# uptime

aug 2006

the magazine for PdM & CBM professionals

## Sensing
### Moving From Hard-Wired To Wireless

**Infrared: Separating Reflectivity from Emission**

**Motors: Ins & Outs of Bar-To-Bar Testing**

**Vibration & Bearing Analysis The Perfect Marriage**

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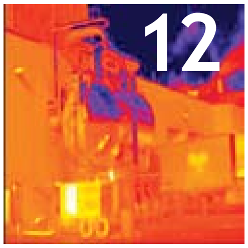
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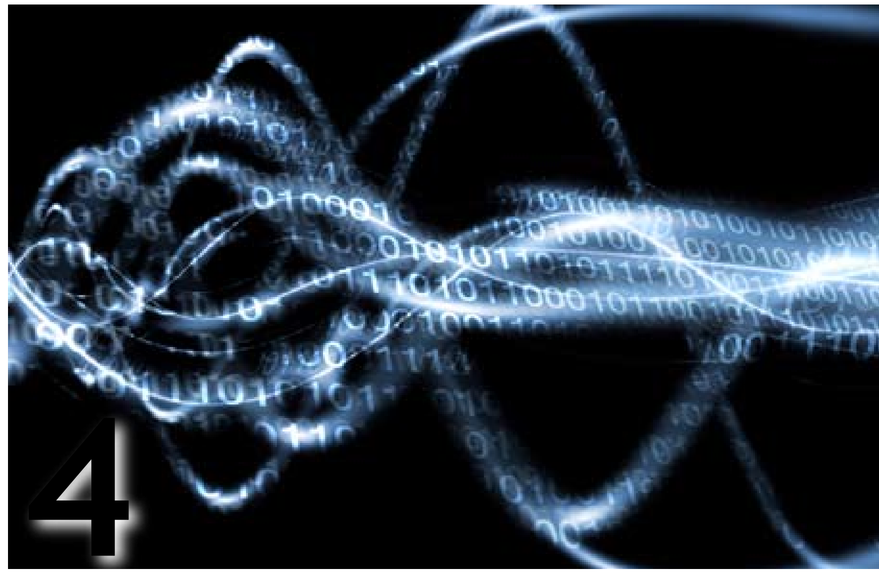
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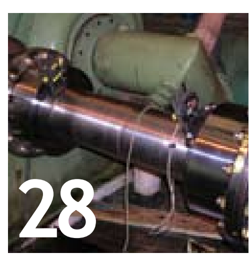
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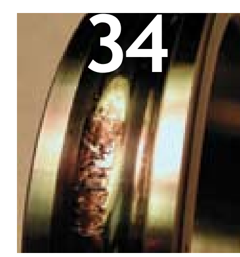
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# Things Are Heating Up

We are officially in the midst of the dog days of summer. And that means it's HOT. I was rudely reminded of this as I was leaving my comfortable, temperature-controlled house the other day. I am sure many of you are familiar with the scenario. I opened the door and was met with a wave of heat that nearly took my breath away.

Now, oddly enough, since joining the wonderful world of PdM, one thing that comes to mind when I think of heat is lubrication breakdown. And when your lubrication breaks down, your machinery suffers, sometimes catastrophically.

Ensuring proper lubrication of your machinery should head the list of proactive steps you can take to increase its reliability, extend its useful life and reduce your maintenance costs. There are many steps you can take, ranging from quite simple to very complex, to make sure your lubrication practices are leading you in the right direction.

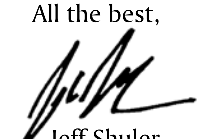
Contamination of lubricants has been, and still remains, one of the top reasons for component and machinery failures. However, with all of the tools and technologies available today, you can virtually eliminate dirty lubricants from bringing down your machinery.

If you'd like to learn more about the techniques and technologies that can put you on the path to lubrication best practices, LubricationWorld is the conference for you. It is being held in Chattanooga, Tennessee from September 12th-15th, and will include workshops, case studies and short courses focused on helping you increase the effectiveness of your lubrication efforts. Visit www.lubricationworld.com for more information.

Chattanooga will be the place to be in September because PdM-2006 will be held simultaneously at the same location. PdM-2006 is the only conference that showcases techniques and case studies from all of the major predictive technologies. Whether you are just beginning in predictive maintenance or are a seasoned professional, PdM-2006 is the hottest event of the year for condition based monitoring professionals. Visit www.maintenanceconference.com/pdm for more details.

Enjoy the rest of your summer. As always, thank you for reading. Feel free to contact me with any questions, comments or ideas that you think will make Uptime more useful for you.

All the best,



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# WIRELESS OPTIONS FOR CONDITION BASED MAINTENANCE

## Get Your Sensor Data Flowing Without Wires

by Jeffrey M. Rybak

...limitations associated with wired links surface quickly on sprawling factory floors and in large industrial settings...

Condition-Based Maintenance, or CBM, requires accurate machinery health monitoring techniques in order to allow machinery to operate to its maximum useful life without being subjected to premature component replacement or unplanned downtime. Machinery health monitoring utilizes sensors to monitor for one or more of many "symptoms" associated with the degradation of rotating machinery. Some of these are temperature, vibration, oil condition, acoustic emission, pressure and electrical current. These parameters are typically gathered and analyzed by specialized "predictive maintenance" systems implemented by the end-user within the factory environment. The data is often gathered with portable data collection equipment by a technician who must physically walk from machine to machine. Vibration signals are obtained using a hand-held data collector and then compared to a vibration signature or baseline associated with that specific data collection point. Symptoms of impending bearing or gear failure due to pitting, fretting, spalling, hairline cracks, corrosion and improper load often show up as extremely low level signals across a broad range of frequencies. These indications can then be used to order replacement components in advance without holding excess inventory and to schedule corrective maintenance during off-peak production periods.

A permanent and continuous monitoring system offers several advantages over a periodic route-based collection system. The first is that, by mounting sensors directly onto the machinery, consistent and accurate results are provided for valid trending, analysis and decision support. Most importantly, alarm levels can be set so operators can be made aware of potential problems at early stages of development before a condition becomes critical. While data is more readily available in a continuous monitoring / remote data access system, which better assures that the data will actually be processed and utilized, traditional cabling is very expensive, making this solution cost prohibitive to most companies interested in monitoring a large number of points. Cabling tethers equipment to fixed locations, thus reducing flexibility in equipment placement and reorganization. Cabling can also be very expensive to install and maintain in terms of both material and labor costs. New runs, moves, or upgrades easily disrupt operations while cable is accommodated, and re-positioning or upgrading equipment can necessitate completely new runs. Moreover, as the distance between equipment and control or monitoring devices increases, cable run length maximums are quickly exceeded. Cable installation accounts for roughly 2/3 of the total cost of obtaining a channel of data in an industrial environment. At a modest $40/ft., a typical 2-channel vibration monitoring system would cost over $13,000 just to run 100 meters of cable for remote alarm notification, analysis and trending.

Distance and cost limitations associated with wired links surface quickly on sprawling factory floors and in large industrial settings, and running cable to new or relocated equipment can interrupt production. These hardwiring drawbacks have led many to seek a longer range and more flexible alternative in wireless networks. Wireless Ethernet, for example, the general descriptor applied to wireless links within an Ethernet network, is any over-the-air connection between Ethernet network nodes or devices. As is often the case with new technology applications, there is a wide range of wireless network implementations on the market, and there is no single wireless standard. Wireless network solutions typically fall into one of two classes of over-the-

...These hardwiring drawbacks have led many to seek a longer range and more flexible alternative in wireless networks...

air protocols: those based on open system standards (like IEEE 802.11 for WLANs and Bluetooth® for WPANs) and those based on proprietary protocols designed specifically for a given application. The big difference between the two is cost. The ubiquitous nature of open system solutions lends themselves to economies of scale, offering the consumer a more cost effective solution.

Open system wireless data acquisition has greatly enabled the continuous monitoring of critical assets. Wireless systems are now available that reduce that 2-channel installation mentioned earlier from $13,000+ to under $2,000 for a savings of over 80%. Wireless network deployment issues can be best understood if placed into the following three service classifications:

- Wireless Personal Area Networking (WPAN)
- Wireless Local Area Networking (WLAN)
- Wireless Wide Area Networking (WWAN)

All of these types of wireless networks have advantages and disadvantages depending upon the type of industry needing the technology, the physical environment and the types of applications and coverage needed.

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WWAN

## Wireless Wide Area Networks

Wireless wide area networks (WWANs) use various devices—telephone lines, satellite dishes, and radio waves—to service an area broader than that which can be covered by WLANs and WPANs, although typically with lower bandwidth (the amount of data that can be transmitted in a fixed period of time, typically measured in "bps"). WWANs are generally publicly shared data networks designed to provide coverage in metropolitan areas and along traffic corridors. WWANs are owned by a service provider or carrier, wherein data rates are low and charges are based upon usage. While a WWAN system may be practical for mobile phones, pagers and even open field steady-state sensor data acquisition, they are generally poor choices for industrial applications due to low bandwidth, spotty coverage and the expense of service contracts.

While satellite based systems can be viewed as an augmentation to WWAN services, the value of service is often limited to specific applications, most notably those applications that benefit from one-direction broadcasting of content or communication to locations on the globe not serviced by other means. Bi-directional communication using satellites to support high-speed and/or pervasive connectivity is not a very practical approach, so I've listed the major cellular systems here, as being most representative of WWAN technology.

- GSM (Global System for Mobile Commu nications) variations are used in Europe, Asia, and North America and operate in 900, 1800, and 1900 MHz bands with a typical maximum data rate of 14.4 Kbps.
- GPRS (General Packet Radio Service) is a digital mobile phone technology enhancement to GSM, providing data rates to 150+ Kbps. GSM and GPRS are considered rivals to CDMA technologies.
- CDPD (Cellular Digital Packet Data) is a data transmission technology developed for use on the 800 to 900 MHz cellular phone frequencies, to transmit data in packets at rates up to 19.2 Kbps. Low cost but slow.
- CDMA (Code Division Multiple Access) is a transmission technol ogy that accommodates multiple signals in the same channel ("multiplexing"). It uses direct sequence spread spectrum technology to vary the transmission frequency according to a defined code pattern.
- 1xRTT (1x Radio Transmission Technol ogy) also known as CDMA 2000 increases data transmission rates over existing CDMA networks. Provides 144 Kbps of data and voice.

WLAN

## Wireless Local Area Networks

The term wireless networking refers to technology that enables two or more computers to communicate using standard network protocols, but without network cabling. Strictly speaking, any technology that does this could be called wireless networking. The current buzzword however generally refers to wireless LANs. This technology, fueled by the emergence of cross-vendor industry standards such as IEEE 802.11, has produced a number of affordable wireless solutions that are growing in popularity with business and schools as well as sophisticated applications where network wiring is impossible, such as in warehousing or point-of-sale handheld equipment. WLAN systems are designed to supplement and in some cases replace traditional wired-based Local Area Networks. The predominant standards-based WLAN technology being deployed in the United States is based on the IEEE 802.11b standard.

In a basic 802.3 Ethernet LAN, Cat5 cable connects LAN stations to a hub. In a wireless LAN, Cat5 cable is replaced by a radio channel, connecting stations to wireless Access Points (APs). Each wireless station -- laptop, desktop, or server -- has a radio Network Interface Card (NIC). APs are essentially hubs, outfitted with a radio transceiver, Ethernet uplink, and 802.1d bridging software. Wireless stations transmit to an AP over a shared channel, carved out of the unlicensed 2.4 GHz band. There are 2 types of wireless networks. An ad-hoc, or peer-to-peer wireless network consists of a number of computers each equipped with a wireless networking interface card. Each computer can communicate directly with all of the other wireless enabled computers. They can share files and printers this way, but may not be able to access wired LAN resources, unless one of the computers acts as a bridge to the wired LAN using special software. (This is called "bridging"). A wireless network can also use an access point, or base station. In this type of network the access point acts like a hub, providing connectivity for the wireless computers. It can connect (or "bridge") the wireless LAN to a wired LAN, allowing wireless computer access to LAN resources, such as file servers or existing Internet Connectivity.
There are two types of access points:

- Dedicated hardware access points (HAP) offer comprehensive support of most wireless features.
- Software Access Points, which run on a computer equipped with a wireless network interface card as used in an ad-hoc or peer-to-peer wireless network.

Approved in 1997, the original IEEE 802.11 standard uses the 2.4 GHz band to provide shared bandwidth at a maximum rate of 1 to 2 Mbps. In 1999, the IEEE approved the 802.11b High Rate (Wi-Fi) amendment, increasing the rate to 11 Mbps.
802.11 is an IEEE standard for wireless local area networks (WLANs) that covers the wireless LAN media access control (MAC) and physical layer specifica-

Each type of wireless technology is discussed in detail in the section below.

### Capturing the Data To Transmit

In any system, the interface between the sensor and the transceiver device (Fig 1), which transmits the wireless signal, is an extremely important and challenging part of the system, as sensors by nature can vary in many ways.

First of all, a sensor can be defined as a device that provides an electrical signal relative to some physical stimulus. The parts of a sensor may include, but are not limited to: a transducer element, power conditioning, signal conditioning, and output electronics.

The type of measurement being made determines the type of sensor that is required, and there is often more than one sensing method that can be employed to make the same measurement. A vibration measurement for instance requires a device referred to as an accelerometer (Fig 2). While there are many accelerometers on the market, the appropriate selection of an accelerometer requires an

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tion. 802.11b and 802.11a are extensions of this standard, also referred to as WIFI (Wireless Fidelity), which is an interoperability certification. 802.11b is a well-accepted standard for WLANs optimized for the unlicensed 2.4 GHz band, with speeds up to 11 Mbps when using DSSS. 802.11a is a standard that improves upon 802.11b with support for speeds up to 54 Mbps in the less-crowded 5 GHz band by using OFDM (Orthogonal Frequency Division Multiplexing, which splits a high speed signal into a number of low-speed signals transmitted in parallel, thus more efficiently using bandwidth, but decreasing wireless range. 802.11g is a WLAN standard comparable to 802.11a (uses OFDM for speeds up to 54 Mbps) but operates in the 2.4 GHz spectrum.

WPAN

## Wireless Personal Area Networks

WPAN systems have evolved from "cord" replacement technologies. Some examples are: cordless communication between your keyboard and computer, cordless communication between your Personal Digital Assistant (PDA) and your computer and cordless communication within your home between your cell phone and your home phone. Because of their initial function focus, WPAN wireless implementations to date have been low-powered and offer limited coverage range. The most hyped of all WPAN wireless technologies today is called Bluetooth®, which got its unusual name in honor of Harald Bluetooth, king of Denmark in the mid-tenth century, Bluetooth is a product of the telecommunications and computer industry "Bluetooth SIG" and is rapidly gaining wide acceptance throughout the industry. Bluetooth is a telecommunications industry specification that describes how mobile phones, computers, and personal digital assistants (PDAs) can be easily interconnected using a short-range wireless connection. Using this technology, users of cellular phones, pagers, and personal digital assistants can buy a three-in-one phone that can double as a portable phone at home or in the office, get quickly synchronized with information in a desktop or notebook computer, initiate the sending or receiving of a fax, initiate a print-out, and, in general, have all mobile and fixed computer devices be totally coordinated. Bluetooth requires that a low-cost transceiver chip be included in each device. The transceiver transmits and receives in a previously unused frequency band of 2.45 GHz that is available globally (with some variation of bandwidth in different countries). In addition to data, up to three voice channels are available, and each device has a unique 48-bit address from the IEEE 802.15 standard. Connections can be point-to-point or multipoint and can lock out other devices selectively, preventing needless interference or unauthorized access to information. The maximum range is typically 10 meters for battery-powered devices, as transmission distance is directly linked to power consumption, and data can be exchanged at a rate of up to 3 megabits per second. A frequency-hopping scheme allows devices to communicate even in areas with a great deal of electromagnetic interference, and built-in encryption and verification are provided for security. There are three classes of Bluetooth radio: Class 1 - 100 meters, Class 2 - 15 meters, Class 3 - 10 meters. The lowest power radio within the network defines the maximum transmission distance allowed.

Zigbee is also becoming a popular standard for wireless personal area networking designed to be simpler and cheaper than Bluetooth, and is aimed at applications with low data rates. The ZigBee protocol utilizes the IEEE 802.15.4 physical and MAC layers, with network, security and application software layers as specified by the ZigBee Alliance, a consortium of technology companies. While Bluetooth and Zigbee have much in common, some technical differences between the two are shown below.
Due to the slower data rate, Zigbee is less suited for machinery condition monitoring applications that require transmission of broadband vibration data. Similar to Wi-Fi, Zigbee also incorporates a direct sequencing form of spread spectrum technology (DSSS) as opposed to the frequency hopping method used by Bluetooth (FHSS) to battle interference and noise. The proper choice of direct sequence or frequency hopping as a spread spectrum technique depends on the actual environment in which the system will be deployed. If there are narrowband interferers of moderate level, then a DSSS system that will completely reject them may be designable. Should there be any large interfering signals, then a DSSS link may completely fail while FHSS is likely to continue operating, even though the interference is not completely rejected.

| | Bluetooth | Zigbee |
|---|---|---|
| Modulation Technique | FHSS (Frequency Hopping Spread Spectrum) | DSSS (Direct Sequence Spread Spectrum) |
| Max Network Speed | 3 Megabits/sec | 250k bits/sec |
| Network Range | Up to 100 Meters (depending on radio class) | Up to 70 meters |

Technology Differences of Bluetooth and Zigbee understanding of the mechanical phenomena to be measured as well as the limitations of the various technologies that are used.

