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dec 2006

the magazine for PdM & CBM professionals

Infrared Inspection Standards Made Simple

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Six Sigma & RCM2

ScottishPower Sheds New Light on Maintenance

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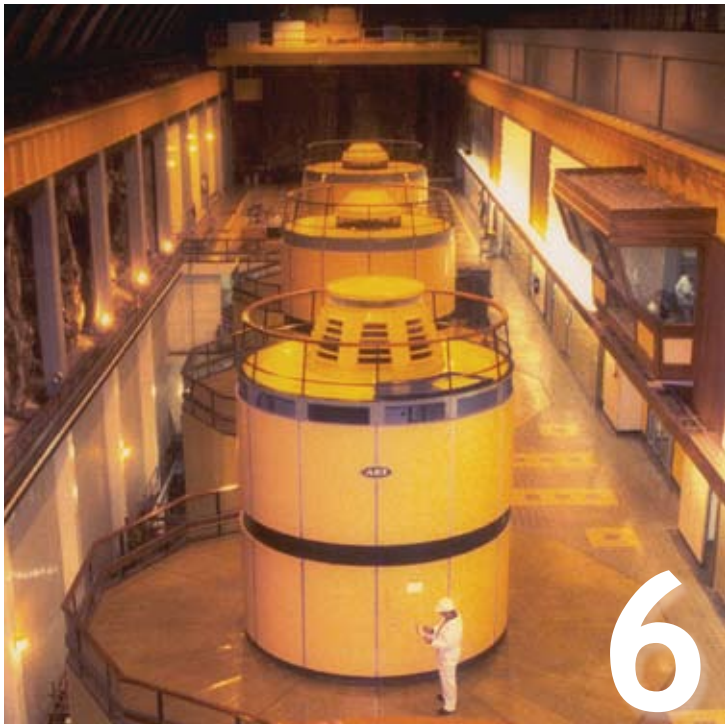

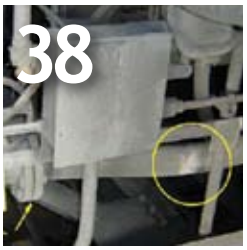

A New Way Forward

Revolutionary or evolutionary? As you will read in the feature article this month, ScottishPower's approach to maintenance is certainly not mainstream. I hope, when we look back on it 5,10 or 20 years from now, we can consider it both.

Revolutionary implies a rather abrupt break from commonly accepted patterns, an interruption of the status quo. By integrating Six Sigma so heavily into the improvement process of their maintenance program, they are clearly breaking new, and important, ground for maintenance professionals the world over.

Six Sigma is a highly structured program for improving business processes that has been adopted by numerous companies, including powerhouses like Motorola, Honeywell International, General Electric and more. The benefits of adopting Six Sigma are well documented. However, in the reliability and maintenance world, the biggest benefit may be that virtually every CEO in the world has heard of it, respects the process and knows it works. Unfortunately, the same can't be said for Reliability Centered Maintenance, even though it is a powerful tool that can deliver returns on investment that would make most CEO's drool.

By incorporating Six Sigma, you would immediately be speaking a language that decision makers either understand or would like to understand. And in the maintenance and reliability world, where we struggle to find ways of communicating our compelling story, that is Revolutionary.

Hopefully, this approach will be evolutionary as well. Evolution is the process of change in a certain, hopefully better, direction. Typically, there is a long period of slow, gradual change with major advances made, intermittently, in short bursts. Perhaps ScottishPower's experience can provide a blueprint for many companies to follow, and if they do, it could be the next big leap forward in the evolution of the maintenance and reliability world.

Would you like to make a quantum leap in your maintenance program? Six Sigma provides a methodology to make major improvements to your processes, and do so within a context that fully engages CEO's and other decision makers because they respect and understand it.

Sounds revolutionary to me.

I hope you enjoy the December issue. We are always looking for ways to improve, so please feel free to contact me with any questions, comments, suggestions or contributions that you think will help Uptime to be more helpful to you. Thank you for reading.

Happy Holidays,

Jeff Shuler
Editor In Chief
jshuler@uptimemagazine.com

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PUBLISHER
Terrence O'Hanlon

EDITOR IN CHIEF
Jeffrey C Shuler

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

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

Jeff Shuler, Editor In Chief
Uptime Magazine
PO Box 07190
Ft. Myers, FL 33919
888-575-1245 x 116
jshuler@uptimemagazine.com

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http://www.reliabilityweb.com/rroadmap/playback_reg.htm

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

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

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£6 Million for ScottishPower

by David Campbell & Derek Hastings

ScottishPower, an international energy company serving gas and electricity customers in the United Kingdom and United States, is known for its aggressive application of business improvement tools to enhance efficiency, reliability, profitability and customer satisfaction. This innovative approach was recently applied to the management of its power generation assets. The result is a ground-breaking blend of two respected business improvement strategies: Six Sigma and Reliability Centered Maintenance (RCM2) producing a cost savings of £6 Million ($11.3 Million).

Six Sigma Stalled Without Valid Data

Six Sigma is a rigorous methodology that uses statistical analysis to measure and improve manufacturing and service-related processes through five procedural steps: define, measure, analyze, improve, and control (DMAIC). The objective is to increase profitability by improving performance and reducing variability.

Since 2001, ScottishPower has successfully implemented Six Sigma to its Energy Retail business by drawing data from an environment of frequently reoccurring transactions, allowing statistical analysis, and the delivery of a textbook DMAIC process.

However, the same could not be said for ScottishPower's asset-intensive Energy Wholesale business where assets do not fail often enough to produce data which is statistically significant. At the heart of the Energy Wholesale business is 6,400 MW of complex generation assets ranging from state of the art combined cycle gas turbines to seventy-year-old hydro schemes, advanced control software and brand new wind farms as well as thirty five year old coal fired power stations. In this environment, it was possible to "Define" the business problem and validate the business opportunity, but without the appropriate statistical data, there seemed to be little opportunity to get to the six sigma "Control" phase within a time scale acceptable to the business.

"It was a good news/bad news situation," said Paul Parry, Business Transformation Manager, with the Energy Wholesale Business Improvement Team. "If our generating facilities had been experiencing failures at the statistically relevant rate, we'd have been out of business. Yet, at the same time, without the appropriate asset performance data we couldn't use Six Sigma to measure analyze and improve. Rather than give up on Six Sigma we had to reconsider what Six Sigma meant to us."

RCM2 and Six Sigma Combine to Drive Improvements in an Asset-Intensive Environment

This resulted in an approach which is now an established mantra within Energy Wholesale:

Start with Define
End with Control
Use the right analysis tool

The right analysis tool in this case is RCM2, an established process used to determine what needs to be done to keep physical assets, systems and processes continuously doing what the business wants them to do. RCM2 looks at safety, environment, output, throughput, speed, range, and carrying capacity. By gathering detailed system information, it identifies the ways in which a system can fail to meet business goals and pinpoints the events which are reasonably likely to cause the failure. Finally, RCM2 identifies appropriate actions to manage each failure mode in terms of both its technical and business consequences of failure.

Based on prior experience, the Business Improvement team was convinced that RCM2 could produce the robust analysis required to complete the DMAIC cycle. In collaboration with Hugh Colman of Aladon, the originators of RCM2, the Six Sigma process was successfully redefined. Using this new approach the required asset information could be gathered from, and validated by, the supervisors, operators and maintenance professionals - even when there was no formal historical data available. This proved to be a significant departure from traditional Six Sigma thinking.

RCM2 and Six Sigma's strengths compliment each other very well but it must be noted that they also share many common values. Both methodologies focus on defining business goals up front and both use cross-functional review groups of users and maintainers to supply performance information and apply the process. The resulting approach provides an effective solution to an asset-intensive environment.

Applying the RCM2/Six Sigma Solution

A pilot project was conducted on the oil burners at one of ScottishPower's coal fired power stations, Cockenzie, located near Edinburgh. The required information was gathered from a cross section of station operators, maintainers and engineers. This process that required only four three-hour sessions, which was significantly less time than any previous 'Analyze' phase. From this work the group was able to develop an asset management program focused on improved availability and reliability. The pilot project lasted three months and delivered significant financial benefits.

Bolstered by this success, the new approach was applied across a range of generation assets including:

- Hagshaw Hill wind farm
- Ash Disposal Facilities at Cockenzie Power Station
- Refurbished Generation Machines at Cruachan Pumped Storage Scheme

What is Six Sigma?
And how does it apply to reliability?

By Ricky Smith, CMRP

Six Sigma is a methodology to manage process variations that cause defects and to systematically work towards managing variation in order to eliminate those defects. Defects are defined as unacceptable deviation from the mean or target. In asset reliability these defects are known as equipment failures. The objective of Six Sigma is to deliver high performance, reliability, and value to the end customer.

The process was pioneered by Bill Smith and Dr. Mikel Harry of Motorola in 1986 and was originally defined as a metric for measuring defects and improving quality, and a methodology to reduce defect levels below 3.4 Defects Per (one) Million Opportunities (DPMO), or put another way, a methodology of controlling a process to the point of ± six sigma (standard deviations) from a centerline. Six Sigma has now grown beyond defect control in all segments of total business world to include asset reliability.

The Six Sigma methodology uses many tools which may be applied to asset reliability in its toolbox. A few of these tools include, Lean, Visual Factory, Statistical Analysis and the DMAIC Process (define, measure, analyze, improve, and control). The value of Six Sigma is to provide not only a process to reduce defects, and reduce cost, but to increase shareholder value both tactically and strategically.

The objective of Six Sigma is to provide performance breakthrough. In most attempts to improve reliability, a company will implement a strategy which minimizes risk and thus minimizes the outcome. Using the Six Sigma methodology performance breakthrough is the objective and, when applied in an asset reliability initiative, it minimizes risk while maximizing the outcome which results in "optimal reliability at optimal cost".

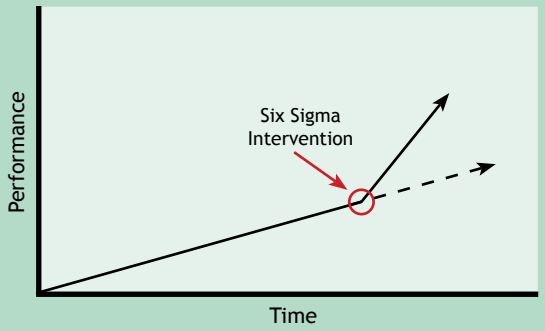

Fig. 1 - Longannet Power Station - One of the largest coal-fired power stations in Europe. It has four 600 megawatt (MW) units.

A Practical Application of RCM2/Six Sigma Combined

Primary Air Fans at Longannet Power Station

Longannet Power Station is one of Europe's largest coal fired stations. The loss of a primary air (PA) fan represents a 300 MW loss or 12.5 % of the station's total output. In the UK's deregulated electricity market a loss of this magnitude is extremely significant and costly. A Six Sigma/RCM2 analysis was performed on the PA fan system to define a proactive maintenance program and optimize the performance of this critical asset. The steps included:

Define

The 'Define' phase focuses on validating the problem, nominating a project leader, defining the project scope and assembling the Six Sigma/RCM2 review team. The research demonstrated clearly that the PA fan issue was a real problem and not simply someone's "pet project".

Measure

Historically the plant did not measure and track individual asset reliability, which is an essential success metric of any asset performance improvement program. During the "Measure" phase of the project, availability was selected (downtime in relation to generated output) as a representative measure of reliability. This was a departure from the traditional, because at the start of the project, in 2004, the importance of reliability and availability was not obvious to all involved. Yet, its importance became evident once station availability was defined in financial terms. For example, a reduction in availability from 99.8% in February 2003 to 98.11% in March 2004 represents a loss of revenue of £1M.

With the importance of availability now clearly understood, research established that PA fan availability had deteriorated over time, dropping from 99.91% in January 2000 to 94.66% in April 2005. This reduction in reliability, and its potential impact on business results, justified further work to establish a resolution to PA fan failures. Availability was established as an ideal measure of project success.

A key element of the 'Measure' step is a clear definition of what is to be measured (current and achievable states) as well as its boundaries. RCM2 provided the ideal tool to achieve this: the operating context. The operating context includes a basic history of the plant, the historical, current and projected operating profiles of the station as well as a detailed description of the equipment or system to be analyzed.

In addition, during the 'Measure' phase online condition monitoring data was reviewed to define and quantify the improvement opportunity. As seen in Figure 2, the PA fan's bearing gradually deteriorated over a 9 to 10 month period and eventually failed in April 2004. When the bearing reached this point it was too late to avoid incurring downtime costs.

