uptime

the magazine for PdM & CBM professionals

jun 2006

Foggy Future for U.S. Manufacturing?

Constant Thermal Monitoring

A Study in Lubrication Selection

Vibration: A Big Picture Approach

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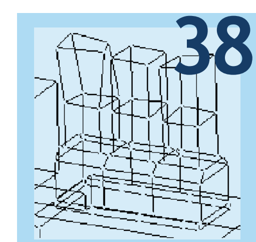

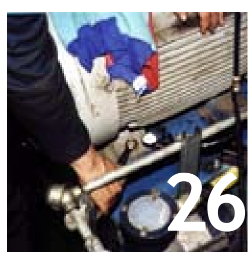

The Asset Issue

Assets. Assets. Assets. Business is all about using your assets. Good business is about using assets wisely. The best businesses focus on maximizing their assets - getting the most out of what they already own. It is a remarkably simple concept. Perhaps even more remarkable is the alarming percentage of companies who ignore it.

In our feature article, Christopher Meyers and Terry Wireman do a very nice job of laying out some fundamental problems in the way maintenance is viewed by most business executives & non-maintenance personnel, and the steps that need to be taken to resolve these issues. If companies wake up to the fact that maintenance is, as Mr. Wireman eloquently calls it, "a competitive weapon", we can reverse the trend fate of U.S. manufacturing. This is an important subject, and we would all be wise to keep it on our agendas.

This much is clear. Until maintenance becomes more than a cost number on a spreadsheet to the people who make the ultimate decisions, companies will continue to suffer. Maintenance professionals will not get the kudos they truly deserve. They will not get to deliver the massive return on investment that a high quality maintenance and reliability program can produce.

In many ways, we have only ourselves to blame. Those of us in the maintenance industry have apparently done a poor job of educating our non-maintenance comrades and management about the true benefits maintenance and reliability can bring to our companies. In many cases, the data is there - captured by our CMMS software, EAM software, or in our work order system. Where we have fallen down is in translating our maintenance data into the language of business....accounting.

Maintenance is not just a necessary evil. It is quite possibly the single most overlooked opportunity within industry today. One thing everyone in the maintenance and reliability profession should agree upon. We should all agree to do whatever it takes improve the way in which we communicate our value to the bottom lines of our companies.

Let's agree to make it impossible to be overlooked.

Thank you for reading. We would love to hear any questions, comments or ideas that you think will make Uptime work better for you.

All the best,

Jeff Shuler
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uptime
volume 1, issue 8

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

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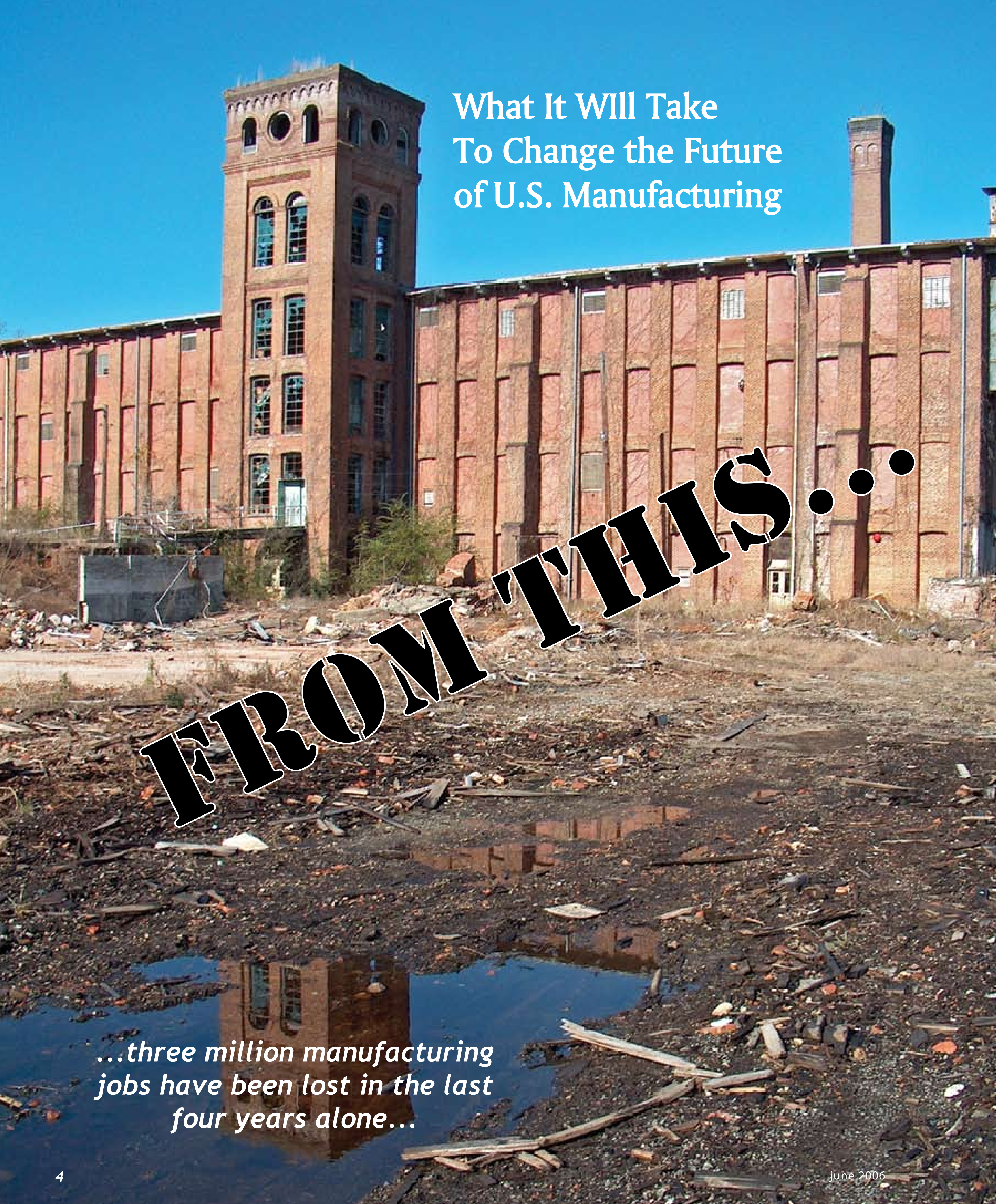
What It WIll Take To Change the Future of U.S. Manufacturing



FROM THIS...

...three million manufacturing jobs have been lost in the last four years alone...

Regaining America's Manufacturing Competitiveness Through Maintenance

The Issues

by Christopher J. Meyers

For decades, America has been battling the threat of cheaper and faster manufacturing from foreign competitors and we are losing. Whether from cheaper labor costs in places like Mexico, China and even Viet Nam, or from more efficient production techniques used in countries like Japan and Korea, the fact is America's manufacturing base is eroding. Three million manufacturing jobs have been lost in just the last four years alone and the current level of manufacturing employment in the U.S. is at its lowest level in over 50 years. Throughout this struggle, we have focused our competitive efforts on improving production processes and lowering costs by utilizing the latest techniques, consulting fads and business school buzz words of the moment, yet we still find ourselves at risk. Given all our efforts and progress, we have never truly addressed the area of maintenance despite its dramatic effect on costs, throughput and quality.

American industry has instituted Just In Time (JIT) to lower inventory costs, Total Quality Management (TQM) to improve quality, Six Sigma and Lean Manufacturing to help increase productivity, while virtually ignoring maintenance and reliability. This is an amazing oversight given the fact that American companies spend nearly $2 trillion a year on maintenance (half of which is held up in inventories). If we applied the same effort and metrics to increasing turns and reducing the levels of our maintenance, repair and operation (MRO) inventories that we have to improving production inventories, billions could be driven to the bottom line. The other half of that $2 trillion lies predominately in labor where, in the majority of maintenance organizations, maintenance craftsmen spend as little as 2 hours per day doing actual hands-on work activities. Mix in a lack of fundamentally sound maintenance processes and technologies across most manufacturers and the opportunity grows exponentially. Only one-third of all organizations have some type of work-order system and only about one-third of those, or 10% of all organizations, actually track such work-orders to best manage their time, activities and inventories. If we include the impact proper preventative maintenance has on throughput and quality, it is clear that we are missing an opportunity to drastically improve our competitive position, and, ultimately, our bottom line.

There are certain economic realities associated with manufacturing in America. Our standard of living is relatively high, which continually pressures our already high and fairly immovable wages. Health care costs are an ever increasing burden for employers and our corporate social responsibilities only continue to grow. While our government must delicately balance the needs of our workers with the reality of a competitive world market, it is ultimately our ability as a nation, and as manufacturers, to be competitive within this system that will determine our manufacturing position going forward. And while we have exhausted ourselves from the shop room floor to the executive suite in pursuit of becoming a leaner, more efficient, cost effective producer of quality goods, we have left virtually untouched, under researched and under utilized the entire area of maintenance and reliability. By way of example, while attending a well known and respected business school in Boston, MA, I was required to take a class on manufacturing. The class was given a "must read for all executives in manufacturing" that contained 389 pages of the most progressive thinking around manufacturing. In that entire text, there was exactly one full sentence dedicated to maintenance.

Unless we can convince our executives, the professors within our foremost academic institutions and our leaders of the future to embrace, research, teach and exploit the importance and benefits that lie within maintenance, we will not, as a nation, take full advantage of one of the last tools we have left to be truly competitive in the world market.

So...where do we go from here?

Regaining America's Manufacturing Competitiveness Through Maintenance

The Solutions

by Terry Wireman

As discussed previously, American companies continue to take a cost focus on maintenance and reliability. This leads to a focus on the incurred maintenance and reliability costs and a lack of understanding of the impact costs of maintenance and reliability. The incurred-cost approach to maintenance also leads to sub optimization of the asset base. For example in a study by MIT professor Erik Brynjolfsson (http://ebusiness.mit.edu/erik) it was estimated that there are trillions of dollars in underutilized manufacturing capacity in the United States. Why would companies move operations offshore for cheap labor when they are not properly utilizing the hard assets in which their shareholders have already invested? Is it possible that they do not understand the value of their assets, let alone how to optimize their utilization? Does the impact of cheap labor really compare to the value of optimized asset utilization?

If America is to regain competitiveness though improved asset utilization, where do we begin? The answer has many facets that must be addressed; however, it begins with improving the maintenance and reliability functions which impact the asset utilization. The four main facets of maintenance and reliability improvement are:

1. Designing the Maintenance function
2. Utilization of a Maintenance Information System
3. Providing Maintenance and Reliability Education for the Organization
4. Evolving an Asset Centric Business Process

Let's take a close look at each facet individually:

Designing the Maintenance Function

This facet focuses on designing the maintenance function to meet the needs of the organization. This highlights the need for the maintenance organization to have a vision and mission statement. If there are no clear objectives for the maintenance business, then the organization will never be designed in an efficient and effective structure. In order to properly design the maintenance organization, the following are required:

A. Define the vision, mission, goals, and objectives for the maintenance organization

B. Determine the geographic structure for the maintenance organization

C. Determine the reporting structure for the maintenance organization

D. Determine the roles and responsibilities for the maintenance organization

E. Determine the staffing levels for the maintenance organization

F. Determine the performance indicators for the maintenance organization

Utilization of a Maintenance Information System

Once the maintenance business is correctly configured, an appropriate information system should be implemented to properly manage the business. This system is usually referred to as a Computerized Maintenance Management System (CMMS) or an Enterprise Asset Management (EAM) System. This system is utilized to collect all of the maintenance information (such as labor, material, contract cost and history). This information is typically collected against a piece of equipment, a building-floor-room locator, or a functional location. As the information is collected over time, it builds a historical database that allows for proper analysis of the maintenance business function. However, few organizations properly utilize their CMMS/ EAM


...TO THIS

systems. This results in incomplete or inaccurate financial and technical data. This lack of data prevents most companies from being successful with the third step.

Providing Maintenance and Reliability Education for the Organization

It is at this stage that most organizations fail, which results in manufacturing finding itself in the conditions described in the first part of the article. Most business managers have little or no exposure to the maintenance business, so it receives little attention, except when it comes time to reduce expenses. However a competent business oriented maintenance manager can utilize the data that is being collected over time to show manufacturing executives the direct impact the maintenance business has on their profitability. Since the information is being collected in the company's CMMS or EAM system, they have the data to show the direct impact. In addition, the historical case study information to show how other companies have realized these benefits is readily available. As clearly seen from part 1 one this article, this education is not occurring for most senior executives today.

Evolving an Asset Centric Business Process

This process is truly an evolution. It occurs only in companies with a clear vision of how their assets are utilized to produce their products. In addition, the company must also have a clear understanding of the technical aspects of their assets to optimize their financial investment in the assets. This requires a holistic view of the assets, from the time they are designed to the time they are decommissioned. True optimization of the assets only occurs when all departments involved in the asset life cycle focus on asset optimization.

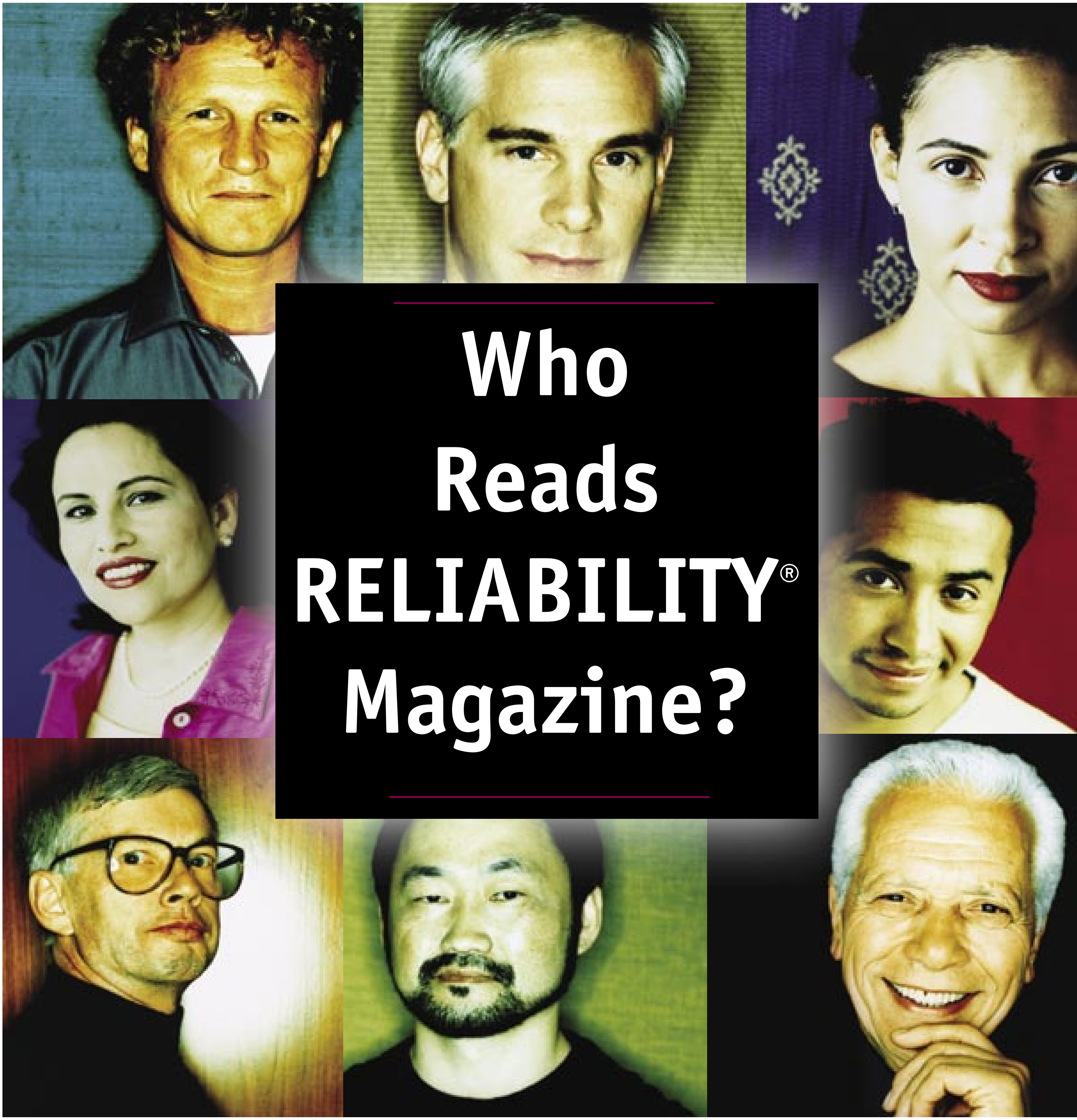
The importance of this approach is highlighted in dozens of publications, including textbooks published by Seiichi Nakajima and Benjamin Blanchard. Particularly in the Introduction to *TPM*, Nakajima states that 95% of the life cycle costs are determined in the design phase of an asset's life cycle. Yet, 75% of the total life cycle costs are incurred in the operational and maintenance phase. If the design engineers do not communicate with the maintenance and operational

personnel, how can the economic investment be optimized? In fact, if all departments involved in the life of the asset are not involved in making decisions about the assets, the life cycle costs are not optimized and the company's ability to compete is severely impaired.

