uptime®

aug/sep 10

the magazine for maintenance & reliability professionals

Get a Grip on Electrical PdM

Find the Right Infrared Camera

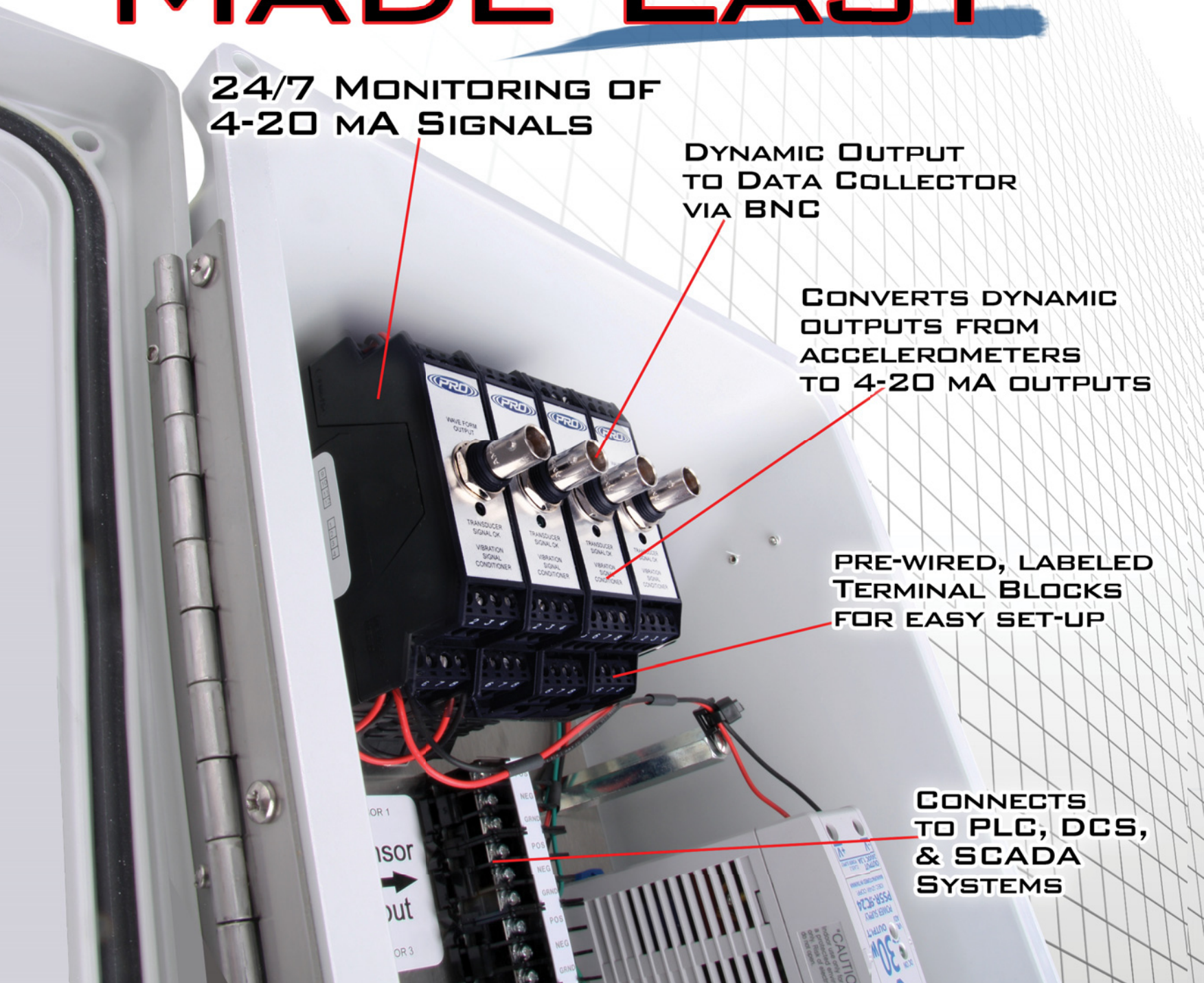
Preserve Efficiency in Motor Repair

Reliability Engineering Pays Off

Where Is Your Ultrasound Program?

XE150 Signal Conditioner Enclosure

4-20 mA Vibration Monitoring Made Easy



PRO OFFERS
COMPLETE 4-20 mA MONITORING

WHY USE 4-20 mA?

4-20 mA Systems Provide You With Continuous Vibration Monitoring or Equipment Status

- Interface With Your SCADA, PLC or DCS
- Day-to-Day Trending, Equipment Performance Over Time
- Gives Standard, Consistent Output from Accelerometers, Peizo Velocity Sensors, Proximity Probes, or Dual Output Temperature & Vibration Sensors

XE150 SERIES
SIGNAL CONDITIONER ENCLOSURE

Converts dynamic outputs from accelerometers to 4-20mA signals. It comes **pre-wired & labeled** to make your 4-20 mA Monitoring System **easy to install & use.**

- Provides 4-20 mA signals & output
- Link to PLC / DCS systems
- Holds up to 12 signal conditioners

ADDITIONAL ENCLOSURE OPTION:

MVR1000 SERIES
COMPACT VIBRATION MONITORING SYSTEM

- Dynamic external links
- For use with standard accelerometers

ALTERNATIVE 4-20 mA MONITORING SOLUTIONS

LOOP POWER SENSORS
LP202 SERIES, LP204 SERIES, LP252 SERIES, LP254 SERIES, LP302 SERIES, LP304 SERIES, LP352 SERIES, LP354 SERIES

- Peak & RMS outputs available
- 4-20 mA output proportional to overall vibration amplitude
- Use to monitor most critical frequencies

DUAL OUTPUT SENSORS
LP401 SERIES, LP402 SERIES, LP404 SERIES

- 4-20 mA velocity & acceleration with dynamic outputs
- Can output to PLC, DCS, SCADA
- Analytical tool

PROCESS CONTROL ENCLOSURE
PMX1000 SERIES

- Accepts 4-20 mA output from Loop Power Sensors
- Relays trigger alarm or shutdown
- Sunlight readable display

CTC
CONNECTION TECHNOLOGY CENTER, INC.

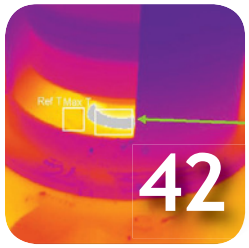
LIFETIME WARRANTY

PRO
PROTECTION & RELIABILITY OPTIMIZATION INSTRUMENTS
A CTC COMPANY

CONNECTION TECHNOLOGY CENTER, INC.
7939 RAE BOULEVARD - VICTOR, NY - 14564
US & CANADA: 1-800-999-5290 INTERNATIONAL: +1 585-924-5900
WWW.CTCONLINE.COM

contents

uptime



Putting Safety First

This issue's feature article outlines the nuts and bolts of implementing an integrative approach to properly maintaining an electrical distribution system. The main focus is on condition monitoring with predictive technologies. Of course, this topic is one about which we at Uptime, and hopefully all of our readers, are quite passionate.

We love it because of the many tremendous benefits it offers companies that implement it correctly. You know, the benefits that all of us are quite familiar with: higher uptime and availability, lower overall maintenance costs, less overtime (more family time) and increased bottom line profits.

There is another, even more important, benefit that sometimes gets overlooked in all of the discussions that usually center around finances. Safety.

At the time of this writing, BP is installing a cap on the Deep Water oil spill that they hope will end the devastating, months long spill. This is truly a tragedy of epic proportions. Of course, the environmental impact is monumental, and will continue for decades, affecting millions of lives, both human and non-human.

But, let's not forget the 11 people who lost their lives in the initial explosion. They are gone forever, and their loved ones are left to pay the emotional costs for the rest of their lives. Eleven families were devastated that day and untold numbers of families have been affected since, because, somewhere along the chain of command at BP, safety stopped being the top priority.

Safety should always be at the top of the list because nothing is more important. Sometimes it can seem like the chances of having an accident aren't very high. But the odds will catch up to us eventually. And when they do, the consequences can be enormous. Just ask BP.

Predictive technologies and the professionals that utilize them, not only make facilities more efficient, but they make them safer. So be sure to include safety at the top of the long list of benefits that predictive maintenance brings to the table.

I hope you enjoy this issue. As always, thank you for reading. We appreciate your support, and hope you find value within these pages, the digital issue and on our website. If you have any questions, comments or suggestions that will make Uptime more useful to you, please let us know.

All the best,

Jeff Shuler
Editor In Chief
jshuler@uptimemagazine.com

uptime®
volume 5, issue 42

PUBLISHER
Terrence O'Hanlon

EDITOR IN CHIEF
Jeffrey C Shuler

EDITORIAL ADVISORS/
CONTRIBUTING EDITORS
Ron Eshleman
Terry Wiireman
Winston Ledet
Jack Nicholas, Jr.
Joel Levitt
James Hall
Heinz Bloch
Jay Lee, PhD
John Mitchell
Jason Tranter

ADVERTISING SALES
Bill Partipilo
888-575-1245 x 125
Intl 239-333-2500 x 125
sales@uptimemagazine.com

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

Jeff Shuler, Editor In Chief
Uptime Magazine
PO Box 60075
Ft. Myers, FL 33906
888-575-1245 x 116
Intl - 239-333-2500 x116
jshuler@uptimemagazine.com

SUBSCRIPTIONS
to subscribe to Uptime, log on
www.uptimemagazine.com

SUBSCRIPTION UPDATES
subscriptions@uptimemagazine.com

Uptime Magazine is a founding member of

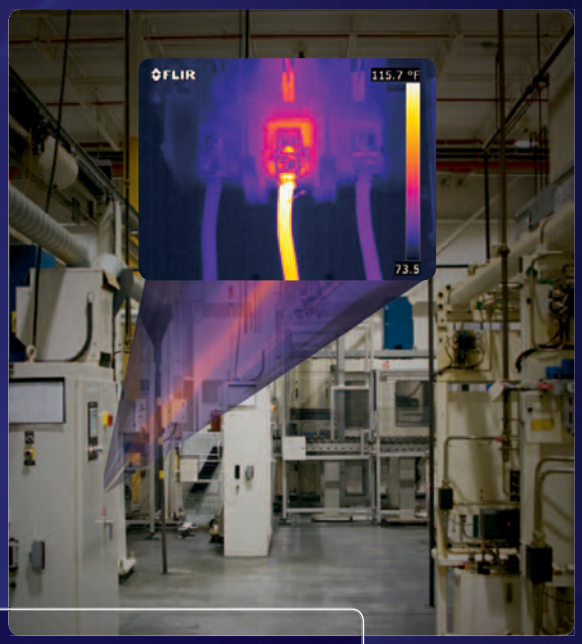
The Association for Maintenance Professionals
Facilitate • Connect • Share

Uptime® (ISSN 1557-0193) is published bimonthly by Reliabilityweb.com, PO Box 60075, Ft. Myers, FL 33906, 888-575-1245. In the U.S. Uptime is a registered trademark of Reliabilityweb.com. No part of Uptime may be reproduced in any form by any means without prior written consent from Reliabilityweb.com.
Uptime is an independently produced publication of Reliabilityweb.com. The opinions expressed herein are not necessarily those of Reliabilityweb.com.

POSTMASTER: Send address changes to: Uptime Magazine PO Box 60075, Ft. Myers, FL 33906.

FLIR's Mission

Catching problems before they turn into nightmares



Know what elite warfighters and plant engineers have in common? No room for error. The #1 manufacturer of infrared cameras in the world, FLIR has been helping engineers and technicians keep aging production lines moving during the worst economy in decades; the cost of failure is catastrophic to families and businesses alike. It's no surpise that FLIR is the #1 manufacturer of infrared cameras in the world.

FLIR provides the same powerful technology that special operations forces use in battle. There are over 250,000 FLIR cameras in the field and on factory floors, all supported by the world's largest Thermography training organization.

i-Series
Point and Shoot

T-Series
Professional

P-Series
Expert

Visit www.flir.com or call 800.464.6372 to schedule your free demo and find out why FLIR has been the most trusted name in thermal imaging for 45 years.

FLIR®

Our Keynote Speaker is America's most trusted contractor, Mike Holmes, host of Holmes on Homes™!

InfraMation 2010

Bally's Hotel, Las Vegas, November 8-12, 2010

Limited Time Offer: FREE Hotel Nights & Spouse Pass

866-872-4647 | www.inframation.org

Join us as we show you what's new, practical, and astonishingly profitable at the world's largest infrared camera applications conference.

Taking

Increase Safety & Reliability with Integrative Predictive Maintenance

Electricity and its uninterrupted distribution through our nation, facilities and lives are inescapable requirements, and the backbone of progress, in today's society. The resurgence of US commerce is not possible without it. Safe and reliable electrical distribution systems typically start out as being well engineered, with bright futures provided they receive regular, adequate maintenance and periodic testing.

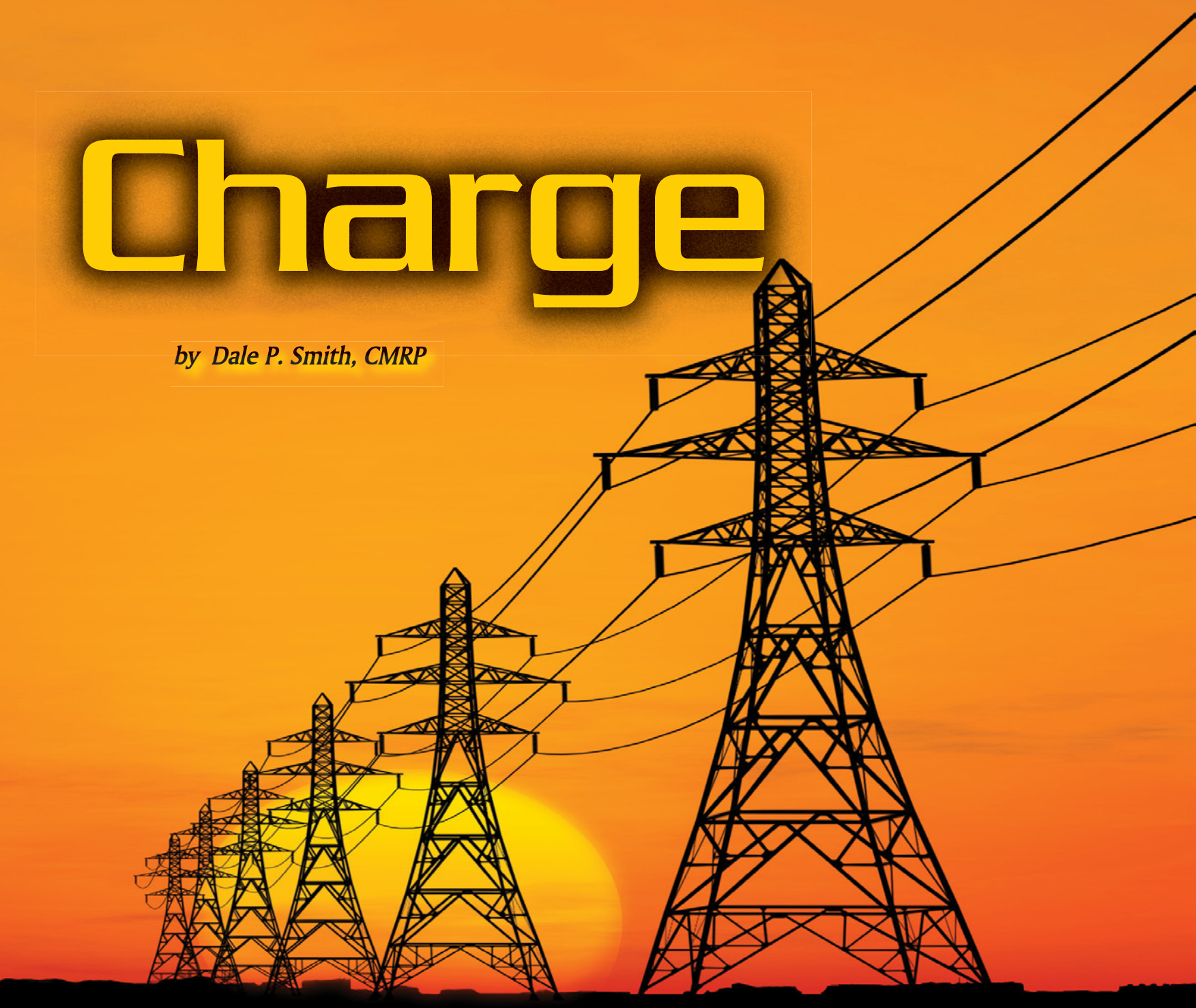
Over time electrical infrastructure changes, facilities expand, load requirements increase and equipment becomes degraded with age or lack of maintenance. It's not uncommon to find functioning electrical distribution equipment that hasn't been maintained and tested, is obsolete, or is well beyond its designed service life. Electrical systems that were appropriate for the loads and incoming power when they were installed may now expose employees to life-threatening hazards. Often, there is no indication of a potential problem until a fault occurs and the overcurrent protective device fails to operate, resulting in injury or damage to equipment and property. Safety, maintenance and reliability professionals can proactively change this scenario and enhance layers of protection (LOP) and sustainability of their electrical systems by deploying an integrated condition monitoring (CM) strategy with predictive maintenance (PdM) technologies.

