweight and easy to cut with a safety knife. They are also reusable as long as they are stored where they won't be damaged.

Oven construction. For motors with very large frames, box the motor by placing the energy-shield directly on the frame, including the top. Seal the joints with aluminum duct-tape.

Placing the energy-shield directly on the frame also minimizes the volume of air that must be heated. This also reduces drying time because the insulation minimizes heat loss.

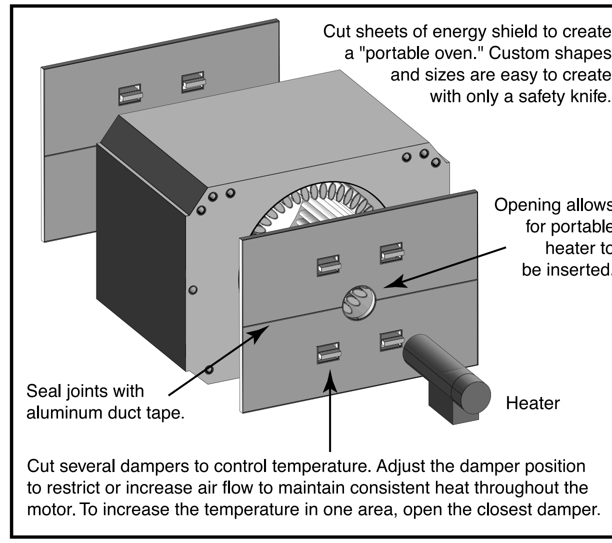


Figure 2 - Temporary oven.

Heat sources. To heat the temporary oven, force air through it from an alternate heat source. If you use a torpedo heater (see Figure 2), position it to blow hot air directly into the center of the bore. Energy calculations for oven design are complex. For this purpose, 100,000 BTU per 1200 cubic feet of oven volume will be adequate to heat the oven and contents within a reasonable time.

Temperature control. For an accurate record of winding temperature, directly monitor the motor's RTDs, if it has them. If RTDs are not readily available, use HVAC instruments or candy thermometers to monitor temperature in each quadrant of the oven. The key is to keep the heat uniform within the motor, and

Common Misconceptions About How To Dry Wet Motors

Two mistaken ideas about how to dry wet windings have persisted for years. The first is that heating the windings with a welding machine is a good way to dry out an electric motor. Before using a welder or other DC power source for this purpose, make sure you know what you're getting into.

For starters most electric motors large enough to warrant consideration have three leads– one per phase. Internally, they are connected either wye (Y) or delta (Δ), as shown in Figure 3. (Incidentally, the terms wye and delta come from the Greek letters that they resemble.)

If you apply DC current to any two leads of a delta winding, two phases will be in series, and the third will be in parallel with them. That means one phase will carry twice as much current as the series pair, so it will get much hotter. For the wye connection, only two phases carry current, leaving the third phase cold.

Whether the winding is connected wye or delta, someone must monitor the current and winding temperature, and periodically move the welder leads. Otherwise, parts of the winding may not dry completely, if at all. Welding machines also have a duty cycle that's a lot shorter than the two or three days it might take to dry out one winding! Welding machines are useful when both ends of each phase are brought out as six leads. An ohmmeter will confirm three separate circuits. In that case, the three phases can be connected in parallel or series, depending on the capacity of the welding machine, and dried simultaneously.

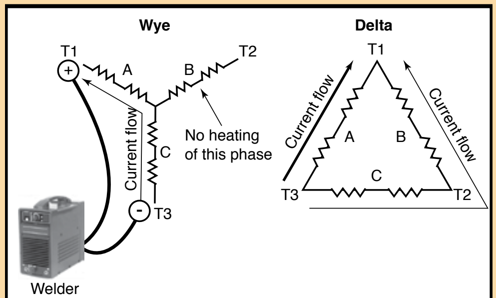


Figure 3 - Drying windings with a welder or other DC power source.

With the welder applying current from T1 to T3, only two phases of a wye-connected motor are heated. If the internal connection is delta, one phase is heated with four times the wattage of the other two phases. In both cases, the welder leads must be periodically moved to heat the entire winding evenly.

Another misconception holds that windings should not be dried at oven temperatures above 180° F (82° C), for fear that trapped moisture will burst the insulation. That might be a valid concern if we could somehow heat a winding instantly to above boiling temperature. The reality is that windings, like anything else placed in an oven, heat up very slowly. Moisture will get out the same way it got in. As the temperature of the winding slowly increases, the moisture (just as slowly) will evaporate. Although IEEE Standard 43 (1974) included an annex with information that may have perpetuated this belief, it was dropped in the next revision cycle.

Every day more than 2,000 EASA service centers steam-clean and then bake stator windings– mostly at oven temperatures of 250 - 300° F (~ 120 - 150°C). Even though many of them repair thousands of motors annually, there is no evidence that this process has damaged a single winding. Burst insulation due to oven temperatures above 212° F (100° C) is simply not a concern.

not to exceed part temperatures of 250° F (121° C).

Because heat rises, it might seem reasonable to open exhaust ports at the top to let it out. But as those familiar with old-fashioned wood stoves can tell you, the best way to control oven temperature is to open or close dampers (exhaust ports) near all four corners on both sides (see Figure 2).

To raise the temperature at one corner, for instance, open that damper farther. The increased flow of hot air through that area will raise the temperature. The ability to regulate temperature in this way greatly improves the drying process as compared with traditional methods such as a DC current source or tarps.

How Long to Bake?

The bake cycle should be long enough to dry the windings completely. If it's too short, you'll need to repeat the process. If it's too long, you'll waste both time and energy. If the windings has RTDs, 6 - 8 hours at 200° F (93° C) should be sufficient. For windings not equipped with RTDs, here's a foolproof way to determine how long the bake cycle should be.

All you need are two lengths of RTD wire or similar small lead wire long enough to reach out of the oven and a DC voltmeter capable of reading millivolts. With the wet winding on the oven cart, attach one lead to the stator frame and the other to a winding lead. Finally, connect the free end of each lead to the DC voltmeter. You can be sure the windings are completely dry when the voltage on the millivolt scale reaches zero.

This procedure is one that many service centers use when they have large rush jobs to process. It often cuts hours from expected drying times, even for normal work. It also reduces the chance of damage that might result from excessive temperatures.

How it works. Like the setup, the principle behind this procedure is fairly simple. The iron frame and copper windings function as two plates of a crude battery. Electrolytic action across the wet insulation causes current to flow. As long as the cell is "wet", it produces voltage. When the "cell" is dry, so is the insulation.

Note: This procedure works for everything except some form coil VPI insulation systems. Some of these windings are sealed so well that they may exclude moisture from the insulation, keeping the "wet cell" battery from developing.

Conclusion

No one could have been fully prepared to deal with a back-to-back series of disasters like hurricanes Katrina, Rita and Wilma. Hopefully, though, the procedures outlined here will speed the recovery for the plants in affected areas, as well as for the local populations that depend upon them both for employment and products. In better times, these procedures can also facilitate plant-service center partnerships and maximize uptime.

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Practical Alignment Tips

Understanding Fundamentals Key to Success

by Richard Henry

As an alignment consultant, I am often asked what I consider to be World Class Alignment. That is actually a tough question to answer. There's a lot involved in completing alignment tasks quickly and accurately. A lot depends on the type and classification of the machine that needs to be aligned. A small pump operating at 900 rpm with a 50 hp motor will require a different alignment than a 3600 rpm compressor. Several things need to be considered when performing these alignments. I believe a firm understanding of what alignment is will be more valuable to maintenance personnel than either the tool being used (laser or dial) or knowing all the "button-ology" of the system.