If organizations cannot progress to a high level of maintenance and reliability maturity across their organizations, they will never be competitive. The majority of companies today are focusing on maintenance and reliability as a cost instead of a competitive weapon. This leads to moving entire factories to other countries due to cheap labor. If they continue to take a cost focus on maintenance and reliability, America will never realize the ultimate benefits from asset utilization. This will lead to a continual cycle of moving plant operations to countries with the lowest labor costs. This defocusing of resources will lead to the ultimate loss of American manufacturing.

Christopher J. Meyers is a Partner in Vesta Partners, and leads Operations and Corporate Business Development for the company. He has over 16 years of experience in private equity and corporate business development and has been involved in over $2 billion of investment activity. Prior to joining Vesta, he was with Spinnaker Venture Partners and Carlyle Venture Partners where he invested in early stage technology companies. Prior to that he spent 8 Years with GE Capital Services where he focused on Strategic Planning and Business Development successfully completing corporate acquisitions world-wide. He has a BA from Ohio Wesleyan University and received his M.B.A., with distinction, from Harvard Business School.

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.


Who
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IR: The Next Generation

Constant Thermal Monitoring

by Robert Kern & Ross Kennedy

In a data center or manufacturing facility not so far away, the manager is on a mission to discover every waiting problem before they have a chance to stop the ultimate goal - No Unscheduled Down Time. Yes, we all imagine a perfect universe with no down time, no problems, and no unforeseen equipment issues. Alas, we all know such a universe doesn't exist, so back to reality.

The mission to achieve No Unscheduled Down Time has taken us on an interesting, and relatively speedy, journey. We have come from first having to essentially guess about our machinery's problems all the way to where we are today. But the quest to develop a better understanding hasn't stopped at the technology commonly used today. After all, what manager wouldn't want to know the state of equipment health, today, tomorrow and the next day, with no guessing and no intrusion?

Lets explore where we've came from, where we are, and where we are going.

The 1st Generation - He who knows it the best...

In the beginning, the person that knew the equipment the best, walked his or her domain just looking, listening and feeling. That person knew the equipment better than they knew own mother. Maybe they could feel the increase in heat radiating from a panel, hear the slower speed of a fan in a cabinet or slower response time from a server. Any little aberration that just didn't seem right sparked investigations to make sure things were just fine. If a problem couldn't be found, well, all they could do was wait and see and hope for more clues instead of a failure.

Of course this method of maintenance was far from perfect, and was dominated by the mottoes "if it ain't broke, don't fix it" and "keep an eye on it". We had to wait for something to break, so we had something to fix. But, at its best, this unscheduled down didn't damage equipment, but still cost companies in lost revenue. At its worst, this wait and see approach created an environment for damaged equipment, fire or explosion.

Figure 1 - Just keep an eye on it.

Of course, this method was lacking in catching subtle problems before they became larger. It was a huge hazard for the person that had to feel around for a problem, open up panels and attempt to manually measure temperatures. All the data was empirical, subjective, and was done at a "convenient" time. Sometimes when further disassembly was needed, the system had to be turned off and didn't always come back on as expected.

The one thing we learned during this period is that most failures have one thing in common - heat. Or, to be more precise, an increase in heat. If a component is going to fail, the connection will increase in resistance. We will not see a "brown out" of the voltage, but will see an increase in radiated heat. As a connection first begins to fail, the temperature rise may only be 5°, and then a month later another 5°, for a total of 10°. These minor increases in temperature are very hard to detect without comparative data. If we could catch that 1st increase in the temperature before it causes a degeneration of the quality of the connection, we could simply repair it and be fine. So, to advance past the first generation of troubleshooting we needed a better way to quantify the temperature measurements.

The 2nd Generation - Thermography

To answer the need to collect quantifiable data fast, thermography became the selected de facto solution.

Even with prices coming down in recent years, thermal imaging cameras are relatively expensive. However, they do collect excellent data, and later that data can be documented, analyzed and corrective action suggested and taken. Small increases in temperature can be documented.

This was a huge step forward. But like most solutions, it has its compromises. While the technician can "stand off" to take the images, the equipment needs to be operational and panels open. The camera cannot see through a panel. If a 10° rise is seen on a panel surface, an object behind the panel could be 50° hotter than the minor "warm" spot. If there is enough of an air gap, and another panel between the heat source and front panel, it's possible that no noticeable temperature rise may be seen. With the panels open we still put the technician at risk.

Thermography is best performed by a technician familiar with systems like yours and experienced with the thermal imaging camera being used. The correct compensations need to be set and the correct lens used for the data to be accurate. One picture of a large area will not do. Due to both camera resolution and the fact that different points of interest may require different compensation settings, individual pictures will be needed of certain areas of interest. The technician must be diligent for the data to be accurate. The use of a trained and experienced thermographer will yield the best results.

Since thermography can still be intrusive and isn't free, in some cases it may be performed only once or twice a year. Keep in mind, that infrared surveys should be performed when the system is at full load or at a time when being "exercised" the most.

To ensure that a system is being properly loaded, some tests are performed using external load banks. While this is an added expense, external load banks will help ensure that the electrical system is loaded to 40% or more to bring more meaningful results to the thermal images. Load banks have their own dangers. Incorrect wiring of the external load banks could cause damage to the electrical system. Since most systems have one utility feed, a major failure at this point could take down the entire system. Intrusive action like wiring in load banks with external wire runs, coupled with the heat from the loads, increase the odds of personal injury or other unforeseen accidents.

Will an accident occur while the load banks are being disconnected? While the arc flash panels are being reinstalled, or while panel is being closed? If the system was turned off for any of the clean up process, will it turn back on correctly?

While thermography yields results that are very useful, due to the nature of the testing in the once or twice a year scenario, no real trend data is being collected. As loads increase during the year, how are certain electrical components responding? Are any connections degrading due to the increased loads? Was all the periodic maintenance performed correctly? Was the actual thermography survey performed correctly? Was the analysis correct? Much is left to human interpretation.

You may not be sure until next year...or until a failure occurs. If only we could see into the cabinets without opening them.

The 3rd Generation - IR Windows

The need to take thermal images on a timely basis and with the least amount of intrusion has spawned the development of infrared windows. The intention of the IR window is to allow the thermographer to obtain the thermal images while the cabinet is closed, as often as needed. This greatly decreases the risk factor to the technicians, while decreasing the likelihood that opening or closing the cabinet will cause problems with the systems. Once installed, they can greatly decrease the intrusiveness of the thermography work.

IR windows have come a long way and there are many choices in the market today. Along with so many choices, comes compromise. The types of material and their compromises have been covered very well in past articles, so this particular information will not be covered in this article. But based on the nature of this article, we'll discuss the highlights.

The IR window should allow the thermographer to take the thermal image while not opening the panels. The goal with the selection and placement of an IR window is that most, if not all, targets should be available for viewing.

IR Windows allow for line of sight, based on the lens used in the thermal camera. Bus bars may cover one another, if there are additional arc flash venting panels installed, bus bars behind them and parts of the circuit breaker will not be available for scanning.

IR windows are made from different materials and each one has its benefits and compromises. Each one will have different ratings for transmission of the available IR signal. The Technician will need to be mindful of this while taking thermal images year to year. The correct compensation will need to be set in the camera for each different thermal window.

One needs to be mindful of the UL or safety ratings of the cabinet into which the IR window is being installed. The addition of an incorrect IR window may invalidate the safety rating of the cabinet. Make sure to consult the manufacturer of the IR window, the manufacturer of the cabinet, as well as the organization that has approved or listed the cabinet.

The 4th Generation - Here Today

If we were to start with a clean slate, what would we really want?
Would you want to increase safety by not needing to open a panel and conduct tests live to know a temperature? Would you want to specify the switchgear and electrical panels with the intelligence to take it's own temperature?
Wouldn't it be nice if the equipment let us know when something inside is too hot? Wouldn't it be great to look to see how our equipment fared on the night that a substantial event occurred?
Wouldn't we also want to be able to know for sure that once all the panels were re-assembled after the periodic maintenance was finished that all was still fine?
Wouldn't we like to be able to look at real time data that's been collected from the last 365 days, and substantiate that there is a sound reason to extend a periodic maintenance, so we don't bring down a system unnecessarily? Wouldn't we want to know immediately how the electrical system is handling the latest server upgrades?

We know from experience that problems start out small. When problems are small, they will exhibit a small temperature rise. The worse the problem grows, the more dramatic the temperature rise. As the temperature rise increases, as with a bad connection, the increased temperature causes accelerated oxidation, pitting and carbon build up - further damaging the connection, causing an increase in resistance, which causes an increase in the heat. The cycle continues until we experience a fire or complete failure. Based on practical experience, the cycle may only take a month, or as much as a year.

If we are lucky, we catch the problem within the thermography cycle established, before it festers to a more expensive repair or a total failure. The bottom line is, the sooner the problem is spotted, the simpler, cheaper, and quicker the repair.

Connections exhibiting a 30° rise, due to added resistance, will hardly register a decrease in current. In fact, in recent testing, a 20 amp branch circuit powering a resistive load with a 50° rise on a connection, barely showed a 500ma change in the load current. How the branch current acts when the source voltage decreases depends upon the load.

You would naturally think that if the source voltage decreased, the current would decrease as well. So you might think a bad connection within the branch circuit would cause the applied voltage to decrease somewhat, then a corresponding decrease in current should be noticed.

But, this doesn't happen with servers. The Switch Mode Power Supply (SMPS) found in the typical server has a negative resistance characteristic. As its input voltage decreases, its input current increases. Due to the negative resistance of a SMPS, when even a minor voltage drop occurs (say from a connection becoming faulty) an increase in current will be experienced. This slight change in branch current can easily be interpreted as just additional processor use, or well within the normal range of load fluctuations, not the lurking "bad" connection. Basically, monitoring load current is a great way to know if the loading is what you've planned it to be, but is no measure for the health of the electrical service and the components that make up the electrical service.

Figure 2 - Unobtrusive installation and the convenience of no maintenance make constant thermal monitoring an attractive option for critical equipment.

If you had data spanning from the last periodic maintenance, and if all the temperatures in the data were fine, there would be no reason to shut down a system, and put a technician into harms way to open panels and check torque. But how would we be able to collect such data?

With constant thermal monitoring, such trend data can be collected in real time automatically and used to substantiate fiscal savings like extending periodic maintenance intervals, monitoring the health of the equipment as loads increase, reducing unscheduled downtime by optimizing scheduled maintenance, realizing the capacity of the system during times of growth.

The Solution: Constant Thermal Monitoring

The next generation is here: 24 hours a day, 7 days a week, 365 days a year thermal monitoring. Using small infrared sensors as well as other temperature sensors, each critical item can be monitored in real time.

Such systems can use their own data loop, which provides for a nice back up to the standard building management system (BMS) loop. Or, you can choose to integrate it into current BMS systems.

Once installed, there is no dependency on the settings of a camera or competency of a technician. Protective panels do not need to be removed to check on a protocol data unit (PDU) or piece of switchgear if changes in loadings occur after bringing new loads online. Since data is logged 24/7/365, the data can be reviewed for abnormal transients that would indicate abnormal events in heat or electrical loading of a system.

With the roll out of the blade servers the increased branch loading also reflects back to the switchgear. The effects of the added power requirements normally wouldn't be noted until the next thermography cycle, and it may be too late by then. The same constant thermal monitoring system can be used to monitor and alarm the hot and cold server rack isles.

Figure 3 - Infrared sensor installed on 1 phase of a feeder to a panel.

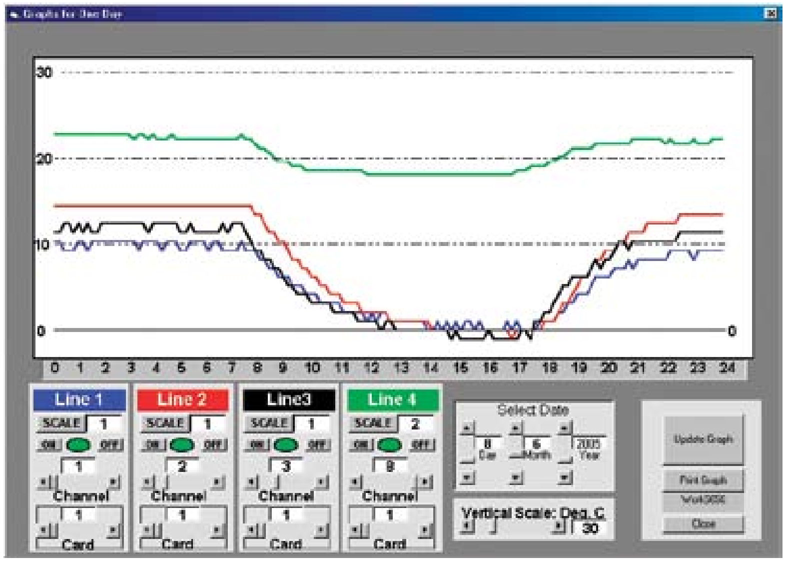

Figure 4 - The Exertherm software has built-in trend graphing, which provides a quick visual of the data.

These high-density blade servers aren't less efficient power wise, they just occupy less space. So they emit more heat per cubic foot due to their density, compared to the old, larger server configurations. When "more" servers are installed into one rack, the result is an increase in the BTU's generated (dissipated heat) from the same rack and an increase in current draw from the branch circuit. So keeping an eye on these hot and cold isles becomes just as critical as the electrical components (PDU's, UPS's, & Switchgear).

While new to the USA, continuous thermal monitoring in critical switchgear has been proven over the past 5 years via numerous successful installations in blue chip multinationals located in the UK, utilizing patented IR technology. Since these small IR Sensors are non-conductive plastic, passive, (requiring no external power), and with unsurpassed mean time between failure, they can be placed inside critical enclosures without concern. Certain switchgear manufacturers in the US are already working to offer OEM installation of this system, which provides trend data and independent alarms from each sensor.

The Data Acquisition Cards to which the sensors are wired can be mounted either in equipment cabinets or external to the switchgear. Each card accepts 8 sensor inputs, and there is a choice of data cards. One type communicates using an ExerTherm data loop and works with the ExerTherm software to manage the system, (this can also provide alarm status flag to existing systems through the supplied dry contacts). Another type of card communicates directly to the likes of Modbus and other key protocols (i.e. Profibus), utilizing existing bus cabling, and providing supervisory control and data acquisition (SCADA) system compatibility. The system can also be web enabled via Ethernet connection enabling access from intranets, or even combined with the latest wireless data transfer technologies to provide continuous monitoring of critical equipment in remote locations. The system can easily be retrofitted during a suitable shutdown, installed during new construction, and be expanded as required in either case. Easy expansion enables progressive installation in critical sites that only have partial system shutdowns.

The available mounting systems provide for a flexible mounting option that's comprised of all non-conductive high temperature material. Since the IR sensors are totally passive and require no bias voltage or current, they never require re-calibration.

In electrical equipment, connections, and components (all known as a target) it's more important to know the temperature "rise" being experienced. The "temperature rise" is the effect of the losses within the "target". For a connection, the losses are a result of the resistance in the connection. As previously discussed, the higher the contact resistance, the higher the losses, so the greater the temperature rise.

Thus, in thermal imaging, the accepted method of temperature measurement for electrical equipment is Delta T (ΔT), i.e. the rise above ambient (surrounding air temp), of the target equipment being measured. The ExerTherm IR sensors employ exactly the same method.

Not Just For Data Centers

Although data centers were used as the pri-

Figure 5 -Sensors installed on 200Amp disconnect.

mary example of where constant thermal monitoring is being used, ExerTherm has many more applications than just monitoring the electrical system, HVAC system and temperature of a data center. Any facility or manufacturing plant that is focused on achieving greater uptime and getting the most from their scheduled maintenance can benefit from this technology.

Monitoring electrical distribution equipment for manufacturing plants will not only maximize uptime, but also maximize safety and minimize damage. Many of the large scale manufacturing plants use much more power than a data center. This potential energy that could be unleashed during a failure or arc flash can damage not only the electrical distribution equipment, but also very expensive robotic and manufacturing machinery, not to mention injuring any personnel that may be in the area.

There are many applications within manufacturing machinery. In high cycle rate and or close tolerance machining, minor bearing wear can increase the rejection rate. Bearings starting to wear will exhibit an increase in their operational temperature. If left unnoticed, loss of critical tolerances will cause rejects, and eventually a catastrophic failure in the machine. This failure will lead to more expensive repair and an extended down time. The same can be said for motors, gearboxes and pumps as well. So this technology can literally be applied to most large scale manufacturing/processing plants and shipping fleets.

A larger cruise line company has deployed ExerTherm on their modern vessels. These floating cities on water not only generate and distribute the power for their small city, but for their electric propulsion. Loss or damage of electrical equipment or drive components is much more than just unscheduled down time for this industry. Like data centers and large scale manufacturing, the consequence will not only be additional costs, but also a significant loss of profit. Continuous thermal monitoring provides a solution which substantially mitigates that risk.

Conclusion

The power to monitor any component of electrical junction or device is now available. Not only to monitor it, but also to record its profile over time, which gives us a level of information we have never had before.

We can now know what occurred in the past, what's happening today and predict what's going to happen in the future. Finally giving us the power for true Predictive Maintenance. So, maybe that mission of No Unscheduled Downtime is within reach after all.

