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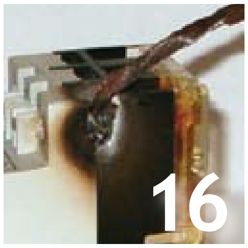
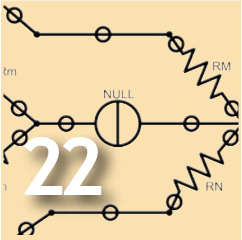
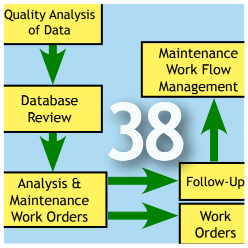






Moving Forward

Welcome to 2007!

Each year, most of us make our New Year's resolutions. Some of them we keep, some fall by the wayside. To kick off 2007, we decided to bring you a feature story that we think will help you throughout the coming year and longer. Consider it a New Year's resolution for your reliability & maintenance (R & M) program.

Esteemed author Terry Wireman contributes this month's feature article that communicates exactly what he thinks is needed to establish a system that effectively measures the success of your reliability & maintenance program. Establishing a true measure of your program is critical for two reasons.

First, the only way to gain long term support from management and corporate decision makers is to prove, beyond any doubt, that your program is successful. I don't think it's possible to overemphasize this fact. Remember that this proof needs to be communicated in terms that they understand. That is why it is so important that the goals, and corresponding measurements (KPI's) of the R & M program be established with input from both maintenance and corporate. The goals and KPI's must be mutually agreed upon or the R & M program will not easily be able to substantiate its advances.

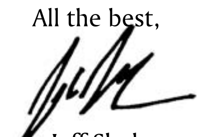
Secondly, an accurate measuring stick is the only way to make improvements in your program. If you don't know where you are, you can't know where you need to go. By clearly identifying what to measure, how to measure it and utilizing the results, you will move your program forward.

Speaking of moving forward, the maintenance program at the National Institutes of Health is a true success story. They have moved from being an organization firmly rooted in reactive maintenance to having a well organized, process oriented condition based monitoring program. Of course, as with any organization that commits itself to a successful CBM program, they have experienced substantial drops in failures, unplanned maintenance work and maintenance costs, and increases in equipment availability and energy efficiency.

The program at NIH won Uptime's 2006 PdM Program of the Year Award for best Precision Maintenance program. Although the folks involved in the program recognize their successes, they have bigger goals they are shooting for. I like that attitude. You can learn more about their program on page 26.

Thank you for reading. Please contact me with any questions, comments or suggestions that will help Uptime be more valuable to you.

All the best,



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Measuring Performance:

More than Just Picking A Number

by Terry Wireman

Performance Indicators or Performance Management – Which one is the focus for Your Company?

In most organizations, the focus is on the numbers. The numbers may take the form of industry benchmarks, internal benchmarks, a corporate mandated number, or just a manager's own personal perception of a number. In these cases, it becomes a matter of managing to achieve a number, not necessarily managing a successful business.

The same is true in managing maintenance and reliability today. Managers may find a presentation, an article, or even a book that highlights certain numbers as goals for a maintenance/reliability organization to achieve. A particular number will usually become the focus for the manager, as it may be related to a current problem in the department or plant. This number then becomes the goal for the organization to achieve. It becomes the base for all management MBO's, scorecards, and incentive plans.

The entire maintenance/reliability organization is mobilized to achieve the "magic number". Unfortunately, this number was derived from an outside source, without understanding the impact of the maintenance and reliability function within the company. The attempt to reach this number has a negative effect on the overall maintenance and reliability function and the total performance of the company's assets.

The desire to manage to a number is one of the largest pitfalls to developing performance indicators. What, though, is the underlying cause of the problem? It is not the lack of desire of the maintenance and reliability organization to perform. It is the fact that few executives understand the maintenance and reliability functions well enough to develop the proper performance indicators to manage maintenance and reliability.

Linked Indicators

Maintenance and reliability are such comples organizational functions that there is no one indicator that can be used to determine their effectiveness. This realization will eliminate the trap of using performance indicators to manage to a number. Achieving success in designing indicators for managing maintenance and reliability is dependant on understanding the maintenance and reliability business sufficiently to be able to link it to corporate goals and objectives and develop tiered indicators that connect functional performance to overall business performance. It is this lack of understanding of the maintenance and reliability business that contributes to the failure of most of the performance indicator systems. For example, a sample business management flow is pictured in figure 1. While this is a typical flow used to manage other business functions, it is rarely used in a disciplined fashion to manage maintenance and reliability. Consider this: How often are items 1 and 2 properly

Managing The Business

1. Understand and Communicate the Maintenance and Reliability Business Goals and Objectives.
2. Determine the criteria for success in achieving the Goals and Objectives and how this supports the Corporate Business Objectives.
3. Develop the Performance Mangagement System to link functional activities to the success criteria.
4. Compare specific performance indicators to the Performance Management System goals.
5. Highlight any deviations or negative trends.
6. Determine the root casue for the deviation or negative trend.
7. Develop a plan to correct the deviation or negative trend.
8. Implement the corrective plan.
9. Measure the success of the corrective plan (the impact on the specific indicator).
10. Begin again at Step 4 - (Continuous Performance Management).

Figure 1 - Steps to Manage the Maintenance and Reliability Business.

understood, communicated, and tracked in most companies? This leads directly to the issue of how clearly the maintenance and reliability strategies are understood throughout the company.

Developing the Maintenance and Reliability Business

In figure 2, the steps necessary to develop the maintenance business are highlighted. As with any other business, these steps begin by defining why the "business" exists. This begins by establishing the goals and objectives of the maintenance business. The goals and objectives of the maintenance organization determine the type of maintenance organization that is established. If the goals and objectives are progressive and the maintenance organization is recognized as a contributor to the corporate bottom line, variations on some of the more conventional organizational structures can be used. Typical goals and objectives include:

1. Maximize Production
2. Identify and Implement Cost Reductions
3. Provide Accurate Equipment Maintenance Records
4. Collect Necessary Maintenance Cost Information
5. Optimize Maintenance Resources
6. Optimize Capital Equipment Life
7. Minimize Energy Usage
8. Minimize Inventory On Hand

While these goals do not form a comprehensive, all-inclusive list, they highlight the impact that a proactive maintenance organization can have on a company and its assets. Maintenance can be - and should be - more than a "fix it when it breaks" function. Unless the maintenance organization works with a proactive list of goals and objectives, its effectiveness will always be compromised and, therefore, sub-optimized.

Organizing to Execute the Business Plan

Maintenance organizations may be considered in two different models. The first is geographical. The second is by the reporting structure.

Designing The Maintenance and Reliability Business

1. Develop the Business

A. Vison Statement
B. Mission Statement

2. Organize to Execute the Business Plan

A. Geographical and Reporting Structures
B. Roles and Responsibilities
C. Determine Staffing Levels

3. Develop a Performance Management System

A. Determine linkage necessary to connect the Maintenance and Reliability Business with the Corporate Business Objectives (Profitability)

Figure 2 - Steps to Develop Maintenance and Reliability Business

1. Geographical Organizations

Organizations can be structured geographically in three basic ways:

a. Centralized Organization
b. Organization by Area
c. Hybrid Organization

Which is the best arrangement? The rules of thumb are that central organizations are more effective in smaller, geographically compact plants; area organizations usually perform well in midsize plants; and combination organizations are best for large plants. When developing any maintenance organization, one must give the plant size and organizational geographical structure careful consideration. If one uses the wrong geographical structure, excessive staffing may be required to properly service the equipment. For instance, if a central organization is used to service a large plant, the travel time to get to the equipment and the resulting downtime may create havoc, with production schedules constantly disrupted.

2. Reporting Structures

Another way to look at maintenance organizations is to consider their reporting structures. Maintenance organizations can use a variety of structures, including:

a. The Maintenance-Centric Model
b. The Production-Centric Model
c. The Engineering-Centric Model

Whatever the structure of a maintenance organization—and structure does vary from organization to organization—it must have the proper focus. Maintenance is a technical discipline. Maintenance personnel are the stewards of the technology in a plant or facility. If the maintenance organization does not have a technical focus, the assets and equipment will be sub-optimized. Therefore, if maintenance is sacrificed to achieve short-term production goals or to support engineering construction projects, the maximum return on investment in the existing assets is never achieved. This situation weakens a company's competitive position in its marketplace. If any organizational redesign is proposed for maintenance, both short-term and long-term issues must be examined.

3. Roles and Responsibilities

In order for maintenance organizations to be effective, certain roles and responsibilities must be defined and assigned. While it is beyond the scope of this material to consider all possibilities, the following are general guidelines that can be used. Although an organization may not use each of the individual job titles listed in this section, each of the task lines must be assigned. Thus, an orga-

nization may not specifically have a first-line maintenance foreman or supervisor who has a responsibility for each individual line item. Nevertheless, the line-item task descriptions are essential if maintenance is to be managed and, ultimately, the company's assets cared for .

First-Line Maintenance Foreman or Supervisor

The following tasks are typically the responsibility of a first-line (or front-line) maintenance foreman or supervisor:

1. Directs the maintenance work force and provides on-site expertise.
2. Ensures that work is accomplished in a safe and efficient manner.
3. Reviews work planning and scheduling with the planner.
4. Ensures quality of work.
5. Ensures equipment availability is adequate to meet the profit plan.
6. Works with plant or production supervision to ensure first-line maintenance is being performed by operators.
7. Verifies the qualifications of hourly personnel and recommends training as needed.
8. Enforces environmental regulations.
9. Focuses downward and is highly visible in the field.
10. Champions proactive maintenance vs. reactive maintenance.
11. Administers the union collective bargaining agreement.
12. Monitors the CMMS.
13. Implements preventive and predictive maintenance programs.

The Maintenance Planner

Another individual in a maintenance organization is the Maintenance Planner. The maintenance planner is different from a supervisor or foreman. Whereas the supervisor manages the maintenance craft workers, the planner provides logistic support to them. The following are the typical responsibilities for a Maintenance Planner:

1. Plans, schedules, and coordinates corrective and preventive maintenance activities.
2. Develops a weekly schedule and assists the maintenance first-line maintenance foreman or supervisor in determining job priorities.
3. Ensures that the CMMS software data files are complete and current.
4. May assist with stores and purchasing functions.
5. Identifies, analyzes, and reviews equipment maintenance problems with maintenance engineering.
6. Assists in educating operations or facilities personnel in maintenance management.

Maintenance Engineer

The following tasks are typically the responsibility of the Maintenance Engineer:

1. Ensures that equipment is properly designed, selected, and installed based on a life-cycle philosophy.
2. Ensures that equipment is performing effectively and efficiently.
3. Establishes and monitors programs for critical equipment analysis and condition monitoring techniques.
4. Reviews deficiencies noted during corrective maintenance.
5. Provides technical guidance for CMMS.
6. Maintains and advises on the use and disposition of stock items, surplus items, and rental equipment.
7. Promotes equipment standardization.
8. Consults with maintenance craft workers on technical problems.
9. Monitors new tools and technology.
10. Monitors shop qualifications and quality standards for outside contractors.
11. Develops standards for major maintenance overhauls and outages.
12. Makes cost-benefit reviews of the maintenance programs.
13. Provides technical guidance for the preventive and predictive maintenance programs.
14. Monitors the competition's activities in maintenance management.
15. Serves as the focal point for monitoring performance indicators for maintenance management.
16. Optimizes maintenance strategies.
17. Responsible for analyzing equipment operating data.

In brief, the Maintenance Engineer is responsible for properly managing assets. The engineer is a key individual if a company is going to maximize asset utilization. It's important to know that a Maintenance Engineer is different from a Project Engineer. A Project Engineer concentrates on new construction and new equipment. The Maintenance Engineer concentrates on optimizing existing equipment or assets. Ultimately, it is the Maintenance Engineer's goal to ensure that his or her company gets as much or more production from its assets than any other company does that has the same kinds of assets.