For instance, A low amplitude, high frequency vibration measurement associated with early signs of bearing degradation and gear tooth chipping will require a low mass, piezoelectric accelerometer. This is due to the fact that high frequency response (governed by the natural frequency of the sensor and its interface with the test article) is reduced as the mass increases. Resolution (governed by the output of the transducer element relative to the noise floor of the conditioning circuitry) defines the lowest measurable signal. Piezoelectric materials such as PZT (lead zirconate titanate) offer very high charge per unit force. These transduction elements coupled with low noise impedance conversion circuitry offer the most widely accepted industry standard in machinery health monitoring accelerometers, while versions utilizing competing technologies like piezoresistive and silicon variable capacitive simply can not reliably measure low amplitude, high frequency signals. Vibration measurement resolution should be at least 80 mg's at 100 RPM and 115 dB dynamic range. The measurement should also accommodate a frequency bandwidth of 1.5 Hz to 7 KHz.


**Fig 2 - Wireless Data Acquisition and Processing Module**

These other accelerometer technologies mentioned will, however, provide DC or static response, while piezo-electric technology can only measure down to a fraction of a cycle. So, their value starts to become practical (but not exclusive) in low frequency applications including vehicle dynamics, seismic monitoring, etc.

Fig 3 - Industrial Accelerometers

Most sensors require input power, which comes from some external source, such as a battery or a power supply. These excitation requirements also vary greatly from sensor to sensor. An ICP® sensor for instance requires 18-28Vdc with a constant current of 2-20mA to provide a +/- 5V output about an 8-12Vdc bias level. This is an industry standard for dynamic test and measurement and condition-based maintenance (CBM) sensors used to measure force, pressure and vibration. Other sensors used in process monitoring to measure static or low frequency parameters like temperature, flow, steady state force and pressure, etc. may require standard 5, 12, 18 or 24Vdc power supplies for typical 4-20mA, 0-5Vdc, 0-10Vdc outputs, but virtually any AC or DC power scheme can be required. Interfacing a data acquisition (DAQ) device to this vast array of possible sensor configurations to provide the necessary power and condition the sensor's output signal to be recognizable by the DAQ device is critical in preserving the integrity of the measurement.

## Choosing a System that Works

So, which wireless system is best suited for continuous monitoring of sensor data to perform condition-based maintenance in an industrial environment? Is it bandwidth rich Wi-Fi, utilizing direct sequence spread spectrum, which has some limitations in noisy, interference-ridden environments? Or is bandwidth sufficient Bluetooth, utilizing frequency hopping spread spectrum technology, which is very robust and noise immune a better choice?

In reality, they both have earned their places within a corporate and industrial setting. Many existing infrastructures are suitable for wireless Ethernet interface to sensor data, wherein the environment may also not be too hostile for Wi-Fi's direct sequencing spread spectrum technology limitations. Where the environment is more appropriate for a noise immune frequency hopping spread spectrum system, Bluetooth could be used in conjunction with Wi-Fi. While Bluetooth and Wireless LAN were earlier labeled as competing technologies, manufacturers have discovered over time that this is not necessarily the case. Some have even gone so far as to develop products that feature both technologies, such as wireless access points. There is now widespread market acceptance of both Bluetooth and WLAN, which has lead to a greater incidence of coexistence between the two, most commonly in computer network environments. Coexistence in the unlicensed 2.4 GHz band however, comes with a price. Unlicensed means that competing, or complementary, technologies are free to operate in this frequency band, which has in turn given rise to interference that impinges on the quality of communication. To most users, deterioration of quality may be more apparent in voice centric applications than in data centric applications. For example, you is more likely to notice of poor sound quality while using a Bluetooth headset than the retransmission

of data packets while sharing information between your notebook PC and a network access point. The Bluetooth industry, through the Bluetooth SIG, has responded by taking measures to reduce interference in environments where multiple wireless technologies coexist. Version 1.2 of the Bluetooth Specification, adopted in 2003, includes Adaptive Frequency Hopping, a technique proven to be an effective remedy to the problem of interference in WLAN and similar environments. Also referred to as AFH, this technique can be implemented through various methods, each with its own inherent set of advantages and drawbacks. Ericsson, a leader in the field of Bluetooth wireless technology, uses a method well suited for its broad based Bluetooth design solution sold as intellectual property. Ericsson's implementation of AFH is further enhanced through the use of other standard and proprietary techniques, providing excellent audio quality for voice centric applications in the presence of multiple wireless technologies.

It's important to note that there are proprietary systems out there that battle noise and interference problems with proprietary radio solutions, and while these systems may solve an immediate application requirement, proprietary solutions will always be more costly than those adopting open system standards. Vendors can ensure considerable repeat business because their customers have committed to proprietary systems, which don't allow for interface to cost competitive open system standard third party hardware and application software.

As for commercially available wireless data acquisition systems, there are several that incorporate proprietary technology, yet very few that utilize open system standards. Oceana Sensor offers a wireless sensing system that is suitable for industrial applications, employing both open system Bluetooth and Wi-Fi technology (see page 11 for more information).

## The Future

Issues that continue to drive wireless technology for condition based monitoring forward are:

- Size -Self-contained, miniature wireless sensors
- Power - Power scavenging features for extracting power from the environment
- OEM Integration - Incorporation of wireless, remote monitoring systems into machinery at the point of manufacture
- Open System Architecture - Inter-operability amongst system components and data handling applications

As for the future of wireless networking standards:

- 802.11e is being developed to help wireless LANs handle interference--by moving away from it--and to provide better support for those big streaming multimedia files by using error-correction and better bandwidth management.

- The IEEE P802.15.3 High Rate (HR) Task Group (TG3) for Wireless Personal Area Networks (WPANs) is chartered to draft and publish a new standard for high-rate (20Mbit/s or greater) WPANs. Besides a high data rate, the new standard will provide for low power, low cost solutions addressing the needs of portable consumer digital imaging and multimedia applications.

- WiMAX: a marketing name bestowed on a new technology standard that adheres to a certain derivation of the IEEE 802.16 standard, provides wireless broadband Internet connections at speeds similar to Wi-Fi but over distances of up to 30 miles from a central tower.

Once again, open system architecture is at the core of universal acceptance and the economies of scale that provide cost effective wireless solutions for industrial applications.

*Jeffrey M. Rybak is co-founder of Oceana Sensor Technologies, Inc., specializing in the manufacture of Wireless e-Diagnostics® products, highlighting open system wireless platforms including Bluetooth and 802.11b. Prior to moving to Virginia Beach to start Oceana Sensor, Jeff managed sales at PCB Piezotronics, Inc. in Buffalo, NY, represented the Western New York region for Niagara Electric Sales Company and ran structural and environmental testing as Project Engineer and Calibration Lab Manager at MGA Research in Akron, NY. Jeff has over 20 years of experience in the area of sensors and instrumentation, a degree in electrical engineering from the State University of New York College at Buffalo, and he's currently the Vice President of Sales and Marketing at Oceana Sensor, in Virginia Beach, VA. Jeff and his wife Leah enjoy writing and performing music together and spending time with their children; Nicole, Catey, Zack, Kasey and Parker.*

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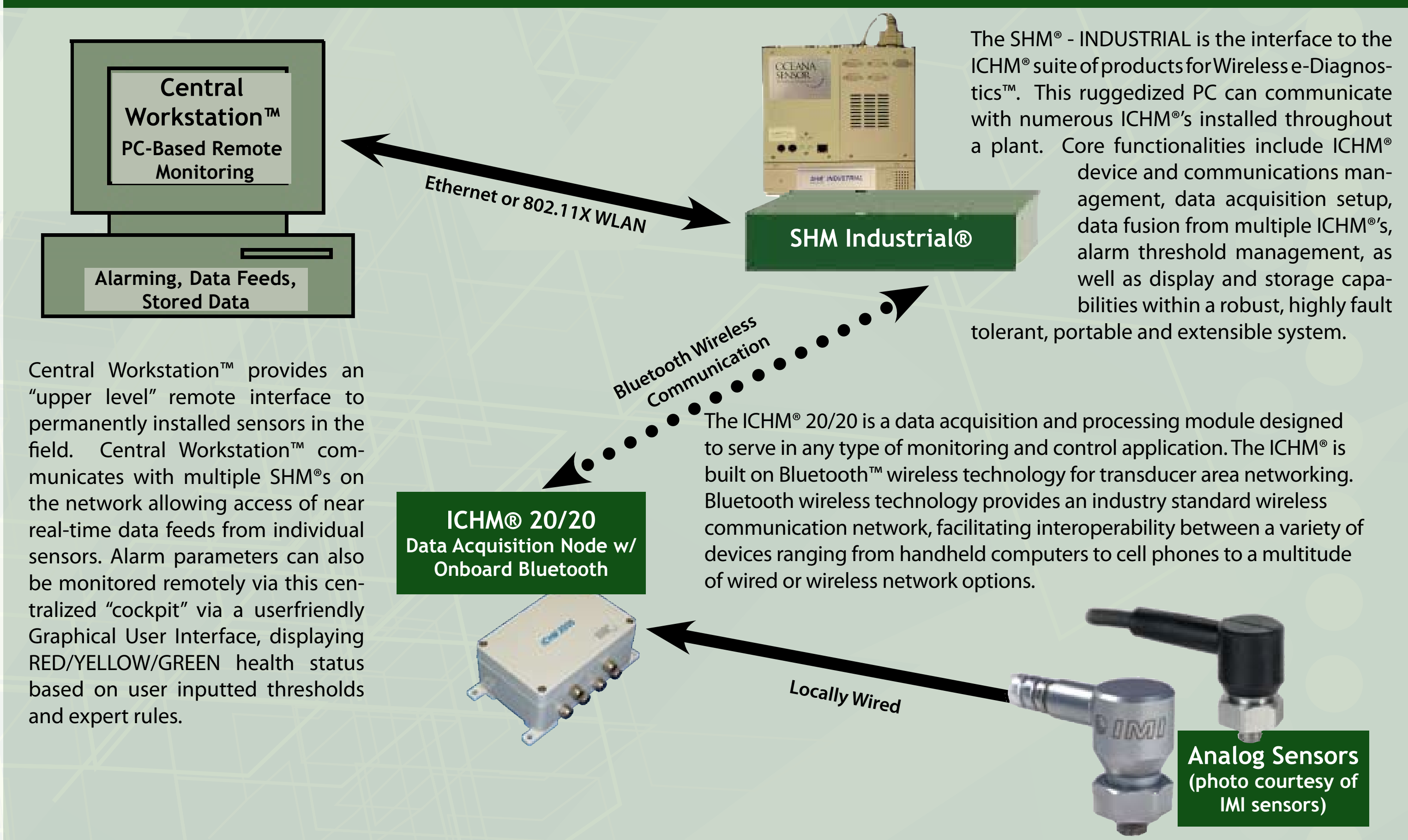
## Oceana Sensor Wireless Condition Monitoring System



# Give Yourself A Thermal Lobotomy

## Severing the Concepts of Reflection and Emission

*by Greg McIntosh*

When dealing with low emissivity surfaces thermographers are taught to try to 'eliminate the reflections' and, once they do, to proceed with performing the inspection. While removing the obvious source of reflection is the proper first step, many thermographers then believe that the emissivity problem is solved. We will discuss why we need to consider reflectance and emittance as separate issues and why both need to be considered and addressed independently.

### Definitions

Brain: An organ usually located in the skull responsible for thought, emotions and body activity. In competent thermographers the brain needs to be present, active and educated.

Brain (Right Side): The side of the brain primarily responsible for intuitive thought and recognition. The right side integrates many inputs at once, processes information diffusely and simultaneously. In thermographers this part of the brain identifies patterns associated with such things as reflections and the signatures of real thermal anomalies.

Brain (Left Side): The side of the brain primarily responsible for logical thought, analysis and time. The left side can only deal with inputs one at a time in a linear and sequential manner. In thermographers this part of the brain deals with the complexities of emissivity and background energy and is utilized when quantitatively evaluating the radiometric computation of temperature.

Lobotomy: The act of physically severing the nerves joining the two sides of the brain in the front cortex in psychotic patients to prevent them from suffering destructive repetitive thoughts.

Thermal Lobotomy: The 'virtual' act of severing the concepts of reflection from that of emission in order to prevent thermographers from suffering destructive repetitive inspection methodology.

Radiance: The total amount of radiant infrared energy that is leaving a surface (per unit area) due to both reflected and emitted components. (definition restricted to an opaque surface where transmission equals 0)

Thermographers are taught a number of principles in ASNT Level 1 and Level 2 courses that promote an integrated way of thinking about emissivity and reflectivity of surfaces. Kirchhoff's Law states that a = e (absorptivity equals emissivity). The law of conservation of energy for radiation striking a surface states that the r + a + t = 1. The all important principle of infrared radiance from an opaque surface (t=0) combines these equations into r + e =1 or r = 1 - e. The bottom line is that reflective surfaces have low emission. Conversely, efficient emitters are inefficient reflectors. As an extension of this then is that in many situations we assume, quite correctly, that a low emissivity surface will appear cooler than a high emissivity surface because the reflected background is often cooler than the low-emissivity "hotspot" we are observing. But it is easy to slip into complacency and assume that this relationship is always a given. Few of us actually take the time to think about the meaning behind this relationship. When dealing with lower emittance surfaces, many thermographers simply change or control their scan angle or shield the environment to 'eliminate the reflections'. Unfortunately, we can only either (a) eliminate the obvious reflection by changing our scan angle, or (b) reduce the amount of energy being reflected by reflecting a background with a lower temperature. The reality is, however, that we cannot change the reflectivity value of the surface without treating it with some sort of coating. (We are assuming that practicing thermographers know about avoiding extreme scan angles and utilize, where possible, the proper scanning technique of being approximately perpendicular to the surface.)

Snell Infrared conducts a Level I class experiment to dramatically illustrate this point. We use a cardboard disc with an aluminized reflective surface on one side and plain paper on the other. We place it on the floor with the aluminum side up and have the students measure the 'apparent temperature'. Students will adjust their camera angle to eliminate any obvious sources of reflection and then make their measurement. We then flip the disc over and have them measure the plain paper side. The readings will often be within a few degrees of one another. We then ask them to take the disc outside (on a clear day) and repeat the exercise. The aluminum

Figure 1 - Typically, aluminum-clad pipes and vessels will register as cold (dark).

side measures an extremely low temperature, often below the measurement limit of the camera (typically –40°C) and the paper side is very close to ambient air temperature.

When they are inside, the students are really measuring the temperature of the floor when observing the plain paper side of the disc. When observing the aluminum side of the disc the 'temperature' may, in fact, read the same as the plain paper side. Many students, however, fail to realize they are actually measuring the temperature of the ceiling reflected by the foil side. This only becomes obvious when the disc is taken outside and the 'ceiling' becomes the very cold sky. Equally obvious is the fact that this is an impossible measurement situation: the aluminum surface simply emits too little for a signal to be detectable.

## Cold Sky 'Reflections'

After this class exercise, it is common for the students to talk about trying to eliminate 'the reflection' of the cold sky. But this is a case where the left side of the brain must predominate and force the right side of the brain to accept that this 'reflection' should not be eliminated. In essence, any situation where the background temperature is very low is preferred because we are better able to evaluate the true signal (due to emission) that remains, without the radiance being dominated by reflection. In fact, there is no such thing as "cold sky reflection!" Rather a low emissivity surface appears cooler when "looking at" a cold sky because the energy contributed by reflection is such a small part of the total radiance. What the thermographer must do at this point is determine whether there is any signal left to evaluate by adjusting span and level downward. However, if the apparent blackbody temperature (based on total radiance) is below the lowest detectable limit of the camera, then there is no signal to evaluate. We must either find a way to make the surface emittance higher, or pack up and go home.

A practical example is that of performing outdoor inspections of insulated aluminum-clad pipelines or process vessels with a (daytime or nighttime) clear sky. We will typically observe the shiny aluminum showing up as very cold (see Figure 1). The right side of our brain will recognize this as a 'reflection' and we will often change our camera position to eliminate it so that the vessel no longer shows the 'cold' reflection. However, this is a case where we must let the logical side of our brain prevail: if the total radiance is showing 'cold,' then replacing the sky with a warmer background surface actually makes things worse. If we are to have any chance of detecting emitted thermal patterns on the vessel, we must reduce the span and level in order to detect a variation in the emitted signal—while the reflected energy is not dominating the emitted energy (see Figure 2).