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Ross Kennedy graduated in Business Studies in 1970. Various managerial posts with International responsibility followed with Reed International, Unilever, Turner & Newall, as well as a major UK based retail chain. QHi Group was founded in 1988, initially as a consultancy, but subsequently expanding into a leading provider of innovative technology solutions in a diverse cross section of industries including Rail, Process manufacturing, Predictive Maintenance, Wireless Telemetry, & Building System Integration. Ross can be contacted at +44 (0)1582 461123 or ross@qhigroup.com

Bevel Gears Get Better Grade

A Lubrication Selection Analysis

by Mike Johnson

A North American manufacturer recently made an 'upgrade' from a commodity grade gear oil to one that was promoted as a 'high performance' lubricant as part of an effort to improve energy efficiency and drive reliability on a particular gear driven variable speed wire extrusion line. The mill had previously used a single grade of lubricant in the combined group of 6 bevel gear and 5 worm gear drives for the purpose of maintaining simplicity and minimizing the risk of top-off error during TPM-oriented activities.

There was a lubricant functional failure in the form of a highly aerated (foamy) constant state. The failure was initially believed to be moisture related but was later attributed to air entrainment. Air has no load bearing potential and contributes to a variety of lubricant failure mechanisms. Management chose to respond proactively by conducting a critical review of the OEM recommendations and current selection for the operating conditions in an effort to eliminate the risk factor.

The extrusion line drive system contains a group of five worm type and six bevel type gear drives similar to those shown in Figure 1. The line operates at variable speeds, depending on the size of material that is produced. Additionally, each individual drive operates at differing speeds depending on where it is located in the production sequence.

Reliability is considered borderline acceptable, but mill management has concerns that reliability will suffer if the lubricant conditions are not improved. This case study will review key operating and environmental issues that were considered in improving the lubricant selection for the bevel type drives.

Figure 1 - Bevel Gears

Operating Conditions

Lubricant Condition – An ISO 460 EP gear lubricant was selected to replace another ISO 460 product. A significant 'haze' forms in the lubricant promptly following normal machine operation, and is resident through the lifecycle of the lubricant. Oil analysis indicated periodic elevated levels of Calcium, which is believed to be an atmospheric process contaminant, but no other significant levels of chemical contamination. There is no evidence of base oil degradation but there is occasionally a drop in additive concentration and viscosity. The fluctuations are found to coincide with oil changes, and are believed to reflect batch differences in lubricant quality. A new oil sampling process was recently initiated to verify incoming lubricant integrity. There is little evidence that the failed lubricant condition is a consequence of lubricant degradation. The oil is changed frequently due to concerns about the haze, so the lubricant does not have time to degrade.

Contamination Condition – Filtration is not conducted on any of the units on a routine basis. Particle counts are not provided by the laboratory, but under the circumstances, there is a high likelihood that solid contaminant levels will be high in each of the 11 drives. There is no ready source for or evidence of water contamination. The heat load is low. Ambient temperatures in the northern plant are low, with the highest temperatures reaching the 35°C range, and gear sump temperatures reaching a 45°C range during summertime operation. Plant ambient temperatures may fall below 25°C during wintertime operation.

A reasonable estimate of a 25°C gear interface temperature increase (above sump temperatures) would still have the lubricant operating between 60°C to 70°C. These operating temperatures could contribute to moisture accumulation if there was risk of moisture, but analysis suggests that moisture is not present.

Lubricant Level – an incorrect lubricant level can increase air entrainment if the level is high enough that the normal gear action can 'churn' air into the sump. The oil level was verified to be accurate early on by the attending mechanic, and is maintained at what is considered correct for the angle of installation.

Lubrication Regime – Bevel gears should operate between boundary (metal contact) conditions to full film (Hydrodynamic and Elasto-hydrodynamic – thin film but full separation) conditions, depending on a variety of factors, including:

- Tooth form
- Gear wheel speed
- Gear wheel size
- Operating temperature
- Fluid viscosity (at operating temperature)
- Presence of contaminants that compromise film integrity (air and moisture)

It is critical that the lubricant recommendation provide sufficient viscosity for the operating conditions to provide for complete fluid film formation. This means heavier viscosities for highly loaded and low speed conditions, and lighter viscosity for lightly loaded and high-speed conditions. Excessively high viscosity may not be helpful, and may be harmful for a variety of reasons, including excessive fluid friction, increased heat, premature lubricant degradation, energy losses and cold start channeling.

Method of Lubricant Selection

Gear speed, sump temperature and gear type are the primary factors used by AGMA (American Gear Manufacturer's Association) and individual gear manufacturers to target the best viscosity fit for a gear set. In the most recent version of the AGMA lubrication standards (AGMA 9005-EO2), Pitch Line Velocity (PLV) is a central criteria used to make viscosity selections. Bearing lubricant selection must also be reviewed prior to making final decisions.

The PLV determines the contact time between the gear teeth. Generally, high PLV values are associated with high speeds and low loads, where low PLV values are associated with high loads and low speeds. This relationship appears to hold true for the set of gears under consideration. The lower PLV values tend to require higher operating viscosities and surface-active (AW and EP) additives.

Based on the provided inputs, the production line drive PLV's are shown in Figure 2.

Per AGMA 9005 – E02, the viscosity selec-

PLV = π * D * N		Pinion	Crown		Pinion	Crown
Pi	π	3.1415	3.1415		3.1415	3.1415
Pinion Pitch Diameter	D	0.08			0.08	
Pinion Speed - Maximum	N_X	1775			1775	
Pinion Speed - Minumum	N_M	450			450	
Crown Pitch Diameter			0.3232			0.3232
Crown Speed - Maximum			481			481
Crown Speed - Minimum			127			127
PLV	Maximum	446.093	488.3751	Minimum	113.094	128.9473

The line speeds are provided in revolutions per minute, which produces units of meters per minute. Once the PLV maximum and minimum values are calculated, each must be converted to a value per second, which is done by dividing the value by 60.

In Meters/sec	Maximum	Minimum
Pinion PLV	7.434883	1.8849
Crown PLV	8.139585	2.149121

Figure 2 - Pitch Line Velocity Calculations

tion is based on the PLV of the lowest speed gear mesh in a set. This bevel set has only one mesh, but the pinion and crown PLV values are appreciably different as you might expect. Since the crown has the lower speed, use the PLV values for the crown to select the initial viscosity target for each operating speed.

Since the input speeds are variable, the range of speeds must be considered. The lowest crown speed is provided in Figure 3. The target viscosity for this type of gear set, while operating at its lowest input speed, at its highest ambient temperature conditions would be an ISO 220 for each of the type of lubricant base stocks noted in Figure 3.

When the driver is turning at the high end of the operating range, the crown PLV is much higher at 8.1395. Using the same selection chart, we see that the target viscosity selection would begin at an ISO 100.

Crown PLV = 2.149121	45°C	PLV 1.0 - 2.5	PLV 2.5 +	PLV 5.0 +	PLV 10.0 +
VI = 90 (G1 min oil)		220	150	100	68
VI = 120 (G2 min oil)		220	150	100	68
VI = 160 (G4 PAO)		220	150	100	68
VI = 240 (G5 PAG)		220	100	100	68

VI = Viscosity Index

Figure 3 - Targeting the Viscocity

Judgment Call

It is a common interest to minimize the number of viscosities and types of products in use in a production area or line, but to do so at the risk of the lubricant or health of the machine takes consolidation too far. The correct technical recommendation for these drives is dependent on a continuously changing speed factor, the result of which will require one of 3 different grades between an ISO 100 and an ISO 220. All of these are well below the ISO 460 that was previously selected.

Additionally, there is a significant amount of viscosity difference between the 100 and the 220. It is appropriate to consider how the machines might be operated differently to minimize the degree of variation in viscosity requirements.

If there are multiple production lines, and there is flexibility in scheduling the product type per production line, then it would be clearly beneficial to dedicate the high speed production to a particular line, and minimize the viscosity differential to fewer grades and fewer machines.

If it is not possible to dedicate high speed production to specific lines, then it will be necessary to consider each of the 3 grades for each of the production lines. The owner already knows that the machines will provide marginally acceptable reliability when operating with a product that is two to four grades off (of the ISO 460). There is some risk to selecting the 150 for the drive that requires a 100, but it is still much less risk than the current condition.

Final Selection

At the low operating temperatures, little lubricant lifecycle extension value will be realized with the high performance product. An extra measure of surface protection may be warranted, but there is not enough information on the actual failures at this stage to fully justify the step toward the higher performance product.

Additionally, group one (G1) products contain types of molecular structures that are known to improve lubricity and surface protection (Naphthenic bases contain ring structures that impart higher pressure viscosity coefficient effects for the finished lubricant. Those ring structures are missing in PAO, G2 and G3 base stocks). Obviously, there are unique additive systems that can be selected that impart superior low temperature performance to the other (Group 2 – 5) base stocks, but until a clearly defined need can be identified, the G1 mineral oil should perform well if it is maintained in an appropriate state of health and cleanliness.

To select the correct viscosity, it is necessary to identify the top input speed for each stage of the six bevel drives, and determine the amount of time that each unit will be operating at the maximum input speed, and let the machine operating profile drive the final viscosity choice. The new product viscosities will range between 220 and 100, with the highest speed units benefiting most from the proper production selection. All of the viscosity grades should be selected from a common product type to minimize any risk of chemical cross contamination.

It is highly likely that the ISO 220 will minimize the extent of the current aeration problem, so even it if is not the 'ideal' selection, a single ISO 220 grade would be an incomplete but beneficial step in the right direction.

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

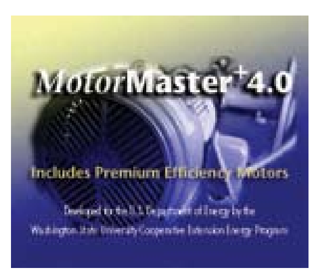
MotorMaster Plus

US Department of Energy Contributes to Reliability and Maintenance

by Howard W. Penrose, PhD, CMRP

In the early 1990's, the US Department of Energy (US DOE) released a Windows® DOS-based software program designed to assist companies in making individual repair versus replace, retrofit and new motor purchases. This software, MotorMaster, was a freeware program available upon request. However, it was challenging to use as the user had to perform analysis on one motor at a time while, at that time, there were a number of utilities that were offering retrofit incentives. In 1993 and 1994, the US DOE requested feedback from groups throughout the USA on how to move this software forward, along with other Motor Challenge materials. In general, the response was that there needed to be a way to analyze groups of motors simultaneously and the program would need to be Windows® based.

At the Motor Challenge 1995 conference in Chicago, the US DOE's Office of Industrial Technologies (OIT) officially unveiled MotorMaster Plus Version 1.0. This powerful tool included: a database of over 25,000 electric motors from provided manufacturers' catalogs, a hierarchy database that would allow a company to develop a motor database including operating information, a utility information and rebate schedule that was customizable, general repair cost information for repair versus replace decisions, the ability to run batch decisions, right size motors and track results, the ability to compare individual motors, a cost/benefit module, and, many more capabilities.



Over the next few years, additional capabilities were developed, including the ability to operate from a server. Data could be imported from other databases or spreadsheets, multiple companies could be maintained and the Reliability and Maintenance (R&M) capabilities were built into the program. During the whole development process, motor manufacturers, vendors, end-users, utilities and other stake-holders worked closely with the US DOE resulting in a huge and extremely successful government and civilian co-operative project.

At the end of the 1990's, the Motor Challenge program combined with all of the other US DOE Challenge programs including the Steam Challenge, Combined Heat and Power, Air Challenge, and others into the US DOE's Best Practices program. As a result of the change, all of the software and published tools are available on individual CD ROM's and via the internet.

Motor Management Programs

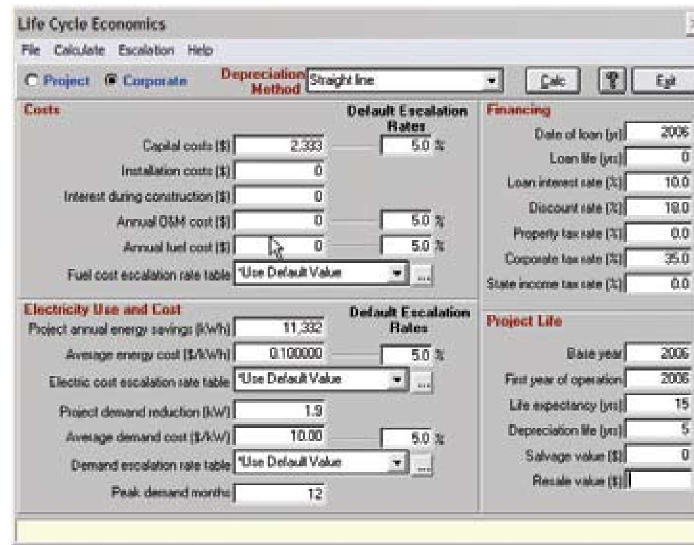
The MotorMaster Plus software lent itself very well to maintaining and tracking electric motor information, history, financial analysis and energy tracking. Because of these capabilities, it was incorporated into a number of motor management programs and offered by vendors. Each of these had varied success, based upon the resources brought to bear and the ability of the program managers to maintain them. One of the more successful programs was the DTM2 (Dreisilker Total Motor System Maintenance and Management Program), which started in 1994 and continues to use MotorMaster Plus as the database tool to this day. The pre-made report decisions of repair versus replace were invaluable. In general, the average impact measured from the tens of thousands of dollars to millions of dollars per year for a medium sized manufacturing site (> 1,000 motors over 5 horsepower).

At the end of the 1990's, a public utility wished to incorporate motor management as part of their offering to end users in order to promote energy efficiency. A suite of data collection tools was selected for determining load profiles and general motor condition. The purpose was to select critical electric motors at facilities and make retrofit decisions based upon the condition of the electric motors. This was important because, in order to determine payback in a standard retrofit, you had to use the cost of the new motor plus all of the costs associated with replacing the existing motor. However, if you were considering replacing a motor in poor condition, you only had to look at the repair costs versus the new motor cost. This had the impact of not only improving energy consumption, for both the user and utility, but improving the company's electric motor reliability as well.

There was only one problem. While the MotorMaster Plus software allowed for the ability to enter maintenance data of motor diagnostics, vibration and insulation to ground testing, it did not allow for the sorting of motors by condition.

Industry To The Rescue

As I was the developer of the concept for the public utility and the DTM2 program, we worked with the US DOE and Dreisilker Electric Motors, Inc., Pruftechnik and ALL-TEST Pro, LLC, in the collaborative funding and modification of MotorMaster Plus to allow for the ability to sort electric motors by condition. This ability was incorporated in 2001 in later copies of Version 3.2, and fully incorporated into the present Version 4.0.



Screen shot of Life Cycle Analysis Feature

With the present version, the user can directly enter or import an electric motor database, develop a hierarchy for their company on an individual PC or intranet, enter operating information, track motor history, enter condition-based testing information, sort motors by selected criteria, perform repair versus replace analysis then support the recommendations with the Life Cycle Analysis calculator. In addition, the user can choose just to use the individual motor comparison capability to compare an existing motor against a database of over 27,000 catalog motors, including metric, special frame, special duty and others up through 6,600 Volt machines.

Open Screen for MotorMaster Plus 4.0

Applications in Reliability & Maintenance

Now, with Motor Current Signature Analysis (MCSA), Electrical Signature Analysis (ESA) and Motor Circuit Analysis (MCA) devices being more prevalent in the marketplace, the data provided from these instruments, regardless of manufacture, can be entered directly (in most cases manually) into the software. The resulting data can provide accurate load, efficiency and other information to assist the user in making logical choices in the reliability and maintenance of the electric motor system.

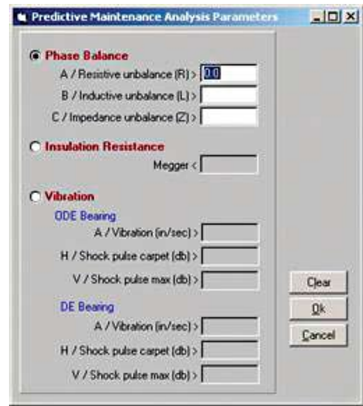
For instance, if a company makes the decision to replace all existing motors with IEEE-841 (petroleum, chemical and automotive duty motors), that can be selected in the Batch Analysis module and the software will provide a list of motor model numbers that are economical to replace the existing motors. The same can be done for a number of other scenarios, as well.

Another excellent fringe capability of the

MotorMaster Plus software is the ability to directly access the motor catalog database. A growing number of the manufacturers who provide their catalog data include such items as the no-load and full-load current, efficiencies, power factors, and the number of rotor bars and stator slots. All of this information can be invaluable to the reliability and maintenance professional for vibration and MCSA/ESA analysis.

Conclusion

The US DOE's MotorMaster Plus is an invaluable tool for both energy and R&M. However, most potential users consider just the energy part of the equation. The software tool, instead, actually represents years of collaborative work between industry and the US DOE to develop a tool that will benefit the company that utilizes it. To date, a growing number of small, medium and large manufacturers, vendors, utilities and others continue to use some, if not all, of the capabilities of MotorMaster Plus.



Diagnostics Screen

To access your free copy of MotorMaster Plus software, go to http://www1.eere.energy.gov/industry/bestpractices/software.html where you can download any of the US DOE Best Practices software tools. You can also access a free tutorial on the use of MotorMaster Plus by going to http://www.motordiagnostics.com/presentations.htm.