A very good example of this is spacer shaft alignment and understanding how your machine dimensions, offset measurement points and shaft angularity will affect the overall alignment of the system.

Rotor speed, coupling type, number and size of motor feet, thermal growth, dynamic alignment changes, pipe strain, soft foot and alignment methods are just a few of the machine specific characteristics that need to be considered.

Typically, the faster the rotor speed, the tighter the alignment has to be. A 900 rpm machine may operate fine with 7 mils of offset misalignment, but this is very likely to cause problems like seal and coupling wear and bearing failure on a machine operating at 3600 rpm or higher.

Coupling types will have an impact on both the amount of coupling backlash and the type of misalignment to correct (offset or angle) should the machine become bolt bound or base bound with no other options to correct the problem. Hopefully this never happens, but sometimes it needs to be considered, especially on vertically mounted machinery.

The number and size of the motor feet will determine the best shim practices, the size of the shims required and the method used to measure and correct motor soft foot.

Thermal growth and dynamic alignment changes are probably the most often overlooked problems with completing a world class alignment. Almost every machine will experience some type of dynamic alignment changes from off line to running at normal operating conditions. Sometimes these changes are small and negligible; sometimes they are the root cause of repeated machinery failures. As a general rule, if the machine will cost a lot to repair, either in parts and labor or in lost production, the dynamic alignment changes should be measured and corrected for. Temperature changes, rotor torque, generator loading, piping growth/strain and discharge pressure are all factors that can take an alignment from excellent to catastrophic

Laser Alignemt in Progress

during a machine's normal operating cycle. These changes can easily and inexpensively be measured and accounted for with the technologies currently available either as a service or by purchasing the proper fixtures from your alignment representative.

Pipe strain from improper machine installation or post installation design changes can force alignment changes within a pump or compressor casing. These alignment changes occur between the bearings within a machine forcing a preloaded condition on the bearings. If severe enough it will even bend a shaft and cause vibration symptoms similar to unbalance. Moderate to severe pipe strain and soft foot can typically cause electrically related vibration.

Regardless of the tool used to perform the alignment, the pre-alignment considerations should all be completed prior to starting your alignment task. These include measuring the shaft and coupling run-outs, roughing in the alignment with a straight edge or a skilled eye, roughly correcting motor soft-foot, checking for pipe strain, inspecting foundations for deterioration and inspecting shim packs for the type and number of shims. You should also give some thought to how you will be lifting and moving the machine when adding shims or making horizontal corrections. When ever possible, lift and lower the machine in a smooth and controlled manner. Try not to drop the motor back onto the base when removing the pry bar while lowering the machine. Also, try to use horizontal jacking bolts or a hydraulic jack to reposition machines horizontally.

Most people would never strike their car's wheel bearings with a hammer, but it seems that repositioning motors or pumps with some sort of blunt force trauma is an all-too-common occurrence. The shock pulse from the hammer travels directly to the machine bearings even if the machine foot is what is being struck. There are, of course, exceptions. In the real world, almost everybody aligning machines has had to resort to this at one time or another. However, it is wise to avoid it if at all possible.

Repeatability and reproducibility are key factors in completing a World Class Alignment. Always measure the shaft alignment at least twice to verify repeatability of the measurement prior to making any alignment corrections. If the readings are not repeating, something is wrong with the alignment tool, the measurement procedure, the tool setup or the machine itself. This could be anything from excessive coupling backlash to a loose bearing to an un-seen pipe "bumping" the alignment fixtures as the shaft is rotated.

Finally, to complete your world class alignment you should be able to measure an acceptable set of alignment readings without moving the machine. Always measure the final alignment after the last bolt is tightened. Don't rely on the "live data" or the "move mode" for your final set of alignment values. Any stray bump on the fixtures or shock pulse can force an error in the "live data" significant enough to take you way out of acceptable alignment tolerances.

Thanks for your time. I hope you find some useful information in the article above.

Richard Henry is a former US Navy Nuclear Plant Operator. His maintenance background includes 8 years in the US Navy, 17 years in machinery maintenance, vibration analysis, dynamic balancing and geometric machinery measurement. He has worked as an alignment specialist and instructor covering all methods and types of systems. He has contributed to and invented system innovations for major alignment system manufacturers. Rich currently works as an Alignment Consultant and Instructor for ADVANCED Maintenance Solutions. He can be contacted at rich@theadvancedteam.com

Rich lives in Cincinnati, OH with his 3 sons, an 11 year old and 4 year old twins. He enjoys spending his leisure time with his horse shoe pitching league and with his boys out in the back yard.

Listening To Lubrication

Using Ultrasound For More Precise Lubrication

by Jim Hall

World class lubrication programs are shifting away from time-based re-greasing schedules to condition-based re-greasing schedules. Choices for tools range from simple high frequency ultrasonic detectors and audio stethoscopes to digital data collectors that can directly interface with the grease gun. Lube techs are facing new challenges as they harness the power of ultrasonic inspection. Hopefully, this article will de-mystify the technologies and techniques surrounding acoustic lubrication as an effective lubrication practice.

The term "airborne ultrasound" when used with Predictive Maintenance (PdM) refers to the practice of using an ultrasonic receiver to listen for air leaks, bearing analysis, steam trap troubleshooting, and electrical scanning for arcing, tracking, and corona discharge. Airborne ultrasound in a PdM application typically refers to sound above 20 kHz. Most airborne ultrasound receivers today center around 40 kHz.

True Story

While supporting many ultrasonic testing programs, I came across technicians that were relying on time-based re-greasing schedules. Many of these technicians were merely following the recommendations of others before them, as to how much grease to pump into the bearing.

One instance really sticks out in my mind. It happened while I was demonstrating how to trend motor bearings with an ultrasonic instrument.

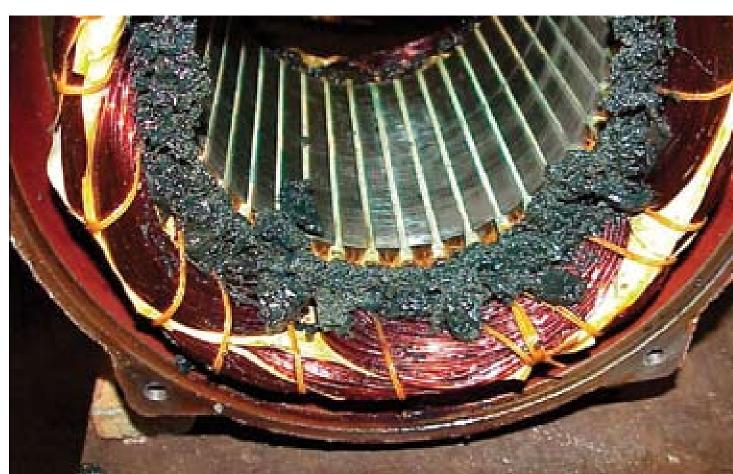

FIG 1 - Over-Lubrication, blown seal allows grease into windings

The engineer and I used headphones with a Y-connection that allowed us to listen to the same ultrasound instrument. The instrument we were using was set to 30 kHz and "linear mode" (time averaging). We placed a contact probe next to the zerks fitting to listen to the bearing for sound quality as well as to record the sensitivity setting and decibel reading for trending purposes. Right away I noticed the bearing sound resembled the sound of a dry bearing.

Imagine, if you will, a bearing with no grease, spinning next to your ear. Think of that scratchy sound the metal balls make when rotating and hitting the race and other balls. Well, that is exactly what the ultrasonic receiver translated through a piezoelectric transducer by heterodyning the signal and then converting that signal to a low-frequency sound that can be heard through the headphones. Needless to say, it is not a pleasant sound. And it is certainly not one you want to hear.