One significant problem occurs when the sky is the background because it may have a highly variable 'apparent' temperature due to clouds, humidity, pollution or position in the sky. The horizon, for instance, has a higher apparent temperature due to the increased thickness of the atmosphere, and this increase will be seen in a reflection of the horizon as well. It is always a good idea to quickly check the apparent temperature of the entire sky (with emissivity set to 1.0) and observe what variations exist compared to a clear sky. If the entire sky appears very cold and close in value to the 'apparent' object temperature, then we probably do not have enough signal for inspection of that surface (e.g. average sky temperature reads –20°C and object temperature reads –20°C).

## Equivalent Surfaces

Another good example of when we must let the logical side of our brain dominate occurs when we are observing surfaces of equivalent radiance. The right side of our brain tells us that these surfaces are the same color and

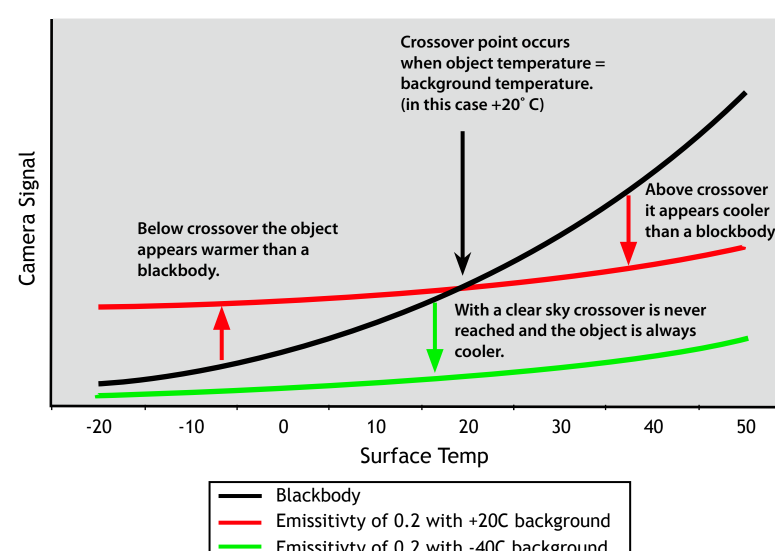
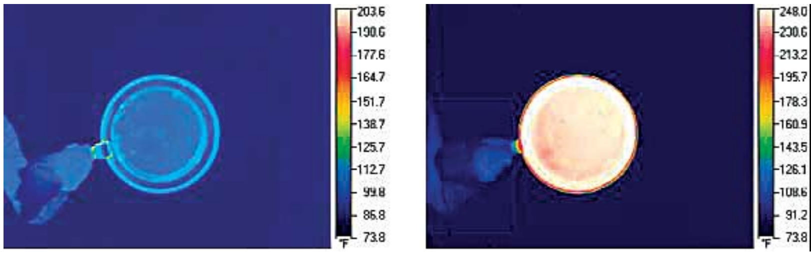



Figure 2 - Effects above and below crossover point




3A Figure 3 - Hand and aluminum frying pan. 3B

therefore 'must be' the same temperature.

Refer to Figure 3A, showing a hand and the bottom of an aluminum frying pan. The hand and the aluminum appear to be the same temperature because they are the same color. In reality, however, the frying pan is much higher in temperature as can be observed when we turn the frying pan over and observe the (high emissivity) Teflon side of the pan. (Figure 3b). If we were to take this one step further, it would be best to evaluate the aluminum side of frying pan outside with a clear sky as the background. It would appear cooler than the person's hand, but nearly all of the remaining signal would be associated with radiation emitted by the surface, which is exactly what we want when trying to detect real, or emitted, thermal patterns.

## Thermal Shadows

When inspecting very low-emissivity surfaces, we must not let the intuitive side of brain rule. We must think through whether there is, in fact, any emitted signal to be detected and then optimize the camera for span and level on that signal. We must look for thermal shadows, particularly our own, since that means we are blocking out radiation from a background higher than our body temperature. But when we observe a shadow (on a reflective surface), we should look at whether it is a 'cold' shadow or 'warm' shadow. When our body casts a 'cold shadow', as seen in Figure 4, this tells us that we have a reflected background temperature warmer than our body. When we see a warm shadow this is indicative that the reflected background is cooler than our body. In either case, the elimination of our 'shadow' does not automatically mean that it is OK to proceed with inspecting a surface that is highly reflective.

## Field Inspection Technique

In reality the very coldest 'reflection' (e.g. -40°C apparent temperature) is actually the absence of signal: our camera detects no apparent radiance. This should tell us something, either to quit or to change our technique as discussed below. When we try to avoid a 'cold reflection', then all we are usually doing is changing our angle so that a warmer object is now in the background and the new source of reflection. That's like saying that we should use a hot boiler rather than an ambient wall as the background. If there is ever a chance that we can detect an emitted thermal pattern on a low-emissivity surface, it will only happen when there is a very low background

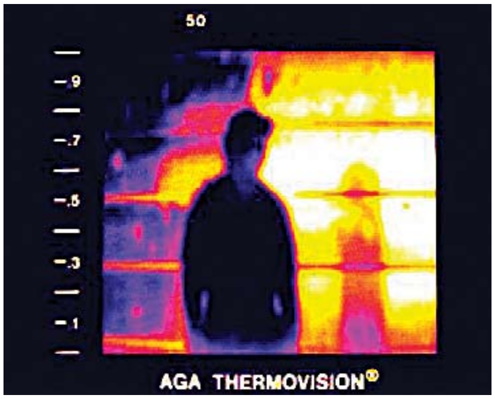



Figure 4 - Body as Cold Shadow.

temperature and we've adjusted our span very narrowly and level low enough to observe the cold spots. It is not, however, intuitive to do this.

There are a few instances when poor inspection techniques create a 'cold reflection' due to an angular variation of emittance (e.g.: looking upwards at a glass building). In such a case, instead of trying to eliminate the cold sky reflection, we should try to alter our inspection angle to improve emittance.

## Summary

It is almost impossible to analyze thermal images without using both the intuitive and logical parts of our brain. During the inspection we must use our intuition to analyze the thermal patterns in the image and react to them by changing such things as our scan angle and span and level. But we must also use the logical and deductive side of our brain—both during the inspection and subsequent analysis—to determine the collective impact of emissivity, reflectivity and background. Post-inspection analysis should include imagery of the potential background sources, illustrating both their size and blackbody apparent temperature.

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

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# No More Garbage In-Garbage Out

## Practical Tips To Boost Oil Analysis Effectiveness

*by Mike Johnson*

It is easy to become intrigued with the minutiae of modern instrumentation's technical capabilities during sourcing activities. Application of sophisticated measurement technology and its potential uses can have great appeal to a technical mind. However, if one fails to consider the nature of how the sophisticated instrumentation may actually be used, then the investment of time and capital may be more than just unproductive. Good technology applied recklessly produces misleading and confounding results. The computer programmers term 'GI-GO' (short for 'garbage in – garbage out') comes to mind. If the input is poor then the output will be as well.

Experience suggests that there is perhaps no area as prone to 'poor inputs' as measurements for machine lubrication. The argument can be applied to two major categories of machinery lubrication effectiveness measurement: 1.) Oil Analysis, 2.) Ultrasonic Energy Analysis.

Ultrasonic energy (UE) analysis has several brand specific aliases: SEE, Spike Energy and Shock Pulse, to name a few. The general idea is to measure asperity contact by measuring the high frequency 'pulse' or pressure wave that asperity contact produces. High frequency energy is tenuous. A variety of normal machine operating parameters and design characteristics can rapidly dampen the signal. Where the risk of attenuation is understood then the technician should make every effort to capture the UE signal at a point of maximum strength and with a high degree of consistency. Unfortunately, when the risk of signal loss is not understood, and proper 'data collection' steps are not defined, then the instrument operator may make many poor decisions (regarding relubrication volume and frequency) on behalf of management. Relatively few organizations rely on systematic UE measurements to provide guidance for their CBM activities.

However, the same type of data collection problems exist around the use of oil analysis instrumentation and services. This article will address a few of the common problems and provide guidance in how these problems may be easily resolved.

### Not As Easy As It Seems

As observed through the eyes of the data user, oil analysis seems surprisingly easy. Analysis can be purchased at a low cost (relative to other forms of technical machine data), it is available from many different suppliers, the terms and conditions seem largely the same, and all with the promise of high quality results. Add to this the fact that initiating an oil analysis routine doesn't require using precious capital money (no large investment up front) before the cost reducing benefits will begin to accrue, and you might see why programs are started on a whim. Unfortunately, the apparent ease of entry into this technology is a two-edged sword. Without the requirement to fully understand, and justify, the contribution that oil analysis can provide, it is altogether too easy for a well intentioned manager to jump into a program without a clear expectation of how the program should be conducted, or how the delivered data can best be used.

### Three Parts of Oil Analysis

The term 'oil analysis' is actually a misnomer. Most of the oil analysis data is not about the oil. There are three clear considerations for the use of oil analysis.

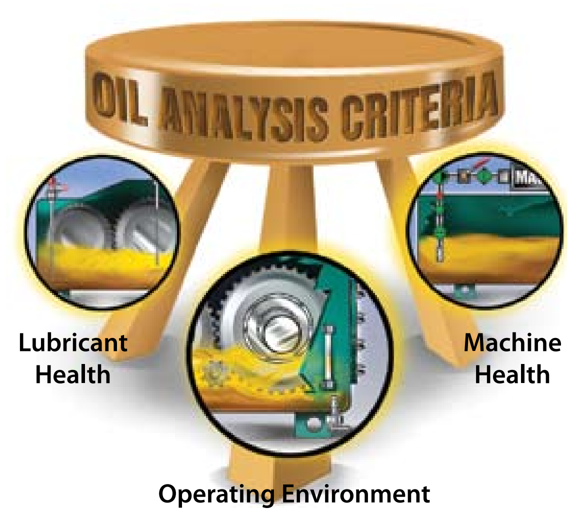


Fig 1 - Three Parts of Oil Analysis

They are:

1. Measurement of the health of the lubricant – the part that most people understand.
2. Measurement of the health of the machine – the part that some people understand.
3. Measurement of the operating environment for the lubricated component – the part that most folks seem to fail to understand.

One could argue that a small portion (call it 1/3) of the value of oil analysis data is about the oil. Lubricants represent a rapidly rising cost category. Management of the lubricant lifecycle is therefore worth consideration. Even so, it is no more that two to three percent of the total cost of maintenance, and as such, is practically a rounding error.

If 'oil health' (i.e. oil chemical health) measurement is all that is expected from the process, then the sample collection quality can be hit or miss, with little loss of value. This is because oil chemical properties are 'homogenous', meaning that the chemical changes occur throughout the system. However, where understanding machine condition and sump contaminant conditions are also important, then the sample collection process must be conducted with the same care that would apply to other sophisticated technologies - location and repeatability must be precise.

## Sample Collection Location

Since the other 2/3's of the available information is also carried in the oil, it certainly makes sense to look at that information as well. For this 2/3 though, the location of the sample port, and consistency from one sample to another, is central to making good decisions. The information about machine condition, and the amount and type of contaminants around the lubricated components, differs from one area of the machine to another. For instance, in a hydraulic or circulation system, once the oil passes through a return line filter and enters the tank, any metallic or atmospheric debris that would point to a problem at a specific type of component is 'lost' in the volume of the tank (see Fig 2). Information about chemical health does not change, but the information about the machine is effectively hidden from view.

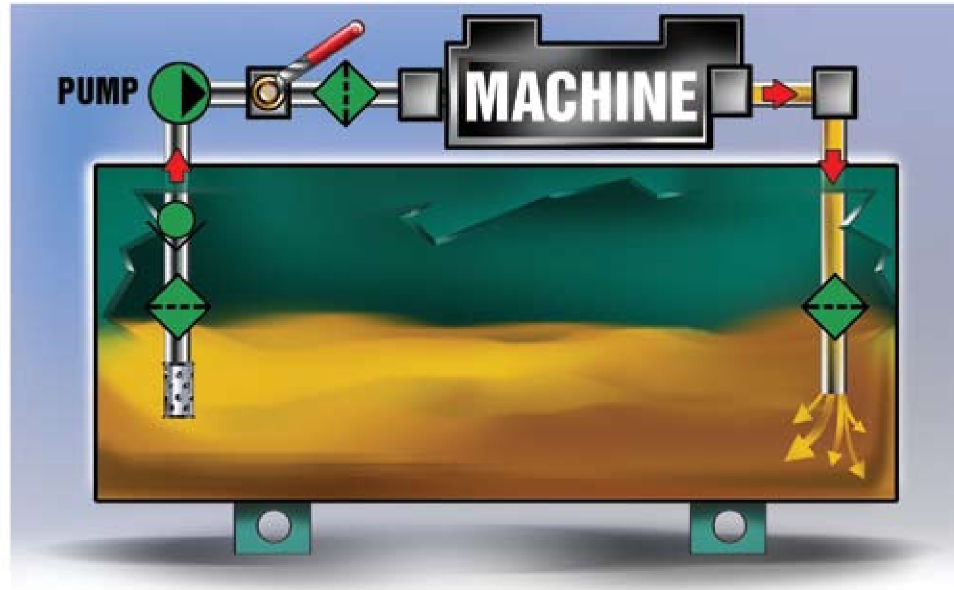

**Fig 2 - Good Information Can Get Lost in Hydraulic Tank.**

## Sample Collection Method

The same issues exists in non-circulated systems when the information about wearing components settles out of the circulating oil into a stagnant area, such as at the bottom of the reservoir and at the drain line (see Fig 3). If the sample is collected with a straw (siphon) from the top during one sample interval, and from the bottom during another sample interval then the portion of the analysis that points to machine wear and contaminant concentrations will, most likely, look very different.

Taking this common problem one step further, if two different technicians use a straw to collect samples in the same way, but the straw settles at different locations in the sump then, again, the wear and contaminant type results can be very different (see Fig 4). The problem for the analyst occurs when one set of data suggest a clearly addressable problem, and the other set of data suggest that no issues exist. Regardless of the date of the sample pointing to the problem, it is impossible to know which condition is correct without conducting additional analysis, which takes time.


**Fig 3 - Due to Varying Levels of Dirt Load in Gear Box, Consistent Sampling Location a Must.**

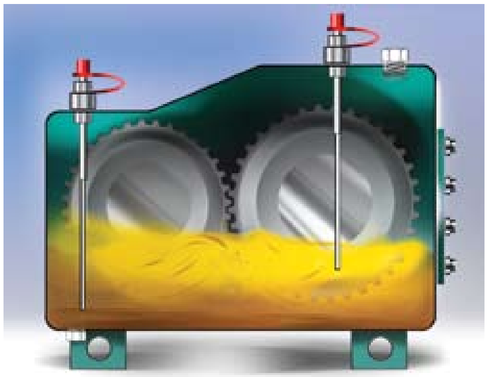

Fig 4 - Siphons drawing from areas with different levels of contaminants

### Sample Bottle and Sampling Materials

Sampling multiple reservoirs with a single drop tube is a bad idea for the same reason that it is a bad idea for everyone in the kindergarten class to eat with the same fork. It is inevitable that someone using the fork has a condition that the remaining diners don't want.

Samples taken with a common sample straw create opportunities for contaminated sample results, and eventually misdiagnosed condition that leads to neglect of a real condition or the scheduling of counterproductive work. The same argument would be made for the re-use of sample bottles used for on-site analysis.

Additionally, particularly when the 'contaminant' quality is being closely observed, some care should be given to assure that the sample bottles themselves were not packaged and shipped in an open state. Even though it is a seemingly small amount, dust from the air can certainly accumulate in the bottle and lead the analyst to incorrect conclusions about the nature of the contamination control capability of the system. This is particularly true for those systems that are most sensitive to solid particle contaminants, such as high pressure CNC controlled hydraulic circuits.

### Documentation - Help for the Analyst

Beyond precise and effective sample collection, the next most troublesome set of problems pertains to the information, or lack of information, that is provided to the analyst about the machine, environmental condition and the lubricant.

Commercial laboratories use machine specific coding systems that, once established in the database, increase the speed and accuracy of sample processing. When the customer provides samples with the laboratory designated machine identification number the laboratory can layer the current results on top of the previous results, which produces a useful machine history. Trending, plotting and statistical analysis is, or can be, performed once a machine analytical history is compiled.