Figure 3 demonstrates the benefits achievable using the P-F interval as described by RCM2. Had Potential failure (P) and Failed state (F) been properly defined, vibration analysis data would have been used to confirm that the PA fan bearing was failing prior to a scheduled outage and corrective action would have been undertaken during the Fall

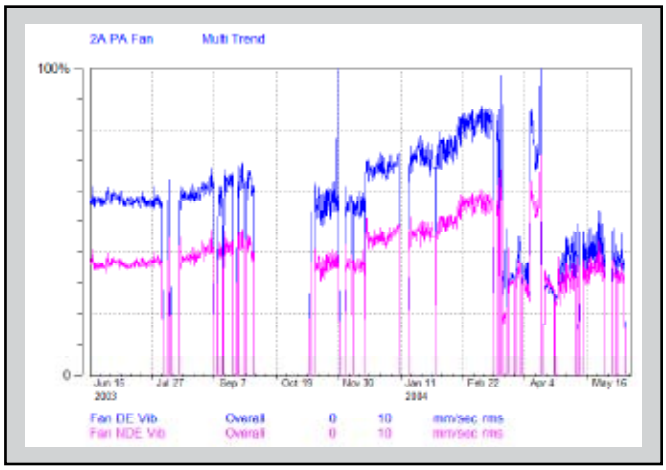

Figure 2 - Vibration amplitude plot for PA fan 2A

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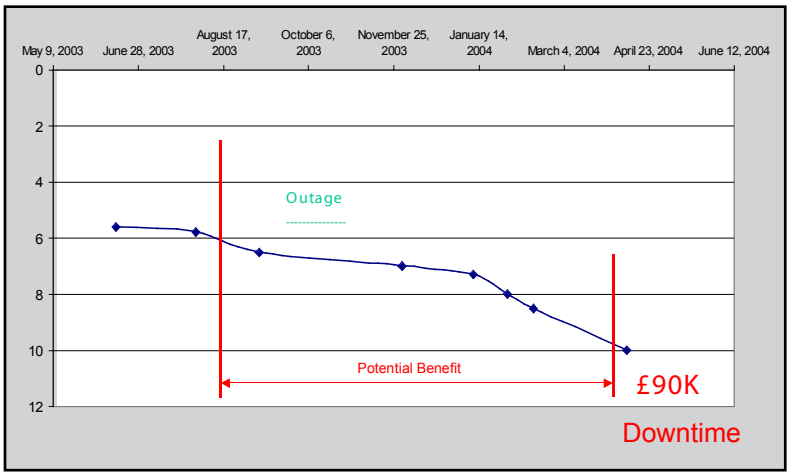


Figure 3 - P-F Vibration View of the Primary Air Fan

scheduled outage of 2003. This would have eliminated the resulting unplanned outage and saved the organization £90,000 in lost revenue.

Analyze

During the 'Analyze' phase, the information gathering phase of RCM2 is executed and Functions, Functional Failures, Failure Modes and Failure Effects are identified. At this stage, it is critical that those involved understand the RCM2 process as RCM2 relies on knowledge and experience rather than statistical data as with the DMAIC process. The review team in question had over 100 man-years of experience with these PA fans.

Improve

During the "Improve" phase of the DMAIC cycle, solutions are identified to eliminate the root causes of failures. The project team used the RCM2 decision diagram to develop sustainable solutions aimed at preventing failures which could have a significant business impact, be it safety, environmental, operational or non operational.

In total 50 maintenance recommendations were identified. They encompass: procedures, investigations, modifications, specifications, actions, routine tasks and training. The recommendations were reviewed by the project team as well as maintenance and operations staff to ensure the proper level of scrutiny and secure buy-in from those who will implement and use the program. The recommendations were then consolidated into a report for senior management approval.

Control

Senior management approved the final project report and the recommendations were implemented using strong change management techniques from the Six-Sigma tool kit. Asset performance improvements were sustained by applying the rigor of the Six Sigma "Control" phase. The ongoing tracking of PA fan availability ensures performance remains at a level acceptable to the business.

Results: The New Maintenance Strategy

The Six Sigma/RCM2 analysis conducted on the primary air fans resulted in a new proactive maintenance program that defines the right maintenance work at the right time. An example of this new program is the PA fan bearing recommendations:

Recommendation #1: Vibration and temperature monitoring of PA fan bearings.

In developing vibration and temperature indicators for the bearings, severity levels were defined such that an impending bearing failure provides early warning sufficient to allow for a planned and scheduled intervention. This predictive approach has proven very effective in preventing an unscheduled outage and is well received by the station staff.

The recommendation included an increase in internal vibration monitoring capabilities and the associated training program. Today, sev-

Figure 4 - Turbine Hall at Cruachan Power Station, a 440MW reversible pumped-storage Power Station.

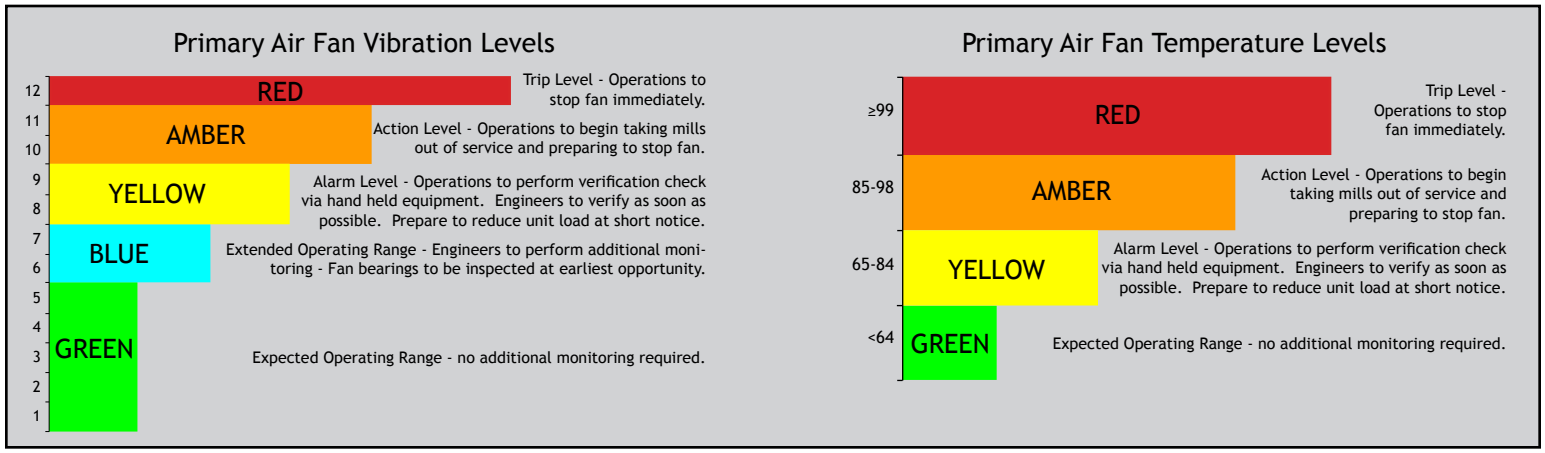


Figure 5 - Primary Air Fan Vibration and Temperature Limits

eral employees are conducting vibration and temperature monitoring activities every day.

The charts in Figure 5 illustrate the new, more graphical approach that has been adopted as well as the severity levels and actions to be taken. The computerized control desks have had their software updated to reflect these new levels and now the operators, maintenance and engineering staff all work to the one set of values. This approach offers a common basis for decisions.

Recommendation #2: Develop an alignment procedure for the PA fans that lists target alignment values. Final alignment values provided by 3rd party staff are to be witnessed by Engineering/Maintenance.

Recommendation #3: Specify bearing grease type and quantity.

Recommendation #4: Ensure that suitable spares and grease are available.

Recommendation #5: Replace the PA fan bearing sets every 4 to 5 years.

Given the increasing pressures to control costs and reduce budgets, power stations no longer have the same number of staff at their disposal that they once had. As a result, outsourcing is common as well as assigning maintenance work to an internal team who are not normally responsible for this work. In both instances, there are 'work control' implications, e.g. record keeping, ensuring that the correct instructions are given and ensuring that up to date information is available.

The PA fan bearing recommendations outlined above clarify the work that is required to ensure the bearing operates at optimal performance. All of the recommendations resulting from the bearing analysis are captured in ScottishPower's Computerized Maintenance Management System, ensuring that these critical tasks are not overlooked.

The Six Sigma/RCM2 PA fan analysis set the benchmark for fan reliability at Longannet. ScottishPower Engineers are starting to use this approach across the organization for both old and new installations.

Implementing and Sustaining an RCM2/ Six Sigma Initiative

ScottishPower understands that sustainable improvements are key to its long-term corporate wide strategy. To sustain improvements resulting from the Six Sigma/RCM2 initiative, considerable effort must be applied when embedding the change. This is where the Business Transformation team relies on the rigor of the Six Sigma methodology, specifically the 'Improve' and 'Control' phases of the DMAIC model. Through vigorous project tracking and monitoring of "critical to quality" (CTQ) metrics agreed upon by the project sponsors and key process owners, the business aims to make permanent improvements within its asset base.

To validate the improvement effort and prove a return on investment, the Business Transformation team employs the services of a qualified management accountant. "It's important that our improvement projects are treated with the same rigor as any other company investment," explains Paul Parry. "The financial benefits from our Six Sigma projects are published in the company results and undergo independent verification."

Benefits To-Date from the RCM2/Six Sigma Initiative

Considerable business benefits have been derived from the improvement initiative. Highlights include:

- The financial return from the initiative has grown from £150k in its first year to over £6m cumulative benefits in its third year.
- Numerous soft benefits including signifcant safety and environmental improvements.
- Recommendations free up manpower resource to attend to other critical activities.
- Knowledge sharing has been a significant feature of this deployment; at least once in every project someone has said, "I never knew that."
- Staff members enjoy Six Sigma and RCM2 and feel engaged with the change. They like the inclusiveness of the process as well as being part of the solution.

Solution Greater Than the Sum of Its Parts

Six Sigma and RCM2 work well together in an asset-intensive environment as they are meticulous processes created to develop solutions that specifically meet established business goals. Both also focus on identifying and correcting the root cause of obstacles and highlighting concrete, achievable solutions.

ScottishPower continues to reap the financial, safety and environmental benefits of its new business improvement practices and has successfully completed over a dozen Six Sigma/RCM2 implementations. There are ten more currently in progress. The program is targeted to deliver in excess of £10 Million ($18.8 Million) by the end of FY 06/07.

David Campbell is a Charted Mechanical Engineer, having graduated in 1986 with an Honours Degree in Mechanical Engineering, achieving an MBA in 2005. Various maintenance and operations posts followed at hydro, pumped storage and thermal power stations with ScottishPower. David moved into the Business Improvement Team in 2003 and is now a Six Sigma Master Black Belt and RCM2 Practitioner.

Derek Hastings is a Chartered Mechanical Engineer. He joined ScottishPower in 2004 as a Six Sigma Black Belt and RCM2 Facilitator and is currently one of the senior engineers at Longannet Power Station. Previous to this Derek has worked in various engineering and project roles within underground railway systems, hydro power station refurbishment and engineering and pump design.

Figure 6 - Hagshaw Hill Windfarm, part of ScottishPower's expanding portfolio of windfarms.

PdM Program of the Year Award Winners: Profiles in Excellence

by Terrence O'Hanlon, CMRP

Uptime Magazine is proud to feature a special group of people and companies who have risen to the challenges presented by most maintenance improvement programs and have earned the prestigious Uptime PdM Program of the Year Award. This award is designed to acknowledge exceptional predictive maintenance programs and the teams that make them that way.

The winners of the 2006 Uptime PdM Program of the Year Awards assembled for the award presentations at PdM-2006 – The Predictive Maintenance Technology Conference and Expo, co-located with LubricationWorld, from September 12-15, 2006 in Chattanooga, Tennessee. We are pleased to tell you more about the award winners below.

The 2006 PdM Program of the Year Award Winners

Best Overall PdM Program – Duke Energy McGuire Nuclear Station

McGuire Nuclear Station is located on Lake Norman in Mecklenburg County, North Carolina. Lake Norman is the state's largest man-made lake and was built by Duke Power in 1963 by damming the Catawba River with Cowans Ford Hydroelectric Station.

The lake provides cooling water for both McGuire and the coal-burning Marshall Steam Station. McGuire was the second of three nuclear stations designed and built by Duke Power. Unit 1 began commercial operation in 1981, followed by unit 2 in 1984. McGuire has two Pressurized Water Reactors, which drive two Turbine/Generators rated at 1200 Megawatts each.

