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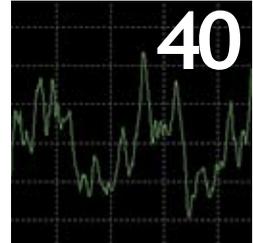
Level 1: AC Induction Motor Maintenance & Diagnostics
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Staying Grounded

As you'll read in our feature story this month, the predictive (aka condition monitoring) technologies on which this magazine focuses took flight in the 1960's with the introduction of the Boeing 747. It began as the search for a way to predict the failures that could not be avoided by using traditional time-based maintenance. According to the research an airline industry group conducted, these types of failures accounted for an astounding 89% of all failures.

Imagine learning that the time-based schedule upon which you have run your entire maintenance program for decades only addressed 11% of the component failures you experienced. Now that was a real eye opener...and the beginning of a new industry.

The new industry that emerged included not only predictive technologies, but a completely new methodology for maintenance programs as well - the Reliability Centered Maintenance (RCM) process.

I just returned from Reliabilityweb.com's RCM-2006 conference (which also included Enterprise Asset Management-2006). One thing I walked away from the event thinking is that the RCM process gives maintenance programs the best chance to be a major contributor to the success of their companies.

With the incredible advances in predictive technologies, it would be easy to fall into the trap of thinking that if only you purchase the latest and greatest technology, all of your maintenance problems would be solved. It's just not true.

That may sound blasphemous coming from the editor of a predictive technology magazine, but the truth is that the technologies are only tools. Nothing more, nothing less. If you want your maintenance program to have the best return on investment possible, then predictive technology is an essential tool, but still just a tool.

In order for the technology to pay dividends you must have a solid planning and implementation process. That is exactly where RCM comes in. It is a well defined process that leads you to the best decisions for your maintenance program. In short, RCM optimizes the entire maintenance function.

I hope you enjoy the April issue, and please contact me with any suggestions you have for making Uptime more informative and useful to you.



All the best,

Jeff Shuler
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uptime

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Best Lubrication/Oil Analysis

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Best Vibration Analysis

Best Total PdM Program

Uptime Magazine is devoted to Predictive Maintenance and Machinery Condition Monitoring. Part of our mission is to promote and acknowledge best practices. We have created the Uptime PdM Awards to provide positive exposure and acknowledgement for predictive maintenance professionals from around the world.

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The Complimentary Roles of
Reliability-Centered Maintenance and
Condition Monitoring

Richard Overman, M.S., CMRP
By Roger & Collard, CMRP



For decades now Condition Monitoring (CM) technologies, such as vibration analysis, infra-red thermal imaging, airborne ultrasound and many others have been widely used to detect eminent equipment failures in a wide variety of industries. Of course, some companies have been more successful with condition monitoring than others. Unfortunately, an unsuccessful attempt at implementing a CM technology sometimes leads people and companies to discount the benefits these technologies can provide. Even so, today there is little doubt that Condition Monitoring technologies are founded in sound scientific practice and, if implemented correctly, display proven track records.

It seems large capital investments are made into the latest technologies with minimal thought given to an effective applications program.

In other words, companies can realize a significant return on investment from Condition Monitoring technologies. However, the programs must be administered using best business practices and value added efforts in order to maximize the benefits of the CM technologies. One way to do this is to apply the Reliability Centered Maintenance (RCM) methodology. Using the RCM methodology is such an effective tool in maximizing the benefits of CM technologies because the entire goal (and the outcome) of the process is to apply the correct maintenance procedure at the correct time and by the correct person(s). The RCM analysis not only identifies the correct Condition Monitoring technology to use, but also the acceptable interval for the inspection. We also discuss the economic considerations of Condition Monitoring technologies as part of the RCM analysis, allowing the user to investigate the level of expertise required to produce acceptable results for a given technology.

It seems that each year, large capital investments are made into the latest technologies, with minimal thought given to an effective applications program. Often times this results in a substandard return on investment. Integrating CM technologies with an appropriately developed RCM analysis will dramatically

increase the effectiveness of your Condition Monitoring technologies. Such integration avoids duplication of effort and misapplication of CM technologies, ensuring inspection efforts are directed at pre-determined failure modes and avoiding the consequences of those failures.

When we think of the integration of RCM and CM technologies, two conversations come to mind. While both of these conversations involved vibration analysis, they could have as easily involved any of the other CM or predictive maintenance technologies.

The first conversation involved a plant that used large fans during their production process. While talking with one of the maintenance engineers, he mentioned that they use vibration analysis to tell them when the fans need cleaning. Later in the conversation, he stated that they shut the fans down every 6 months to clean them. The obvious question is...why do both? If the vibration analysis adequately predicts when the fans need to be cleaned, why have a scheduled shutdown just to clean them? On the other hand, if the plant is already being shut down, and cleaning the fans at that time will let them operate for another 6 months, why do vibration analysis? The RCM analysis process is designed to provide a well documented, structured way to evaluate these and other function preservation strategies.

The key point is that CM technologies are often treated as an end product rather than one of many possible function preservation tools.

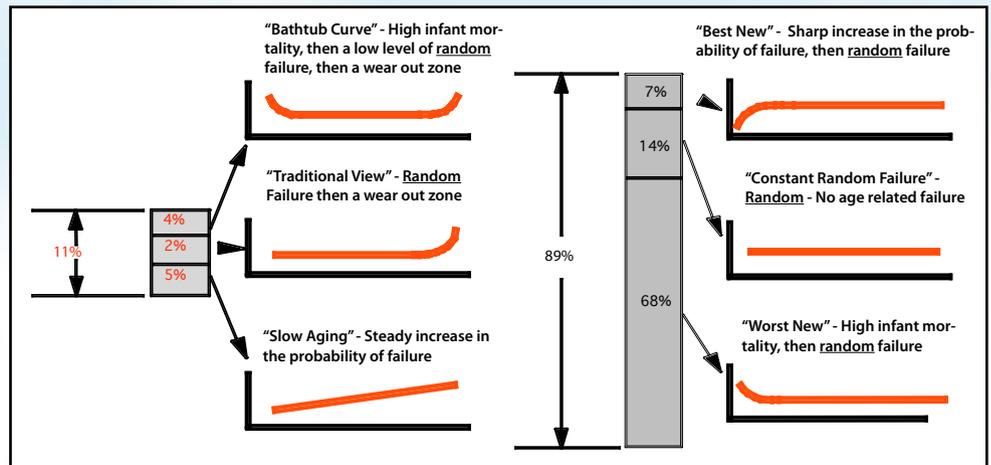


Figure 1 - Aircraft Component Failure Characteristics²

The second conversation involved a plant that uses a lot of pumps. The plant maintenance personnel stated that they perform vibration analysis on the pumps once a month. When asked why, the response was that this is what the vibration equipment vendor recommended. Upon further questioning, the technicians revealed that the pumps would run about 6 months after a potential problem is detected by vibration analysis. A reasonable question in light of the 6 month warning is, why perform vibration analysis every month? Why not every 2 or 3 months? An additional, and very important, piece of information is that the plant requires 100 percent pump availability in the summer months, but can accept pump failures during the winter months. This raises the question, why do vibration analysis at all in the winter months?

The key point is that CM technologies are often treated as an end product rather than one of many possible function preservation tools. The RCM analysis process provides a well-documented, structured method for evaluating the efficient, effective use of CM technologies.

Condition Monitoring Technologies

A plethora of condition-monitoring technologies have sprung up over the last 40 years in response to a specific need. This need was revealed in a study performed for the commercial airline industry in the early 1960s during the development of the preventive maintenance program for the "new" Boeing 747. "The FAA initially envisioned this program to be 3 [times] more extensive than the 707 program under the rationale that the 747 would carry 3 [times] more passengers."¹ The airlines knew that such a program would not be economically viable and launched a major study to validate the failure characteristics of aircraft components. Figure 1 shows the results of that study.

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Figure 2 - Criticality of pumps varied by season, but intervals between vibration analysis remained constant.

Reliability Centered Maintenance

The study that spawned the development of Condition Monitoring technologies also spawned the development of the Reliability Centered Maintenance process. To identify the appropriate maintenance requirements for the Boeing 747, representatives of various airlines developed a process that became known as the maintenance steering group (MSG) logic. In 1978, the Department of Defense asked Stanley Nolan and Howard Heap, both from United Airlines, to expound upon MSG philosophies for application to military aviation. Their report coined the name "Reliability-Centered Maintenance."

In figure 1 we see that only 11 percent of the components demonstrated a failure characteristic that supported a scheduled overhaul or replacement (scheduled removal). Eighty-nine percent exhibited random failure characteristics for which a scheduled removal was not effective. Since a scheduled removal was the primary scheduled maintenance program at that time, new ways were needed to deal with the 89 percent not applicable to scheduled removal. Enter Condition monitoring technologies. CM technologies were developed to predict the onset of failure for components that exhibit a random failure characteristic.

Over the years much attention has been devoted to the development of these technologies. A reasonable question to ask ourselves is, "Should we focus more attention on the efficient and effective use of these technologies?" To do this we need to ask, how does one decide which of the many CM technologies to use? How often should a CM technology be applied? Is continuous CM worth the investment? How good are CM technologies at detecting the onset of failure? These and other questions need to be addressed for specific equipment within the specific application of the equipment. The RCM process provides a well-documented, structured process for evaluating these questions.

After MSG-1, RCM development followed three distinct and separate tracks as shown in figure 3. The three tracks are the commercial aviation track, the military aviation track (led by the Navy) and the commercial industry track. The commercial industry track became the most diverse track with many different groups and people entering the market. RCM became divided into two main groups: the "classic" RCM processes and hybrid RCM processes. Hybrid RCM includes a number

Over the years, various names have been given to the family of CM technologies, such as on-condition maintenance, condition based maintenance, preventive maintenance, and predictive maintenance. New CM technologies are continually being developed with increasing focus on computerized systems to perform continuous CM of equipment. We will define a CM technology as one that checks the condition of the component or process on a regularly scheduled basis to look for the onset of failure. Regularly scheduled can be measured in terms of months, operating hours, or microseconds, as would be the case for "continuous monitoring" tasks.

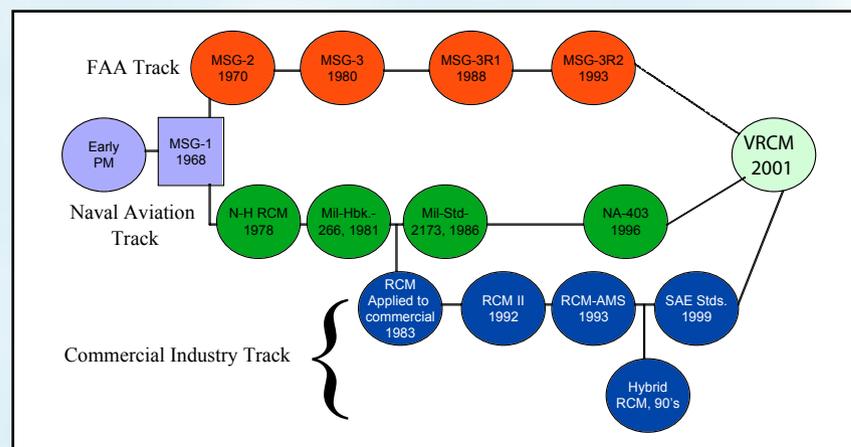


Figure 3 - History of Reliability Centered Maintenance

of methods which attempt to simplify and shorten the RCM process. The Society of Automotive Engineers (which involves every mode of transportation including rail, aviation, automobiles, and space) saw a need to write a standard³ that defines what a process should include in order for it to be a “true” RCM process – that is, a process that conforms to the original RCM concept and one that includes all of the steps necessary to keep from being dangerous. This standard was published in 1999.

The SAE standard defines RCM as, “A specific process used to identify the policies which must be implemented to manage the failure modes which could cause the functional failure of any physical asset in a given operating context.” It can also be looked at as a process for evaluating function preservation strategies. The goal of the RCM process is to ensure that the right people perform the

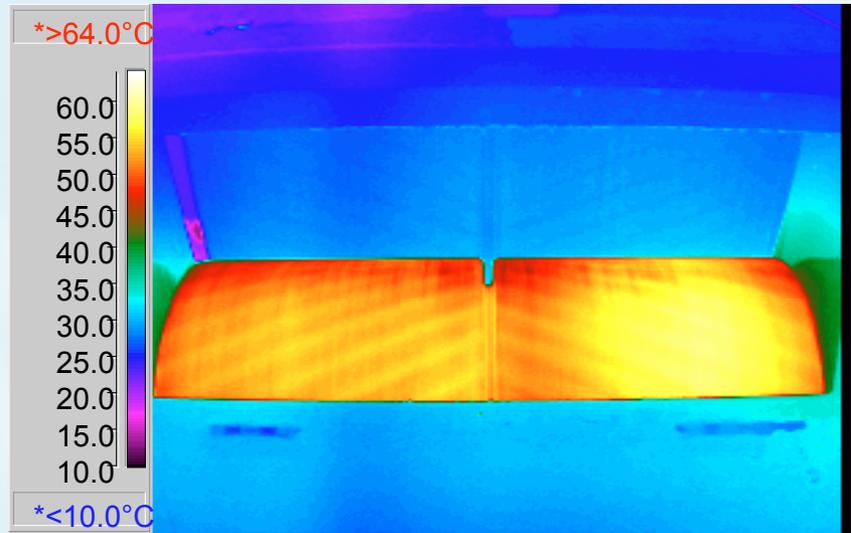


Figure 4 - Infrared image of a mill drive pinion. IR is an interesting way to check alignment on large gears. The hot spot should be centered.

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right maintenance, at the right time, in the right way, with the right training and tools.

CM is one of the many function preservation strategies evaluated during an RCM analysis. The other function preservation strategies are other scheduled maintenance, design changes, training improvements, operational changes, on-time changes, and run-to-failure. Let's take a look at the RCM evaluation of the application of CM technologies.

Putting CM and RCM Together

In our earlier examples of CM, we came up with four key questions. They were:

1. How does one decide which of the many CM technologies to use?
2. How often should a CM technology be applied?
3. Is continuous CM worth the investment?
4. How good are the CM technologies at detecting the onset of failure?

RCM provides the analytical philosophies to effectively answer these questions.