The engineer asked, "What does a dry bearing sound like?" I replied, "Just like that." To this day, I can see the grimaced look that came over his face. It was painful.

Procedure

The lubrication practice that I am accustomed to is to pump a half-stroke of the grease gun and watch for a response on the analog meter either "up" or "down". If the needle on the analog meter moved upward, after a half-stroke of the grease gun, you should then wait 15 seconds for the needle to return to the original setting or lower before proceeding. If the needle does not move downward or back to the mid-range after 15 seconds, suspend lubricating at this time. You can assume that the bearing has enough grease. If the needle moves lower than the mid-range after a half-stroke or several half-strokes, then the procedure is to continue until the needle does not move downward, but starts to move upward again. You should implement the 15 second rule at this time before proceeding or ending the lubrication practice.

The sensitivity of airborne ultrasound can best be illustrated by imagining someone taking an electric pencil and scratching a ball of a bearing. After placing this bearing back in service and performing vibration analysis (20 kHz or lower) on the bearing, the scratch will not be detected. However, if the ultrasonic receiver and contact probe are then interfaced with the vibration analyzer providing a high-frequency demodulated signal, the scratch can be detected.

Back to the Story...

I asked the technicians to retrieve a grease gun so that we could lubricate the bearing. The technicians smirked and replied, "Jim, can't you see we just greased this bearing? Look at the fresh grease on the 14 inch fill tube!" I asked the men to bear with me. Both of us, the engineer and I, were listening to the bearing as I made an adjustment to the instrument raising the sound level to a point that was mid-range on the analog meter. I then asked the technician to pump a "half-stroke" of the grease gun. We saw no movement, up or down, as we watched the analog meter for a response.

In fact, after several half-strokes of the grease gun no sound difference was heard. But, after the 18th half-stroke the needle on the analog meter went to "zero" and the sound in the headphones disappeared. Now, just because the grease had finally reached the bearing and lubrication was now taking place, the job was not over. I then raised the sound level back to a mid-range on the analog meter and proceeded to have the technician pump half-strokes again. After 3 or 4 more half-strokes of the grease gun the needle moved upward and stayed after 15 seconds. The sound quality of the bearing had gone from a scratchy sound to a smooth sound much like the sound of rushing air.

Acoustic Lubrication Practice

After years of supporting airborne ultrasound equipment and training companies in the proper use of airborne ultrasound instruments, I developed an acoustic lubrication

Acoustic Lubrication with Digital Instrument

FIG 2a: Before grease starting dB @ 49.6

FIG 2b: After 5 half-strokes dB @ 45.6

FIG 2c: After an additional 2 half-strokes dB @ 31.7

FIG 2d.: After another 2 half-strokes dB started upward stopped greasing and re-checked decibels. Final dB was 19.2

adaptor for one company that could be interfaced with an ultrasound instrument. The adaptor could be attached to the contact sensor to sense the decibel changes while lubricating a bearing. I feel this method is substantially superior to other methods for several reasons. One reason is when the adaptor is mounted to the zerks fitting or other lubrication points, the contact probe has little or no sound attenuation loss. A second reason is that an instrument that has a digital display or sensitivity meter can compensate for a technicians loss of hearing. Many devices in the marketplace today use sound only and no indicator, depending solely upon the technician's sense of hearing to determine whether or not to pump grease. Several of these manufacturers even suggest that the technicians pump grease until a "difference" is actually heard. This suggests that every bearing being checked actually needs lubrication, which is not the case, and could prove to be seriously detrimental to the motor.

Recommended Practice

CAUTION: ONLY USE THIS PRACTICE TO SERVICE A BEARING. THIS IS NOT INTENDED TO BE A PROCEDURE FOR NEW OR NEWLY INSTALLED BEARINGS.

- Calibrate grease gun: No matter whose ultrasound instrument you are using, the grease gun should always be calibrated. Use a one-ounce container (shot-glass), pump grease into the container using half-strokes while counting the number of strokes it takes to fill the container. Typically, "7" full strokes or "14" half-strokes are required to fill an ounce container.

- Always be sure the area and fittings are clean. Wipe away dirt or grease before and after lubricating.

- Know the lubricant to be used. Do not mix lubricants or grease.

FIG 3 – Over lubrication, grease in end cap of motor

- Designate a grease gun to be used with an acoustic grease adaptor and clean the adaptor each time the adaptor is moved to another grease gun.

- Use half-strokes as opposed to full strokes when using a manual level grease gun.

- When using a battery pack or pneumatic handheld grease gun, use a timing method such as 1001, 1002, etc… while holding the trigger to simulate half-strokes of a grease gun.

- Make sure that drain plugs are accessible, open, and unobstructed.

- Know the type of bearing being lubricated.
    - A sealed bearing cannot be re-greased.
    - Shielded or double shielded bearings can be greased, but done slowly as to not over-pressurize the cavity and push the bearing's seal against the cage.

- Use a grease gun with very little or no loss of movement of the pump handle.

- Periodically, clean and/or route the inside diameter of the pipe supplying the grease to the motor.

Note: Dry grease build-up can clog and reduce the inside diameter of the supply line limiting the amount of grease supplied to motor.

- If grease or lubricant is seen exiting the bearing, schedule replacement of the bearing.

When Using an Ultrasonic Instrument

- Use an ultrasonic instrument that has an indicator which indicates decibels or level of sound either as a numerical value or as a slide indicator.

- If applicable, find a mid-range setting with your instrument. This allows you to see movement or change of sound level while lubricating as well listening to change.

- When possible, use a dedicated lube adaptor or sensor designed to limit the loss of sound attenuation while lubricating the bearing.

- Allow for the minimum amount of time (15 seconds), for the bearing's internal sound and pressure to reduce or lower before proceeding with lubrication.

- Trend or record the decibel levels for future reference.

Over-Lubrication

Acoustic lubrication is a practice that I believe will reduce over-lubrication of a bearing. Recently, I was training a company on how to apply the acoustic lubrication procedure. While greasing the bearing of an electric motor the technicians noted that after just three half-strokes of the grease gun the decibel level moved upward two-to-three decibels and did not return to a mid-range or lower level. Afterwards, the technician noted that one of the other shift workers had actually greased the bearing just the day before. Take into consideration the sensitivity of the airborne ultrasound instrument and remember that every three decibels doubles the sound level.

To give you some perspective, a desktop PC is 48db and a library —where no one's allowed to talk — is 40db." So, if we double the power, we can use the fact that the logarithmic scale of 2 is 0.3, and this would be a gain of 0.3 bel or 3 dB. Remember, doubling the power is a 3 dB increase.

Used as a Service Procedure

Do not use acoustic lubrication as a new motor greasing procedure. Only use this procedure as a re-greasing or servicing procedure. Another engineer called me to discuss the acoustic lubrication as a new installation procedure to grease newly installed bearings. What he discovered was that the new bearing never emitted enough sound. When applying the grease using the acoustic lubri-

Acoustic Lubrication with Analog Instrument

Analog meter was set to "*50" (no picture) before greasing.

FIG 4a.- After 5 half-strokes needle went to "39".

FIG 4b - After 5 then 2 more Half-Strokes needle went to "22".

FIG 4c.- After 2 more half-strokes needle started upwards and greasing was stopped. Needle settled at "4".

Note: This instrument is not in decibels, but a scale of 0-100 increments. Sensitivity Set @ 6.75 all throughout procedure. From 50 to 4 represents 46 decibels. Every 20 increments on this scale is 3 dB's.

cation procedure, he found that he would "blow or rupture" the seal of the bearing before a notable change or increase could be heard. Afterwards it was determined that several hours of "run-in" time was needed before an adequate amount of sound would aid in determining when to stop greasing.