Maintenance Manager

The following list describes the tasks for the Maintenance Manager, or the individual responsible for managing all of the maintenance functions for a company:

1. Responsible for the entire maintenance function, including the planning, supervising, and engineering staffs.
2. Coordinates closely with counterparts in other in-house organizations.
3. Promotes proper understanding of the maintenance
function to other organizations.
4. Ensures that all supervisors, planners, technicians,

and maintenance engineers are properly educated and trained.

5. Takes responsibility for planning, cost control, union activities, vacation planning, etc.
6. Has responsibility for delegating assignments to the appropriate personnel.

4. Maintenance Organization and Staffing

In this age of downsizing, organization and staffing are among the most critical issues affecting maintenance. How is the maintenance organization staffed? While companies have tried many different staffing formulas over the years, the only perennially successful one is staffing the maintenance department based on work backlog.

Backlog Management

A maintenance work backlog is the amount of work currently identified as needing to be performed by the maintenance department. This amount of work is measured in hours. Many have tried to measure back log by the number of work orders, percentage of production hours, etc., but these measures ultimately never work. The only true measure of backlog is based on hours of work to be done. When calculating the backlog, it is necessary not only to know the hours of maintenance work needed, but also to understand current work force capacity.

The goal should be to maintain the backlog in the two-to-four-week range. If the backlog begins to increase or trend above four weeks, then more resources should be added. From the formula, one can see that there are three options for resources. A company can contract out more work, its employees can work more overtime, or it can hire more employees. Conversely, if the backlog begins to trend or drop below two weeks, the company can reduce resources that are required to perform the work. The company could reduce the amount of outside contract work, reduce the amount of craft overtime, or ultimately reduce the size of the maintenance work force. If the backlog is calculated weekly and tracked annually, seasonal trends and other spikes can be clearly seen. By reviewing these types of records, a manager can ensure that the department is properly staffed.

Maintenance Staffing Options

Staffing is an important component of any maintenance organization. Four methods are commonly used to staff the maintenance organization.

1. Complete In-House Staff
2. Combined In-House/Contract Staff
3. Contract Maintenance Staff
4. Complete Contract Maintenance


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This is not a no-brainer decision. There is not a one-size-fits-all answer. The answer will come but it should be approached with an open mind and a great deal of research.

Developing a comprehensive maintenance/asset management business is a fundamental step in developing a performance management system. If the strategy is not defined, then what does the performance management system measure? Companies need to dedicate proper resources to insure that the strategy is clearly defined and approved, before any attempt to develop performance indicators for maintenance/asset management is undertaken.

Performance Management – A Sample

When an organization has the proper alignment between the business process it is measuring/ managing and the indicator system, data linkage can be developed between the process and the corporate business objectives. This is illustrated in figure 3. If the corporate indicator, such as Total Cost to Produce is increasing, (producing a red light in the stoplight) there should be a contributing indicator for maintenance, such as Maintenance Cost to Produce. If this indicator is also increasing, then it may be contributing to the increase in the Total Cost to Produce.

Just knowing the maintenance cost is increasing is not sufficient. There needs to be an additional level of detail that examines the cause of the increase. For example, if the maintenance efficiency (perhaps productive, or wrench, time) was trending down, this would drive the maintenance cost upward. This would be addressed in the efficiency and effectiveness tier. If the cause was lower maintenance efficiency, then one would need to investigate the indicator further.

The issue could involve proper planning ratios or even proper supervisor ratios. If the planner to technicians ratio is outside the 15-20:1 or the supervisor to technician ratio is out of the 8-12:1 range, then the problem with lost efficiency could be a tactical or deployment issue. Conversely, it could also be any change that has recently occurred in organizational structures, such as going from a centralized organizational structure to an area organizational structure, without proper justification. This change could result in excessive travel time, resulting in lost productivity.

Finally, the resulting lost productivity could have a root cause in a maintenance function, such as the preventive maintenance program. If the PM program is out of compliance, resulting in an increase in equipment breakdowns, the additional reactive work could also be the cause of lost maintenance productivity.

Conclusion

Managing the performance of a business

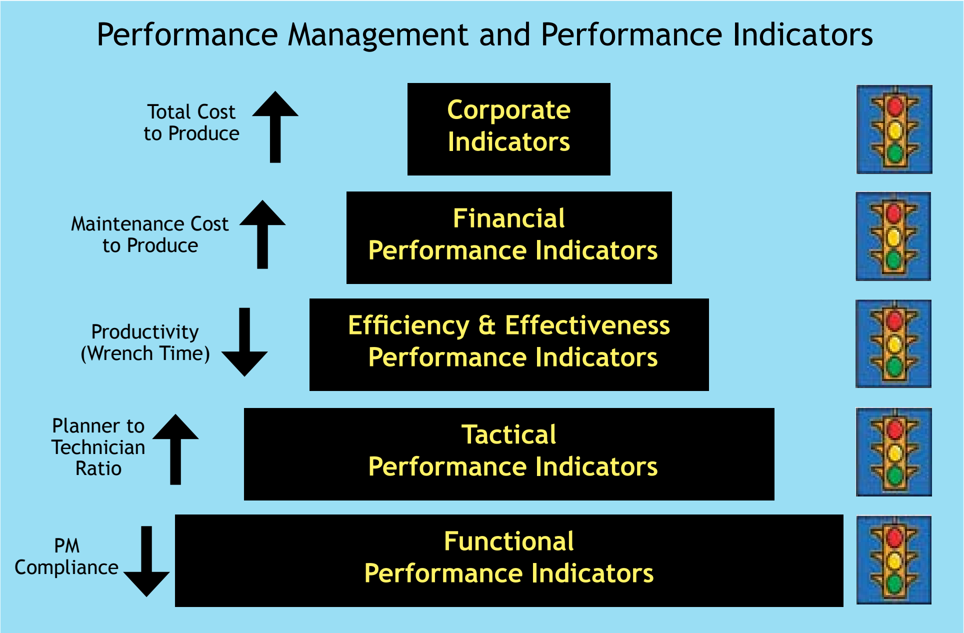


Figure 3 - Relationship between Performance Management & Performance Indicators

requires that all aspects of the business be tracked by performance indicators. These indicators, when properly structured and properly monitored can provide a wealth of information that will allow for proper management of the business. While it may seem like a numbers game, it is proper evaluation of the right performance indicators that lead to effective performance management. The data collection adds no value unless the business is properly managed, based on the data. If organizations today are to optimize their maintenance and reliability businesses, they must change their focus from performance indicators to performance management.

Terry Wireman is Vice President and a member of the Vesta Advisory Board. For over two decades, he has been specializing in the improvement of maintenance management and reliability. Mr. Wireman helps customers develop "World Class" maintenance and reliability policies and practices. As an international expert in maintenance management, he has assisted hundreds of clients in North America, Europe, and the Pacific Rim to improve their maintenance effectiveness. In addition, he has authored twelve books and numerous white papers and articles related to maintenance management process and technology.

The Domino Effect

Find the Problems That Cause Bigger Problems

by Jeffrey L. Gadd

Infrared inspection of electrical distribution and other critical equipment is a cost-effective, proactive way to protect your company's assets. Electrical infrared thermography can be a maintenance manager's crystal ball - allowing him into the future. As thermographers, we find many problems from minor to severe. Sometimes, we find problems that I like to call "Show Stoppers" which can cause a chain reaction of production failure… or the Domino Effect.

Proactive vs. Reactive

Taking a proactive approach to maintaining your company's assets by having an infrared inspection performed is an easy choice. Exact return on investment (ROI) varies with each operation, but is at least 4:1 or $4 return on every $1 invested. Even if I weren't involved in the infrared service industry, I would buy stock in this. Where else could I invest $1000 and get a $4000 return?

The insurance industry believes in infrared inspection and is becoming a major driving force in the industry. Insurance companies are very good at making money, so the fact that they are increasingly interested in infrared inspection provides a significant clue as to its value. Many companies would be wise to take note of this trend. As a condition of the policy, some insurance companies require annual infrared inspections along with annual fire system testing. They offer discounted premiums to get you to conform or increase your deductibles or premiums if you do not conform. Insurance companies minimize their risks by requiring or "encouraging" facilities to perform IR electrical surveys.

The reactive approach to maintenance can only be described as 'Run to Failure' and is obviously not the correct method. How many of you reading these words are currently working for, or have in the past, worked for companies that use this reactive approach? A machine or line goes down and the parts needed are nowhere in sight. All of a sudden, money is no object, you find the part three states away and have it expedited 1st class on AirForce One. To borrow a line from Jeff Foxworthy, Your company might be reactive…

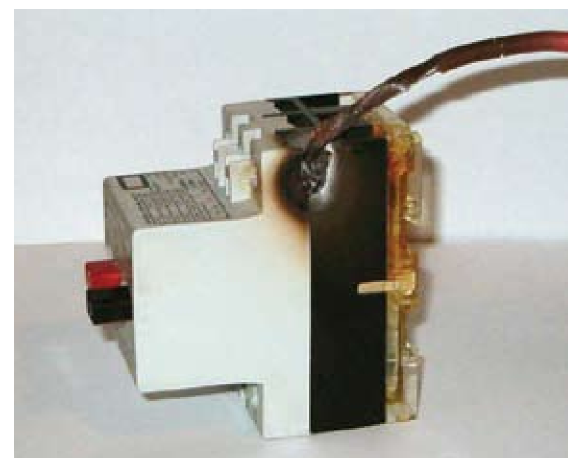


Figure 1 - Damaged Electrical Component

...if you open your electrical cabinets and see an image like this (Figure 1).

This is not necessary and could have been prevented. It actually took many months for the component to reach to this point. Did the company save money by not having an infrared inspection performed? Absolutely not. The machine was down for 36 hours while the part was found, shipped, received, installed and put back on-line. Most successful companies have annual or semi-annual infrared inspections performed either by in-house technicians or contractors. Infrared cannot find or eliminate every problem, but if your competitor is doing proactive maintenance by using infrared and other PdM technologies and you are not, then your company's future could be quite dim. I have yet to meet a customer who regretted having an infrared inspection performed. Your operation can't afford NOT to use infrared.

Crystal Ball

Once a maintenance manager has his/her infrared report in hand, it can serve as the crystal ball of the health and reliability of the electrical and mechanical systems. He/she is aware of the problems yet to come. Armed with this information, they can allocate the appropriate people and resources to make corrective actions - before a failure occurs. No one wants the light [heat] shining on himself or herself when there is an outage or catastrophic failure which could have been prevented. Scheduled downtime to make necessary repairs is much more palatable to management, especially when you have a graphic report of a potential problem with pictures. How better to show your superiors that you were on the ball, avoided downtime and the exponential costs associated with it, and how nice it is to take these reports to your next job review.