The RCM process addresses the first two questions in the determination of the degradation interval (see figure 5). Figure 5 is rather complicated, but here are a few main

points to note. The RCM standard gives the following criteria for the technical feasibility of a CM task.⁴

1. "There shall exist a clearly defined potential failure" (point B on figure 3).
2. "There shall exist an identifiable P-F interval" (P-F stands for "potential to

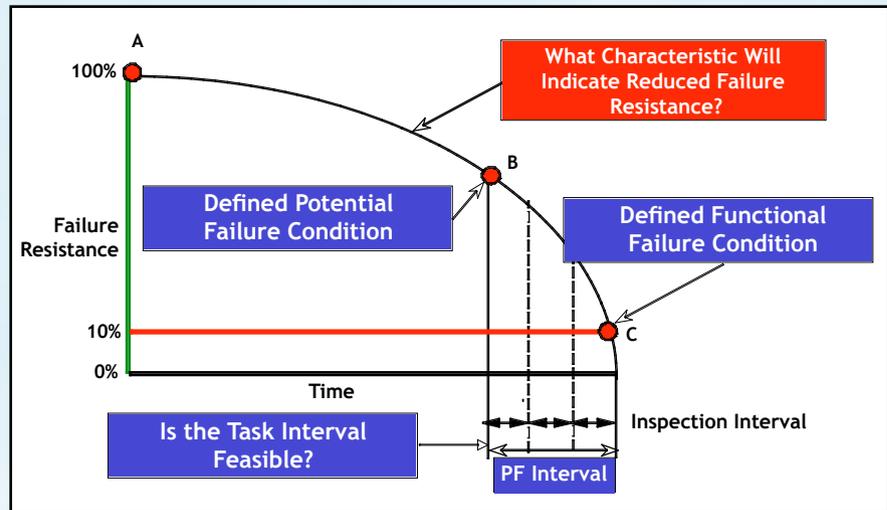


Figure 5 - Degradation Interval



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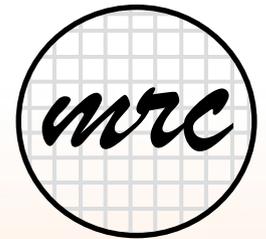
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Figure 6 - Eddy Current test on a ballstud.

(the degradation interval minus the task interval) shall be long enough for predetermined action to be taken to avoid, eliminate, or minimize the consequences of the failure mode.”

During the RCM process, the technically feasible criterion is applied to all CM technologies that might be used to detect the potential failure. An inspection interval is identified for each one. The inspection interval may be different because different CM technologies can detect the onset of failure at different places along the degradation curve. For safety and environmental consequences, the task is technically feasible if the task at the identified interval reduces the probability of failure to a defined tolerable level. For operational and non-operational consequences, the task at the identified interval is technically feasible if it is cost effective. A cost analysis is performed on all of the technically feasible technologies to see which is the most cost effective.

functional failure” interval and is the same as the degradation interval on figure 3, interval from point B to point C).

3. “The task interval shall be less than the shortest likely P-F interval” (inspection interval < degradation interval).
4. “It shall be physically possible to do the task at intervals less than the P-F interval.”
5. “The shortest time between the discovery of a potential failure and the occurrence of the functional failure

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One of the technically feasible options may be to install a system that continuously monitors the asset to identify the potential failure condition as soon as possible. A cost analysis of this option along with the other options is part of the RCM process. The continuous monitoring option is the one worth doing if it is the most cost effective.

Finally, a word about the fourth of our key questions listed previously. Part of identifying the inspection interval involves an estimate of the task effectiveness. This is usually addressed as the probability that a potential failure will be found, assuming that it exists. This is a part of the overall CM technology development that needs more attention. Academic studies into how effective CM technologies are at various levels of expertise are in order. A great deal of work has been done to develop the technologies; however, more work needs to be done to determine how effective they really are.

Conclusion

Condition Monitoring technologies are excellent tools for identifying potential failures. As tools they need to be applied in the right circumstances and only when necessary. The RCM process is designed to identify those circumstances and to determine when they are necessary.

Mr. Overman served on the Society of Automotive Engineers' committee that developed the SAE RCM standard and authored the guidebook. He has been a certified practitioner in the RCM II process and is a former Chief RCM Engineer for Wyle Laboratories, Inc.

Mr. Collard is an experienced RCM practitioner in the RCM II process with extensive CM experience on mobile and stationary equipment. He is currently the Chief RCM Engineer for Wyle Laboratories, Inc.

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1. "RCM Comes Home to Boeing", Robert J. Ladner, et. al., MAINTECH SOUTH Conference, December, 1998

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4. "Evaluation Criteria for Reliability-Centered Maintenance (RCM) Processes", SAE JA1011, Society of Automotive Engineers Surface Vehicle/Aerospace Standard, Aug. 1999, p 8.

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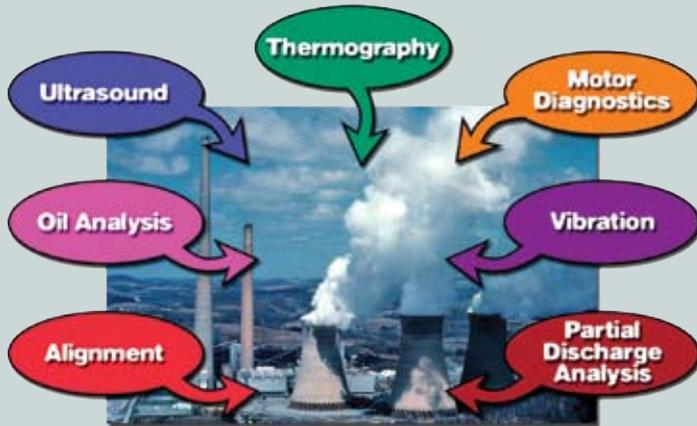
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Based in Charlotte, NC, EPRI's Maintenance Center assists plants with maintenance related topics, and has been involved with Predictive Maintenance and vibration analysis for over 20 years.

The Predictive Maintenance Users Group (PdMUG) will meet for 2-1/2 days on July 10-12, 2006 and the Vibration Technology Forum (VTF) will meet for 2-1/2 days on July 12-14, 2006 in Annapolis, MD. The PdMUG and VTF both provide a forum to exchange information, ideas, successes, problems, and experiences regarding diagnostic monitoring and condition assessment technologies used in predictive maintenance programs. The goal of these forums is to achieve maximum benefit from predictive maintenance programs.



The Vibration Technology Forum focuses specifically on vibration data collection, analysis, and problem resolution. Each meeting will provide open discussions and presentations in a relaxed environment along with utility problems and solutions, programmatic issues, and technical and application information. Training sessions will be provided on Wednesday morning. New technologies and innovations will also be highlighted during each meeting.

Utility Roundtable

Portions of both meetings will feature utility roundtable sessions. These roundtable sessions will provide opportunities for utility personnel to share tips, techniques, and information, pose questions to their peers, discuss and attempt to resolve any technical or programmatic issues which their plant may have, and discuss their respective maintenance program.

Case Studies

These meetings frequently contain case studies or plant experience reports that are informally presented and/or discussed by utility personnel. Case studies typically discuss current or past equipment problems; completed, planned or potential corrective actions; cost benefit information, pictures, data, and any other pertinent information that may assist attendees.

Participants are encouraged to bring and discuss/present their case studies. If you



plan to bring a case study, please let us know to facilitate planning. Guidelines for case study content is available from EPRI. Utility attendees consistently agree that roundtable sessions and case studies are one of the most beneficial aspects of these meetings. These sessions are what make these forums so successful and a learning experience above any other. Previous meeting minutes and agendas are available via PdMUG and VTF Meeting Minutes from 2005 ([hyperlink](#)) or via e-mail jsharkey@epri.com.

Who Should Attend

These meetings are intended to benefit utility maintenance, engineering, and persons responsible for predictive or condition-based maintenance and/or programs

within their organizations. Individuals who are new to predictive maintenance or are starting new programs are encouraged to attend, as they will benefit from the experience and information provided by individuals with more mature programs. We all learn from each other.

Vendor Fair

A vendor fair related to predictive, diagnostic, and condition monitoring equipment, training and services, will be featured Tuesday and Thursday evenings, 5:30 - 8:00 PM. Vendors interested in participating in this vendor fair should contact Linda Parrish (704-595-2061 or lparrish@epri.com) and request a vendor fair information packet.

Agenda

A detailed agenda is available via www.epri.com and will be updated regularly as needed and will be distributed via e-mail to registered participants.

Sponsors

These meetings are sponsored by EPRI's Maintenance Management and Technology (MM&T) group and Operations and Maintenance Development (O&MDev).

Uncovering Electrical Panels

To Remove or Not To Remove

by Gregory R. Stockton

As infrared thermographers, from time to time we are asked if we could perform an electrical infrared survey without removing the panel covers...because it might be a more efficient way to perform the survey. This is a great question. It would certainly be a faster survey, but not a more efficient survey. For a process to be efficient, it must be productive. An Infrared survey should not be performed without removing panel covers because it is simply not as productive.

Why Not?

There are two reasons why someone might be inclined to ask to do an IR survey without removing the panel covers:

1. They want to reduce the risk of tripping a breaker or causing a failure during the panel cover removal and replacement process.
2. They want to save some time [money] because the removal and replacement process takes longer.

These are both noble causes and I don't blame any manager for considering either a valid reason to ask the question. However, I have to take issue with the rationale because saving money and reducing risks are the very motivation for performing the infrared surveys in the first place. True, surveying the panels without removing the panel covers will reduce the risk of tripping a breaker, is safer and will save time on the survey. But, surveying with the covers on, while better than no infrared survey, is largely ineffective and could actually increase liabilities.

Physics and the Case for R&R

The reason for performing this type of survey is to find

electrical problems so that maintenance personnel can repair them. Faults need to be found in their nascent

stage, that is, before damage has occurred and especially before component failure. This infrared technique is predicated on the fact that there is a locked relationship between temperature [rise] and an increase in the chance of failure. Electrical (and mechanical) problems in this stage often show very little temperature rise. It takes an experienced thermographer with a good piece of infrared equipment to find and document problems in this stage. Anybody can point an imager at anything that is burning hot and find a problem. And, while finding 'hot spots' is important, that is not why professional thermographers are hired. They are hired because they have the expertise to distinguish between a real problem and a non-problem and for the expert documentation of all the components – not just the hot ones. Small problems seen on an IR survey will often become big problems if not addressed. A skilled thermographer would probably find some true positive results while surveying with the covers on, but these true positives are not all the problems.



Figure 1
Typical electrical panel

Infrared pictures (thermographs) show ONLY surface temperatures. So, can all problems inside electrical panels be seen through solid steel? Absolutely not. However, one could argue that a guess (albeit an edu-

cated guess) can be made from looking at the surface temperature patterns of the panel and the exposed surfaces of the breakers. And then just the [few] panels showing potential problems could be removed and inspected, narrowing down the R&R operation and, thereby, reducing the associated risks/costs proportionally. The theory sounds viable at first look, but there are several crucial flaws:

1) It is almost impossible to tell the difference between a medium-loaded breaker in a panel and a breaker with a loose bus connection (see Figures 2-5). So, in order to perform a dutiful survey, the thermographer would need to report for removal, almost every panel that contains even a slightly loaded breaker. What is the sense in examining, for example, 500 panels, finding some heat on 400 of them and having them taken apart and re-inspected on a separate mobilization - or waiting around for the electricians to remove the panel?

2) The space between the panel cover surface plane and the component is filled with air – an excellent insulator [of heat]. Even if there is a serious problem there may not be enough mass to send a recognizable amount of heat to the surface. These types of problems will be missed.

3) What about all those lightly-loaded circuits or the less-obvious problems like a component that is in an annealed state –relatively cool at the moment because it is making a

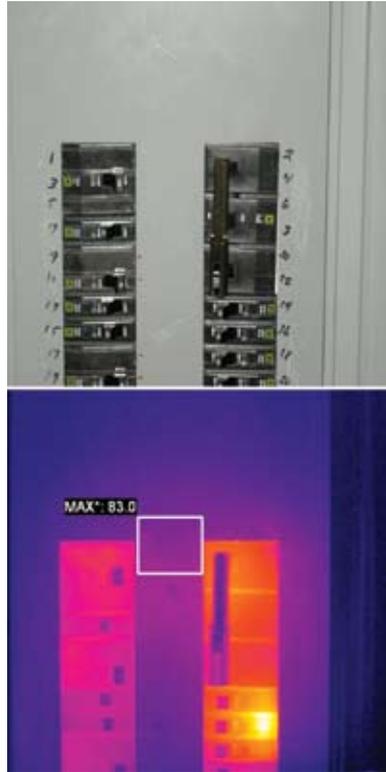


Figure 2
Visual and thermal image of a panel with covers on.

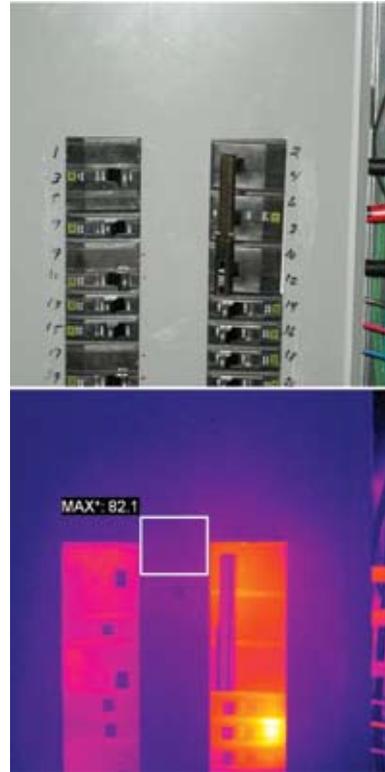


Figure 3
Visual and thermal image of a panel with only the deadfront cover on.

pretty good connection in that part of the fault cycle? These problems will also be missed.

4) Visual inspection of the inside of a panel by a trained eye is a bonus by-product of any infrared inspection and should not be discounted. Visual inspections sometimes reveal problems that cannot even be seen with infrared...like broken components and burn marks left from a cyclical thermal event, or a circuit that is not operating or a failed component (see Figure 6).

Typical standards for infrared thermography

address the issue of panel cover removal. At present, no one has to follow any particular standard, but liability is increased if a catastrophe occurs and an accepted procedure has not been followed.

Real Documentation

There can be no valuable documentation of panels that are covered. For reasons stated above, recording video or snapping an infrared image of the covered panel would be almost meaningless. In fact, documenting the fact that the survey was performed without removing panel covers will increase the liability to all parties. What is needed is hard documentation of all of the infrared imagery of all the panels and components, whether or not there is a perceived problem.

This protects the client (and the thermographer) because in the case of a failure claim, the insurer (and your boss) will want to know why the component failed, since it was just checked. If there is complete documentation, the thermographer can show the exact thermal state of that particular component at the time of the inspection. This methodology is sound business practice. Think about it...the contractor will be all the more conscientious owing to the fact that he is documenting everything.

Complete documentation is also needed with panel covers removed. With modern infrared imagers, thermographers can digitally record the infrared video and/or save fully-radio-

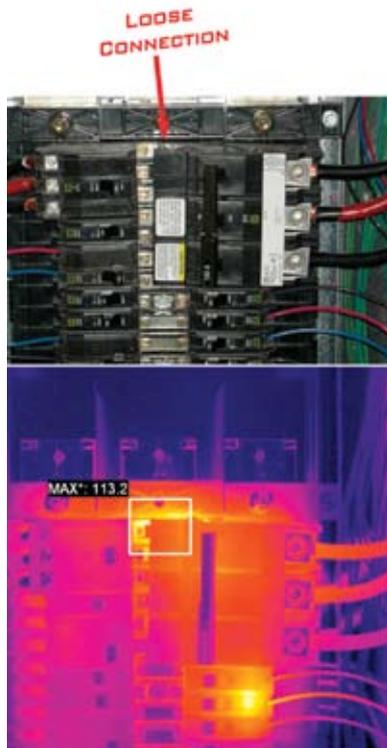


Figure 4
Visual and thermal image
of a panel with both covers
removed.

metric images to an on-board drive. There is basically no documentation for all those components that were considered not to be a problem by the thermographer, if the thermographer only takes pictures of what he considers to be a problem.