Laboratories provide standardized information forms that contain fields for details that

**Sample ID Data**

Sample ID# ______________________ Sample Date _______________

Description_______________________________________________

Oil Mfg. and Name ____________________ Oil Grade _____________

Time on Oil _______________________ ☐ Miles ☐ Hours

Equipment Mfg. and Model ___________________________________

Time on Equipment ____________________ ☐ Miles ☐ Hours

Testing requested__________________________________________

Comments _______________________________________________

**Fig 5 - Sample ID Data**

the analyst needs before he/she can provide substantive help with analysis. Laboratories request, but cannot demand, that each sample be submitted with the proper documentation. Filling out these forms is a time consuming and tedious task, but one that needs to be completed. These details become the template upon which future trending is developed. Fig 5 shows a form that identifies the type of details that the laboratory requires.

Following the initial setup, there is additional machine specific information that must be supplied with each sample event that the analyst will consider during a review of flagged (identified by alarm status) sample results. This is particularly important if there have been any changes since the initial sample was sent to the lab. Requested details could include:

- Oil type
- Oil viscosity
- Top-up and additions to the sump
- Operating hours since the last sample
- Change date or change information
- Change in filtration practices
- Change in operating conditions

Without this type of information, the analyst cannot provide reasonable assistance to the customer.

## Defining Alarms and Limits

The third level of problematic practices pertains to the nature of the alarms that should be established for each defined machine. Oil analysis is no more a 'one size fits all' proposition than thermography or vibration analysis. The vibration measurement criteria and alarm set for a high-speed element bearing will be quite different from the configuration for a high-speed plain bearing, even if both components happen to reside within the same mechanical system. This is, of course, because the two different types of mechanical components have different failure modes and patterns.

Similarly, the alarm parameters for machine condition measurement, as derived from the lubricant sample, by their nature must reflect the failure modes that pertain to the component at hand. The amount of 'normal' ferrous metal produced by a large reducer driving a 60" inclined belt will be drastically different from that which is produced by a hydraulic system. This much differentiation is self evident. But what about two reducers sitting side by side with the same function, but different failure patterns? Perhaps one has a hard-piped shaft mounted pump and filter system that filters the oil with normal operation, where the other has no filtration. The difference in cleanliness between the two drives will likely be substantial. It is unreasonable to expect that one alarm standard should fit both machines, even if the drives are identical. Further, if one machine has a higher machine priority due to its position in production, its repair history, its difficulty of access, or for any other reason, the alarm structure should reflect the different degree of production dependence.

Laboratories may wish to provide alarms, but unless a laboratory representative is involved in the changing operations there is little hope that the lab will have the depth of perspective to make many of the necessary decisions. That is not to say it is impossible for the lab to provide that insight, but outside of machines that truly operate similarly (steam turbines for example), end-users should assume responsibility for establishing their own limits.

So, whose job is it to create an effective alert and alarm rating system for a given machine? A common but short sighted argument is that these decisions belong to the person(s) that understand(s) the instrument best: the analyst (or lab).

## Summary

Oil analysis programs are only as good as the quality of the process behind them. Sample location, sample methods and practices, completeness of the background details, and machine specific alarms and limits all play a pivotal role in determining whether the laboratory analyst or the plant reliability engineer can create lasting value for the organization through the technology.

There are no shortcuts to quality. Choosing to ignore any of these items will compromise the effectiveness of the effort. The end result could likely be that crucial plant decisions are made from suspect data. The cost to devise sample methods, install the right ports and train personnel on the use of correct methods is very low relative to machine replacement cost and is on par with the full cost of a couple of oil changes.

Ultimately, the only real defense for conducting oil analysis without these fundamental bases being covered would be lack of awareness of the importance of the details. And, now, we have eliminated that reason, haven't we?

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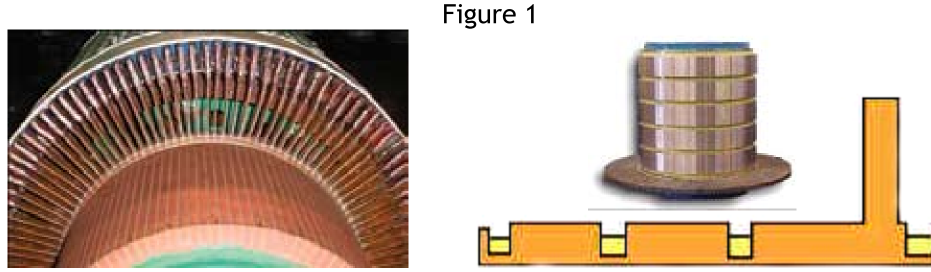
# Getting To Know Armatures

## An In Depth Look at DC Motor Bar-To-Bar Testing

*by Richard Love*

DC armatures are complex components in which precision construction, assembly, and repairs are necessary for satisfactory performance. Armatures consist of a laminated core with slots that hold the armature coils in place. When placed in the slots the armature coil ends are connected to a commutator which, along with the laminated core, is mounted to a shaft. The commutator is made up of individual copper segments that are electrically separated from each other using segment mica. The bars have slotted risers that are used to connect the armature coils to the commutator. The type of riser in a commutator depends on whether the riser is part of the machined commutator bar (solid riser) or if the riser is a separate part that is inserted and brazed to the commutator bar (flexible riser).

Figure 1



Armature Winding Segment
High-Riser Commutator

Banded Commutator Bar
Segment - Solid Riser

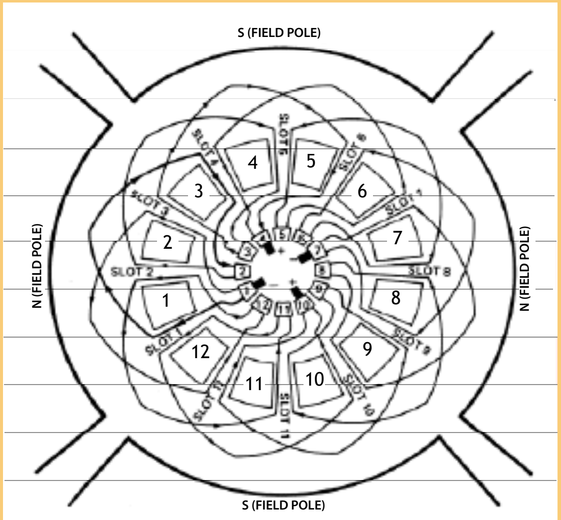
An armature winding consists of a series of coils that are connected to commutator bars which form two or more circuits within the armature. During operation, brushes riding on the commutator surface provide power to the armature winding. Many times the brush wear pattern provides valuable information regarding dc machine performance. Brush sparking conditions and commutator bar and film wear patterns are good indicators of satisfactory or unacceptable dc machine performance. It is important that motor repair shops and maintenance technicians are trained to evaluate and correct unacceptable brush sparking and commutator wear conditions before they lead to failure. If not corrected, brush sparking and commutator wear may eventually lead to catastrophic failure of the dc machine, drive, and/or driven equipment.

### Armature Winding Types

Most armatures are wound with either a lap or wave winding configuration. However, in some cases a combination of both the lap and wave winding is used. This winding is known as a frog-leg winding. An understanding of the two winding configurations, and their differences, is very helpful when testing or troubleshooting dc armatures.

**Lap Windings** - Lap wound armatures have as many circuits in parallel as there are main poles. For example, a two-pole motor has 2 circuits, a four-pole motor has 4 circuits, a six-pole motor has 6 circuits and so on. A simplex lap wound armature has the coils exiting the slots and closing on themselves to connect to adjacent commutator bars. The brush box location (spacing) depends on the number of poles in the motor. For two-pole motors the brush boxes are 180 degrees apart, in a four-pole motor the brush boxes are 90 degrees apart, and in a six-pole motor the brush boxes are 60 degrees apart. For instance, a four-pole, lap wound motor must have four brush boxes spaced exactly 90 degrees, or one-fourth of the commutator bars apart. See figure 2 for an example of a lap winding.

NOTE: Lap wound armatures having four or more poles often require an additional winding known as equalizers. Equalizers are installed to join commutator bars of equal potential- bars that are 360 electrical degrees, or two pole pitches apart. If equalizer coils were included in Figure 2




**4 Pole Lap Wound Armature**

- 12 slots
- 12 commutator bars
- Connection 1 & 2
- Pole pitch = Slots / Poles = 3 slots spanned
- One coil side goes in slot 1
- Other coil side goes in slot 4
- Equals 3 slots spanned
- Coil side in slot 1 connects to commutator bar 1
- Coil side in slot 4 connects to commutator bar 2

**Figure 2 - 4-Pole Lap Winding**

the equalizer coil ends would connect to bars 1 & 7 or six bars spanned. Armatures wound with equalizers require special bar-to-bar testing techniques so one must know before testing if the armature has equalizers.

**Wave Windings** - Wave wound armatures have two circuits regardless of the number of poles. Hence, only two brush boxes are required. Tracing the circuits out in Figure 3 proves only two current paths exist. Note that one circuit has 5 coils connected in series while the other circuit has six coils connected in series. The coil ends of a simplex wave wound armature must connect to the commutator plus or minus one bar equal to twice the pole pitch- no equalizers required.

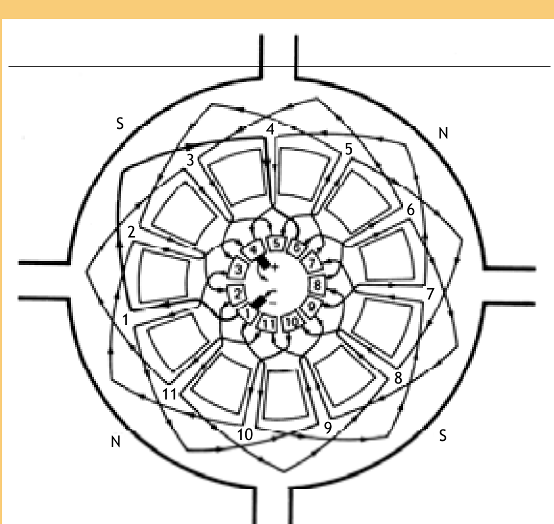
For example, one coil side goes in slot 1 and the other coil side goes in slot 4- same as the lap winding. However, the coil ends connect differently - coil side in slot 1 connects to commutator bar 1 and coil side in slot 4 connects to commutator bar 6.

## Preliminary Bar-To-Bar Testing Considerations

A visual inspection of an armature should be performed before testing. Note any unusual commutator film and bar conditions, evidence of solder coming from risers, burnt or discoloration of armature windings and bands, loose coils or armature winding bands. Proper armature testing should be performed to condemn the armature for repair or replacement or qualify it as "acceptable for service."

## Conducting Advanced Bar-To-Bar Test

Bar-to-bar testing is relatively easy to do in the field and in the motor repair shop. Many methods are available to perform bar-to-bar testing on dc armatures. However, the following information is based on a test method using the MCE™ tester to measure resistance between a segment or definite number of bars, where the individual segment resistance values must be consistent. MCE bar-to-bar test data is measured and stored digitally on a computer which is plotted and graphed for analysis. The test data can be easily saved in a spreadsheet format for precise data analysis. Armature winding resistance measurements are typically very low values in the milli-ohm or micro-ohm range. In order to obtain accurate and repeatable test values it is necessary to use a Kelvin type bridge circuit for conducting the test. The allowable tolerance or variance of




**4-pole Wave Wound Armature (no equalizers required in wave windings)**

- 11 slots
- 11 commutator bars
- Connection 1 & 6
- Pole pitch = Slots / Poles = 3 slots spanned
- One coil side goes in slot 1 Other coil side goes in slot 4
- Equals 3 slots spanned.
- Coil side in slot 1 connects to commutator bar 1
- Coil side in slot 4 connects to commutator bar 6

**Figure 3 - 4 Pole Wave Winding**

## Helpful Armature Data When Performing Bar-To-Bar Testing

1. Winding Type
   a) Lap
   b) Wave
2. Number of Poles - Not determined by nameplate speed
3. Armature Connection - Number of bars spanned separating coil ends
4. Equalizers
   a) How many, every bar, every other bar, every third bar, etc.
   b) Equalizer connection (span)
5. Commutator Bars
   a) Number of bars
   b) Solid or flexible risers

NOTE: Many industrial end-users require their motor repair shop to include the armature winding data in the motor repair reports when repaired motors are returned to the plant site.

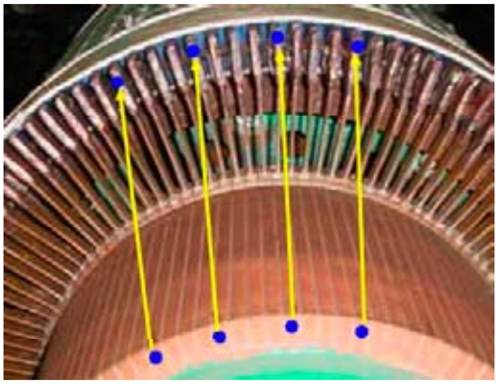


**Figure 4 - Armature Segment Using Spanned Bar Test Metod**

resistance between bar-to-bar measurements or spanned bar tests are different. Resistance values within +/-5% of the known bar-to-bar resistance are usually acceptable. However, maximum variance between spanned bar tests should not exceed +/-1% of the known spanned bars resistance value. Spanned bar tests that exceed the 1% variance should have a bar-to-bar test performed on that particular segment to isolate and correct the suspect condition.

NOTE: There is no industrial guideline stating maximum bar-to-bar resistance variance. The allowable variance may vary depending on end-user's specific guidelines.

## Test Results

In Figure 4, the dots on the bars and risers represent the spanned segments included in the measured resistance values. A maximum variance of plus or minus 1% is expected or additional bar-to-bar testing on each suspect spanned segment should be performed. Resistance measurements should be obtained by connecting the test probes to the commutator bars.

NOTE: Armatures with flexible risers may develop loose or high-resistance connections where the riser connects to the commutator bar. If suspect variances exist, measurements may be obtained by attaching the test probes on to the flexible risers. If the resistance values are now within tolerance, the problem is most likely due to loose or high-resistance riser to bar connections. In all cases, the surface contact points where the test probes are attached must be clean.

## Spanned Bar Testing Guidelines

1. Number of bars spanned must not exceed pole-pitch.
2. Maximum variance between spanned segments, +/- 1%
3. Out of tolerance segments must be tested bar-to-bar.
4. Bar-to-bar variance must not exceed +/- 5%

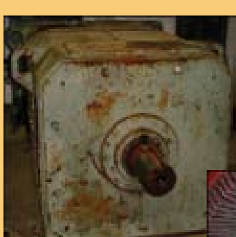
The pole pitch or number of bars per pole equals the number of commutator bars/main poles.

# Identifying High-Resistance Armature Winding Connections

## Alabama Motor Shop Prevents Potential Catastrophic DC Motor Failure Using MCE™ Bar-To-Bar Tester

During a routine motor recondition in an Alabama repair shop the MCE bar-to-bar tester revealed varying unacceptable resistance measurements in the armature winding. The suspect condition was isolated and found to be loose connections where the risers connect to the commutator bars. After discussing the test data and suspect condition with the customer, the decision was made to remove the old armature winding, repair or replace the risers and rewind the armature. While removing the old armature winding the high-risers pulled out of the bars without any effort - pointing to the reason for the high-resistance connections. Additionally, the loose risers were most probably causing brush sparking which was contributing to the destructive commutator bar and film wear.

Had it not been for the motor shop's reliance on all its available tools and resources, this opportunity would have been missed. The figure below shows the high-risers that easily came out of the commutator bars during removal of the old winding. New high-risers were purchased, installed and tested before rewinding the armature.



700 HP
DC Motor

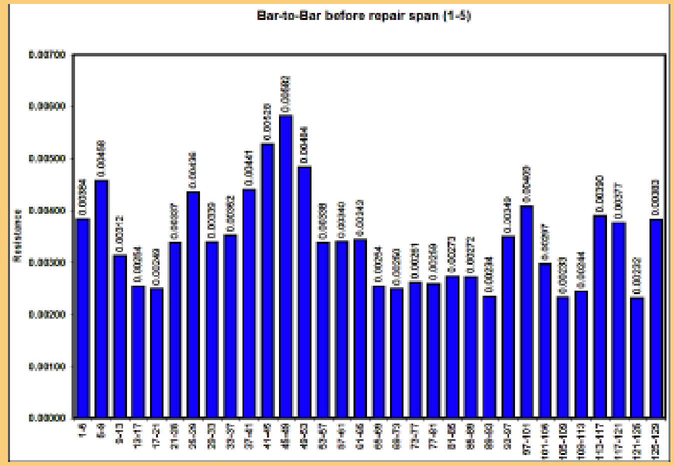
Armature with
High Risers

Failed
High-Risers

**Key Armature Data**

Poles 6
Bars 126
Connection 1 & 2
Equalizers every other bar, equalized 50%
Number of bars per pole = Bars / Poles
126 bars / 6 poles = 21 bars
Bar Pole Pitch = 1 & 22

NOTE: Number of poles in dc motors can't be determined by nameplate speed.