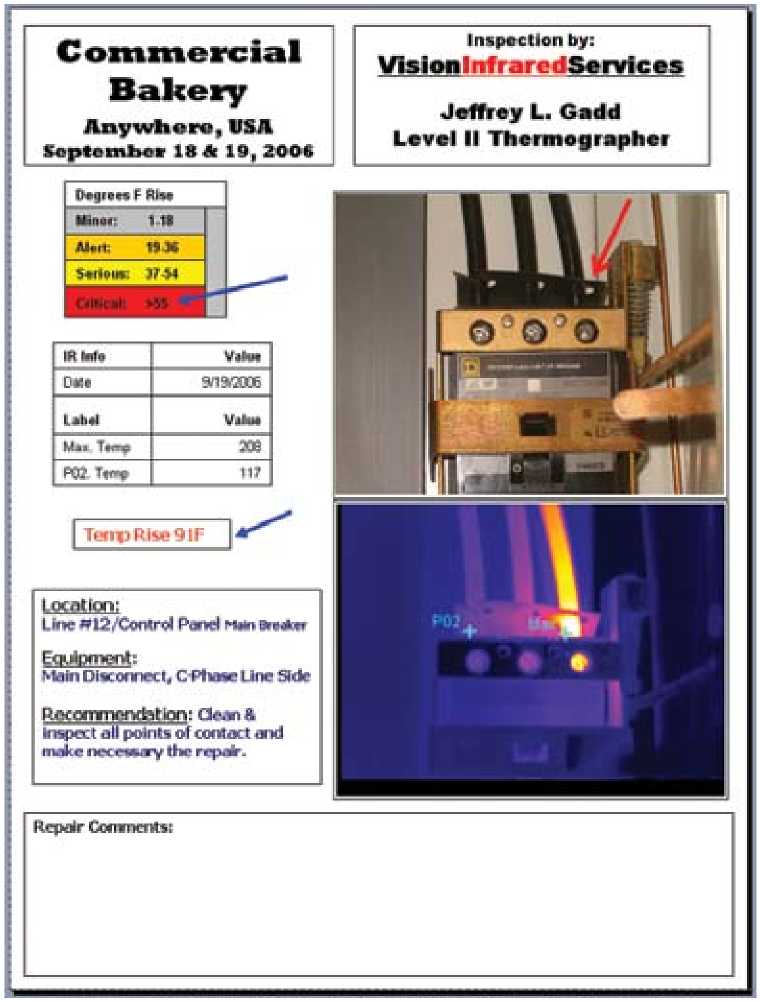


Figure 2 - Typical Thermographic Report

Domino Effect

The domino effect is when one event has a cause/effect on something else and so on. The sample shown in Figure 2 represents a one page thermographic report that was part of an electrical IR survey that we performed in a Midwest commercial bakery, which operates three shifts. This sample was a real "Show Stopper". It would have had a catastrophic impact on the business operations at this facility. An interruption in power here would have shut down the conveyor in this bakery. If this conveyor shuts down without warning, it will create the following Domino Effect. [These are the exact numbers that the engineer at bakery gave me.]

Assuming 4 hours downtime:

1. The bakery will loose the entire contents of the oven and all contents on the conveyor line.
2. Cost of 40 production workers while repairs are made.
3. Cost of 6 maintenance workers to make necessary repairs.
4. Lost production
   Cost per hour of downtime = $10,000, which includes expenses and lost revenues. Minimum Total Cost Avoidance for 4 hours = $40,000
5. Worst-case scenario. The oven can't cool down fast enough and the oven band (conveyor) could be destroyed from the heat while sitting idle in the oven. This is rare, but has happened and the cost is $15,000 for the band along with 2 ½ days of downtime at $10,000 per hour. So, the worst case cost for 60 hours of downtime plus oven band = $615,000.

This was the most severe problem found during the two-day inspection, but by no means the only problem. A total of 33 problems were found, of which we have only assigned cost avoidance to this one. The costs would obviously vary depending on impact to this business, but let's say we assign a $300 price tag to each problem. This equates to $9,600 for the other 32 anomalies. So, along with the "Show Stopper", we get a total cost avoidance of $49,600 during a two-day infrared inspection.

Conclusion

In today's competitive world, taking a proactive approach is the only feasible means to maintain a company's assets. Using infrared inspections as well as other PdM technology can benefit a company and keep the heat off the maintenance professional. A company taking the reactive approach can only expect to struggle to survive, while their competition uses these technologies to strive ahead. Having a "crystal ball" is priceless when maintaining a facility. Not every problem found with infrared is a Show Stopper, but it only takes one. If your facility hasn't had an infrared inspection or it's been a few years, I urge you to become proactive and have it done ASAP. It only makes "cents" to save a whole lot of dollars.

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

Gearing Up for Energy Savings

Higher Price Doesn't Necessarily Mean Higher Cost

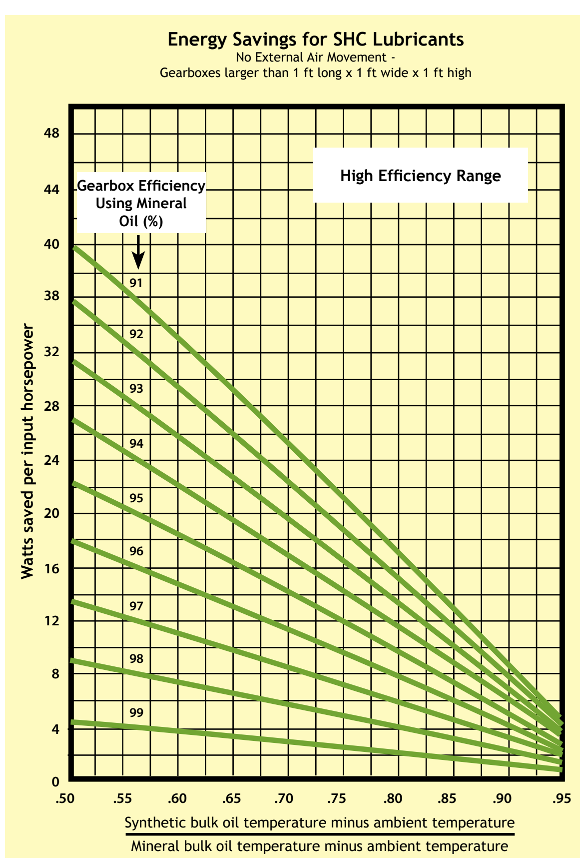
by Andy Donlon

Let's face it – there are nearly as many opinions about synthetic lubricants as there are products to choose from. Some think synthetic products are much too expensive, too exotic or don't perform well enough in the real world. Still others feel that synthetics are superior in every application. It comes down to qualifying a synthetic lubricant's overall value, as compared to a conventional lube, by measuring its net performance in a given application.

In almost every instance, gearboxes lubricated with synthetic oil will run cooler than those lubricated with mineral oils. We have created a graphical method (see chart) for estimating the energy savings or efficiency achieved when a synthetic lube is used in place of a conventional one.

Temperature Measurement

This gain in efficiency can be calculated by first measuring the difference in operating temperature between the mineral and synthetic product. Other considerations include a baseline rating of the equipment's input energy and factoring the physical dimensions of the gearbox. Finally, if your gearbox is externally cooled, whether by fans, blowers, wind, or air, the impact of efficiency can be factored into these calculations as well.



Why is temperature a good way to gauge efficiency? Excess heat generated in a gearbox represents energy lost to the surroundings and, thus, the motor driving the gearbox must work harder to compensate for this loss.

Since reducing friction in a gearbox usually lowers operating temperatures, it means the motor expends less input energy to perform the same amount of work. This yields a net gain in efficiency and reduction in operating cost, which can be easily calculated.

And because synthetics can lower operating temperatures in many applications by as much as 30° F, the corresponding energy savings over time can be significant.

Input Horsepower

Determining the baseline efficiency of a gearbox requires knowledge of the drive motor's efficiency as

Figure 1 - In most instances, gearboxes lubricated with synthetic oil will provide better lubricity and protection than those lubricated with mineral oils.

well. This information typically is available from the motor manufacturer, but can also be calculated from the input amperage and voltage to the electric motor and horsepower rating. Input horsepower can be estimated approximately from the motor amperage and horse power rating by using the following equation:

$$hp_{in} = \frac{hp_r}{i_r} * i_a$$

Where:

hp_{in} is actual input
hp_r is rated horsepower
i_r is rated current draw
i_a is actual current draw

Other Factors

Other factors to consider when assessing the value of using a synthetic product in place of a conventional lubricant include:

- Lubricant- actual cost of both the conventional and synthetic product
- Labor- the frequency of change-outs for both lubricant types and the time required to complete the job in each case
- Filters- Frequency of replacement/cleaning and associated cost
- Component Life- time span between installation and replacement or upgrade
- Downtime savings- overall productivity of the equipment with and without synthetic

When you chart the projections (mineral versus synthetic) for each aspect of the operations listed above and calculate the total sum of expenses, a clear picture will emerge. By totaling the sum of their respective costs, you can evaluate the potential savings (or loss) to decide whether a synthetic product is a good choice for you and your company.

Summary

Calculating whether to use a mineral or synthetic product can be a rather straightforward process. In many cases one product will stand out as the clear choice. In other cases, the decision won't be as black and white. No matter which product you choose to use, synthetic or conventional, you should be able to back up the decision with solid data. Your local lubricant representative should understand the importance of making the right decisions and help you develop a well-planned lubrication management strategy. More than that, he or she should serve as a resource to provide ongoing support and assist you in monitoring success. The goal is to help you meet and exceed your operational and maintenance initiatives.

Figure 2 - ExxonMobil field engineer, Dale Hikes, conducts an open gear inspection as part of the company's ongoing support and assist in monitoring success.

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Om....Ohm....Om....

Meditations on Electric Motor Testing with an Ohm Meter

by Howard W. Penrose, PhD, CMRP

In the last two months of this series, we have discussed how to test energized electric motors using Volt Meters and Ammeters. This month, in Part 3, we will discuss using Ohm meters for troubleshooting AC induction motors that are de-energized.

The use of the Ohm meter has been around since long before AC induction motors. In these modern times, we have instruments that can measure extremely high resistances and those that can measure extremely low resistances. In this article, we will concentrate on Ohm meters, milli-Ohm meters and micro-Ohm meters. Properly selecting the one to use for analyzing your machines, within the capabilities of simple DC resistance testing, is extremely important.

Selecting the Right Measurement Tool

There are both analog and digital Ohm meters, just as with other basic measurement instruments. In the past, analog Ohm meters provided an excellent means of measuring the condition of machines, but today's modern digital instruments provide an additional level of accuracy.

When taking resistance measurements on electric motors, one of the issues has to do with the resistance of the electric motor circuit. A rule of thumb on machines under 600 Volts AC, is that the resistance will become less as the horsepower increases. For instance, an average one horsepower motor may have a resistance of 40 Ohms while an average 100 horsepower may have a resistance of 0.010 Ohms. Electric motors over 1,000 Volts AC will tend to have resistances over a few Ohms.

The type of measurement method used by the instrument is of great importance as to the accuracy of the test. We will cover the basic circuits: the Wheatstone bridge, the Double Kelvin Bridge and the 4-Wire Kelvin Bridge.

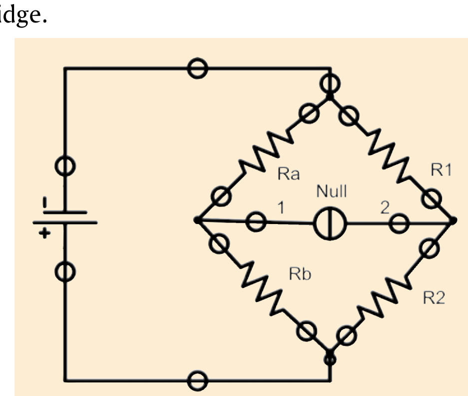

Figure 1 - Wheatstone Bridge

The Wheatstone Bridge (Figure 1) works by comparing resistances and a null balance meter to compare DC voltage in the circuit being tested. Basically, when the voltage between point 1 and the negative side of the battery is equal to the voltage between point 2 and the negative side of the battery, the null detector will show a zero voltage, and the bridge can be considered balanced. With the circuit, the state of balance is solely dependant upon the ratios of Ra/Rb and R1/R2. When used to measure an unknown resistance, the unknown is connected in place of Ra or Rb. The remaining three resistors are precision and any of these resistors can be replaced or adjusted until the bridge is balanced. Once the balance is obtained then the unknown value can be determined by the ratios of the known resistances. The accuracy of the meter depends upon the stray voltages (which result from wire and connection resistances within the bridge) that exist in the conductors that affect the null detector and the accuracy of the precision resistors.