As a buyer of infrared services, you will find resistance to this methodology even if you are willing to pay for it, for these reasons:

- Many thermographers feel that it is a waste of time to save an image just to prove they did a proper job.
- Some thermographers are worried that they might miss something and that this fact will be documented. We are human. Thermography is not a perfect science and is still somewhat subjective.
- The thermographer will have to find and

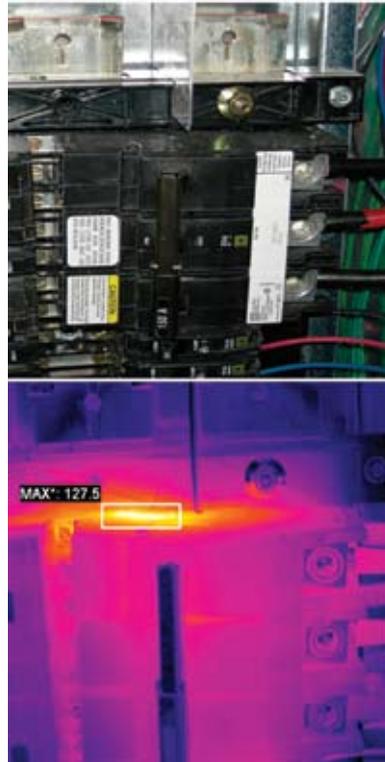


Figure 5
Visual and thermal image
of a panel with both cov-
ers removed at the proper
angle to see the problem.

survey every panel and it is more work since all the items on the equipment list cannot merely receive a checkmark.

- Often contracts for infrared thermography are written as a lump sum and finishing 'early' allows for more 'profit'.
- A tape recorder and/or a data logging device is just another piece of equipment that the thermographer must buy and maintain, and another piece of equipment that could fail in mid-survey.

Corporations benefit greatly from standards which managers, engineers and thermographers can hold as the way to perform infrared surveys. With specifications in place, all professionals bidding on infrared work are on a more level playing field. Any company with high value sites, mission critical and/or critically insured properties is remiss if they

do not use a written set of specifications to prevent misunderstandings and sub-standard work.

Risky Business

Which panels can be opened without removing any covers? The answer is none. All exposed electrical circuitry in all buildings must be in an enclosure of some type. All electrical panel covers can be surveyed by using a safe procedure. If the panel cover cannot be removed while energized, the manufacturer will have designed it that way. For those panels, infrared windows are a great option.

How much more does it cost and how much more risk is thereto removal and replace the panel covers? I can't answer this question for several reasons. I am not privy to actuarial data from failure analysis vs. maintenance activities at any corporation. I have searched for this data but never found any reliable source. Nor can I find any data [facts] about how many people are hurt or killed each year while performing infrared surveys, or how many thermographers are following NFPA 70E to the letter and what thermographic hard data, was used to come up with it, if any.

There is little hard data available on how much money has been saved by building owners doing infrared, although there has been no shortage of case studies presented over the years by thermographers. Where case studies are great for marketing purposes, they have little actuarial value. Insurance companies are requiring more infrared every day. Maybe they know the numbers...they should, since risk IS their business.

The power/influence pendulum has swung over the last few years in favor of the risk managers. We have had to change our Certificates of Insurance by upgrading the limits and the liabilities that we incur in favor



Figure 6 - Fused disconnect showing blown fuse.

of our clients. This trend has cost independent thermographers, and in turn, our clients more, but they do not seem to mind the increased costs based on the reduction in liability that they now enjoy.

Conclusions

Since reducing risk is increasingly becoming a high priority, facility managers should be willing to pay a few more dollars per day to remove the covers or install infrared windows so that thermographers can do a proper job. One fact is beyond question. Infrared as a predictive/preventive maintenance (P/PM) activity is more popular than ever and has proven to be a very effective P/PM activity.

Should an infrared survey of any building be carried out without removing the panel covers or inspecting through infrared windows? ABSOLUTELY NOT. In fact, the specifications should specifically disallow this practice. Your infrared surveys will not be completed as quickly, but they will be much more productive...and efficient.

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

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Good Grease

Electric Motor Greasing Basics

by Howard W. Penrose, Ph.D., CMRP

One of the most important components of any electro-mechanical maintenance program is the lubrication of bearings. Yet, this vital aspect of preventive maintenance remains one of the least understood functions of maintenance. There is constant debate concerning whether a bearing should be ‘flushed,’ a limited amount of grease added, how often or if the motor should be operating or tagged-out. Many motor manufactures outline the preferred, and safest, method for lubricating electric motor bearings. There are specific physical properties for this process in the motor bearing housing and in order to protect motor windings from contamination.

The general procedure for greasing is as follows:

1. Lock and tag out the electric motor
2. Wipe grease from the pressure fitting, clean dirt, debris and paint around the grease relief plug. This prevents foreign objects from entering the grease cavity.
3. Remove the grease relief plug and insert a brush into the grease relief if possible. This will remove any hardened grease. Remove the brush and wipe off any grease.
4. Add grease per Table 1.
5. Allow the motor to operate for approximately 30 to 40 minutes before replacing the grease relief plug. This reduces the chance that bearing housing pressure will develop.

Bearings should be lubricated at an average frequency as found in Table 2. Note: Operational environment and type of grease may require more frequent lubrication.

One concept that has been presented is that grease will eventually fill the bearing housing, causing the same problem as an overgreased bearing. We will be addressing this particular issue, as well as discussing why the motor should be de-energized during greasing. We are limiting this paper to a standard deep-groove ball bearing without shields or seals.

How a Bearing Works

The most common type of bearing is the AFBMA-7 C-3

Table 1- Amount of Grease to Use

Bearing Number	Amount in Cubic Inches	Approximate Equivalent Teaspoons
203	0.15	0.5
205	0.27	0.9
206	0.34	1.1
207	0.43	1.4
208	0.52	1.7
209	0.61	2
210	0.72	2.4
212	0.95	3.1
213	1.07	3.6
216	1.49	4.9
219	2.8	7.2
222	3	10
307	0.53	1.8
308	0.6	2.2
309	0.81	2.7
310	0.97	3.2
311	1.14	3.8
312	1.33	4.4

rated bearing. C-3 relates to the internal clearances of the surfaces of the bearing. In most motor rated bearings, there is a clearance of between 3-5 mils (thousandths of an inch) in which lubrication flows to reduce friction and wear of the machined surfaces. The bearing consists of an inner race, an outer race,

Get Your Bearings

Table 2 - Bearing Lubrication Frequency

Motor RPM	Motor Frame	8 hours per day	24 hours per day
3600 (2-pole)	284T-286T	6 months	2 months
	324T-587U	4 months	2 months
1800 (4-pole)	284T-326T	4 years	18 months
	364T-365T	1 year	4 months
	404T-449T	9 months	3 months
1200 and below	505U-587U	6 months	2 months
	284T-326T	4 years	18 months
	364T-449T	1 years	4 months
	505U-587U	9 months	3 months

balls and a cage which evenly distributes the balls (see Figure 1). Common bearings are designed to allow for a radial load with some limited axial loading. ALL BEARINGS ARE LUBRICATED WITH OIL.

Grease, itself, is an oil sponge. The base (spongy) part of the grease varies depending on the manufacturer, temperature, environment and user preference. The grease holds the oil in suspension and allows the oil to flow during operation. The oil compresses between the bearing balls, inner and outer races and the cage, reducing friction. Ball

bearings have small, microscopically rough surfaces on the balls, these surfaces move the oil, holding it to the ball during operation.

When too much grease is added, the grease is compressed between the bearing surfaces, increasing pressure and resulting in heat. Too little grease causes the surface friction to increase, resulting in heat. In any case, once bearing noise is audible, it has failed. Reducing noise by lubrication requires excessive grease, endangering the motor, and giving the technician the false

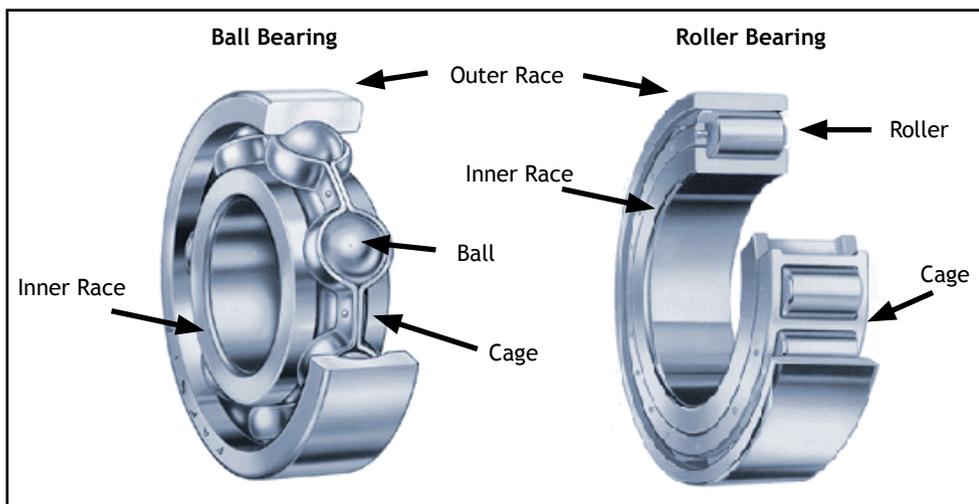


Figure 1 - Bearing Construction

Race Materials

General Purpose

Through-Hardening Steel, 1.5% Chromium, 1% Carbon

Case-Hardening Steel, Chromium-Nickel and Manganese-Chromium Alloyed Steel (0.15% Carbon)

Corrosion Resistant

Chromium or Chromium Molybdenum Stainless Steel: Lower loading due to reduced hardening

Higher Speeds and Temperatures

Hybrid Ceramic: Steel inner/Outer races - has greater stiffness

Cage Materials

Molded Polyamide: Glass fiber reinforced polyamide (-40° to 250° F)

Steel: Reduced friction and wear

Machined Bronze: Heavy duty and larger bearings. Can be used up to 450° F. Resistant to corrosive attack.

Brass: Small to medium bearings up to 450° F.

Phenolic (Bakelite): Machined, cotton fabric impregnated with phenolic resin. High speed applications less than 225° F.

Grease Classification

Group I: General Purpose: Greases that are expected to give proper lubrication to bearings whose temperatures vary from -40° to 250° F

Group II: High Temperature Greases: Greases that are expected to give proper lubrication to bearings whose operating temperatures vary from 0° to 300° F

Group III: Medium Temperature Greases: Operating temps from 32° to 200° F

Group IV: Low Temperature Greases: Operating temps from -67° to 225° F

Group V: Extreme High Temperature Greases: Operating temps up to 450° F

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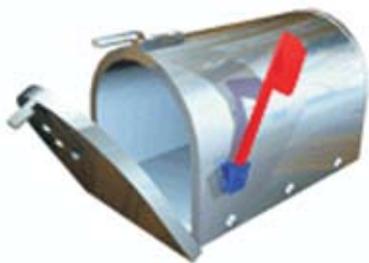
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security of extending the motor life when, in reality, additional damage is occurring to machined surfaces.

Bearings may also have shields or seals mounted on them. Bearing shields are metal fittings that have small clearances between the inner race of the bearing and contact the outer race on either side of the balls and cage. The small clearances near the inner race allows some oil and grease to move into the moving parts of the bearing, but prevents particles of large size from passing into the bearing potentially damaging machined surfaces. Sealed bearings have seal surfaces touching the inner race, while 'non-contact' sealed bearings have extremely close tolerances between the seal surface and the inner race preventing particles under several thousandths of an inch. Sealed, and some shielded, bearings are referred to as non-greaseable bearings.

What Happens When The Bearing Is Greased With The Motor Running?

Oil is an 'incompressible' fluid, which is important when considering the developing issues within the bearing housing (Figure 2) while greasing an operating motor. The 'soap,' or grease medium, acts as a suspension in the oil, although grease is normally represented as a base with an oil suspension. This becomes an important issue in the physical world of hydrodynamics.

With the bearing housing partially filled with grease, grease is added to the housing. Some of the grease flows through the operating surfaces of the bearing, causing stress. The reduction of clearances causes an increase in friction within the bearings. This will cause the bearing temperature to increase as the bearing surfaces reject the grease medium. Once the temperature drops, the grease is no longer within the bearing surfaces and oil from the grease provides lubrication. The increase in

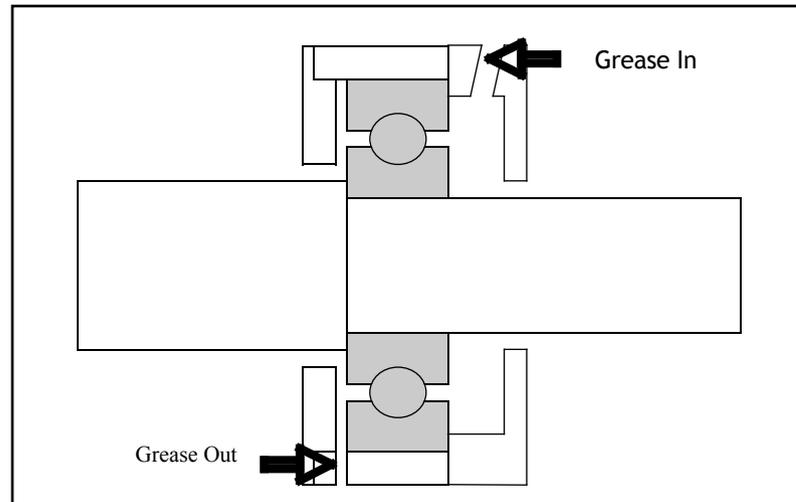


Figure 2 - Bearing Greasing

temperature causes a reduction in grease viscosity, allowing it to flow freely, albeit slowly, and excess grease is rejected through the grease plug (grease out). The change in viscosity ensures that enough flow should occur, when the grease plug is removed, and the maintainer does not count on 'grease relief plugs,' the housing should remain less than full, regardless of the number of greasing operations.

Grease that comes into contact with the shaft, bearing cap opening or housing opening (usually less than 0.010 inches) becomes pumped through the openings due to Couetti Flow. This process is the result of a turning cylinder (motor shaft) with a close, stationary, cylinder (shaft openings) and an incompressible fluid. The excess grease is literally pumped into the motor housing.

What Happens When The Motor Is Not Running?

In the type of bearing that we are discussing, the grease enters the bearing housing. Some grease comes into contact with

the bearing surfaces. When the motor is restarted, this excess grease is ejected from the bearing. The temperature may briefly rise, then fall, once grease has passed through the bearing. The shear stresses and temperature reduce the viscosity of the grease, allowing it to flow.

While some grease is moved into the motor housing, due to Couetti Flow, the amount is considerably less than if the motor is operating.