When I See the Grease Coming Out....

Often, when I am at industry meetings, I ask others how they know when to stop greasing. The response I get repeatedly is, "When I can just see the grease coming out of the bearing." Many technicians revert back to tactics they learned at a previous job or trade if they have not had proper training on bearing lubrication. While training a group of technicians on acoustic lubrication at a nuclear site, I asked, "Who has greased bearings on front-end loaders, tractors, or other heavy equipment?" Ninety percent of the room raised their hands in an affirmative manner. I soon realized that many of those who raised their hands had difficulty grasping the idea of precision lubrication.

Some technicians even try to use touch to determine whether lubrication is needed. For example, at one major motor manufacturer, the senior lubricator/mechanic prefers to use his finger atop the motor to determine when to stop lubricating. Another motor manufacturer had numerous reports of motors being shipped without proper lubrication. I was asked to come and discuss acoustic lubrication. Having been a plumber at one-time in my life, I easily spotted their problem. Galvanized pipe was used to supply the grease from the grease drum to the line technician who lubricates the motor. I knew that most grease has paraffin in it and that, over time, paraffin may harden - very much like a kitchen sink drain pipe with grease build-up. I asked the engineers, "When was the last time you removed and routed the supply line?" They replied, "Never." Once the lines were opened, we saw that the internal diameter had been reduced by half. Since the technician had become accustomed to using time as the factor in how long to hold the trigger on his pneumatic grease gun, he had not been putting nearly enough grease into the motor during motor build-up.

Stop Unneeded Repairs and Downtime

Do you outsource your motor repairs? Have you ever received a call telling you that if you would only stop over-lubricating the bearings a problem would not have occurred? Even though over lubricated bearings could be good for business, reputable motor shops know that educating a customer is even better for business. In Figure 1, this motor had the seal blown and the grease entered into the windings. In Figure 3, the end cap of the motor was also flooded with grease from a blown seal.

To Sum It Up

Acoustic lubrication is not a cure-all to end-all lubrication. It is, however, a methodology that can be learned and used to standardize a Best Practice within a plant. As with any new program, all personnel must be onboard, from management to the person pumping the grease. It does take time to implement. Time is money and in today's world of cutbacks, reduction of force, and more for less, it may be hard to totally implement. However, I firmly believe, that if an acoustic ultrasound lubrication program is implemented, your organization will see an increase in uptime and a significant reduction of repairs.

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

Editor's Note: Many companies are reporting success using similar methods. However, there is no conclusive public research on the proper procedure for using sound or ultrasound as a basis for bearing lubrication. Make sure to check with your equipment supplier requiring warranty issues. We will continue to follow developments in this area and report them as they occur.

Maximizing Potential

Increasing the Effectiveness of Your Vibration Analysis

By Jason Tranter

Vibration analysis is a fantastic field. For the analyst it is challenging and stimulating, and it should be rewarding. For the employer, it offers great financial rewards. But the question is -- Are you taking full advantage of the potential of vibration analysis?

On the face of it, vibration analysis can seem fairly simple. If you follow the set-up recommendations of the data collector vendor, and make sure that you mount the sensor on the bearing, then you will capture a spectrum that looks about right. It will have peaks and patterns which look just like the spectra you see in the case studies. So you must be doing it correctly, right?

Not necessarily.

Unfortunately, it is very easy to assume that you are doing everything correctly. The measurements look good, and you will see changes in the vibration levels and patterns if the bearings are damaged. But you have to ask yourself:

1. Do you understand the machine you are testing?
2. Are you getting an early warning of the fault condition?
3. Are you able to detect all possible fault conditions?
4. Are your measurements repeatable?

A Little Bit of Background

I have been involved with vibration analysis for around 20 years. Over the past six years I have focused 100% of my efforts to training. In the last 12 months I have been developing and delivering a series of intermediate and advanced courses that follow the ISO 18436 standard. I have had the honor of teaching some very experienced analysts; people who have been successfully performing vibration analysis for many years. I love the moment when the analyst says "Thanks, until now I have never really understood that."

But the main point is that there has been a common theme amongst trainees – generally, people do not understand the importance of measurement locations/axes, data collection settings (windowing, averaging, resolution, Fmax), analysis techniques (time waveform and phase analysis) and reporting practices. Many people leave the course vowing to make changes to just about every aspect of their program.

I don't want to sound too critical. First, if you have not received training, or if you have only received the typical basic training, then how can you be expected to understand these issues? Second, most analysts have tried hard to improve their diagnostic skills, and have set up their programs with the best intentions, so any failings are not normally a result of laziness or lack of effort.

The fact is that most people do not receive sufficient training, and most people have so many responsibilities that it can be difficult to perform all of the analysis and fine tuning that is necessary for excellent vibration programs.

The Analyst's Checklist

While this article will not cover every detail of the following topics, it should give you a general overview of areas to consider on an on-going basis. Hopefully, this will be the first of many contributions to Uptime, and we can explore more details in future articles.

Are you:

- Collecting data from the correct measurement axes
- Setting the correct Fmax and lines of resolution (LOR)
- Setting the correct number of averages and overlap percentage
- Using correct mounting techniques
- Using additional technologies and special tests to confirm diagnoses
- Generating reports to document successes and financial benefits
- Performing root cause analysis and acceptance testing to improve reliability

We will now take a closer look at each of these areas.

Collect Data from the Correct Measurement Axes

As you know, machines vibrate vertically, horizontally and axially. Depending upon the orientation of the machine, the type of bearings, the orientation of machine components and the nature of the fault condition, the vibration pattern that best reveals the existence of the fault condition could be present in all axes or in only one axis. If you are not measuring in that axis, you may miss the fault.

Also, it is often very useful to compare the data from one axis to another in order to compare levels or check for the existence of harmonics or sidebands. If you have attempted to save time by only measuring in one axis, you will not be able to make these comparisons, and faults could be missed.

Measuring and keeping data comparing multiple axes also allows for historical data analysis and the ability to see trends over time.

Setting the Correct Fmax and LOR

It is essential that you use the correct Fmax and LOR (lines of resolution). If the Fmax is not high enough you could easily miss important information. And if the LOR is insufficient, you will miss important detail.

You may be familiar with the following equation: Measurement time = LOR / Fmax. You can see that if you increase the Fmax the measurement will complete more quickly – which is is good. However, as you increase the Fmax, the effective resolution decreases – which is not good. If you increase the LOR from 800 to 1600 or 3200 lines, the time to collect the data will double or quadruple.

In the past, we tended to use 400 or 800 lines because of memory storage limitations and data transfer rates. Since those limitations no longer exist with modern data collectors and computers, you should seriously consider changing to 1600 or even 3200 line spectra.

Here is an interesting example. In Figure 1 we have an 800 line spectrum with an Fmax of 1600 Hz. On the surface, the high 2X peak points to possible misalignment and the possiblity that that the noise floor has been lifted.

In Figure 2, using an Fmax of only 200 Hz and 1600 lines of resolution, our results now look much different. We have a high peak at 100 Hz (the line frequency was 50 Hz) and there are pole-pass-frequency sidebands. Instead of misalignment, we actually have a fault with the motor.

It is essential that the Fmax is set high enough to see all of the frequencies of interest (and harmonics of those frequencies), but it is also essential that you have sufficient resolution to correctly distinguish between those frequencies.

The time record must be long enough to see five repeats of the lowest expected fault frequency. In most cases, the lowest fault frequency may be the slip frequency times the number of poles (electrical fault) or a cage frequency defect from a rolling element bearing. So, how exactly do you increase the time record without affecting the frequency span? Answer: increase the lines of resolution. Measurement time = LOR / Fmax.