Program Highlights

Even among programs for nuclear powered electricity generating stations, which are typically well supported, Duke Energy's program stands head and shoulders above all others.

(from left) Ralph Carver, Dennis Roinick, Steve Michael, Rodney Martin
Not Pictured: Anne Wallace, Matthew Stroupe

Key features that resulted in this award included the long range (3-year) training plan for PdM team members and the annual PdM Program Health Report which looks in depth at every aspect of the effort being undertaken in this area of plant maintenance.

The summary of proposed action items in the report sets a major part of the agenda for the following period for further program growth and refinement. The documentation describing the program and current issues is most comprehensive. Performance goals are challenging and performance indicators very meaningful.

Best Infrared Thermal Imaging Program - Johns Manville

Front Row (from left): Bob Weyand, Nick Bohonik
Back Row (from left): Chris Hoffman, Ian van der Hoeven, Matt Willems

The Johns Manville (JM) Plant in McPherson, Kansas was constructed in 1974. The facility manufactures fiberglass building insulation which is sold in the commercial, residential, and retail markets. The facility currently encompasses approximately 17 acres under roof and is set in 160 acres of rural area.

The team has done an excellent job developing a "Criticality Matrix" which is the key driver for both RCM and PM Optimization.

Program Highlights

90% of critical equipment is monitored. The thermography routes include all motor control centers, disconnects, electrical control cabinets and high voltage distribution. Detailed histories of each inspection are logged and kept for further analysis such as trending, histograms, etc.

Since the inception of the PdM and Infrared program on March 2004, the plant's uptime performance has increased substantially. Safety performance at the facility has increased due to the elimination of a wide range of threats and problems.

The McPherson infrared program has made a rapid rise to a high quality program in a short time.

Best Lubrication Program - PBR Automotive

Jeanette Simmons, Douglas Hypes, Tim McCullough, Lee Churchwell, Sharon Livingston, Stewart Dyches and Albert Blanding

PBR Automotive started business in 1927 as Paton's Brake Service Station in the Melbourne, Australia suburb of Carlton. Since then it has grown to be a leading manufacturer of brake parts. With facilities on 4 continents, PBR supplies advanced brake system products and technology to the global automotive market.

The 236,000+ ft^2 (5.5 acre) facility located in West Columbia, SC manufactures brake calipers, the Banksia parking brake and brake modules.

Program Highlights

PBR Automotive started their program after it became obvious it was needed at all levels from storage and delivery through in service filtration and on to lubricant selection and upgrade. PBR has set up a lubricant storage area with a kidney loop filter system to pre-filter all hydraulic oil prior to use. The storage area is well labeled, organized and environmentally correct. Their program ensures tagging all of their oil reservoirs that identify the proper oil to use in the applications as well as level indicators to ensure proper levels of oil.

Particularly impressive is the upgrading of procedures and incorporation of best practices for sampling, greasing and other lubricant and hydraulic fluid additions to avoid human error.

Best Motor Testing Program - TransAlta Utilities

Abbas Dhalla, John Bass, Bob Cargill, Harvey Henkel, Mark Kumar, Tatiana Buritica
Not shown-Dwaine Thomsen Frans Borsboom

TransAlta is a power generation and wholesale marketing company that was founded in 1911. The TransAlta has transformed from an integrated, regulated Alberta-based utility to become an international power generator and wholesale marketer of electricity.

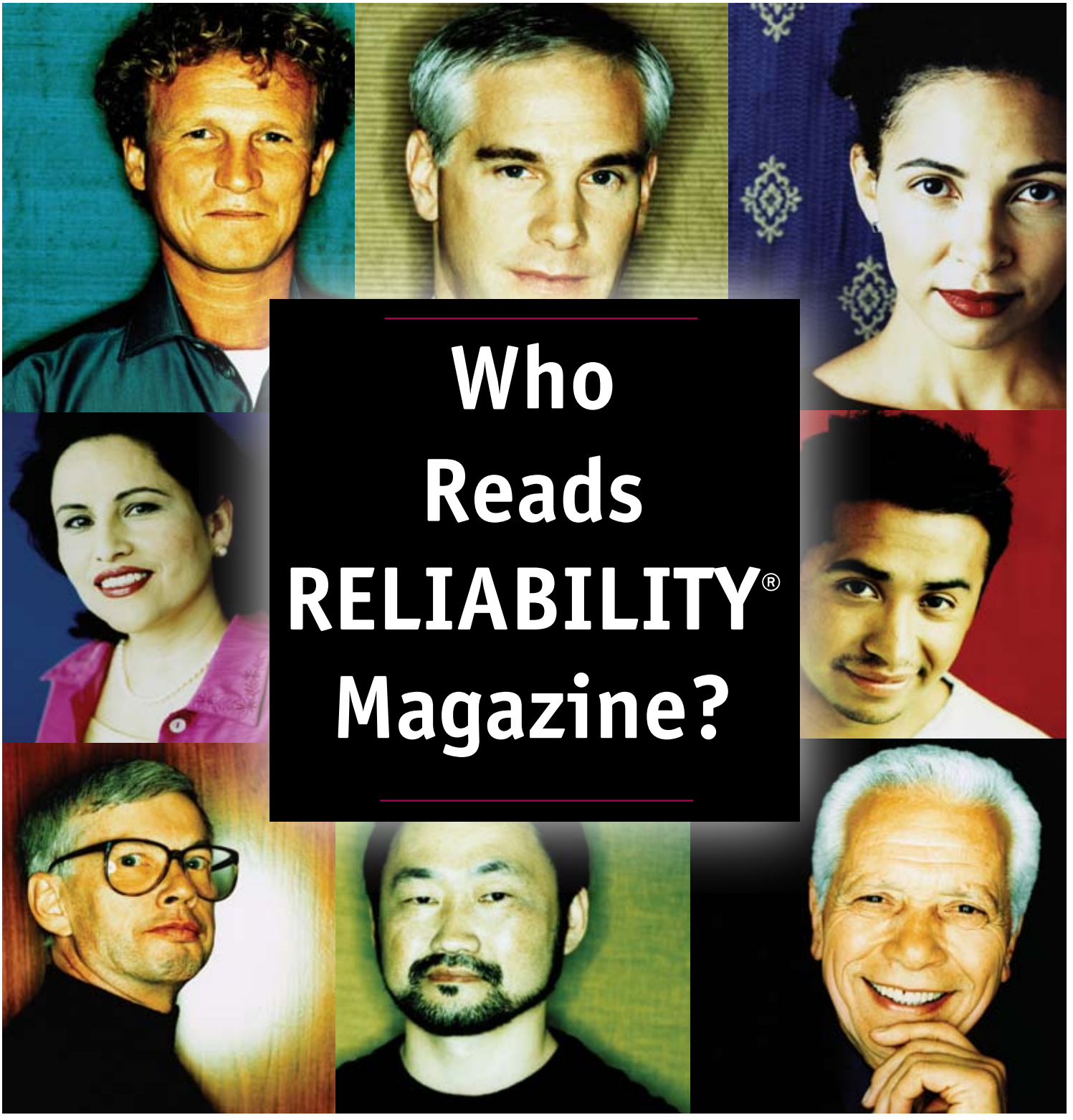
As one of the few pure power generators, TransAlta has learned how to operate plants safely, reliably, and with a commercial mind-set. TransAlta's 50 power plants, fueled by coal, natural gas, water, geothermal energy and wind, are located in Canada, the United States, Mexico, and Australia.

Program Highlights

There has been a 30% reduction in lost Gigawatt hours production in the three years since the inception of the motor testing program at TransAlta Utilities' Sundance Plant in Duffield, Alberta.

This reduction amounts to an average of $279,000(CN) increased revenue each year due to better motor reliability compared to the period before program startup.

Particularly impressive is the development of Motor Report Cards that summarize results from all PdM technologies used on motors. These are used for long term planning for motor maintenance.



Best Oil Analysis Program - Westar Energy

Westar Energy has a generating capacity of more than 5,850 MW (mostly from fossil-fueled facilities) and serves 660,000 electricity customers in Kansas through its utility subsidiaries. It also supplies wholesale electric power to 48 cities in Kansas and four electric cooperatives that serve rural areas.

Program Highlights

In 2002 Westar Energy made the decision to aggressively implement a lubrication management program throughout its 6 plant facilities. The Oil Analysis program started out utilizing a professional lab service and quickly evolved to an in-house program consisting of seven PdM technicians who are actively involved in the oil sample collection and data analysis process.

The Westar PdM Team

Now Westar Energy's program combines in house lubricant analysis backed up by sample analysis by an external laboratory. Best practices for lubrication, sampling and analysis have been incorporated into all procedures at Westar Energy.

Best Precision Maintenance Program - National Institutes of Health

The National Institutes of Health (NIH) is the Federal focal point for medical research in the United States. On the main campus in Bethesda, MD, some 20,000 doctors, researchers, and scientists work in over 60 buildings to advance the state of medical knowledge and research. The Building Maintenance Team (BMT) provides operation and maintenance support to the Division of Property Management for the care of all campus buildings. This includes routine and emergency maintenance on assets including utilities and a vast distribution system for steam, chilled water and compressed air.

Program Highlights

This is a unique cooperative effort between government agencies in which the U.S. National Institutes of Heath (NIH) Bethesda MD, is supported by U.S. Naval Sea Systems Command Logistics Center, Mechanicsburg, PA. The emphasis has been placed on improving the reliability of new and old equipment for heating, ventilation, air conditioning and other critical equipment in six major buildings and several other vital areas such as Bio-safety Labs on the campus in Bethesda, MD.

The NiH PdM Team

Navy Logistics Center personnel act as advisors and trainers for NIH, provide special alignment and balancing kits, tools and training to NIH craftspersons and have trained NIH design personnel on how to specify equipment for labs and building operation to have the lowest life cycle cost and highest reliability.

In its 6 years of operation, the program has been expanded to support the design, installation, commissioning operation, maintenance and re-engineering of facility equipment.

Best Ultrasound Program - Minnkota Power

Minnkota Power Cooperative, Inc. is a regional generation and transmission cooperative serving 11 member-owner distribution cooperatives. Minnkota's service area of 34,500 square miles is located in eastern North Dakota and northwestern Minnesota. The Milton R. Young Station is located near the town of Center, N.D., and consists of two units that are supplied with lignite coal from the adjacent mines of BNI Coal, Ltd. The Young Station consistently ranks among the nation's lowest-cost, coal-fired generating plants.

Program Highlights

This group of five specialists conducts Ultrasound inspections on steam traps, compressed air systems and selected electrical equipment, and also makes corrective repairs as required and/or permitted by plant conditions.

Since implementing their program, the mean time between failure (MTBF) has moved from 1-3 years to 8-10 years. Emergency call outs have been nearly eliminated, and overtime has been reduced from 15-20% to 5-7% annually. This has been accomplished while utilizing a smaller maintenance staff than when the program was started. Also impressive is the fact that 95%+ of work is planned and scheduled. This has vastly improved the working relationship between maintenance and operation personnel.

Tod Baer, Tom Fryslie, Fred Rose, Gary Kurtenbach, Tom Heilman

Best Vibration Analysis Program - Dofasco Steel

Dofasco is Canada's most successful steel producer and a global industry leader. Hamilton, Ontario has been home to Dofasco's head office and main manufacturing facilities since the company was founded in 1912. Dofasco's operations hub is its 730-acre steelmaking complex in Hamilton - one of the most efficient, flexible and technologically advanced steel plants in North America.

Program Highlights

The Dofasco group wasn't satisfied with the other commonly used commercially available ways of collecting vibration data. So, they have invented new ways of obtaining and interpreting vibration data on critical plant components. They have been awarded one Canadian patent and a second is pending for their work, which has already been proven and is in daily use in their plant.

Kevin Hunt & Geoff Generalovic

100% of critical equipment is monitored by the program. There is lubrication analysis, vibration, infrared, and motor testing employed on all critical (on-line and off-line) equipment. Trend (ICAS) computers are used to complete trend analysis of critical equipment data (pressure, flow, vibration, temperature) with a link to process data to take the program to the next level. Work is also being done on including small but critical supply equipment (such as air supply fans) into the PdM program to ensure further reliability of critical equipment.

Special Award of Merit - Chugach Electric

Chugach Electric is the largest electric utility in Alaska, serving more than 69,000 wholesale and retail customers in a service area the size of the state of Delaware.

Chugach Electric Association is headquartered in Anchorage, Alaska's largest city, which sits at the base of the Chugach Mountains. Chugach provides power to Alaskans from Homer to Fairbanks through sales to wholesale and economy energy customers Matanuska Electric Association, Homer Electric Association, the City of Seward, Golden Valley Electric Association, and Anchorage Municipal Light & Power.