Conclusion

Electric motor bearing greasing requires the motor to be de-energized during the procedure. The result is reduced risk of excess grease entering the electric motor stator, due to Couetti Flow, and reduced viscosity, due to heat. Combined with safety issues, proper lubrication can maintain the electric motor reliability. Therefore, a limited amount of grease should be added to the bearing housing periodically with the grease plug removed.

Some Guidelines for Grease

Table 3 - Grease Base Temperatures

Base	Lower Temp (°F)	Upper Temp (°F)
Lithium Base	-22	230
Lithium Complex	-4	284
Sodium Base	-22	176
Sodium Complex	-4	284
Calcium Base	14	140
Calcium Complex	-4	266
Barium Complex	-4	266
Aluminum Complex	-22	230
Inorganic Thickeners	-22	266
Polurea	-22	284

Table 4 - Grease Compatibility

Compatibility	Aluminum Complex	Barium	Calcium	Calcium 12-Hydroxy	Calcium Complex	Clay	Lithium	Lithium 12-Hydroxy	Lithium Complex	Polyurea
Aluminum Complex		I	I	C	I	I	I	I	C	I
Barium	I		I	C	I	I	I	I	I	I
Calcium	I	I		C	I	C	C	B	C	I
Calcium 12-Hydroxy	C	C	C		B	C	C	C	C	I
Calcium Complex	I	I	I	B		I	I	I	C	C
Clay	I	I	C	C	I		I	I	I	I
Lithium	I	I	C	C	I	I		C	C	I
Lithium 12-Hydroxy	I	I	B	C	I	I	C		C	I
Lithium Complex	C	I	C	C	C	I	C	C		I
Polyurea	I	I	I	I	C	I	I	I	I	

I = Incompatible

C = Compatible

B = Borderline

Dr. Penrose is the President of SUCCESS by DESIGN Reliability Services, based in Old Saybrook, CT. He also serves as the Executive Director of the Institute of Electrical Motor Diagnostics (IEMD). Starting as an electric motor repair journeyman in the US Navy, Dr. Penrose lead and developed motor system maintenance and management programs within industry for service companies, the US Department of Energy, utilities, states, military, and many others. Most recently he led the development of Motor Diagnostic technologies within indus-

try as the General Manager of the leading manufacturer of Motor Circuit Analysis and Electrical Signature Analysis instruments and training. Dr. Penrose taught engineering at the University of Illinois at Chicago and served as a Senior Research Engineer at the UIC Energy Resources Center performing energy, reliability, waste stream and production industrial surveys. Dr. Penrose is a Past Vice-Chair of the Connecticut Section IEEE (Institute of Electrical and Electronics Engineers), a Past-Chair of the Chicago Section IEEE, Past-Chair of the Chicago Section Chapters of the Dielectric

and Electrical Insulation Society and Power Electronics Society of IEEE, is a member of the Vibration Institute, Electrical Manufacturing and Coil Winding Association, the International Maintenance Institute, NETA and MENSA. He has numerous articles, books and professional papers published and is a US Department of Energy (US DOE) MotorMaster Certified Professional, a US DOE Pump System Specialist, NAVSEA RCM Level 2 certified, as well as a trained vibration analyst, infrared analyst and motor circuit analyst.

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Out of Sight, Out of Mind?

Spare Motors Need Maintenance Too

by Cyndi Nyberg

Because downtime can be so costly, most facilities have spare motors on site to keep production moving when one fails or needs an overhaul. But can you depend on the motors you have in storage? How you store your spare motors will make a big difference in performance when you need them the most. By following some simple guidelines, you can make sure they'll be in good condition when you need to place them into service.

Short-term storage

No special procedures are needed for motors stored less than a few weeks – unless they have space heaters. In that case, maintain the winding temperature at 5 - 10° C above the ambient temperature to prevent condensation from forming inside the motor. If the motor will be stored more than a few weeks, there are several things you can do to protect the bearings and windings.

Storage area

The ideal place to store a motor is indoors in a clean, dry, vibration-free area. If that's not possible, place it on suitable skids or blocks and cover it with a tarpaulin or sheet plastic that extends to the ground. Tie the tarp tightly enough to keep it from blowing off or letting moisture in, while allowing sufficient air circulation.

Depending on the location, take steps to prevent insects and rodents from nesting inside the motor. They can damage the winding insulation or block ventilation and drain openings.

Bearings

Excessive vibration of a non-rotating motor can cause brinelling (Figure 1). This type of damage will be uniformly spaced at the same intervals as the rolling elements (Figure 2). To prevent this, avoid storing motors near sources of ambient vibration like rail lines, busy roads and compressors. Another way to prevent brinelling is to rotate the shaft every 1 - 3 months. Rotating the shaft every 1 - 3 months also keeps the balls, rollers and raceways lubricated. This is especially important for motors that will be stored for a year or more. (Tip: If you have lots of shafts to rotate, place the keyways in the 12:00 position to start. Then advance each shaft 90 degrees as you complete each maintenance cycle. That way you can quickly see if you've rotated each shaft.) Periodic shaft rotation is extremely important for very large motors with heavy rotors that may sag if left in one position

for too long. Rotate those shafts for several minutes at each maintenance interval. If the motor may have been subject to vibration while in storage, inspect the bearings for damage before installing the motor (see Figure 2). Another way to



Figure 1

Brinelling caused by vibration in a non-operating condition. When motors are sitting in storage, repetitive impact between the rolling elements and the races leads to impact damage. Facilities located next to train tracks, a highway or where there is a lot of truck traffic on site are particularly vulnerable.

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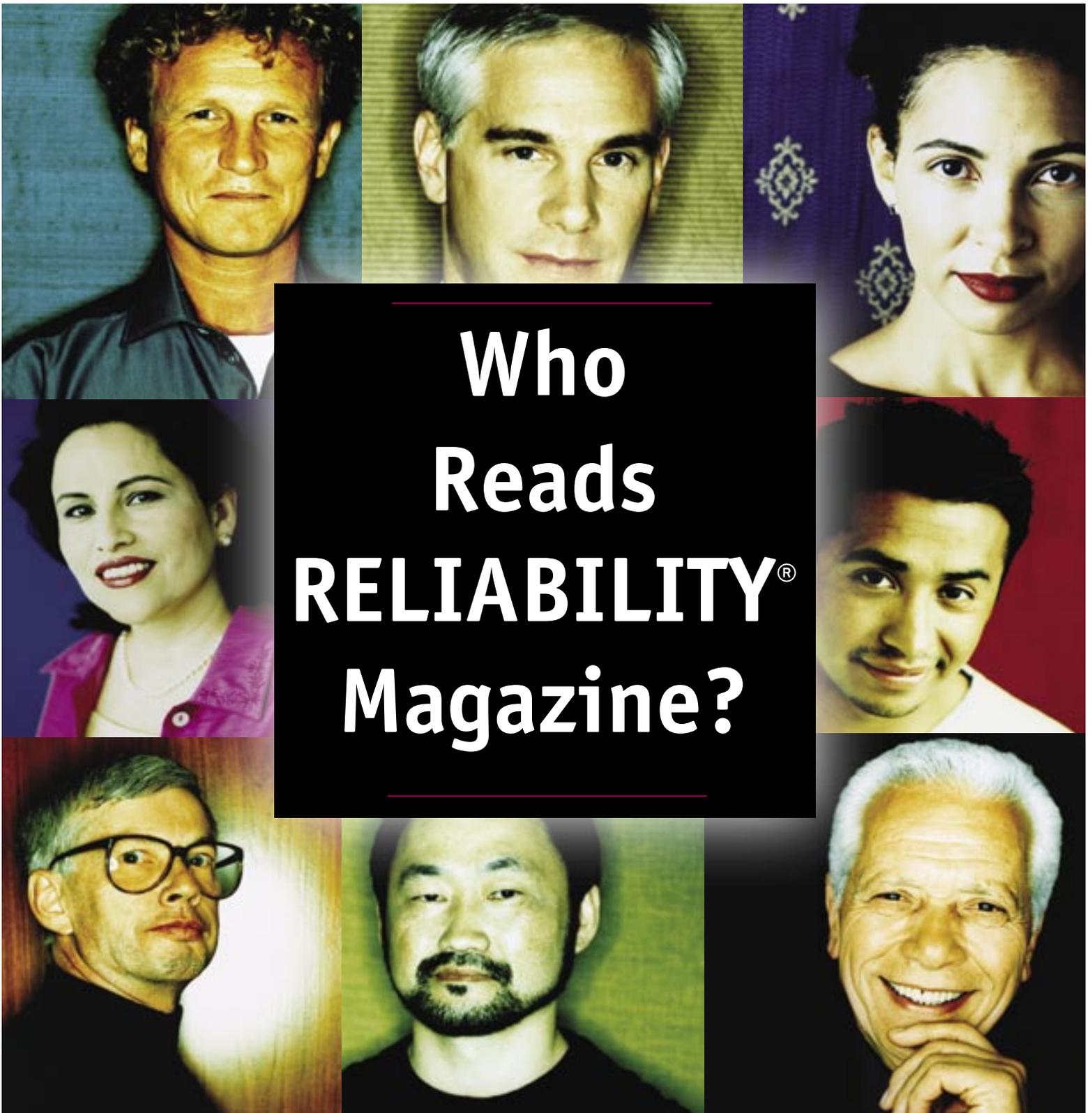
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detect bearing damage is to run the motor uncoupled and perform vibration analysis. Always replace damaged bearings before putting a motor into service.

Lubrication

When storing motors that have grease-lubricated bearings, fill the bearing cavities to capacity – especially if the motors will be stored a long time. Periodically drain small amounts of grease and replace it if contains moisture or other contaminants. Before putting the motor into service, replace the grease with the manufacturer's recommended fill. Purge excess grease by running the motor without a load for at least 10 minutes with the drain plugs removed. Be sure to insert the drain plugs before applying load. Motors with oil-lubricated bearings are shipped dry. Fill these bearings to capacity when you receive the motor. Use oil with a rust and corrosion inhibitor for long-term storage. Periodically inspect the oil and

replace it if it contains moisture or other contamination, or every 12 months if the motor is idle.

Moving a motor with oil in the reservoir can contaminate the windings and shorten motor life. Drain the oil first, and then immediately replace it when the motor is in its new location. Always drain and replace the oil before putting the motor into service.

Windings

Motor windings must be kept clean, dry and at a stable temperature to prevent insulation breakdown during storage. If the area is damp, keep the windings 5-10° C above ambient temperature to prevent moisture from accumulating on the windings. This can be done by energizing the space heaters (if supplied) or by applying low-voltage DC trickle-heat to AC windings, or low-voltage DC to DC field windings. If the motor doesn't have space heaters, remove all drain

plugs and clear any weep holes to drain condensation.

Insulation Resistance

Measure the insulation resistance of the winding(s) before storing a motor, and again before installing it. That way, any drop in the insulation resistance can be addressed before the motor is installed.

Putting the motor into service

When removing a motor from storage, clean any accumulated dust or dirt and change the grease or drain the oil (before moving the motor). Then check the insulation resistance and the polarization index (PI) for form coil windings) or dielectric absorption (DA) for random windings. With large motors that are prone to shaft/rotor sag, rule out potential vibration problems by checking shaft runout during installation. If runout is present, the shaft may need to rotate slowly for several hours to correct the problem. Many DC motors are sold without auxiliary blowers, so they come with shipping covers to protect the inside of the motor. Unless these covers are removed prior to installation, the motor will run hot. Similarly, for DC motors that were repaired prior to storage, check for any masking material that may have been placed on the bottom openings to protect the inside when the motor was painted.

Following these simple guidelines, any motor that has been in storage for an extended period of time is much more likely to perform as expected when you need it the most.

Cyndi Nyberg is a Technical Support Specialist with Electrical Apparatus Service Association, Inc. (EASA), St. Louis, MO; 314-993-2220; Fax: 314-993-1269; Web site: www.easa.com. EASA is an international trade association of more than 2,150 firms that sell and service electrical, electronic, and mechanical apparatus.

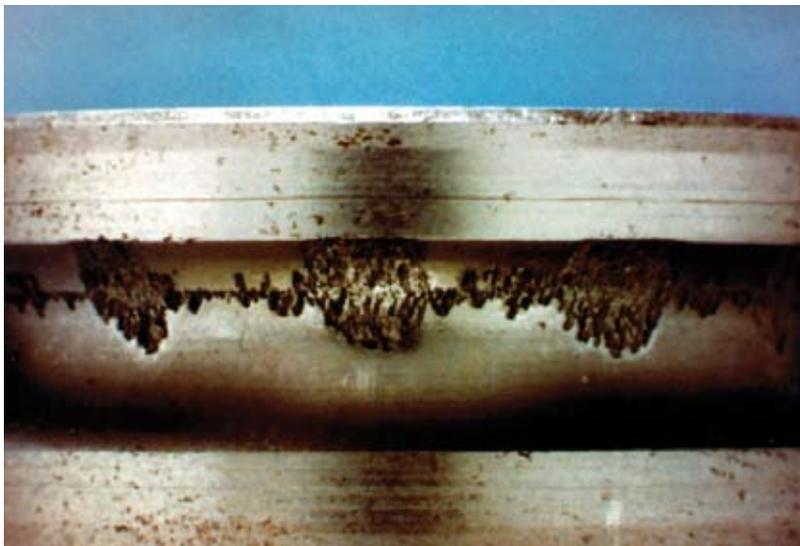


Figure 2

This damage started as non-rotating vibration during shipping or storage. The spacing of the most severe damage matches the positions of individual balls. The damage is concentrated in these areas because the vibration occurred while the motor was at rest and the positions of the individual rolling elements were always the same.

Steady As You Go

Active Balancing Brings Equilibrium To Equipment While It's Running

by Andrew J. Winzenz

In this article, we will discuss common vibration problems experienced on large centrifugal fans that lead to forced outages and unscheduled maintenance. I will describe the use of an Active Fan Balancing System used to control unbalance related vibration levels in fans; and also detail a few active balancing installations and describe the benefits these users have experienced.

Common Causes of Vibration in Centrifugal Fans

Ever since centrifugal fans have been manufactured they have been subject to vibration related problems. These problems range from simple unbalance conditions caused by mass variations on the fan rotor to much more complex issues related to shaft alignment, bearing fatigue, or resonance issues. In many cases excessive vibration levels in fans lead to unplanned, forced outages to perform maintenance. Once to this stage, these outages are necessary to maintain safety. However, most often, they are costly both from a maintenance and lost production standpoint.

Standards have been set as to what are acceptable vibration levels for corresponding operating speeds. The chart shown in Figure 1 is commonly accepted as criteria for vibration levels in most rotating equipment. Other sources that outline acceptable balance and vibration levels for fans include ANSI/AMCA 204-96, "Balance Quality and Vibration Levels for Fans" and ISO 14694:2003, "Industrial Fans – Specifications for Balance Quality and Vibration Levels".

Below are brief discussions of the most common causes of vibration in centrifugal fans along with the corresponding symptoms and methods for correction.