Setting the Correct Number of Averages and Overlap Percentage

Averaging helps us achieve repeatability, and ensures that we collect data while the machine goes through a number of cycles (rotations). Without going how overlap averaging works in detail, there are two important points to consider: data loss and repeatability.

Data Loss

The Hanning windowing process "suppresses" the data at the beginning and end of the time record – we may therefore lose important data. Overlap averaging ensures that this data will not be lost.

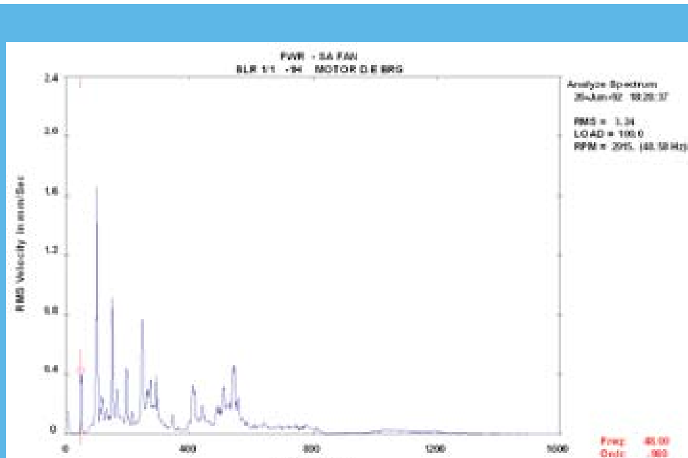

Figure 1: 1600 Hz and 800 lines of resolution

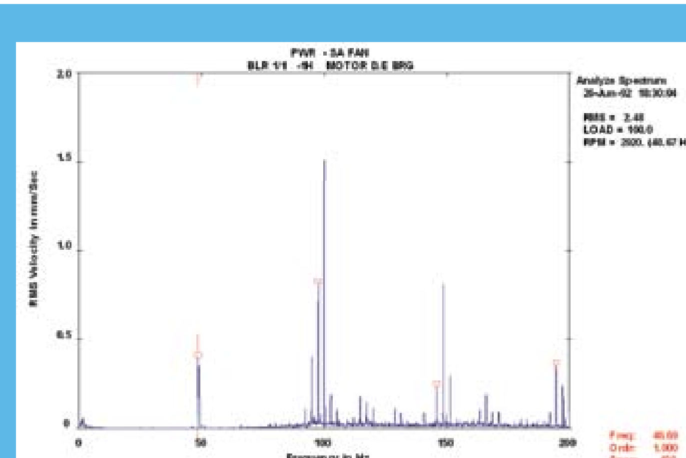

Figure 2: 200 Hz and 1600 lines of resolution

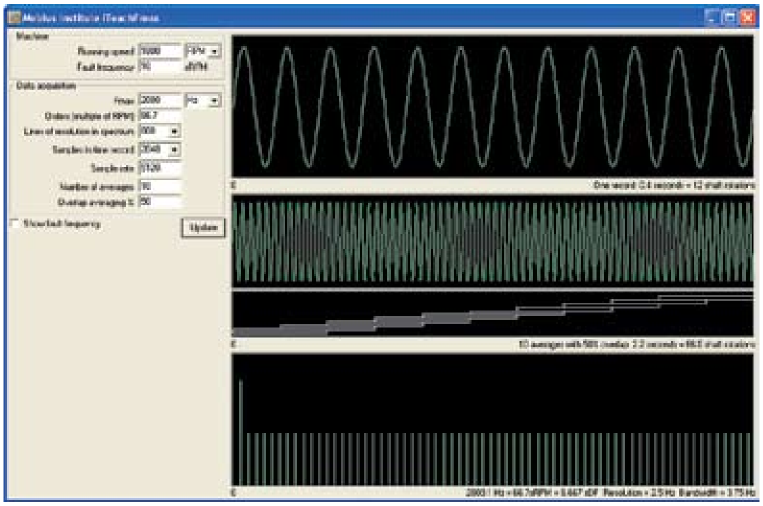

Figure 3: Fmax = 2000 Hz, 800 LOR, 10 averages
with 50% overlap

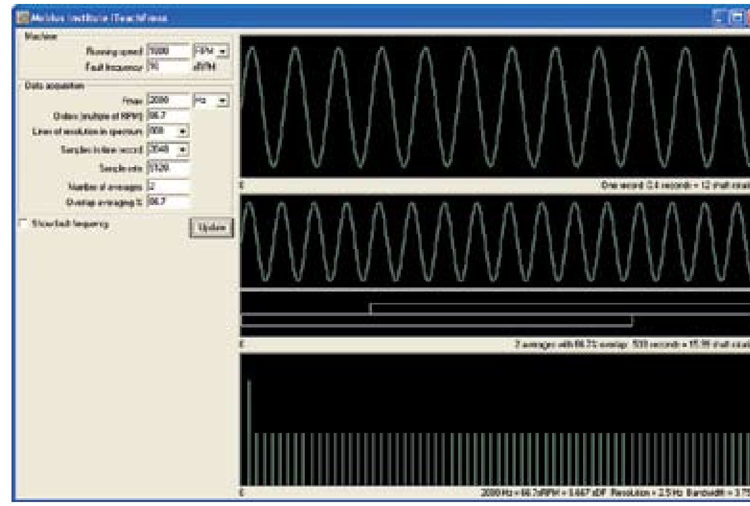

Figure 4: Fmax = 2000 Hz, 800 LOR, 2 averages
with 67% overlap

Repeatability (noise reduction)

A higher overlap percentage and lower number of averages will reduce the required time to complete the measurement – which can appear (at first glance) to be an attractive option.

For example, a 2000 Hz measurement with 800 lines of resolution will require a 0.4 second time record. If we use 10 averages with 50% overlap, the test will take 2.2 seconds to complete, and the shaft will rotate 66 times (synchronous speed 1800 RPM), as illustrated in figure 3. However, if we use 2 averages and 67% overlap, the test will now only take approximately 0.5 seconds and the shaft will rotate 16 times, as illustrated in figure 4.

The question you have to ask is:

a) Have you collected enough vibration data so that the random noise and vibration can be averaged together to produce a repeatable test? and

b) Has the machine gone through enough rotations while capturing the vibration data? (Visualize the rollers in the raceway, the gear teeth meshing together, etc.)

The vibration readings must be repeatable, and they must capture multiple instances of all the cyclical mechanical events. (Note: if you increase the lines of resolution you can afford to reduce the number of averages.)

Try an experiment. Use your data collector and take a reading with your current number of averages and overlap percentage. Now repeat the test with a larger number of averages, and perhaps a lower overlap percentage. Now compare the two spectra. They should be almost identical if your initial settings were correct. Now repeat this experiment on a few machines: an electric motor, a compressor, and a gearbox.

They will not be perfectly identical, but there should not be significant differences in the amplitude at the major peaks or in the noise floor. Figure 5 illustrates the results of such a test. The red spectrum was the result of just 3 averages, while the blue spectrum was the result of 8 averages. If you watched the data in real time, you could see the peaks rise and fall.

This means that you could take a measurement today that looks like the blue spectrum, and in one month repeat the test to get a measurement that looks like the red spectrum. If you tried to compare these two measurements, you could incorrectly interpret the changes in amplitude as a fault condition.