Just a Few Numbers

Reviews of insurance/risk statistics and every day media headlines remind us of the extreme failures and unfortunate circumstances caused by the mismanagement of electrical distribution systems.

Charge

by Dale P. Smith, CMRP



For example, insurance statistics between 1992 and 2001 identify that electricity was the leading cause of fires and explosions causing nearly 1,400 insurance losses costing over $788MM[1] (~$1 Billion in 2009 dollars).

From a people perspective, Canada's Ministry of Labor reviewed a decade of electrical incident records to find that 50% of the 1,200 electrocution deaths and critical and minor arc flash injuries came from performing basic maintenance and repair on or around energized equipment. An interesting statistic is that 79% of the fatalities involved occupations outside of the traditional role of electricians. These included maintenance workers, millwrights, apprentices, laborers, heat, ventilation and air conditioning (HVAC) technicians, equipment operators, supervisors and drivers." [2]

These events are a mix of management and human errors and equipment failures which weaken existing "barriers" or layers of protection for personnel safety. Successful organizations recognize that ensuring sustainable asset and safety cultures starts with understanding these gaps, the types of exposures, and the electrical system failure modes and associated hazard potentials that may increase the risk of an incident.

Failure Modes and Hazard Indicators

Any device involving electrical current can overheat and spark a fire. Before changing or deploying new LOP, facility leaders must understand how and why electrical assets may fail. The good news is that most systems have known failure modes and are accompanied by early warning hazard indicators.

Electrical Leakage –

a. Electrical Arcing occurs in all voltages. Extreme arcing produces a stream of vaporized metal between conductors and through air or bulk insulation systems, destroying electrical equipment. Arcing can cause overloads, defective contacts, uninterrupted faults and overheating.

b. Tracking is often referred to as "baby arcing" and follows the path of damaged or dirty insulation across component surfaces. Tracking occurs most often in medium voltage (MV) to high voltage (HV) equipment of 1,000 volts (1kV) or greater.

c. Corona is the partial discharge, electrical stress or leakage of 1kV or more at sharp points along an electrical path. It is commonly explained as being intermittent, un-sustained arcs which are shot off of the conducting material like a stream of electrons. It occurs inside electrical components such as transformers, switch gear, and insulated busbars.

The leakage ionizes the surrounding air, producing faint sparks, cracking, hissing, humming, frying noises, radio/TV interference, conductor vibration and ozone. In case of visible corona, the conductor will glow with a blue or green light.

Corona also forms ozone (O3), which will conduct current and can follow a direct path to ground, resulting in catastrophic results, especially in enclosed switchgear. Corona also produces nitrogen oxides, and in an aqueous form, nitric acid. This further destroys the insulating material and metal components causing possible thermal problems.

2. Overheating: The Real Equipment Killer – Every 18°F (10°C) rise above equipment's nameplate operating temperature will reduce the its operating and insulation life by 50%! Typically, this overheating is caused by high resistance within conductors or at over-tightened or loose connections, uninterrupted fault currents, and environmental factors (see item #5). 70% of thermal anomalies are due to loose connections.

3. Uninterrupted Fault Current – causes enormous amperage spikes which rapidly heats components to very high temperatures destroying insulation, melting metal, starting fires and even causing explosions if arcing occurs. These are caused when a circuit breaker, relay or fuse unsuccessfully interrupts current.

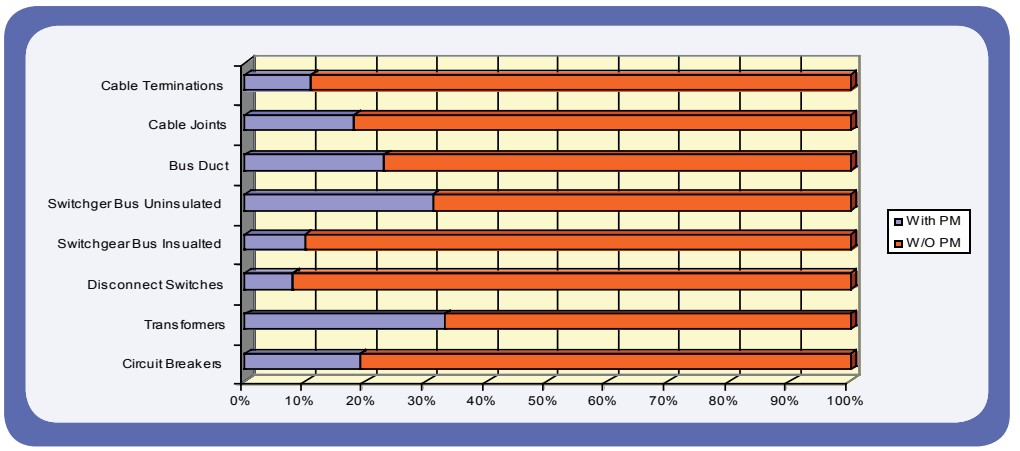


Figure 1 - Equipment Failure caused by lack of Preventive Maintenance

4. Voltage Irregularities – are caused by unstable utility supply, line surges, lightning strikes, transient voltage, unbalanced loads and harmonics.

5. Environment Factors – include contaminating conditions like excessive dust, dirt and debris, high or low ambient temperatures, humidity, corrosive atmospheres, water, vibration, high-resistance connections and contacts.

6. Operational and Maintenance Factors – include overloading, equipment malfunction, inadequate sizing, jumpered or modified systems and lack of maintenance. Based upon a review of fires caused by failed electrical components, 70-90% were due to lack of maintenance (Figure 1).[3]

Condition Monitoring with the Integrated PdM Tool Box

Condition monitoring (CM) with predictive maintenance (PdM) technologies is an important maintenance strategy for management of components in the distribution system. CM is an early warning system only triggering maintenance activities based upon condition. This allows maintenance and reliability managers to identify maintenance priorities, plan work assignments and schedules, arrange for outside services, order necessary parts and materials and make repairs on a controlled outage basis.

Thus, it typically extends the interval between successive maintenance and, therefore, incurs less cost. Self-induced failures ("infant mortalities") caused by improper installations are also minimized. From a safety perspective, this equals fewer times personnel are working on or near energized equipment.

Summary of CM/PdM Toolbox Benefits for Program Leaders

- Increased Safety
- Greater System Reliability
- Increased Revenue
- Reduced Outage Costs
- More Efficient Inspections
- Improved and Less Expensive Maintenance
- Reduced Spare Parts Inventory
- Reduced Operational Costs

At this point, we know the typical contributing factors/failure modes and the equipment categories affected most. The next step is to determine which PdM technologies are the best at capturing equipment failure modes/indicators. Although there are numerous CM/PdM approaches, the following are discussed in detail: Common Senses, Infrared Thermography, Ultrasound, Oil Analysis and Motor Circuit Analysis.

Making "Dollars and Senses" of the Situation – One of the most important set of tools in a facility's PdM tool box is each person's common senses. From a reliability perspective, these include seeing, hearing, smelling, touching, and common sense. Merge the senses with a little awareness training and they can identify general early warning indicators in up to 70% of all safety and reliability problems.

When it comes to identifying potential OSHA and NEC violations and associated fines, these low-cost senses are unmatched by most hardware and software system. Most of the fines carry a "minimum possible" fine of $2,000 each. This equates to an average exposure of $10,000 for every 100 pieces of electrical

equipment inspected[4]. The findings are very apparent and are a great indicator of a site's safety and reliability culture.

The drawbacks are that senses are subjective and identify late stage failures increasing the hazard exposures and minimizing trending and early warning information.

The following lists basic physical conditions easily identified with "senses":

- Discoloration of connections, terminations and live parts on the air switches.
- Poor wiring practices (Figure 2) and conditions (Figure 3) such as burnt and cracked wires, mismatched components, missing covers, and "rats nest" of loose wires.
- Broken skirts on insulators and cracked insulation.
- Excessive vibration denoted by noise, and usually causes loose connections to appear on live parts, laminations and improperly supported buses inside transformer housings.
- Gray power on outside of cable indicating corona or arcing.
- Sounds of arcing are indications of corona, which leads to ozone. Ozone puts a sharp taste in the back of your throat. OSHA has limits on ozone - somewhere around 20 parts per billion (ppb) which is far below the level at which it can be smelled.
- Poor Housekeeping – Excessive dirt, grease, dust, fibers on components. The surrounding area should be evaluated for accumulation of trash or combustible storage, clearance violations, component integrity, poorly sealed panels allowing dust ingress, etc.
- Poor Operating Environment - Hot room temperatures, corrosive and moist atmospheres.

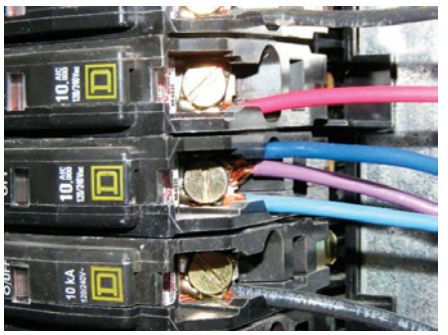


Figure 2 - 1 wire per terminal (NEC 110-14a) Minimum Possible Fine: $2,000

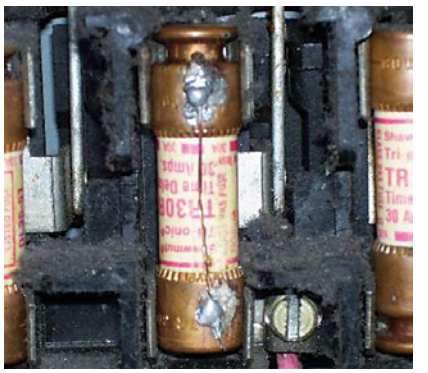


Figure 3 - Soldered Wired Jumpering Fuse Lack of Component Integrity (NEC 110-12c) Minimum Possible Fine: $2,000

- Lack of Documentation – Missing or outdated system/component specification sheets, OEM manuals, service logs and drawings.

Infrared Thermography (IR) – Normal operating electrical equipment radiates energy as heat, specific to that piece of equipment. This temperature range varies based upon the component size, rating, ambient temperature, and amperage loading. Infrared thermography is fast, accurate and picks up these temperatures and risk factors without interrupting

service. IR is a recommended best practice by NFPA[5], helps facilities comply with insurance company recommendations and eliminates over-heated connections wasting energy[6] and reduces carbon footprint exposures for every kilowatt not consumed.

Ultrasound – Ultrasound is extremely valuable for inspections of medium and high-voltage electrical systems. Ultrasounds occur in wavelengths above 20,000 Hz frequency, which are higher than human hearing. Loose connections and the deterioration of high voltage insulation, cables, broken sheds or contaminated porcelain produce an electrical leakage known as corona and tracking. This leakage creates turbulence, friction or "white noise" in the air which is picked up by the ultrasound receiver.

Ultrasound is also a great resource when operational or safety factors prevent the use of infrared on enclosed, energize electrical equipment. The receivers have rubber cone-shaped adapters to scan through door gaps and air vents helping to detect the presence of arc flash hazard potentials.

Transformer / Switch Oil Analysis – Oil is used to cool and insulate the internal components of transformers and certain types of switches. Because it bathes every internal component, the oil contains a great deal of diagnostic information. Just as a blood test provides a doctor with a wealth of information about the health of a patient, a sample of transformer oil can tell a great deal about the condition of a transformer.

The oil analysis is broken into two parts.

1) Physical, electrical and chemical tests that evaluate oil for indicators of dielectric (insulation) breakdown, power factor, interfacial tension, acidity and color.
2) Dissolved gas analysis (DGA) looks for certain gas quantities and combinations that can determine the likely failure mode (See Figure 4).

Key Gases	Most Likely Failure Mode/Cause
Hydrogen (H2)	Partial Discharge (Corona)
Methane (CH4)	Overheating
Acetylene (C2H2)	Arcing
Ethylene (C2H4)	Localized Overheating
Ethane (C2H5)	General Overheating
Carbon Monoxide (CO)	Cellulose Overheating
Carbon Dioxide (CO2)	Oil and/or Cellulose Overheating

Figure 4 - Dissolved Gases and Probable Causes

PdM Toolbox	Primary Equipment Toolbox				
	Incoming HV/ MV Service	Cables/ Busbars	Trans-formers	Circuit Breakers /Fuses	Motors
Senses	X	X	X	X	X
IR Thermography	X	X	X	X	X
Ultrasound	X	X*	X	X	
Oil Analysis			X	X*	
Motor Circuit Testing					X

* Oil analysis on oil-filled MV / HV CB

Figure 5 - PdM and Electrical Equipment Matrix

Motor Circuit Analysis – Motor circuit and motor current analysis (universally termed MCA) evaluates the integrity of the cabling and insulation starting at the motor control center (MCC) components on down to the motor's rotor and stator windings and grounding. Defects and faults include developing shorts, resistive unbalances, insulation to ground faults, cable defects and rotor defects. MCA can be applied to any size or voltage motor, capturing over 50% of all potential electrical and mechanical motor faults.

Figure 5 shows a matrix of the PdM technologies and which electrical equipment that each technology can evaluate effectively.

Facility Survey Highlights

For purposes of this article, a typical facility distribution system includes medium voltages (MV) at a property's substation or pole/pad mounted transformer on down to 120 volt branch circuits. This voltage range covers hundreds of system types but for simplicity, the equipment and PdM concepts are segmented into the following key equipment categories: main medium-voltage incoming service, transformers, conductors, circuit breakers/fuses/disconnects and motors.

Main Medium-Voltage Incoming Service

A facility's main service is comprised of equipment that transfers high- or medium voltages down to lower voltages used within the facility. This equipment includes bushings, insulators, steel support structures, high voltage lines, step-down transformers, and switch gear (interrupting, control, metering protective and regulating devices and assemblies). This equipment is designed to be outdoors either directly or in weatherproof housings.

Typical issues include dirt, dust, debris, and salt residue (coastal regions or equipment near salted roads) coating connections and lines increasing the chances of corona, tracking, and arcing (Figure 6). Partial discharge accounts for the largest percentage of disruptive failures of medium voltage switchgear.