Howard W Penrose, Ph.D., CMRP is the President of SUCCESS by DESIGN, a reliability services and publishing company (http://www.motordoc.net) and is the Executive Director of the Institute of Electrical Motor Diagnostics, Inc. (http://www.iemd.org). He has been involved in the evolution of MotorMaster Plus, International MotorMaster and other US DOE tools and materials since 1993 and is a US DOE Certified MotorMaster Professional. For more information, please feel free to contact Dr. Penrose at howard@

An Alignment Journal

The Nuts and Bolts of a Four Day Alignment Job

by John Piotrowski

In the spring of 2002, our company was contracted to align a center gas compressor drive system and measure off-line to running (OL2R) machinery movement using both optical alignment and the Ball-Rod-Tubing Connector (BRTC) system. We were also going to measure vibration at start up and at high ball pressure conditions. The following outlines, in diary format, our alignment process and our observations and recommendations....

Tuesday, March 19, 2002

Removed shim packs under compressor and measured thickness of each pack as shown in Fig 1. Checked for soft foot conditions on compressor by anchoring a magnetic base near the south east foot bolt, placed a dial indicator on top of the motor foot and loosened the bolt. No movement was observed at that foot. One by one, loosened the remaining three hold down bolts and observed no movement of the compressor case. Unable to insert 2 mil feeler gauge under any of the four compressor feet.

Performed similar procedure to the motor. The existing shim packs thickness are also shown in Fig 1. Checked for soft foot conditions on compressor by anchoring a magnetic base near the north east foot bolt, placed a dial indicator on top of the motor foot and loosened the bolt as shown in Fig 2. 3 mils of movement was observed at that foot. One by one, loosened the remaining three hold down bolts and observed a total of ten mils of movement. Raised the motor up to clean the undersides of the motor feet and the baseplate contact points. Discovered that the undersides of the motor feet were “hollow”, that is, the contact pattern at each foot was a half inch wide horseshoe shaped contact pattern as shown in Fig 3. Because the foot was 3.5” wide, the B size (3” x 3”) shims were not wide enough to contact part of the horseshoe shaped contact pattern so C size (4” x 4”) shims were installed. Measured gap conditions with feeler gauges and cut and installed soft foot shims as shown in Fig 1. Began by installing 200 mils under both back feet and 215 mils under both front feet. Performed Reverse Indicator method between motor and

Fig 2 - Checking for lift with a dial indicator.

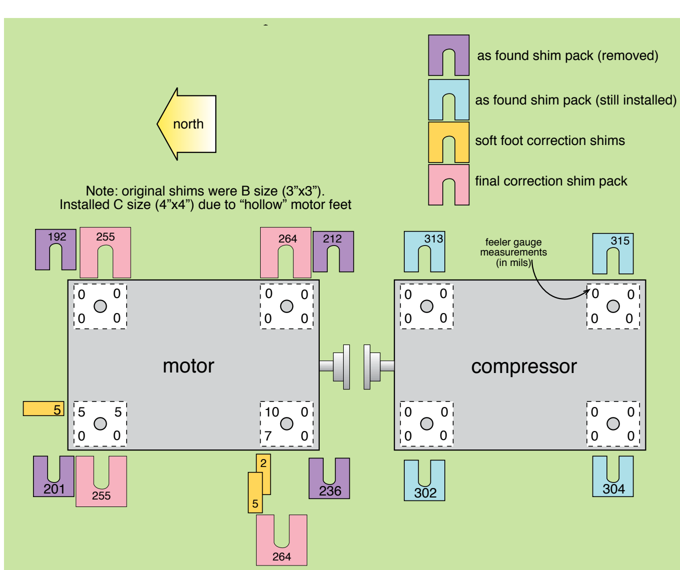


Fig 1 - Shim packs for Soft Foot Corrections

Fig 3 - Hollow under-side of motor foot.

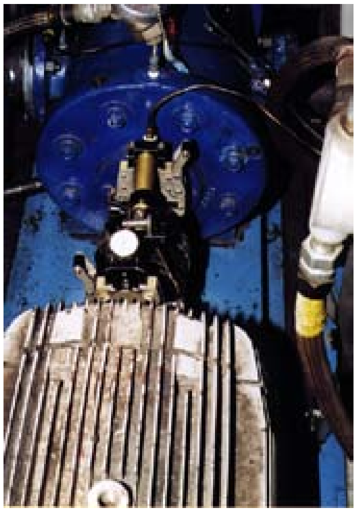


Fig 4 - Shaft alignment measurements taken using the Reverse Indicator method.

compressor as shown in Fig 4. Installed an additional 55 mils of shims under the outboard feet.

Wednesday, March 20, 2002

Finished aligning motor and compressor in the lateral direction. Figure 5 shows the initial and final alignment positions. Prepared drawings to fabricate brackets to hold BRTC system in place. Epoxied angle iron optical scale target platforms to the motor and compressor. Attached BRTC brackets to motor and compressor and modified brackets to position BRTC equipment. There was 8 mils of Total Indicated Runout (TIR) on the compressor coupling hub with the high spot in the same angular position as the set screw indicating the possibility that the coupling hub hole is bore too big. The motor coupling hub had 2 mils of TIR.

Thursday, March 21, 2002

Mounted holding brackets and BRTC equipment on motor and compressor as shown in Figs 6 and 7. Leveled optical Jig Transit as shown in Fig 8, set scale targets

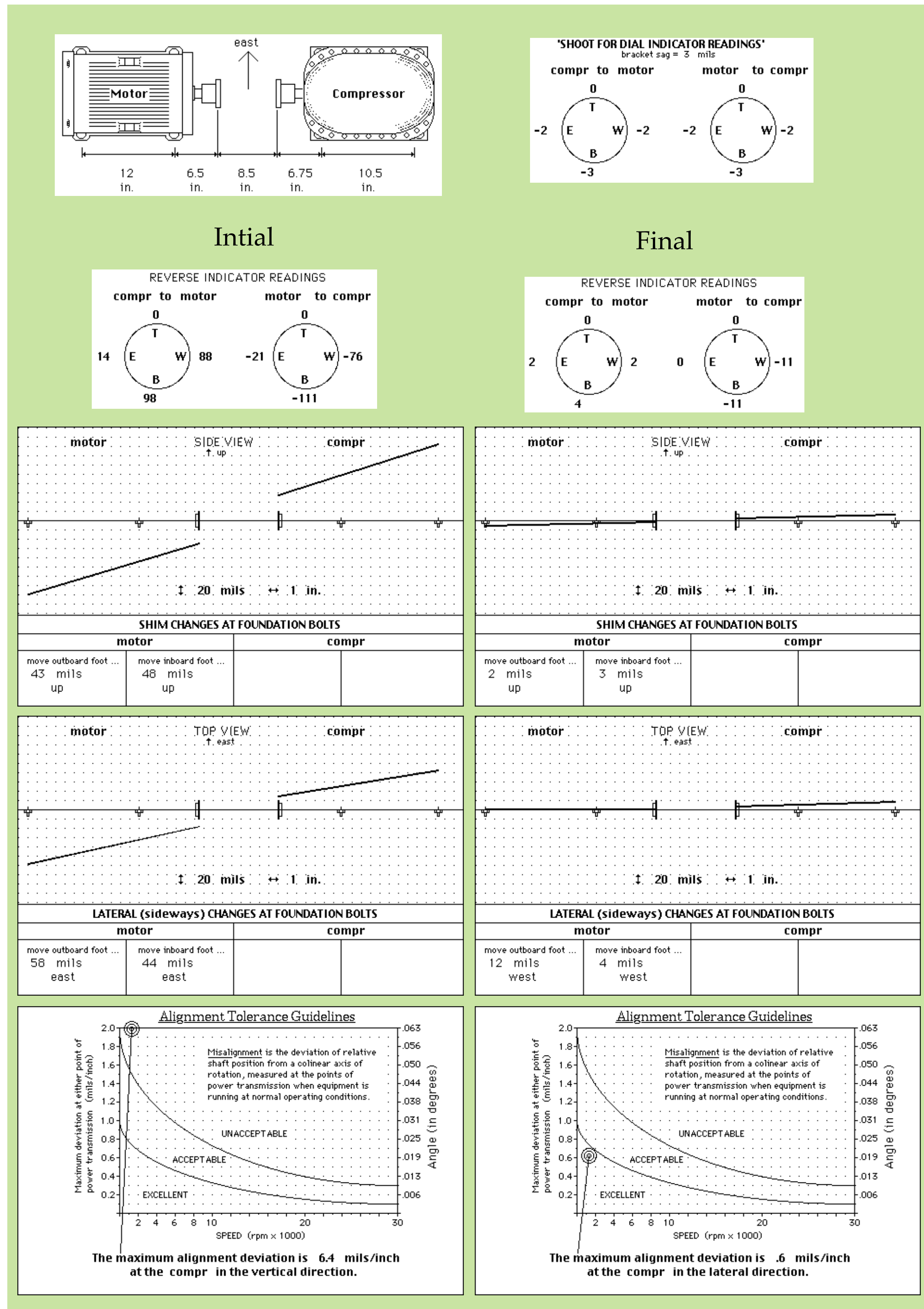


Fig 5 - Inital and Final Shaft Alignment Models

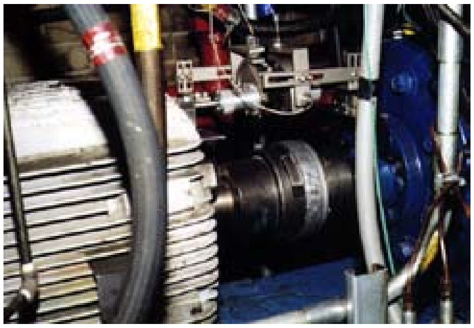


Fig 6 - Ball-Rod-Tubing Connector set up

on platforms, measured off-line / "cold" positions at inboard and outboard ends of both the motor and the compressor. Captured off-line / "cold" probe gaps on the BRTC system. Started center and south compressor up at 1105 hrs. CST. Began capturing running data with the BRTC system and the optical alignment equipment. Operated units until Gas Storage Vessel attained 22 psig. Shut center compressor down to allow it to cool back to ambient temperature overnight.

Friday, March 22, 2002

Measured off line positions again after the unit was allowed to cool back to ambient conditions and then disconnected the OL2R instrumentation.

Observations, Comments, and Supporting Data

As shown in Fig 1, the soft foot problem that existed on the center gas compressor motor was principally due to the uneven shim pack thicknesses at the outboard and inboard ends of the motor. The slightly uneven shim pack thicknesses on the compressor did not seem to have an effect on causing a soft foot condition there however.

Fig 9 shows the time line with optical alignment elevation data, ball pressure, motor current, water

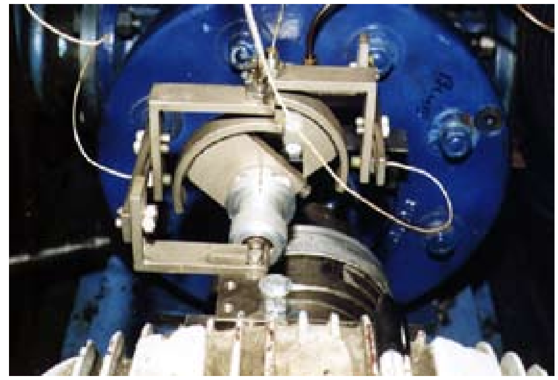


Fig 7 - Ball-Rod-Tubing Connector set up

temperature, and inboard and outboard compressor bearing temperature data. Due to the myriad of pipes, wiring, and cramped space, I was unable to use the optical alignment equipment to capture lateral (sideways) movement data. Fig 10 shows the tabular data captured with the Ball-Rod-Tubing Connector (BRTC) system.

Fig 11 shows the results of the observed off-line to running and running to off-line movement with the optical alignment equipment in the vertical (Side View) direction. Fig 12 shows the results of the observed off-line to running and running to off-line movement with the BRTC equipment in the vertical (Side View) direction. Fig 13 shows the results of the observed off-line to running and running to off-line

Fig 8 - Optical alignment set up

movement with the optical alignment equipment in the vertical (Side View) direction. Fig 14 shows the comparative results of both optical alignment and BRTC methods for movement. Notice that in all cases (optical and BRTC) the compressor moved DOWNWARD (an average of 7 mils at the inboard / north end) and DOWNWARD (an average of 10 mils at the outboard / south end) with respect to the centerline of rotation of the motor from off line to running conditions. Although this is opposite of

			Hammond Sanitation District								
			Hammond IN								
			Center Gas Compressor								
		Optical Alignment · OL2R · Elevation Measurements Only (no lateral measurements taken)									
date	time	Status	Motor Outboard	Motor Inboard	Compressor Inboard	Compressor Outboard	Storage Ball	motor	H2O	IB Bearing	OB Bearing
		off-line?					Pressure	current	temperature	temperature	temperature
		running?	(elevation in inches)	(elevation in inches)	(elevation in inches)	(elevation in inches)	(psig)	(amps)	(degF)	(degF)	(degF)
03-21-02	09:55:00	off-line	10.738	10.704	10.996	10.813					
03-21-02	10:37:00	off-line	10.737	10.703	10.994	10.813					
03-21-02	11:02:00	off-line	10.737	10.703	10.996	10.812	9.00	0.00		75.00	72.00
03-21-02	11:05:00	started					9.50	40.50	85.00	106.00	107.00
03-21-02	12:15:00	running	10.736	10.699	10.994	10.812	11.50	41.50	87.00	129.00	133.00
03-21-02	13:15:00	running	10.736	10.699	10.993	10.812	13.50	43.00	90.00	133.00	140.00
03-21-02	18:20:00	running	10.737	10.703	10.998	10.815	18.40	48.10	93.00	150.00	161.00
03-21-02	19:20:00	running	10.739	10.703	10.998	10.817	20.30	49.90	95.00	156.00	167.00
03-21-02	20:20:00	running	10.736	10.705	10.995	10.816	21.40	50.80	97.00	158.00	175.00
03-21-02	21:15:00	running	10.739	10.702	10.999	10.818	22.00	51.70	98.00	166.00	171.00
03-21-02	22:15:00	running	10.737	10.703	10.998	10.818	22.00	51.60	98.00	165.00	173.00
03-22-02	06:30:00	off-line	10.734	10.698	10.985	10.802					
			Motor Outboard	Motor Inboard	Compressor Inboard	Compressor Outboard					
			off line -> running	off line -> running	off line -> running	off line -> running					
			gap distance	gap distance	gap distance	gap distance					
		off-line	10.737	10.703	10.995	10.813					
		running (AVG)	10.738	10.703	10.999	10.818					
		OL2R	**-0.001**	**0.001**	**-0.003**	**-0.005**	= (off-line) - (running AVG)				
		running (AVG)	10.738	10.703	10.999	10.818					
		off-line after shutdown	10.734	10.698	10.985	10.802					
		R2OL	**-0.004**	**-0.005**	**-0.014**	**-0.016**	= (off-line) - (running AVG)				
		+ number means point moved upward (i.e. if the elevation measurement is a larger number @ off-line than @ running, then the point moved upward from OL2R)									
		- number means point moved downward (i.e. if the elevation measurement is a smaller number @ off-line than @ running, then the point moved downward from OL2R)									

Fig 9 - OL2R and R2OL data using the optical alignment equipment

Hammond Sanitation District
Hammond IN
Center Gas Compressor
Ball-Rod-Tubing Connector (BRTC) System • OL2R measurement data

Date	Time	Status					Notes
Date	Time	Status	Motor	Motor	Compressor	Compressor	motor horizontal probe on east side of target
			Horizontal	Vertical	Horizontal	Vertical	compressor horizontal probe on west side of target
			Prox Probe	Prox Probe	Prox Probe	Prox Probe	
			Gap Voltage	Gap Voltage	Gap Voltage	Gap Voltage	
			(VDC)	(VDC)	(VDC)	(VDC)	
03-21-02	09:55:00	off-line	8.61	8.65	7.89	8.21	these gaps were used in the averaged readings
03-21-02	10:37:00	off-line	8.55	8.58	7.85	8.21	these gaps were used in the averaged readings
03-21-02	11:02:00	off-line	8.63	8.63	7.91	8.24	these gaps were used in the averaged readings
03-21-02	11:05:00	started					
03-21-02	12:15:00	running	8.55	8.61	7.90	8.40	
03-21-02	13:15:00	running	8.53	8.69	7.96	8.41	
03-21-02	14:22:00	running	8.55	8.70	7.96	8.40	
03-21-02	18:20:00	running	8.50	8.63	7.95	8.26	
03-21-02	19:20:00	running	8.47	8.63	7.98	8.26	
03-21-02	20:20:00	running	8.47	8.61	7.97	8.26	
03-21-02	21:15:00	running	8.50	8.62	8.02	8.30	these gaps were used in the running averaged readings
03-21-02	22:15:00	running	8.46	8.61	8.03	8.28	these gaps were used in the running averaged readings
03-22-02	06:30:00	off-line	8.31	8.27	7.93	8.39	these gaps were used for the off-line after shutdown readings
			Motor	Motor	Compressor	Compressor	
			Horizontal	Vertical	Horizontal	Vertical	
			Prox Probe	Prox Probe	Prox Probe	Prox Probe	
			Gap distance	Gap distance	Gap distance	Gap distance	
			(mils)	(mils)	(mils)	(mils)	
		off-line AVERAGE	42.98	43.10	39.42	41.10	
		running AVERAGE	42.40	43.08	40.13	41.45	
		OL2R	**-0.58**	**-0.02**	**0.71**	**0.35**	=(running avg) - (off-line avg)
		slope (mils/inch)	**-0.321**	**-0.014**	**0.389**	**0.192**	+ slopes indicates that the probe moved away from the target from OL2R
							- slopes indicates that the probe moved toward the target from OL2R
		running AVERAGE	42.40	43.08	40.13	41.45	
		off-line after shutdown	41.55	41.35	39.65	41.95	
		R2OL	**0.85**	**1.73**	**0.47**	**-0.50**	=(running avg) - (off-line avg)
		slope (mils/inch)	**0.467**	**0.948**	**0.261**	**-0.275**	+ slopes indicates that the probe moved away from the target from OL2R
							- slopes indicates that the probe moved toward the target from OL2R

from off-line to running, if the probe gap decreases, the probe moved closer to the target
from running to off-line, if the probe gap inreases, the probe moved away from the target

Fig 10 - OL2R and R2OL data using the BRTC equipment

what was anticipated would happen, both methods indicate that the compressor appears to move in a downward direction with respect to the motor. Based on the data collected with the BRTC system, the sideways movement of the compressor moved differently when going from off-line to running conditions compared to running to off line conditions.