This example is real, but a little more severe than normal. Thanks to modulation, beating, and various sources of external vibration and noise, 4 or fewer averages may be insufficient. So, rather than choosing default settings for all machines, or reducing the number of averages in order to save data collection time, carefully consider each machine you are testing and try the experiment above. A little ex-

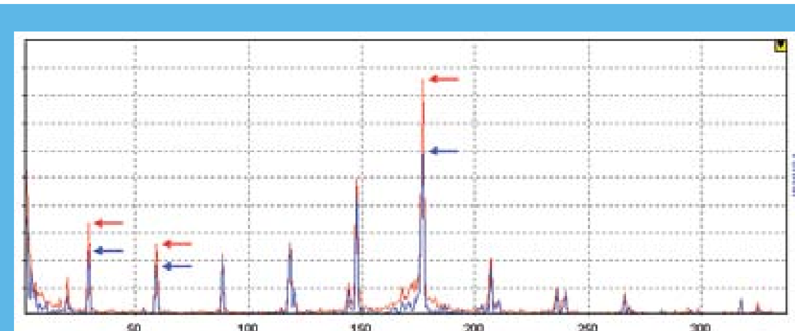

Figure 5: 3 averages versus 8 averages

tra time spent during data collection will pay dividends.

Using Correct Mounting Techniques for Improved Repeatability and Frequency Response

We just discussed repeatability in terms of setting the correct number of averages. But it is also essential that you mount the accelerometer correctly, and that you follow appropriate practices to ensure repeatability. There are two key issues to consider: repeatability and the mounting surface.

Mounting repeatability

You must mount the sensor in the same place every time. Changes in location can cause the amplitude levels to change. If the same person always collects the data, then this is less likely to be a problem. Otherwise it is important to mark the correct test location, or better yet, add a mounting pad.

Sensor mounting

The most common problem is sensor mounting. It must make good solid contact with the bearing housing. High frequency sources of vibration are attenuated when they must cross air cavities (e.g. gaskets, grime, dirt, etc.). If you are performing envelope measurements (or "demod", PeakVue, shock pulse, spike energy, HFD, or any other measurement that utilizes high frequency data), your measurements can be greatly affected if you do not correctly prepare the mounting surface.

You should prepare a clean, flat surface, and wipe it with a clean cloth if you work in a dirty environment. A strong magnet is a minimum requirement, and stud-mounted sensors provide the best results. And of course, avoid surfaces that may resonate at operating speeds such as motor end bell cowlings or guards.

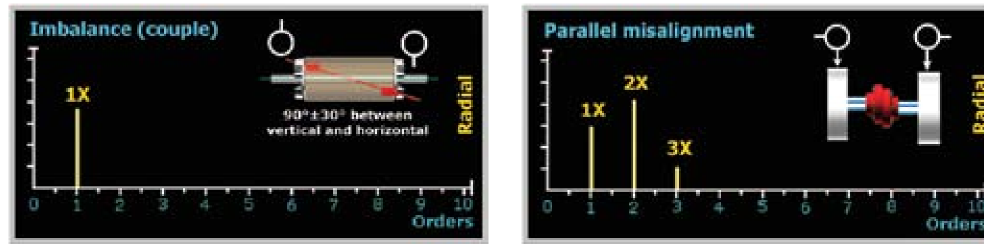

Figure 7: Sample diagnostic charts with phase relationships

Using Additional Technologies and Special Tests to Confirm Your Diagnosis

Vibration analysis is powerful, and spectra can tell you a great deal. However relying on the spectra that you collect routinely will not give you the whole picture. There are other data types, special tests and condition monitoring and performance data that will help you improve the accuracy and timeliness of your diagnosis.

Time waveform analysis

It is very easy to collect time waveform measurements, and you should use these measurements to help confirm the diagnosis. Time waveforms can help you rule in or out certain fault conditions. Impacts, rubs, and looseness can be seen clearly in the waveform. Time waveform can also aid diagnosis of misalignment, imbalance, and bearing faults. And time waveform measurements are essential when studying low speed machines and gearboxes.

Phase analysis

Many fault conditions - including misalignment, imbalance, looseness, cocked bearing, bent shaft, and structural resonance - can be confirmed with phase data. While you will not collect phase on a routine basis, phase readings are not difficult to collect and interpret, especially if you have a two channel data collector.

You should therefore learn how to collect phase readings, learn how to interpret them, and then utilize this powerful tool to help diagnose faults.

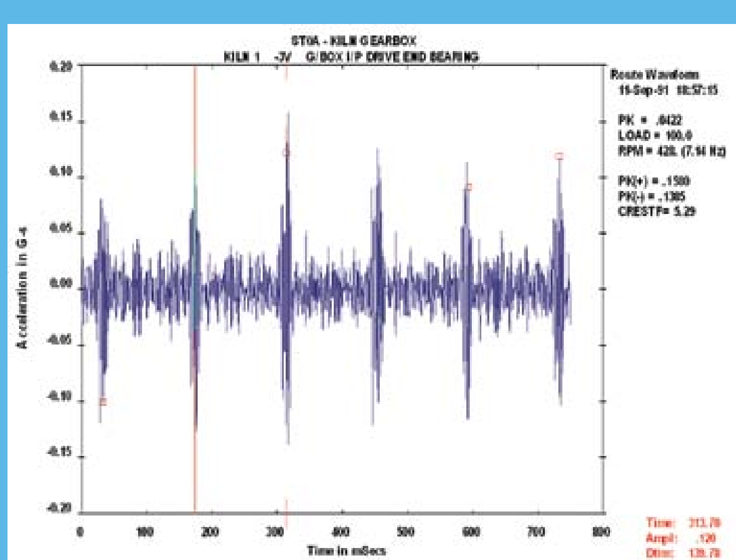

Figure 6: A sample time waveform from a gearbox with a broken tooth

Many times the success of your program can be determined by how well you advertise the benefits of your program.

Other Condition Monitoring Technologies

You should take advantage of ultrasound, oil analysis, wear particle analysis, thermography, motor tests (on-line and off-line) and other condition monitoring and performance data. Each of these technologies can help you better understand the condition of the machine. In many cases, one of more of these test types will reveal fault conditions earlier than vibration analysis, or in some cases, faults will be revealed that vibration analysis is unable to detect.

You can adopt the technology yourself, hire a consultant who has experience with these technologies, or befriend the people/person within the plant who collects this kind of data. Don't work in isolation!

Generate Reports to Document Your Successes and Financial Benefits

Do you do a good job? Do you do an important job? Of course you do. But who have you told recently? How well have you communicated? An analyst is only as good as his or her ability to communicate the highlights of the analysis and recommendations to follow. Many times the success of your program can be determined by how well you advertise the benefits of your program.

It is essential that you spread this message. Everyone must know of the financial benefits of your program. You must determine how to report on this information within your organization. If you detect that a bearing may fail and you correctly recommend that it be replaced, how much have you saved your company? You could argue that a catastrophic failure at night during production could incur huge costs: downtime, secondary damage, overtime, and so on. But if you claim $500,000 on every bearing fault that you detect, management will not take you seriously.

You have to come to an agreement with your management so that you can report on the benefits of your program in a meaningful, believable manner. And then you must generate your reports and communicate your findings regularly.

Root Cause Analysis and Acceptance Testing to Improve Reliability

Some vibration analysts believe that their sole job is to detect and report fault conditions. That is simply not true. Locked inside your vibration data (and other condition monitoring data) may be the reason why the fault occurred in the first place. It is important that you can report a potential bearing failure, but even better if you can substantiate with your data what caused the bearing to develop the fault (or why the machine is misaligned, out of balance, etc).

You can report the fault and wait for the fault to develop again, or you can do your best to ensure that the failure doesn't happen again. Precision balancing and alignment, correct lubrication, acceptance testing (to ensure that machines are in good health when they are put into service) and other practices combine to improve the reliability of the equipment. Vibration analysis and the other condition monitoring technologies are still essential, but improved maintenance, purchasing and repair practices will ensure that machine life will approach the design life.