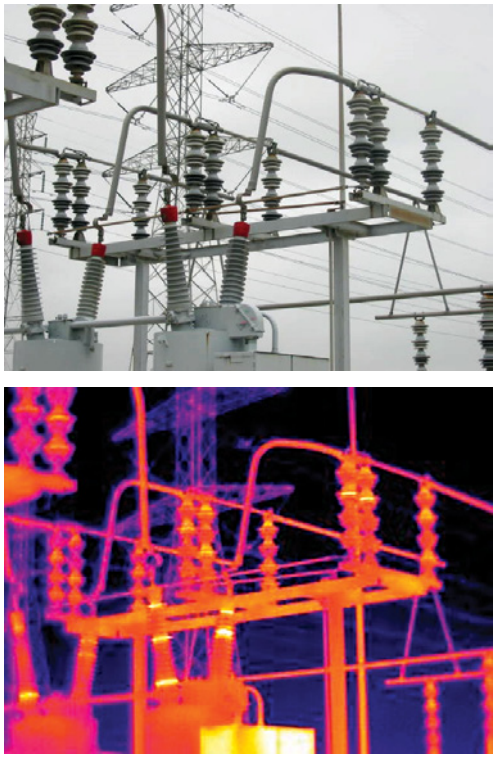


Figure 6 - Visual (top) and IR (bottom) Images of HV Bushings/Insulators Showing Tracking on HV Insulators.

Look for broken bushings, insulators, arrestors, vandalism and weather damage.

Failure Example: Lights Out during Peak "Sold Out" Production – In the example shown in Figure 7, mist from cooling towers caused the pole insulators to become dirty, in turn, causing arcing and tracking across the insulators. The pole caught fire which weakened the transmission line supports. The top "T" section tipped 90 degrees causing phase-to-phase shorting. The plant was in a "sold-out" condition and was completely down for 8 hours and didn't get full production for over 24 hours. The new procedure requires quarterly IR and ultrasound and semi-annual PMs with qualified contractors cleaning the "live" insulators.

Figure 7 - Tracking and Arcing Caused Pole to Ignite and Collapse Horizontal "Tee" Support.

Transformers

Facilities use dry-type or oil-filled transformers to step-up or step-down voltages to meet the specific needs of a site. Transformers have an estimated 20-30-40 year life expectancy under normal operating conditions. Transformers run hot and require proper air and/or fluid circulation to ensure they don't overheat.

Step-down transformers are comprised of insulated primary windings (higher voltage) and secondary windings (lower voltage), iron core laminations, tap changers, bushings, and connections, but typically, no mechanical moving parts. The physical design of transformers presents the potential for primary-to-secondary shorts from insulation failure. As they age, their ability to withstand heat, and stresses such as being exposed to mechanical vibration, switch surges, line surges and limited short circuits also reduce life expectancy.

Oil-filled Transformers - Oil-filled transformers have radiators, cooling fins filled with mineral oils or insulating fluids. The windings are wrapped with pressboard paper and have spacers to provide physical dielectric clearance distances to withstand movement. The insulating fluids are cooled by fans and/or ambient air which ensure oil's dielectric strength and preserve transformer paper and windings. Larger or utility transformers may also have pumps to circulate fluids. The preservation of windings, load tap changers, and accessories is crucial to transformer performance, but still end up being 50% of all failures and insurance losses[7].

Oil-filled transformer Issues - Mineral oils are the most common insulating fluids and present the greatest fire hazards due to their flammability. Incipient faults, internal arcing and overheating produce explosive gases, increasing the probability of tank rupture, which could lead to an ignition of transformer insulating fluid. Many oil-filled transformers are sealed with an inert blanket of nitrogen. Ultrasound is used to identify failures of the rubber bushings, allowing nitrogen to escape and be replaced with oxygen.

Visual Inspections - Make a through inspection of the transformer and the surrounding area, looking for possible incident indicators such as animal carcasses, bulged tank or cover, discolored tank, fallen tree limbs, vegetation, vandalism, oil leaks, burnt oil aroma, cracked or broken bushings and any short circuits in the secondary or service-side. Additional information to consider includes extreme weather conditions (storms, lightning, snow, ice, outdoor temp and air humidity), excessive loads, lack of maintenance, ageing, and wear out.

Infrared Thermography - Similar to the switchgear, use the thermography to examine high- and low-voltage external bushing connections, as well as external surfaces such as cooling tubes, fans, and pumps. IR testing is great for identifying low and high-temperature areas caused by a fault, bad oil or foreign materials blocking cooling passages in an oil-filled transformer (Figure 8).

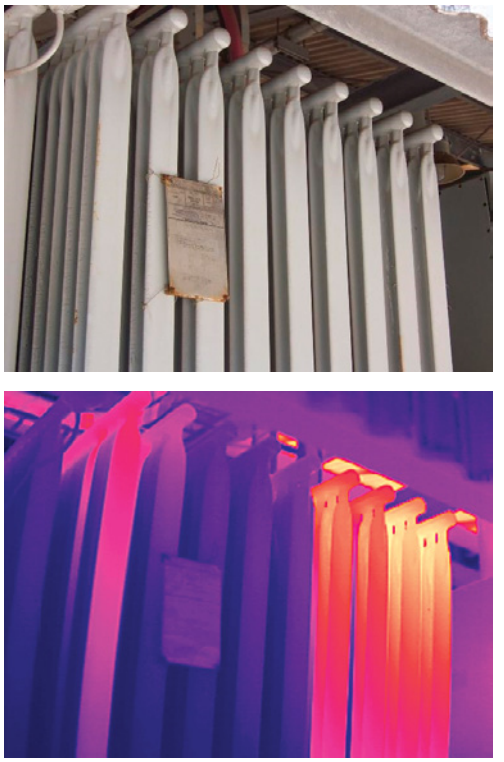


Figure 8 - Blocked Passages
(in both images, darker = cooler)

Dry Transformer Hazard Indicators - Dry-types use ambient air and convection currents (sometimes fans) to keep laminated windings cool. Check to assure maximum ventilation air flow by ensuring air intake grates are not obstructed. Observations of dust, dirt and debris on windings, which prevent cooling, could combust causing a fire (Figure 9).

Conductors (Cables and Bus Bars)

Cables and bus bars are the crucial superhighways of power distribution in facilities as they quickly and efficiently carry power throughout a facility to do useful work. Power can only be distributed safely through conductors with tight, clean, cool and dry connections with proper insulation or metal clad covers. The main conductor hazards are poor connections and insulation breakdown. Connections, terminations and splices are usually the weakest points in cable and bus bar systems. Loose or corroded connections will generate high resistance and heat, and so both are great candidates for infrared inspections.

Figure 9 - Combustible Materials

Insulation is King - The insulation is rated at a specific dielectric (insulating) strength. Premature insulation failures are due to absorption of moisture, dirt, dust, grease, excessive heat, sunlight, vibration/abrasion, loose connections, oily deposits, loss of polyvinyl chloride (PVC) oil and compounds, power surges, overvoltage and aging. These contributing factors cause insulation to become brittle and crack, which allows current to have a low resistance path outward or shorting to ground.

Any arcing can ignite the combustible insulation under the sheath. The PVC insulation provides fuel for the fire and continues to burn even though the initial arc may be stopped by the operation of the over current device. Research has shown that even heat generated by faults in low-voltage signal wiring may generate damaging off-gases and burn adjacent combustible materials[8] and horizontal cable trays[9].

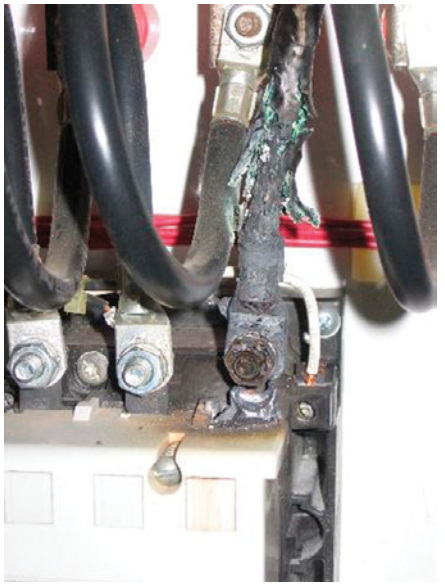


Figure 10 - Burnt Wire, Minimum Possible Fine: $2,000

Moisture and dirt also allow tracking and even flash over. Another problem with moisture and the overheating of insulation is the creation of off-gases. One of the off gases is hydrogen chloride which when mixed with water forms hydrochloric acid. This highly corrosive acid damages sensitive relays, instruments, control apparatus, copper bus bars and base metals such as iron, brass, aluminum or zinc alloys. It can cause significant fire and non-thermal damage. Lastly, manufacturing deformities during the insulation manufacturing process create high electric field stresses and can cause insulation failure.

Circuit Breakers / Fuses / Disconnects

A circuit breaker (CB) is a protective device that carries load, and if it senses a higher circuit load than the established setting, it rapidly opens the circuit interrupting the flow of electricity to/or within electrical equipment (i.e. transformers, motors, switchgear, etc.). It can be reset. CBs come in many types, sizes and voltage ratings.

Concerns - Typical CBs are installed, sit in place supplying power, and then are forgotten for years. This is contrary to the regular maintenance requirements of the OEM, NFPA 70, IEEE and National Electric Manufacturers Association (NEMA). Several studies by IEEE show that up to 50% of low voltage CBs can fail within 5 years, if not maintained properly.

Most power system failures and hazards are caused by short circuits and failure of a circuit breaker/fuse to open the circuit during overload, electrical fault or other abnormal operating condition. If it can't interrupt the fault it may fail, destroying the enclosure and creating a hazard for anyone working near the equipment. In some instances, arcing can occur and ignite combustible materials due to the delay. The combustible insulation tied to CBs, and oil inside certain high voltage CBs, become fuel sources for a fire which can spread to adjacent circuit breakers, fuses or other combustibles.

Some warning signs of an aging or faulty power distribution system include breaker nuisance tripping or main breaker failure. The problem is that after high level fault, "it is not always clear to investigating electricians what damage has occurred inside encased equipment."[10] By design, CBs can be reset, but nuisance trips may see the CB being reset 3-4 times. Numerous authorities having jurisdiction (AHJ), like OSHA, no longer allow the multiple resets since numerous burns resulted from explosions.[11]

Failed Barrier Example: "Human Error and Disregard for Safety"[12]

February 2001, an operator made an "Extraordinary attempt" to close a molded case circuit (MCC) breaker to start a 100 HP, 480 volt, 3 phase power roof vent. The operator received a massive "arc flash" and burns to unprotected parts of hands, arms, and face. Injuries were aggravated due to the fact that the operator had opened the module door, gaining access to apply added force to close the breaker, after attempts from the outside had failed due to apparent linkage binding.

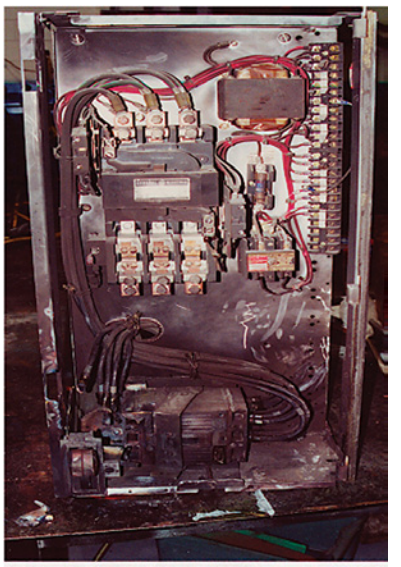


Figure 11 - The Damaged circuit breaker and cubicle.
Image Courtesy of Jack Nicholas.

Fuses & Disconnects - Fuses and fused disconnects are common electrical protection devices that provide overload and/or short circuit protection. The fuses are secondary protection in the event circuit breaker contacts don't trip. If a fuse shows up hot on a thermal scan, it might be at or near its current capacity. However, not every problem shows up as hot. A blown fuse, for example, exhibits a cooler than normal temperature.

Motors & Motor Control Centers

The electrical condition of plant equipment is as important as their mechanical condition.

Motors - Motors are electrical rotating equipment that convert electrical energy into mechanical energy. Motors, and associated windings and insulation, are typically classified based on enclosure type, speed, efficiency and service factor.

Motor Concerns - Analyzing insurance related motor failure and loss data from 1989 to 2005 indicated that 65% of the failures and 71% of the losses were related to windings and electrical connections.[13]

Motor Control Centers (MCC) - Motor control centers house the control and protective devices for motors that drive equipment. To evaluate a motor control center under load, open each compartment and compare the relative temperatures of key components: bus bars, controllers, starters, contactors, relays, fuses, breakers, disconnects, feeders and transformers. It is important to measure the amperage load of each phase at the time of each scan, and to trend and evaluate your measurements against normal operating conditions.

Infrared thermography and Motor Circuit Testing of MCCs and motors is an excellent combination since they can be applied to all types of motors to detect problems like poor connections in the motor terminal box and overheating windings, bearings, and motor couplings.

Poor electrical connections in the motor terminal box (Figure 12) and overheated bearings (Figure 13) often signal active breakdown and potential failure. Thermography accurately pinpoints which areas of the motor overheating and how much.

Overheating is caused by inadequate air flow, which can be caused by clogged air intake grills. Fault current motors may experience single-phase ground faults which increase temperatures and go undetected. Figure 14 shows an example where the intake screen was plugged because oil from the bearing got on it and collected dirt. Over time it clogged and overheated the motor and windings.

Electric motor testing provides both offline (Motor Circuit Evaluation) and online (Motor Current Analysis) testing of the motor and circuits to determine the motor's health and identify any potential operational concerns. Typical tests performed include resistance and capacitance to ground, phase resistance and inductance to ground, current and power quality analysis, voltage unbalance and total harmonic distortion. Unbalanced voltages and overloading are usually caused by a high resistance connection in the switchgear, MCC or disconnect.

It is a good practice to regularly trend reference temperatures, comparing the operating temperatures of like equipment performing similar functions, to OEM requirements and previous readings on that unit. This helps you see abnormal readings when they occur.

IR troubleshooting tools and/or a motor circuit tester can perform power diagnostics and quality analysis and pinpoint the issues. IR is also great for identifying mechanical issues such as bearing failures and alignment issues.

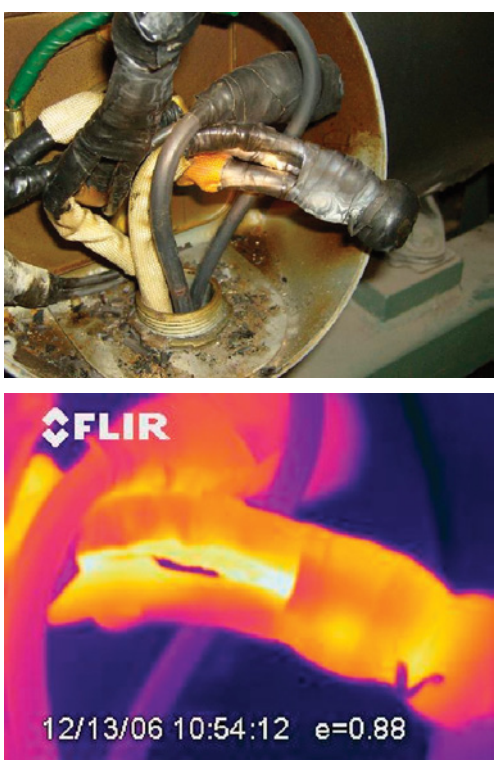


Figure 12 - Visual (top) and IR (bottom) Images of Failing Pump Motor Connections.