Shaft Misalignment

Proper alignment between a drive motor shaft and a fan shaft is an important step that needs to be properly addressed during new fan installation or if a shaft/rotor assembly is replaced. Misalignment between a drive motor shaft and fan shaft typically results in a 1X and 2X harmonic component of vibration. Often times, misalignment conditions will also lead to excessive levels of axial vibration. Since most

fans are not equipped with axial vibration probes this is often not detected unless the 2X vibration component exists. Misalignment can be caused by careless installation of new equipment, but is more commonly caused by bent shafts or improperly seated bearings. Misalignment should be able to be detected prior to startup of a fan by using a dial or laser alignment system to verify proper alignment between the drive motor shaft and fan shaft. However, a bent fan shaft may not be detected by the alignment system, which may allow the above symptoms to persist.

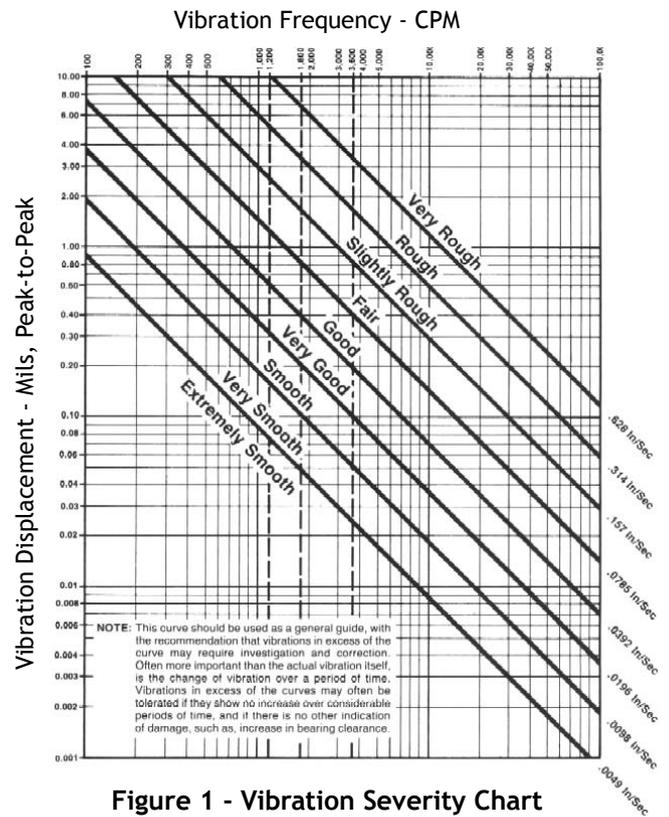


Figure 1 - Vibration Severity Chart

Resonance

Resonance problems are often twofold on large fan assemblies. The first component that has to be addressed is critical speeds. Critical speed mapping is typically a task that is addressed during new fan design. Most fans are designed to operate below first critical speed. The factors in avoiding critical speed in fan design are overall rotating mass, span between bearings, and necessary operating speed to produce the required airflow. If a fan operates above first critical speed then careful attention has to be paid to vibration levels as the fan accelerates up to operating speed and, more importantly, coasts down to a stop from operating speed. Excessive levels of vibration while passing through a critical speed can lead to severe damage to bearings, seals, and other related equipment.

The second factor, structural resonance, can be much more challenging to predict. Every structure has a natural frequency at which it will resonate. If a fan operates at a structural resonance point that is not corrected it can also lead to component failures. Structural resonance can occur at 1X operating speed or at a harmonic frequency (2X, 3X, etc.). Structural resonance will vary depending on

operating speed and can be easily identified by performing a signature plot mapping vibration amplitude, versus frequency, versus rotational speed.

Mechanically Loose Connections

Looseness in any mechanical connection between bearing caps, bearing pedestals, or foundations can cause excessive vibration levels or amplify an already existing unbalance problem. In most cases, a mechanically loose connection will yield harmonic levels of vibration (2X, 3X, etc.) and may also yield sub-harmonic levels of vibration (X/2, X/3, etc.). Vibration caused by mechanically loose connections is often misdiagnosed due to the presence of sub-harmonic vibration levels.

A second type of vibration caused by mechanically loose connections can take place if there is looseness in the connection between the fan rotor and fan shaft. In many cases this will induce an extremely high unbalance related vibration level that is not necessarily at 1X operating speed. This type of vibration can be very difficult to determine, but easily corrected if found. In most cases, properly designed interference fits between the rotor hub and fan shaft can be implemented to avoid this condition.

Cracked Shafts or Rotors

Crack propagation in either a fan shaft or rotor can lead to one of the most dreaded failure modes in any type of rotating equipment. If undetected, a crack in a shaft or rotor can eventually lead to catastrophic failure of the fan. Early crack detection can take place if vibration trending and analysis takes place on a piece of equipment. The common symptoms of a crack propagating in a fan are both an emergence and growth of a 2X component of vibration along with a change in the phase and amplitude of the 1X vibration component.

Rotor Mass Unbalance

Rotor mass unbalance is the most common cause of excessive vibration in most rotating equipment and fans. The primary symptom of rotor mass unbalance is a high 1X vibration level. Rotor mass variation leading to an unbalanced condition is typically caused by four primary factors.

1. Variations in manufacturing can lead to unevenly distributed mass in the fan rotor.
2. Exposure to high air stream temperatures can cause uneven growth of the fan rotor.

Balancing Case Study - GCC Dacotah Cement

A severe vibration problem was being experienced in an ID fan that draws hot gas and cement particulate off the rotary kiln before sending it to the bag house for particulate removal. Since the fan is in the process airflow, some of the particulate would stick to the fan and produce a hard coating up to an inch thick. As temperatures and process conditions changed, large chunks would break off and cause the fan to go out of balance. Every two months it was necessary to shutdown to sand blast the fan. The cleaning time alone was six hours and by the time everything was ready to go back into service 12 hours of production had been lost.

A fan balancing system was installed on the Kiln ID Fan. Vibration levels that regularly reached levels of up to 25 mm/s at 1330 RPM are now kept to between 0.6-1.3 mm/s. Scheduled outages now take place every 6 months at which time cleaning is performed. Emergency outages, which regularly took place, have been eliminated.



Installation at GCC Dacotah Cement

3. Deterioration of the fan rotor caused by either high speed particle collisions or corrosive material passing through the fan.
4. Uneven material accumulation or fouling on the fan rotor.

This final issue can be compounded by large chunks of material flaking off and causing very sudden, excessive vibration levels.

Excessive amounts of rotor mass unbalance can have two detrimental effects on fans. The primary concern is the excessive long-term, fatigue caused by beating forces that occur when running at elevated vibration levels. The second concern, although uncommon in fans, is passing through critical speeds on start-up or coast-down. Excessive amounts of rotor mass unbalance can also amplify other vibration conditions, such as a loose bearing cap or instability in a founda-

tion.

Many of the unscheduled forced outages that take place due to excessive vibration are simply due to excessive amounts of rotor mass unbalance.

Correcting For Unbalance Conditions In Fans

Corrective actions can be taken to reduce the amount of unbalance, including removing particulate build-up from the fan rotor or performing a mechanical balance of the fan. However, both of the actions require a stoppage of the fan for some period of time. There are two methods for making a mass unbalance correction to compensate for 1X vibration, either a manual balancing system that is often portable and can be used on multiple pieces of equipment or a dedicated active balancing system.

Manual Balance Corrections

A manual balance correction or off-line balancing procedure is a common action that takes place during new equipment installation or as a maintenance procedure during a planned outage. The balance correction is typically a six part process that follows these steps:

1. Clean the impeller of any particulate build-up.
2. Measure the initial vibration phase angle and magnitude.
3. Stop the fan and add a known trial mass at a known location.
4. Start the fan and measure the resultant vibration phase angle and magnitude. This information is then used to compute the fan sensitivity or response to unbalance.)

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Figure 2 - Active Balancing System

5. Once this calculation is made the fan is stopped and one can determine the proper amount of mass for the balance weight and what location to attach the weight.
6. The weight is attached and the fan is restarted.

Steps 3-6 of this process may be repeated multiple times depending on the level of experience of the technician and sensitivity of the equipment.

Although a manual balance correction is typically necessary for new equipment installation and during planned outages, it does have drawbacks if you need to employ this technique regularly between planned maintenance intervals. The amount of time required to perform a manual balance correction can be very difficult to determine, particularly as it relates to permit issues, co-operation between services, and ease of balancing the fan. Multiple starts and stops of the motor may lead to shortened life expectancy of the motor and other associated equipment. Variable speed applications may find that different balance corrections are necessary for different operation speeds. And, although uncommon in most fan applications, for equipment passing through

critical speeds, the excessive vibration levels experienced while passing through a critical speed can lead to excessive bearing and seal wear.

Automatic Balance Corrections

A second type of balancing system has been in use since the early 1980's and allows users to continuously monitor fan vibration levels and make balance corrections without shutting down the fan. These systems have been termed automatic or active balancing systems. Active balancing

systems consist of a control system, balance rings, actuators, and vibration sensors. The balance ring permanently attaches to the shaft of the fan. The balance ring contains internal weights that can be repositioned to offset the mass unbalance and compensate for excessive 1X vibration levels (see Figure 2).

Operation of an Active Balancing System

Active balancing systems operate on a simple concept of sense, and then adjust. The balancing system is set up to continuously monitor fan vibration levels. Users program in a fixed tolerance range within which they would like to keep the vibration level. When vibration levels reach the upper limit of the tolerance range, the control system determines the necessary magnitude and phase angle of the required balance correction. The control sends power and data to a stationary actuator that communicates with a rotating balance ring. The actuator commands the internal weights in the balance ring to move to new positions in order to offset the unbalance and bring the 1X vibration level back within the tolerance range. Figure 3 provides a schematic of a typical system configuration.

Applications for Active Balancing Systems

Active balancing systems have been applied to numerous types of rotating equipment. Their effectiveness in controlling 1X vibration levels caused by rotor mass unbalance in industrial ID fans continues to be a primary area of application. There are three primary types of ID fans that active balancing systems

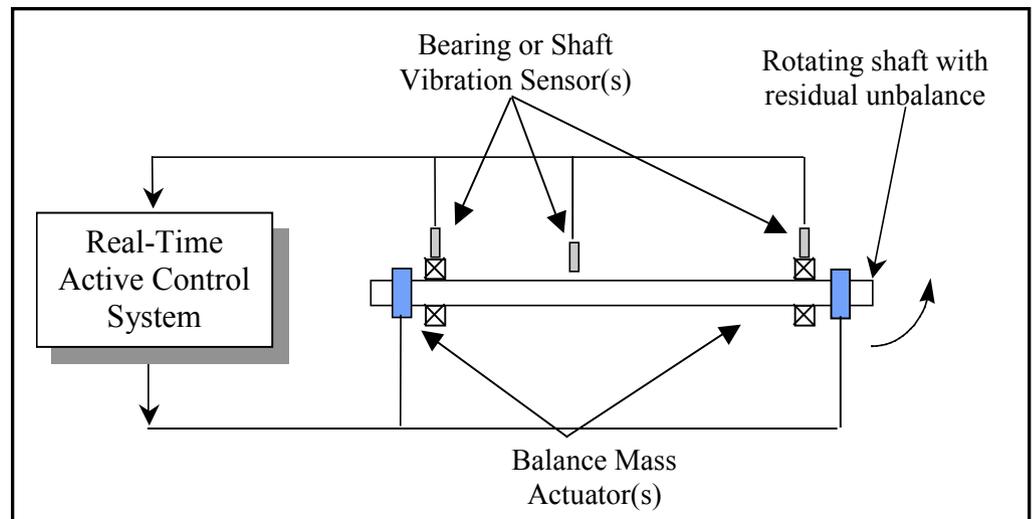


Figure 3 - Active Balancing System Schematic

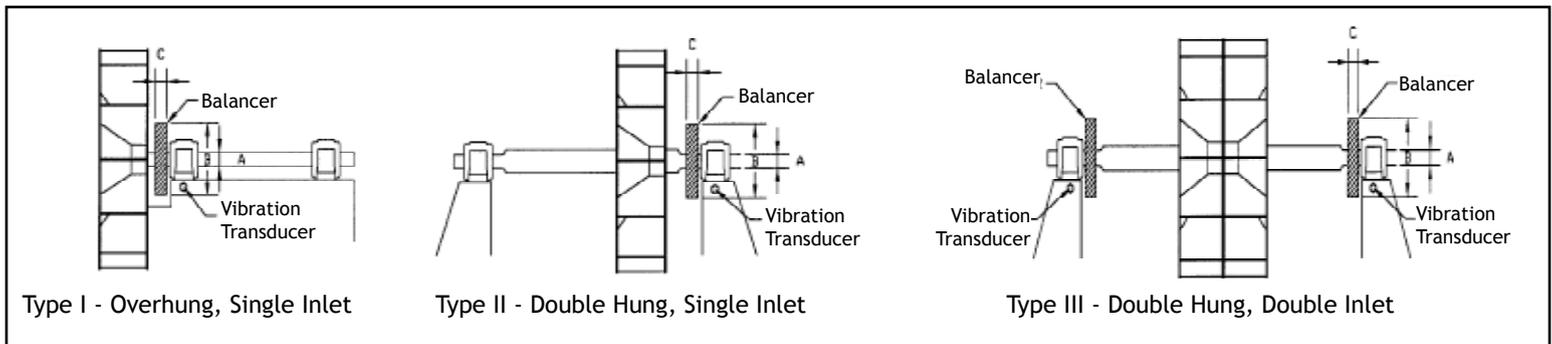


Figure 4 - Typical Fan Configurations

have been applied to. They are overhung single-inlet, center-hung single-inlet, and center-hung double inlet (see Figure 4).

The configuration of the fan defines the number of balance correction planes required. Variation in the size and operating speed of the fan, as well as process conditions, dictate the necessary correction capacity that is built into the active balancing system.

Benefits of using Active Balancing Systems

The primary objective of an active balancing system is to maintain low levels of vibration while the process continues to operate. Maintaining very low vibration levels typically has positive impacts on a plant both from a production and a maintenance standpoint. The most visible benefit is the ability to improve fan reliability and availability. This leads to reductions in both scheduled and unscheduled maintenance outages, which are typically used for more conventional means of correcting for unbalance problems. Many users also find that in addition to eliminating unscheduled, intermittent maintenance outages they can often extend the period between planned maintenance outages. For plants that plan to run 1-2 years between planned maintenance outages, this can have a very positive impact.

Secondary benefits include extending equipment life, such as motors, bearings, and seals by operating for longer periods of time at low vibration levels. Another benefit is the reduction of fuel and power consumption by limiting the number of starts and stops of the process.

Interfacing with an Active Balancing System

One of the most useful pieces of information that can be obtained from an active balancing system is an event log that tracks the usage of the balancing system. This log will display beginning and ending vibration levels and phase angle as well as the amount of time required to complete a balance correction. The stored data can also be used effectively to calculate a required manual correction, therefore reducing the time and efforts required during a planned outage. This information can be accessed through Windows based control software. The system can also be tied into a plant's Digital Control System (DCS) through a PLC interface. This puts control of the system and data in front of an operator at all times.

The balancing system can also be accessed via a remote interface module (see Figure 4) that allows the system to be linked to a plant's network through an Ethernet connection. This remote interface provides a secure connection for remote users to download historical data, access and change parameters, monitor vibration levels and permits complete control of the system from any location around the world.