In addition to the bearing temperature data collected on the center gas compressor during the OL2R survey, late into the run I began to notice that the bearing temperatures on the south gas compressor seemed to be 30-40 degrees hotter than on the center unit. I'm not sure why this was happening since the motor current draw on both machines was about the same.

As indicated in the table in Fig 9, there was at least a 100 degree F rise in temperature

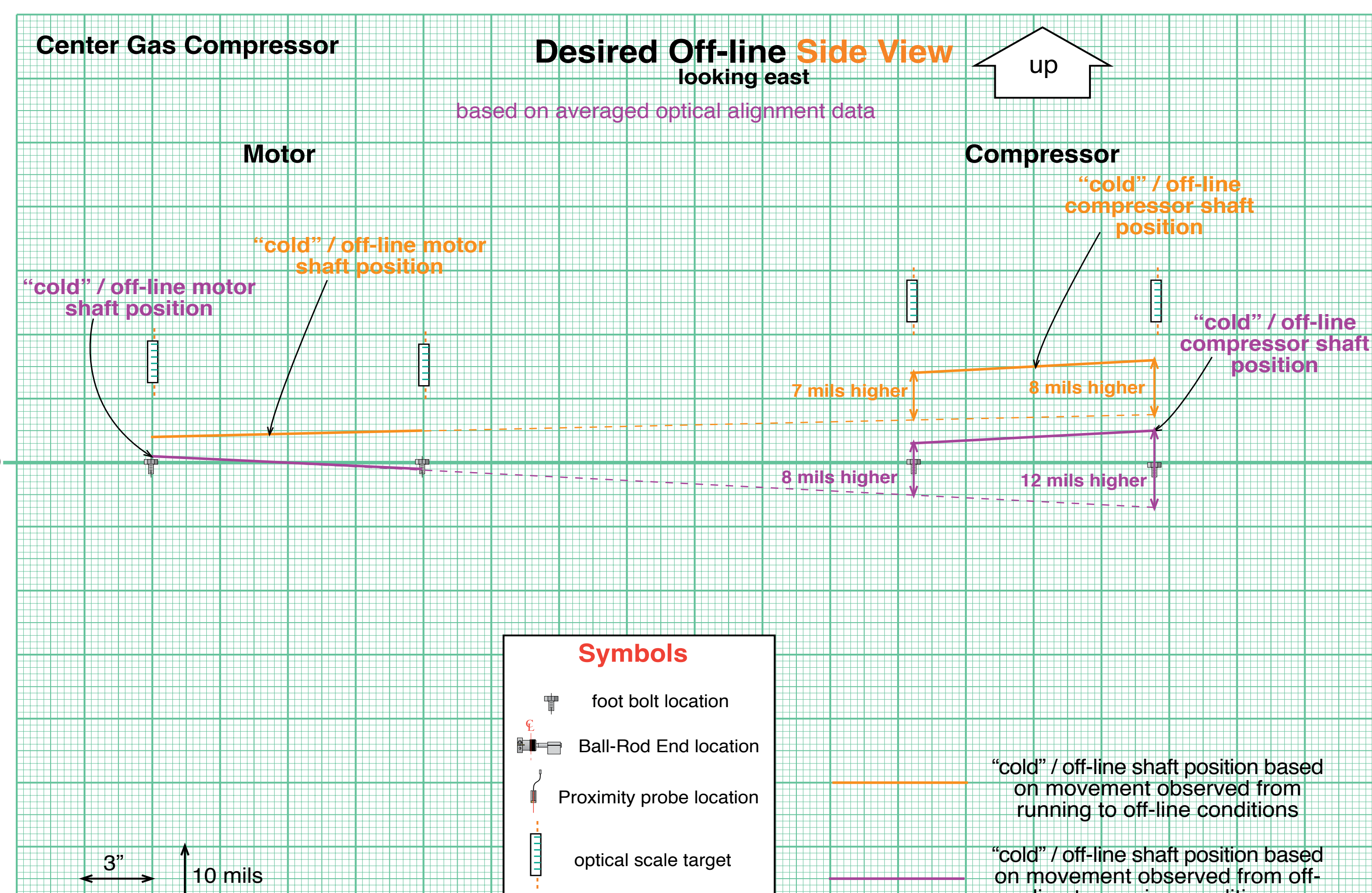


Fig 11 - OL2R and R2OL desired off-line vertical shaft position results using the optical alignment equipment.

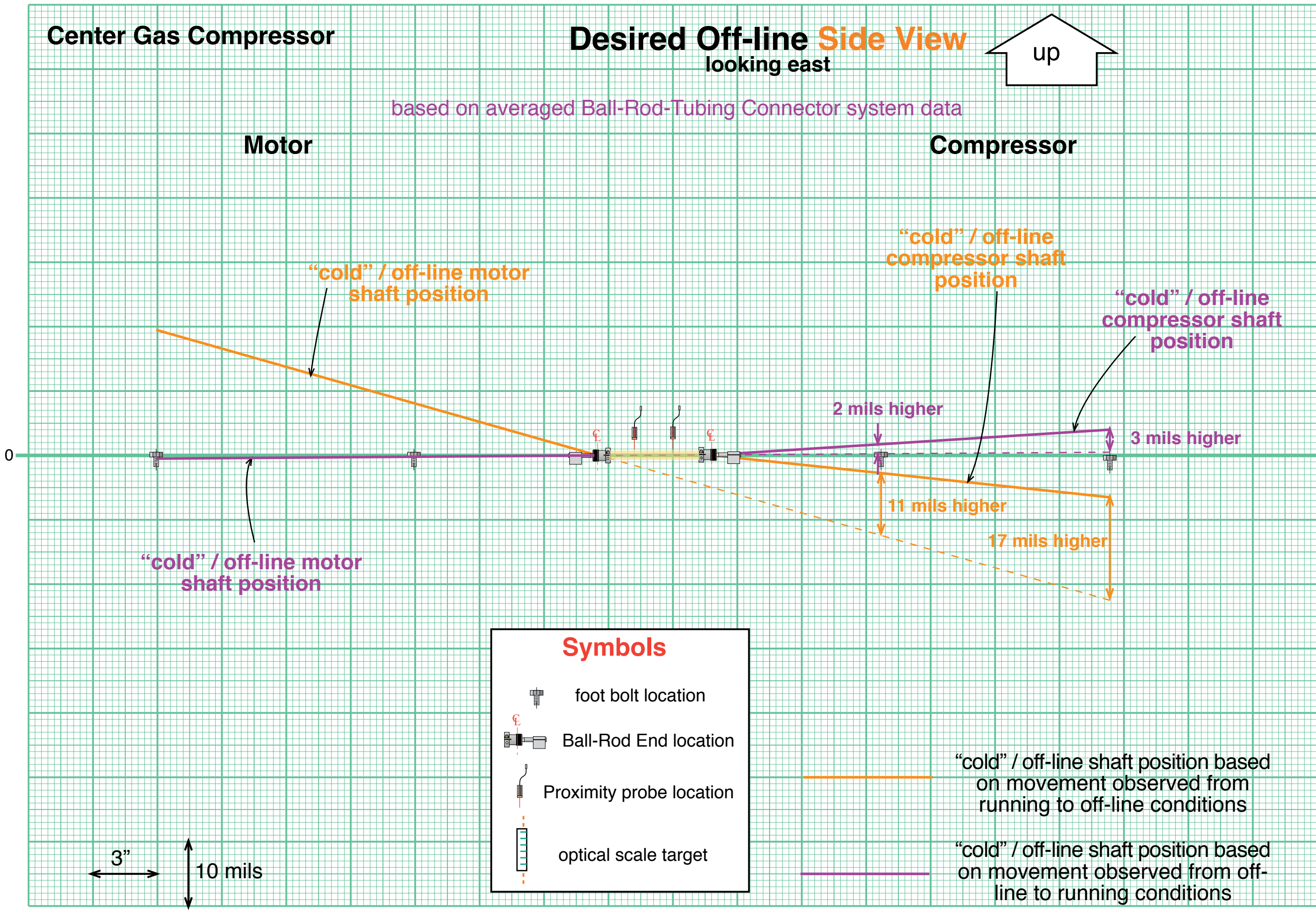


Fig 12 - OL2R and R2OL desired off-line vertical shaft position results using the BRTC equipment.

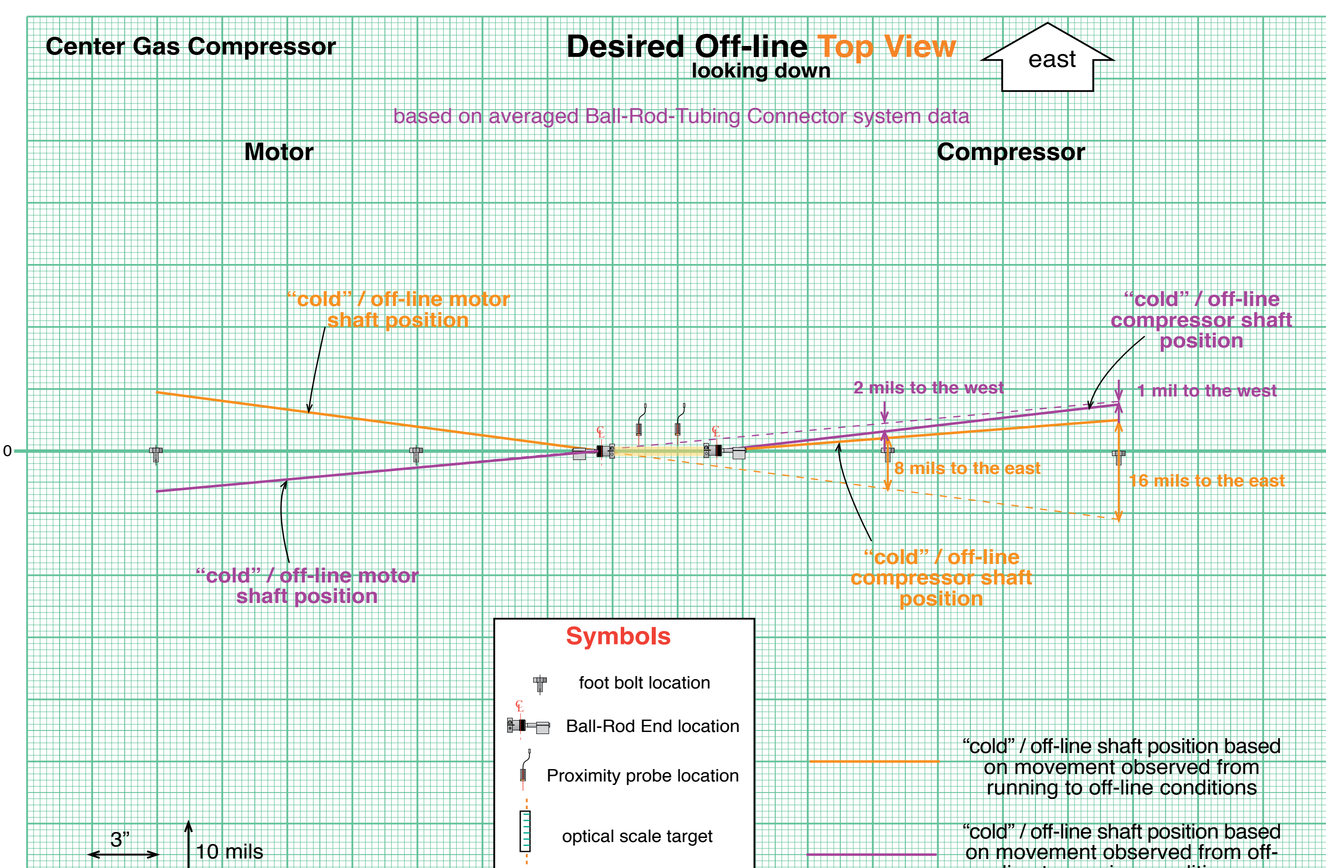


Fig 13 - OL2R and R2OL desired off-line lateral (sideways) shaft position results using the BRTC equipment.

Center Gas Compressor Off-line to Running Movement Summary			
		Compressor	Compressor
Technique	Which Way?	inboard bolt plane	outboard bolt plane
	off-line to running? running to off-line?	desired off-line position with respect to motor CL	desired off-line position with respect to motor CL
Optical Alignment	off-line to running	8 mils higher	12 mils higher
Optical Alignment	running to off-line	7 mils higher	8 mils higher
Ball-Rod-Tubing Connector (BRTC) System	off-line to running	2 mils higher	3 mils higher
Ball-Rod-Tubing Connector (BRTC) System	running to off-line	11 mils higher	17 mils higher
AVERAGE		7 mils higher	10 mils higher
Ball-Rod-Tubing Connector (BRTC) System	off-line to running	2 mils to the west	1 mil to the west
Ball-Rod-Tubing Connector (BRTC) System	running to off-line	8 mils to the east	16 mil to the east
AVERAGE		3.5 mils to the east	7.5 mils to the east

Fig 14 - Desired off-line shaft position summary with the BRTC and optical alignment equipment.

in the bearings from off-line to running conditions. But why did it appear that the compressor moved in the downward direction? During operation, I also noticed that there was a difference in temperature between the bearing housings where the temperature sensors are located and the compressor case itself, which was cooler than the bearing housing areas. It is not uncommon for a machinery case to exhibit a temperature difference between the bearing locations and other points on the machine case. The shaft centerline will change its position (usually raise upwards) only if the entire machine case makes a change in temperature (usually increases) from off-line to running conditions. It is not known exactly why the compressor moved in the downward direction, but it may be due to the expansion or contraction of the suction and discharge piping attached to the compressor.

Figs 15 and 16 show the vibration data captured on the center compressor. The vibration data on the center and south units were taken immediately after start up and then again late into the run so the vibration spectral plots compare the motor at start up vs. high ball pressure and the compressor at start up vs. high ball pressure.

The following vibration spectral peaks were predominant in the data:

1190 cpm - running speed
8377 cpm - approximately 7 times running speed (possible bearing defect?)
9510 cpm - 8 times running speed (matches the number of sliding vanes)
19035 cpm - 16 times running speed (double the number of sliding vanes)
28562 cpm - 24 times running speed (triple the number of sliding vanes)

Notice in the center gas compressor vibration data (Fig 17) that the 19035 and 28562 cpm peaks change in amplitude from start up to high pressure conditions. Also notice that the overall vibration levels ranged from 0.02 to 0.06 inches per second, which is very low. I think I noticed that the overall vibration amplitudes as displayed in the data acquisition system were showing much higher amplitude levels than that (0.3 ips?). You may want to check the calibration of your vibration sensor inputs into the data acquisition system.

Conclusions and Recommendations

The 8 mils of Total Indicated Runout (TIR) on the compressor coupling hub is more than the maximum recommended amount (5 mils) for that shaft speed but the vibration data at the compressor inboard bearing (where it usually appears) shows that it doesn't seem to have a significant effect on the running speed vibration amplitude.

Based on the OL2R survey, my recommendation is to align the motors and compressors with compressor set 7 mils higher at the inboard bolting plane and 10 mils higher at the outboard bolting plane as indicated in Fig 14. Currently the motor is 2 mils lower at the outboard end and 3 mils lower at the inboard end as shown in Fig 5. Although this is not precisely where the motor should be positioned based on the OL2R survey, it is not necessary to immediately change the alignment of this unit since it is still within 1.5 mils per inch at this position based on the new information. I would also recommend that an "as found" alignment check be made on the north and south compressors and that they be checked for soft foot conditions. Additionally, larger (C size) shims should be installed under the motor feet of these two units.

As mentioned above, I also noticed that there was a significant difference between the overall vibration levels that I measured (around 0.03 ips) and what was being measured by the permanently installed vibration sensors (0.30 ips). I would recommend that the sensors be checked for calibration and that the data acquisition system is converting the sensor outputs correctly.