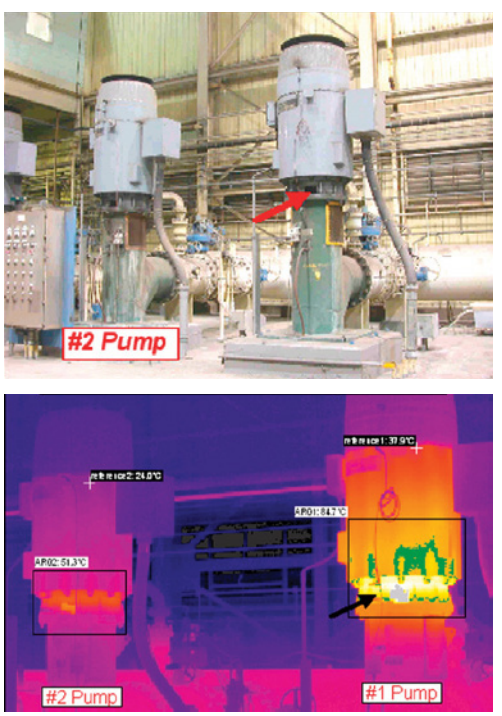


Figure 13 - Visual (top) and IR (bottom) Images Identified Overheated Motor. MCA Confirmed Short-to-Ground.

Figure 14 - IR Identified Overheated Motor Due to Clogged Air Intakes. MCA Then Confirmed Short-to-Ground.

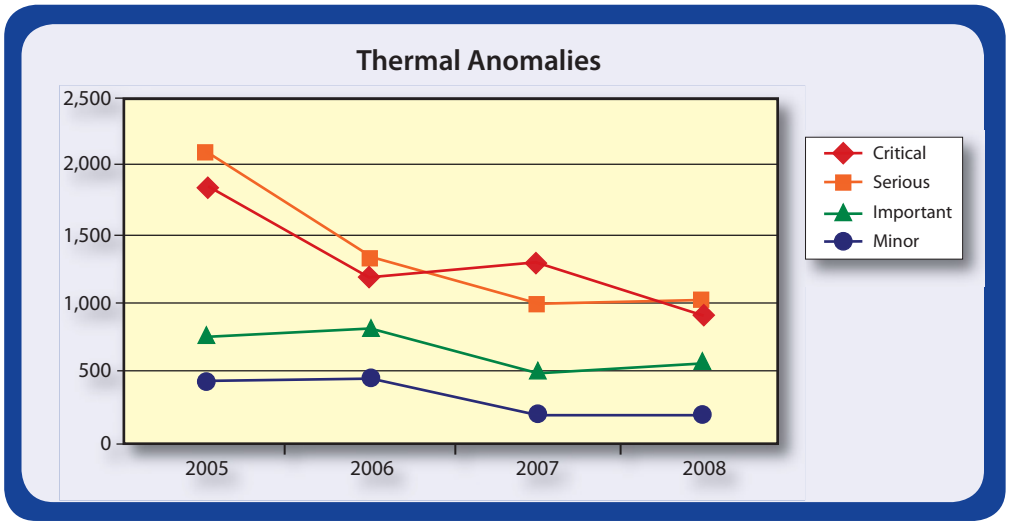


Figure 15 - Client with 50% Reduction of Thermal Anomalies Over 3 Years

KISS the Program for Optimum Results

Safety, maintenance and reliability professionals can enjoy significant reductions in personnel exposures and enhanced reliability of electrical distribution systems by deploying an integrated condition monitoring (CM) strategy with predictive maintenance (PdM) technologies. (See Figure 15)

Achieving these results requires discipline and applying the KISS (Keep It Super-Simple) strategy which ensures program data is small, accurate and manageable. You have limited resources and time. Initially, focus on the assets that have the best and highest probability of success. Your efforts and communication strategies must build a return on investment (ROI) case for investing in your program, personnel and PdM technologies. Some thoughts to include:

1. Use simple MS Access database or MS Excel to track and analyze specific information.
2. Use simple reports with easy to understand pictures and graphics to help stakeholders understand the failure modes and hazards, the magnitude of the risk with comparative failure data and the potential people, production, and time impact of a loss.
3. Regularly and consistently "blow your own horn" about the program's successes and challengers.
4. Document everything within your program.
5. Don't give up – These programs can require multiple data points and time, but will significantly drive down electrical system exposures and losses over time.

Dale P. Smith, CMRP is the Corporate Programs Manager for Predictive Service.

He has 20 years of experience within the engineering, risk/safety, facilities management and reliability consulting industries designing, implementing and running successful multi-site corporate safety, reliability and energy programs for medium, large and Fortune 500 companies such as Alcoa, General Motors, Kaiser Aluminum, ADM, Schering-Plough, Wyeth and many others.

Dale formerly served as the Director of Technical Sales/ Marketing for a global engineering consulting and safety services firm. He managed combustion system safety and asset reliability programs with three global automotive, aluminum and pharmaceutical clients which represented over 300 facilities worldwide.

Current projects include overseeing the development, management and growth of facility roofing and reliability programs for over 250 facilities, the associated roofing assets and 100,000 electrical / mechanical assets. The focus is ensuring that clients achieve the most cost effective, reliable, safe and competitive facility capacity.

Dale is also regularly published within the safety, risk and reliability industries and delivers numerous technical papers and training sessions at national safety, energy optimization, reliability and risk conferences. He is a Certified Maintenance and Reliability Professional (CMRP) through the Society for Maintenance and Reliability Professionals (SMRP). Dale can be reached at 216.263.7493 or at dsmitty2@cox.net.

References

1. FM Global. 2004. Field Engineering Equipment Hazards Fundamentals.
2. Ontario Ministry of Labor. October 27, 2008. Safety Blitz Targets Industrial Workplaces Mcguinty government committed to eliminating workplace injuries (retrieved February 10, 2009) (http://www.labour.gov.on.ca/english/news/2008/08-99.html).
3. Institute of Electrical and Electronics Engineers (IEEE) 1998. IEEE Guide for Maintenance, Operation, and Safety of Industrial and Commercial Power Systems. Piscataway, NJ.
4. Taken from Predictive Service's inspection / asset management database of with over 1,000,000 pieces of electrical equipment.
5. National Fire Protection Association. Recommend Practice for Electrical Equipment Maintenance, Section 18-16.5.
6. Smith, Dale P. Predictive Maintenance (PdM) Centralization for Significant Energy Savings. ReliabilityWeb. (http://reliabilityweb.com/index.php/articles/pdm_centralization_for_significant_energy_savings/)
7. FM Global. January 2007. Transformer Property Loss Prevention Sheets. 5-4 Factory Mutual Insurance Company.
8. Chan, Kai Foo. Understanding Fire Hazards in Computer Rooms and Data Centres. Asia Pacific Fire. June 2005: 5-8
9. National Fire Protection Association. March 1994 Telephone Exchange Fire Los Angeles, CA. Fire Investigations. Quincy, MA
10. "NEMA offers MCCB inspection and testing guidelines". EC&M Jan. 1995
11. Occupational Safety and Health Association. OSHA 29 CFR 1910.33 4 (b) (2).
12. Nicholas, Jack and Young, R. Keith. 2008. Root Cause Failure Analysis, 6th edition, NetexpressUSA.com.
13. FM Global. January 2007. Motors and Adjustable Speed Drives Property Loss Prevention Sheets.5-17. Factory Mutual Insurance Company.

Choices, Choices, Choices...

Choosing The Right Camera For Your Particular Needs

by R. Wayne Ruddock

In today's world of infrared thermography, there are an increasing number of manufacturers offering a wide range of infrared camera packages. In the past 10 years the price has been reduced dramatically and the spatial resolution has increased. There is far more acceptance of the technology today than in the past and an increase in the applications to which infrared thermography is applied. The internet is also used to advertise, and in some cases, even sell infrared cameras. With this ease of accessibility and expanded choice in camera systems, it is often difficult to decide exactly which infrared camera system is right for you or your company.

The best place to begin in the process of choosing an infrared camera is to have a firm understanding of the requirements of your proposed application. Determine first whether your application is qualitative or quantitative in nature. Qualitative applications are those where thermal patterns are the definitive principle in your application. In this type of application a thermal imager is all that is required. These include applications such as security and surveillance as well as many process control and quality assurance applications. When accurate temperatures are a requirement of your application, you need to consider an imaging radiometer, which is a quantitative instrument. Table 1 is a guide to some of the principles that should be considered when looking at the purchase of an infrared camera.

The only way to determine which camera is the right one is to consider all of the requirements of your application, and then see which camera fits. For example, if you are going to do electrical inspections and require accurate temperatures, you need to determine the smallest object you will require a temperature of and the farthest distance you will be from that object. Using the information in the IFOV and IMFOV section of this paper, you can calculate the value you need for an IFOV number and compare this to the manufacturer's specifications. If you need to be able to measure 400°C, a camera which only measures up to 250°C will not be suitable, no matter what the price.

Qualitative	Quantitative
NDT	NDT
Security & Surveillance - Civil	Predictive Maintenance
Homeland Security - Military	Research & Development
Search and Rescue	Industrial Heat Loss
Firefighting	Process Monitoring
Building Inspections	Continuous Monitoring
Predictive Maintenance	Quality Assurance
Process Monitoring	Medical
Continuous Monitoring	
Quality Assurance	
Research & Development	

Table 1 - General Infrared Thermography Application Chart

Price

Although many infrared camera purchases are driven by price, price should be a secondary consideration after the cameras specifications and features have been considered. The price of infrared systems vary from approximately $4,000 US to in excess of $100,000 US. Sometimes budgetary restrictions are a determining factor when choosing an infrared system.

It must be realized that the saying "you only get what you pay for" is true when considering an infrared camera. There is no sense in buying a camera strictly on price if the camera is not capable of performing the application it was purchased for. On the other hand, there is no benefit in paying for features and functions in a system that will never be used in the application the system was purchased for.

Specifications

Before even beginning to look at the purchase of a specific infrared camera, it is wise to first define the parameters of your application, and then research the available cameras. You should draw up an application matrix in which you will enter all of your needs including specifications, usability and ergonomics, accessories, software, and after-the-sale support.

Most manufacturers publish a standard set of specifications. Some of these specifications can be valuable while others are not, depending on your application. Some of the specifications below may or may not apply to your specific application, but we will try and include the main considerations. There are two types of resolution, Thermal Resolution and Spatial Resolution. Thermal resolution defines the ability to see and or measure energy/temperatures, while spatial resolution defines the ability of the

Who says INFRARED WINDOWS have to be ROUND?

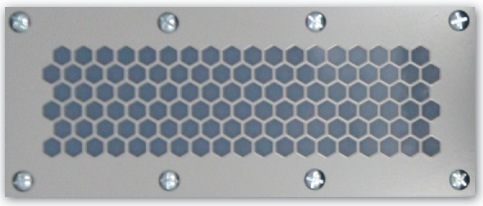
IRISS CAP-V 24 installed in high voltage panel

IRISS, Inc. introduces you to the future of infrared windows.

IRISS uses the unique properties of the IRISS VPFR series, "The World's Only Industrial-Grade Infrared Window" as the cornerstone for innovation in the IRISS CAP Series.

IRISS CAP Series, engineered and manufactured in the USA, is available in standard sizes of 6, 12 and 24 inches. The entire IRISS CAP Series allows more freedom to inspect multiple components through one infrared window, reducing the number of IR windows required as well as the installation time and costs associated with them.

- IRISS CAP has IR window only
- IRISS CAP-V offers visual inspection pane with IR inspection
- IRISS CAP-VC offers visual inspection pane with IR inspection plus a cover for the IR window
- CAP-VCH offers protective covers for both the IR inspection and visual viewing panes with a single door



IRISS CAP-12

IRISS CAP-VC 6
with open cover

Need a different size or have a Custom Application? Contact IRISS today: phone **877-704-7477** or **sales@iriss.com**.

Visit our website to get your FREE copy of our e-book "10 Things You Need to Know About Infrared Windows"

www.iriss.com

IRISS®
See What You've Been Missing!

system to see physical detail.

Thermal Resolution

These are fixed values given by the manufacturer.

Temperature Range – What will be the highest and the lowest temperatures of the objects you will be trying to look at? This is the first question you must consider. Many of the newer, simple, low cost cameras only view objects from – 20°-40°C to 150°C. Some of these cameras measure up to 250°C. These temperature ranges are usually suitable for many building science, electrical, or mechanical applications, but often not suitable for process, NDT or many R&D applications. There are a great number of more complicated, higher priced systems, that can inspect objects in excess of 2000°C.

Accuracy – Many of the infrared cameras on the market today publish a temperature accuracy of + or – 2°C or 2% of the range, whichever is greatest. In general, they are much more accurate than the published figures. These accuracy figures are given for blackbody references and do not take into account errors introduced by factors such as emissivity and background reflected energy. This accuracy can be greatly increased by comparing a known temperature close to the temperature of the object of interest. In most predictive maintenance and NDT applications, these values are acceptable. R&D applications often require greater accuracy and a blackbody reference source can be a viable option.

Thermal sensitivity – While temperature accuracy might seem to be fairly rough, thermal sensitivity has become very fine. There are cameras on the market today that are capable of detecting a thermal difference as low as .05°C or less. In general, there are two tests to determine the thermal sensitivity of an infrared camera. The NETD (Noise Equivalent Temperature Difference) tests only the temperature difference required to raise the signal from the detector, to a measurable level above the electrical noise of the system. This is an instrumentation test only. It is not a good test of overall system performance.

The MDTD (Minimum Detectable Temperature Difference) test is the best test to compare the sensitivity of the entire system as it takes the entire system into consideration. This test requires a technician to be able to see a temperature difference using the visible image of the camera. When comparing systems, one must be sure that the figures given by the manufacturer are from the same type of test. Your application will determine which test is the best to help you choose the right camera system.

Spatial Resolution

These values are given by the manufacturer, but are dependent on the lens used on the camera. Some cameras do not offer interchangeable lenses, which means that the values are fixed. With other camera systems, there are a variety of interchangeable lenses available. Each camera/lens configuration has a separate set of spatial resolution specifications. These specifications describe the performance of the entire system. Manufacturers often stress the size of the detector, which is only a piece of the information necessary to determine what the system can see. A camera with a 320 X 240 focal plane array may or may not be able to see better spatial resolution than a 160 X 120 detector, depending on the optics of the specific system.

Field of view (FOV) – The total area that our camera sees is defined by the FOV value given by the manufacturer for each specific lens/camera system. This value is determined by a combination of detector size and lens optics as well as camera design. This specification is usually given in degrees. Various applications may require that the technician can view a certain object in its entirety at a set distance. Once the field of view requirements of your specific application have been defined, you can compare various camera FOV specifications to determine the right camera/lens combination for your application. As an example, in an ongoing NDT test, the technician must look at a 2 meter by 2 meter composite panel and be able to image the entire panel in one field of view for later analysis. The camera being considered, has a field of view specification of 20° X 20°. This camera does not have interchangeable lenses. The distance available from the panel is 4.5 meters. The formula to determine the area viewed by this camera is:

Area = FOV in radians X Distance

To change the field of view in degrees to radians you must multiply the angle in degrees by .0175 (1 degree = .0175 radians, so, in this example, 20° = .35 radians).

The area viewable at the available distance is:

Area = .35 radians X 4.5 meters = 1.57, so
Area = 1.57 meters X 1.57 meters

This camera cannot view a 2m X 2m panel in one frame at a distance of 4.5 meters. Another camera must be chosen or the distance to the object must be increased.

Instantaneous field of view (IFOV) – The IFOV value describes the smallest spot that your system can geometrically resolve, or see the size and shape of. It is given by the manufacturer as an angle defined in milliradians.

It is called either the IFOV or Spatial Resolution specification. It is determined by not only the size/angle of the lens, but also by the number of pixels that make up the field of view. Other parameters, such as the fill factor of the detector elements, also come into play in determining this number.