Conclusion

At the end of the day, you have to set your own goals. You can take measurements as quickly and economically as possible and aim to detect the most common faults before the machine fails, or you can take more care, and run a program that provides an earlier warning of a broader range of fault conditions.

Jason Tranter is the founder of Mobius (in 1999) and the Mobius Institute (in 2004). Jason developed both the iLearnVibration and ILearn Alignment computer-based training systems, which are now used by companies in over 65 countries and have been translated into Spanish, Chinese, Korean and French. Jason earnied his Bachelor's Degree in Electrical/Electronic Enigineering (with honors) in 1983. He formed his first business, ARGO, in 1986 and developed the ALERT series of vibration analysis software products. He sold ARGO to DLI Engineering Corp in 1990. He was Director of Vibration Products for DLI when he left in 1996. He continued consulting with DLI until 1999 and helped to develop ExpertAert, the DCX data collector anf the DCX on-line monitoring system. Jason can be contated in his home country of Australia at +61 3 5989 7285 or by e-mail at jason@iLearnInteractive.com

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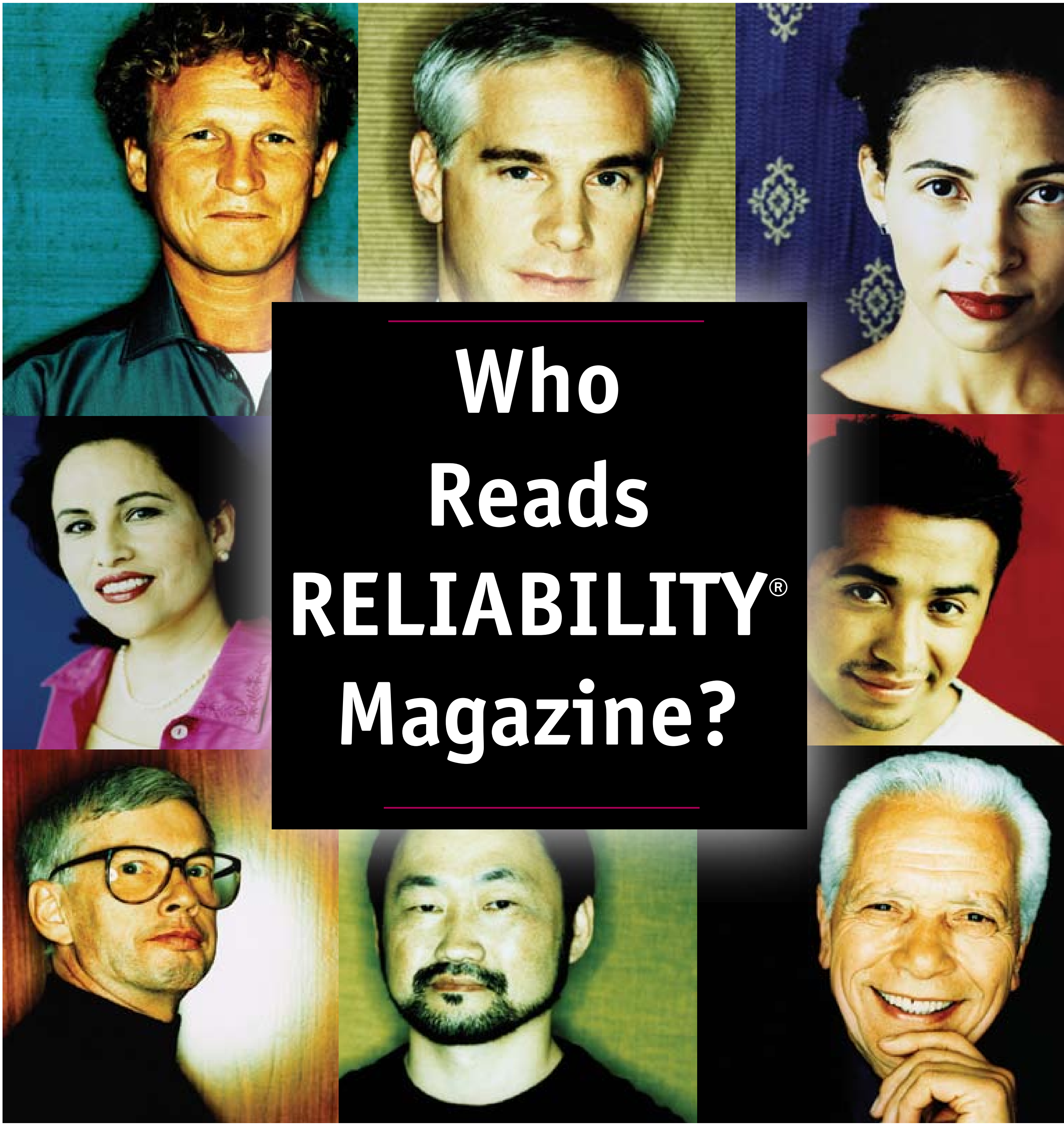
Who
Reads
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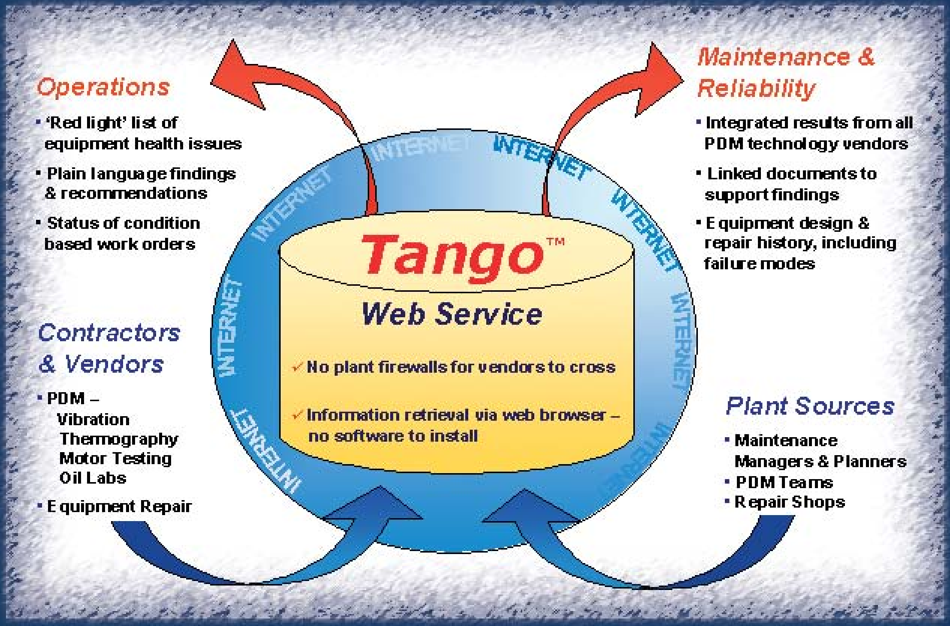
Are You Ready to Tango?

Tango: a web-hosted database system for Integrating, managing, and communicating an industrial plant's reliability information.

The idea behind Tango seems so elegant in its simplicity. So basic, yet in many facilities completely overlooked. Make it simple for people to get information they need to make better decisions about maintaining equipment and increasing reliability. We tracked down Dick Hancock, Sales & Marketing Consultant for 24/7 Systems, Inc., to tell us a little more about 24/7's Tango system.

So, are you ready to Tango?



Why did you develop this product?