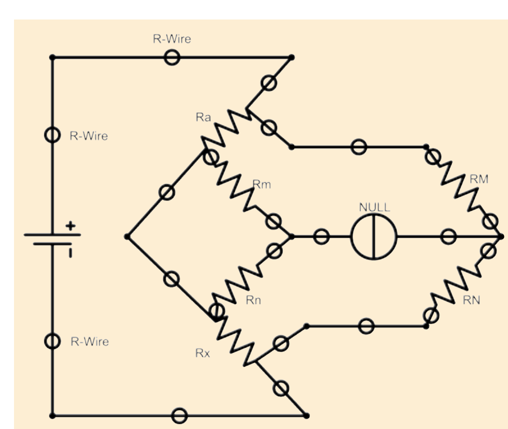

Figure 2 - Double Kelvin Bridge

The Double Kelvin Bridge (Figure 2) is a modified version of the Wheatstone bridge. It compensates for the stray voltages within the circuit, and the circuit being tested, due to the wire and connection resistances. With the ratio Rm/Rn set equal to the ratio of RM/RN, Ra is adjusted until the null detector indicates balance. The actual balance equation for the Double Kelvin Bridge can be found in Equation 1. The accuracy of this type of bridge is at least 0.05% and usually used for circuits measuring in the milli-Ohm range.

$$\frac{R_x}{R_a} = \frac{R_N}{R_M} + \frac{R_{wire}}{R_M}\left(\frac{R_m}{R_m + R_n + R_{wire}}\right)\left(\frac{R_N}{R_M} - \frac{R_n}{R_m}\right)$$

Equation 1- Balance Equation Double Kelvin Bridge

The next type is the **4-Wire Kelvin Bridge** (Figure 3) which uses Ohms Law in order to determine the resistance. Its particular application is in circuits where there are long test leads and significant stray voltages. It also allows for very low (micro-Ohm) measurements with a high degree of accuracy. Figure 4 shows a more common Kelvin circuit in which the losses and inaccuracies due to an Ammeter are compensated for by using a calibrated shunt resistor, which also sets the accuracy of the instrumentation.

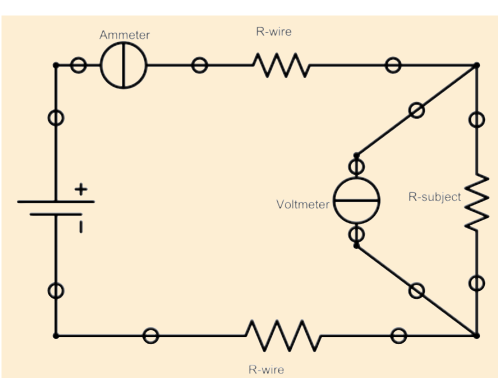

Figure 3 - Basic 4-wire Kelvin Bridge

In digital instrumentation, the circuit board is used in part to provide a portion of the bridge with the logic providing the adjustment for the null circuit.

Some instruments will use the 4-Wire Kelvin Bridge for very accurate micro-Ohm measurements and others will compensate for circuit resistance, using a Double Kelvin bridge by measuring through the test wires first, before measuring the circuit under test.

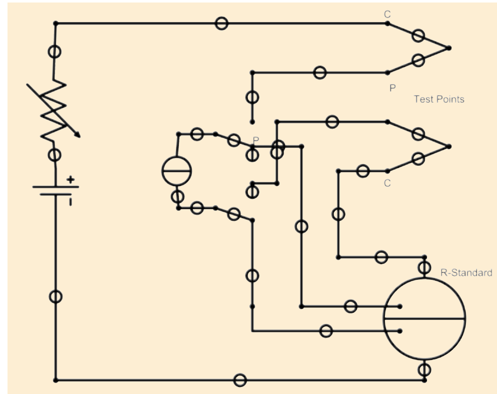

Figure 4 - 4-wire Kelvin Bridge

Considerations When Using an Ohm Meter

There are a number of things to consider when using an Ohm Meter to test an electric motor circuit. These considerations include:

1. Voltage present on the circuit when testing from a Motor Control Center (MCC), or disconnect. This voltage may include Electro-Magnetic Induction (EMI);
2. The temperature of the motor windings;
3. Connections through the circuit, as well as differing lengths of conductors, when testing from an MCC may cause an unbalance; and/or,
4. Whether or not there are series or parallel resistances in the circuit.

In precision instruments, EMI or other voltages present in the circuit will cause readings to be non-repeatable. This can be observed if the measured value does not 'settle' during the measurement.

The temperature of the motor windings must be compensated for when trending measurements. If you are troubleshooting an electric motor, comparing phase to phase does not require compensation. The reverse can be performed, as well, in order to determine the winding temperature of a motor, if an original temperature and resistance are known.

In both of the formulae below, the K (constant) is based upon the material being tested, with Aluminum = 225 and Copper = 234.5, and RC being the resistance of the winding cooler than during the test and vice-versa.

$$R_C = R_H \times \left(\frac{K + T_C}{K + T_H}\right)$$

Equation 2 - Resistance of Cold Winding

$$R_H = R_C \times \left(\frac{K + T_H}{K + T_C}\right)$$

Equation 2 - Resistance of Hot Winding

For example: If a copper motor winding was measured as 2.5 Ohms at 25°C, the technician later tests the motor at 3.6 Ohms. What is the winding temperature?

$$3.6 = 2.5 \times \left(\frac{234.5 + T_H}{234.5 + 25}\right)$$

Answer - Solving this equation produces 139.2°C

The next consideration is whether or not the windings are in series or parallel. This will affect the total resistance such that, for instance, if the induction motor is connected in series for the high voltage connection or parallel for lower voltage connections. It is also important to understand if there are multiple wires in parallel, even of different resistances, should one or more be broken.

$$R_S = R_1 + R_2 + R_3 + \ldots + R_n$$

Equation 4 - Series Resistance (R_S)

$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots + \frac{1}{R_n}$$

Equation 5 - Parallel Resistance (R_P)

If a circuit has a combination of series and parallel circuits, solve for the parallel circuits individually, then solve for the system as a series circuit.

Troubleshooting Motors With Ohm Meters

When testing from phase to phase on an electric motor circuit, you must connect the motor for operating voltage. This way you are testing three equivalent circuits. Alternately, you may be testing from the MCC or a disconnect from phase to phase.

The most accurate way to test an electric motor is to ensure that you are using an instrument capable of testing out to 0.001 Ohms, or to 0.0001 Ohms for higher horsepower 460 Volt motors. It should be noted that the low voltage and high voltage resistances of the motor will be different.

If you have a resistive unbalance, the losses measured in Watts will relate to the resistance of each circuit and the amount of current. Additionally, spot resistance, such as with a loose connection, will cause local heating. Both in relation to Equation 6.

If a circuit is carrying 100 Amps and a connection has a resistance of 0.1 Ohms, then the loose connection will generate 1002 x 0.1 Ohms = 1000 Watts, or 1kW, at that point.

$$\text{Watts} = I^2R$$

Equation 6 - Resistive Losses

Depending upon the standard used, the allowable Resistive unbalance, from phase to phase, should be no more than 2% at the motor. Unbalances greater than this amount, or unbalances that have increased, will often relate to loose connections, direct shorts or broken conductors within the motor or conductors.

Conclusion

The primary use for resistance measurements in electric motors is to determine if there is a direct short, loose connections or broken conductors. The measurements can also be taken and corrected for temperature, in order to provide valuable information such as winding temperature, or if there are other changes. The impact of loose connections can also be determined. However, the correct instrument must be selected for the application in which the instrument will be used and must be able to measure resistance at least one decimal point greater than the circuit being tested.

In the next part of our series, we will cover the use of insulation to ground measurements, often referred to as MegOhm testing for induction machines. This will include information on the latest version of the IEEE Standard 43, the "IEEE Recommended Practice for Testing Insulation Resistance for Rotating Machinery."

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.

PdM Program of the Year Winner

CBM the Right Way

National Institutes of Health Aims for Model Program

by Donna Phillips, Ken Gilliam & Jeff Evans

The National Institutes of Health 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 electrical, mechanical, and structural assets including utilities and a vast distribution system for steam, chilled water and compressed air from a main plant on campus. Critical environments include Bio-Safety Level 3 and 4 research facilities, animal research facilities, and patient care units.

Over the last 6 years, the BMT has partnered with the Naval Sea Logistics Center (NAVSEA) and Blue Cardinal/MSI to provide program support, PdM technology services, training, and expertise to transition from a reactive maintenance environment to a strategic Condition-Based Maintenance (CBM) program. The approach that has evolved now includes:

- Predictive Maintenance (PdM) diagnostics for periodic equipment condition monitoring and acceptance testing of new equipment installations (including vibration analysis, oil/grease analysis, infrared thermography, motor circuit analysis, and ultrasonic leak detection)
- Machinery alignment and balancing to improve reliability and equipment life
- Automated operational data collection using mobile PC's with barcode scanning
- Integration of systems to support the CBM process (Building Automation System, TEAMM/WebView for diagnostic data integration, CMMS)
- Utilization of root cause analysis techniques to eliminate recurring problems
- Targeted training to address machinery issues and increase the skills of the maintenance staff
- Proactive maintenance through design changes for machinery with poor reliability

This unique cooperation between government agencies and commercial consultants has demonstrated improvements in equipment reliability by identifying improper equipment installation, design issues, and maintenance practices. As a result, the BMT has been able to address underlying equipment deficiencies, and introduce a new CBM program that has enhanced NIH's ability to fulfill their mission for Public Health.

The Early Years

When the program started 6 years ago, the NIH maintenance approach was 95% reactive. Initially, PdM technologies were introduced and used to troubleshoot recurring equipment problems and equipment in a state of poor reliability. As these problems were resolved and root-causes were determined, it became evident that machinery alignment and installation practices were key areas where improvements could be made (see Figure 1).

Early Findings on HVAC Equipment (2003-2004)

- 75% of machines evaluated were misaligned
- 75% of machines evaluated were operating above industry/OEM acceptable vibration limits
- 60% of machines evaluated had belt problems (slip, worn, misaligned, mismatched, etc.)
- 50% of machines evaluated exhibited at least one unanticipated failure per year
- 25% of machines evaluated had inadequate lubrication (no lube lines, grease mixing, etc.)
- 20% of machines evaluated had bearing problems (imminent failure)
- 20% of machines evaluated had sheave problems
- Use of variable pitch sheaves for normal operation was prevalent
- 15% of electrical equipment evaluated had infrared-related problems

Figure 1 - Problems found early in program implementation.

To address these issues and facilitate a change in culture and maintenance practices, training programs were developed to educate maintenance technicians in PdM technologies and precision maintenance techniques. NIH also invested in acquiring key tools for mechanics to enhance their corrective and proactive maintenance practices. For example, a "CBM Toolkit" was assembled for NIH maintenance teams to ensure optimized configuration of belt-driven machinery whenever maintenance is performed. This "CBM Toolkit" includes a belt laser alignment system, belt tensioning tools, dial indicators, sheave gauges, and specialty tools to allow precision installation, maintenance and modifications to these rotating machinery (see Figure 2).

Figure 2 - CBM Toolkit for Precision Maintenance

PdM technologies were also introduced in the installation of new equipment and the construction of new facilities in order to effectively assess the health of equipment being turned over to BMT following new construction. By identifying design/reliability problems BEFORE equipment was turned over to NIH, the BMT was able to:

- Hold installation contractor accountable for repairs (due to deficiencies in installation and/or maintenance practices prior to turnover)
- Receive new systems/equipment in a reliable and maintainable state- thus reducing the lifecycle costs and resources required to maintain equipment after it's been turned-over
- Provide independent QC oversight to new system installation by measuring and affirming system performance (from a reliability/maintenance perspective)

The results of this targeted use of PdM technologies and the implementation of Best Maintenance practices during the early years was significant - a drastic reduction in vibration levels on machines repaired and properly aligned, reduced trouble calls/failures, lower maintenance costs, reduced maintenance/resource requirements, and a significant improvement in the overall reliability of the equipment.

CBM Program Development

In 2005, as a result of the success in demonstrating the benefits of PdM and the implementation of Best Maintenance Practices, BMT management decided to move forward with the development and implementation of a formal CBM program. To facilitate this, a CBM Steering Committee was formed to direct how a formal program would be implemented. This Committee was made up of NIH Maintenance supervisors, NIH building engineers, NIH mechanics, and NAVSEA/Blue Cardinal personnel. In order to provide a clear direction for the program, the CBM Committee developed a CBM Mission Statement which clearly defined the overall vision and goals of the program (see Figure 3).

National Institues of Health - CBM Mission Statement

Implement a proactive Condition Based Maintenance program which focuses on maximizing equipment reliability, optimizing maintenance, and implementing best practices (i.e. procedures, processes, and technologies) to increase the efficiency and effectiveness of the maintenance department and its ability to meet or exceed customer expectations on a continual basis.