Spanned Bar Resistance Readings As Received

## Bar-To-Bar Test As Received

The MCE tester was used to perform the bar-to-bar test using the spanned bars method. The graph above shows the unacceptable variance of resistance.

NOTE: When performing bar-to-bar testing using the spanned bars method, the span should be no more than one pole-pitch, preferably one-fourth pole-pitch or less.

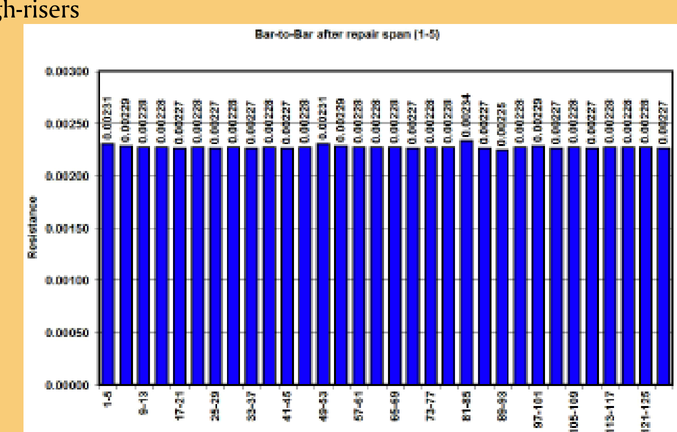
## Repair Procedure

The repair procedure included removing the old armature winding, replacing the high-risers, installing a new armature winding and proving by tests, the quality and expected reliability of the repaired armature. The photo on top at right shows the commutator less the high-risers after stripping and cleaning. The photo on bottom at right shows the completed rewound armature with new high-risers.

The graph at right shows acceptable spanned bar resistance values after completing rewind.

Commutator Less
High-Risers

Completed
Armature
Rewind




MCE Bar-To-Bar Data After Risers Replaced & Armature Rewind

## Conclusion

While finding and solving this dc motor problem was a great success (it potentially saved a southern paper mill hundreds of thousands of dollars in unexpected motor repair cost and unscheduled downtime), the real story of this case study points out the importance for motor repair shops and field service technicians to use proven tools and advanced technology to ensure first-rate motor repair and reliability.

If missed during the motor repair process the case study armature might have experienced a catastrophic failure due to the high-risers coming out of the bars during operation, damaging the armature and field windings, as well as potentially destroying the commutator and all the other internal motor parts.

### Helpful Hints When Performing Bar-To-Bar Resistance Testing

1. Obtain important armature winding data before bar-to-bar testing.
2. Armature winding type, lap or wave.
3. Number of poles.
4. Number of commutator bars
5. Equalizers, if so how many and what is the connection span.
6. Maximum bar-to-bar variance, plus or minus 5%.
7. Maximum spanned bar variance, plus or minus 1%.
8. Span bar tests should span a maximum of 1/2 pole pitch.
9. Rely on your motor shop for help, but know their capabilities.

It is very important to use all of the tools and technologies available to you. In the case study, the MCE tester identified a problem in an armature that the motor shop's conventional bar-to-bar tester missed.

### Summary

With proper training, testing dc armatures in the motor shop and in the field is relatively easy. Advanced test equipment often provides more precise measurements and a means for detailed analysis of the test results. For instance, the MCE tester gives technicians the means to obtain precision bar-to-bar resistance measurements, digitally store the test results, plot and graph the test data for analysis. End-users should never underestimate the importance of periodically assessing their motor repair shop, including the shop's motor repair expertise, tools and the technologies they employ.

*Richard Love is the founder and president of Richard Love Associates, RLA. Richard has been associated with the electric motor industry for more than thirty-two years. He has extensive motor repair experience with rewinding, repairing and testing alternating and direct current motors up to 10,000 horsepower. Richard works closely with industrial end-users throughout the United States helping them solve critical motor problems. Richard Love Associates provides a full compliment of motor management services including, but not limited to, writing motor repair specifications, conducting motor shop assessments, and providing a broad array of alternating and direct current hands-on motor maintenance training. Richard can be contacted at (205) 590-1810 or at rlahelp@ earthlink.net*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# Back to Basics

## A Quick Refresher on the Fundamentals of Shaft Alignment

*by Damian Josefsberg*

Performing a correct shaft alignment saves time and money. Misalignment is the most common cause of machine vibration. Understanding and practicing the fundamentals of shaft alignment is the first step in reducing unnecessary vibration, reducing maintenance costs, and increasing machine uptime. Every alignment should be performed from start to finish using the same fundamental process. Once you employ this process into all shaft alignments, the average time spent on an alignment will go down and the quality of the alignment will go up.

While shaft alignment is an essential component of plant maintenance, safety is the first thing to think about before any alignment begins. All equipment that is to be aligned must be locked out and tagged out. The locks and tags should not be removed until all persons working on the equipment are finished. Every individual should be responsible for their own lock and tag.

Cleaning up is also an important step when performing an alignment, and I'm not talking about your hands. The twenty to thirty minutes that is spent cleaning up the machines before the alignment will save an hour and a half at the end. So break out the wire brushes and solvents and clean up the machines to be aligned. Make sure all dirt, grease, and rust are removed from the base and the machine feet. If there are any rusty shims, replace them. Even make sure that there isn't any foreign object trapped under the machine (this has gotten me into trouble before). After all contact surfaces between the base and the machine are clean, we can move on.

All hold down bolts to the machine should already be loose from cleaning. Notice if there are any obvious gaps between the machine feet and the base. If there are any gaps, fill them. Don't worry if any of these gaps appear to be uneven, we will take care of that later. Once you are satisfied with the cleanliness of the contact surfaces, and all of the gaps are sufficiently filled, you can tighten the hold down bolts.

Now it's time to decide which machine is going to be moved and which machine is going to remain stationary. This is almost always decided by which machine is not going to be moved. Sometimes it is like deciding between the lesser of two evils. There are some questions to ask to help make this decision easier. Is one machine heavily piped in? Is one machine much heavier than the other? Does one machine have no access to its feet? If there is no clear answer to any of these questions then just pick one machine to be the movable one.

Alignment shim change - Putting in new shim to change the machine vertical position.

Does the machine have a rigid or a flexible coupling? If it is flexible, great, you will have no problem taking accurate misalignment readings with a variety of methods. For rigid couplings, there are two ways to get accurate misalignment readings. The bolts in the coupling can be loosened to the point that each shaft will move about its own centerline of rotation. This can not always be accomplished, the bolts may be too short to loosen sufficiently or there may be some other obstruction preventing the coupling from coming apart. If this is the case, the coupling must be completely separated in order to take misalignment readings.

Once all misalignment can be exhibited at the coupling, the misalignment can be measured. The methods to measure misalignment vary widely. I would highly recommend using a laser alignment system to measure misalignment. They are extremely accurate, versatile, easy to set up, and provide results fairly free of human error. Don't get me wrong, you can perform an excellent shaft alignment using dial indicators, but it requires much more training and will take much longer to complete the alignment. Given the choice, I would rather drive a Dodge Viper than a Model T.

Whatever alignment tool is chosen to perform the alignment, it must now be bracketed to the machines. The bracketing chosen will depend on many different variables. Are the shafts rotatable? Are the shafts coupled together? Are there obstructions during rotation? The bracketing and measurement method chosen are a subject for an entirely different article. For right now I will just say, acquire misalignment readings at the coupling as accurately as possible.

The misalignment readings are comprised of the four elements of misalignment: vertical offset, horizontal offset, vertical angle, and horizontal angle. Sometimes offset is described as parallel misalignment and angularity is described as gap at the coupling diameter. Whatever the terminology, it is all misalignment. From these misalignment readings we can determine the proper feet correction to make in order to improve the misalignment at the coupling. These moves are comprised of a vertical move on the drive end and non-drive end feet and a horizontal move on the drive end and non-drive end feet. All moves made at the feet are made in order to improve the coupling misalignment. Don't ever lose sight of this during the alignment.

When moves at the feet are made, all vertical corrections should be made first and the horizontal corrections made second. This is because any vertical corrections are going to affect the horizontal position. The easiest way to make horizontal corrections is with jacking bolts. If you don't have them, install them, you will be glad you did later on. The proper procedure to make the corrections is to take measurements, make vertical corrections, then take measurements, and make horizontal corrections. Notice that measurements at the coupling should be taken after each move is made. This is because the previous set of readings is invalid after each move is made. The first set of feet corrections is just a rough alignment. The rough alignment is only meant to get the feet corrections to within .025".

Tightening bolt for soft foot check.

After the rough alignment is completed the soft foot correction can begin. A soft foot is not necessarily at the feet. The definition of soft foot is actually a machine frame distortion. This is anything that causes the machine frame to distort. The condition of soft foot is most commonly caused by the following ailments: one or two feet being out of plane with the other feet, one or more feet being angled, or pipe strain. Often a combination of these problems exists. It can be very difficult and time consuming to correctly diagnose and correct a soft foot. An entire week-long course could be devoted to soft foot diagnosis (and is). Suffice it to say that you should do whatever is necessary to correct the soft foot. The soft foot is akin to internal misalignment; until the internal misalignment is corrected the shaft alignment will only solve part of the problem. A general rule is to keep any foot deflection to within .002".

Final alignment should now be performed to within an acceptable tolerance. This tolerance will usually come from the machine or coupling manufacturer or some other in-house specifications. Wherever the tolerance comes from, it is important to use it. By this, I mean your tolerance is there to protect the machinery and help the personnel that align the machine. You will never be able to remove all of the misalignment that exists. Even if your measurement device reveals a zero for each parameter of misalignment, a tool with higher resolution will show that some misalignment still exists. Because of this state of imperfection that we must live with, it is necessary to use a tolerance. I like to think of a tolerance like the end zone in football. Whether the ball is caught at the front, back, side, or middle of the end zone it is a touchdown. As long as your shafts are aligned to within the specified tolerance, your alignment is complete. There is no reason to waste time continuing the alignment in order to get a displayed .000" for all values.

Now that the machines are aligned within acceptable tolerance, the hold down bolts should be torqued to the proper amount. Take a final set of alignment readings, just to make sure that nothing moved and for documentation. Remove the measuring device, perform any necessary reassembly on the coupling, and remove the lock and tag.

Congratulations, you are finished.

*Damian Josefsberg is an applications Engineer for Acquip, Inc. He currently performs service work and teaches training classes. He has performed numerous laser shaft alignments, bore alignments, diaphragm alignments, machine train alignments, and thermal growth monitoring studies. Damian has performed internal and shaft alignments on compressors, gearboxes, motors, pumps, and turbines. He has provided plant maintenance support for the power, oil and gas, pulp and paper, food processing, automotive manufacturing, pipeline, and marine industries. Damian has a degree in Mechanical Engineering from Florida Tech. He is also certified in vibration analysis and on several laser alignment systems and can be contacted at 866-405-1065 or damian@acquip.com*

# Think Leak Detection is Expensive?

## Consider the Cost of Not Detecting Them

*by Jim Hall*

Here are the facts. 20-30% of all wasted energy is contributed to compressor output. Compressed air systems account for 10 percent of all electricity, and roughly 16 percent of U.S. industrial motor system energy use. Seventy percent of all manufacturing facilities in the United States use compressed air to drive a variety of equipment. A report from the Department of Energy (DOE) compressed air assessment project reported that the average facility has 30% to 35% overall compressed air leakage if it hasn't taken any "recent" action regarding leaks. And, on top of that, as many as 57% of all plants have not had an air leak audit performed in the past two years.

Just think of the wasted energy if no leak survey has been completed in several years? Whether you are a small manufacturing plant or a large industrial site, ultrasonic leak detection is for you. Whether you spend $450.00 or $10,000.00 for an instrument the return-on-investment can be huge.

Most industrial applications such as leak detection, bearing analysis, steam trap troubleshooting, electrical sounds such as arcing, tracking, and corona discharge, gear box inspections will certainly have an ultrasonic signature. Therefore, an ultrasonic receiver is a very valuable tool in nearly all plant environments.

### Maybe Not the Least Expensive, Maybe Not the Most Expensive

Sometimes you have to draw the line between what can be called an "instrument" and what has to be considered a "trinket". When searching for a leak detection instrument, you may not need a high-end instrument that can perform multiple tasks or has spectra-analysis software. However, you may need something more than the bare bones, lowest end instrument.

One plant I visited had only three technicians. However, the facility in which they worked is considered a high noise environment. For them, a mid-range priced ultrasonic unit ($3k) with noise reduction headphones, narrow band frequencies, frequency tuning and the sensitivity to locate leaks at a great distance met their needs perfectly. The mid-range instrument allowed them to locate air leaks during normal working hours, use long range modules (no more climbing), and allowed them to use the instrument during normal plant production hours and not have to come back during down-time or after hours to locate the leaks.

Keep in mind one drawback to purchasing a low-cost instrument can be simplicity. Many of these instruments are "wide band" (30-42 kHz) with no frequency tuning. This means an air leak may be masked by competing ultrasound, a sound that this instrument cannot distinguish from the actual air leak. Even so, several of these low-cost instruments are able to distinguish between the background and a leak and also have options such as a long range horn, focusing cones, and/or parabolic dish. Many of today's manufacturers will rent or lease equipment. It may be wise to try before you actually buy.

Let's not forget headphones. Take the time to examine the headphones, try them out in your plant environment. Most of these units may use a simple 1/8" or 1/4" stereo or mono-stereo headphone jack. You can easily replace the headphones with a set suited for your environment or application. A couple of manufacturers have noise reduction headphones as options for the low-cost instruments they sell. A low-cost instrument that is worth its salt should be warranted for at least one-year.

**Scanning for compressed air leaks with SDT 170M.** Photo courtesy of All Leak Detection, LLC

Look for low-cost instruments that have:

- The sensitivity to distinguish between background noise
- Accessories to aid in leak detection (long range horns, close-up cones)
- Headphones for your environment
- Warranty (minimum one year)
- Flexibility (rpm sensor, thermometer, etc...)

Of course, the higher the cost of the instrument, the more bells and whistles it will have.

While you are researching what equipment may be best for your environment, particular needs or application, keep in mind many of these same low-cost instruments may come with a contact probe or tone generator that could be useful for detecting faulty bearings on smaller compressor motors or listening to valves or to troubleshoot steam traps. Again, do your homework.

Let's be very clear about one thing, if you currently have no ultrasound instrument in your plant, now is the best time to purchase an instrument. Now is much better than tomorrow, next week, next month or next year. Why? Because you can start saving money almost immediately after turning the instrument on. Wouldn't you prefer to start improving your bottom line now instead of next year?

I recommend looking closely at an instrument that can perform a number of pdm tasks such as leak detection, bearing analysis, acoustic lubrication and electrical scanning (arcing, tracking & corona discharge) with or without accessories such as a temperature probe, an rpm sensor, and associated software for data-logging readings and waveform analysis software. In many cases, this added versatility will end up paying for itself many times over because of its abilities to diagnose many different kinds of problems. In the end, this will make your ultrasound program a more valuable asset to your company.

**Leak Testing a Valve with the CTRL UL-101.** Photo courtesy of CTRL Systems, Inc.

## Don't Over Purchase Your Need

One pipefitter I chatted with recently said that they had a habit of purchasing more equipment than is necessary to do the job. Therefore, they never used the equipment for all the applications for which it was made. His company is now making a concerted effort towards purchasing just what they need. For instance, they argue, why buy an instrument with a contact probe if they are not going to use it? Why, have a partial kit sitting in a corner never to be used. Another technician said that they use their ultrasound instrument primarily for PdM (bearings and electrical scanning), but the pipefitters are always borrowing their instrument to locate air or gas leaks. This is a good example, not only of the versatility of ultrasound, but of putting the instrument to good use instead of letting it sit idle when it is not being used for the primary reason for which it was purchased.

Another Fortune 500 company with thousands of employees, has very little background, or competing, ultrasonic noise in the plant. They recently purchased a low-end instrument for $995.00 and found four leaks (each one with about a 1/8" opening) so far. They estimated that the leaks represented $8,000.00 a year.

Just yesterday I spoke to a polymer pipe manufacturer using a very inexpensive unit (less than $500.00). During the manufacturing process he has very little competing ultrasound and is able to get in close with his instrument. He is quite pleased with the reduction of defects and leaks he has seen since he started using an ultrasonic leak detector.

## It's Not Just About How Much You Pay for Equipment

In the end, a leak detection program is not defined by how much your ultrasound instrument costs. It will be defined by its success or failure. Success is all about having the desire, the will power, the man-power, and the fortitude to bring the issue of air leaks up front and on the table. Most likely, this is not something you will do in one day or five. Start your program and work at it consistently over a period of months or even a year if you have to. But, keep on locating, identifying and fixing the leaks. Fix the larger ones immediately, and write work orders to fix the medium and then smaller leaks.