The smaller the IFOV number, the better the resolution your camera/lens combination will have when examining small objects in the field of view. In your application requirements, you must determine the smallest object you will need to image and the maximum distance you will be viewing the object from. Once this is decided, you can examine the specifications of various cameras to determine which one will perform best for your application needs. The formula to determine this spot size is:

Size of Spot Resolvable = FOV in radians X Distance

The IFOV value is usually given by the manufacturer in milliradians. To change the given specification to radians, simply move the decimal place 3 positions to the left (so, for example, 1.4 milliradians = .0014 radians).

An electrical maintenance technician needs to look at a conductor 2cm (.02 meters) in diameter. Due to safety regulations, the closest the technician can get to the conductor is 1.25 meters. For the camera with an IFOV of 1.4 milliradians, the smallest spot the technician can resolve the size and the shape of is as follows:

Size of Spot Resolvable = .0014 radians X 1250 cm, so
Size of Spot Resolvable = 1.75 cm

In this case, the camera considered above is capable of seeing or imaging this 2cm conductor at 1.25 meters.

The IFOV specification is an important consideration when evaluating an imaging camera.

Instantaneous measurement field of view (IMFOV) – When evaluating an infrared camera where temperatures are required, the IMFOV is a more valuable specification than the IFOV. This is really a combination of spatial and thermal resolution.

The IMFOV defines the smallest area or object size that you can evaluate, and still accurately measure the radiated energy from that area or object, at any specific distance. If the area or object is not large enough, the energy the camera sees from the spot will be eclipsed by energy from the background and the camera will not calculate the actual temperature of that object or area. The IMFOV is defined by an angle that is usually given in milliradians because of its small size. Many manufacturers do not publish this value despite its obvious importance when trying to calculate the temperature of small objects in the field of view.

In the past 20 years, I have conducted literally thousands of experiments to determine this value. Generally, I've found that the size of an object necessary to achieve accurate measurement is usually 3–4 times larger than the size calculated by using the IFOV value published by the manufacturer.

Size of Spot Measurable = IMFOV in radians X Distance

Using the example in the section above on the IFOV, we will consider a spot size of 2cm at a distance of 1.75 meters. Let's assume that this camera is better than average and the IMFOV is only 3 times that of the IFOV. This gives us an IMFOV for the above camera of 4.2 milliradians.

Size of Spot Measurable = .0042 radians X 1250 cm, so
Size of Spot Measurable = 5.25 cm

This reveals that the above considered camera cannot accurately determine the temperature of a spot any smaller than 5.25cm at 1.25 meters.

Wavelength

Today there are basically 3 different wavelength camera systems generally available. The long wave system uses a band width of approximately 8–14 microns. The shortwave or midwave system utilizes approximately the 2–6 micron window. The nearIR camera views approximately the 0.9–1.75 micron range. There are a number of specialty applications that require a camera system which utilizes a specific narrow wavelength band. An example of this is the "gas camera", which has the ability to see fugitive emissions in petrochemical plants. This application requires a shortwave, cold shielded, filtered camera.

There are a number of application specific cameras and filters available utilizing specific wavelength regions. Theoretically, a long wave system is better for normal near ambient temperatures, whereas a shortwave system works better on above ambient temperatures while the nearer system will only work on objects with emitted or reflected temperatures above approximately 250°C. In practice, there are a number of other considerations such as the low maintenance with a longwave, uncooled camera, that are more important than the wavelength issue.

Frame Rate

While the frame rate is not usually an important consideration in PdM type applications, it can be a very important specification in many NDT and R&D applications, as well as some quality assurance situations. A frame rate of 30 or 60 hertz is the standard on many hand held systems. For most electrical, mechanical

and even process applications, this difference is not usually significant. Today there are systems available, that when windowed, can capture over 1000 frames per second. In a research application, where the burn in time on a component is only .25 seconds, frame rate can be a primary consideration.

This also requires specialized, auxiliary hardware and a software package that is capable of capturing images at this rate and analyzing them using a number of various software functions. The requirements of your application concerning frame rate and analysis issues must be clearly defined before starting a consideration of any infrared camera system.

Usability and Ergonomics

There are a number of considerations when trying to determine the usability of a camera in a specific application. Some of these are as follows:

Camera Controls – For almost all applications, an infrared camera must have manual focus level, and span controls. Without being able to control the level and the span manually, many thermal anomalies will not be seen in the infrared image, especially in electrical inspections where there are often hotter objects, such as transformers and resistors. In AGC (automatic gain control) with no manual override, the camera looks at all the energy levels in the field of view and automatically adjusts the level and the span in the camera, constantly changing the settings on the image. This means that whenever the field of view changes, you cannot really compare anything from image to image. In an electrical inspection with a small hot transformer in the image, you will lose all of the thermal detail on the connections and conductors. Manual focus allows the operator to get a good image of the object of interest in the field of view. Most infrared cameras have a very shallow depth of field.

Weight – If the camera is to be used in a portable application such as electrical inspections, then the weight of a camera is an issue. If the camera is to be used in a fixed mounted application, weight is not an issue in general.

Battery Life – The life of the battery, and the cost of extra batteries, can be important considerations in a portable application.

Inputs – Depending on the application, the allowable power inputs can be an important consideration. Many cameras can accept voltages from +6 to +16 VDC. For some R&D type applications controls such as an external synchronization can be an important consideration.

Outputs – In portable, PdM applications, the presence of various outputs is not usually an important consideration. In many other applications, outputs such as video, USB and firewire can be important.

Image Storage – The ability to store images in the camera is usually accomplished by the use of onboard memory or a removable memory card. In some applications, the ability to exchange memory cards when there are multiple users can be an important consideration.

Display – In many applications, the technician must view the screen to evaluate the object viewed. Considerations such as being able to rotate or angle the screen, an eyepiece for bright light conditions, or a remote view screen could be important.

Remote Control Capability – Today there are some systems available with remote wireless image capture and camera control. This can be a crucial consideration in some applications where a hostile environment is present.

Environmental Specifications – There are many environmental considerations such as operating temperature, storage temperature, and IP rating to be taken into account according to application requirements. These specifications can be acquired from the manufacturer.

Accessories

Many infrared camera systems have a wide selection of accessories available. Items such as an AC power supply are not included as part of the camera purchase with many hand held cameras, while battery power sources are not usually supplied with fixed mounted systems. In some instances, accessories such as a solar power supply can be purchased through a third party.

There are a number of specialized applications which require unique accessories such as narrow wavelength filters. With some camera packages there are a number of different lenses that can be purchased as accessories. On the other hand, there are less expensive cameras that do not have any available alternative lenses. Before selecting a camera package, list all of the requirements of your application

and match them to the accessories available for each system.

Software

Infrared camera software can perform three basic functions. Software can control camera/data acquisition functions, image analysis, and reporting. Most handheld cameras come with analysis and reporting type software only. Today many higher end cameras can still be portable, but allow for functions such as sequence image capture, and acquisition triggering to be controlled through a laptop computer. Most manufacturers have demo software or will have a sales person come to your location with a functioning copy of the software on their computer. Before purchasing a camera, make sure that you test the software to ensure that it performs the tasks necessary for your application easily and expediently.

It is important in some applications to have a software package that will export and import data from programs such as Excel. One of the key issues with infrared software is the ability to install the software and use it on a number of different computers. Some packages can only be installed and used on one computer per license. This becomes very awkward if there will be a number of technicians working with a camera.

For PdM applications, the software must be able to produce templates to ensure that your reports can be produced accurately and efficiently in a minimum time frame. This ensures continuity over time.

There are also a number of 3rd party software packages available in the market today for most types of applications. In many process control/continuous monitoring applications, only the camera head will be purchased from the IR camera vendor. The control portion of the application, including other necessary hardware and software, will be provided by a third party integrator.

Warranty and Support

Warranty and support considerations are also application driven. There is also a "gut feeling" factor that should come into play.

Warranty – Warranty is fairly clear. Most cameras have a 1 year standard warranty with extended warranties available at a set price. More important than the warranty time period is what the warranty includes and how warranty work will be conducted. Before buying a camera system, you should have these issues clearly defined and on paper as part of the camera purchase. An important question that must be answered is "Does the warranty cover all parts and labor?". There is also the issue of shipping charges and where the system must be shipped to for warranty work.

The other part of the warranty principle is how long can you be without your infrared camera working in your specific application? It has been known to take over 6 months to get a camera repaired due to a number of complicated issues. The manufacturer would not supply a loaner camera, and the only option the camera owner had was to rent a similar camera at an exorbitant price. The buyer should be realistic in their expectations, but should not settle for less than is necessary. If the longest you can operate without a camera is two weeks, then part of the purchase agreement should include a clause that, in the event of warranty issues, the unit is either replaced within two weeks or a free loaner supplied until your camera is repaired. With some specialty cameras this is often not a viable expectation. You should then look at all of the options suggested by the various manufacturers and select the one most appropriate for your application.

In determining how important the warranty issue is, you should also consider the rigors of the application itself. If your application requires a fixed mounted, longwave, microbolometer, Focal Plane Array camera, in a gentle environment, then warranty may not be a large issue. These cameras have basically no moving parts, and if they do not fail during burn in times, then they have been known to operate flawlessly for years.

On the other hand, if your application requires a camera that is a handheld, shortwave, sterling cycle cooled camera, that will be handled by a number of individuals with various skill levels, in a rough harsh environment, warranty is a very important issue. With these cameras, the cooler has a limited life no mater what the warranty, due to the moving parts and the components which make up a compressed gas system.

Support – Support is often something that can be attributed to the "gut feeling" factor. Some manufacturers treat their customers fairly and openly while others can be difficult to deal with and offer very little support after the sale. More importantly than the manufacturer, is the representative who will be personally looking after you. Usually you can tell by the general character and knowledge of the sales person and their support team while you are evaluating cameras, the type of support you will receive after the sale. This is not something that a dollar value can be specifically placed on, but in some cases, can make or break the success of your infrared project.

Summary

To choose the best infrared camera for your application, you must have an intimate knowledge of the thermal requirements of your specific situation. The camera specifications must match the application requirements. If they do not meet these needs, despite an attractive price or incredible warranties, the camera should not be considered. Do not be lured by promises of future upgrades or features that are not available today, unless a money back, time dependent, written guarantee is provided. The second variable that should be considered is the practicality of a specific camera due to its design and functionality. A camera that is hard to use, and difficult to attain results from, will often spell disaster for your application. Although important, price is the last consideration in purchasing an infrared camera. If all other factors are even, then price may be the determining factor, but it should not be the driving force behind your choice.

Wayne Ruddock has been involved in Infrared Thermography and Infrared Thermographic Training since 1979. He is a seasoned veteran of hands on infrared inspections, giving him the ability to teach real life thermography. He has been conducting Level 1 training courses throughout the world since 1980. Wayne was the North American Director of training for an established infrared company from 1990–1999, at which time he became the owner/director of Advanced Infrared Resources (www.infraredthermography.com) Wayne has written training curriculums for various infrared equipment manufacturers and is currently the chairman of the Mexican Institute of Infrared Thermography. He now presents unbiased, manufacturer independent Level 1 and Level 2 training courses throughout North America, Australia, New Zealand and Mexico, as well as specifically tailored in-house training programs throughout the world. The material in these courses adhere to the guidelines set out in ASNT-TC-1A. These courses are also recognized by AINDT in Australia and New Zealand. He makes learning easy for individuals from all backgrounds and with all educational levels. You can reach Wayne at 250.682.0515 or wayne@infraredthermography.com.

The Bear(ing) Minimum

Minimum Loads of Spherical Roller Bearings and Some Lubrication Basics

by Charles Kropewnicki

In my experiences as both a Bearing Applications Engineer and Reliability Engineer there seems to be a common problem with double row "spherical roller bearings" (SRB) operating well below their minimum load ratings. This is especially prevalent in overhung fan and blower designs utilizing couplings to transfer power. This issue will usually raise its ugly head in the form of elevated temperature on the coupling side pillow block bearing. In some cases, due to the overhung load distribution, the coupling side bearing will have a load facing upward or even none at all. The worst case is when the SRB acts as the fixed bearing and takes a thrust load, despite having little or no radial load.

This condition will cause the rollers to slide rather than roll over the lubricant, increasing shear forces within the lubricant and increasing friction/drag within the cage pockets. This will elevate temperatures and decrease lubrication viscosity. It will also significantly shorten bearing service life since the bearing life is related to lubrication viscosity between the rolling surfaces: "elements & raceway" and between the sliding surfaces: "cage pockets & roller side faces". It is also important to note that SRB's typically need more radial load than thrust load at fan and blower operating speeds since the set of rollers "opposite of thrust load" can become unloaded and will drag within the cage pockets. This can result in rapid cage failure of the unloaded side roller set.

As a rule of thumb that has stood the test of time in typical operating conditions, an SRB should have approximately 21cSt of lubrication viscosity at operating temperature. This can be determined from a viscosity/temperature chart once you have obtained the data. For speeds that are unusually fast or slow due to a gearbox reduction or increase, a more advanced calculation would be recommended. Speed is the key variable in this calculation, and can change viscosity and lubrication requirements dramatically at both sides of the spectrum.

Since the SRB is widely used in fans and blowers because of its misalignment capabilities and robust design, the minimum load condition is often overlooked, with more attention usually focused on max loading conditions. Some primitive bearing calculator tools utilizing the basic L10h bearing life formula may give millions of hours of L10h life for light loads since this basic calculation is only based on fatigue. However, it doesn't take into account lubrication viscosity, contamination factors and minimum loading factors, so designers beware! More advanced online bearing programs utilize newer L10 life formulas that will take these factors into account...or better yet, an applications engineer at a bearing company may provide this service. If you have any questions concerning minimum loads on a specific bearing, most major bearing manufacturers have these factors in their bearing catalogs, or the information can also be found in some online bearing programs.

If the SRB doesn't cut it due to minimum load, there is a solution. A "double row self-aligning ball bearing" (SABB) can be used, and has the same external dimensions as an SRB up to a certain size range. This bearing has a much lower minimum load rating, and in most cases, will run cool and work well. However be careful not to use this bearing as the fixed bearing in this application since these bearings don't typically do well with thrust loads unless it is relatively light in comparison to the radial load. They should mostly be used as the floating bearing in this fan/blower scenario with the SRB utilized as the fixed bearing on the blower side, taking both the radial and axial loads. I do realize, however, that there might be applications requiring a different approach, but this fix could certainly help some of those blower & fan applications in question.

General Maintenance & Lubrication Basics

Common made mistakes include not using the most suited lubricant, relubrication intervals and/or quantity required for specific applications. This is often due to misinformation or simply an attempt to utilize the grease or oil that is currently stocked in the store room for other equipment. While it is a good practice to consolidate some lubricants to streamline inventory, it is crucial that this is done correctly since it can cause major problems if the improper lubricant finds its way into equipment. It is important to note, however, that there is some equipment that requires a specialized lubricant with certain properties due to the nature of the application, and these lubricants should not be consolidated.

Particular attention needs to be given to the type of lubricant required for a specific application, even though

a stocked lubricant may meet the oil viscosity requirements. It may have an additive package that was not developed specifically for that application. For example, I have seen a motor oil utilized in a pump application. Although it did have the correct base oil viscosity requirements, the additive package was developed primarily for automobile engines. Interestingly enough this oil was recommended from a vender as a substitute for the OEM specified lubricant. While this lubricant worked, it probably didn't provide the best properties for the application or provide the optimum service life for the equipment. Care should be taken, especially during a lubrication consolidation program, to assure that any new lubricant will not only have the proper viscosity requirements, but is the specified lubricant from the OEM manufacturer.

In applications that utilize grease, attention should be given to thickener types since they are not all compatible. This is also an important issue to consider in a consolidation process since incompatible greases will result in a mixed lubrication regime, which can dramatically alter grease thickener properties. This can result in a softer thickener which will lower the grease's resistance to slumping (the greases ability to stick to a surface and provide lubrication).