Tusi Faafetai, Tyler Chubb, Scott Girard

Program Highlights

Chugach Electric in Alaska has developed and implemented a Reliability Centered Maintenance analysis based, comprehensive PdM program for substations. Technologies applied include, Infrared Thermography, Partial Discharge Detection, Combustible Gas detection, Substation Diagnostic Analysis, Vibration analysis, Airborne Ultrasonics, and Dissolved Gas analysis.

The program has experienced avoided costs of US$2.2M to date and projects further avoided costs of over US$500K over the next five years.

Special Award of Merit - Sidor

Sidor is an integrated steel complex located in the region of Guayana in the south of Venezuela. Today it is the leading steel producer not only in the country but also in the Andean Community region. It is one of the largest plants of its kind in the world. In the last year record production has been seen in almost all of the production lines.

The Sidor PdM Team

Program Highlights

Sidor's steel-making operation in Puerto Ordez, Bolivar, Venezuela has a comprehensive program overseeing 6300 pieces of rotating machinery with vibration, ultrasound, infrared thermography, laser alignment, lubrication & wear particle analysis, flow pattern analysis and non-destructive testing.

Some unique metrics, such as Optimized Manpower Index - Quotient between quantity of PdM work orders and total work orders, Diagnosis Certainty Index – Quotient between quantity of successful diagnosis and total diagnosis and Repair Quality – quotient between quantity of good condition equipment after intervention and total of all interventions are unique.

In addition, the quality of example Root Cause Failure Analysis reporting is outstanding in support of improving machine reliability.

Impressed? You should be as these PdM teams and the companies they support have made tremendous accomplishments and have led their programs to amazing results. It was no easy task for any of them.

There are more details about each program along with a list of the equipment and software used in each program online at www.uptimemagazine.com. Watch for more information about these award winning programs in future issues of Uptime as editor Jeff Shuler works with award winners to present case studies for your review.

Many of the Award winners will be on hand at PdM-2007 - The Predictive Maintenance Technology Conference and Expo on September 11-13, 2007 in Las Vegas to present case studies about their programs and to help us present the 2007 awards.

Is Your PdM Program an Award Winner?

If you are interested in nominating your program for a PdM Program of the Year Award, please visit www.uptimemagazine.com and look for PdM Program of Year links. There is no cost to nominate a program and winners get free passes to PdM-2007. The entry period begins January 1, 2007.

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Where You Turn

Infrared Inspections - By the Book

A Guide to Infrared Thermography Standards

by Terry Clausing

There is a lot of confusion regarding the industry standards applicable when performing traditional infrared inspections of electrical and mechanical equipment. This article offers an overview of the standards, and the interpretation of those standards. So, exactly what are "standards" and why are they important to us? Perhaps the best answers to these questions are illustrated in areas where we all have personal experience and interaction with standards in our lives.

How many of you use a telephone? These days, most everyone is familiar with touchtone phones. Telephones are manufactured by a large number of companies and there are many service providers. Telephones come in many shapes and styles, but the tones they generate, DTMF, are industry standards that allow phones from all manufacturers to work with each other around the world. DTMF stands for "dual tone multi-frequency". The words you probably are familiar with are "TouchTones". Did you know that the term touch tone is actually a registered trademark?

OSHA & NFPA

There are several additional standards that govern thermographers. The Occupational Safety and Health Administration (OSHA) is a branch of the US Government. OSHA's mission is to assure the safety and health of America's workers by setting and enforcing standards; providing training, outreach, and education; establishing partnerships; and encouraging continual improvement in workplace safety and health.

OSHA recognizes the National Fire Protection Association (NFPA) as the consensus organization that determines the most appropriate guidelines for how we behave in the workplace. NFPA publishes two standards that pertain to thermography.

NFPA 70E is the Standard for Electrical Safety Requirements for Employee Workplaces. According to OSHA, NFPA standards are not in or of themselves law. NFPA produces the National Electric Code (NEC) which many municipalities adopt and legislate into law, but the adoption of the NEC is not required by national law.

But, the bottom line is this: OSHA's application of the Federal Register IS law.

The purpose of the Occupational Safety and Health Act of 1970 (OSH Act), 29 U.S.C. 651 et seq., is "to assure so far as possible every working man and woman in the nation safe and healthful working conditions and to preserve our human resources." 29 U.S.C. 651(b). To achieve this goal, Congress authorized the Secretary of Labor to promulgate and enforce occupational safety and health standards. 29 U.S.C. 655(b) and 654(b).

A safety or health standard "requires conditions, or the adoption or use of one or more practices, means, methods, operations, or processes, reasonably necessary or appropriate to provide safe or healthful employment or places of employment." 29 U.S.C. 652(8). A standard is deemed reasonably necessary or appropriate within the meaning of Section 652(8) if:

- A significant risk of material harm exists in the workplace and the proposed standard would substantially reduce or eliminate that workplace risk;
- It is technologically and economically feasible;
- It is cost effective;
- It is consistent with prior Agency action or supported by a reasoned justification for departing from prior Agency action;
- It is supported by substantial evidence; and
- In the event the standard is preceded by a consensus standard, it is better able to effectuate the purposes of the OSH Act than the standard it supersedes.

While OSHA does not directly adopt NFPA's NEC or 70E as "law", OSHA is directed to judge the actions of us as employees in a workplace in accordance with current consensus standards. In simple terms, this means that in the event of an accident, OSHA may apply the current version of consensus standards in assessing whether appropriate safety precautions were taken.

NFPA 70E establishes requirements that each of us needs to understand because the rules today are substantially different from the past. There are three specific requirements in regards to thermographers working with energized electrical equipment.

1. Persons doing work must be trained and qualified.
2. Personal protective equipment (PPE) must be used in accordance with hazard exposure.
3. Arc flash assessment must be made to properly determine the level of PPE required.

These requirements are rapidly approaching the mainstream and we are held accountable for their use.

The NEC and NFPA 70E are very specific in their requirements for "qualified persons". Most of you are familiar with ASNT—the American Society for Nondestructive Testing (ASNT). ASNT establishes qualification standards for establishing the education and training requirements of personnel involved in non-destructive testing including infrared and thermal testing. The standard from ASNT that relates to thermography is SNT-TC-1A. This standard is a rigorous guideline for us to use in establishing the qualifications of people involved in many areas of non-destructive testing, including infrared thermography. The two specific requirements for compliance with SNT-TC-1A are that we have a written practice describing our qualifications and that we keep records documenting our qualifications in accordance with our written practice.

NFPA 70B

While most everyone is familiar with the National Electric Code and OSHA, another important standard is NFPA 70B – *Recommended Practice for Electrical Equipment Maintenance*. The purpose of 70B is to recommend consensus practices to reduce hazards to life and property that can result from the failure or malfunction of industrial type electrical systems and equipment.

NFPA 70B includes comprehensive information on establishing an effective electrical preventive maintenance program (EPM). Included in the descriptions of an effective EPM program are the concepts of charting the gradual deterioration of your equipment over time (baseline trending).

The four basic steps that should be taken in the planning and development of an effective electrical preventive maintenance program, in their simplest form, are:

1. Compile a listing of all equipment and systems.
2. Determine which equipment and systems are most critical and most important.
3. Develop a system for keeping up with what needs to be done.
4. Train people for the work that needs to be done, or contract for the special services that are required.

As a consensus standard written specifically in regards to safety in the workplace as related to the possible failure or breakdown of electrical equipment, NFPA 70B is certainly something that OSHA could choose to enforce. NFPA 70B, Section 20.17 deals specifically with the application of infrared inspection of electrical equipment. Key elements outlined here include:

1. Infrared inspections should be performed by trained and qualified personnel.
2. Infrared inspections should be performed using infrared imaging cameras (spot radiometers are not adequate for identifying anomalies).
3. Infrared inspections of energized electrical systems should be performed annually, or more often as deemed appropriate for criticality and safety.
4. Electrical load and ambient conditions must be taken into account.
5. Equipment enclosures must be opened for a direct view of electrical components whenever possible.
6. NETA maintenance testing specifications for Electrical Power Distribution Equipment and Systems suggests temperature differences for use in establishing the criticality of observed anomalies.
7. A database is recommended to facilitate tracking the condition of equipment over time and comparing current and past conditions.

ASTM E1934

ASTM International is another organization that establishes consensus standards for materials and testing procedures. While NFPA focuses on consensus standards for fire prevention and safety, ASTM focuses on industrial standards for materials and practices. Having been established in 1898, ASTM is one of the oldest and most highly respected standards organizations in the world.

ASTM is active in the infrared community and publishes several standards related to the use of infrared cameras and, in particular, publishes E1934 – *Standard Guide for Examining Electrical and Mechanical Equipment With Infrared Thermography*. While NFPA 70B provides a few simple (but critical) guidelines for thermography, ASTM's E1934 provides much more detailed directions for the proper methodology for conducting an infrared inspection. Some of the key elements of E1934 include:

1. Compile a listing of all equipment and systems to be inspected.
2. A report system is recommended to facilitate reporting anomalies and tracking the condition of equipment over time for comparing current with past conditions.
3. A qualified thermographer should conduct infrared inspections of energized electrical equipment and be assisted by a licensed electrician, professional engineer or other person who is familiar with the equipment and qualified to work on the energized electrical equipment.
4. Infrared inspections should be performed using infrared imaging cameras (spot radiometers are not adequate).
5. Electrical load and ambient conditions must be taken into account.
6. Equipment enclosures should be opened for a direct view of electrical components whenever possible.
7. A subjective prioritization scale should be established to judge the criticality of observed anomalies.

While the identified key points are not all inclusive, the intent here is to illustrate that the NFPA and ASTM standards have a great deal of similarity - as one might expect from consensus standards.

The NFPA 70B and ASTM E1934 practices offer a solid foundation for the establishment of your written practice for how infrared inspections should be conducted within your company.

How are standards developed?

Various organizations have differing rules on

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how things are done, but standards in general are developed by everyone who has a desire to participate. In the early 1980's the personal computer industry was created. Companies such as IBM, Texas Instruments, DEC, and many others each introduced their proprietary versions of the personal computer as each required specific versions of the operating systems and specific versions of application software. Then, around 1983, three men formed a company called Compaq Computers and developed the first IBM-compatible computer – they established a "standard" for compatibility. ASTM, NFPA and ASNT each provide a more formal structure for establishing relevant standards for society.

Who participates in establishing standards?

With ASTM, anyone who desires to participate is welcome. You do not even need to be a member of ASTM to participate in meetings; they are open to all, and as such are the basis for true consensus standards. With ASNT, anyone who desires to participate is also welcome to attend the committee meetings where the standards are discussed and drafted.

Who votes on the standards?

Voting is a slightly different matter, since in order to vote, it follows that you need to be registered to vote. Organizations generally require membership in the organization to vote on issues.

Who is required to use standards?

Required? No one. In the case of the telephone and DTMF, you can choose to make any kind of phone you want. The bigger question is: if you do not use the standard, who will buy it, and will it be safe to use? The purpose of standards is to facilitate trade and to promote health, safety and the environment.

Conclusion

Standards have no substance other than that which society instills on them. Some standards such as the National Electric Code are so well grounded that many government bodies choose to adopt them into law. OSHA does not directly adopt standards but cites consensus standards as best practices and, as such, bestows upon them significant authority.

The practice of infrared thermography is growing in large part due to the technological advancements of lower cost infrared imaging equipment. As infrared cameras become increasingly affordable, both the benefits and the risks grow as well. Lower cost equipment enables us to catch more developing problems earlier, avoiding breakdowns and reducing total maintenance and repair costs. However, it is essential that the people using this equipment be properly trained and qualified to perform the work. Infrared thermography is a tremendous tool that allows us to see developing problems but the equipment must be on, under load, with live electrical conductors exposed in order to see the developing problems during an infrared examination. Standards such as these from ASTM, NFPA and ASNT provide tremendous guidance in the safe and effective application of infrared thermography.