John Piotrowski is president of Turvac, Inc which provides industry with industrial training in shaft alignment, vibration analysis, balancing and performance analysis. Conducts field service in machinery realignment, off-line to running machinery movement surveys, balancing, and performance monitoring. John is the author of The Shaft Alignment Handbook (© Marcel Dekker, 1986) and Basic Shaft Alignment Workbook. John is feverishly working on an e-book tentatively entitled the "Turvac Field Service Files", which will assist people in applying the principles and methods covered in the Shaft Alignment Handbook. This article is one of many case studies that will be included in his e-book. John is happily married with three children and six grandchildren. He enjoys fishing, backpacking, white water rafting and makes a mean salsa. John can be contacted at 513-932-2771 or at contactus@turvac.com

motor vibration @ startup

motor vibration @ 22psi ball pressure

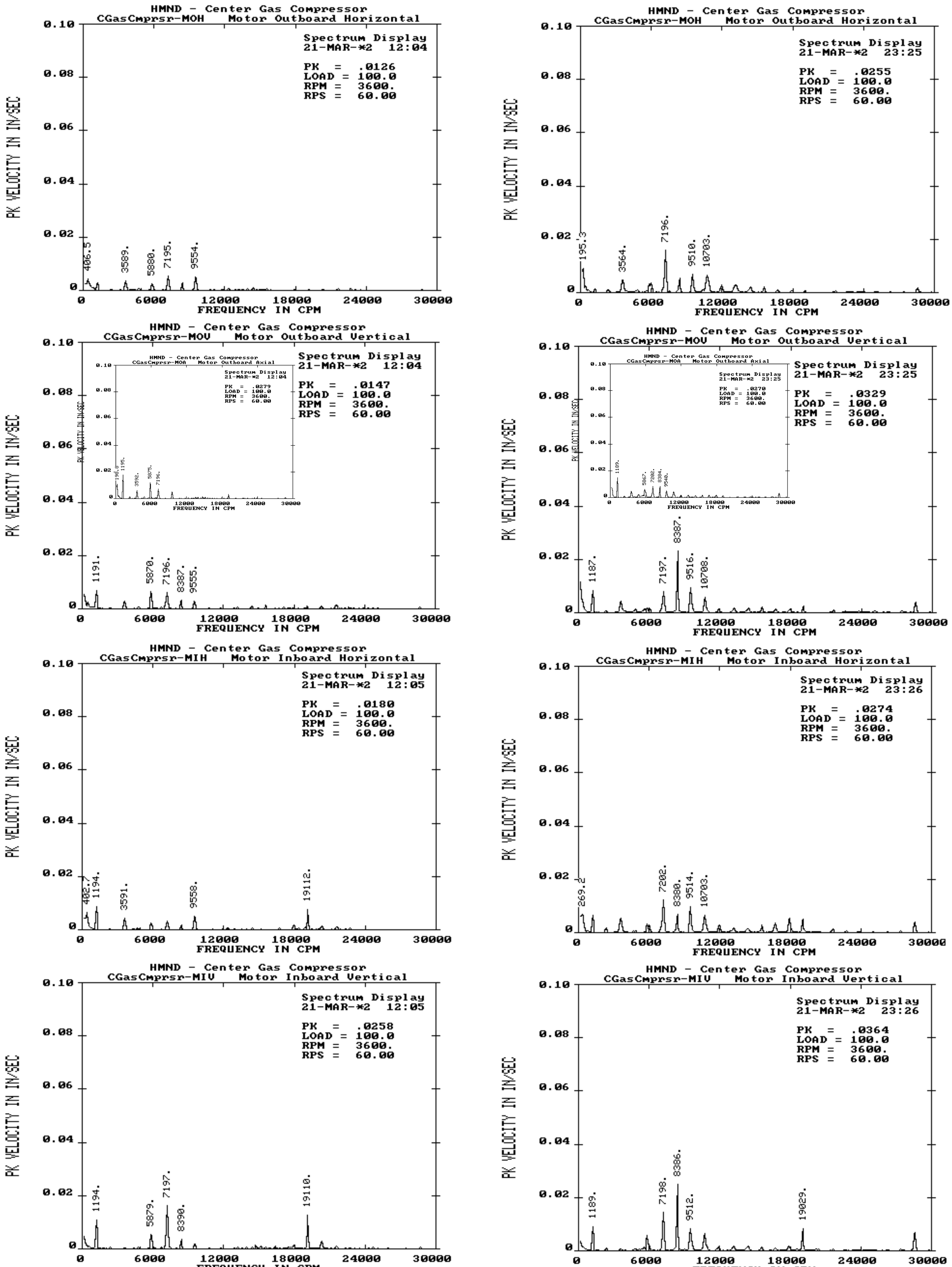


Figure 15 - Motor vibration spectral data on the center gas compressor drive system.

compressor vibration @ startup　　compressor vibration @ 22psi ball pressure

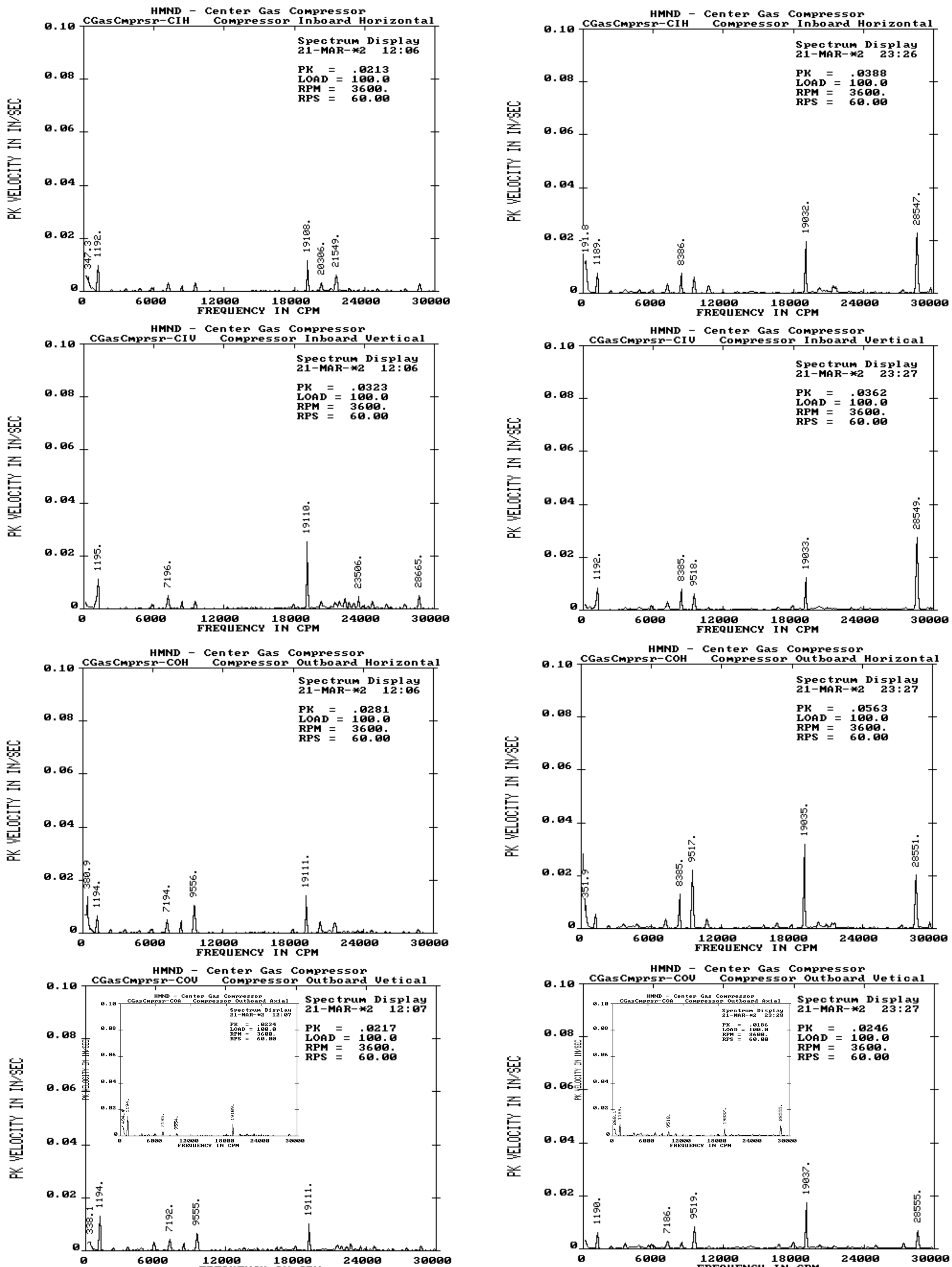


Figure 16 - Compressor vibration spectral data on the center gas compressor drive system.

Ultrasound for Tone Testing

An Overlooked Use for This Versatile Predictive Technology

by Jim Hall

We normally think of airborne ultrasound as a great tool for finding air leaks, analyzing bearings in motors, troubleshooting steam traps, and a variety of other tasks. However, many building maintenance technicians do not associate the use of airborne ultrasound as a tool to find leaks around doors, windows or other building envelope applications. Inspecting vaults and clean rooms, or integrity testing of walls (interior or exterior) and roofs are a few applications to which ultrasound is being successfully applied by many companies.

For several years, the transportation industry has been using ultrasonic tone testing for quality assurance by testing for wind/water leaks on windshields, doors and windows. Have you noticed just how quiet your new car or truck is? Also, for years the aviation industry has been using airborne ultrasound and tone testing for inspecting their aircraft fuselages, skin, windows and doors for leaks and/or potential leaks of cockpit pressurization.

Ultrasonic "tone testing" refers to placing an ultrasonic tone generator in a "volume" (i.e., compartment, vault or tank) and flooding that volume with an ultrasound. An ultrasonic receiver is then used to detect the sound being transmitted through an opening such as a pinhole in a weld seam, a crack or fracture of the wall. Like air, water or other fluids, ultrasonic waves will follow the path of least resistance. Ultrasound is short-wave, typically 1/8" to 5/8" long, and very directional. The transmitted ultrasound will deflect off hard or solid surfaces and penetrate through existing openings, such as holes, faulty gaskets or seals. Since ultrasound is above the human hearing range it can be used in many environments without disturbing other personnel. One ultrasonic transmitter is referred to as "bisonic" and another in the industry is referred to as a "warbler". Tone generators are offered by most airborne ultrasound manufacturers as part of an ultrasonic kit or as optional accessories.

Figure 1 - Tone Testing with Ultrasound

Tone Generators

Tone generators emit an ultrasonic signal. All ultrasonic receivers use a piezoelectric crystal typically mounted in the front of the instrument or at the end of an accessory such as a wand or handheld probe. The crystal acts as a microphone to receive the signal which is then converted to an audible signal that is heard by the end-user through headphones or a speaker. Just as the piezoelectric transducer is used to receive an ultrasonic signal, it can also be used to transmit an ultrasonic signal. The transmitted signal is used to flood a compartment, pipe, vault, an aircraft fuselage and/or cargo bays or hatches with ultrasound. This sound is above the human hearing range of 20kHz. Depending upon the application, the tone generator can be placed inside or outside the compartment. The sound floods the volume (i.e., vault, compartment, cargo bays) and then an ultrasonic receiver is manipulated into tight spaces or to scan large open areas concentrating on the tone on tone sound (a sound similar to birds chirping). The frequencies at which the sound is being admitted can easily be heard by the ultrasonic receiver. After identifying the leak location - say, on the "inside" of the compartment - the end-user can now reverse the inspection procedure, placing the tone generator/transmitter on the inside and scanning the outside of the compartment to locate the leak source or point of intrusion.

Different Sizes

Multi-Directional tone generators may have several transducers that transmit in several directions at one time. These generators can be used, for instance, to flood a Boeing 747 aircraft with enough ultrasound to perform a total fuselage inspection for voids, missing screws, cracks, windshield/windscreen leaks and door leaks.

Some ultrasonic transmitters have volume control to control the intensity of sound being emitted. The volume that has to be filled determines the intensity level needed.

Marine Applications

There are transmitters specifically made for marine environments. These transmitters fill areas like the cargo bays of ships. Ships at sea often encounter bad weather conditions, including high winds, high waves and pounding rain. A cargo bay door or hatch with a bad seal could lead to massive amounts of water intrusion which could damage the cargo. Figure 2 shows tone testing on a ship.

Building Envelope Inspections

When performing ultrasonic tone testing, you should be equipped with a hand-held ultrasonic receiver, high-impedance headphones, and an ultrasonic tone generator or transmitter.

A typical building envelope inspection may include roofs, wall integrity, windows, and doors for leaks and/or for structural defects. Tone testing is a very good choice for structural inspections of clean rooms. A clean room may have a false floor below it and false ceiling above it. Therefore the potential for leaks outside a clean room that may be under a positive pressure is greatly needed.

The nuclear industry uses airborne ultrasonic tone testing when performing containment wall inspections for minute holes and/or cracks in a containment wall. Building envelope inspections should be performed by personnel that are certified in the latest inspection techniques, equipment, building codes and procedures.

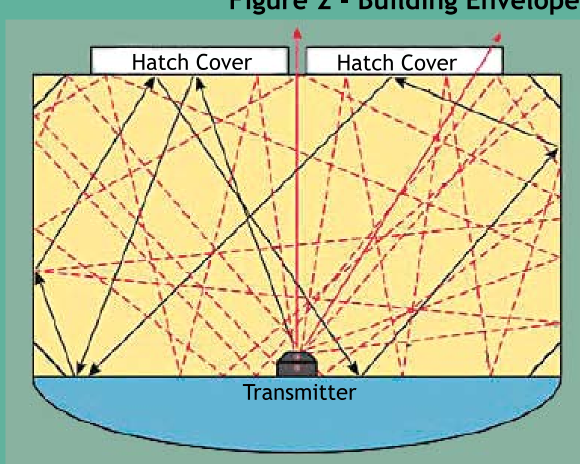
In Figure 3, a building maintenance technician is using a “flexible wand” and the ultrasonic receiver to hear the ultrasound emitted from a transmitter placed outside the office window. In this example, the sound from the “bisonic” transmitter could be heard in the upper left hand corner of the window. This opening had been allowing sound and smells from the manufacturing floor below to penetrate the office space, and the wind blowing through it created a howling noise.

An ultrasonic tone generator was placed on a table outside the entry way to flood the doorway with ultrasound while an ultrasonic receiver was used to locate the source of the intrusion.

Automotive Industry

Many of the world’s top automobile manufacturers use an airborne ultrasound instrument and tone generator to periodically check the automotive production line for quality assurance. Wind and/or water leaks of windshields, doors, windows, and

Figure 2 - Building Envelope Inspection

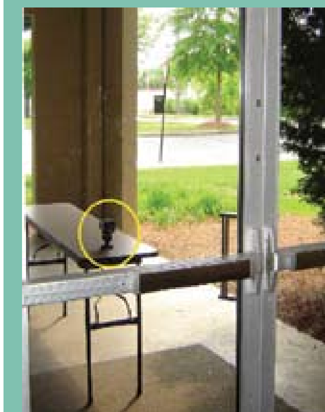


A Multi-Directional Ultrasonic Transmitter is placed in the middle of the ship’s cargo bay to provide enough sound to adequately fill the volume of space.

Scanning hatch cover for leaks while ultrasound is transmitted inside, flooding the cargo bay.

Graphic & Photo, courtesy of SDT North America.

Figure 3 - Building Envelope Inspection



A. This transmitter incorporated four transducers to flood a large area.

B. Using a flexible wand and an ultrasonic receiver to hear the ultrasound emitted from the ultrasonic transmitter placed outside the office window.

C. About midway up the door jam, the door seal was found to have a very fine split.

trunks are routinely checked to assure quality A tone generator is placed inside the vehicle. As the signal floods the interior of the vehicle, a technician scans the exterior of the door, window, or windshield with a receiver and can hear the signal through the headphones if there is a leak (Figure 4).

Ovens or Autoclaves

I was recently at a plant that has a 15 year old annealing vault. They had ordered a tone test to try to locate leaks around the door. This is an excellent application for tone testing. Loss of heat from door hinges, door corners, and door latches can mean longer run-time of products, which means wasted energy and money.

The use of airborne ultrasound and tone testing is a proven method of non-destructive inspection. When "line-of-sight", which is needed to use an infrared imager, is not available , ultrasound tone testing can be a good alternative. And, during building envelope inspections, the integration of both airborne ultrasound and infrared imaging can prove especially helpful.

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, petrochemical 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). You can contact Jim at jim.hall@ultra-soundtech.com

Figure 4 - Automotive Inspections

Above an automotive worker inspects the exterior of a tractor's cab for leaks along the bottom of the back window.

Below an automotive worker inspecting the top of the tractor cab for leaks.

Photos courtesy of SDT North America

Plotting Tough Problems

Applying Operating Deflection Shapes in Predictive Maintenance

By Thomas J. Murphy

With the best will in the world, some machines just will not obey statistics. Reliability information and predictions are all too frequently corrupted by a fundamental flaw. They assume that the "as new" condition was actually present at the moment of installation or repair. There is also a second problem. Predictive maintenance methods are micro – they look inside the machine to try to establish what is going on with a bearing or a gear. Sometimes the micro perspective is simply not helpful. We also need a macro approach which looks outside the machine. We need answers to questions like...How is the machine moving in space? What condition is the foundation in? How is the machine interacting with its environment (e.g. pipework)?