For instance, the most common greases found in fan and blower applications utilize a Polyurea, Lithium or Lithium Complex thickener. Depending on the manufacturer of the grease, these may or may not be compatible. When in doubt, you can be 100% assured of success if you don't mix them. When in question, there are grease compatibility charts that can help you determine what thickeners and base oils will work together if cleaning out existing grease from a bearing housing is not an option.

Another common maintenance malpractice is the over greasing of bearings in any application. Contrary to certain beliefs, more is not always better! Using too much grease can drastically increase bearing operating temperatures by pressurizing the housing. In addition, forcing extra grease into the bearing rolling elements creates added friction/drag and possibly too much oil bleed. It is no surprise that over greasing can indeed lead to premature failure.

It is a good practice to ask the equipment manufacturer for the type of grease, quantity and lubrication interval recommended for a particular application. Guessing should not be an option since it can be based on false assumptions and improper facts. This simple measure can save thousands of dollars in equipment downtime, repairs, replacement parts and even yearly bonuses. Relubrication intervals and quantity formulas can also be found in catalogs of some bearing manufacturers. There are also online programs, like SKF Dialset, that will calculate relubrication intervals and quantity. You do need specific bearing application information including: speed, load, duty cycle, bearing size/type, environmental conditions and temperature etc. The correct relubrication intervals are key in flushing out oxidized lubricant, moisture and particle contamination. This practice is one of the most vital variables in maximizing bearing service life.

Pillow block housing designs that utilize open labyrinth seals are very popular in blower/fan applications. However, in extreme dusty/dirty environments they allow for a greater amount of fine particle contamination to get into the housing. This is especially true when the bearing becomes idle and the block cools down, which induces a negative draft drawing air into the pillow block. Some of these labyrinth seal designs do, however, incorporate a contact seal as an option up to a certain speed limit. This will help greatly if the pillow block is outside and subjected to heavy dust/dirt environment, like, for example, in a cement plant. Even if the seal face wears down and no longer makes contact, it can still provide an added barrier to hold grease and help block out contaminants.

Grease serves multiple functions:

1) It helps seal out contaminants,
2) It helps to transfer heat from the bearing,
3) It provides lubrication by bleeding oil,
4) It isolates water from the metal surfaces,
5) It provides antioxidants to fight oxidation at higher temperatures,
6) "Extreme-Pressure" EP additives chemically bond themselves to the metal surfaces to avoid metal-to-metal contact, especially when shaft speed is slow or idle and has no hydrodynamic film.

Grease is made up of three basic ingredients, thickener, base oil and additives. Think of the thickener as a sponge. While a sponge absorbs and holds water, the thickener holds oil and clings to bearing components while bleeding small quantities of oil. The bleed rate increases with temperature. As the grease ages and goes through multiple temperature cycles, it will eventually bleed itself out of oil and become a hard stiffened thickener. If left unattended, the grease will no longer provide lubrication, which is one reason why relubrication intervals, and flushing out contamination and spent oxidized lube, are so important.

In actuality, most bearings don't need very much lubricant, a thin layer of Elasto-Hydrodynamic oil film during operation can be approximately 200 times thinner than a sheet of paper and yet provide an adequate film to keep the contact surfaces separated. Hydrodynamic lubrication is a term used to describe the lubricant's ability to increase film thickness and pressure with increasing speed of the rolling element. This is similar to a car tire hydroplaning on water and lifting away from the road surface.

This behavior also explains how different lubricants, like mineral based paraffinic oils and synthetic oils, have different pressure coefficients and film thickness variations with respect to speed. For example, synthetic and ester based lubricants don't tend to build up as much pressure and film thickness with increasing speeds as do mineral oils. For these reasons synthetic oils have been known to conserve energy, lower friction and temperature and are also used in high speed bearing applications.

Over Filling of Oil Housings

When equipment utilizes oil as the lubricant, beware of over filling. This can be as dangerous as too little lubrication since it will churn excess oil between the bearing rolling elements and raceways. When the oil film builds up, it creates a high pressure zone between the rolling element and raceway which adds friction and shear within the lubricant. This will elevate bearing temperature, lower oil viscosity and can result in bearing failure.

When installing a pillow block, it can be hard to establish a proper oil level. You may not be able to clearly determine if the oil level is at the middle of the lowest roller, which is the proper setting, in certain pillow block housings. I observed this first hand when installing a new pillow block in a blower application.

UPTIME® TRAINING GUIDE LISTING

Uptime® Magazine has searched the planet to locate independent training courses that provide new ideas, new strategies, new techniques and new tools to improve maintenance and reliability at your organization.

company	date	title, speaker/location & website
LIFE CYCLE INSTITUTE	Oct. 26–28, 2010	***Root Cause Analysis*** by Josh Rothenberg www.lce.com
GP Allied INSPIRED.RELIABLE.GLOBAL	Oct. 26–28, 2010	***Reliability Centered Lubrication*** Denver, CO www.gpallied.com
LUDECA INC.	Sept. 20–22, 2010	***Balancing 3-Day VIBXPERT*** Miami, FL www.ludeca.com/training
SKF	Sept. 21–24, 2010	***Level II Dynamic Motor Monitoring*** Fort Collins, CO www.skf.com
People and Processes	Oct. 12–13, 2010	***Maintenance Management Principles*** University of North Florida, Jacksonville, FL www.peopleandprocesses.com
MOBIUS	Aug. 23–26, 2010	***Category I Vibration Course*** Knoxville, TN www.mobiusinstitute.com
commtest The Revolution	Sept. 13–15, 2010	***Advanced Ascent Software Applications*** Knoxville, TN www.commtest.com

for more information and additional training listings, please log onto www.reliabilityweb.com and then click on the 'events' menu tab.

Although the bearing catalogue provided an oil level dimension from the base, it was still somewhat difficult to set the automatic oil leveler with great accuracy. It is also important to note that the volume of oil in this housing was relatively small and provided little margin for oil level deviation. In an application such as this, there is little or almost no room for error, which makes it risky and unrealistic from a maintenance standpoint.

If conditions permit, utilizing grease in an application like this can help make life simpler, as well as provide better protection from outside contamination, especially with open labyrinth seal designs. The grease will also act as a heat sink to help dissipate heat through the pillow block. In fact, after utilizing grease in this blower application, we observed lower temperatures and have had no other issues.

If you ever experience hot running pillow blocks and are unsuccessful in lowering pillow block temperatures despite utilizing different greases or oils, there is a possible solution. There is a type of pillow block housing that utilizes a slinger ring just like the ones used in most API pumps and smaller steam turbines. Utilizing a slinger ring type pillow block bearing housing will help bring down the bearing operating temperature. This is due to a thinner oil film created from oil splashing, which minimizes oil churning and added friction. Some of these pillow block housings also have an option to use internal water cooling jackets for added cooling capacity. If the budget permits, oil mist lubrication has proved itself as one of the most reliable means of lubrication in the industry, since it provides a constant source of fresh uncontaminated oil and maintains a light film that promotes cooler operation and added bearing life.

Each specific application will dictate what type of solution is most appropriate, since it is based on operating speeds, loads, temperature etc. However engineers involved with the designing or maintaining of equipment need to familiarize themselves with basic lubrication theory since it explains how these lubricants actually work and provides more insight into their limitations. Also knowing the basic characteristics of both mineral and synthetic oils will help determine which is best suited for the application, since they both have limitations and there is no such thing as a "one for all" solution like some individuals will try to sell you.

After graduating with an Associates Degree in Applied Science from Camden County College in 1989, Charles Kropewnicki began working as an AutoCAD Draftsman and Designer. He decided to go back to college full time and graduated from Widener University with a BSME in 1998. After graduation, he utilized his CAD skills and worked as a Designer/Engineer with Pro-Engineer 3-D CAD. After a couple years, he accepted a position with SKF as an Application Engineer. At SKF, he assisted customers by giving bearing presentations and wrote bearing failure analysis reports with recommendations; this provided insight to causes of shortened bearing life. Charles also received training from SKF College in Lubrication Tribology, which provided a theoretical basis for grease and oil behavior within a bearing. In looking to expand his knowledge regarding rotating equipment, he accepted a position with Western Refining in Gallop, NM and is currently working at Western as a Project Engineer. Charles can be reached by phone at 610 316-9841 via e-mail at ukpcak1@yahoo.com

Why do PdM Programs Fail?

Lack of Consistency in Methodology

by Tom Francisco, PE, CMRP

There are a number of reasons why Predictive Maintenance (PdM) programs fail. In recent years we have seen an industry shift toward outsourcing these functions to PdM service providers and/or equipment vendors in order to remedy the issues that have made it difficult for plants to run their own programs. This article will focus on the common problem of a lack of consistency in how the PdM program is run and managed; more from a technical level than a personnel level – although the two are often related. If your plant has not received the advertised 10:1, 20:1 or even 30:1 return on investment (ROI) promised by these programs then this article may provide you with one of the reasons why.

PdM vs. Troubleshooting

The first and probably most important stumbling block many PdM programs have faced is the simple lack of understanding the difference between using a technology such as vibration analysis in the context of a PdM program versus using it for troubleshooting. Both are valid uses for the tools and technology, but it is only the PdM approach that results in large and long-term ROI. In PdM, the goal is to monitor a large population of assets in a repeatable fashion over a long period of time; and thus, trending the data and monitoring changes in machine health to minimize the cost of maintaining that equipment and reduce the amount of downtime, especially unplanned downtime. This methodology provides information about the condition of the plant's assets, allows for reducing planned downtimes and eliminating unplanned outages, while enabling just in time parts delivery and more efficient repair cycles. If performed correctly, PdM will change the way the plant approaches maintenance.

Troubleshooting is simply the process of using a technology to confirm a known problem or to gain a deeper understanding of the cause of the problem. For example, perhaps a motor pump set is making a screeching noise and we want to know if it is coming from a pump bearing or from a motor bearing, we can use vibration analysis or perhaps Infrared Thermography to make the determination, and, thereby, overhaul the correct part of the machine. This is a valid use of the technology but it will not transform maintenance practices. Nor will it make a big difference in overall profitability. In this case, we already knew we had a problem. The technology was simply giving us more specific information about the source of the problem. PdM, on the other hand, if done correctly, should include a paradigm shift and provide a huge payback on investment.

Doing PdM Right

In order to run a successful PdM program, which means a program based on trending, one needs to spend some time defining how the assets will be tested in a repeatable and consistent fashion. From a technical standpoint, we are saying that if we hold all variables constant (test speed, test load, test location, sensor mounting, test set-up etc.) and notice a change in vibration (or other PdM technology variable) then we can definitively say that the machine has a problem. Typically we can also tell the severity of the problem and its source, especially as the fault evolves over time. Once a problem is identified, we can increase the test frequency and monitor changes in the severity of the problem (i.e. changes in the data) until it is time to make a repair recommendation.

If you take a moment to consider this in light of how we are using the technology today, or in light of the skills of the person running our program or in light of the type of training courses we sent our resident expert to, we might notice some inconsistencies that may point right to the root of the reason why our program is not as successful as it should be. Let's take a step back. In order to do PdM right, the particular asset should be tested in exactly the same way, every time, month to month, quarter to quarter, and year to year and then simply look for changes in the data. In this context, changes in the data will indicate a fault or problem with the asset. Based on this, where does it seem that most effort needs to lie? In understanding all of the different aspects and options and test types supported by our data collector, or in defining standard test procedures for each of our assets? In standing by the machine taking 10 different tests and moving the sensor around like a stethoscope, or in making sure a technician knows exactly where to place the sensor on each asset and exactly how to line the asset up for a standard test? In spending hours pouring over graphs trying to read squiggly lines like tea leaves, or in simply comparing a new set of data to a well developed baseline and looking for obvious changes? In taking courses in dynamics and the nuts and bolts of vibration analysis, or in taking courses in PdM program management and working at improving general organizational skills? In hiring the hot shot analyst troubleshooter guy, or in hiring someone who is well organized, dependable and able to write out procedures and follow them?

It may seem counterintuitive, and perhaps this is why

so many PdM programs have failed over the years, but a successful program is the result of following a standard set of procedures and remaining consistent year after year, not in being an expert at looking at graphs. Yet in the industry, we often see people taking certification courses that teach a lot about looking at graphs and little or nothing about managing a PdM program. Or we get training from an equipment vendor that focuses on data collector and software features rather than program management. Then we wonder why we are not getting the results we should be getting.

Some Tips on Methodology

In order to run a successful PdM program, each asset should be tested in the same way each time. Assets need to be tracked to make sure it is the same as before (i.e. - perhaps someone replaced a pump with a similar one made by a different manufacturer...we need to know this) and a good set of baselines or meaningful alarm limits must be developed. In order to evolve from PdM to Proactive Maintenance, root cause failure analysis must be performed to understand how some machines deteriorate, wear out and fail in comparison to other similar machines. This allows the purchase of equipment appropriate for the application. All of these items require keeping good records over time, in a consistent way, and looking at trends.

Repeatable Test Conditions — Regarding test conditions, each asset must be tested the same way each time. Any significant (say 10% or more) change in speed or load will change the vibration produced by the machine. In PdM, the idea is that a change in the vibration means there is a change in machine condition. We can't make this call if the speed and load are not consistent during a test and from test to test, year in and year out. Therefore, it is quite important to understand the asset we are testing, understand how it is used in the plant and how plant process affect its speed and load. Only then can we attempt to define a repeatable test condition. Once this is accomplished, it must be documented and the people testing the machine must be made aware of this documentation and the importance of following it. It should be noted that many machines may need to be tested off-line or under artificial circumstances; valves may need to be aligned to keep compressors loaded or fan dampers in a steady position. In some cases, nearby machines must be secured in order to separate their vibration from the machine being tested.

However test conditions are defined, they must be documented in such a way that the assets are tested the same way every time, year after year after year, no matter who is actually testing them.

Repeatable Test Locations — Although it is important to place a sensor on the machine in an appropriate position, it is more important to always place the sensor in the same position, test after test, year after year. For this reason, the use of sensor mounting pads is highly recommended – for either magnet mount sensors or screw type sensors – to ensure the sensor is always placed in the same spot on the machine. These test locations must also be documented so that in 5 years, if the test pad falls off or the machine is overhauled and the test point is removed or a new person comes to the plant to take over data collection duties, there is no question as to where to place the new test pad.

Consistent Test Types — Regarding test setups, test types and data analysis; these should also be kept constant. It is not up to the analyst to go out each time and test the machine or asset according to his mood that day or according to what particular fault he is looking for. Special tests may be appropriate, but this is troubleshooting, not PdM, and it does not have the same financial implications as PdM. It should also be noted that if PdM is done correctly, there should be little need for troubleshooting. Good, consistent data collection and trending should give you enough information about machine condition that you won't have to troubleshoot.

Understand the best general way to test each asset, with help from an outside consultant if necessary, and stick to that setup. Document this in your software or database (and use software that facilitates this and has a database). When reviewing actual data; do it in a standard manner as well. Use the same graph scaling each time and overlay the baseline or alarm criteria. Train yourself to always look at data in the same way, compared to the same criteria and the actual analysis part of the process will become insignificant in comparison to the other necessary ingredients of running a successful program.

It May Not Be Sexy... But It Works

You don't need to be a CAT IV certified vibration analyst to draw a stick figure of a machine on a piece of paper indicating where to replace the sensor mounting pad when it falls off and where to affix the sensor when testing. You don't need to be a novelist to make a note on the stick figure saying that this pump must be placed on recirc at 60 psi before testing, or the valve on this compressor must be opened to keep it fully loaded throughout the test. You don't need a high tech analyzer with a million features to collect a standard reading. You don't need to be a rocket scientist to write down the name plate information for your assets to make sure one machine wasn't replaced with a different one without your knowledge. However, the fact is that these simple and mostly non-technical steps are the most important features of a successful PdM program.