L. Terry Clausing, P.E., is the president of Drysdale & Associates, Inc. and TrendFormers, Inc. He is an engineering consultant specializing in UV/VIS/NIR/IR spectral analysis including infrared temperature measurement, infrared/thermal imaging (traditional electrical thermography and specialized materials and process analysis), infrared moisture analysis, color and other spectral characteristics of materials. Terry holds an ASNT NDT & PdM Level III IR/T certification in non-destructive infrared testing, earned his BSME (Mechanical and Industrial Engineering) from the University of Cincinnati in 1978 and an MBA from Xavier University in 1984. He is the Chairman of ASTM sub-committee E07.10.04 non-destructive testing, infrared testing methods and Chairman of ASNT Infrared/Thermal Method – personnel qualifications. Terry can be reached at 513-831-9625 or terryc@virtualspectrum.com

This article was originally delivered as a presentation at ThermalSolutions, one of the premier learning events in the world for infrared thermographers. For more info on the conference go to www.thermalsolutions.org

PdM Program of the Year Winner

All the Right Moves

The Evolution of a Lubrication Program

by Danny Moore

PBR Automotive started business in 1927 as Paton's Brake Service Station in the Melbourne, Australia suburb of Carlton. Since then it has grown to be a leading and world class manufacturer of brake components. With facilities on four continents PBR supplies advanced brake system products and technology to the global automotive market. The 236,000 square foot plant, 5.5 acre facility located in West Columbia, South Carolina manufactures brake calipers, the Banksia park brake system and brake modules for various GM, Ford and Chrysler vehicle platforms along with others.

PBR of Columbia, L.L.C. has always prided itself in running a very organized and well maintained operation. However, about two years ago we began to notice that cycle times, which are critical in a foundry operation, and machine reliability began to decrease. Although we consistently performed our PMs, we quickly discovered that we were missing several key components, one of which was our lubrication program.

We have performed lubrication analysis since day one and always performed work based off of what we thought were appropriate guidelines. But, after receiving some additional training and guidance from our suppliers, we began a detailed process to re-evaluate everything we did and thought. We also began a lengthy period of self education into every aspect of lubrication including the evaluation of 'hands-off' predictive maintenance principles.

One of the primary initial steps we took was to call a team meeting that included everyone involved in the lubrication process, including all of our associated suppliers. At first there was skepticism from the competing suppliers, but we persisted and were eventually able to gain participation from the majority.

Stay Open

Open communication is a critical component in gaining support from all stakeholders. In order to foster a team spirit, it was essential for us to be fair and straightforward with all the suppliers. We discovered that creating a bulk e-mail address was an excellent tool. This ensured that when any communication was sent everyone was included. We also made it clear to everyone that we would use what was determined to be the best practices for the need regardless of manufacturer. This meant every stakeholder would probably win some and lose some.

Once this process began we all recognized that everyone had their own philosophy on the resolution of our issues and interpretation of the data. We began a process of incorporating all ideas into one major plan of attack. We surmised that everyone knew something helpful but no one alone had the complete or best answer. We also discovered that, as the end user, we had better be more knowledgeable about what we needed and what the information we collected meant to us. We could then achieve our desired results without a lot of he said/she said or 'my product is better than yours'. From these meetings we developed a ten step improvement process to address each area of concern in our lubrication program (see below) and set about attacking each item step by step.

Ten Step Improvement Process for Cast Shop Hydraulics

1). Determine required standards for oil
2). Make sure all incoming oil stocks meet requirement
3). Reprocess and certify current stock, if needed
4). Eliminate leaks and prevent contamination
5). Ensure PM's are done and are effective
6). Revisit/repeat particle count analysis
7). Configure pump/filter unit
   a). Replace filters with appropriate size units
   b). Fix current draw problems on motor
   c). Convert to quick disconnects
   d). Provide spare parts as needed
8). Configure table and die change area pump unit
   a). Replace filters with appropriate size
   b). Add power connector
   c). Add quick disconnect couplings
   d). Fix strainer issue
   e). Check and replace frail hoses
9). Commence routine cleaning
10). Implement filtration program, particle count analysis and review process

First, we involved Industrial Distribution Group (IDG) to increase and organize a more comprehensive oil analysis process that provided more frequent information combined with on-call analysis during our testing phase. IDG also verified the Castrol product we were using was appropriate for the application, which it was. Our process uses water glycol fluid which is difficult to analyze in-house and can be very costly. During this process we also researched the market for lubricants that might perform better for our application. Although we found a potentially better product, we chose to address our current issues prior to testing something new. In other words, we decided to correct the issues we knew we had and not add another variable!

Surprise

All oil is dirty!....What!....It's brand new? That's what we thought anyway. Needless to say, our first lesson was learned. Unless you buy aircraft grade oil, your oil dirt level is typically higher than most of your critical components can stand. We had to decide if buying aircraft grade oil or filtering and certifying our own was the best choice. After crunching the numbers, we decided that, for us, it was the later. We also had to muddle through conflicting information. Some suppliers would tell us that oil cleanliness wasn't as critical as the other guy wanted us to believe. Others would tell us that it was the most critical part of the oil. We decided to use the worse case scenario and went from there. We started by installing a 24/7 recirculating oil filtration and dispensing system to maintain 17/15/12 oil cleanliness levels continually in their storage totes. We chose to use a Harvard Filtration system that utilizes a bag filter for pre-cleaning and a 1-micron finish filter. The system was set-up so that it continually recirculates the oil in our tote using a drum breather quick disconnect set-up supplied by Y2K Fluid Power. We can also switch to a quick disconnect attached to a transport drum and turn a

Figure 1 - Hydac Filtration System

valve to fill the transport drum. With the same quick disconnects we can take new product from new totes and fill the storage tote with filtration never ceasing.

Next we addressed how to get our oil from storage to the machines. This part was a pretty straightforward process. We installed breather kits from Y2K Fluid Power and ¾" quick disconnects at all transfer points in the system. This allowed our transfer drums to be directly linked to the machine via a Parker Hannifin transfer/filter cart without ever opening any port or access point.

Figure 2 - Quick Disconnect fill system by Y2K

It's important to note that we use two types of hydraulic oil in the facility. We set up the system for the second type of oil using ½" quick disconnects. This set-up prevents cross-use of filter carts, equipment, oil drums, and any other device not specifically set-up for one area or the other. We also found that using different size quick disconnects for different products was an affordable way to control cross contamination from just about any source.

It also discourages the use of pails, bottles and funnels which are a prime source of contamination. To provide another layer of contamination control, we also utilized a sump identification program designed by DuBois Chemical Management that identifies every container, sump and transport cart by color and description.

Now that the oil could be delivered to the machine purified we evaluated the equipment, and quickly discovered that the machines' factory installed filtration was woefully inadequate to maintain the fluid quality - even when delivered clean. With help from Livingston and Havens (Hydac) we researched and installed a more robust, and more cost effective, filtration system. Within 16 hours of installing the system, we achieved and have maintained the results we require. This was crucial because the most critical parts in the machine were the 192 Vickers proportional valves that control the cycle times. We discovered that although we would PM and change our filters, they would clog within 7 days. Unfortunately, the PM cycle was monthly and we had no indication of the failure with basic mechanical type pressure gauges. With the new set-up we anticipate only annual filter changes. However, they have alarms (both visual and audible) that will warn us when they get within a specified range of full capacity. We also addressed several other machine issues such as proper cylinder seal material, sample ports for analysis samples, and relocating a filter that had been installed in an area of the machine that could not be accessed without shutting the machine down.

Next, we updated our automated PM system to reflect all the new information and equipment we installed, and included detailed specifics on how to maintain and manage each piece of equipment in the process. We even have stock part numbers listed on the work orders so that maintenance personnel could verify that the parts they were using were correct.

With the inclusion of thermography and vibration analysis, we have now begun tracking machine performance and addressing issues proactively rather than on a time-based program. As our database grows we are confident that our ability to predict failures will grow as well. We have also added Ultraviolet leak detection to assist in controlling the system since we have 48 interchangeable major components along with 288+ hydraulic cylinders, 300+ hydraulic lines, hoses and quick disconnects and numerous other potential points of failures and leakage.

We have also chosen to display control charts at each machine to inform both maintenance and operators as to the current condition of their machine. Maintenance personnel have been trained on how to interpret and use the data displayed. Our maintenance team then assumed responsibility for management and upkeep of the system with data systems being managed by Danny Moore (DuBois on-site Chemical Management) and Doug Hypes (PBR PM Manager). As we discussed at the PdM-2007 conference in Chattanooga, we continue to refine our process and the data we use.

We continue to do all sampling through our chemical supplier because we don't have the ability to do on-site water glycol hydraulic fluid testing affordably and effectively. We have further adjusted our sampling intervals to provide more accurate data which will allow us to diagnose future issues rather than respond to failures.

In conclusion, we would like to encourage all readers to pursue an effective predictive maintenance program. As we discovered in working through this project, not only did we improve our process and quickly began to reduce downtime, but we also realized immediate and sustainable savings. In today's competitive global marketplace, we can't afford to do business any other way. Our machine reliability continues to increase and this project has helped identify several other opportunities for improvement that we hadn't seen before.

We would also like to acknowledge all those who played a key role in our success:

Troy Harvey – Livingston and Havens
Rob Craig – Carolina Fluid Air
Steve Anderson – Y2K Fluid Power
Joe Langmeyer – Livingston and Havens
Brad Smalls – Industrial Distribution Group
Mike Strickland – Castrol NA
Sandy Horton – Parker Hannifin
Danny Moore – DuBois Chemical Management (co-team leader/ on site manager)

And the whole PBR management team for their support in this project

Danny E. Moore is the JohnsonDiversey Industrial on-site chemical manager. He has 22 years experience in manufacturing. Holds a degree in Business management, is a machinist and a licensed master electrician. Danny has served in management roles for 13 years.

No Advanced Instrumentation? No Problem.

Electric Motor Testing with an Amp Meter

by Howard W. Penrose, PhD, CMRP

Last month, Part 1 of this series discussed how to use a Voltmeter for troubleshooting electric motor systems. This month, in Part 2, we will discuss using an Ammeter (Amp Meter) for troubleshooting AC induction motor systems, which will also build upon Part 1.

Both analog and digital ammeters both have their application, and the special features of some ammeters can provide advanced capabilities. However, in our discussion, we will assume average instruments.

Analog Ammeters

The analog ammeter uses an electro-mechanical deflection of a needle that is directly proportional to the value of current being measured. Hand held meters will normally have a clamp and a display, while panel mounted analog meters will have a Current Transformer (CT) providing a percentage of the actual circuit current to the display. The display is then incremented so that it shows the actual full value of current.

The purpose of these meters is to provide a relative idea of existing load. However, they also provide some additional troubleshooting capability. For instance, because an ammeter measures the 'real time' value of current, with some delay that is related to the CT winding and the coil in the display, it can provide the ability to detect such things as broken rotor bars and torsional load problems.

In the case of broken rotor bars, the needle will deflect at a rate that is similar to the pole pass frequency of the operating motor. As this frequency is often around a fraction of a Hz to several Hz, the movement of the needle will be easily visible to the technician. The result would be a ticking motion that will have a magnitude related to the operating current based upon the severity of the number of broken rotor bars. Unfortunately, this can also occur in applications that have a regular varying torque.

Fig 1 - Testing with a Digital Multimeter.
(Photo courtesy of Fluke Corp)

Digital Ammeters

Digital ammeters come in two types: Averaging and True RMS. The averaging ammeter has a built-in algorithm that compensates for applications that include harmonic distortion, such as variable frequency drives, or systems that have a lot of electronic systems connected on the circuit. True RMS (Root-Mean-Square) meters have a built-in circuit that provides readings based upon the real power of the circuit. In an harmonic environment, an averaging meter and an analog meter will not read correctly. However, a True RMS meter will provide an accurate value.

The power of True RMS digital ammeters, hand held or panel, is the ability to compensate for these harmonic conditions and to provide an easily measurable value. Other features can include a min/max capture capability and datalogging capabilities.

Load Measurements

Knowing the percentage of load can help determine if a motor is being overloaded. The value will change depending upon voltage unbalance and the supply voltage versus nameplate voltage. When the motor is operating above 50% of load, the effective load can be calculated by considering both the voltage and current. The average phase to phase voltage (Equation 1), the average phase current (Equation

2), the nameplate voltage (Vn) and the nameplate current (An) are required.

$$V_a = \frac{V_1 + V_2 + V_3}{3}$$

Equation 1- Average Voltage (V_a)

$$A_a = \frac{A_1 + A_2 + A_3}{3}$$

Equation 2- Average Current (A_a)

$$\% \text{ Load} = \left(\frac{V_a}{V_n}\right) \times \left(\frac{A_a}{A_n}\right) \times 100$$

Equation 3 - Percentage of Motor Load

For instance, let's take an application where the motor nameplate is 460 Volts and the nameplate current is 38 Amps. Measuring the phase to phase voltage, we find V1 = 475, V2 = 482 and V3 = 485. When measuring phase to phase current, we find A1 = 33, A2 = 36 and A3 = 38. If we were to consider the current values only, it would appear that the motor was operating at less than 100% of full load. By using current only, the average current would be 35.7 Amps, and the load would be considered 93.9%. However, including the voltage in the calculation by using Equation 3, the resulting percentage load would be 98% load, over 4 points of efficiency difference.