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

This article reviews the use of Operating Deflection Shapes as a tool used to understand the dynamic behavior of troublesome machines and illustrates how this technique has been successfully used to solve problems where more conventional approaches have failed.

Operating Deflection Shapes, ODS, is a technique which uses vibration data taken from a running machine to show how that machine is moving under operating conditions. Unlike simple modal analysis, ODS makes no assumptions regarding the machine or structure but uses the operating condition alone as the excitation force.

How To Perform Operating Deflection Shape Tests

The tools necessary are quite simple:

- tape measure
- tachometer providing a once-per-rev pulse
- single-channel FFT-based data collector of spectrum analyzer
- ODS software (MDShape used here)

The first stage of the process involves the creation of a mesh model. This model will be animated by the measured data. When creating the model it is important to remember that at each point in the model you will be taking data. Creating a model with an unnecessarily large number of points will involve a considerable amount of time spent at this stage but more importantly, will involve the collection of an unnecessarily large amount of data.

The model should contain enough points to be able to identify the modes you want to see. This is analogous to anti-aliasing in digital signal processing. In simple terms, if you are looking at a beam, you must decide how many points you need to identify the mode of interest. As an example look at Figure 1.

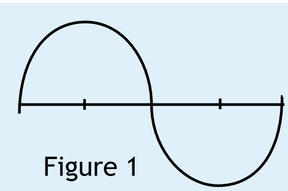


Figure 1

Clearly in this simple case of a first full wavelength mode, taking a measurement at both ends and in the middle of the beam would show the beam as stationary. At least 5 points are needed to identify this mode in its basic form.

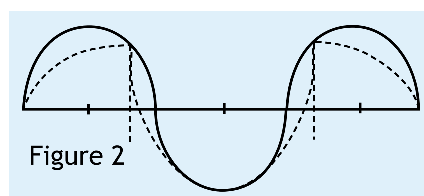


Figure 2

Extending the argument to 1½ wavelengths (Figure 2) shows that 5 points would, in its crudest form, produce something which would not be correct - 7 points would be better. In general, one should work out n, the number of half wavelengths which could be a problem and make sure that you create at least ($2n+1$) points spaced along the length of the beam.

If this kind of ripple effect is not of interest to you, and you just need the whole-body motion (assuming that the plate/cover/beam is rigid), then measurements are only required at the four corners.

Circles often present problems. Take for example a motor casing. Assuming that the frequency you are looking for is not likely to be coming from a wave travelling around the case as might be in the case of a rotor bar or stator problem, the case can effectively and adequately be treated as rigid. Some software manufacturers go to great pains to show elegant models with motors comprising as many as 12 positions around the circumference. Remember, at each of the points you will take 3 vibration readings. So, 12 positions is clearly excessive. Experience suggests that motor cases and bearing housings can be adequately portrayed as diamond profiles with measurements taken at the four quarter-hour positions or just simple square sections.

Having identified the measurement locations and identified them in 3 coordinate space, this information is entered into the ODS software and the points are joined together to produce a mesh model. Each point of the model is a data point and at each point a vibration measurement will be made in 3 axes. The program needs to be told these measurement directions - perhaps the most difficult part of the whole exercise is maintaining consistency in this step.

The data collection step is now the same as any other micro measurement routine. A route can be created and loaded to a data collector. In the absence of such an instrument, a sequence of spectra can be stored in the memory of a spectrum analyzer. The measurements can be taken in any order as long as the directions used are as expected.

This is the stage that the minimalist approach to the number of points created can truly be appreciated. A model with 100 points will produce a route with 300 measurement points, which, if we were to assume 1 minute per reading would take 5 hours to complete. A route with 150 points would take nearly 8 hours!

The tacho must be set up in such a way as to produce a once-per-rev pulse and it is essential that the tacho position remains unaltered for the duration of the test. The key to the success of the technique lies in taking readings which are phase related to each other due to the fact that the phase marker is fixed for each measurement.

Having collected the data, the data collection software is used to extract the amplitude and phase data of the orders of interest. It is this data which is used to create the animation.

Application Example #1

The following example provides a good demonstration of the power of the technique.

The electric motor pump set shown in Figure 3 produced very high vibration levels on the motor. All of the normal "micro" methods such as balance, alignment, hot alignment, changing coupling, etc., had been tried and had failed. Operating Deflection Shapes was then employed to assist.

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

A laser tachometer was positioned in front of the motor fan and a trigger was taken from a white paint marker on one of the blades. The total time to acquire all the data was roughly 4 hours.

Figure 4 shows the machine at running speed and incorporates the locus of all points of motion. This shows the motor rocking front to back on the bed plate. This motor move-

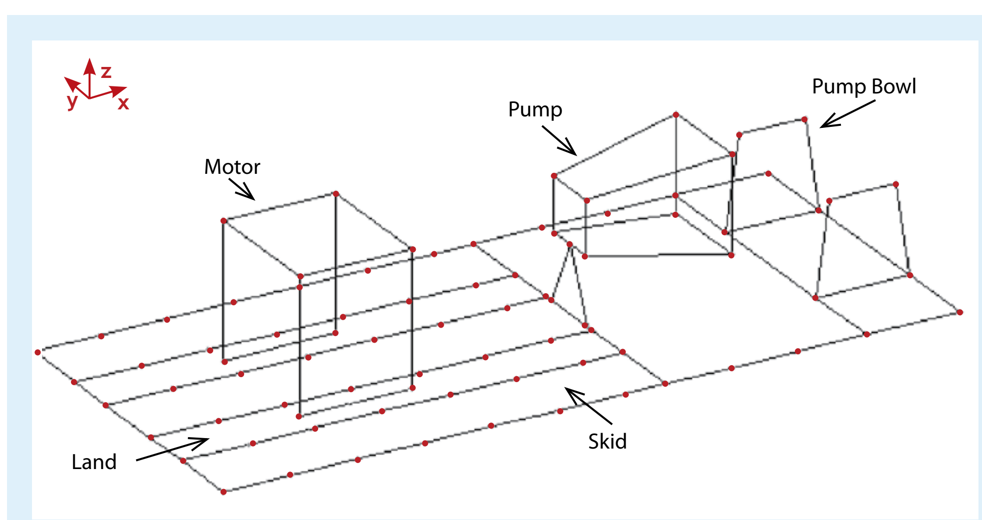


Figure 3 - Setup of Electric Motor Pump Set

ment must be putting the coupling under tremendous compressive stress. There is a general tendency for the pump bearing housing to rock from side to side which puts the coupling under even greater stress.

In figure 5, at 2x running speed, the motor is rocking from left to right. There is also a slight phase difference between the front and back of the motor, which results in the motor case twisting. The activity of the pump increases and there is also an increase in the degree of twisting in the pump.

At the 3x running speed shown in Figure 5, the motor is still rocking from side to side and the pump vibration is increasing.

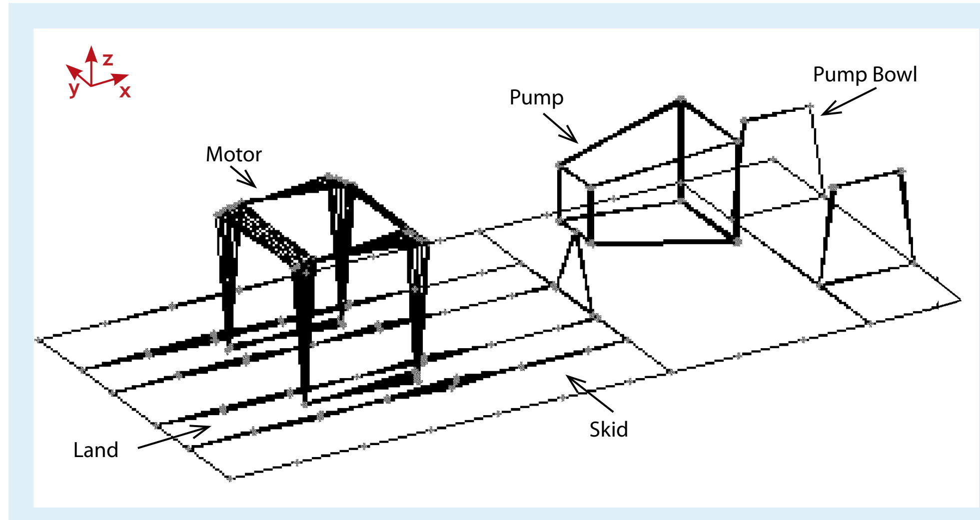
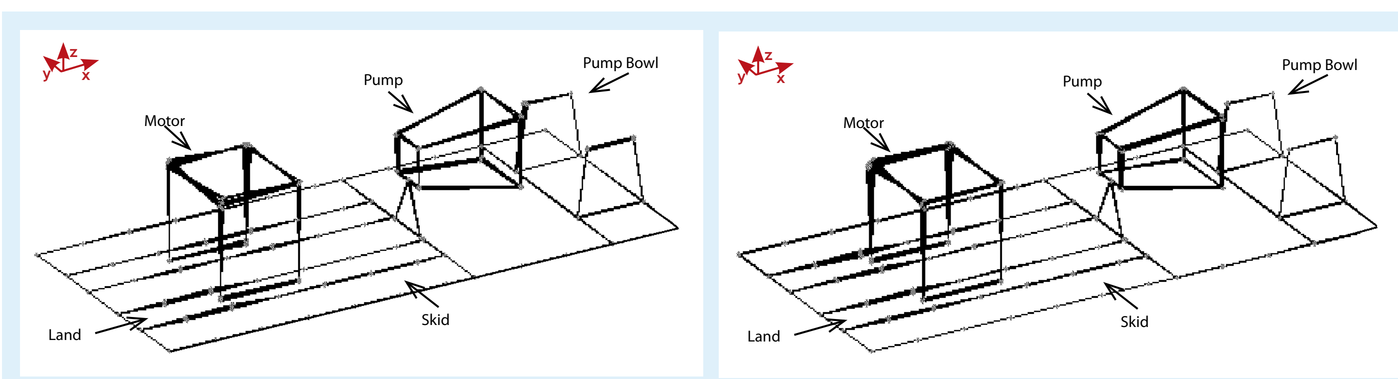


Figure 4 - Readings at Running Speed



2X Running Speed

3X Running Speed

Figure 5

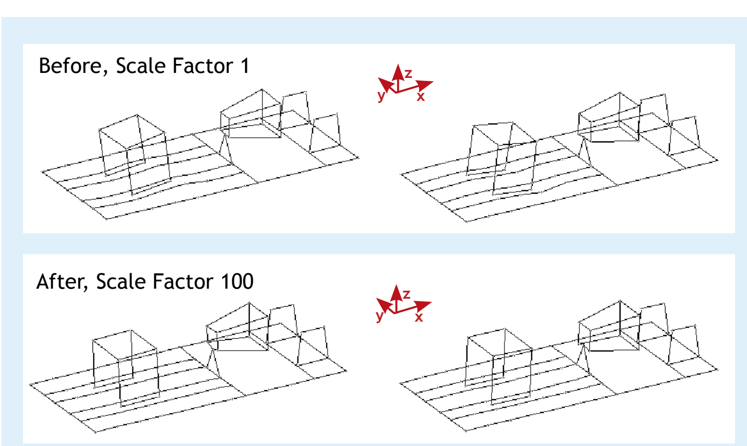


Figure 6 - Comparison, Before & After Modifications at Running Speed

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

To check the efficacy of these modifications and to provide an "after" set of results for comparison, a repeat of this test was performed.

Figure 6 shows the comparison of before and after the modifications. The fundamental mode shape which is causing the motor vibration remains unchanged. What we have succeeded in achieving is a significant reduction in amplitudes of vibration. Table 1 shows the reduction in vibration levels in millimeters per second.

Table 1

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

Vibration levels that decreased between 83.8% and 88% can only be summarized as a significant, meaningful reduction.

Application Example #2

We tested a large three cylinder recip compressor manufactured by Linde. There are 110 points involved in the model for the machine in this example, which corresponds to 330 measurements. This machine was notorious for its high levels of vibration – it had ripped up more than one set of foundations and there were frequent cylinder rubs and scrubbing.

The model shows the motor plinth and the compressor plinth. The points on the bottom of the plinths represent measurements made on the compressor house floor next to the plinth. The points along the base of the crankcase are at the clamping points, with the lower point on the bottom of the clamp and the upper point on the top of the clamp. For simplicity, and keeping in mind the fact that each point on the model represents 3 measurements, the cylinders are shown with a simple square cross-section. In this case, this data acquisition phase took almost 8 hours to complete.

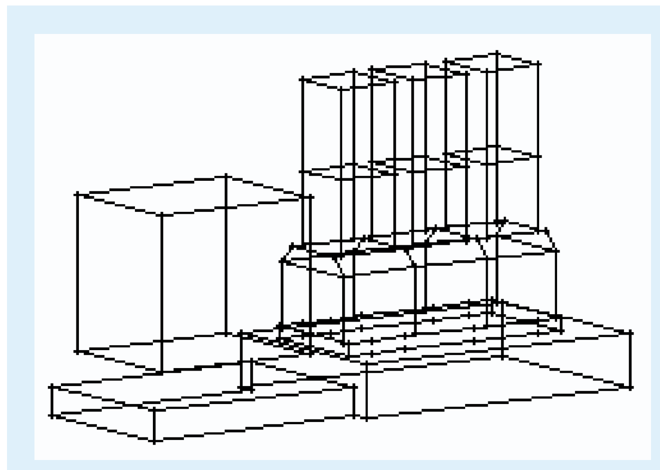


Figure 7 - Three Cylinder Recip Compressor

The two images in Figure 8 show the compressor at running speed complete with the expected 120° phase relationship between the three cylinders. They also show that there is freedom of movement at the NDE of the crankcase and diametrically opposite on the DE. The images in figure 9 are blow-ups of the crankcase region showing the point of movement.

Figure 10 shows the compressor running at the 2nd

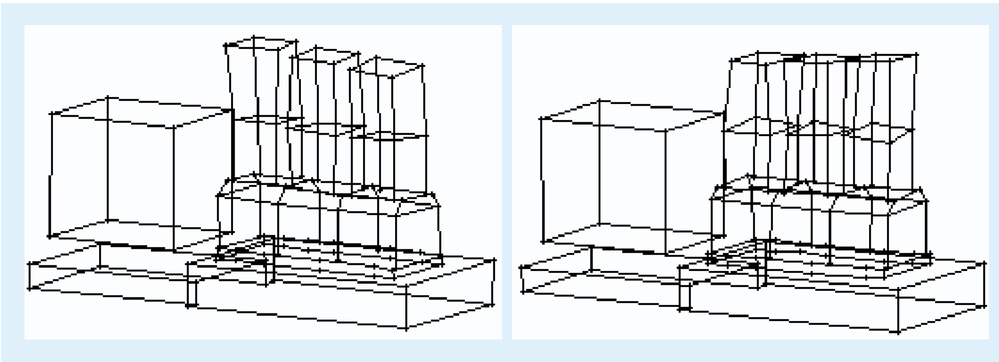


Figure 8 - At Running Speed

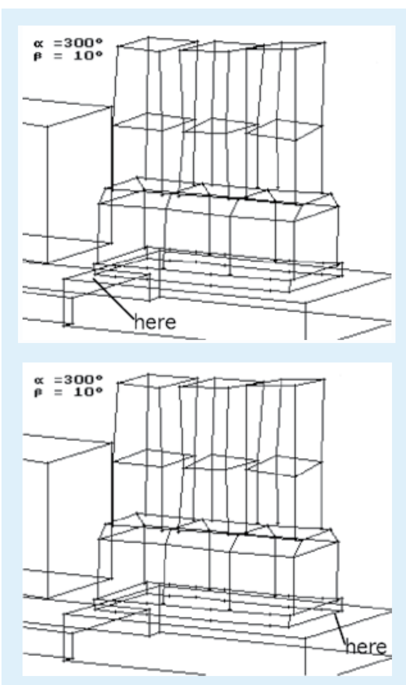


Figure 9 - Movement at NDE and DE

Harmonic (2nd order). The vibration levels at this speed are approximately 40% higher than those at the running speed. The shape is quite complex, but the largest amount of activity is in the 3rd stage (left part of drawing). It has a very clear twisting or corkscrew action. The 1st and 2nd stages are moving out of phase with each other, with a tendency to lean away and then pull together with each half cycle of motion.

Repairs were made to the foundation and stiffening members were attached across the crankcase. Additional bracing was then added between the cylinders to reduce their freedom of movement.

Application Example #3

Not all tests need to be complicated – sometimes there is no time available to make a complicated model, but an answer to the problem is required just the same - and fast.

A simple electric motor driven fan was causing considerable trouble in a plant and was severely inhibiting production. The bearings had been changed, the fan had been balanced, the alignment of the motor to the bearing cartridge had been checked twice and still the vibration level was excessive. Time was of the essence. A very simple model was created which covered the plinth, the top of the motor and the top of the bearing cartridge. The time taken to create the model (shown in Figures 11, 12 and 13), take the data and show the result was less than one hour.