Although these tasks are not particularly difficult, it can't hurt to find a good partner to help define the test points, test types, test conditions and set up your database for you. A good partner will be able to return to your plant on a yearly basis to review the program and verify that new equipment is set up correctly, that test points on the machines match test points defined in the database, that baselines are appropriate and that your fault reports and repair recommendations are correct.

Based on the information presented in this article, it should be clear that a good partner is not the vibration expert guy who is going to come take 100 tests and troubleshoot a single piece of machinery for you. Rather, it is a company with a long history of managing PdM programs that will focus on helping you setup the proper test and analysis procedures and will help you train your staff on following these procedures. In many cases, you might find it cost effective to let these companies continue to manage your program or to remotely analyze data that you collect. Whatever you decide, just note that consistency is the key to success and methodology is more important than analysis prowess!

Azima DLI's Tom Francisco, PE, CMRP, has more than 20 years of machine condition monitoring experience with expertise in vibration analysis, infrared thermography, motor and battery testing and oil analysis. Azima DLI (www.azimadli.com) is the leader and premier provider of predictive machine condition monitoring and analysis services. Francisco, a licensed professional engineer, has been with Azima DLI since 1995 and conducts all phases of client training in the use of Azima DLI vibration monitoring systems as well as in-house training to other Azima DLI engineers and technical personnel. Previously, he worked as a nuclear-qualified machinist mate on the U.S.S Enterprise, an engineering technician, a mechanical engineer and a senior systems engineer.

The Best Defense Is a Good Offense

The Quest For Maintaining Efficiency in Motor Repair

by Kitt Butler

In the June/July issue, we introduced, "Guidelines to a Good Motor Repair" – a document designed to help facilitate communications between a motor repair vendor and the customer. This article will explain why motor repair is important and what the marketplace is doing to ensure quality in the process.

In the United States, electric motors convert an estimated 50 percent of all electrical energy generated into mechanical energy. Electric motors are the largest single category of electric technology in use today. During this conversion, there are losses in motors that typically result in wasted heat, and over time, reduce the motor's operating life. Higher motor efficiencies reduce this wasted heat, which saves energy and ensures the maximum motor life.

Managing motor populations is typically referred to as Motor Management, and organizations actively engaging in this activity are reporting 5-8 percent reductions in total electric energy consumed along with significant increases in overall reliability. At its core, Motor Management is about managing the efficiency of your motor population one at a time. Sound Motor Management practices include: having a new motor purchase specification, a motor repair specification, regularly scheduled motor maintenance, the use of predictive tools such as current signature analysis, considering system driven approaches for certain motor driven processes and motor inventory strategies.

Fortunately, there are many free tools to help motor users better manage the efficiency of motor populations. The United States Department of Energy (DOE) first addressed energy use with regards to electric motors in the late 1980's when it created the Motor Challenge Program. Today motors are addressed under the DOE's Best Practices Programs (http://www1.eere.energy.gov/industry/bestpractices/). In 1991, the DOE supported the development of the HorsePower Bulletin which may be the most widely distributed document on the topic of motor management today. It can be downloaded for free from this url - (http://www.advancedenergy.org/md/knowledge_library/resources/Horsepower%20Bulletin.pdf). The Motor Decisions Matter Campaign (http://www.motorsmatter.org/) also provides education and useful tools from its sponsors, which include motor manufacturers, DOE, energy efficiency advocates and electric utilities.

In more good news from the DOE, The Energy Policy and Conservation Act of (EPCA) 1992 set minimum efficiencies requirements for new motors between 1-200 horsepower (hp). Under the Energy Independence and Security ACT (EISA) of 2007, efficiencies for motors previously covered by EPCA will rise again. In addition, several new categories of motors will be regulated for efficiency for the first time. This law is scheduled to go into effect December 19, 2010 for all electric motors covered. The motor manufacturing industry helped shape these laws and has also simplified the purchasing process by standardizing efficiency for certain motors under one label, NEMA Premium®. Whenever possible, motor purchasers should specify NEMA Premium® when ordering new motors. More information about this program for new motors can be found on NEMA's web site (http://www.nema.org/gov/energy/efficiency/premium/).

What should motor users do when their higher efficiency motors fail? The simple answer: protect your investment. The best research we have today is from the DOE's "United States Industrial Electric Motor Systems Market Opportunities Assessment " (1998) which states that four out of five motors that fail are repaired. While that number may be lower today, there are plenty of reasons to believe that many motors that fail are getting repaired because, obviously, it is good business practice to keep operations running smoothly. What happens to motor efficiency during repair is hotly debated by many, as there is no cost effective way to measure motor efficiency each time motors are repaired with precision. One could certainly test the motor before and after repair, and some companies do this. However, to ensure accuracy this should be done in a controlled environment such as a lab by experienced engineers where repeatability and accuracy are controlled. Many motor service centers have dynamometers for load testing, which is important to the repair process. However, these dynamometers, and the test procedures employed by most motor repair shops, are not designed for accurate efficiency measurement.

Blind studies performed decades ago by motor efficiency test labs in Canada indicate motor efficiency can be compromised by an average of 2 percent when

repaired. The DOE's motor decision tool, Motor Master+, defaults to 0.5 or 1.0 percent drop in efficiency for repair, depending on the size of the motor. Other studies conducted by The Electrical Apparatus Service Association (EASA) and Advanced Energy's motor lab found no reduction in efficiency when motors where properly repaired. If you'd like to gain a better understanding, the "Effect of Repair/Rewinding on Motor Efficiency - EASA/AEMT Rewind Study and Good Practice Guide" is available for purchase (http://www.easa.com/). EASA is the international trade association for the motor repair industry. Advanced Energy's test results on motors before and after repair are the property of the motor service centers that are approved under the Proven Efficiency Verification Program (PEV), a quality assurance program for motor repair. To see these reports contact an approved motor service center by visiting: http://www.advancedenergy.org/md/consulting/repair_shop_selection.php.

$$\text{Annual Cost} = \frac{HP \times 0.746}{eff} \times \text{load \%} \times \text{operating hours} \times \frac{\$}{kWh}$$

Figure 1 - Equation for calculating loss in dollars for drops in motor efficiency.

One half to a full point of efficiency lost may not sound like much, but it is costly in terms of operating expenses (cost of electricity), especially when considering all motors being repaired. Using the equation in Figure 1, we can compute the loss in dollars associated with one half percent drop and a full percent drop on an annual basis.

There are several good examples of industry specifications that can be utilized in the development of your motor repair specification.

The EASA Standard AR100-2006 Recommended Practice for the Repair of Rotating Electrical Apparatus is recognized by the American National Standards Institute (ANSI), and can be downloaded for free (http://www.easa.com/industryinfo/AR100). The Consortium for Energy Efficiency also offers a motor repair specification (http://www.cee1.org/ind/mot-rep/mot-rep-modspec.pdf). Both are helpful tools for developing a required repair specification for your vendors.

Most motor repair vendors will have a specification or procedures that are relevant to their organization's capabilities. You should ask to see your motor repair vendor's repair specification. This is a good opportunity to compare the motor service centers process to your motor repair needs. Ideally, they should match.

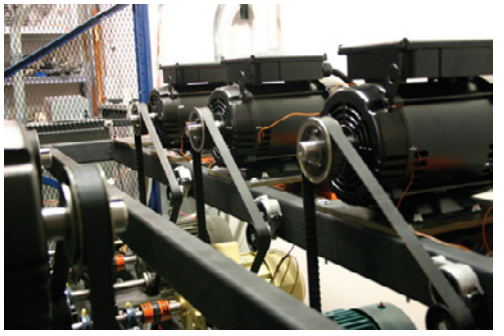
Another area that appears to be growing within the community of motor service centers is quality assurance programs. Quality assurance is necessary for any business. Some of these programs are directly targeted at maintaining efficiency during the repair process. Efficiency is vital to both a smooth operation and the bottom line. Therefore, we recommend that you look for motor repair vendors with these programs in place.

Some motor service centers are International Standards Association (ISO) registered or certified. ISO is a well known quality process that emphasizes documentation. ISO programs are general in nature and not specific to the motor repair process. The documentation is especially helpful for new employees, but ISO programs do not necessarily assure quality as it relates to maintaining efficiency. Some service centers employ ISO because of customer requirements and choose alternative quality assurance programs to document their ability to maintain efficiency during repair.

EASA-Q:2000 is a quality manual for the motor repair industry. It is available for sale from EASA, and, according to the website, "was created to provide EASA members a practical, cost-effective means of developing a quality management system. The manual is a guideline for implementing the ISO 9000 series of quality system standards. EASA-Q is designed so that all electrical apparatus service organizations can use it with minimal assistance. Inexpensive to implement and operate, EASA-Q can assist in reducing operating costs by emphasizing consistency - which often eliminates rework. The package consists of a printed manual and CD-ROM which can be used to customize your program."

The SKF Certified Rebuilder Program periodically audits motor service centers. The program focuses on training motor shop personnel on the aspects of bearing failure, replacements and root cause analysis. The program properly identifies the main cause of motor failure and works to ensure personnel are trained to replace bearings and repair motors. It appears to focus on reliability improvements for motors by focusing on bearing replacement. For more information on this program visit: http://www.skf.com/portal/skf/home/services?contentId=687952.

The Green Motors Practices Group asks participating motor service centers to sign an annual membership agreement and subject themselves to scheduled audits from personnel not currently working in the motor repair industry. Charter memberships in the group are available to shops at no charge. Some of the items in this agreement include an annual commitment from executive and service center management to clearly communicate policies, support system efficiency with customers, submit calibration records and continually improve shop "champions" with 8 hours of documented training per year. A contact person is required to work on marketing aspects of the program and a second contact must be identified to work with the auditors. A unique aspect of this program is that two utilities (Bonneville Power and BC Hydro) and some of their distributors recognize the Green Motors Practices Group under the Green Motor Initiative (GMI) Program and pay incentives to the shops and their customers for qualifying repairs. In the first year of existence (2009), GMI claimed savings of 1,624,400 kWhs and $180,682 in paid in-



Figures 2 and 3 - Images of Advanced Energy's accredited motor efficiency test lab.

centives. For more information visit: http://www.greenmotors.org/index.html.

Proven Efficiency Verification (PEV) is a motor repair quality assurance program developed by Advanced Energy. It is specifically designed to ensure motor efficiency during the repair process. The PEV Program began in 1999 and was originally developed with the assistance of a past EASA president. PEV requires periodic assessments of specific equipment used in the repair process, documentation of procedures, process flow, calibrations for certain metering equipment, process controls, specific materials and repair personnel experience. After each shop assessment, a detailed report is provided which identifies areas requiring attention. The shop is then required to perform before and after repair testing. Once the motor service center achieves compliance with the site assessment and the before and after testing, they are granted certification for one year and have access to all of the marketing benefits associated with being PEV certified. Each subsequent year motor service centers are required to submit documentation through a renewal application and have motors subjected to testing before and after repair (see Report 1) at Advanced Energy's National Institute of Standards and Technology (NIST) accredited motor efficiency test lab. There are fees associated with the program that motor service centers pay. Currently there is no utility support and no direct involvement from the motor repair industry in the management of the program. For more information visit: http://www.advancedenergy.org/md/consulting/repair_shop_selection.php.

Motor repair is a critical service that keeps our businesses and industry running smoothly. We have federal laws in place that mandate motor efficiency, but nothing like this for the motors we repair. When you consider that an estimated 40-60 percent of all electric energy generated in the world is delivered to motors to literally run our lives, maintaining the highest efficiency possible is crucial. Quality motor repair saves energy, money and time (by reducing time between failures), There is one other added benefit when motor repair is chosen over motor replacement and that is recycling. It is estimated that on average 98.5 percent of motor materials are recycled when repaired. When all is said and done, a quality motor repair can save money, increase efficiency and conserve natural resources.

PROVEN EFFICIENCY VERIFICATION TEST COMPARISON

Shop: Any Shop
Address: Anywhere
Test Method: IEEE 112-1996 Method B

Certification No: 0207-AG-06
Date Certified: 3-Jul-02

MOTOR DESCRIPTION

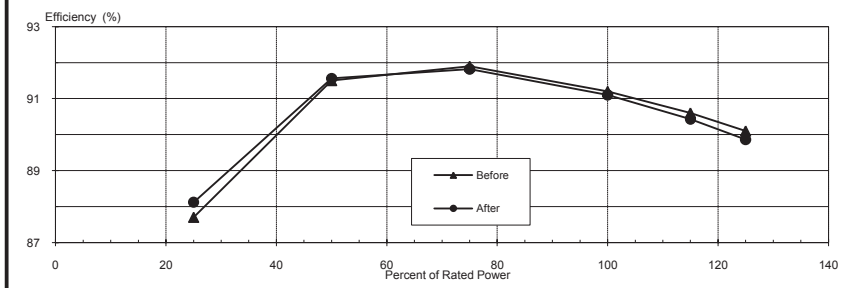
AE Motor ID #:	0056
Manufacturer:	Toshiba
Model number:	B0504VLF1UK
Serial number:	8501317C
Rated Power:	50 hp
Rated Voltage:	460
Rated Current:	63 A
Rated Speed:	1765
NEMA Design:	B
Enclosure:	DP
Frame:	326T
Insulation Class:	F

PERFORMANCE COMPARISON

Parameter	Before Repair	After Repair
Test Data File:	AM0056DA.xls	RM056EA.xls
Test Date:	1/7/1999	6/28/2002
No-Load Performance		
Current:	19.1 A	18.8 A
Power Input:	1.12 kW	1.07 kW
Rated Load Performance		
Speed: (rpm)	1766	1765
Current:	60.1 A	60.2 A
Current Unbalance:	0.3%	0.7%
Power Factor:	85%	86%
Temperature Rise:	47 °C	53 °C

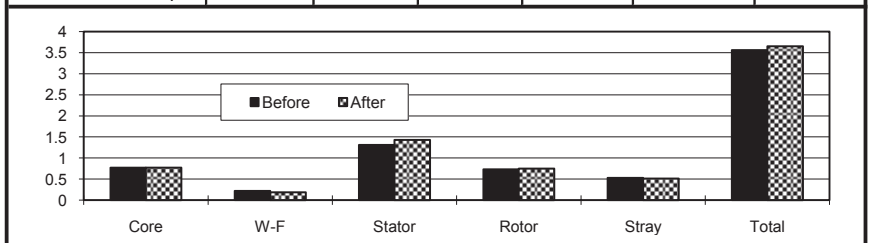
MOTOR EFFICIENCY AT PARTIAL LOADED CONDITIONS

	Load Point (% of rated)					
	25	50	75	100	115	125
Before Repair	87.7	91.5	91.9	91.2	90.6	90.1
After Repair	88.1	91.6	91.8	91.1	90.4	89.9



MOTOR LOSS DISTRIBUTION AT RATED CONDITIONS

	Fixed		Variable (Load Dependent)			
	Core	W-F	Stator	Rotor	Stray	Total
Before Repair	0.77 kW	0.22 kW	1.31 kW	0.73 kW	0.53 kW	3.56 kW
After Repair	0.77 kW	0.19 kW	1.43 kW	0.75 kW	0.51 kW	3.65 kW



Advanced ENERGY

909 Capability Drive, Suite 2100, Raleigh, NC 27606-3870
www.advancedenergy.org/md (800) 869-8001

PEV CERTIFIED

Report 1 - A sample test report from the Proven Efficiency Verification program administered by Advanced Energy.