If the motor is rated at 1.15 Service Factor, the motor would be required to have nameplate voltage and frequency supplied. In the example, above, the motor is operating at 4.3% over voltage and 1% Voltage unbalance (reference Part 1 of this series in the Nov issue). The actual load at 98% would be satisfactory. If, however, the voltage unbalance was greater than 2%, then the motor would be experiencing overload.

Current Unbalance Conditions

The NEMA MG-1 calls for a maximum current unbalance of 7% when a motor is being factory tested. However, when a motor is being tested in a plant motor system, there are a number of reasons that can cause current unbalance. Some of the issues can include changes to the circuit impedance, phase unbalances, etc.

A high current unbalance, with relatively low voltage unbalance, can be caused by conditions of a failing motor winding, loose connections or bad power factor correction capacitors. For instance, in one application, a 100 horsepower motor had current draw of 109 Amps, 109 Amps and 72 Amps. The motor user kept removing the motor and sending it in for rewind (which the repair shop was happy to do). After the third time, it was noticed that the system had power factor correction capacitors. They were tested and it was determined that one of three power factor correction capacitors had a blown fuse. The three capacitor leads were removed and the motor was retested with currents of 102 Amps, 101 Amps and 99 Amps.

Due to other electrical conditions in the distribution circuit, such as single phase loads that cause power factor conditions, and unbalanced loads, not only can there be significant voltage unbalances, but current unbalance can be excessive as well. Where an unbalance of up to 7% is acceptable in factory conditions, unbalanced distribution power factor can cause unbalances far beyond that value. Additionally, this can be exaggerated when the motor is lightly loaded (less than 50% or idle). An idle motor will often have a current draw 20 to 40% of full load current.

Other Current Conditions

Some ammeters have a min/max capability. This allows the operator to determine the actual peak current on each phase, when determining the maximum load. You can also determine the peak inrush for an electric motor by setting the ammeter to capture the peak current and starting the motor. This can be compared to the kVA Code of the motor as shown in Table 1.

The locked rotor current can be calculated from knowing the nameplate information and the kVA/HP code (often listed on the nameplate as 'Code.').

$$\text{kVA}/\text{HP} = \frac{\sqrt{3} \times \text{Amps} \times \text{Volts}}{\text{HP} \times 1000}$$

Equation 4 - Calculating the kVA/HP (3 Phase Motors)

$$\text{LRA} = \frac{1000 \times \text{HP} \times \text{kVA}/\text{HP}}{\sqrt{3} \times \text{Volts}}$$

Equation 5 - Calculating the Locked Rocker Amps (LRA)

For instance, if there is a 10 horsepower, Code F motor at 460 Volts and a nameplate current of 11.2 Amps, the LRA would be ~70 Amps. When testing the motor on startup, the max capture of the ammeter should fall close to 70 Amps. If it does not, then it can indicate a

Code	Multiplier	Code	Multiplier	Code	Multiplier
A	0- 3.15	G	5.6 – 6.3	N	11.2 – 12.5
B	3.15 – 3.55	H	6.3 – 7.1	P	12.5 – 14.0
C	3.55 – 4.0	J	7.1 – 8.0	R	14.0 – 6.0
D	4.0 – 4.5 K	K	8.0 – 9.0	S	16.0 – 18.0
E	4.5 – 5.0	L	9.0 – 10.0	T	18.0 – 20.0
F	5.0 – 5.6	M	10.0 – 11.2	U	20.0 – 22.4

Table 1 - kVA Code AC Induction Motors

rotor defect or winding problems, especially when commissioning a new or repaired electric motor.

With ammeters that can datalog or operate and log the min/max over a long period of time, the loading can be determined over a full operation. For instance, if a motor starts tripping unexpectedly, the loading can be monitored to see if something has changed in either the loading or driven equipment. This type of reading can be used as a trendable value and as a proof test by maintenance to indicate if changes have been made to the system that need to be investigated.

Conclusion

Basic tools such as voltmeters, ammeters and other testing tools are quite powerful when evaluating the condition of your electric motor system. The combined use of a voltmeter and ammeter can be used to identify potential problems such as motor loading, power factor correction capacitor problems, rotor and winding problems and commissioning new and repaired electric motors. In Part 3 of this series, we are going to discuss the application of resistance testing.

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

Fig 2 - Testing a Motor Control with a Multimeter.
(Photo courtesy of Fluke Corp)

Precision Balancing Pays

Reap Long Term Rewards With Precision Installation

by Ralph T. Buscarello

Why wouldn't a top plant or maintenance manager want the plant's production machinery to be operating at its best at startup? Perhaps it simply seems too distant a goal, based on perceived obstacles like their plant's limitations, the knowledge required, the proper procedures, and the time and money it takes to make it really happen. This article will provide the step-by-step knowledge of what is required. Let's start with one of the most important questions on any manager's mind, "Will these extra procedures pay off financially in reduced scheduled maintenance costs as well as increase production running time?"

As most machine defects reveal themselves through increased vibration levels at certain frequencies, there are other machine defects that reveal themselves via increased temperature, increased ultrasound amplitudes and so on. However, the primary vibration increases are relatively simple to list. My company Update International's experience, comes through teaching seminars for over 50 years throughout all of the industrial areas of the US, Canada, and in over 51 other countries worldwide. The following points represent what we have found to be true for most sources that produce increased vibration amplitudes.

We believe that 90% of all machinery trouble can be easily prevented from occurring in the first place.

- Rotor imbalance represents about 40%
- Shaft coupling misalignment represents about 50%
- All other trouble sources such as improperly installed bearings, bent shaft, eccentric armature, rotor bar problems, on and on, add up to only about 10%

We believe that 90% of all machinery trouble can be easily prevented from occurring in the first place.

Starting with the financial side, one paper mill took our suggestion to record the highest vibration amplitudes on approximately 50 ordinary pumps, each with the similar nominal speed of 1800 rpm. Then, they plotted the amplitudes in decreasing order. On the same graph, they also plotted their recorded maintenance costs for the same pumps for a period of two years. Although I have always believed that decreased vibration results in decreased maintenance expense, I was really surprised at the results. The first "surprise" was that they already had pumps with amplitudes in the "precision" amplitude range, which was our goal. The precision was measured in amplitudes of approximately 0.03 in/sec and less. For these pumps, the maintenance costs over the two-year period were approximately $4,500 and less.

For those pumps with amplitudes of approximately 0.03 to 0.05 in/sec, the maintenance costs were around $4,500 to $7,500.

And now comes the surprising results of the pumps that had amplitudes of roughly 0.1 in/sec. Remember, probably 90% (or more) of vibration or condition monitoring specialists usually accept those machines that have vibration amplitudes of 0.1 in/sec or less as "good or okay". Now for the amazing financial difference!

The pumps with amplitudes approximately 0.06 in/sec to 0.1 in/sec all had maintenance costs of approximately $10,000-$17,000 over the same period of time. The difference between the pumps with a precision vibration level of 0.03 in/sec and the ordinary 0.1 in/sec was over $5,000 per pump! For those over 0.1 in/sec you wouldn't even want to know the financial maintenance costs!

Some plant and maintenance managers think these differences in maintenance costs are part of a vibration training company's sales pitch. Not so. I would challenge you to determine your own plant's maintenance costs versus vibration levels by performing a plant survey outlining actual practices and attitudes of your own craftspeople, supervisors and managers combined with their cooperation towards goals for greater precision/proactive maintenance. Let's face it, reducing maintenance costs by 50% would be a dream come true. Let's look at what it will take in actions and time

to accomplish this. Will it really be worth it? Let's find out.

Where to Start

The easiest starting place is to specify that all of your new or rebuilt motors will have a vibration specification of 0.03 in/sec or less (you probably can hear the screaming already!). One plant gave a specification of 0.05 inches per second to their motor rebuilders. They also tested each motor's vibration level upon arrival, placing it on a rubber mat so it wouldn't walk across the floor (which eliminated the need for bolting the machine to the floor). The rebuilder was told that motors beyond 0.05 in/sec would be shipped back at the rebuilder's expense. The result? Let's see!

At first, 75% of all rebuilt motors passed the test. That meant that work would be required for only 25% of the motors. This usually requires the need for better balance and more careful assembly. The rebuilder, of course, now routinely performs better tests and corrections than ever before. Usually one of your own vibration team members can learn the testing and balancing correction procedures in only two days.

A separate phase of this precision-related program involves rotor precision balancing. Obtaining precision balancing on all rotors that go through your own shop or your contractor's shop is a must. Most major new machinery manufacturers will indicate that their balancing tolerances are based on "international standards" or (ISO standards). However, I was on the original ISO committee to determine those standards. The discussions for those standards were held around 1956. Most were supplied by one nation's committee. They did a good job for that time in history, but the standards were based on expectancies during World War II. Today, the world's competitive situation has changed drastically and to be proactive in a precision world we must routinely perform better balancing procedures.

The ISO standard that is used by most new machinery manufacturers calls for ISO G 6.3. Its recommendation is for ordinary motors, pumps and other general machinery; however its considerably closer standard calls for G 1.0. That small tolerance was recommended for equipment such as "tape recorders." However, at around the same time the U.S. Navy prepared a specification for motors, pumps and other general machinery which was 4 W/N ~ 4 times the rotor weight (at that end of the rotor) in pounds. N was the rotor's operating RPM. This standard was created for what used to be called "atomic submarines" (now called nuclear submarines).

Coincidentally the centerline orbit created by a rotor balanced to G 1.0 was only about 20 to 25% greater than the orbit created by 4 W/N. As a result, most plants calling for precision balance for maintenance cost reduction usually settled for G 1.0.

How Much More Work Does It Take?

Let's consider how much more effort it requires to obtain balancing from G 6.3 down to G 1.0 (or 4 W/N). Before starting, recognize that the rotor's centerline around the axis of rotation is approximately 6 times greater than the orbit for G 1.0. Also remember that an orbit resulting from a balance to 4 W/N is "good enough for a nuclear submarine" – and that is really, really good!

The balancing machine's operator has to properly set up the balancing machine whether planning to quit at G 1.0, G 2.5 (usual compromise intermediate tolerance) or going all the way to G 1.0. Setup time is the same for whatever tolerance is to be achieved.

Once approximately G 6.3 is accomplished, further careful balance to G 1.0 would usually require an extra half hour. However, assume that this is a new goal for the operation (who may need a day or two of extra training). Change the ½ hour to one hour!

True precision balance requires more careful rotor assembly (such as proper key length). More careful assembly starts at the balancing machine and continues by the mechanics

performing final assembly. For these careful steps, assume ½ hour (but once it's routine, only a few minutes).

Now let's talk about precision alignment, also "good enough for a nuclear submarine." At most plants the usual alignment times are reduced to about half through proper precision-related training. However, for those new at it, add an extra ½ hour.

And, of course, as with all skills, there are details to learn. For example, there are different balancing procedures for narrow and overhung rotors, compared to balancing rotors with both planes in between bearings. Gears are also not a problem when you know the basics. Field balancing, of course, requires its own special details.

Now what is needed is one more FFT test of the total running machine to determine if any vibration peaks at specific frequencies would reveal possible resonances to those frequencies. The mechanic obtains the FFT readings from the machine position that produced the worst reading. Whether good, bad or indifferent, the mechanic loosens and tightens each hold down bolt, one at a time, while watching for when the greatest decreases in specific vibration peaks occur. This is called the foot-frame-resonance test. Almost all machines will show an appreciable decrease in amplitude at one or more of the vibration peaks. An "appreciable" amount is usually an expectancy of at least a 30% decrease. At the hold down bolt that produced the greatest or desired decrease in amplitude, careful re-shimming is applied. Usually, re-shimming is enough. However, in some situations, further resonance tests are necessary to determine which part of the machine's piping, support system, covers, etc. are resonant and require correction. Usually a member of the plant's vibration team performs these resonance corrections. However, by working with the mechanic that put the machine together and performed the foot-frame-related resonance test, the mechanic usually learns enough to perform future resonance tests without the need for the specialist to always be present.

For the usual FFT measured foot-frame-resonance test and subsequent corrections, add about one half hour. If resonance goes beyond the frame or skid and requires work, for example, on piping, covers, beams, corners between horizontal and vertical pipes, it would require an additional hour.

Now let's look at what the mechanic's or vibration specialist's FFT tests revealed. Sometimes, instead of showing the usual vibration peaks of only 1x, 2x, perhaps 3x or 4x rpm, the plot reveals harmonics (exact multiples of rpm) that are spread across the main part of the spectrum. Although such harmonics usually are the result of a rub or looseness, my

company's more recent experience indicates that the more probable root cause originates from a rolling element bearing that has been installed too tight, too loose or cocked. To determine which bearing caused the harmonics may involve further discussion with the mechanic who performed the main assembly work. Although this may require a half to one hour of discussion, the results from correcting the problem before turning the machine over to operations is invaluable.