**Locating air leaks on fitting with the Accutrak VPE2000.**
Photo courtesy of VTEK Associates.

Man-power is always an issue. Finding man-power in a plant that is already stretched thin for people can be the "silver bullet" that stops any air leak program before it ever gets started. However, I would urge you to find the manpower needed for the leak program. It will be well worth it in the end.

## Air Is More Expensive Than You Think

Ever think air is free? Not when it's compressed. Compressed air is actually one the highest priced "utilities", costing "eight times more expensive than electricity"! In fact, a leak with a 1/4" opening of 100 psig costs $9000-9500 dollars a year. It's very simple math, just a few leaks can mean a substantial cost savings. Also keep in mind that leaks in your plant can create problems in manufacturing by starving air from one system or another. So leaks are not only a cost issue but a production issue as well.

Recently, I was providing ultrasonic training in a plant to where several solenoids were found

| Leakage rates[1] (cubic feet/minute) for different supply pressures and approximately equivalent orifice sizes | | | | | | |
|---|---|---|---|---|---|---|
| Pressure (PSIG) | Orifice Diameter (inches) | | | | | |
| | 1/64 | 1/32 | 1/16 | 1/8 | 1/4 | 3/8 |
| 70 | 0.3 | 1.2 | 4.8 | 19.2 | 76.7 | 173 |
| 80 | 0.33 | 1.3 | 5.4 | 21.4 | 85.7 | 193 |
| 90 | 0.37 | 1.5 | 5.9 | 23.8 | 94.8 | 313 |
| 200 | 0.41 | 1.6 | 6.5 | 26.0 | 104 | 234 |
| 125 | 0.49 | 2.0 | 7.0 | 31.6 | 126 | 284 |

[1]For well rounded orifices, multiply the values by 0.97 and for a sharp-edged orifice, multiply the values by 0.61.

Courtesy of U.S. Dept. of Energy. Dec 2000 Tip #3.

leaking. Many of these had been leaking for years. After I returned to this plant several weeks later I found that the solenoids had been replaced. But, the leaking rubber and vinyl hoses had not been inspected or changed. Take the time to inspect and replace those hoses, clamps and fittings. Be adamant about who is to be involved with leak detection. Leaks are an ongoing problem, three months after you fix some of these leaks they will be leaking again, especially if you are a power plant, steel mill or saw mill facility where vibration can cause a leak or a leak to reoccur. Leak detection audits should be performed twice a year.

## How Much Will You Spend for Leak Detection?

There are instruments in the marketplace that deserve to have a chance for your maintenance dollars. Take the time to research the marketplace. You may be surprised at the sensitivity and accuracy of these units.

While you are researching what equipment may be best for your environment, particular needs and applications, keep in mind many of these same low-cost instruments may include a contact probe and/or tone generator, which will allow you to use the instrument for other problems. A low-cost instrument will save you money, if it fits your needs. There will always be some manufacturing plants that must have the high end instruments. So everyone should examine their needs and get the proper tool or instrument in the proper hands.

Also, do not forget about ultrasound training. Knowing ultrasound theory, ultrasonic applications, equipment orientation, and other characteristics will aid you in locating the air leaks in a very short time.

So, in the end, it's hard to say exactly how much you'll spend for leak detection, bit I do know that in virtually every case, the amount you spend pales in comparison to the amount of money you will save.

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

# Soul Mates

## Vibration Analysis & Bearing Analysis Made For Each Other

*By Andrew S. Calcagno*

When a couple gets together and they really hit it off, eventually the subject of a wedding comes up. This leads to that, and the next thing you know, they're married with children (yes, I know I left out a few details). The dynamics of a family can be pretty complex, but at least one thing is certain: as spouses and parents, the people who were once separate individuals are now forever changed. They have an enhanced perspective on life that would not have been possible if they had remained independent of each other. As a thriving, functional couple, they discover each other's faults, and learn to deal with them. They come to recognize the talents and abilities that each brings to the table and learns to appreciate them. They ultimately accomplish more together than they would have separately.

This same synergistic principle applies to machine tool condition monitoring. The predictive analyst can produce satisfactory results through the mastery of a lone technology, but he stands to gain a new depth of failure mode understanding if he can nurture the growth and development of a family of technologies. This leads to more reliable diagnoses. In the case of precision spindle condition monitoring, the marriage of Vibration Analysis technology with Root Cause Bearing Failure Analysis can produce some pretty incredible offspring: an unprecedented depth of vibration data understanding as well as the powerful knowledge of why spindle bearings fail in the first place (so that something can be done about it).

### "Aren't You Ever Satisfied?"

If your sweetheart-of-a-spouse could comment on the spindle reliability program results that have been produced throughout the years in your facility, it might go something like this: "Why can't you ever get your predictions right –either you rebuild perfectly good spindles, or they smoke, scream and turn blue… and why are they failing, anyway… so-in-so's spindles don't fail… why can't you be more like so-in-so… " I guess what your spouse would really be trying to say is this: you need to improve the reliability of bearing failure predictions AND eliminate unnecessary chronic failure sources.

There are a multitude of predictive technologies available today: Vibration Analysis, Infrared Thermography, Oil Analysis and Tribology, Ultrasonics, and Motor Current Analysis to name a few. Each, or a combination of these technologies is appropriate in certain circumstances (especially oil analysis/tribology for non-greased spindles and gearboxes). However, Vibration Analysis has been and remains the primary predictive technology used for precision spindle condition monitoring.

### Benefits of an Effective Vibration Analysis Program

Anyone who believes that vibration analysis is all "smoke and mirrors" should think again (or stop reading now and go back to playing with your slide rule). Though the basic principles have remained pretty much unchanged for the past couple of decades, technological advances have made vibration analysis "the predictive technology that cannot be ignored" when it comes to precision spindle condition monitoring. Since the focus of this article is not solely vibration analysis, I won't dwell on collection parameters or get deeply into the analysis process. However, it is noteworthy to touch on some of the benefits of an effective program:

- Elimination of Potential Reactive Maintenance Events (breakdowns) by identifying eminent bearing failure and thereby allowing for the scheduling of repairs during off hours
- Avoiding potential quality spills (scrap parts) before they occur by identifying preload loss in angular contact spindle bearings
- Significant Bearing Life Improvement by the reduction of radial loading with Dynamic Balancing
- The Elimination of Costly Collateral Damage to spindle components (shaft, bearing pockets, spacers) as catastrophic bearing failure is averted

- Reduced Spare Part Inventory Costs as "blind-sided failures" are rare and reliability improves

Obviously, when discussing an effective vibration analysis program, EFFECTIVENESS is the key. Anyone with a few bucks can get some gear, put a couple of people on it and call it a vibration analysis program. But from my experience, the proof is always in the pudding. If you don't get results, what do you really have? The components of an effective program would include: capable personnel (with extensive precision spindle / bearing experience), vibration analysis technical training, proper hardware acquisition and strategic placement, optimum data gathering frequencies, appropriate collection parameters, meaningful alarms, effective reporting… I could go on and on, but this article is not the place for it. But once you reach the point where your program is producing results, how do you improve accuracy and consistency?

## Benefits of Root Cause Bearing Failure Analysis

Many of today's most popular TV shows feature detectives, crime scene investigators, and coroners who all work together to solve a mystery. Interestingly, there are many parallels to Root Cause Bearing Failure Analysis. While a coroner works to find the primary cause of death (usually an unexplained, accidental, or violent one), a bearing analyst works to determine the primary cause of a bearing failure. Just as autopsies are performed and forensic tests are conducted, the bearing analyst must gather circumstantial data, and evaluate the most minute physical characteristics of the bearings, spindle components, and lube particles in order to accurately determine the cause of "bearing death". But why go to all that trouble? (It can be a very time-consuming, painstaking process.) Let's take a look at some of the benefits of Root Cause Bearing Failure Analysis:

**Recognition of Common Bearing Damage Physical Characteristics** (ISO Failure Mode Classifications/Sub-Classifications in parenthesis)

- Spalling (surface / subsurface fatigue)
- Fretting Corrosion (frictional corrosion)
- Moisture Corrosion (corrosion)
- Skidding (abrasive wear)
- Particle Indentation (plastic deformation)
- Smearing (adhesive wear)
- True Brinnelling (plastic deformation)
- False Brinnelling (frictional corrosion)
- Particle Size and Shape Recognition
- Thermal Cracking (fracture)

**Bearing Failure Mechanism** – the ability to determine the fundamental process of a specific bearing failure by putting all of the relative circumstances and physical evidence together to determine precisely where and why the failure began. The Root Cause is determined as a distinction is made between the primary cause, primary damage and secondary damage of precision bearing failure. Such causes would include:

- Misaligned or "Cocked" Bearing(s)
- Axial or Radial Overloading
- Loss of Lubrication Barrier between Races and Rolling Elements
- Improper Grease and/or Quantity
- Ingression of Foreign Contamination
- Dimensional and/or Geometric Non-compliance of Critical Spindle Components
- Improper Bearing Installation Practices
- Improper Bearing/Spindle Storage Facilities (vibration, climate)
- Significant Machine Temperature Changes Resulting in Condensation
- Process-related "Crashes"

**Chronic Bearing Failure Elimination** - based on Root Cause information, changes are put into place to end chronic bearing failures.

Certainly, technical training and proper equipment are absolute necessities for an effective in-house Root Cause Bearing Analysis effort, but for the analyst, there is no substitute for extensive bearing and spindle experience. The best analysts have seen a lot of failures over the years and can almost always "smell a rat". Bearing Analysis Training is available from many bearing manufacturers, as well as other reliability training providers.

## The "Offspring" of our Happy Couple

As the years go by, and we change from newlyweds to parents, our offspring change our lives dramatically. If we are truly engaged with their development as we watch them grow, then we have the tremendous opportunity to learn a great deal about ourselves (sometimes more than we want to know). The result is that we become empowered with the knowledge and experience to become "super-parents". (Unfortunately, we're usually grandparents by the time this happens… if only we had known then what we know now!)

These same dynamics apply when discussing the integration of Vibration Analysis and Bearing Analysis. Though not generally classified as a predictive technology by definition, Root Cause Bearing Failure Analysis is the perfect companion to Vibration Analysis when striving for the continuous improvement of precision spindle reliability. If we are truly engaged, the offspring of this merger can teach us the following:

- Clearer Understanding of Future Vibration Data: the process of correlating the observed physical characteristics of a failed bearing with historical vibration data clarifies the understanding of future vibration data and improves the reliability of your predictions
- Improved Root Cause Bearing Failure Analysis Results: as bearing failure is captured in its earliest stages, secondary catastrophic damage (which many times "covers the tracks") is minimized, making it possible to determine the true cause.
- Maximum Mean-Time-Between-Failure is now achievable as chronic failure sources are identified and eliminated, and proper bearing storage, handling, and installation practices are established and monitored.

## The Golden Child: The Organizational Paradigm Shift

What is the level of support for your PdM program? Does your organization understand what you do? Are there seemingly insurmountable "challenges" whenever additional resources are needed like training, equipment, manpower? Are there opponents to your program competing for the same limited resource dollars who may be inclined to "smear" your credibility for political gain? "Those vibration guys had us change out a perfectly good spindle when we have other REAL work that needs to be done around here!" What level of confidence does the organization really have in your recommendations?

Perhaps the most valuable offspring of our marriage may be the one most overlooked: The Resulting Organizational Paradigm Shift. (I know, parents are not supposed to favor any one child over the rest, but this little tyke is hard to resist!) The effective communication of your Root Cause Bearing Failure Analysis along with your before/after Vibration Data will be sure to turn some heads. When it comes to converting "non-believers", a picture is truly worth a thousand words. Throw in a little patience and persistence, and you will eventually win the credibility war as even your opponents will be forced to acknowledge the undeniable value-added contribution of your efforts!

# Case of the Failed Bearing GM Spring Hill Mfg. Engine Plant

At GM Spring Hill Manufacturing, we produce several versions of the Ecotec 4-cylinder engine, including the new turbo-charged version featured in the brand-new Saturn Sky Redline roadster. Our predictive group is charged with monitoring the entire plant (assembly and machining). In machining alone, we have thousands of vibration points to monitor which includes several hundred precision box spindles, spindle clusters, and multispindle heads. Most of them use ISO 4 (ABEC class 7) angular contact pre-loaded bearings. Shaft speeds generally range from 1,000 to 6,000 rpm depending upon the machining process.

### Box Spindle Premature Bearing Failure

The engine block machining area is the largest machining department in the plant. At one operation, the cylinder walls are rough-bored by a belt-driven box spindle. There are two grease-lubricated precision bearing sets: an axially secured front set (DB mount) and a smaller, axially free set in the rear (also DB mount). The spindle employs a non-contact labyrinth seal with air purge to keep contaminants out, and turns at 3591 rpm. Recently, after only two months of service (an extremely brief period of time), the spindle was replaced due to vibration. The used bearings were collected, and Root Cause Bearing Failure Analysis was performed. The following is the language from the actual report which was distributed to all of the affected parties.

#### Introduction

This bearing failure was first identified by means of vibration analysis on October 17, 2005. Though not yet audible, or evident from a quality standpoint, our analysis concluded that significant bearing impacts were occurring.

A Vibration Analysis Report was sent to all affected parties on October 18th, and the replacement of this box spindle unit was scheduled and completed on October 23rd. A vibration feedback report was then sent out to provide post-rebuild communication. Our data confirmed that the spindle replacement was successful.

The predictive technologies group requested that the used bearings be returned after rebuild in order to perform Root Cause Bearing Failure Analysis. The spindle bearings were returned for analysis on November 30th.

The front outboard bearing was selected first for analysis, as it exhibited the most advanced wear. The objective was to identify the bearing failure mechanism and provide this information for the purpose of preventing recurrence in the future.

#### Lube Particulates

The particles were first separated from the lube, and then categorized as ferrous and non-ferrous. There was a significant amount of non-ferrous foreign material (dirt / silica / aluminum) given the short period of time the spindle was in service. The aluminum particles appeared to be from the machining process, based on their size and form.

The ferrous wear metal particles were great in number as well as variety of size and shape. Both laminar platelets and chunky fatigue wear particles were observed. Laminar ferrous particles are consistent with early-stage bearing surface fatigue. Chunky fatigue wear

Microscopic Views of Dirt and Laminar Wear Metal Particles from Lube particles are associated with advanced spalling. They are the result of fatigue cracks that have penetrated and propagated into the subsurface of the rolling element or race. These particles have a low aspect ratio and typically do not exhibit the "rolled" features seen in laminar wear particles.

**Inner Race**

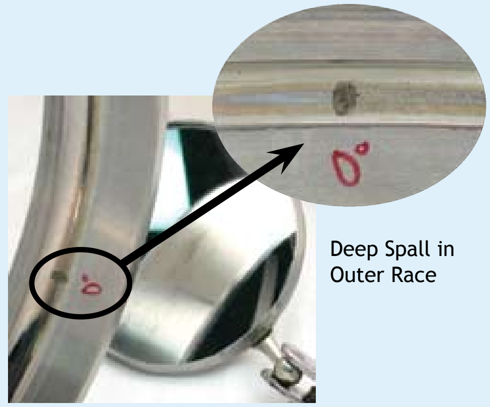
The inner race exhibited a couple of notable characteristics. A faint, blueish-brown discoloration was observed at 360 degrees of the raceway. This is an indication of heat produced at the point of contact between the rolling elements and the inner race.
Extreme fretting corrosion was observed at 360 degrees of the bore. Fretting corrosion occurs on this bearing surface when there is rela-


Blueish-Brown Discoloration
Observed in Outer Raceway

tive movement between the inner race and the shaft. The movement causes small particles of bearing and/or shaft material to become detached from their respective surfaces. These particles quickly oxidize as they are exposed to atmospheric oxygen. It is a definite indication of a worn or undersized bearing seat surface on the shaft.

**Outer Race**

The outer race is the bearing component that experienced catastrophic failure. An advanced, deep spall was observed at a single location on the raceway. Spalling occurs as the bearing material fatigues, cracks and flakes away from the surface. As the rolling elements impact an early stage spall, cracks penetrate and propagate deeper into the subsurface. Deep spalling is the result and can be seen in the photos at the top of the middle column. This type of spall produces the chunky ferrous wear particles mentioned earlier. A region of blue discoloration was observed on either side of the spall. Another distinct blueish region in the raceway was observed at 180 degrees from the spall. These blueish areas are an indica-

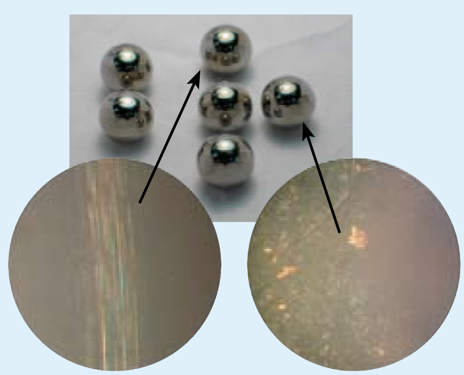


Deep Spall in
Outer Race

tion of heat at the contact point between the rolling elements and the raceway. Two regions of seemingly insignificant fretting corrosion were observed on the outer surface of the race. Though barely noticeable, these regions exactly coincided with the spall, and the blueish region observed 180 degrees from the spall.