Summary and Conclusions

There are many different causes of vibration in rotating equipment. In order to effectively deal with all of the causes it is necessary to implement an effective condition based maintenance program that can identify problematic situations before they turn into potentially catastrophic situations.

Active balancing systems help to solve one of the most common causes of excessive vibration in rotating equipment by compensating for rotor mass unbalance. These corrections are made while the equipment remains in service, avoiding costly outages. Reductions in 1X vibration amplitudes caused by rotor mass unbalance also help to minimize the effects of other vibration conditions such as looseness in bearings or inadequate stiffness in bearing pedestals or foundations. Active balancing systems can provide detailed trending information that can be used for outage planning and to assist in identifying other vibration problems that are not strictly displayed at 1X operating speed. Proper use of an active balancing system allows users to increase equipment availability, run a more stable production process, and, ultimately leads to a safer, more reliable operation.

Andy Winzenz is a Product Manager for LORD Corporation, based in Cary, NC. Andy has been working in the balancing and vibration industry for 11 years and has held a variety of sales and engineering positions during this time. Andy can be contacted at Andy_Winzenz@lord.com or 919-468-5981.

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Balancing Case Study - United States Steel

The level of vibration on the 120" (305cm) diameter exhaust fans, which draw a mixture of air, coal, and miscellaneous gases through thousands of feet of ductwork in the pre-carbon (Coke) plant, would creep to unacceptable levels during operation. Even higher levels of vibration often occurred after the fan had been shut down for several days. Whenever the level of vibration reached 5.5 mm/s, the fan would automatically shut

prematurely. They had to be replaced almost every month during the maintenance shut-downs.

After the active balancer system installation, vibration levels below 0.5 mm/s are maintained. The bearings that had previously been replaced every month are now lasting more than a year and saving



Installation at US Steel, Gary Works
Gary, Indiana

significantly reduced. Emergency shut-downs due to excessive rotor vibration were eliminated while increasing the amount of production per year. In all, US Steel estimates that they have saved over 1,000 hours of maintenance time or \$45,000, which allowed them to concentrate on preventive maintenance instead of performing repairs in a crisis situation.

"Since installation of three LORD balancing systems," said Jim Mays, Maintenance Manager for the U. S. Steel Fairfield Works in Fairfield, Ala., "we average only one scheduled maintenance shut-down and one interim cleaning per year. Since the typical shut-down lasts between 8 and 12 hours, the savings are significant. But beyond saved revenue and time from reduced shut-downs, the technology continuously maintains the balance level of the fans below 0.8 mils, as compared to the previous 1.0 mils low level field balance. Additionally, the motor and bearing life has been increased, resulting in fewer motor rebuilds at approximately \$200,000 each. Our whole steelmaking process has become more predictable and productive."



Installation at US Steel,
Fairfield Works,
Fairfield, Alabama

down. To keep the fan within acceptable levels of vibration, the rotor was manually balanced as often as twice per month at a cost of \$1,000 each time. It also required at least a day of downtime and lost production. In addition to constantly balancing the rotor, the vibration was causing the bearings to wear out



US Steel more than \$80,000 in parts and labor to change them out. Fan downtime for balancing and maintenance was also

Going Subterranean

Underground Leak Detection

by Jim Hall

Ever since I worked in the plumbing industry, I have always been interested in locating underground leaks. In the early 1970's electronic leak detection was virtually nonexistent. A doctor's stethoscope and a good ear was the alternative. However, the most common method in use by contractors then, and sadly to say, even today, is what I call the "search and destroy" method. That is, they use questionable guessing techniques and dig a hole where they think the leak may be. If they don't find it they keep on digging until they do find it. This method can lead to wasted time and money...and some enormous holes!

Underground Main Steam Leak

Early on in my airborne ultrasound career I was asked by a contractor to locate an underground steam leak at the University of Southern California. The contractor was the principal contractor who had originally installed the underground steam pipes. Unfortunately for him, the campus now appeared to have little geysers erupting all over, creating dense condensate clouds all over campus. The appearance of these clouds meant large energy losses.

A new construction project was in progress, utilizing a 16-inch steel casing wound with a fiberglass type winding for insulation (no pitch-tar wrap). This particular project was designed to connect the old steam system with the new system. The older underground steam lines on campus included a 4-inch steam main and a 2-inch condensate line inside of a 16-inch steel casing insulated with a pitch-tar wrapping which was buried 5½ feet below the parking lot. Pitch-tar is a very good sound insulator, and allows almost no sound to be emitted from within the pipe to travel to the surface for detection. Therefore, there was very little chance of an ultrasonic detector hearing a leak 5 ½ feet below ground.

Due to the depth of the buried steam pipe it may be best to pressurize either the condensate line or the steam main to isolate which of the two lines is leaking. It may be necessary to locate the pipe with a pipe locator if there are no signs of previous construction or where the lines were laid.

A pipe's weakest point is at the connecting ends. Gaskets, solder joints, pipe threads and poor installation are the most common reasons a pipe such as this one may leak.

To locate this particular leak, I chose to employ an air compressor to create a positive pressure inside the pipe. I thought the air leaking from the leak site would create a sound that the ultrasonic detector may possibly hear. (When using compressed air for this particular application it may be necessary to modify the pipe, such as welding a pipe nipple with a fitting attached, so that air can be supplied to the condensate line.)

In fact, this leak on campus never registered on the leak detector's ballistic meter as a leak. Instead I saw virtually no movement on the ballistic meter at



Figure 1 - 2½" Water line leak found using sonic sound devise, 2 feet below concrete walkway.

All photos courtesy of All Leak Detection, LLC.

all. However, shortly after my sweep with the ultrasound equipment, I was surprised to hear a very soft hissing sound in the ultrasonic detector's headphones. It was faint, faint enough that if I moved 18 inches left or right I would lose it.

I reached for a can of road marking paint and immediately sprayed a 20 foot "X" to mark the spot. The contractor then cut and opened the asphalt with a large tractor exposing the steel casing that housed the steam main and the condensate line. Armed with a camera, I watched as the welder cut an opening in the casing. He discovered torn insulation around a 2-inch coupling that had split, which caused the steam leak. The contractor wondered if the leak had been caused by vandals. He said he had caught vandals in the past trying to remove copper pipe. It wasn't unusual for the vandals to attach a chain to a car or truck and rip-out as much of the copper pipe as they could, later selling the copper pipe as salvage.

Procedure

Airborne ultrasound is very directional. The high-frequency sound wave is typically 1/8 to 5/8 of an inch long. When performing an underground leak survey, it is best to use a contact probe or, if possible, a ground microphone. This sensor could be the same sensor used to listen to bearings, steam trap troubleshooting and/or valve inspections.

When using airborne ultrasound, select the contact probe and place the frequency setting at 20 kHz, typically the lowest frequency setting on most ultrasonic detectors. Remember - the lower the frequency - the larger the sound waves - the larger the soundwaves - the further they travel - which can make detection much easier. Use extension rods if needed.

Metal pipe (iron, galvanized, copper) will resonate an audible tone that can be detected by the ultrasonic detector. Pushing

compressed air through the leak will increase this resonance, but, if enough turbulence (friction) is present, adding an additional air source may not be necessary. On the other hand, plastic pipe (PVC) makes virtually no noise when leaking.

"Zone-off" or "valve-off" the main steam system by individual zones. This may help isolate the leak. Slowly and deliberately, scan the ground using the ultrasonic contact probe or ground microphone and listen for subtle changes.

Fire Main Loop

Airborne ultrasound was very effective in finding a fire main leak in a Minneapolis, MN manufacturing plant. This pipe leak was part of the fire main system loop. Here is the story....

While performing a routine leak detection survey in the plant, a maintenance technician decided to listen to several pipes in the fire main system. Using the contact probe of the ultrasonic receiver and a frequency setting of 20 kHz, the technician touched a few stand pipes and compared the readings. The pipe with the higher reading or decibels meant the technician was homing in on the target leak. He found the pipe with the highest reading, listened again with the contact probe and gently pushed on it from side to side. After noting which pipe this was, he went to lunch. After lunch, he returned to the site to finish his survey. Unfortunately, he was met with ankle deep water when he returned to the site. The good news was he found the right pipe with ultrasound. The bad news was that moving the pipe side to side fractured the line allowing water from the fire main to flood the area.

Ultrasonic or Sonic-sound?

Neither ultrasound nor sonic sound should be eliminated from your list of instruments to locate underground leaks. Sonic-Sound



Figure 2 - Fire hydrant leak found using ultrasonic instrument with contact probe.

(low-frequency, long waves) is used more by utilities and underground leak detection services world wide. Remember the stories of the old west and how our forefathers would place an ear to the railroad track to hear the sound of a train coming? Or putting an ear to the ground to hear the sound of the Calvary soldiers as they rode their horses across the plains? Low-frequency travels at great distances and therefore is most effective for underground leak detection. Ultrasound or high-frequency sound, has short waves, typically 1/8 to 5/8 of an inch long, and is very directional. Objects in the path of Ultrasound will stop the waves, and, consequently, the sound.

Loose soil does not transmit sound as well as hard compacted soil. Lines buried deeper than 7 to 8 feet tend to absorb water leak sounds. But lines that are only 3 to 4 feet deep are much easier to hear at the ground's surface. Low frequency attenuation of sound is approximately 40 dB per 3 feet of depth.

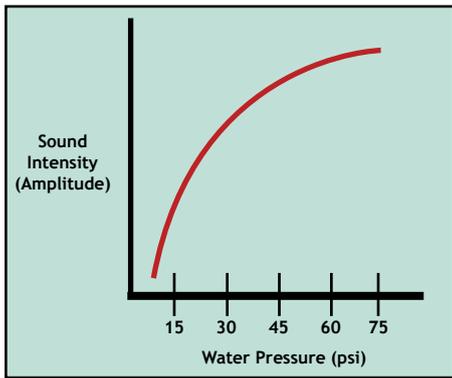


Figure 3
Sound Intensity vs. Pressure Graph

Also, the higher frequencies of sound (short wave) are absorbed more quickly in soil than in low frequencies (long wave).

Copper piping and galvanized or steel pipes produce sounds that are louder (Figure 3) and that are higher in frequencies (Figure 4) than do PVC pipes. Thus, knowledge of the pipe material is important.

If the user knows that the leak is small, (60 psi or more), and is in iron, steel or copper piping, the sounds should be in an audible high frequency range, maybe 400 Hz to 1200 Hz. On the other hand if a leak is large (30-40 psi), and is PVC pipe, then the sounds should be in a lower frequency range, maybe 200 Hz up to 600 Hz.

As seen in Figure 5, copper, steel, or iron pipes (6 -12 inches in diameter) may transmit sound hundreds of feet, while PVC of the same diameter may only transmit sound 100-500 feet.

What Am I Hearing?

Pipe resonance or vibration is often the most intense leak noise, sounding like a “whoosh” or a “hissing”. Water rushing through piping is usually a very weak signal. Although I have been able to use this type of signal to follow a pipe to locate the leak and/or valves on the system, it is rather difficult. However, if the signal is strong at a certain point, then

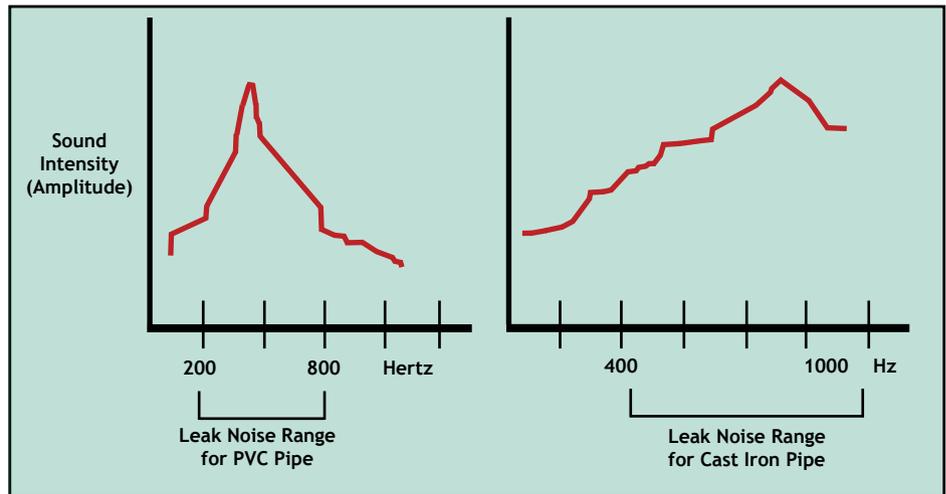


Figure 4 - Comparison of Leak Noise Frequencies in Different Pipes

quickly drops off after moving the sensor, you are probably directly over the leak. Just last week I was called to a job where the water was coming out of the ground directly in the path of underground electric lines. After the utility company had marked these lines, I used those markings to walk a path hoping to find the point where the water main break was. Fortunately, in 5 minutes I

had located the point of the leak, which ended up being a 6-inch water main sitting directly above a power line trench. The sound actually reminded me of a “babbling brook” or a mountain stream. Gross leaks may, in fact, create a cavity underground. If this is the case, you may never hear the sound of the water leaking out of the pipe. Try to turn-off the service and give it a few

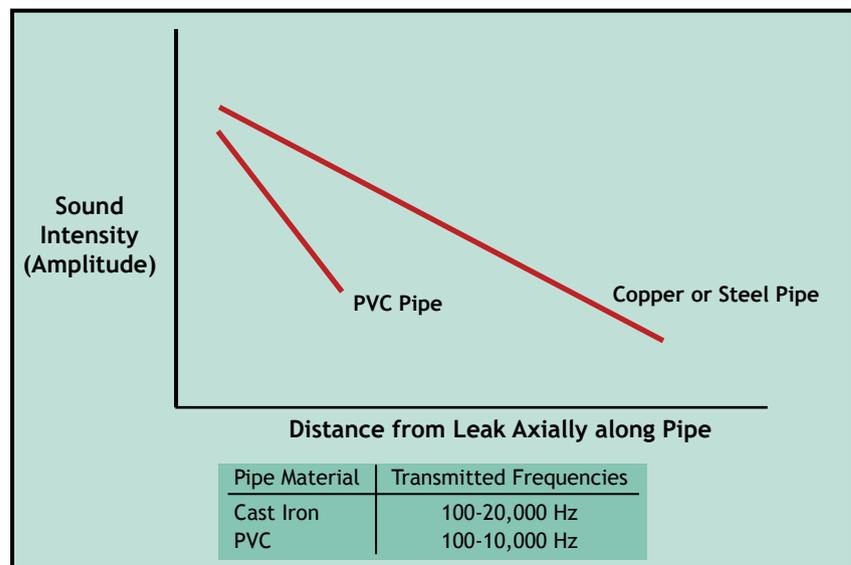


Figure 5 -Sound Transmissions vs. Distance from Leak



Figure 6 - Subsurface leak detection instrument detects both sonic and ultrasonic frequencies.

hours to dissipate, then use the air and water left in the line to start your survey. The leak sound should favor a “spitting” or “sputtering” sound. But once the cavity fills with water again, the sound will be more like blowing air into a straw and creating bubbles, or a “gurgling” sound.