The Costs, The Payback

So let's review the extra work required to get your machines routinely commissioned with vibration amplitudes of 0.02, or at the most, 0.04 in/sec:

Work	Extra Time
Motor Solo Tests	1 Hour
Precision Rotor Balance (G1.0 or 4 W/N)	1 Hour
Precision Alignment	.5 Hour
Foot-Frame-Related Resonance Tests	.5-1 Hour
Add'l Resonance Tests (piping, etc.)	1 Hour
TOTAL	4-4.5 Hours

So if we take 4.5 hours, at a rate of $100/hour, we come up with $450.

That's $450 to get a machine with less than half the usual maintenance costs. But, even more valuable than the maintenance savings, you'll also get less than half the lost production that usually accompanies the machine being shutdown to replace a bearing, rotor or seal. Worth it? You decide! The hardest part is to change your maintenance culture from "ordinary, okay, good enough" to "precision/proactive – good enough for a nuclear submarine." It does take several days of meetings, continuous followup and inspections. With the right process and the right attitude, it should not take longer than about a month.

Ralph T. Buscarello is the founder and CEO of Update International, a leading company in vibration-based machinery maintenance training. As a pioneer and leading authority on vibration analysis, he has conducted seminars in more than 40 countries worldwide. He currently leads the overall development of training and consulting services for the company. Ralph has 48 years of experience in practical vibration-related machinery improvement, teaching it for the last 36 years in over 40 countries worldwide. Although Mr. Buscarello has engineering degrees, mechanical and administrative, both from the University of Denver, he is especially known for his down to earth approach that makes it easy to understand and apply. Ralph can be reached at 800-530-4215 or 303- 986-6761.

Down and Dirty

Auditing Soot Blowers in Coal-Fired Power Generation Plant

by Jim Hall

Today's coal-fired power plants are the workhorses of the U.S. power industry, accounting for more than half of the nation's electricity. All power generating plants, no matter what fuel they use, are high maintenance plants, and within them continuous planning, scheduling and maintenance is a given. Since it can cost from $15,000 to over $30,000 per hour, downtime in a power generation plant is simply not an option. Most, if not all, power generation plants have mature predictive and preventative maintenance programs, which are under the gun to perform 24/7.

Soot blowers are used for removing soot build-up from boiler tubes in fossil fuel burning power generation plants. There are several different types of soot blowers, but most in use today use either steam or compressed air as a means to clear the ash that builds in the boilers and piping. Properly operating soot blowers are essential to profitable operation, allowing increased efficiency and reduction of air emissions, such as nitrogen oxide (NO_X). They also happen to need continuous maintenance. It is not uncommon for a plant to have 2-6 people dedicated full time to the maintenanceof their blowers.

A mid-size coal-fired power plant can have a hundred or more soot blowers. Typically controlled by an "intelligent" computer program, they operate on an automatic, timebased sequence and indiscriminately clean the boiler, dirty or not. These systems were designed to replace the manually operated systems by recognizing patterns or conditions and to make decisions about when to operate the soot blower.

However, these intelligent computer systems do not replace technicians and engineers. Maintenance engineers and technicians still must implement an on-going program of maintaining the system.

A clean boiler means less NOX makes it into the atmosphere through the stack. It also means more power makes it's way to the power grid. Although the difference in efficiency may seem like a small percentage, for a large power plant that runs continuously, every percentage point means significantly more power for us, the consumers.

Soot blowers use high-velocity jets of steam or air to remove carbon ash residue that is deposited on the inside, or fireside, surface of a fossil fuel recovery boiler. The soot acts as insulation and reduces the efficiency of heat transfer from the flame to the boiler water. Unless the soot is removed, the overall efficiency of the boiler will continue to decline. Efficiency is restored by blowing air or steam across the surface of the boiler tubes to knock the soot off. Typically, this task is performed on a daily basis in order to keep the fireside surfaces relatively clean.

Most aging fossil fuel power plants should look at their soot blower systems for added efficiency.

Soot Blower Survey

On a recent air leak audit we were asked to survey the compressed air supply piping for the soot blower system. This system consisted of 50 soot blowers and several hundred feet of piping from the compressor to the ninth floor of the plant.

The piping for this system consisted of two-inch to six-inch solid and flexible braided piping. There were welded

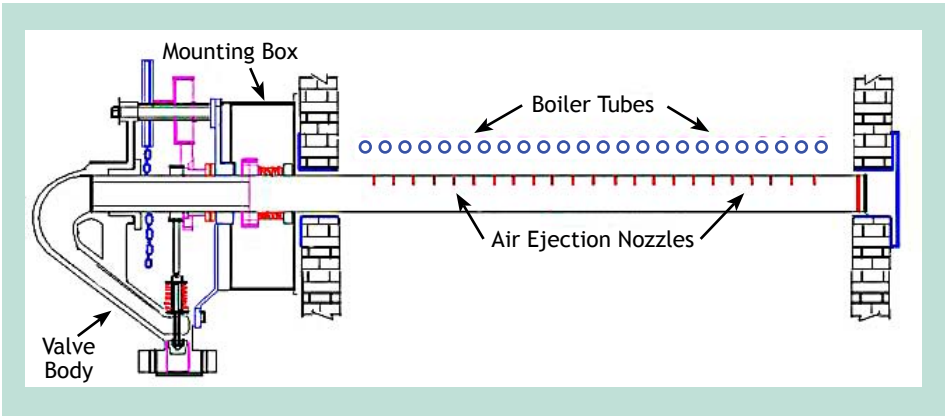


Figure 1 - Typical Wall Mounted Soot Blower

seams as well as flanges and pipe couplings with inner seals that had both braided gasket material and rubber seals.

Figure 2 - SDT 170 MD with Flexible Wand

For this particular audit we chose to use an SDT 170 MD ultrasonic receiver and 31 inch flexible wand (Figure 2.). As you can see by the pictures of this survey, the flexible wand was extremely useful. Rather than tag each leak with a paper tag, we chose to digitally photograph and record leak location and a description of the leak.

The work was hot and dirty, but I couldn't help having a feeling of accomplishment when discovering so many leaks on the system. Some forty-seven leaks were noted. The leaks ranged from xx-large to very small. I defined a leak as extra-large if the reading was 50 decibels or more, a large leak as 37-49 decibels and a small leak as anything below 37 decibels.

Figure 3 - Technician scanning a leaking coupling in a wall mount soot blower.

One of the technicians in the plant had been defining a leak as one that you can hear. However, even at 300 psi, you may not hear the leak with your own ears, especially with substantial background noise. That is one reason ultrasonic receivers are so valuable. Airborne ultrasound receivers are instruments designed to hear sound above the human hearing range. Ultrasound is defined as sound above 20 kHz. In a power generation plant the ability to filter and/or reduce background noise is imperative to finding gas, steam, vacuum and pressure leaks.

Figure 4 - Shut-Off Valve internal packing leaking compressed air.

This system was pressurized to 300 psig but, with this many leaks I cannot believe the system could have been working at optimum level. Typically, systems like the one we audited have the compressor located on the first floor with soot blowers up to the ninth floor. After passing so many leaks, pressure that may have started at 300 psig on the first floor simply had to be much lower on the ninth floor.

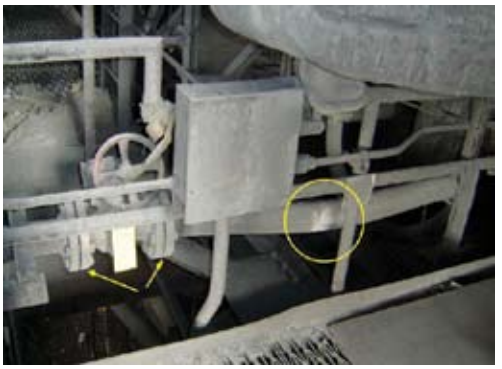


Figure 5 - Shut-Off Valve leaking at flanges (yellow arrows) and ruptured 3" Braided Header Pipe (yellow circle)

Figure 6 - Wall Mount leaking at flange coupling (yellow arrows).

Several of the leaks we found were in high ambient noise environments. The ability of the ultrasound instrument to hear those leaks made the survey much easier to perform. Having an ultrasound instrument with the ability to adapt not only to the ambient background noise but, also to the surroundings is a plus. The SDT 170 model has both an 18" and a 31" flexible wand. The threaded end of the flexible wand can also be adapted to an extension such as a 12 foot telescopic pole (not an option offered by SDT) to reach high into the overhead scan header pipes that would be otherwise out of reach and not practical for scaffolding.

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

Upgrades Improve Reliability

New Sensors, Continuous Monitoring Provide Solid Defense

By Jeff Helfer

Monroe County Department of Environmental Services (MCDES), in Monroe County New York, is responsible for managing the county's solid waste policy, fleet services, engineering/facilities management and wastewater management. Wastewater management, known as the Pure Waters program, is the biggest component of the department's budget and overall responsibility. Pure Waters consists of four different sewer districts and services over 700,000 residents.

Through a cost-effective consolidation of conveyance and treatment services, nearly 40 billion gallons of wastewater are processed annually through more than 1,000 miles of collection system, 55 pump stations, two large wastewater treatment plants and a nationally-recognized 175 million gallon tunnel storage system (Combined Sewer Overflow Abatement Program). MCDES strives to be a progressive, vibrant and dynamic organization while maintaining very reasonable and stable user fees.

Figure 1 - VanLare Wastewater Treatment Facility, Monroe County, NY

The county's VanLare and Northwest Quadrant wastewater treatment plants are located on the south shore of Lake Ontario. The VanLare facility, shown in Figure 1, dates back to 1916 and is the largest treatment plant in Monroe County. The current permit for the plant is at 135 million gallons per day (MGD) with a capability of handling 660 MGD during our larger storm events. The Northwest plant in Hilton is rated at 22 MGD and averages 14 MGD. They both use state-of-the-art centrifuges and biosolid offload facilities to process biosolids for delivery to area landfills. These biosolids are then mixed with garbage to enhance methane gas production, which will be collected and used as fuel for a landfill gas power plant which will sell electricity back to the grid.

The VanLare facility is supplied by a gravity feed siphon from our deep tunnel storage system and the Cross Irondequoit Pump Station, a massive pump station containing five 1500 HP, two 1250 HP and two 700 HP centrifugal pumps. A recent upgrade to this pump station has provided four brand new pumps and new controls for the entire station—including energy monitoring to ensure our compliance with peak demand electrical costs and vibration protection on all associated pumps and motors in three axes on each piece of equipment.

In the past, only one axis was monitored and several problems went undetected if the pump wasn't vibrating in the direction that was being monitored. Now if the problem occurs in the vertical, horizontal or axial plane, the vibration sensors will display the problem and, if the preprogrammed limit is exceeded, will automatically shut down the pump.

There are three large pump stations that serve the Northwest facility. The Buttonwood station houses four 500 HP centrifugal pumps; Flynn Road station houses three 325 HP pumps; and the Island Cottage pump station has three 300 HP pumps. When these pump stations first went on line, the mechanical health of the machine was determined by a route-based vibration data collector and trending. Readings would be taken every three months and the data trended to look for any problems. Process upset events would be missed if no one was actually standing there when it happened. A pump would be reported for shaking, only to find the problem mysteriously gone when later investigated. Problems continued to occur with high pump vibration and determining the source was difficult because the event would not be consistent.

We decided to install the IMI 640B01 4-20 mA sensors (see Figure 2) in all three pump stations. These two-wire loop powered sensors offered continuous monitoring of the overall vibration levels. The data is sent through our SCADA system which has its own securely protected process network (separate from the other county wide area network), and consists of hundreds of miles of fiber optic cables and approximately 40 microwave radios. The current output from the sensors allowed for simple interaction with our SCADA system.

Figure 2 - IMI 640B01 Sensor

In the early 1990's, because of the need for additional reliability, we decided to shift our communication focus away from telemetry and towards these newer technologies. The critical downtime suffered on our leased lines was becoming way too costly. The costs surfaced in a number of ways, including

- Regular communication failures resulting in personnel being dispatched to investigate.
- Waiting for repair through another agency.
- The speed of data transmission. You can transmit more data faster through fiber optics and radio.