**Rolling Elements**

The observed characteristics of the rolling elements consisted mostly of microscopic denting and skidding, however a unique tracking pattern was observed on each of them. This is the result of metal-to-metal contact between the races and the rolling elements.



Microscopic View of
Skidding as a result
of Metal-to-Metal
Contact

Microscopic View of
Denting as a result of
Particle Interference

**Bearing Failure Mechanism Summary**

This bearing suffered severe damage in a relatively short period of time. Though there is evidence of contamination, the most likely root-cause of this premature bearing failure is a distorted bearing pocket in the housing and an undersized bearing-mount surface on the shaft.

Angular-contact precision bearings are manufactured as a matched set. This is to ensure that all relative dimensional and geometric relationships fall within the tight tolerances required to enable an optimal bearing lifecycle. Likewise, the spindle components must also comply with the tolerance standards established for ISO 4 precision bearings. Deviation from these standards commonly results in uneven preloads, misaligned or spun races, etc.

An oval or out-of-round spindle housing bearing bore will cause a distortion of the outer race. (A similar distortion can be caused by a burr or piece of foreign material caught between the outer race and the housing, but the absence of a witness mark makes this highly unlikely in this case.) This distortion causes localized overloading in regions generally 180 degrees from each other. Heat discoloration regions of this nature were observed on this bearing (as well as on the front inboard outer race, which had not yet spalled).

Because of the relative orientation of these regions, as well as the observed minor fretting corrosion (an indication of slight non-contact / movement in these regions of the outer race) it is highly probable that the heat discoloration was a result of localized overloading caused by a distorted outer race. The heat lowered the viscosity of the lubrication at the point of contact and resulted in metal-to-metal interference between the rolling elements and the races.

The fatigue life of the bearing surface was drastically shortened resulting in early stage surface-initiated spalling, which produced thin laminar ferrous wear particles. This early-stage spalling also produced secondary surface damage in the form of microscopic skidding and denting as the resulting particles interfered with the zero-clearance condition between the rolling elements and the races. As continuous rolling element impacts on the spall caused cracks to penetrate and propagate deeper into the outer raceway, more advanced deep spalling occurred which produced the large, chunky ferrous wear particles observed in the lube.

**Recommendations**

Our recommendation would be to remove this spindle from circulation until all spindle components have demonstrated compliance with ISO tolerances for ISO 4 bearings . In addition, an investigation should take place to determine how contamination is entering the front of these spindles in spite of the labyrinth seal.

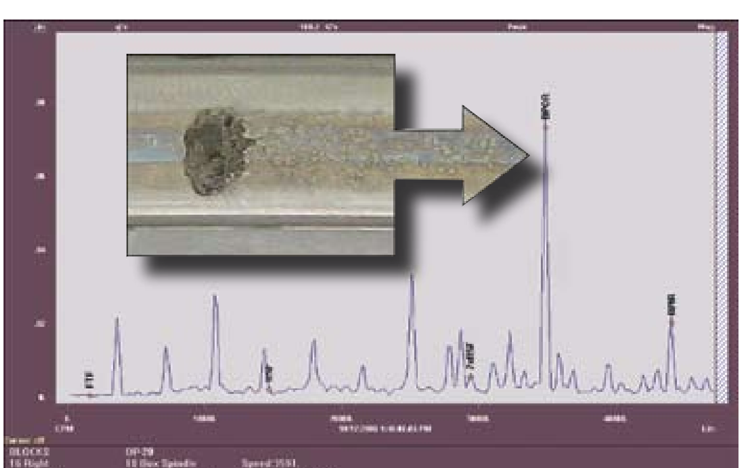
## Case of The Failed Bearing: The Epilogue

So what has resulted from the marriage of vibration and bearing analysis data?

### A Clearer Understanding of Future Vibration Data

As I stated earlier, the process of correlating the observed physical characteristics of a failed bearing with historical vibration data clarifies the understanding of future vibration data and improves the reliability of your predictions. In this case, acceleration spectral data taken prior to spindle replacement shows significant peaks at both the inner and outer race defect frequencies (software generated using shaft speed and bearing geometry data).

As shown in the figure below, there was a reason why the BPOR (outer race defect frequency) had a greater amplitude than the BPIR (inner race defect frequency). This peak, generated by the deep spall observed in the outer raceway, should be noted for future reference. Certainly, predictions should never be made based on any one amplitude in an FFT spectrum. Many other factors need to be considered in the analysis process before making the call for spindle replacement (velocity spectral data, spike energy, digital and analog overall trending, etc.). But, I can assure you that it will definitely get my attention the next time I see a similar peak at this frequency! Maybe the best way to put it would be this: though not absolute, the conclusions drawn from the data correlation between our "happy couple" will be much more valuable to future vibration analysis than any generic alarm levels.



### Improved Root Cause Bearing Failure Analysis Results

As the clearer understanding of vibration data leads to better predictions (not too early, not too late) the recovered bearings are in a moderate stage of failure. In our case study, there was a significant amount of secondary damage to the bearing components, but not enough to mask the primary source (heat discoloration pattern found in the outer race). The improved accuracy of the prediction made it possible to prevent the "tracks from being covered" as to why it really failed. Anyone who has been in this business for any amount of time has seen a few bearings and particles that looked something like the photos at the top right of this page.

Any root cause conclusions that could be drawn from these extreme examples would be pure speculation at best (certainly nothing you could "hang your hat on"). They're simply too far gone; the secondary damage has completely obliterated any of the original physical characteristics that could have told the story as to why they began to fail in the first place. We also may have continued to end up with the same non-compliant spindle components (assuming they would have survived) repeating the failure cycle over and over.

### Maximum Mean-Time-Between-Failure

So what is the Maximum Mean Time Between Failure (MMTBF) for this spindle? We would definitely never have any idea if we didn't identify and eliminate the chronic bearing failure sources. Root Cause Bearing Analysis is the way to identify them, and

the appropriate actions must be carried out to eliminate them. As stated earlier, they can include improper bearing storage, improper handling, and improper installation practices and, as in our case history, the ingression of foreign contaminates combined with the dimensional and geometric non-compliance of critical spindle components (shaft and housing). As all of the chronic failure sources are identified and eliminated, we will discover what MMTBF really is for this spindle (a work in progress as this article is being written).

### The Resulting Organizational Paradigm Shift

Last, but not least, my favorite. In our case study, the spindle was only two months old. To the skeptic of predictive technology, it would be absolutely ridiculous to replace a two-month old spindle because the "vibration guys" saw a few peaks and valleys on a chart. It wasn't making any noise yet, and there were no part quality issues. There were people (as there are in every organization) who were pretty adamant about letting everyone know that "this spindle doesn't need to be changed". In most organizations, that's where it ends; the spindle may get changed, and the predictive analysts are criticized for replacing "good" spindles. Then, if one burns up, they get hammered for that, too! (Can anyone else relate to this?) As your reputation is damaged, it becomes harder to justify the resources needed to maintain or grow an effective program.

In our case study, we not only widely published our vibration reports before and after the spindle replacement, but also the Root Cause Bearing Analysis report. We didn't just get the word out, we provided a plethora of quantitative and qualitative data which supported our assertions and claims. Nothing defuses hearsay better than the facts. And one of my favorite facts to throw around is Cost Avoidance. Show me the money! That's what it's really all about, isn't it? So to aid in changing the mind-set, we maintain a display board in front of the main office that details our latest successes, and emphasizes the cost avoidance.

The new Saturn Sky RL Roadster

Special thanks to my colleagues: Brad Noel, Tom Holloway, and Rick Ratz as well as John Della Villa, Harold Robinson and Joe Conyers of SKF USA Inc. for their technical assistance.

### Summing It All Up

These are exciting times in the world of reliability. With the pressures of ever-increasing global competition, and the constant drive to "do more with less", now more than ever, it makes sense to maximize the effectiveness of your condition monitoring efforts. Whether you monitor machine tool spindles or some other type of rotating equipment with rolling element bearings, the effectiveness of your condition monitoring program will be greatly enhanced by the marriage of Vibration Analysis and Root Cause Bearing Failure Analysis and their offspring:

- A Clearer Understanding of Future Vibration Data
- Improved Root Cause Bearing Failure Analysis Results
- Maximum Mean-Time-Between-Failures
- The Resulting Organizational Paradigm Shift

Finally, here are a few famous words about offspring for those of you "still playing with your slide rules":

"Children are the world's most valuable resource and its best hope for the future." John F. Kennedy

*Andy Calcagno is a predictive analyst certified in four technologies. He is a machine repair journeyman with an Associates in Industrial Technology and over 25 years experience with machining equipment. Once a hardware store manager and talk show host, Andy is a happily married, proud father of two college students who enjoys gardening, good conversation, and his Detroit Tigers! He can be contacted at andrew.calcagno@gm.com*

References

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2. "High-precision Bearings", SKF Publication 5002 E
3. "Bearing Failures and their Causes", SKF Product Information 401

# Full Steam Ahead for GM

## Save Energy Now Program Yields $750k in Savings

*by Howard W. Penrose, Ph.D., CMRP, Robert Varcoe, UAW,
Rick Rosine, UAW & Robert Johnson, GM*

On December 12-15, 2005, the US Department of Energy (US DOE) worked with General Motors' World-Wide Facilities Group (WFG) and the United Auto Workers (UAW) on identifying key opportunities for steam conservation at the GM Flint Assembly plant. Even in this Steam-System Award-Winning facility, significant findings and continuous improvement opportunities totalling over $750,000 in savings were discovered because of the combined efforts of the UAW/WFG Joint Task Teams, GM Energy and Utilities Services Group, Flint Assembly UAW Local #598 and Management and the US DOE.

The UAW/WFG Joint Task Teams were formed during the 1999 National Negotiations between GM and UAW-GM. The focus of the Joint Task Teams include: Construction and Building Maintenance, Tools, Truck Repair & Battery Operations and General Cleaning and Specialty Cleaning. The teams are made up of UAW and management representatives from WFG, who work jointly to develop best practices. The Construction and Building Maintenance team is tasked with construction and building maintenance best practices that are intended to improve the effectiveness of the UAW skilled trades workforce and address related maintenance costs.

In July, 2005, the Construction and Building Maintenance Joint Task Team shifted its focus from the development of construction best practices to maintenance best practices. In the last quarter of 2005, the Joint Task Team developed a series of best practices with information obtained from site visits, industry best practices and US DOE best practice software tools and materials. The US DOE tools identified so far include: MotorMaster Plus 4.0 Diagnostic Tool for electric motor systems; Airmaster Plus Diagnostic Tool for compressed air systems; Pumping System Assessment Tool for pumping systems; and, Steam System Assessment Tools for steam systems.

In November of 2005, the US DOE contacted the Construction & Building Maintenance Joint Task Team to offer an opportunity to have a UAW Represented GM facility selected as one of the first six of 200 sites to take part in a new Steam and Natural Gas initiative called 'Save Energy Now.' The UAW/GM Joint Leadership Council eagerly accepted the offer. The UAW/WFG team was tasked with coordinating the opportunity and the GM Energy and Utilities Services Group was tasked with selecting a site. The Flint Truck Assembly Plant was selected. The plant had previously been awarded the 2001 Chairman's Honors award for their development of a Steam Team, which reduced steam usage by 21% and reduced water consumption by 20% between 1999 and 2000. The focus was Truck Assembly GMT-800 and GMT-560 Lines.

### US Department of Energy Best Practice Tools

The US Department of Energy's Industrial Technologies Program (ITP) maintains an industrial best practices website that contains materials and software developed in cooperation with industry. A number of these tools and best practices have been adopted as UAW/WFG Best Practices for application within all General Motors facilities. While these tools and best practices focus on energy applications, they also have a significant impact on reliability and maintenance improvements as well as the benefit of greenhouse gas emission reduction.

The Best Practice tools selected by the UAW/WFG, at the time of this article, included:

- MotorMaster Plus: An energy-efficient motor selection and management tool, MotorMaster Plus software includes a catalog of over 27,000 AC motors with complete information such as cost, efficiency, nameplate, current draw and other important reliability information. The tool includes such motor management features as inventory, maintenance log tracking, efficiency analysis, savings evaluation, energy accounting and environmental reporting capabilities. In 2000, an industry-funded modification to MotorMaster Plus allowed for the data entry of condition-based maintenance data and the search of motors by condition.

- AirMaster Plus: A comprehensive tool for assessing compressed air systems including modeling existing and future system upgrades. The tool allows for the ability to evaluate savings and effectiveness of compressed air strategies within a facility.

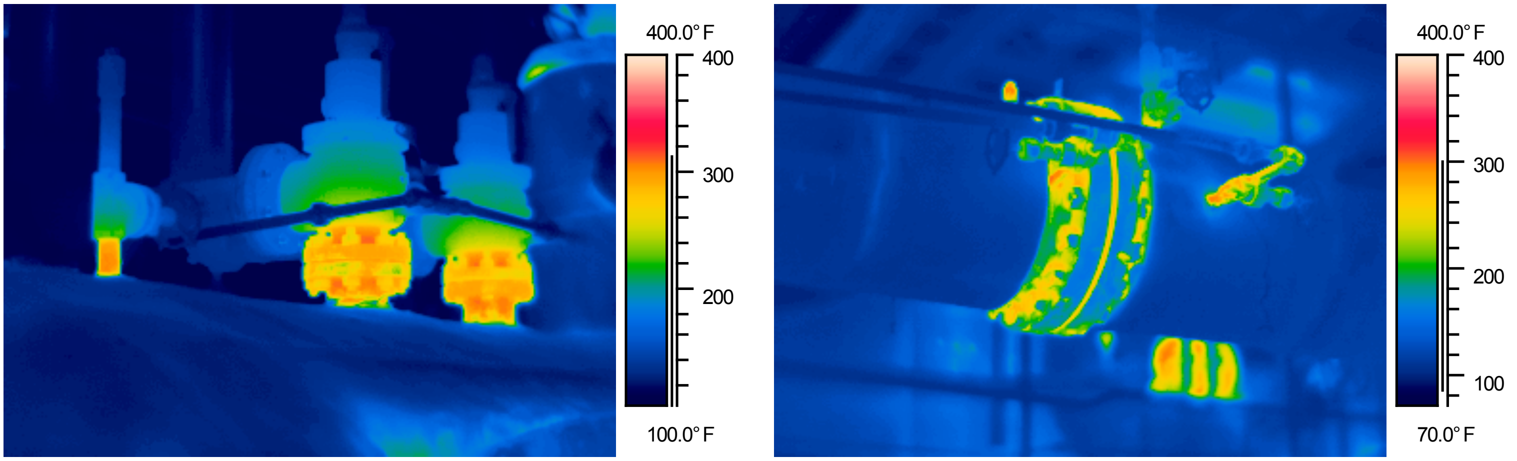



Fig 1 - Images of power house taken during steam system assessmentat GM's Flint Truck Assembly Plant

- Pumping System Assessment Tool (PSAT): This tool assists industrial users in assessing the efficiency of existing and potential pumping systems. PSAT utilizes pump performance data from the Hydraulic Institute and MotorMaster Plus database information to calculate energy and associated cost savings.

- Steam System Tool Suite: This suite of software tools is designed to assist the steam system owner in improvements in both energy and reliability and includes:

—Steam System Scoping Tool: Is designed to provide an initial self-assessment of a plant's steam system through a series of basic questions that are compared to a data base of industry-recognized best practices.

—Steam System Assessment Tool (SSAT): This tool allows steam analysts to develop approximate models of real steam systems. Utilizing these models, the magnitude, energy, cost and emissions can be evaluated and options identified. It includes such features as steam demand savings projects; user-defined fuel models; boiler stack loss work sheet for fuels; a boiler flash steam recovery model; and steam trap models.

—3E Plus: This tool provides simple calculators for determining optimum insulation systems based upon user inputs and a database of insulation materials.

Additional information, as well as the tools and materials, can be downloaded from the US DOE ITP best practices website: http://www1.eere.energy.gov/industry/bestpractices/.

## The Save Energy Now Program

In November, 2005, a national campaign called 'Easy Ways to Save Energy' was unveiled by Dr. Samuel W Bodman, the US Secretary of Energy in order to identify ways that Americans could save energy in the aftermth of Hurricanes Katrina and Rita. One part of this program is the 'Save Energy Now' program, which is designed to provide process steam and heat surveys in approximately 200 energy-intensive industrial users. The focus is to identify immediate opportunities for energy and cost savings within USA industry that can be achieved within 2006.

US DOE provides support by sending trained steam experts to both train the facilities in the use of the tools and to perform, as part of a team, a steam and process heat applications assessment of up to three days. The US DOE has identified these types of systems as consuming nearly 80% of the natural gas energy used by industry. The first round of applications opened on November 8, 2005 and closed on January 20, 2006, combined with a selection of six initial sites for analysis in December, 2005.