Ultrasound Can Be Limiting

Using airborne ultrasound (high-frequency, 20 kHz –200 kHz) for underground leak detection is not as common as sonic sound (low-frequency, 100 Hz – 1200 Hz). But the use of compressed air is sometimes needed to aid in the leak detection when using low-frequency. Sonic or low-frequency is what you and I hear, so it is sometimes hard to use in heavy traffic areas. High frequency or ultrasound can also be limiting. I’ve actually heard what sounds like calipers grabbing the brake pads of trucks or automobiles as they approach an area that I am surveying. Just keep in mind that planes, trains and automobiles may interfere with finding the leak. Their presence

could also extend the amount of time it takes to find a leak because you may have to stop and wait for traffic or airplanes to pass before continuing your survey.

On the other hand, high-frequency is sound above the human hearing range. So what is typically noisy to you or me, is not noisy to the ultrasonic receiver. Manufacturing or industrial plants with wade pools, fountains, pressurized water systems, as well as piping systems of compressed air and/or other gases may want to invest in both a sonic and ultrasonic detection system. Both systems



Figure 7 - 2 ½ inch water main split at the *elbow. Located leak from surface using sonic device in clay soil. The leak was approximately 5 feet below surface.

*Note: Elbow schedule 40 PVC, should have been schedule 80 PVC for this application. Three such elbow leaks were found this day, same size and same schedule PVC pipe.

are useful under different circumstances. If you have both, you will have a much better shot at finding those underground leaks.

Special thanks to Sub-Surface Instruments, Website www.sslocators.com, Houston, TX for technical data and information.

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Out of Balance

Digging Deeper Into Data Helps With Diagnosis

By Robert Pyle

Steve Goldman states that unbalance is a common forcing function in industrial machinery¹. Victor Wowk is more specific, saying that 40% of all vibration problems are due to imbalance². With those kinds of statistics, recognizing and solving out of balance problems should be one of the first steps in learning to analyze vibration spectra.

Out of balance occurs when the center of rotation of a rotor and the center of gravity do not coincide. This can be due to an error in machining, porosity of castings, damage to the rotor, build up of contamination, etc. It can also be due to the poor mounting of a rotating member on the drive or driven shaft. Although tapered couplings are normally fool-proof, they can be improperly and unevenly tightened producing an off center sheave, coupling, or other rotating member.

In my experience, on fans in HVAC units, scrubbers, or any other applications that use squirrel cage fans, improper mounting and contamination are the most frequent cause of imbalance, followed by damage to the fan. Most of these devices are running below their first critical speed which means that the imbalance causes any contamination buildup to further imbalance the wheel.

At many of my clients' units, I have found poor or poorly sealed filter units that have allowed dust to accumulate on the wheel producing high imbalance and, eventually, failure of the bearings.

...recognizing & solving out of balance problems should be one of the first steps in learning to analyze vibration spectra...

In one case, a scrubber fan (not a squirrel cage but a large paddle type rotor) was running in an atmosphere where sticky particles were entrapped in the air. These particles contaminated the paddles immediately. No matter how well the wheel was balanced initially, it began vibrating on startup and continued to grow worse each day. The only solution to this was a PM clean out on a very frequent basis – something the client was unwilling to, and did not, do. The vibrations eventually destroyed the shaft and bearings.

In sheaves, couplings, and other solid rotors, my experience is that mounting errors, errors in boring,

and damage to the component are the most common sources of out of balance.

Residual Unbalance

Every rotor vibrates. Because of minute imperfections in machining, casting, mounting, and maintenance, there is residual unbalance in every rotor. The secret is to ensure that the residual unbalance is well below a level that will cause a vibration large enough to damage the rotor, the bearings, or other components of the machine.

How much residual unbalance should one allow? It depends on the reference. There isn't one hard and fast standard to use. However, for clients who do want a standard to work from, I suggest this one.

All rotors can be balanced to a residual unbalance force defined by this formula:

$$\frac{U}{W} \leq 8 \cdot e^{(-\ln(N)+0.69)}$$

Where U = residual unbalance measured in oz.-in.
W = weight of rotor measured in pounds.

$V =$ normal operating speed measured in revolutions per minute.

This will normally produce a vibration of less than 0.1 in/sec.

Unbalance spectra

“Unbalance shows up as a single spike at rotor speed.”

That’s a good theory. It also holds for most of the cases found in the field. However, it can mislead you when you look at a spectrum.

For light to moderate unbalance on a stiff machine, this will almost always be true. For very heavy unbalance, one can expect to see a large 1X spike and multiple harmonics up to 4X or 5X. In fact, a very large unbalance can fool you into thinking there is a misalignment problem present also. If you try to rid yourself of the problem by aligning the shafts, you’ll be at it for a long time.

Look at the spectra presented in Fig 1, which was generated on a machine in my lab. In the lower plot, we have the residual unbalance in the machine. There is a 1X spike of about 0.8 in/sec. The overall vibra-

tion level is 0.124 in/sec – one that would put the machine in alarm in most applications. (I will be working on that residual unbalance as soon as I can find a couple of days in the shop to do so.) You see the effects of adding unbalance to the machine in the second plot. The 1X spike is still there but has actually decreased in size. Overall vibration, though, is up to 0.126.

How could an unbalance weight be added and the 1X spike decrease? That has to do with phase. The unbalance on the sheave is at a particular location. The putty was added

to the load at a random location. If the putty had been added at exactly the same angle as the unbalance in the sheave, there would have been a large increase in the 1X spike. If it had been added exactly opposite of the residual unbalance, there would have been a large decrease in the 1X spike – because the two weights would have cancelled out. I would have been balancing the machine. As it was, the unbalance weight was added so as to partially balance the machine.

BUT! This is two-plane balancing – not single plane. The residual unbalance is on one end

of the shaft and the induced unbalance is on the other. Even though the over all 1X has been decreased, we are still moving the shaft in the bearings – in fact, producing a swirling motion of the shaft. This will be important later to explain where the overall increase in vibration level came from.

Now, look at the highest plot. This is with a 10 gram piece of putty put randomly on the load at a radius of 1.8 inches producing an OOB of 0.63 oz.-in. The 1X spike has risen to 0.15 in/sec and the overall vibration has risen to 0.181 in/sec. This spectrum is very typical of what you will see when you have a pure unbalance on a rotor: a very clean 1X spike.

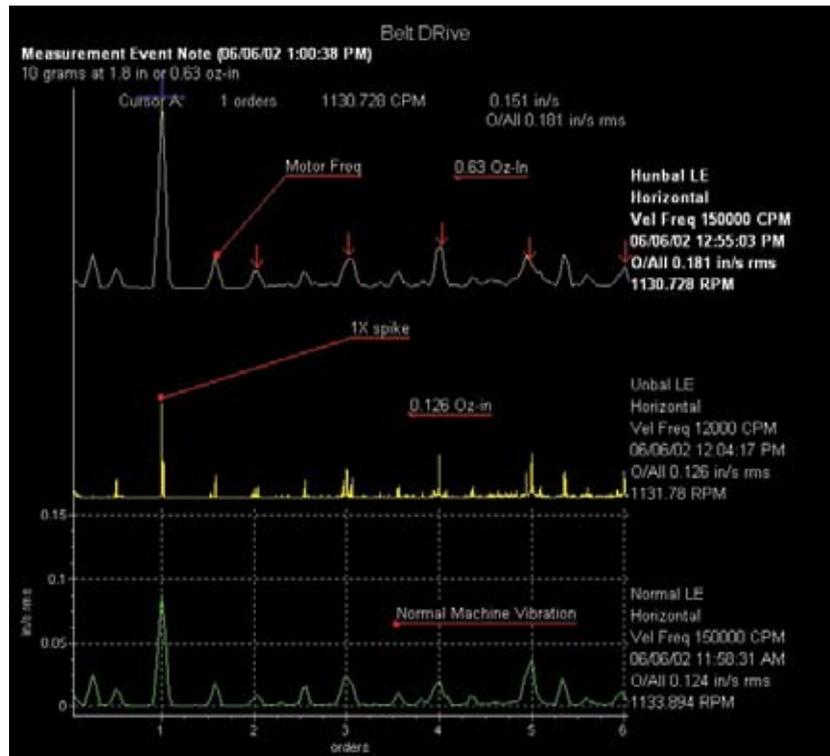


Figure 1 - A Study in Unbalance

Harmonics

There are, though, some troubling spikes in the last spectrum. Notice all the spikes are harmonics of the load speed. There are especially high spikes at 3X and 4X. Of course, they are there in the original plot but have increased in amplitude in the last plot. In the second and third plot, these spikes account for the difference between the overall energy

level and the energy found only in the 1X spike. Where did they come from?

Remember, your machine is not producing spikes of frequency as shown on the spectra. Your machine is vibrating in a waveform. For very simple vibrations, this waveform is sinusoidal, or close to it. To extract the spectrum from this waveform a mathematical technique called Fourier Transform is used.

The technique extracts all the frequencies that make up the wave. It works very well on sinusoidal waves and on various combinations of those waves.

A square wave is made up of a sine wave and all of its harmonics ad infinitum. A Fourier Transform of a square wave will produce a spike at the base frequency and at every harmonic (multiple) of that frequency. We can

If...the vibrations get very large and the shaft begins to bang into the bearings, we will begin to see a squaring off of the waveform - and the FFT will produce harmonics.

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begin to suspect, then, where the harmonics are coming from in our plot. If we are beginning to square off the waveform read by our vibration analyzer, then the FFT function that is producing the spectrum will begin to indicate harmonics, even if there really aren't any harmonics occurring in the actual physical movement of the machine.

Think about the movement of the shaft that is producing the vibration. If it has room to move, it will oscillate in a sinusoidal motion: and we will see a single spike in the spectrum. If, on the other hand, the vibrations get very large and the shaft begins to bang into the bearings, cutting short the sine wave, we will begin to see a squaring off of the waveform – and the FFT will produce harmonics.

Time Domain

If you are using a good analyzer you should have a Time Domain function on it. If you use this in conjunction with a tachometer trigger and non-averaging data collection, you can collect a representation of the waveform being produced with time (or revolutions) on the horizontal axis and amplitude on the vertical axis. From that data, you can get a picture of what your vibration really looks like.

Look at Fig 2. This is a time domain representation of the residual vibration in the test machine and the vibration with .63 oz.-in. of unbalance induced. Neither of them is very clean, explaining why we see multiple harmonics in both spectra. Look, though at the 0.63 oz-in plot. Notice the squaring off of the tops of the peaks. In almost every case, there is an oscillation occurring at about 0.3 in/sec before the waveform drops back across

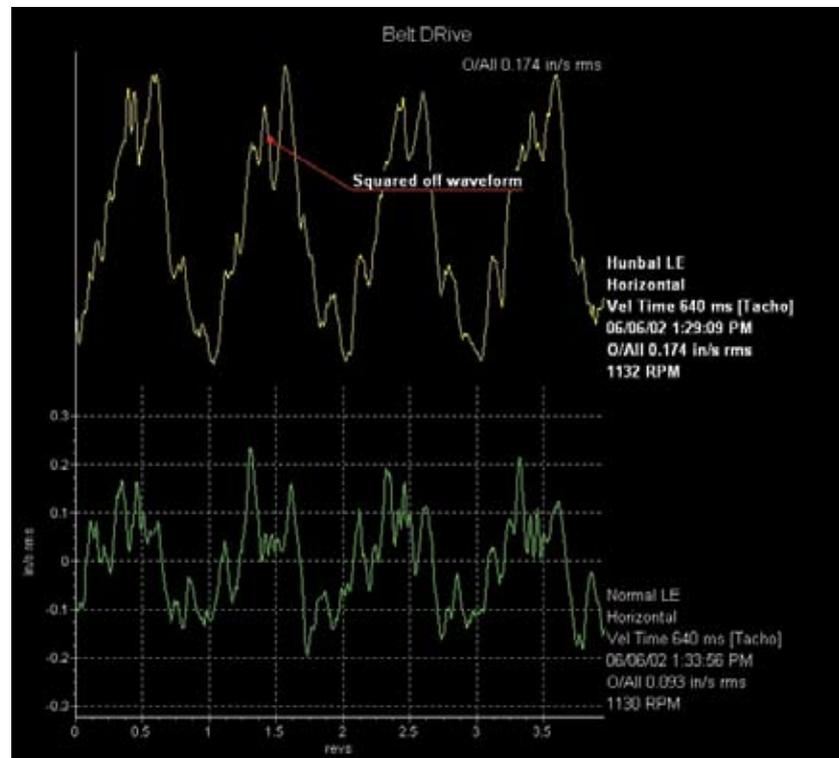


Figure 2 - Time Domain of Residual Unbalance

the neutral position. When FFT is applied to this plot, it interprets that oscillation as the presence of harmonics; giving the spectrum we see in Fig 1.

Conclusion

Unbalance can be caused by a number of forces, and is a very common problem in industrial applications. Many times unbalance shows itself in the classic single spike at rotor speed. However, it can present itself in a number of other variations, so think twice before eliminating unbalance as a root cause for vibration problems.

Robert Pyle is the President of Systemaitec, Inc., a maintenance consulting firm. Mr. Pyle holds a bachelor's degree in Mechanical Engineering and has 30 years of experience in maintenance and production. When not doing experiments or visiting clients, Mr. Pyle enjoys hunting and fishing as well as freelance writing. Systemaitec, Inc. (www.systemaitec.com) can be reached via the web or at (316) 204-5132.

References

1. Goldman, Steve, *Vibration Spectrum Analysis* (New York, Industrial Press, Inc., 1999), P84.
2. Wowk, Victor, *Machinery Vibration* (Boston, McGraw Hill, 1991), P214.

Innovative features make this small camera a big surprise.

VIS-IR by Thermoteknix

Thermoteknix Systems has released a portable infrared camera that is truly unique. We recently chatted with Thermoteknix' Alistair Brown as he demonstrated the camera, its innovative software capabilities and the possibilities this system opens up for thermographers. We'll let him tell you about it in his own words....

With infrared, pardon the pun, being such a hot market, what makes the VisIR stand out?

The VisIR camera package has many unique features including a DayBrite™ touch screen which provides crisp images even in bright sunlight or when wearing goggles and VisIR's real time live simultaneous visible and thermal image display enable rapid fault identification. The superior infrared detector core technology delivers excellent image clarity and Thermoteknix unique through lens calibration gives accurate temperature measurement for performance you really can count on.

VisIR is ergonomically designed for single-handed operation with electronic focus and synchronized IR and Visual image zoom for the perfect picture capture with a dust and water resistant cast aluminum clamshell case for long-term service and reliability – still the only camera to benefit from this quality of robust housing. Most cameras are made of plastic but we wanted to built VisIR to take the everyday knocks that a thermal imaging camera can be expected to take in an industrial plant.

VisIR automatically stores the thermal and corresponding visual images combined with up to 100 seconds of voice notes per image. Removable PCMCIA and SD memory cards offer user-selectable storage options from 32Mb to Gigabytes. From hundreds to thousands of images in single or sequence capture modes which can be simply and quickly transferred to your PC via a USB cable or card.