After evaluating all of these factors, we decided that the leased lines were no longer

Figure 3 - New Sensor System in Charlotte, NY pump station.

the best option for us. The upgrade to fiber optics and continuous monitoring has allowed us to identify key process upsets as they happen and display the conditions of the station in real time. The data is available to anyone in MCDES with a computer via our CITECT internet display client which we have installed on all our computers. This allows technicians that aren't in the control room, access to vibration data and the hundreds of other data points such as pressure, level, flow, RPM, temperature, etc. at each site.

The control room at the VanLare facility is a state-of-the-art communication center that is the hub of our maintenance operation. It has four 8 foot by 8 foot projection screens for displaying weather radar, our deep storage tunnel system and our wide array of varying pump stations and security cameras. All maintenance activities for the sewer collection system and plant operations are coordinated through dispatchers that monitor all the alarms from these pump stations and tunnel sites as well as the fire and security

Figure 4 - Author Jeff Helfer inspecting the sensors on pump #2 at Charlotte Pump Station.

systems for Monroe County facilities. The upgraded facilities and data provided instant results. As one co-worker put it: "It was like turning a light bulb on in a dark closet."

We began to see a pattern developing at all three pump stations. Due to the fact that we use variable frequency drives, at certain speeds the vibration would go off the scale, but then return to normal as the pump changed to a different speed. Impeller build up was usually suspected, and the pump was back-flushed or pulled, only to find no debris in the pump. With a simple bump test and a run up and coast down test, what we actually discovered was a case of resonance. As with most resonance issues, the problem was to stiffen or not to stiffen. We just didn't want to arbitrarily place braces just anywhere because of the possibility of shifting the problem to another area or exciting another natural frequency. This prompted us to have an Operational Deflection Shape (ODS) analysis completed to show us just how these pumps were shaking. They were all of similar

design and base construction, so solving the problem on one meant solving the resonance issues on all of the pumps. The ODS and a finite element analysis are now being used to construct a model to properly support and stiffen the structure to move any unwanted natural frequencies away from the operating range of the pumps. This problem would not have been so easy to find and troubleshoot had we not installed the on-line sensors and trended them versus the pump RPM.

We now use these 4-20mA sensors as a first line of defense against problems that can arise during start up or acceptance testing of new or rebuilt pump stations. Because they offer a current output, they can be easily incorporated into existing systems without the burden of sophisticated data analysis procedures and equipment. We are standardizing the use of these sensors in all of our new upgrades and installations of critical equipment. We now incorporate a vibration limit into all our pump specifications and critical machines in our treatment plants and collection system. Reliability has become a major focus of our maintenance department and using these on-line sensors has helped us move toward achieving our goal. They have become as important as our route-based vibration program and alignment and oil analysis. All of these tools add up to more ways to determine the health of your machinery and to add confidence that critical downtime can be avoided by using different ways to monitor, control and detect vibration problems that occur when no one is there.

Figure 5 - Close-up of Sensor Mounts at Charlotte Pump Station.

Jeff Helfer is a Station Mechanic with the Monroe County Department of Environmental Services in the Instrumentation and Electrical Department. Jeff has worked in the Predictive Maintenance field for the last 10 years and in Rochester, New York for the last 16 years. He is responsible for the test, calibration, and repair of wastewater instrumentation and a level 2 certified vibration analyst, based out of the Frank E. VanLare wastewater treatment plant on Lake Ontario.

Communication is the key to having a successful relationship.

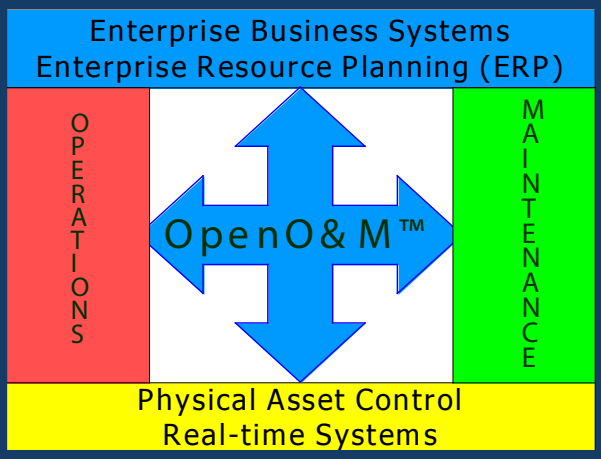
MIMOSA

Opening the doors of communication for greater efficiency

What is true for people is also true for your information systems. The EAM, CMMS, PCS, Distributed Control System and all Condition Monitoring software programs should be able to speak the same language. In most facilities, this is accomplished by having a software engineer (either in-house or contracted) spend a lot of time writing interface programs. In the end, all the programs will speak to each other, but each facility (or company) spends a lot of their precious resources to make that happen. Imagine every factory in the world having to go through this process.

Wouldn't it be better all of these software packages spoke to each other right out of the box? Sort of like Plug and Play for the manufacturing industry.

We caught up with Ken Bever, the CTO and Technical Director of MIMOSA, an organization which develops and promotes open information exchange standards for operations and maintenance, to check on the progress his organization is making in this area.



What is MIMOSA?

MIMOSA is an alliance of Operations & Maintenance (O&M) solution providers and end-users developing consensus-driven open standards to enable Open Standards-based O&M Interoperability. MIMOSA is officially organized as a not-for-profit trade organization. MIMOSA members are industry leading solution providers and end-users who are shaping better O&M solutions that can be delivered quicker at lower costs. MIMOSA's membership includes over 60 corporations, universities, and military bodies.

Explain why open information standards for Operations and Maintenance data so important to the industry right now?

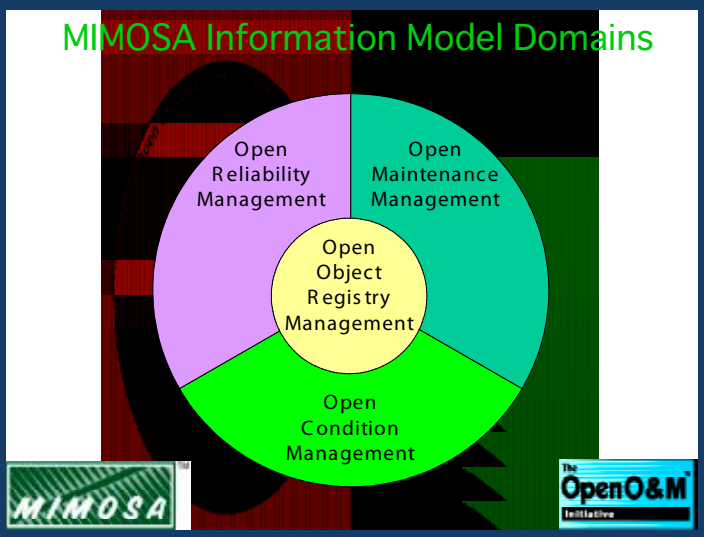
Currently, most asset-intensive enterprises are collecting a vast amount of data, but lack information on which to base vital decisions, such as whether to accept an order to produce a product with a given set of constraints (cost, time, delivery location, penalties, environmental/safety requirements, etc.). Enterprises that are critically dependant on complex physical assets in their plants, fleets and facilities have focused their systems integration efforts in two significant horizontal layers; Real-Time Control and Business Information Systems. The subject matter experts in these two communities seldom work directly with each other and they have not focused on integration between the two layers, resulting in a significant vertical information gap. This gap is compounded when the O&M processes, systems and people in these same enterprises are poorly integrated with each other, producing a corresponding horizontal information gap. Together, these gaps create a large hole in the very center of enterprise process and information integration.

Historically, the resulting operational inefficiencies have been overlooked or assumed to be irresolvable, due to the lack of interdisciplinary understanding. Overall optimization requires proper integration of O&M processes, systems and people. With today's increasing competitive pressures, effective solutions must be found to eliminate such major impediments to efficiency. MIMOSA's Open Systems Architecture for Enterprise Application Integration (OSA-EAI) provides a valuable "how-to" integration model to industry. The MIMOSA OSA-EAI open model includes the domain areas shown in the graphic on the following page.

Who do you think stands to benefit the most from the adoption of open standards?

Open information standards enable end-users, suppliers, and integrators to focus on higher value added activities that are specific to their organization.

End-users arguably benefit the most from open information standards since the enterprise now can "own" its data and information, rather than being dependent on proprietary systems and vendor-driven formats. These standards are critical enablers for information models that are needed to provide plant-floor visibility to multiple sites and applications. Estimates of the impact on the savings achieved from integrating business processes using open information standards range from 3 – 7%. This would translate into an additional profit of $1.34/barrel for a petro-chemical enterprise based on the



price of gasoline @$2.75/gallon!

However, we shouldn't neglect the value for product suppliers, since open information standards stimulate the development and deployment of new classes of value added applications leveraging this open information. Another "hidden" value of adopting an open standard is to enable multiple products from the same supplier (perhaps acquired over time) to rapidly integrate with each other!

Finally, integrators also stand to benefit because customer integration projects which could not be funded before – because of the incredibly high initial and life-time cost of developing point-to-point interfaces – are now cost-effective through the use of open information standards.

At the end of the day, adopting open standards seems to be a win-win situation - good for end users and vendors. What do think is holding some people and companies back?

More than anything, I believe end-users are confused by the plethora of standards around today and do not have the time to make sense of which open standards are applicable for a particular integration effort.
While MIMOSA is dedicated to providing open standards for Operations and Maintenance, integrated O&M solutions will also need to leverage other appropriate standards. Since there are dozens of other potentially applicable open standards, MIMOSA and other leading standards groups agreed to collaborate through the OpenO&M Initiative. This effort enables standards-based interoperability for O&M information systems, business processes and professionals. The current participating organizations are: ISA (SP-95 and SP-88), OPC Foundation, Open Applications Group (OAGi), and World Batch Forum (WBF). Other appropriate organizations are encouraged to join.

I know many companies are members of MIMOSA now. Which companies were among the earliest to begin working with you?

We have appreciated the input from a wide variety of members. Early on, the Hartford Steam Boiler Inspection & Insurance Company provided us with valuable technical assistance and support. Since this company insures about 40% of the domestic machinery in the U.S., they assisted in providing input to MIMOSA's OSA-EAI Open Registry which allows an as-designed, as-built, and as-maintained view of the lifecycle of all types of assets as they are installed in functional segments in plants, facilities, or fleet equipment. Also, BP has been a valuable end-user of MIMOSA's open standards and have assisted us in continual improvement of the standards.

Earlier this year the U.S. Department of Defense mandated the use of MIMOSA standards in order to conduct business with the U.S. military services. How has this influenced the progress of your work with open standards?

This is an important milestone for MIMOSA adoption in the U. S. military services. MIMOSA standards were inserted as mandated standards in the Department of Defense (DoD) Information Technology Standards Registry (DISR) Baseline Release 06-1.0 on 21 February 2006. Mandated standards are standards deemed essential for providing interoperability and net- centric services across the DoD enterprise, which facilitate the flow of information to the warfighter. The Software Engineering Directorate (SED) at the U.S. Army Aviation and Missile Research, Development, and Engineering Center has established a MIMOSA Center of Excellence to assist DoD organizations in the implementation of the MIMOSA standards. SED personnel have assisted in organizing the OpenO&M™ Military Joint Working Group, which provides a collaborative forum to help enable standards-based interoperability in the Joint Military Services. We look forward to continuing collaboration with the DoD in the OpenO&M™ Military Working Group.

What are some of the toughest challenges you face right now?

One of our biggest challenges is education – helping end-users, suppliers, and integrators to understand and utilize the standards which are available today for their real project needs. We encourage end-users to commit technical resources to learn about the OpenO&M standards and understand when and where to specify these on future RFQ's. We value input from end-users on the highest priority areas where we need additional standards development. Another challenge is to continue to expand our supplier and integrator organizations. We are vitally dependent on their technical expertise to assist us in the MIMOSA Technical Committee.

At this point, what has to happen to move the adoption of open information standards for O&M forward the fastest?

The speed of adoption is driven by the end-user organizations. We need informed end-users who communicate the strategic importance of supporting these efforts to their key vendors and integrators. This includes mandating the use of MIMOSA and OpenO&M standards whenever integrating O&M systems to the enterprise.

How can interested people get more information about MIMOSA and open standards for O&M?

Additional information, can be found on our website - www.mimosa.org

For organization information contact MIMOSA President Alan Johnston at (205) 553-8104 or atjohn@mimosa.org

For technical information contact MIMOSA CTO Ken Bever at (513) 276-4105 or kbever@mimosa.org

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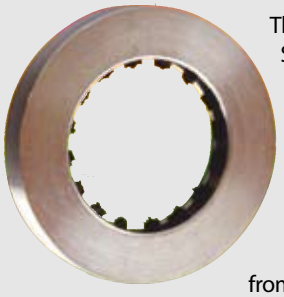

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