Figure 3 - CBM Mission Statement

Given the vast number of buildings and systems under the responsibility of the BMT, the next step was to determine where and how the initial CBM program would be implemented. In order to determine this, the CBM Committee went through a structured process to prioritize buildings, systems, and equipment based on their importance to the overall operation and mission of the NIH. Three Critical areas were initially defined and targeted for consideration: Bio-Safety labs (BSL), animal research facilities, and patient care units. Given the criticality of the BSL labs and the need to establish compliance with regulatory requirements for containment and life safety, seven (7) buildings containing BSL labs were chosen as the first areas where a formal CBM program would be implemented. Subsequently, the role of the CBM Steering Committee evolved and a BSL CBM Team was formed, in order to provide strategic direction and oversight for this targeted initiative. This team was made up of NIH personnel with direct responsibility for BSL labs, NAVSEA, and Blue Cardinal personnel.

In order to effectively develop and implement this BSL CBM program, it was necessary to distinguish equipment/systems according to the degree of reliability impact to BSL labs within each building. Some equipment is dedicated to the operation of the BSL lab, some is common to both the BSL lab and other building areas, and some are unrelated to the BSL lab but located in the building. For this reason, the BSL CBM Team developed a methodology to classify assets based on their functional importance; three categories were developed: BSL-Life Safety, BSL-Business Operations, and General Bldg Operations.

BSL Life Safety equipment are the most critical assets and provide primary containment integrity and life safety support for the BSL lab. By definition, the loss of any BSL Life Safety components compromises containment, increases the risk of a loss of containment, or creates a risk to personnel or animal safety. As a result, the CBM plan defined for

Bldg	Facility# (Equip ID)	Type of System	System ID	Function	Classifi-cation	Gen Inspection	Vibration	Oil/Fluid Analysis	IR Thermo	Motor Circuit Evaluation	Leak Detection	Lubrication	PM (stream-lined)	Calibration	Functional Test	Other
A1	99001	Air Han-dling Unit	AHU1	Lab Supply Air 100% Make-up	BSL Life Safety											
A1	99001FAN00001	AHU fan	AHU1		BSL Life Safety	7d	30d	-	180d	-	-	180d	AR	730d	-	BAS Daily Review
A1	99001MTR00001	AHU motor	AHU1		BSL Life Safety	7d	30d	-	180d	365d	-	180d	AR	730d	-	BAS Daily Review
A1	99001VFD00001	AHU VFD	AHU1		General Bldg Ops	7d	-	-	180d	365d	-	-	AR	730d	-	BAS Daily Review
A1	99002	Air Han-dling Unit	AHU4 W/RF-1	Supply to Offices	General Bldg Ops											
A1	99002FAN00001	AHU fan	AHU4 W/RF-1		General Bldg Ops	7d	90d	-	365d	-	-	180d	AR	1825d	AR	BAS Alarm Review
A1	99002MTR00001	AHU motor	AHU4 W/RF-1		General Bldg Ops	7d	90d	-	365d	-	-	180d	AR	1825d	AR	BAS Alarm Review
A1	99003	Steam	STM	Steam Station for Bldg	BSL Busi-ness Ops											
A1	99003HM00001	High-Med	STM		BSL Busi-ness Ops	7d	-	90d*	365d	-	365d	-	-	-	-	BAS Daily Review
A1	99003HM00002	High-Med	STM		BSL Busi-ness Ops	7d	-	90d*	365d	-	365d	-	-	-	-	BAS Daily Review
A1	99003ML00001	Med-Low	STM		BSL Busi-ness Ops	7d	-	90d*	365d	-	365d	-	-	-	-	BAS Daily Review

* - Water Chemistry Analysis

Figure 4: Example CBM Matrix

BSL Life Safety equipment would be the most comprehensive and generally involve more proactive monitoring and diagnostics and more frequent intervals to ensure the integrity of BSL primary containment boundaries.

Assets categorized as BSL Business Operations include equipment and/or systems that do not provide BSL 3/4 primary containment or life safety functions, but do provide functions to support reliable operation of the BSL facilities. This includes general area HVAC systems, chilled water systems, reheat systems, controls not directly related to maintaining primary containment boundaries in BSL labs, and certain subsets of the compressed air systems, steam system, electrical distribution system, vacuum systems, and other building support systems. The CBM plan defined for BSL Business Operations Equipment would still be very proactive in nature, but will be less comprehensive than that for BSL Life Safety, and tasks would be performed at less frequent intervals.

Assets categorized as General Building Operations include equipment and/or systems that are found within BSL building boundaries, but are not classified as critical to BSL Life Safety or BSL Business Operations. The CBM plan defined for General Building Operations Equipment will be less comprehensive than that for BSL Life Safety and BSL Business Operations Equipment, and tasks will be performed at less frequent intervals. Some equipment in this category may also be categorized as “run-to-failure.”

Once equipment was classified by functional importance, NAVSEA experts (familiar with RCM techniques and maintenance strategies) worked together with NIH personnel (familiar with the equipment operation and maintenance history) to determine the optimal mix of maintenance strategies to be defined as part of the CBM plan for each of the BSL buildings. As part of this development, PMO strategies were also utilized to identify opportunities to optimize PM scope, extend conventional PM intervals, and/or apply PdM techniques in lieu of the traditional PM tasks. The result was a CBM matrix that defined what PM, PdM, and PAM (pro-active maintenance) activities would be done and the frequency of these tasks (see Figure 4).

CBM Implementation - Initial Baselining & Program Startup

Once the CBM plan was developed, an initial Baseline Condition Assessment was performed within each BSL building utilizing PdM technologies and various inspection techniques to understand the current health and operating condition of the equipment. From this assessment, 179 equipment problems were identified which required corrective actions to bring the equipment to the desired level of reliability and performance (see Figure 5). Currently 90% of critical BSL assets have been baselined, 129 of the initial assessment deficiencies have been resolved. As a result, the overall health and reliability of critical equipment in these BSL buildings has been improved and the amount of reactive maintenance and trouble calls has been reduced.

Concurrent with the resolution of baseline deficiencies, a routine inspection, testing, and diagnostic program has been implemented as defined in the CBM matrix. NIH personnel are responsible for selected PM tasks, repair maintenance (CM), support for PdM tasks, and proactive activities to resolve existing equipment deficiencies. NAVSEA/Blue Cardinal personnel are responsible for most of the PdM activities and equipment baselining, training/coaching NIH personnel on core PdM techniques, and support in the management of the overall CBM program and processes. Figure 6 illustrates the key elements that are part of this integrated CBM program. Not all elements are in place yet, but the plan continues to progress toward this vision.

BSL Initial Baseline Condition Assessment Findings

- 60 vibration/alignment/ bearing related issues
- 63 visual inspection problems from walk-around inspection activities
- 33 infrared problems on steam systems, electrical and mechanical components
- 11 leaks on air/steam systems from ultrasonic inspections
- 7 electrical winding problems on critical motors from MCE motor testing
- 5 lube oil analysis problems from oil quality/wear analysis

Figure 5 - Baseline Assessment Findings

By definition, the CBM process that is being implemented involves collecting data, integrating the data from all applied methods and technologies (PM, PdM, and PAM), and

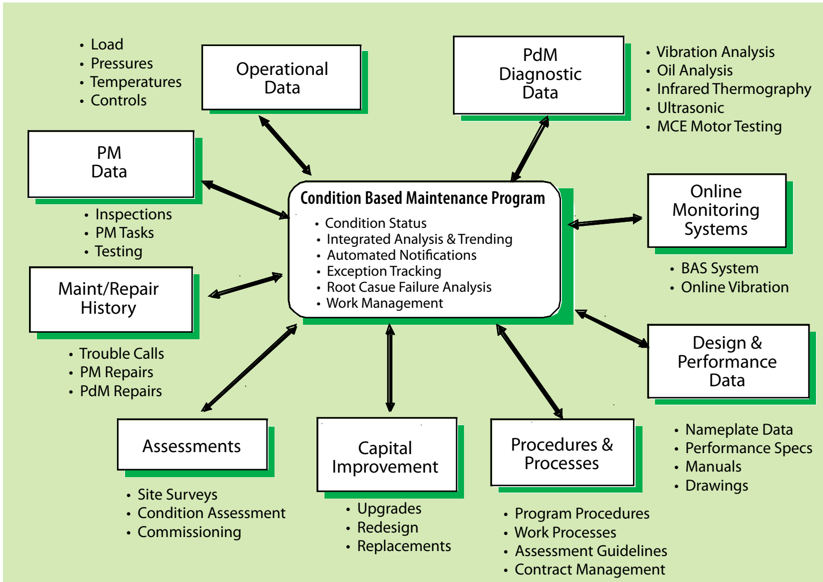

Figure 6 - CBM Program Elements

analyzing the data to convert it into actionable information. All activities performed in support of the CBM program are being documented, tracked, and managed in various Data Management Systems. Real-time data is being managed within the Siemens Building Automation System (BAS); routine inspection, shift rounds and PdM data is being managed with NAVSEA's TEAMM/WebView system; and work orders are being managed within MS2000 (NIH's CMMS system). Plans are currently being implemented to integrate these systems to create a work flow and CBM process where data drives decisions (see Figure 7 below).

CBM Implementation-Program Support & Training

As part of developing and implementing the CBM program, there are numerous training and programmatic activities that are being performed in order to change the maintenance culture and develop an efficient and effective process to optimize this CBM plan. Technology alone, while capable of providing benefits to a program, does not provide long-lasting improvement without the implementation of fundamental maintenance strategies and processes that support proactive thinking and the CBM approach.

Program Support Activities

A broad range of programmatic issues are being implemented to enable the transition from a technology program to a work process that will facilitate continuous improvement and an optimized maintenance program. For example, initially when maintenance was mostly reactive, no Root Cause Analysis (RCA) was being performed. Equipment failures occurred and components were simply replaced and returned to service. Today RCA is a key element in our CBM program with a focus on preventing the reoccurrence of common problems. This has allowed NIH to address underlying equipment deficiencies, improper installation and design issues, and inadequate maintenance/repair practices. As a result, RCA has become a source of information to identify training needs and/or changes that may be needed to our CBM matrix/plan. We are also tracking top 10 root causes as a performance indicator to identify generic issues across the campus so we can proactively resolve them before additional failures occur. The following items have been implemented or are in process of being developed to support the CBM program:

- Developing and implementing CBM work flow processes & procedures
- Implementing the use of Mobile PC's to capture field inspection data
- Developing and implementing periodic CBM reporting requirements
- Developing and tracking CBM program metrics
- Implementing and utilizing Root Cause Failure Analysis techniques to resolve recurring equipment problems
- Updating work management processes and how CMMS is utilized
- Developing a planning, scheduling, and work prioritization process to optimize resource allocation
- Periodic meetings to review and update CBM program activities and priorities (i.e. weekly BSL CBM Team meetings)
- Developing and issuing a quarterly CBM Newsletter that identifies CBM successes at NIH and industry best practices that could be considered for adoption at NIH

Training Activities

Training is a significant aspect of the program and occurs on a regular basis. Initially, equipment assessments and Baseline Condition Assessment activities used PdM diagnos-

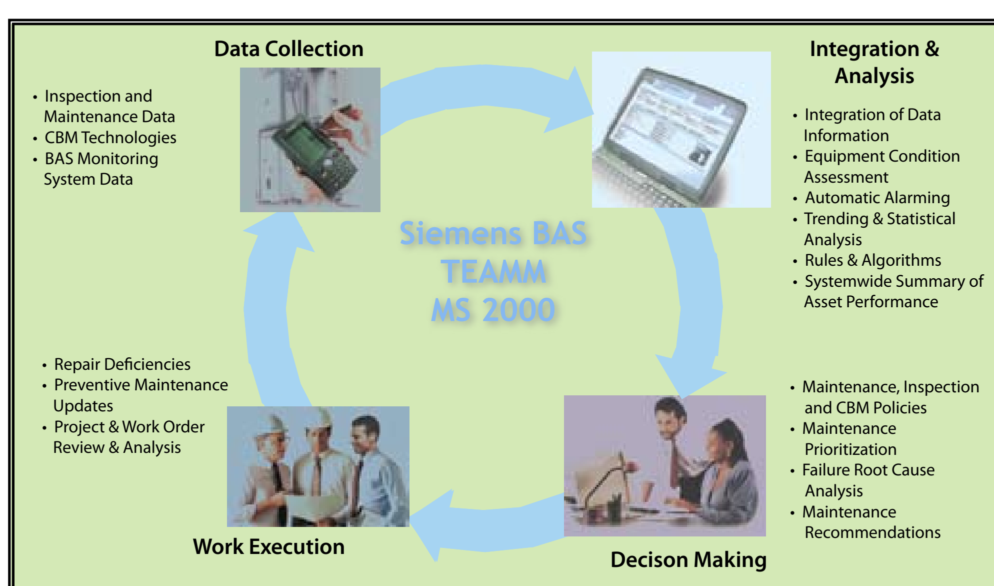

Figure 7 - CBM Work Flow Process

Communication and management support is critical to the present and future success of this CBM effort.

tics to identify the highest impact reliability issues. As these problems were resolved and root causes were determined, training programs were developed to educate maintenance personnel on the use of PdM technologies and Precision Maintenance techniques needed to improve reliability and overall craftsmanship. As the CBM program has matured, the bi-monthly training program has been expanded to introduce Best Maintenance Practices in a variety of other areas, to raise the level of competency of the NIH personnel in support of the routine PM/PdM activities being performed.