Tango was designed to integrate and manage reliability information in a single database so that plant personnel can quickly find and use that knowledge. The owners and engineers at 24/7 Systems had worked for a major condition monitoring manufacturer in the 1980's and 90's, so they had first hand experience with plant customers asking about linking condition monitoring results with CMMS work execution. Then in the late 1990's, an electrical engineer at Alcoa's Tennessee Operations asked for help managing motor lifecycle information, and at about the same time a predictive maintenance engineer at Eastman Chemicals in Kingsport, TN called with a need for integrating and communicating their condition monitoring results. So, the initial specifications came from those three sources, and 24/7 Systems launched Tango near the end of 1999. Since then more than 200 other plant sites have started Tango databases for managing their equipment reliability information.

One of the two main functions of Tango is to manage the findings and recommendations coming from condition monitoring activities. Typically each separate technology issues reports in different formats and e-mails those to a different group of recipients. The end result is that no one in the plant actually has a complete and timely view of all known equipment health issues. Tango bridges that gap between predictive maintenance results and maintenance execution. Regardless of which technology or brand of equipment is being used, PdM technicians document findings and recommendations about equipment health problems in Tango under a common name for the equipment location. Other plant personnel such as maintenance planners or operations supervisors then use their web browser to view a simple report listing all the equipment with known health issues. One of the reliability engineers at Eastman Chemicals says response to condition-based issues has improved significantly since the 'bosses' now see equipment health status so easily.

The other main function of Tango is to manage information about critical equipment's lifecycle history. It records the history of locations and equipment ID's as equipment migrates from place to place over time. For individual pieces of equipment, it also tracks design details, warranty information, and failure/repair history. That means a reliability engineer can have all the information about condition monitoring calls and the actual faults found during repair in a single database, and he can investigate whether repetitious failure modes are following a specific piece of equipment as it moves from location to location in the plant.

That's enough about the types of reliability information managed by Tango – what's more important is the communication path for that information. Tango Web Service hosts the database on a secure web server, so outside PdM contractors and repair shops can be given permission to enter information directly. That's something they'd never be able to do if the database were inside a plant's IT firewalls. The end result is that the plant's reliability team gets the information they need in a single database, plus they get their vendors to enter the information.

What makes Tango different from a CMMS?
That's pretty straightforward. Maintenance work management is the forte of a CMMS – issuing and tracking work orders, 'counting the beans' for man-hours, parts cost, tool crib management, etc. Tango doesn't duplicate any of those work management functions – it delivers integrated equipment health status information to the plant those making day to day decisions about what work should be managed by the CMMS, and it then tracks more detailed information about long term equipment failure modes to help reliability engineers find and eliminate chronic problems.

If an organization already has CMMS implemented, can Tango help?

Absolutely – the plant needs a good maintenance work management tool in place. In fact, many Tango databases start with an equipment location structure imported from the CMMS system. Tango handles several functions that are usually weak or non-existent in the CMMS – we've already discussed the integration and communication of condition monitoring results above. In our experience most CMMS systems focus on plant equipment locations and are weak in identifying what's happening with specific pieces of equipment. Tango tracks the unique equipment ID as it moves from location to location in the plant or out to a repair shop, and captures the failure mode and repair details. That's how it helps reliability engineers find chronic problems associated with a specific ID or with a particular supplier's equipment design.

Can Tango help a Condition Based Monitoring program that is already in place?

That would be strength #1! Many plants with technical proficiency in predictive maintenance still execute too much reactive or preventive maintenance work simply because the equipment health information is poorly distributed and managed. Tango standardizes the reporting from different PdM technologies and distributes all known health status information for an equipment location via web browser – that puts equipment health problems in plain language and in front of a wide audience of plant people, including managers. At Eastman Chemical that changed the focus of their predictive maintenance team from 'doing the monitoring' to 'making sure maintenance has responded to equipment problems prior to failure'.

What are some of the reporting features in Tango that our subscribers would find useful?

PdM techs, operations managers, or reliability engineers can see at a glance what equipment locations have severe health issues and whether or not maintenance response is under way.
Maintenance planners can quickly search failure history of a location or specific equipment ID to support their decision about maintenance response to a condition problem.
Reliability engineers can analyze what types of failure modes have occurred most frequently for different locations or equipment types, to focus longer term reliability improvement efforts.
Tango provides the basic measurement of equipment reliability, Root causes of Failure, Mean time between Failure (MTBF), and cost of failure broken down many ways

What are some of the warning features that Tango is capable of?

When a piece of equipment is sent for repair, a warning notice pops up if that equipment is still under an OEM or repair warranty. It's absolutely amazing how many plants pay for repairs on equipment that could be covered by a warranty. Another warning pops up if equipment is sent for repair before the expected Mean Time Between Failure is met.
Tango provides a current inventory of Critical condition problems – Great for work planning
Tango provides information to identify basic reliability needs and assist in justification

What kind of impact does Tango have on overall plant and machinery reliability?

That falls into two broad categories:

1) Preventing failures in service by integrating and communicating condition monitoring results to those responsible for maintenance response.
2) Helping reliability engineers reduce equipment lifecycle cost by providing a single source of equipment lifecycle information for MTBF, failure mode, and cost of failure analysis.

Put another way, Tango is focused on helping a plant get the reliability improvement it expected when it invested in condition monitoring and CMMS.

Is Tango only effective for large organizations with multiple facilities?

With the database located on a secure web server, Tango Web Service makes a lot of sense for multiple facility organizations - especially when they have a corporate reliability engineering function. However, we haven't observed that number or size of facilities is a key factor in effective use of Tango. Any size organization that believes reliability improvement is important for their business can benefit. Plants using Tango range in size from a few hundred critical assets to over 20,000

Can a business case be made to justify the cost of Tango?

That would be part of the same business case that applies to any reliability program – long-term increase in production uptime from existing assets while reducing overall maintenance cost. A more specific case for Tango Web Service ROI could be made with the warranty recovery warnings we discussed above. Tango Web Service is based on a monthly subscription fee instead of a large capital software purchase, so just one or two motor repairs covered under warranty could cover the cost.

What is the best success story you have heard from the implementation of Tango?

Eastman Chemicals in Kingsport, TN stands out. The Integrated Condition Status Report is reviewed in weekly maintenance planning meetings for each operating area to help determine work priorities – those meetings include a representative from area operations. That process forces the PdM team, maintenance, and operations to focus on timely maintenance follow-up to condition problem reports, and has measurably reduced the number of problems detected over the last 5 years. Eastman's Reliability Group Manager recently said that he's been able to use that information from the Tango database to reduce the frequency of vibration surveys on some equipment and reassign several vibration technicians to higher value reliability analysis work.

To learn more about Tango visit 24/7 System's website www.tf7.com

ITT has launched the PROsmart wireless machine health monitoring system which continuously monitors and automatically predicts machine health and alerts operators and maintenance personnel of existing and impending problems. The "plug and play" PROsmart system can reportedly be implemented within hours, with no wiring required, and provides reliable 24/365 monitoring for less than $2 per day from day one.

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The MikroScan 7400 is battery-operated and self-contained in a rugged, IP54-rated metal case for simple, point-and-shoot versatility. It includes on-board digital voice recording and can simultaneously record high-definition 14-bit thermal images with digital visual images. It comes standard with extensive onboard image processing software and stores images and data to PCMCIA cards. Images can also be viewed in real time via video output or optional built-in IEEE 1394 (Firewire®) interface.

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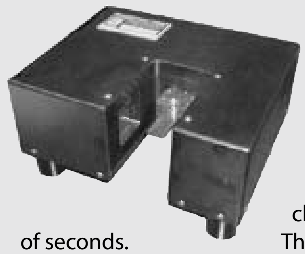

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