Points 1 and 2 are the top of the motor. As can be seen in Figures 11 and 12, the motor is clearly moving axially. However, the cause is not misalignment, but a weakness in the foundation which can best be seen when all motions are overlaid (Figure 13).

A pivot point between points 11 and 12 (under the motor) and a weak area at point 13 were both detected. Essentially, the foundations required complete renovation and a new plinth was also needed. The temporary fix was sandbags!

Conclusion

Frequently there are cases of machines which suffer from chronic defects. Sometimes these chronic problems are a result of dynamic behavior which is abnormal. Understanding this dynamic behavior can dramatically enhance the engineering knowledge of the machine and can sometimes simplify ap-

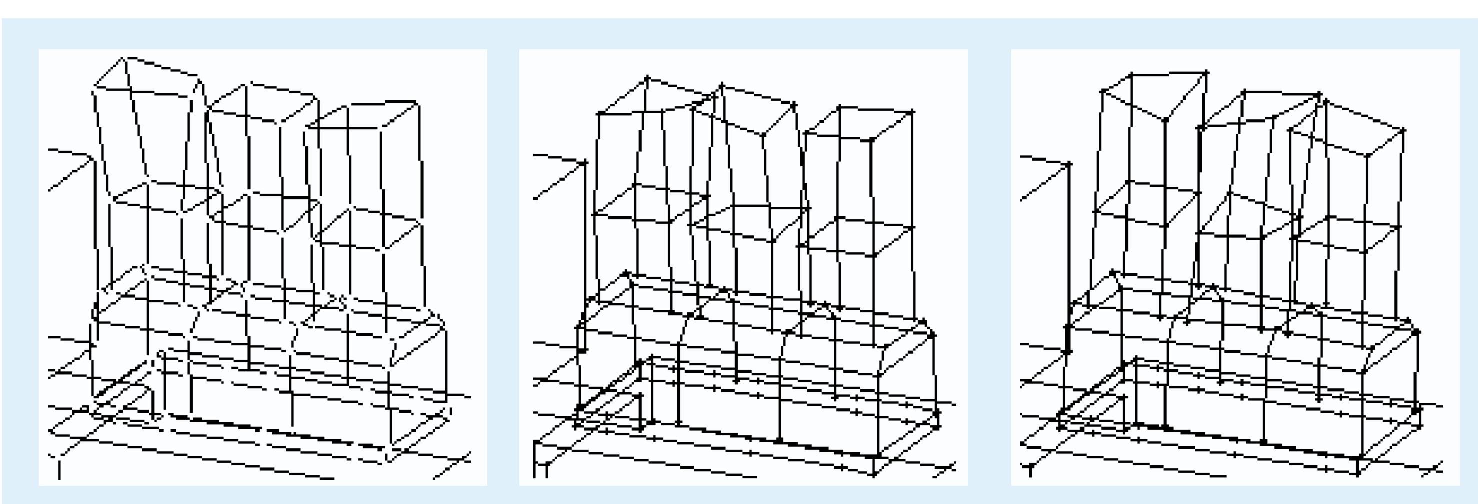


Figure 10 - Setup at 2nd Harmonic

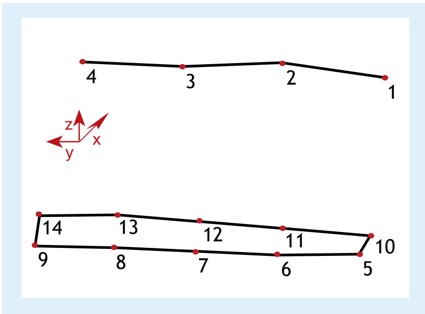


Figure 11 - Simple, Fast Setup at Running Speed

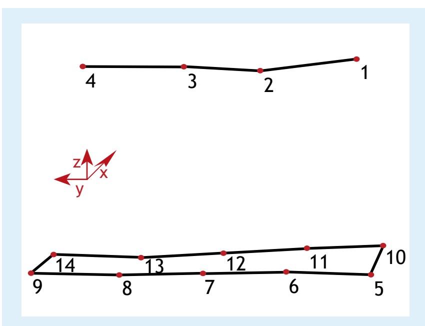


Figure 12 - Setup at 2X Running Speed

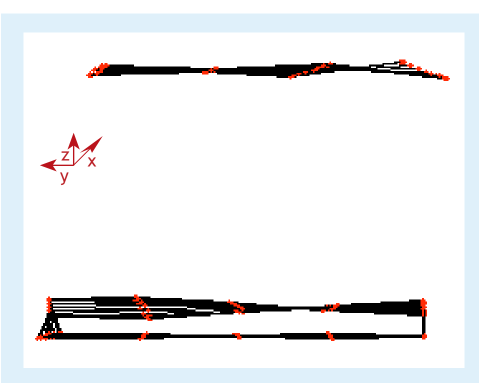


Figure 13 - All Motions Overlayed

parently complex problems to a few clamps, brackets or stiffeners.

The application of Operating Deflection Shapes to a chronic machinery problem provides invaluable data to develop engineering solutions to the problem. The ODS technique can be used to qualify the efficacy of the modification. Modern software programs for predictive maintenance and Operating Deflection Shapes greatly simplify the testing procedure allowing all practitioners of vibration analysis the opportunity to solve expensive nagging problems.

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

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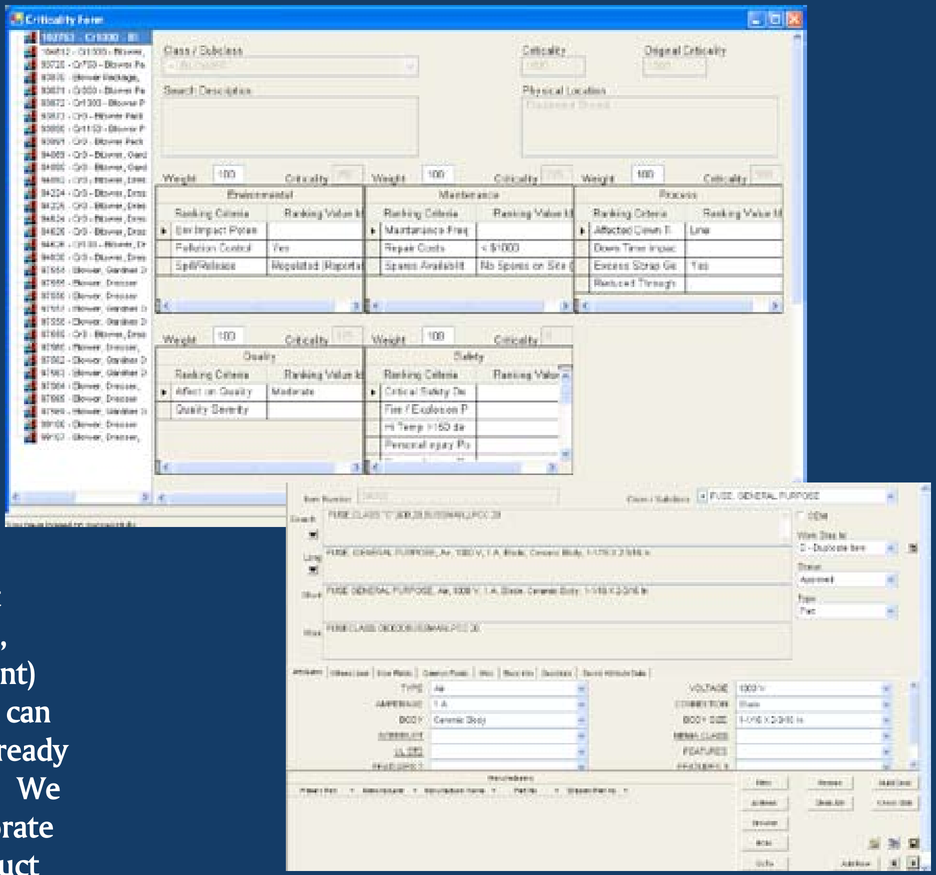


Screen shots of the Criticality Ranking Page and the Item Management Page of the Enterprise Reliability Suite

In today's market, the ability to remain competitive is the difference between success and failure. Many times the equipment a company purchases is the largest investment it will ever make. And many times, the potential of that equipment (and investment) isn't fully realized. Investing in a product that can help you optimize the use of the assets you already own may be the smartest move you can make. We spoke with Will Goetz, VP Marketing & Corporate Development for MRG, Inc., about a new product designed to help you unleash the power of asset optimization. Here's what Will had to say...

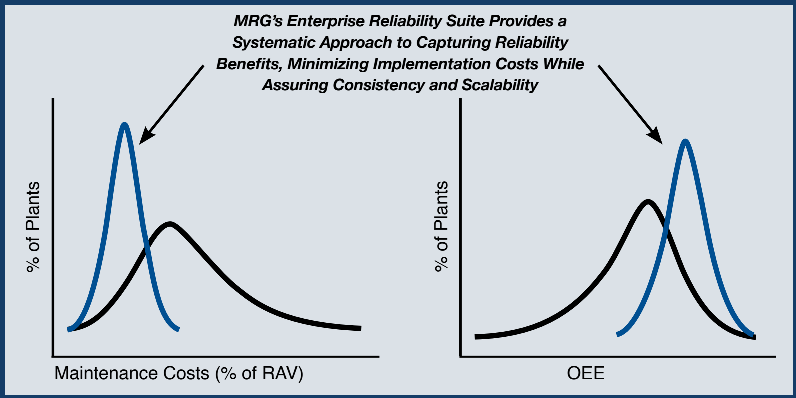
Explain to us the basic premise of the Enterprise Reliability Suite (ERS) product.

ERS is designed to assure the rapid deployment, standardization and sustainability of asset management implementations. When MRG began designing ERS, we took a hard look at the wide distribution in reliability performance (*see graph on following page*) across systems, lines, plants, companies and industries. In figure 1, the blue line reflects the performance we typically encounter within a company and the black line depicts the results of a continuous improvement-based approach. We concluded that variation persisted because there was no systematic way for an organization to improve its reliability practices. At the time, MRG had been building reliability programs for nearly two decades and had amassed powerful but independent tools and a tremendous amount of information that together accelerated the development of reliability programs. ERS is an integrated suite that brings together tools and preexisting content to quickly and efficiently establish corporate standards for reliability. By delivering reliability benefits more quickly than service-based solutions, ERS assures that those benefits are scalable and sustainable.

Would you give us the top five features of ERS?

That's tough because ERS provides a myriad of benefits. However, since you are putting me on the spot, here are my top five:

1. Enables business-based reliability strategy development by allowing "what if" comparisons between alternative strategies
2. Assures that reliability strategies cover 100% of failure modes
3. Enables the prioritization of strategy development and work orders using MRG's Criticality Ranking Tool
4. Provides a platform for creating and disseminating standard ref-



erence libraries (e.g. FMEA templates, PdM procedures, criticality criteria, BOMs) in support of corporate reliability objectives

5. Imparts a taxonomy to both asset and inventory catalogs that ensures reliability programs are repeatable and scalable across plants by enforcing consistency in naming conventions.

Can ERS help companies that are just getting started in a reliability program/initiative or do they need to have a lot of experience?

Yes, it can. ERS can be configured to build a program off of pre-existing MRG standards that represent best-practices gleaned from years of business experience, enabling inexperienced companies to advance rapidly. ERS will help companies that are just starting out to prioritize their work, establish standards, test alternative strategies, load-level their resource requirements, understand where predictive technology can add value and a host of other key activities.

Do companies need to have a CMMS system already up and running to benefit from ERS?

Not necessarily. ERS enables companies currently utilizing a CMMS to manage their work to accelerate reliability implementations. For those companies not equipped with a CMMS or EAM, ERS can be instrumental in setting up a CMMS that will, in turn, be optimized by ERS, from a reliability perspective. CMMS and EAM systems are built on sophisticated data models that must be populated to provide full functionality and reliability program support. ERS imparts a taxonomy to each implementation that assures full functionality. In addition, ERS includes data entry safeguards that protect foundational data quality on an ongoing basis.

For companies that have a CMMS already in place, is ERS compatible with all CMMS systems?

ERS is designed to complement CMMS and EAM functionality. It is designed to function as a technical 'sandbox', where reliability professionals can test and validate optimal strategies without impacting day-to-day operations. ERS can interface with all systems. Interfaces range in complexity from simple batch loads to webservices-based, real-time synchronization, depending on the environment and customer needs. Ideally, ERS will serve as the reference repository, assuring that corporate standards are observed.

What kind of impact can customers expect ERS to make on overall plant and machinery reliability?

Our customers have realized dramatic improvements in equipment availability with simultaneous reductions in maintenance cost. ERS eliminates the false starts and missteps that customers frequently make in designing and implementing their reliability programs, thereby delivering greater reliability sooner.

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

ERS will save a company 20% to 40% on the cost of a services-based enterprise wide implementation. ERS will enable the use of continuous improvement techniques, setting a path for ongoing realization of benefits. Moreover, ERS will ensure that the Reliability program is sustainable, greatly reducing the risk of having to re-implement or redesign a failed program.

For what size company is ERS best suited?

ERS is suited for any company that is looking to implement a world class reliability program. ERS can economically support the development of a program for a single plant but is ideally suited to implementation of large scale programs.

Can ERS help companies with a mature Condition Based Monitoring program?

CBM should never be confused with reliability. A mature CBM program can still involve the inefficient application of technology to assets. ERS helps define whether a CBM program efficiently addresses 100% of the failure modes in an asset base, driving misallocated CBM costs out. Moreover, ERS forms the hub of a continuous improvement program, where reliability strategies can be developed and refined, with documentation provided explaining the basis for improvements.

What's the best way for people to get more information about Enterprise Reliability Suite?

They can find more information about ERS on our website www.mrginc.net and can contact us at our offices at 203.264.0500.

New SKF® Type SAF Split Pillow Blocks incorporate unique design features to enable easy alignment and installation, proper bearing lubrication, and longer bearing life. These two-piece assemblies mount quickly to shafts and can accommodate heavy radial loads. Applications include fans and blowers, conveyors, and other equipment used in the mining, rock and cement processing, paper, steel, and metalworking industries, among others.

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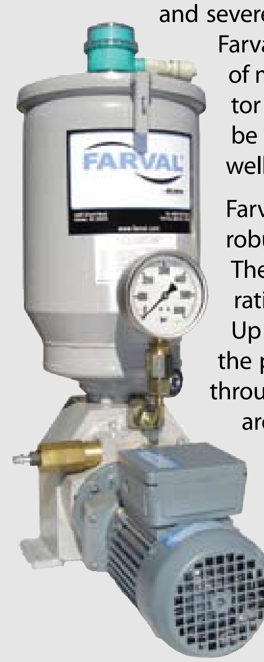
Life Cycle Engineering (LCE) has published the "Maintenance Planning & Scheduling Handbook: Streamline Your Organization for a Lean Environment."

Taking the guiding principles of Lean Manufacturing and Lean Maintenance, this unique handbook goes beyond the theory of planning and scheduling to clearly illustrate sustainable techniques to improve performance, reduce costs, and extend the life of plant machinery.

The handbook is available at either
www.elsevier.com or www.Amazon.com.

New High-Pressure Lubrication Solutions for Industrial Environments

Farval, a leading manufacturer of centralized lubrication systems and components for over 80 years, has introduced a new line of high-pressure lubrication pumps for the American marketplace.



The BS-B lubricator is a robust high-pressure dual-line pump capable of delivering oil and greases up to NLGI No. 2 in harsh and severe conditions. It can be used with standard Farval dual-line valves as well as its new series of modular dual-line valves. The BM-B lubricator is also a high pressure lubricator that can be used in dual-line, single-line progressive as well as ExactoServe injector systems.

Farval has also added to their line a series of robust multi-line lubricators, FZ-A and FZ-B. These pumps feature multiple outlet configurations for direct feed to bearings and gears. Up to 12 points can be serviced directly from the pump or additional points can be serviced through progressive dividers. These lubricators are also ideally suitable for gear spray applications.

These pumps will be assembled in the USA and are available through the Farval network of distributors. For more information, contact Dave Gervasi at 1-800-227-1063.

Larson Davis has introduced the Model 831, a Class 1 handheld sound level meter with exceedance-based logging analysis (ELA) for community noise assessment. It features a small, lightweight ergonomic design; real-time 1/1 and 1/3 octave spectra, and comes standard with a 120 dB dynamic range. Ten customizable markers are provided to annotate time history data. The sound level meter also has audio/voice recording with replay, supported by up to 2 GB of on-board memory and optional USB 2.0 data stick.

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New MRC Marathon® "XDs" mounted bearing units incorporate cast or machined stainless steel housings and stainless insert bearings to provide optimized durability and corrosion resistance for challenging food and beverage industry applications. Their housing construction offers added strength and toughness for applications where loads are very heavy or shock loads are possible. The AISI 300 series stainless housings can further withstand exposure to extremely aggressive washdown chemicals, even when present in strong concentrations.

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

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

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Voller Energy Group PLC, the leading commercial supplier and manufacturer of portable fuel cell systems, announces the launch of a new industrial fuel cell system, the VE100 Rack Mount. The new fuel cell system can charge remote monitoring equipment, surveillance cameras and industrial equipment in remote locations. The VE100RM can also be used in conjunction with other power sources such as Photo-Voltaic ('PV') solar panels or wind turbines to provide continuous power over an extended period of time.

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