Some of the training provided includes:

- Overview of CBM Program and Processes
- Use of Mobile PC's to capture critical inspection and condition data
- Use of Vibration analysis to improve machine reliability
- Utilization of IR thermography & ultrasonics to assess condition of electrical, mechanical, and steam system components
- Proper Machine Lubrication Techniques
- Application and use of Oil Analysis to monitor machine condition
- Alignment workshop for pump shafts and belt sheaves
- Leak Detection in air/steam/vacuum systems utilizing Ultrasonics
- Maintaining proper Water Chemistry & Coil Cleaning Best Practices

In the future as the program matures, bi-monthly training will continue to be a key element in developing and maintaining a skilled and qualified workforce that is aligned with reliability objectives. This may include "refresher" courses on previously presented topics, more detailed courses in targeted areas where expanded knowledge is needed, or new topics that arise from RCA and periodic CBM program reviews.

Communication

Communication and management support is critical to the present and future success of this CBM effort. As a result, there have been numerous methods developed for communicating benefits and program effectiveness to all levels of the BMT.

1. All management and maintenance personnel are involved in regular CBM training sessions where actual case examples are presented and shared.
2. A quarterly CBM bulletin called "Innovative Maintenance" is published and distributed which highlights key activities, case examples, and benefits from the CBM program. This newsletter also provides a forum to recognize BMT personnel who are utilizing Best Practices and/or new techniques learned from training sessions to improve asset reliability and equipment performance
3. Weekly and monthly management meetings are held where significant "saves" are presented to keep them regularly aware of the value the program is generating.

The CBM Team is also in process of implementing other initiatives to track and communicate program benefits to management:

1. KPI's are being developed to track and present to management on a regular basis (some are already available online through TEAMM web);
2. In 2006 we began performing Cost Benefit Analysis (CBA) on selected equipment problems identified through CBM activities. This information provides financial benefits of proactively resolving equipment problems prior to failure. Summary CBA data will eventually be presented either as a "live" performance indicator (KPI) or in a periodic report sent to targeted management personnel.

CBM Benefits

The BSL CBM Program being implemented utilizes an optimized mix of Preventive (PM), Predictive (PdM), and Proactive Maintenance (PAM) activities designed to improve the overall reliability and performance of

BSL facility equipment. The use of Predictive technologies plays a significant role in this CBM approach, given the criticality of these BSL facilities and the need to effectively understand equipment condition and proactively identify and resolve degraded equipment conditions before failures occur. By collecting, analyzing, and trending these diagnostic parameters, the CBM program is providing NIH personnel with the capability to predict equipment problems, direct what maintenance is required, and help prevent costly repairs and unscheduled downtime.

To date, the results of this CBM initiative have been significant - a significant improvement in the reliability and performance of BSL assets, reduced trouble calls/failures, lower maintenance costs, reduced resource requirements to maintain equipment, and improved energy efficiency. Ultimately, this approach minimizes the lifecycle costs of facility equipment and reduces the risk of containment breach and life safety threats.

Three specific areas where this CBM initiative has had a positive impact include:

1. Improved belt and bearing life on HVAC equipment- Prior to CBM, belts were being replaced several times per year and bearings were failing generally within 5 years of installation. This was due to poor alignment, improper installation, worn sheaves, bad foundations, etc. Today, as a result of training, monitoring, and the use of Precision Maintenance techniques, belt life is dramatically improved (1-3 years) and bearing failures are rare.

2. Loss of live steam due to defective steam traps- Prior to CBM, there were numerous traps that were not installed properly, not primed properly, defective, blocked, etc. Today, many of the defective traps have been replaced, and a routine monitoring program is in place to identify subsequent performance issues.

3. Acceptance of new equipment that has inherent design and/or installation problems – At NIH there is always a significant amount of new construction and building renovations ongoing. Prior to CBM, new equipment was installed and tested to verify proper operating parameters only; this equipment was never assessed from a reliability or maintainability perspective (proper alignment, acceptable vibration, good oil, no elevated temps, etc). As a result, BMT personnel were inheriting new equipment with reliability issues (improper design, foundations, misalignment, grease mixing, etc) and ten had failures within the first 1-3 years. To improve this situation, CBM Baseline Condition Assessments are being incorporated into the startup of new facilities and after major renovations to perform a thorough reliability assessment using PdM diagnostics. Plans are also being developed to work with engineering personnel to modify procurement/construction specifications to incorporate more "reliability-focused standards" (i.e. standards for

alignment, vibration levels, oil cleanliness, etc) as part of the commissioning and acceptance testing process.

Next Steps

The implementation of CBM combined with targeted training programs for the NIH maintenance staff has resulted in measurable improvement in the reliability and performance of facility equipment, and in the capabilities and confidence of the maintenance staff. Although this foundation has better positioned the BMT to effectively and efficiently meet the critical needs of their NIH customers and researchers, there are many opportunities which still exist to build upon this program.

While the current focus for the CBM program is clearly targeted at optimizing the reliability of equipment in BSL facilities, CBM methods and technologies continue to be applied in other targeted areas (new/upgraded facilities and areas where reliability is low or recurring failures are prevalent). Plans are also being developed to expand the CBM program into other critical areas across the Bethesda campus and other remote NIH facilities.

The use of PdM diagnostic technologies and advanced maintenance strategies and work processes has been well established in industries such as utilities, manufacturing, and other capital-intensive industries. The joint efforts and partnership formed between NIH, NAVSEA, and Blue Cardinal/MSI in this CBM initiative has demonstrated that there are significant benefits to be gained by applying these technologies and strategies to facilities as well. The comprehensive CBM program at NIH is a strong example of such success, and the program continues to grow to transition maintenance from a reactive environment, to a planned and proactive program which optimizes available resources and equipment lifecycle costs.

Donna Phillips is the Maintenance Supervisor for National Institutes of Health and is responsible for property management and maintenance at numerous NIH facilities. She provides leadership, sponsorship, and strategic direction for the CBM program.

Ken Gilliam is a Project Manager for Naval Sea Logistics Center and provides project management for CBM initiatives at NIH and other government facilities. He manages the inter-agency agreement between NAVSEA and NIH, and the partnership between NAVSEA and Blue Cardinal/MSI.

Jeff Evans is Vice President of Technology for Blue Cardinal/MSI, a commercial company providing consulting and PdM services to the government, utilities, and large industrials. He has over 18 years of PdM experience and is the Program Manager for the NIH CBM program and all consulting and technical support services. Jeff can be contacted at jevans@msicorp.com and 267-249-7947 or 800-676-6565.

Ultrasound Completes the Package

Moves Programs from PdM to 'TPdM'

by Jim Hall

Surprisingly, many of today's industrial plants are still without an airborne ultrasound instrument for predictive maintenance. Why? Is it the cost? Is it the lack of knowing what applications ultrasound can be used for? Or, has it just been over-looked in favor of the big ticket items such as vibration analysis or infrared imaging? Why not ultrasound? It is relatively low-cost, portable, and versatile and most can master the use of ultrasound in a short period of time. I believe ultrasound should always be at the forefront of any predictive maintenance program.

You know the old saying, "You have to crawl, before you can walk"? Many have skipped the crawling and started running without taking the time to first build a complete or Total Predictive Maintenance program or "TPdM" (not to be confused with TPM or Total Productive Maintenance or Test Procedures Development Managers). Stop the presses , a new PdM acronym!

Many of the top Fortune 500 companies did not start out with vibration and infrared. They had ultrasound and oil analysis, for instance, to determine motor deterioration or failures. Ultrasound was used to hear and trend bearings over-time. Oil analysis was used in sampling the oil of critical motors and bearings to predict early deterioration of the bearing surfaces, gears, etc. They had to crawl before they could walk.

Then along came vibration analysis and infrared imaging. Now those same plants are using ultrasound, infrared imaging, vibration analysis and oil analysis. This is a more complete package, this is TPdM.

Just recently I was able to attend The International Maintenance Conference where several maintenance and reliability professionals from all over the world gathered to hear Reliability Professionals such as Terry Wireman, author of Benchmarking Best Practices for Maintenance Management, and others such as Jack Nicholas, Jr., P.E., CMRP teach a workshop on Reliability Centered Maintenance (RCM) Methodologies, Metrics, Readiness Factors and Relationships to Other Elements of Asset Management.

Yet, I am amazed to hear the same engineers and technicians attending those workshops ask, "How can ultrasound help my reliability program?" My answer is always the same, "You have no reliability program if you do not have an airborne ultrasound program." Honestly, I do know that most of these attendees are far removed from the actual maintenance in the plant and the larger the plant the further removed they are.

I do believe if we were to take a census of all the reliability engineers and technicians at one of these conferences (800-900 attendees) we would probably find that a little over half are not familiar with what a basic ultrasound program has to offer. To most of these, it is still "just a leak detector."

One of the keynote speakers at this year's IMC 2006 Conference was Paul Campbell, the (now retired) President Alcoa Primary Metals. Does Paul Campbell know about airborne ultrasound? Maybe not, but I personally know that Alcoa world wide is very familiar with airborne ultrasound and its many applications.

It is time to educate, from top to bottom, all plant maintenance personnel in the use of airborne ultrasound and the many applications that this instrument can perform. One way to do this is by planning to attend a conference about predictive maintenance such as the PdM-2007 coming up in September. While waiting for a specific conference to attend, why not search on-line for sites offering free tutorials. Also call in vendors to perform a demonstration of their product. Do not let the vendor control the demonstration from the conference room. Have him or her put on a hard hat, a pair of safety glasses, grab some ear plugs and go into the plant with you. There is no better way to understand just how a particular ultrasound instrument is going to work in your plant, than by utilizing your plant's equipment and environment (background noise, etc…).

Figure 1 - Ultrasonic readings taken from screw compressor and stored in the SDT 170 MD database for trending.

I sat down with one plant manager of a plant that manufactures plastic medical devices who said, "I have NO predictive maintenance program. Where do I start?" His plant is experiencing downtime due to maintenance problems. They operate in a "run to failure" mode. You know the drill - equipment fails, production line stops, repairs are made and production line starts up again. He recognized that his workforce were neither college graduates, nor did they have .the skills necessary to run an elaborate PdM program. He also realized that in the near future he needs to recruit some talent to come into his plant. But until then he wanted to make the best of the personnel he has now.

Figure 2 -Ultrasonic readings were taken on the pump motor and stored in the SDT 170 memory.

My first suggestion was to first purchase an ultrasound instrument for predictive maintenance, including air leaks, bearing analysis, steam trap diagnostics, electrical scanning of switchgear and acoustic lubrication. This plant manager was astounded by the many applications of one ultrasound instrument. My second suggestion was for him to purchase an infrared pyrometer. My third suggestion was to identify what equipment would shut-down the production line if it were to fail. Then, if funds were available, out-source a vibration tech to come in take readings, and out-source an infrared technician to scan the switchgear and possibly out-source an oil analysis program.