"The US DOE reports that aggregate results of the first twelve energy savings assessments identified over $51 Million per year in potential energy cost savings and potential reduction in natural gas consumption of more than 6 Trillion BTU per year," according to a US DOE spokesman, "That amount of natural gas is equivalent to the quantity consumed by more than 80,000 typical US homes."

## The Flint Assembly Plant Assessment

The steam assessment at the Flint Assembly Plant was performed from December 13 to 15, 2005, with training and support provided by the US DOE consultant, Riyaz Papar, PE, CEM of Hudson Technologies, Texas.

On December 13, 2005, a kick-off meeting was held and a schedule was approved for the three-day assessment. The first day consisted of a review of the powerplant system including losses from the boilers. The second and third days involved a look at the steam use throughout the facility, where the team noted a temperature differential in different areas within the facility that were identified as opportunities. On the evening of December 14th, the team reviewed Air Supply Houses (ASH) located on the rooftop and there identified a number of unexpected opportunities that would require minimal to no investment.

The boiler assessment and plant survey required accurate surface temperature data for steam tool calculations. A Flir P65 infrared camera was used to scan and collect boiler insulation data on the first day. Normally used for evaluating rotating machines, conveyor bearings and robots, GM Quality Network Planned Maintenance (QNPM) personnel used the camera on two of the boilers in use at the time of the survey. For the remainder of the plant survey, a Raytek hand-held infrared thermometer was used for data collection of exposed steam piping and condensate return lines. The data was used within the US DOE SSAT tool to establish energy and payback op-

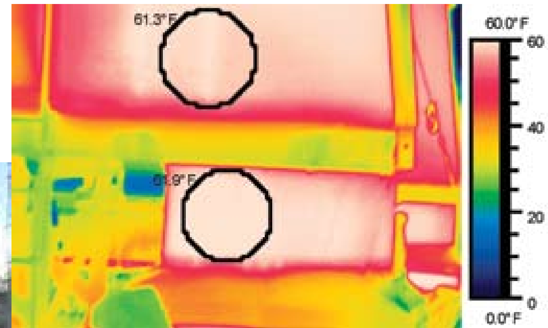



**Fig 2 - Air Supply on roof of Flint Truck Assembly Plant (Visual below, Inrared right)**

portunities through the application of pipe insulation systems.

On the afternoon of December 15, 2005, the close-out meeting was held. Initial recommendations identified savings of over $750,000 within a six month period (winter) if followed. A very conservative $500,000 of these savings was directly related to the air supply houses which yielded an immediate return. Additional findings were identified and presented, some of which represented continuous improvements from existing initiatives.

With the findings at this site, the UAW/WFG Joint Task Team are working with the GM Energy and Utilities Services Group to identify additional plants to perform similar surveys. The US DOE agreed that two additional GM sites would now be included in their program.

## Conclusion

The 'Save Energy Now' program initiated by the US DOE has the potential to have a significant impact on energy costs within energy-intensive industries. The benefits that can be identified within the 200 facilities, including the improvement of steam and process heating opportunities in world-class facilities, such as the GM Flint Assembly plant, should encourage other sites to adopt the best practices provided, at no cost or obligation, by the US DOE.

The UAW/WFG Joint Task Team has identified the opportunities for reliability, maintainability and incidental energy and environmental improvements through the application of the US DOE ITP best practice tools. While these tools make up a few of the many Best Practices adopted by the joint UAW and management team, they have shown immediate and significant impact on R&M, profitability and productivity where they have been implemented throughout the General Motors World-Wide Facilities Group.

For more information on this article, please contact Dr. Penrose at info@motordoc.net or phone 860 575-3087.

*A Simple, Effective Solution For Cleaner, Longer-lived Lubricants*

# The Customizable Filter Cart

Whether you are filtering new fluids before putting them into your machinery, are reconditioning fluid already in use, or transferring fluids from drums to reservoirs, filter carts are a great way to move fluids. They are an easy way to make sure your fluids are clean before putting them into your precious machinery. Cleaner fluids make happier machines. Des-Case now offers filter carts that can be fully customized for your needs via the web. We asked Jon Haworth, Director of Operations at Des-Case, a few questions about their filter carts. Here are his thoughts...

*Why don't we start with you giving us a brief explanation of the benefits from using a filter cart for lubrication handling.*

There are really four benefits that you realize by using filter carts: an easy, time-saving means to transfer oil, a portable off-line filtration system , a cost-effective technique to extend lubricant life and a simple method to contribute to a best practices lubrication program.

*Tell us what makes your Filter cart different from others out there.*

Our online cart customizer is helping to modernize the filter cart industry. Customers are finally able to fully customize their filter cart via any computer with access to the internet. We also offer the option to build-a-cart by a simple order form too. Our user-friendly format gives consumers a maximum return on their investment.

Our filter cart is designed by you, the consumer, which gives you the specific filtration requirements, providing you the most details possible and a solid return of your money.

*When did Des-Case Corporation develop the idea for your customizable filter cart?*

In 1983, entrepreneur and founder Jim Waller created and sold filter carts to customers who needed efficient ways to transfer oil (see pictures). When the interest in breathers superseded filter carts, they ceased to be manufactured, and he concentrated solely on breathers. More recently, we have had the resources and the supply chain management to return to investing in filter carts again. So, in essence, we've returned to our roots.

*Give us a rundown of the options that are available and customizable with the FlowGuard™ cart.*

The use of the Filter Cart Customization tool is very simple and direct. The end user starts by going to the web site and selecting the Oil Handling section of the home page. This directs them straight to the Filter Cart Customization section of the web site. From there, simply follow the steps of the page.

Step one; the customer selects the desired flow rate for the pump as well as the desired power source. The initial options include 2 gpm pump with 1 hp electric motor, 5 gpm pump with 1 hp electric motor, 10 gpm with 1 hp electric motor, 20 gpm with 1.5 hp electric


First filter carts produced by Des-Case founder, Jim Waller, in 1983.

motor, 2 gpm with 1.9 hp air operated motor, or 8 gpm with 1.9 hp air operated motor. Each of the electrical options are available in 110V AC or 220V AC. Each of the pump flow rates and motor configurations specifically states the viscosity rating in SUS and ISO.

Step two; the user selects the drain connector for the suction side of the cart. The options include flush face, ISO A, ISO B, wand, or threaded end. In addition, there are three initial sizes being offered. The sizes are ½ inch, ¾ inch, and 1 inch. The customer can configure any connection type with any size they wish.

Step three; select the fill connector for the pressure side. The same options apply here as for the suction side connectors. It is recommended through industry that the pressure side be sized smaller than the suction side. This ensures that the two never get connected incorrectly. Users will find the web site automatically defaults to one size smaller on the pressure side than on the suction side.

The initial offering allows the customer to select two filters to insure double filtration of the oil. This allows for multiple filtration configurations, which include water removal, as well as a variety of micron ratings.

Steps 4 and 5; select filters A and B. Typically filter A is used as either a water removal filter or as a pre-filter. Since the oil will flow through filter A before filter B, it is recommended that filter A be used to remove either water, or large particulate.

Step 6; the filter cart can be fitted with a filter bypass valve. This will allow for oil to be pumped from one reservoir to another without filtering it. While it is recommended to filter oil any time there is a risk of contaminants being present, it is not always necessary to filter all oil all the time.

Step 7; here the customer selects whether or not the unit is to be fitted with sample ports. By fitting the unit with a sample port, the user is able to sample oil directly from the filter cart. This can be beneficial is that the sample is able to be drawn from an agitated oil supply, which will offer a more representative sample.

Step 8; the customer selects electrical cord storage options. This can involve a cord wrap, or a convenient 25 foot cord reel.

Step 9; choose whether the unit should be equipped with a relief valve. This is a safety relief valve designed to relieve pressure at 65psi. This option is very good for preventing excess pressure build up in the filter cart. The relief valve is simply designed to provide piece of mind that the unit will function with no concerns of excess pressure build up.

Step 10; choose the color of your filter cart. This is a good time to assign a color for each cart and lubricant in use. Currently there are six colors to choose from, but additional colors can be selected through personal service.

*What kind of impact can the FlowGuard™ filter cart have on overall plant and machinery reliability?*

Filter carts ensure higher levels of cleanliness when used in daily operations. They are the ideal way to pre filter and transfer fluids into reservoirs. Fluids should always be filtered upon arrival and before putting into service. Contamination, both particulate and water, may be added to new fluid during processing, mixing, or handling. This contamination can be prevented or removed with the use of one or more of our filter carts.

Filter carts are an integral part of the reliability chain. Most plant personnel are aware of the need for keeping lubricants clean, but they might not recognize that utilizing a filter cart saves an enormous amount of time in comparison with using the typical fluid transfer routines.

*Tell us how a company can justify the cost to purchase the FlowGuard™ filter cart.*

When discussing a proposed filter cart purchase, management might feel that it's not necessary because the plant has not come across any lubrication-related problems yet. However, purchasing a high-quality FlowGuard™™ filter cart is a proactive step companies should take toward meeting best practices guidelines, which can also be considered a safeguard against a multitude of problems, including equipment failures and plant shut downs. Once in the plant, the customized filter cart can bring added benefits; including cost and time savings, quality return on investment, and increased uptime.

*What types of industries have shown the most interest in the customizable filter cart?*

So far we have seen a great interest from mining, power gen, and the military sectors.

*How can our readers get more information about the filter cart?*

We offer electronic and print versions of our catalog, filter cart order form, and readers can access the Cart Customizer at www.des-case.com can contact us through our website or call

The IMI Sensors Division of PCB® Piezotronics, Inc. launches the all new 686A Series two-wire electronic vibration switch. This ground-breaking switch technology is microprocessor controlled with no moving parts or mechanical adjustments required. The introduction of the new two-wire switch is revolutionizing the vibration switch market by combining the reliability and dynamics of an electronic switch with the convenience of a mechanical switch, in one innovative compact design.


**IMI Sensor Division** **800-959-4464**
**PCB Piezotronics, Inc.**
**imi@pcb.com** **www.pcb.com**


## 3-D Service Upgrades Web Site, Adds Equipment Maintenance Forum

Have an electric motor that is running too hot? Too much moisture in your compressed air system? Need to decide between a single- and three-phase power system? 3-D Service has upgraded its website with a new section titled: Ask the Pros. Ask the Pros provides plant maintenance and operations personnel 24/7 equipment troubleshooting support through a series of frequently asked questions and also lets site visitors ask questions and receive answers. Ask the Pros equipment topics include: Motors, Generators, Power Systems, Compressed Air Systems, Mechanical Equipment and Specialty Equipment.

**www.3-dservice.com**

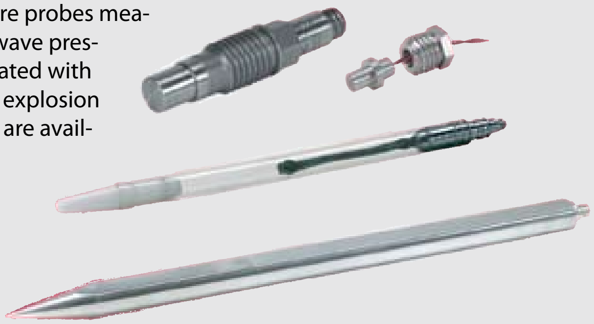
Automatic self cleaning filtration system from Riveer Environmental eliminates the toughest maintenance issue with filtration systems. Mud from the settling chamber is automatically conveyed to an external self dumping hopper for easy disposal.
The Cyclonator III system has a large 850-gallon stainless steel settling chamber with inclined plate sheer walls. The Cyclonator III is easy to operate and easy to maintain. A robust, stainless steel structure ensures years of corrosion- and trouble-free operation.

**Riveer Environmental**
**888.857.7304**
**sales@Riveer.com**
**www.cyclonator.com**

## High-Frequency Explosion, Blast, and Shock Wave Pressure Sensors

High-frequency sensors from the Pressure Division of PCB® Piezotronics, Inc. are designed for a broad range of explosion, blast, and shock wave testing. Applications include free-field and underwater blast testing, shock wave and time-of-arrival measurements, shock tube research, closed bomb testing, and squib lot acceptance testing.

General purpose ICP® and charge output blast sensors feature extremelyfast response, with resonant frequencies to 500k Hz. ICP® microsensors provide rapid rise times of ≤ 0.5 microseconds for projectile detection and time of arrival measurements. Free-field blast pressure ICP® pencil probes measure blast effects on structures, vehicles, and humans, and feature integral microelectronics for long cable driving. Underwater blast pressure probes measure shock wave pressures associated with underwater explosion testing, and are available in ICP® and charge output versions.



**Pressure Division** **PCB Piezotronics, Inc**
**888-684-0011** **pressure@pcb.com** **www.pcb.com**

## The 24th CMVA Machinery Vibration Seminar and Annual General Meeting

"From Theory to Reality"
October 25 to 27, 2006
Montreal, Quebec, Canada

www.etsmtl.ca/evenement/acvm2006

If you have an interest in the operating performance of machines, we encourage you to attend this year's Annual General Meeting and Seminar of the CMVA, to be held in Montreal.

**Marc Thomas, Professor,** **École de technologie supérieure**
**Dept of Mechanical Engineering** **marc.thomas@etsmtl.ca**

NILOS®-Ring "Type LSTO" steel-disk seals can provide superior protection for grease-lubricated bearings exposed to extreme levels of contamination. Applications for these specialized bearing seals include lubrication and fluid power equipment; construction, mining, paper, and agriculture machinery; and conveyor rollers, among others. Type LSTO steel-disk seals satisfy key performance requirements by minimizing bearing friction losses and heat build-up and preventing lubricant leakage and penetration of dirt.

**Kody T. Fedorcha, SKF Linear Motion & Precision Technologies**
**800-541-3624 or 610-861-3733**
**www.linearmotion.skf.com**

### Kittiwake's New ANALEXrs Moisture Sensor

Paul Froome
Tel: +44 1903 731470
paulf@kittiwake.com
www.kittiwake.com

Remote online sensor technology is increasingly being recognized as the way forward in the 21st Century and Kittiwake has merged the features of their current onsite and lab based equipment to develop the ANALEXrs online moisture sensors. Water contamination in critical fluids certainly produces problems; additive depletion, oxidization, bacterial growth, component wear and corrosion to name but a few, but the ultimate issue is critical failure of your plant!

Moisture sensors can be used in Hydraulic Fluids, Lubricating Fluids, Dielectric Fluids and Fuel Oils, they need not be in the oil itself, and are of use in the headspace of a piece of machinery, for example, in a gearbox High moisture levels through a failed breather to the airspace above oil will dissolve into the oil – so this is a good place to monitor moisture – before it gets into the oil.

The intelligent Moisture Sensors are constructed from high grade stainless steel, designed to screw directly into the oil flow and are extremely robust in all conditions. The inherently stable nature of the materials and technology employed in the sensor negates the need for periodical recalibration, thus the sensor can be permanently installed, and is considered maintenance free robust in all conditions.

The Vibration Division of PCB® Piezotronics, Inc. introduces a new nose cone designed to be used with ½" (6 mm) condenser test and measurement microphones. The Model 079B21's aerodynamic shape is designed to minimize noise from wind and other high-speed laminar flows, while allowing the sound intended to be measured to pass through. The nose cone also protects and minimizes damage to the diaphragm due to sand, dirt and other contaminates.

**Vibration Division** **888-684-0013** **www.pcb.com**
**PCB Piezotronic, Inc.** **vibration@pcb.com**

Onset Computer Corporation has introduced the HOBO® U-Shuttle, a new data transport device for use with HOBO® data loggers. The new Shuttle allows users to offload HOBO U-Series and FlexSmart data loggers at multiple locations in a facility and safely, transport the data back to a PC or Mac computer for analysis. Key features include a bright LCD display that provides current sensor readings, battery and logger status, memory capable of storing data from multiple data loggers, convenient, direct USB connection to host computer and easy and fast offload with Onset's HOBOware® software.

**Onset Computer Corp** **1-800-LOGGERS**
**sales@onsetcomp.com** **www.onsetcomp.com**

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


**Jon Chynoweth**
**888.506.3900**
**jon@mikroninfrared.com**
**www.mikroninfrared.com**

The Force/Torque Division of PCB® Piezotronics, Inc. offers a series of strain-gage reaction torque sensors for torque measurements on accessories such as Starters, Alternators, Air Conditioning Compressors, Power Steering Gearboxes, and Water Pumps. Series 2300 and 2500 reaction torque sensors feature high torsional stiffness, flange mounting, and are available in full-scale capacities from 5 to 500 k in-lb (0.56 to 56.5 k N-m).

**Force/Torque Div** **888-684-0004** **force@pcb.com**
**PCB Piezotronics** **www.pcb.com**

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