For what kind of applications is the VisIR most suited? VisIR has been designed as a powerful tool for use in the full range of Industrial Predictive Maintenance applications. VisIR's wide temperature range allows the camera to be used in building inspections, even in sub-zero conditions. The camera's high sensitivity can reveal fine details in the fabric of buildings, pinpoint heat loss and hidden construction defects. Medium voltage electrical inspection is another primary application for which VisIR camera was designed. The combination of thermal and visual images allows easy identification



of both the component and abnormal phase. The VisIR Ti 200 outstanding performance makes it ideal for use as a diagnostic aid for applications such as detecting fluid levels in vessels. Pumps, motors and rotating machines can be monitored for signs of poor lubrication, shaft misalignment or bearing failure. In petrochemical applications, VisIR's wide dynamic range ensures that both ambient and high temperature objects are equally visible, even in the same image. Inspection of HV transformers routinely identifies a wide range of faults from a safe working distance and the accompanying visual images ensure reliable phase identification. In short, VisIR provides the Maintenance Professional with the vital evidence needed to enable decisions and steps to be taken to prevent equipment or process failure.

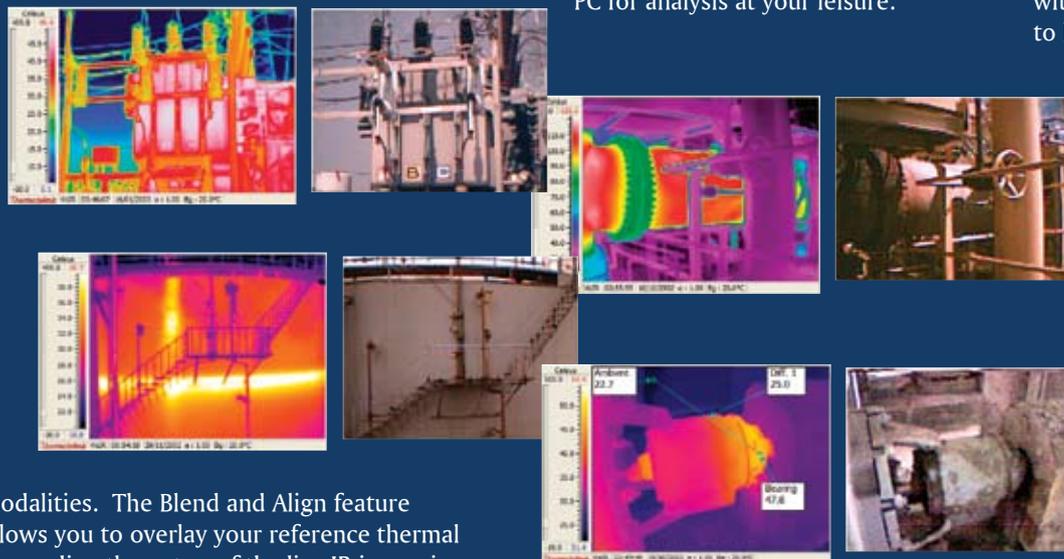
The camera seems really small (it weighs 1.5 kg, or 3.3 lbs). Does this inhibit performance in any way?

In the past, infrared cameras were bulky, heavy pieces of equipment with complex refrigeration systems to cool the detectors to several hundred degrees below freezing. Things are very different these days – VisIR incorporates a state-of-the-art highly sensitive Vanadium Oxide uncooled micro-bolometer so the VisIR camera is not only practical in terms of size and weight but also delivers the high performance expected from a thermal imager today.

I'm impressed with the ability of the camera to overlay what you are currently looking at through the viewfinder with historical images. Explain the benefit that feature brings to IR programs.

The unique Blend and Align facility you mention is actually a feature of Condition RED® - Thermoteknix' new, comprehensive PC based asset management system which streamlines your thermographic inspection processes. With Condition RED®, you can upload routes, baseline (reference) thermal and visual images, typical operating

values and camera settings directly into Thermoteknix' VisIR® Ti 200 thermal camera for on the spot inspection and comparison of plant asset conditions. Full trending, search and Microsoft WORD template based reporting are included as well as incorporation of data from Vibration and other PM



modalities. The Blend and Align feature allows you to overlay your reference thermal image directly on top of the live IR image in the camera. This ensures exact alignment at every inspection, even when performed by different thermographers; making trending and comparisons routine and repeatable (see picture). Condition RED® is available both as a stand alone PC product supporting other manufacturers' cameras (FLIR, Inframetrics, Avio, Agema), and also with full VisIR® camera survey integration.

If a Company already owns another IR camera do they need any other software in addition to Condition RED to analyze and report on their images?

Condition RED includes full image importing, viewing, analyzing, trending and reporting software in the single Condition RED package. This means that customers do not need any other IR software packages. By upgrading from their old software to Condition RED, or buying Condition RED at the time of their new camera purchase they can enjoy full functionality with new features combined with asset management at a considerable cost saving.

What are some of the highlights of the VisIR's on-board software?

The VisIR Ti200 isn't just an infrared image collector. The camera has many powerful in-built analysis tools including live hot and cold spot tracking for instant temperature measurement and difference read-out. There are

re-sizeable area tools which give Maximum, Minimum and Average temperatures on live, frozen and recalled images. It's simple to accurately position the tools using either the touch screen or the integral joystick. Plus, included with every camera is VisIR PC software which puts all the camera tools on your PC for analysis at your leisure.

Tell us a little about the voice-recording feature

This feature comes as standard with every VisIR camera. It allows you to record voice notes when taking images. You might want to make a comment about where a particular piece of equipment is located in a facility or record thoughts on the condition of an asset during a survey for later reference. Up to 100 seconds of voice notes can be recorded per image. These can be played back at any time, either on the camera or from your PC Thermoteknix software – and even when producing reports within Microsoft Word. Each time an image is saved, both a thermal AND visual image are always saved into one file with the voice notes. The image files really can contain a lot of information which do not get separated. Of course, this feature is very useful if the files are being viewed or transferred to someone other than the original thermographer.

Increased portability of IR cameras is a relatively new phenomenon. What opportunities for using infrared thermography do we have today that didn't exist just five years ago?

Portability can be defined by a number of parameters rather than simply size and weight. The VisIR camera has a cast Aluminium case and a protective window in front of the optics. As a result VisIR cameras are

used in many applications where the environmental conditions are pretty aggressive, such as, Pulp and paper, steel plants and Cement plants. In large primary manufacturing facilities such as these, the camera has to withstand airborne debris, excessive heat and aggressive handling. VisIR works easily with single-handed operation, allowing users to have a spare hand to hold on to a ladder or guard rail when working in hazardous locations.

Do you have a success story from the VisIR?

We have many happy VisIR customers but I'd like to tell you about the way in which VisIR helped hundreds of Florida homeowners following Hurricane Charlie and Frances in 2004. Infrared thermography has long been recognized as the most reliable and cost-effective method of determining moisture levels in buildings. Alternative methods are much more time-consuming and can generally test just small areas of a building at a time.

The VisIR® Ti 200 was used extensively to pinpoint the site of entry and damage to insulation and drywall by the change in temperature which occurred in floors, walls and roofs when water penetrates the surfaces. Identification of the entry points for water damage and early remedial work to repair the damaged structures are vital factors in preventing further deterioration and widespread growth of mould which flourishes in the hot humid Florida and Southern US climate if left untreated. With costs running into tens of thousands of dollars to remove and replace floor coverings, flooring, boarding and trusses once mould has taken a hold, early identification and rectification helped save huge sums for home and business owners alike. Insurance companies regularly stress the importance of taking the initiative to prevent mould formation after water damage and VisIR was instrumental in settling claims in many cases.

Where can people get more info about VisIR? Simply go to our website www.visir.net where you can request a FREE interactive VisIR demo CD or contact our sales office to arrange a free demo.

***Dick Ludwig – Sales Manager (USA)
Tel: 1 425 746 6080
Fax: 1 425 746 4536***



PEAK Industrial Solutions, LLC, announces a new eBook "How to successfully implement a CMMS". This eBook provides an overview of a Computerized Maintenance Management System (CMMS), and teaches you a step by step procedure to effectively implement a CMMS. It helps you identify your problems, determine benefits from a CMMS for your organization and define features for your CMMS. It guides you through justification process and teaches you how to evaluate and select a CMMS for your application.

Kris Bagadia **krisb@peakis.com**
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Larson Davis, a PCB Group company, has announced the enhancement of the Soundtrack LxT™ to include a comprehensive time history data logging option. The new sound level meter offers an innovative approach to sound measurement for compliance and worker noise exposure monitoring. Available in Type 1 or Type 2 versions, the SoundTrack™ provides an easy way to manage route or task-based workplace noise surveys. With operator route prompts and digital voice annotation, surveys are done quickly and easily by operators at all skill levels.

Molly Bakewell **mktg@pcb.com**
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Sentinel® Current Data Loggers are a new line of loggers that record True RMS measurements of current parameters. The current loggers include integral flexible current probes for three-phase measurements up to 3000A.

The loggers are small, portable and battery-operated (Alkaline and rechargeable NiMH models available). The loggers are able to store up to 480,000 points (1MB) and 64 samples per cycle.



Jenny Pellerin
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Des-Case's new FlowGuard™ hand carts offer end users greater flexibility over traditional hand carts, which provide little customization. Des-Case's unique approach offers end users a chance to create their carts entirely on Des-Case's website at a very affordable price. The design of the hand cart incorporates the cleaning capability of dual filter media and the sealing capability of the quick disconnects. Pairing it with FlowGuard™ quick connect adaptors makes oil handling even easier and cleaner.

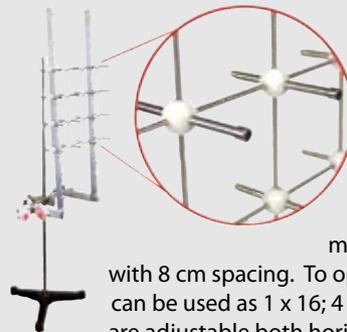


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Dataprobe has released a direct current (DC) version of its iBoot remote power solution. The iBoot DC is a single circuit power switch that allows remote equipment to be rebooted or power-controlled over an IP network using a simple Web browser interface. Users can connect any DC electrical powered device to the iBoot for simple and instantaneous power-on, power-off or reboot. This allows users to protect and maintain the uptime of devices in areas that cannot easily be accessed or serviced.

David Weiss
201.967.9300
dweiss@dataprobe.com



PCB Piezotronics, Inc. announces the addition of the Model 379A01 Microphone Array Stand to its line of acoustic measurement products. The Model 379A01 array stand includes the grid and all necessary configuration hardware for proper mounting of a 16-microphone array with 8 cm spacing. To optimize design flexibility, the 379A01 can be used as 1 x 16; 4 x 4; or 2 x 8 grid configurations; arrays are adjustable both horizontally and vertically; rotated; or can be tilted forward and backward.

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The Vibration Division of PCB Piezotronics, Inc. introduces Model 377A60 externally polarized, 1/2" Random Incidence (Diffuse Field) type microphone. The distinguishing feature of this model is its enhanced sensitivity of 50 mV/Pa. It has wide dynamic range (15 to 146 dB (A) re 20mPa) and a frequency range from 3.15 Hz to 10,000 Hz (+/- 2 dB). This traditional type condenser microphone has a +150 °C (+302 °F) operating temperature range, and –when combined with the PCB Model 426A30 preamplifier –can operate from a 200 V power supply for externally polarized microphones.

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AE Light introduces the Power Light 14™ a powerful, lightweight flashlight, they like to describe as a personal searchlight. It produces 800+ lumens of true white light in a compact beam. Protective rubber lens & end caps, strap rings and a strap are included. The end cap houses the charger receptacle for convenient access when charging. It comes with a 100/240VAC charger with automatic over charge protection and for maximum versatility; a 12/24VDC charger is available.

Marc Allsman
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Patented filtering optics give Mikron Infrared's new MikroScan 7400 thermal camera the unique ability to "see" through furnace flames for boiler-tube monitoring, or to be used for standard predictive maintenance monitoring of electrical cabinets, motors, bearings, etc. The

camera offers three selectable temperature ranges, including a high-temperature (400°C - 1600°C) range needed for infrared imaging inside furnaces where combustion temperatures can exceed 1100°C. It also captures simultaneous visual images with on-board voice annotation.

Mikron is now producing the industry's only uncooled, microbolometer, long-wave infrared (8-14 μm) cameras with multi-band imaging capability in the midwave range. The 8-14 μm capability is ideal for typical PdM applications because it is unaffected by sunlight or smoke in a plant, but is normally ineffective with midwave radiation.

The MikroScan 7400 is built around a high-resolution (320x240 pixels) microbolometer that offers four times the resolution of standard 160x120 cameras. Additional lenses include wide angle, telephoto, close focus, and the patent-pending SpyGlass™ lens that allows imaging of electrical cabinets through the half-inch-diameter, UL-approved Viewport.

Jon Chynoweth
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www.mikroninfrared.com

PCB Piezotronics, Inc. released a new 8-channel calibration coupler to its acoustic test products line. Model 079A31 is designed for simultaneous calibration of up to 8 1/4" microphones, reducing set-up time for large channel microphone calibrations. The unit is designed to be used with a PCB CAL250 Handheld Calibrator (94 dB at 250 Hz), and comes standard with 18" tubes, with modification options for variant length requirements.



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American Sensor Technologies introduces a new media isolated, high-quality digital pressure gauge designed for use with any gas, liquid or solid media that is compatible with 17-4 PH stainless steel. Incorporating a solid one-piece, 17-4PH high-strength stainless steel sensing element that is free of welds, internal O-rings and fluid-filled cavities, the AccuGauge Media Isolated Digital Pressure Gauge is built for applications that require high proof and burst pressures.



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PCB Piezotronics, Inc. introduces a prepolarized, 1/4" Free Field response-type microphone which operates from ICP® sensor power. The distinguishing feature of Model 377B01 is its enhanced frequency rating of 90 kHz (+/- 2 dB.) It has a sensitivity rating of 3 mV/Pa and a wide dynamic range (30 to 166 dB(A) re 20 μPa). This microphone has a 120 °C operating temperature range.



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Powered by a 2 to 20 mA signal conditioner and standard coaxial cables, this design allows for significant savings in power supply and cabling cost, greater ease-of-use and operate from the same power required for ICP® accelerometers.

New Series JM240 ICP® Ground Isolated Strain Sensors measure quality on resistance welding machines for delivery of zero defect product components. The strain sensors use piezoelectric sensing elements to indirectly measure dynamic and quasi-static stress forces on resistance welding machinery structures. ICP® Strain Sensors feature sensitivity stability, repeatability, high resolution, and extremely long life. Mounted on a C-frame or actuator with a single screw keeps the sensor out of the current flow and high electrical noise environments do not affect the ground-isolated design.



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SteelHead Design, Inc. announces the MTech™ System, their innovative new storage and workspace solution. The system can be customized to maximize workspace storage and efficiency. Available in many different combinations, the MTech System can be re-configured quickly and easily as needs change, so the system never becomes obsolete. Constructed with heavy 16-Gauge stainless steel or powder-coated steel, and fully welded for strength and easy setup.



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