After the first hour we were able to identify a lot of equipment that was easily accessible, and for the motors that were not, there were similar motors nearby that could be used to compare readings and set baselines.

Figure 3 - Vacuum leak found on robotic lift arm of the injection molding machine.

We were able to focus on the production line, scanning with the ultrasound instrument's open microphone for air leaks. Several air leaks were found that were starving air from other parts of the assembly line creating problems for packaging. This particular plant utilizes vacuum to lift small parts during the manufacturing process. These leaks could easily be identified with ultrasound during the process.

On one injection mold machine, scraping could be heard on one of the hydraulic rams. The contact probe is more than just for bearings. Think of it as an extension of your own hearing, except with frequency tuning to tune "out" or tune "in" what you want to hear or do not want to hear.

Ultrasonic readings on a screw compressor's bearings were taken and recorded along with readings from pumps. They will begin acoustic lubrication on one pump motor once training is completed.

Electrical switchgear was scanned for anomalies

Figure 4 - Electrical switchgear panel scanned, no anomalies were heard.

such as arcing, tracking and corona discharge. The importance of scanning with ultrasound before opening switchgear was greatly emphasized. As well as integrating the two technologies for report writing and identifying corona as an ultrasound since corona can not be seen by infrared under 240 kV.

Figure 5 - Scanning air manifold for leaks.

This month's article was not intended to be so much about the applications of ultrasound but to encourage discussion among engineers and technicians on how airborne ultrasound can greatly enhance any predictive maintenance program. Reliability has always started with a great PdM program, let's try to TPdM, integrate all your PdM programs.

Start the New Year thinking "TPdM" and practice Total Predictive Maintenance and you will always be ahead of the curve.

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

How Does Your Program Stack Up?

A Guideline for Auditing a Vibration Condition Monitoring Program

By Brain Graney

Over the years I have had the privilege of implementing many vibration condition monitoring programs at many different facilities. I have also conducted untold numbers of PdM reviews on existing programs. In my experience, I have found that whenever PdM programs fail to provide the expected results, or simply fail, the lack of success can generally be attributed to at least one of three primary factors. These factors are:

1. The program was not properly implemented in the first place.
2. The maintenance department has poor work flow process.
3. The maintenance manager does not have confidence in the PdM technician.

I have created a technical review process that helps to determine the effectiveness of a Vibration Predictive Maintenance Program (PdM). The process calls heavily on ideas developed by Jack Nicholas, Jr, in his work on the RCM scorecard, John Mitchell in his work on the Reliability Scorecard and Bill Pryor in his work on the PdM scorecard. As you will see in going through the steps, the scorecards are an important, even vital, part of this evaluation process. The following is not so much an article as it is a practical guide that lays out a step by step procedure you can follow to help evaluate your program.

So let's get started. Here are the 10 steps you will need to perform to get an accurate assessment of your program:

1. Asset Criticality Study

An Asset Criticality Study needs to be reviewed to determine if the most critical assets are being monitored, and if so, are they being monitored at optimum intervals. If an Asset Criticality Study has not been completed then my first recommendation would be to have one completed.

2. Technology Matrix

A Technology Matrix should be completed and reviewed for applied technologies and the frequency of the measurements based on their criticality.

3. Technical Qualifications

A review of the technical qualifications (ISO/Vibration Institute/ASNT) of each technician should be conducted. A recommended training program should be developed for any technician that is not fully qualified. It is also very important to identify a PdM champion for the facility.

4. Quality Assurance Audit

A Quality Assurance Audit should be performed to assess data is collected. This includes Calibration Certificates, Types of Transducers – (Sensitivity/Frequency Response Characteristics), Mounting Method and Method for Repeatability of Measurements and Cable Noise Measured for Transducers. The following list provides parameters that will assure that high quality data will be collected.

A) Continuous Calibration Method for all accelerometers.
B) Annual Calibration Certificate for Portable Vibration Analyzer.
C) Premium Accelerometers 100 mv/g +/- 5% on Sensitivity.
D) Premium Accelerometers should be used for Route Data Collection.
E) General Purpose Accelerometers 100mv/g +/- 10% on Sensitivity should be used for On-line and Remote Accelerometers.
F) Tri-Axial and Quick Connect Accelerometers may use General Purpose Accelerometers.
G) Single Channel Accelerometers Frequency Range 5Hz -4-5 KHz +/- 5%, 3 Hz – 5-7 KHz +/- 10%
H) Tri-Axial Accelerometer Frequency Range 5Hz-2 KHz+/- 5%, 3 Hz – 3 KHz +/- 10%
I) Low Frequency Measurements should use 500 mv/g Accelerometer.

Type of Mounting Method	Points	Frequency Response Characteristics	Points
Stud Mounted	5	Stud Mounted	5
Quick Connect	4	Quick Connect	4
Mounting Disk w/ Mounted Accelerometer	4	Mounting Disk w/ Mounted Accelerometer	4
Tri-Axial Mounting Pad	4	Tri-Axial Mounting Pad	2
Ferrous Disk with Flat Rear Earth Magnet	3	Ferrous Disk with Flat Rear Earth Magnet	3
Paint Marker or Vib. Tag	2	Paint Marker or Vib. Tag	2
Eyeballing It	1	Extension Probe	1

Chart 1 - Quality Assurance Audit
Points Awarded for Different Methods of Data Collection

Number of Measurement Planes	Points
3-Planes Per Bearing	3
2-Planes Per Bearing	2
Tri-Axial Accelerometer	2
1-Plane Per Bearing	1

Chart 2 - Quality Assurance Audit Points Awarded for Number of Measurement Planes

J) LF measurement with bearing demodulation should use a specialty low frequency accelerometer with high frequency range to 7 KHz or use a high sensitivity 500 mv/g accelerometer with high frequency capability.

Once the audit is performed, you can use the scorecards shown in Charts 1 and 2 to tally the points your mounting methods and measurement planes earn. The general rule is that if the total number of points earned in this section are higher than 8, you will have a high quality of data. If the total is 6-8, you will have a moderate quality of data and if it is below 6 you have low data quality.

General Guide for Frequency Response Range	
Sleeve Bearing	10 - 15 x RPM
Anti-Friction Bearing	5 x Inner Race Defect - for over 1000 RPM - 40-50 x RPM
Ball Bearing	40x
Roller Bearing	50x
Slow Speed Bearings	5 x Inner Race Defect
A/C Motors	# of Rotor Bars x RPM + 2 x Line Frequency - # of Stator Slots x RPM + 2 x Line Frequency - 75 x RPM
D/C Motors	1200 Hz
Reduction Gears	# of Teeth x RPM + Side Band Frequencies
Diesel Engines	# Cyl x RPM/2 for 4 stroke and RPM/1 for 2 stroke x # of Cyl.

Chart 3 - Database Review
A General Guide for Frequency Response Ranges

5. Database Review

The next step is a thorough Database Review. This should begin with a review of the total number of machines, and include recording all of the following information:

A) Number of Points Per Machine, Frequency Max, Lines of Resolution, and Type of Averaging.

B) Type of Overall and Narrow Band Alarming – (Analysis Parameter Sets/ Alarm Banding)

C) High Frequency Natural Bearing Resonance Indicators (Spike Energy g-SE, Shock Pulse SPM, High Frequency Detection Band HFD and High Frequency Band HFB).

D) Discrete Frequency Indicator (Acceleration Enveloping, Demodulation, Peak-Vue and Spike Energy Spectrum).

General Guide for Overall Alarms							
	# of MAC 100+ HP	# of MAC 21-99 HO	# of MAC 1-20 HP	Overall Velocity IPS			
Machine Types				PdM Alert	PdM Alarm	Proactive Alert	Proactive Alarm
A/C MT 1200-3600 RPM				0.3	0.45	0.2	0.3
VFD MT				0.3	0.45	0.2	0.3
DC MT				0.3	0.45	0.3	0.45
Cent Pump Horiz				0.25	0.375	0.167	0.25
Cent Pump Vert				0.375	0.56	0.25	0.375
PD Pump Horiz				0.2	0.3	0.133	0.2
Cent Fans				0.3	0.45	0.2	0.3
Axial V Fans				0.35	0.53	0.23	0.35
Comp Rot				0.425	0.64	0.28	0.425
Comp Rep				0.45	0.675	0.3	0.45
Air Blower Rot				0.425	0.675	0.28	0.425
Belt Driven Equip				0.4	0.6	0.27	0.4
Turbine Steam				0.2	0.3	0.133	0.2
Turbine Gas				0.25	0.375	0.167	0.25
Gear Boxes				0.25	0.375	0.168	0.25
Diesel Engines				0.675	1.0	0.45	0.675
Generator				0.27	0.4	0.18	0.27
Paper Rolls - 100-200 RPM				0.10	0.15	0.067	0.10
General 1000+ RPM				0.3	0.45	0.2	0.3

Chart 4 - Database Review
A General Guide for Overall Alarm Levels

Vibration Condition Monitoring Score Card		
	Points	Score
Overall (Digital/Analog) Vel In/Sec Peak*	5	
Narrow Band Alarming	3	
400/800/1600/3200 LOR FFT Spectrum*	5	
True Zoom Analysis	2	
Time Wave Form Analysis	3	
Phase Analysis - True Phase/Relative Phase	3	
Duel Channel Orbit Plots	3	
Real Time Analysis	2	
Slow Speed Analysis	2	
High Frequency Natural Bearing Resonance Indicator* - g-SE/HFD/HFB/SPM	5	
Discrete Frequency Indicator - Bearing Demodulator/Peak-Vue	3	
TOTAL SCORE		

Chart 5 - Vibration CBM Scorecard

E) Phase Analysis Capability True Phase and Relative Phase.

F) Review of all technologies such as Ultrasound, Motor Circuit Analysis, Infrared Scanning and Oil Analysis

After completing this step, you can use the Vibration Scorecard shown in Chart 5 to measure the effectiveness of your Vibration Analysis program. A score of 15 or below identifies a low effectiveness, a score of 24 would be a moderately effective program and a highly effective program would score 36 or higher. The items in Chart 5 identified with an asterisk (*) mark the 3 items that must be in place to have a minimum level vibration PdM program.

6. Review of Analysis Methods and Written Reports

A thorough review of Analysis Methods and Written Analysis Reports is now needed, followed by a

7. Review of Maintenance Work Orders and Follow-Up Reports

PdM integration into the maintenance department work flow management is a critical component of a successful Condition Based Monitoring program. It is important to document the time it takes for Maintenance Work Orders to be completed. All completed work orders should have follow-up reports for PdM Champion and Reliability Engineer.

Chart 6 provides a checklist that will help document the answers to pertinent questions from items 6 and 7 above.

Analysis & Reporting Checklist		
Complete Review of Technical Analysis Procedure	Y	N
Written Analysis Reporting	Y	N
Priority of Repairs	Y	N
Emergency		
30 Days <		
45 Days <		
60 Days <		
90 Days <		
Continue To Monitor		
Work Orders Generated	Y	N
Priority of Work Orders		
High		
Medium		
Low		
Follow-Up Reports	Y	N

Chart 6 - Checklist for review of Analysis & Reporting Procedures

CONTAINERSHIP VIBRATION CONDITION MONITORING ASSET HEALTH REPORT October 12, 2004			PROBLEM RECORDED	RECOMMENDED ACTION
Percentage of machines in GREEN CONDITION		77.63%		
Percentage of machines in YELLOW CONDITION		7.89%		
Percentage of machines in RED CONDITION		14.47%		
Number of machines in GREEN CONDITION - ACCEPTABLE		59		
Number of machines in YELLOW CONDITION - ALERT		6		
Number of machines in RED CONDITION - FAULT/ADVANCED FAULT		11		
Total Machine Count In Program		76		
Total Machines Collected This Semi-Annual Survey		76		
Location ID	**Engine Room**	**STATUS**	**PROBLEM RECORDED**	**RECOMMENDED ACTION**
	13-ABS-VCM #1 STEERING GEAR PUMP			
	14-ABS-VCM #2 STEERING GEAR PUMP			
	15-ABS-VCM #1 LUBE OIL SERVICE PMP STBD			
	16-ABS-VCM #2 LUBE OIL SERVICE PMP PORT			
	17-ABS-VCM #1 CROSS HEAD L.O. PUMP INBD			
	18-ABS-VCM #2 CROSS HEAD L.O. PUMP OTBD			
	19-ABS-VCM #2 FUEL OIL BOOSTER PMP INBD			
	20-ABS-VCM #1 FUEL OIL BOOSTER PMP OTBD			
	21-ABS-VCM #1 LT FW COOLING. PMP INBD	ALERT	High Freq. Elect. Vib.	Continue to Monitor
	22-ABS-VCM #2 LT FW COOLING. PMP OTBD			
	23-ABS-VCM #1 MN SW COOLING. PMP			
	24-ABS-VCM #2 MN SW COOLING. PMP			
	25-ABS-VCM #3 MN SW COOLING. PMP	FAULT	Mechanical Looseness	Check Motor BRG Housing
	26-ABS-VCM #1 M/E JACKET WATER PMP	ALERT	Imbalance	Continue to Monitor
	27-ABS-VCM #2 M/E JACKET WATER PMP			
	28-ABS-VCM #1 PISTON COOL. WT PMP FWD			
	29-ABS-VCM #2 PISTON COOL. WT PMP AFT			
	30-ABS-VCM #2 FUEL VALVE COOL. PMP INBD			
	31-ABS-VCM #1 FUEL VALVE COOL. PMP OTBD			
	32-ABS-VCM #1 FIRE,BILGE & BALLAST PMP	ALERT	Lower MT BRG Wear	Continue to Monitor
	33-ABS-VCM #2 FIRE,BILGE & BALLAST PMP	FAULT	Pump Brg Housing Looseness	Inspect Pump Bearing Housing

Chart 7 - Example of an Asset Health Report for Vibration Condition Monitoring

8. Asset Health Reporting

Management should receive Asset Health Reports and up-dates on Continuous Improvement Methods for Increasing Reliability. Chart 7 shows an example of an Asset Health Report for Vibration Condition Monitoring.

9. Management of Changes/ Modifications of Database

Based on follow-up reports and trending analysis – Root Cause Failure Analysis methods should be used for modifying maintenance procedures and management of changing Work Flow Procedures.

10. Feedback from Management

It is very important for management to be aware of not only the PdM program in general, but receive reports that identify exactly what the program is accomplishing. This is the only way that you can get effective feedback from management in order to implement continuous improvement.

Conclusion

In conclusion, once evaluated, Predictive Maintenance Programs will fall into the following three basic categories:

Pro-Active VCM Program with the following characteristics: Qualified Technical Personnel – Asset Criticality and Technology Matrix implemented - High Degree of Quality Assurance for Data – Data collected every 720 Operating Hours of Machine – Pro-Active Alarming - Proper Fmax, LOR and AP/AL sets for Complete Data Analysis. High degree of Maintenance Work Flow Management – Score of 36 or higher on the Vibration Scorecard.

PdM VCM Program with the following characteristics: Qualified Technical Personnel – Asset Criticality and Technology Matrix implemented – Moderate Degree of Quality Assurance for Data – Data collected every 720 - 2160 Operating Hours of Machine – PdM Alarming - Proper Fmax, LOR and AP/AL sets for Complete Data Analysis. Moderate to High Degree of Maintenance Work Flow Management – Score of at least 24 on the Vibration scorecard.

PM VCM Program: Qualified Technical Personnel – No Asset Criticality Study – No Technology Matrix – Moderate to Low Degree of Quality Assurance for Data – Data collected every 2160 Operating Hours of Machine – PdM Alarming - Proper Fmax, LOR and AP/AL sets for Complete Data Analysis. Moderate to Low Degree of Maintenance Work Flow Management – Score of 15 or lower on the Vibration scorecard.

Hopefully, this guideline to auditing a vibration program will assist PdM Managers, Reliability Engineers and other personnel in performing an honest evaluation of their programs, and in doing so, will provide fuel for the improvement process.

Brian Graney is currently the project manager for Vibra-Metrics responsible for the overall Vibra-Metrics product portfolio development. Brian worked as a Regional Manager for Industrial Vibration Consultant and was an Engineering Consultant for Computational Systems Incorporated prior to coming to Vibra-Metrics. He has 26 years of engineering experience and 18 years of experience in the reliability field. Brian is certified in Vibration Analysis Level II and is an American Bureau of Shipping Recognized Condition Monitoring External Specialist. He has also been a Formal Trainer for Vibration Analysis Level I & Level II for CSI and EPRI. Brian has extensive knowledge of Predictive Maintenance Programs and their Applications. He is also a member of Vibration Institute, Society of Maintenance Professionals and ASNT.

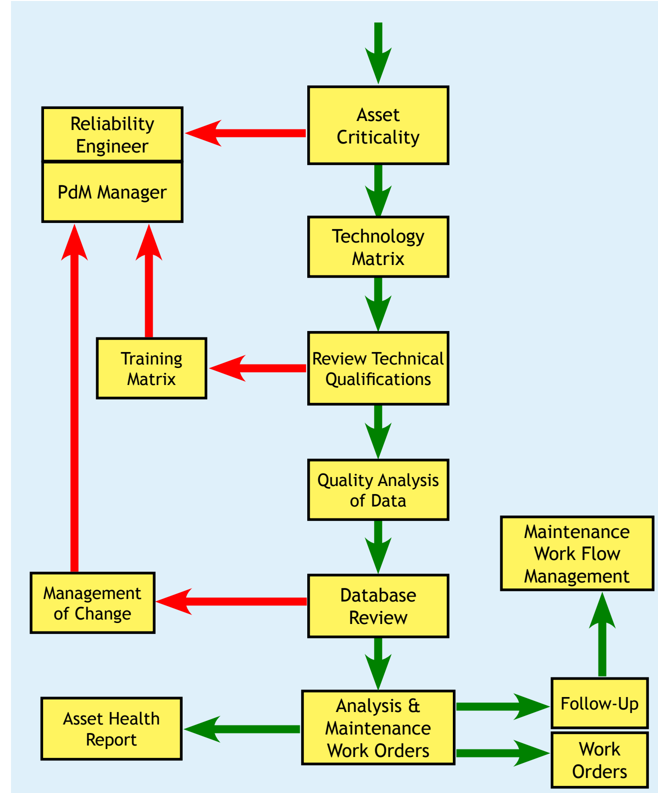

Chart 8 - Flow Chart of the Process of Auditing a Vibration PdM Program

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- The bidders review the specs and fill in the prices.
- ConnectIR™ sends the profiles of companies and their bids to the client.
- The client then sorts the profiles by all sorts of criteria like price, report features, experience of the thermographer, etc. and selects the three profiles that best fit what they are looking for in a contractor.
- The service provider contact info is then sent by ConnectIR™ to the client who decides which one will do the work. The price and specifications have already been determined, so only minor points need to be addressed in order for the client to write a contract with the service provider.

That was six bullet points, Greg.

Sorry.

I get it, but how does ConnectIR™-the web site work?

Well, there are three components:

1) *The Interface - This is the Internet site.*
2) *The Database - The database is filled with the profiles of infrared service providers, which are provided by the participating thermography company. The profiles are made up of all sorts of information about the company, the thermographers, their IR equipment, training, experience, geographical location and the like.*
3) *The Algorithms - The algorithms are the 'code' written to go back and forth between the interface and the database and automatically retrieve information and supply it to those who need it. By the way, the code is written by evil software engineers in dark cubicles who drive giant BMWs. These people speak a strange form of the English language, have no sense of budgetary constraint, deadlines or accountability. But the algorithms they created work incredibly well, which is good news for anyone looking for thermography services and for thermography service providers. It's a real win-win.*

OK, so the database is like a huge list of infrared service companies. Then why not just provide the clients with a list of all of the thermography companies in the database?

Great question. Because the client will have to go through the onerous process of finding a good contractor. The client must:

- Find a service company out of hundreds to suit his/her needs by wading through the mire of advertising hype, puffery and personalities.
- Make initial contacts. (Have you left any voicemails for people you don't know lately?)
- Write a set of specifications. (This is particularly difficult for first-time buyers.)
- Receive the bids in all different forms and evaluate them.

How much does the client pay for this service?

This is the wonderful part - They pay nothing. The thermography companies pay a small monthly listing fee and a finder's fee after they perform the work and have received payment from the client.

Who owns ConnectIR™?

Stockton Infrared Thermographic Services, Inc., based in Greensboro, NC.

Stockton Infrared's ElectriSCAN™ division performs electrical infrared surveys. Aren't you competing with the thermographers in the database?

No. We are not listed in the database. We used to perform some of the IR surveys ourselves, but earlier this year, we made the decision to aggregate the services only and we now contract out all of our electrical division work. In fact, that was one reason for coming up with ConnectIR™ in the first place. We got work from all over the US and Canada and were constantly looking for sub-contractors to perform work far away from our base of operations. We picked the best thermographers we have worked with and know many thermography companies. This was a way to automate the infrared services referral system that we have been using since 1989.

I can understand why a client would like this service, but what does the thermographer get out of it?

ConnectIR™ is the "hot spot" in the electrical infrared testing industry.

Most thermography companies are small - one to three people operations. Even if they are good at being thermographers, often they don't have the time to be good marketers, salesmen and/or businesspeople. Also, most of them work in a limited area, say, a 100-mile radius around their home. Advertising, marketing and sales is a tough job in any business and a small infrared service company struggles to find effective advertising in a limited geographical area. Local TV, radio, print and yellow pages in a specialized business such as infrared services are not very effective. Cold-calling, the most effective marketing for this type of business, is just not something they can do much of. That leaves the internet, which is not local, but worldwide…nationwide at best. A small company's efforts are wasted in a worldwide medium like the internet. That's where ConnectIR™ can help. We advertise worldwide and bring work to them so they can spend their time doing what they are good at…infrared surveys.

The concept is not unique, but it is certainly unique in this industry. Tell me how you came up with this idea.

Well, our family got a satellite television service and a TiVo®. My two sons filled up the hard drive in a couple of months to the point where I could not even record a thirty-minute program. So, I decided to erase all the recordings. I was going along at a good clip when I happened upon an MSNBC report about E-bay. I watched it four times. It dawned on me that a bid-system was just what the IR service industry was lacking and as I said earlier, we needed to automate our referral system. But IR services are not a 'product' that you can show a picture of and bid out, so we had to have a custom-made system designed from the ground up. We spent a ton of time on the design of the thermographer's profiles and the specifications.

About the specifications, how did you design this for the wide range of needs of the potential clients?

The specifications are where the rubber meets the road. As you just pointed out, there is a wide range of possible levels of service. We designed the site with the client's needs in mind and tried to make allowances for every type of job in every business sector, from office building managers to plant engineers at huge manufacturing facilities, single sites to multiple sites. The specifications allow the client, for instance, to choose all the lowest specs. Doing this will obviously get the lowest pricing. They can choose high specs and get only the top infrared thermograph companies. They can accept any or all bids at any time or reject them all and re-bid the job. All along the spec writing process, we help the clients by pointing out options that they might want and ones that might not need.

Finally, what future plans do you have for ConnectIR™?

Well if it is as successful as we anticipate, we will implement the same system for other PdM technologies. In fact, we have already begun building additional modules. We officially launched ConnectIR™ at IMC-2006 and the response was fantastic. We really think this is a great way to provide a direct link between companies that need thermography services and qualified thermography companies. Time will tell whether the marketplace thinks as much of it as we do.

Visit the website www.ConnectIR.com to experience this new service.

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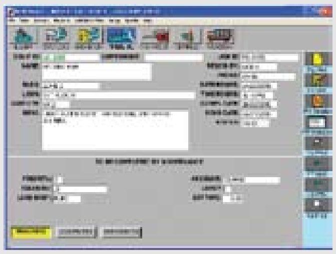

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