Kitt Butler is the Director, Motors and Drives at Advanced Energy. He facilitates delivery of successful consulting and testing services to motor manufacturers, distributors, original equipment manufacturers (OEMs) and industrial customers. He is known for his expertise in helping customers explore key issues that affect the reliability of their products, productivity of their processes and overall economic well-being. Kitt participates in a variety of industry groups and helps shape motor efficiency legislation by supporting the work of the U.S. Department of Energy (DOE). Through utility programs, Butler has helped introduce innovative new motor and drive technologies that have significantly reduced energy consumption and demand in California. Butler is intimately involved with product development, market planning and budgeting for Advanced Energy. He is currently managing all aspects of the motor and drive services group including building the organization's new motor reliability team. Kitt can be reached at kbutler@advancedenergy.org or at 919 857-9017 .

RELIABILITY® PERFORMANCE INSTITUTE

Are you seeking a *Starting Point* for your Maintenance & Reliability improvement program?

Try a **Zero2One**™ learning event.

2011 SCHEDULE GUIDE

Reliability® Performance Institute™ events are produced by Reliabilityweb.com® and Uptime® Magazine and endorsed by the Association for Maintenance Professionals.

Goal & Mission:

If you are at the beginning of your journey or have already made progress, the *Reliability® Performance Institute™* offers learning and networking events designed to provide a comprehensive view of available strategies, techniques, technologies, training and tools so that you can build resources that will be effective in your organization. Learn from subject matter experts and practitioners who do what you do and have already made the journey.

February 7–11 | Reliability Leadership Zero2One™ Series I

Please join Reliabilityweb.com® for a unique learning event designed for anyone who is responsible for managing maintenance and ensuring reliability. This series has been specially designed to start at the beginning and deliver basic concepts to provide a foundation for designing a sustainable and ongoing improvement program. The subject matter experts and noted authors who lead these programs have also designed a series of interactive exercises to reinforce the proven strategies, techniques, technologies and ideas covered.

Attend this event before you begin a Reliability Improvement Project and you can avoid common pitfalls and learn proven concepts.

- ***Benchmarking Best Practices for Maintenance Management*** by Terry Wireman, Author, *Benchmarking Best Practices for Maintenance Management*
- ***Advancing Reliability and Maintenance*** by Jack Nicholas Jr., Author, *Advancing Reliability and Maintenance*
- ***Operational Excellence*** by Ron Moore, Author, *Making Common Sense Common Practice* and *Selecting the Right Manufacturing Tools*
- ***Journey to the Precision Domain*** by Winston Ledet, Coauthor of *Don't Just Fix It, Improve It! A Journey to the Precision Domain*

March 21–25 | RCM-2011 Reliability Centered Maintenance Managers Forum

The top 20% of effective maintenance programs all use some form of Reliability Centered Maintenance to ensure the right work is being done at the right time.

Attend RCM-2011 to learn about using Reliability Centered Maintenance, PM Optimization and FMEA to create an effective maintenance program with presentations from subject matter experts combined with actual case studies from organizations that have used these techniques. Various approaches to Reliability Centered Maintenance are covered to allow you to form a blended approach based on asset criticality to create an effective maintenance program. Pitfalls are also discussed. This event is designed for people who are new to the concept of RCM; however we are sure everyone will benefit regardless of experience level.

April 12–15 | CMMS-2011 Computerized Maintenance Management Summit

According to research only 20% of CMMS implementation produces the results desired by the organizations using Computerized Maintenance Management Systems. This learning and networking event is designed for those seeking to implement a new CMMS/EAM or reimplement an existing CMMS/EAM for more effective maintenance management and decision support.

May 3–6 | CBM-2011 Condition Monitoring Forum

This learning event is designed for anyone who is responsible for establishing, creating or managing a condition based maintenance program.

Research shows that leading organizations use condition based maintenance to direct corrective maintenance actions and avoid unexpected failures while laggards are dependent on time based or reactive maintenance.

Advanced sensing technologies such as vibration, infrared, motor testing, oil analysis and ultrasound are utilized to predict possible failures early enough to plan repairs when they will be less intrusive to operations or manufacturing.

Attend the Condition Monitoring Summit to learn more about the technologies, information management and program management to support a World Class Reliability Program.

June 13–17 | Reliability Forum for Water/ Wastewater Utilities

Leading water utilities are placing a focus on optimizing asset performance and management to deal with aging equipment and infrastructure and to meet regulatory challenges. The result is benchmarked performance well beyond laggard utilities that are basing maintenance tasks on OEM and other time based reactive directed tasks.

Attend this learning and networking event to discover new ideas to improve the performance of your utility. You will learn how utilities are using Reliability Centered Maintenance and other analysis techniques to drive more condition monitoring to replace ineffective time based maintenance strategies.

July 12–15 | PAS 55-2011 International Benchmark For Optimal Management Of Assets

According to the Institute for Asset Management BSI PAS 55:2008 provides a clear and concise definition of what needs to be done to tune physical assets for business objectives at any point in their lifecycle. PAS 55 covers every organization—whether private or public—in any sector. It is already in use within public services and property, utilities, transport, manufacturing, mining, oil and gas, defense, pharmaceutical, process and heavy engineering.

Now for the first time ever, Reliabilityweb.com® has assembled the world's leading experts and practitioners to provide you with a three day educational session designed to enlighten you on PAS 55, explain the opportunities and challenges, discover different PAS 55 road maps and explore certification options and business advantages.

August 15–19 | Reliability Leadership Zero2One™ Series II

Please join Reliabilityweb.com® for a unique learning event designed for anyone who is responsible for managing maintenance and ensuring reliability. This series has been specially designed to start at the beginning and deliver basic concepts to provide a foundation for designing a sustainable and ongoing improvement program. The subject matter experts and noted authors who lead these programs have also designed a series of interactive exercises to reinforce the proven strategies, techniques, technologies and ideas covered.

Attend this event before you begin a Reliability Improvement Project and you can avoid common pitfalls and learn proven concepts.

- ***Operator Driven Maintenance*** by Terry Wireman, Author, *The Maintenance Strategy Series*
- ***Predictive Maintenance Management*** by Jack Nicholas Jr., Author, *Predictive Maintenance Management*
- ***Total Productive Maintenance – Reloaded*** by Joel Levitt, Author, *TPM Reloaded*
- ***Asset Operational Excellence*** by John Mitchell, Author, *Physical Asset Management*

October 4–7 | Reliability Centered Maintenance for SAP Plant Maintenance

Learn about the strategies and tools available for the SAP Plant Maintenance/EAM platform that support using Reliability Centered Maintenance, PM Optimization and FMEA to create an effective maintenance program. This event features presentations from subject matter experts combined with actual case studies from organizations that have used these techniques. Various approaches to Reliability Centered Maintenance are covered to allow you to form a blended approach based on asset criticality to create an effective maintenance program. Pitfalls are also discussed. This event is designed for SAP users who are new to the concept of RCM; however we are sure everyone will benefit regardless of experience level.

RELIABILITY® PERFORMANCE INSTITUTE

8991 Daniels Center Drive, Suite 103, Fort Myers, FL 33912
Toll Free: 888-575-1245 | Phone: 239-333-2500
Website: www.maintenanceconference.com

Do you have a topic you would like to present?

Reliabilityweb.com® is always seeking presentations from organizations that have made or attempted to make reliability improvements in the past. We value presentations about "what did not work" as much as presentations about "what did work". No organization has achieved perfection in maintenance reliability; however, many have made great strides and we are looking for those who are willing and able to share those stories so we can all learn.

The cycle of *Learn—Do—Teach* is a proven way to enhance your professional development and to build your professional network. Visit http://uptime4.me/rpizero2one to propose a presentation.

MARK YOUR **2011 CALENDAR** AND JOIN US!

Care For Your Spares

Poor Spare Parts Maintenance Can Kill Your Plant's Efficiency

by Wally Wilson, CMRP, CPIM

You could, unknowingly, be introducing premature failure to your equipment assets. And inadequate inventory management practices for spare parts in your Maintenance, Repair, and Operating supplies (MRO) storeroom could be the cause. The storeroom is one of the foundation blocks that support the maintenance department's efforts to keep production equipment running at the most efficient levels possible. Most every company competing in the fast-changing global market has recognized the need to identify waste and inefficiencies in each business unit and to implement best practice processes and business practices to increase their competitive advantage. The overall success of your business, and its employees, hinges on each block of the foundation performing at the highest level possible.

The person responsible for storeroom operation plays a key role in the level of equipment reliability and outcome of operational efficiency for your plant. But it's only the storeroom – how can it play such an important role in the success of the business? There are typically several million dollars invested in the MRO inventory and many of the parts are critical to the operation of the business. I'm sure if we had several million dollars of our money invested we would insist that it was cared for and checked each day to ensure we were getting the most benefit possible from our investments.

Let's consider a couple of common scenarios. If the inventory management system indicates there is inventory available and the part cannot be found, the routine repair now becomes an emergency-expedited purchase and the charges start to mount. What if the storeroom employee receives a requisition for a part or assembly, goes to the storeroom location, pulls the part, issues it to the work order only to find that the part has been in the inventory for over ten years and has never been checked or cared for since it was put on the shelf? A high probability of failure is introduced into the equipment when the neglected part is installed. To compound the problem, if the newly installed part does fail to perform, the situation will probably be repeated again when the next part is pulled from inventory and put into service. If that part has been neglected like the first unit, it is a sure bet that the situation will be repeated and lost production time, along with the added cost to have the supplier expedite a replacement part, will far exceed the cost and effort to properly care for the original units.

The care and preventive maintenance practices of the storeroom inventory are essential for ensuring that rotating spares like motors, gearboxes, pumps and some actuator valves will operate at full capacity and for the expected service life of the unit. The following pictures are some vivid examples of situations resulting from motors and other equipment that were purchased from a certified supplier, but due to poor storage practices and lack of a preventive maintenance program in the storeroom, began to fail almost as soon as they were put into service.

The vertical mount motor in Figure 1 was stored in the correct position, but was not maintained under a scheduled preventive maintenance program, and was stored in a storage facility that was dusty and not environmentally controlled. These were all factors that led to the premature failure of the unit. Thirty minutes after the motor was put in service the technician took a thermo-graphic photo of the main drive bearing, and as you can see in the photo, there was a problem. The motor ran for about six more hours and seized up. Since a second motor was not available, the damaged motor was removed and expedited to the supplier to have it rebuilt and returned to be re-installed. Since there was not a redundant system, the process was

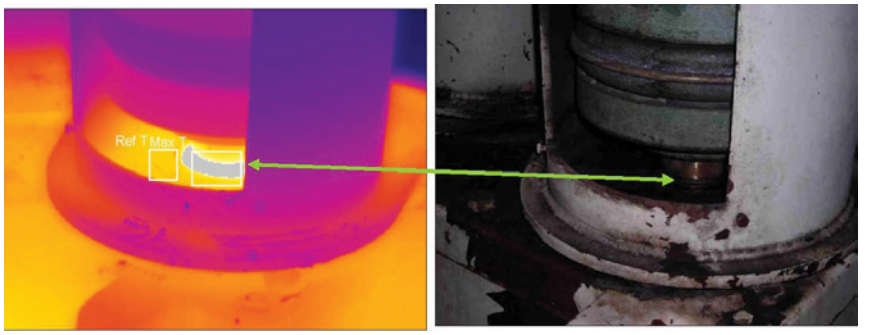


Figure 1 - Infrared thermography detected a fault condition after this vertical mount motor ran for only 30 minutes.

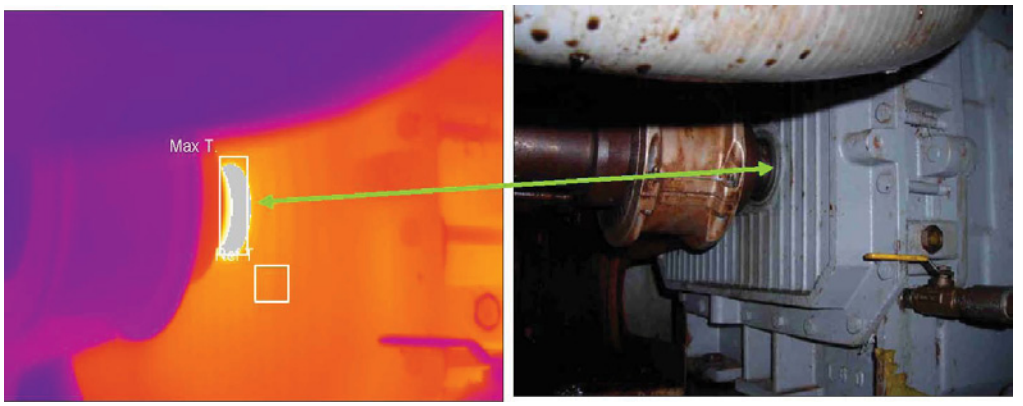


Figure 2 – Blower unit that was stored for over 10 years in the same environment developed a fault and would fail within hours of being put in service.

forced to shut down until the rebuilt motor was returned from the supplier.

Figure 2 is an example of a blower unit that was stored in the same environment for more than 10 years. When it was requisitioned to replace the existing failed unit, the replacement unit began to show signs that it too would fail within hours.

These scenarios and others like them are repeated daily in organizations around the world, and cost millions of dollars in lost production and, in many cases, an excess investment in storeroom inventory. Ensuring the right parts are available at the right price, quantity, quality and within established stocking parameters is essential to supporting a proactive business operation. Deciding to stock or not to stock a spare part should focus on the criticality of the part to the sustained operation of equipment assets.

It is always appealing to have the supplier stock and maintain spare parts at their site, making these parts available within a few hours notice for equipment repairs. Sometimes this option is not viable and stocking a spare part is required by the insurance underwriter or a reliability engineer, or is necessary due to a lack of availability from the supplier. When the decision is made to stock a spare part in the storeroom inventory, it can be held in the inventory for many years. With thousands of dollars invested in spare parts, it is important to have a program to ensure these parts remain in service-ready condition. Rotating spare parts like pumps, motors, gearboxes, blowers and other parts can be damaged by the environment, site storage conditions or careless handling by storeroom employees. Managing these spare parts under a preventive maintenance program identifies these issues and can prevent a defective unit, predestined for failure, from being put into service.

As a general rule, rotating spares and large bearings should be exercised at least 450

degrees every 45 to 90 days. Motors held in the storeroom inventory over five years should be bench tested to ensure they will perform as expected when put into service. According to the storeroom environment, rotating spare units should have the bearings repacked every five to seven years with compatible grease to ensure the grease doesn't dry out or become compacted.

A preventive maintenance program will not solve all the problems for these spare parts. To ensure proper material handling and storage of the MRO inventory, it's important to train employees on how to maintain spare parts to keep them in service-ready condition. Careless handling of a motor (for instance, a direct impact to the drive line), will compromise the integrity of the unit and shorten the service life of the motor. In the earlier examples of the blower unit and the vertical pump motor, the root cause analysis concluded that the bearings failed due to dry, compacted grease and brinelling of the bearing and bearing race, causing premature failure of the units.

Housekeeping, and the implementation of a scheduled cycle count program, will support a scheduled preventive maintenance program. Dust and debris can contaminate stored bearings and other spare parts that have been removed from their original packaging, contributing to premature failure when put into service. A visual management program, including 5S and Kaizen training to implement and sustain housekeeping, is essential. In many cases, storeroom employees are unaware that how they handle, store and manage the storeroom inventory is causing equipment failure.

Implementing a scheduled cycle count program is more than just counting selected items of the MRO inventory. The cycle counting process should also include a general assessment of the spare parts in storage and answer the following questions:

- Have parts been removed from the spare?
- Is the unit free of dust and debris?
- Is exposed metal corroded?
- Does the physical location of the part match the location in the warehouse management system?
- Are there item count discrepancies?
- Are count discrepancies noted and adjusted in the inventory system?

It is essential to have spare parts readily available to maintain your equipment. Having those parts perform as expected when they are put into service should be an expectation of your storeroom. If you are not getting the expected service life from parts used to maintain your equipment assets, look at how these spare parts are being stored and maintained in your storeroom. The lack of standard work practices and a scheduled preventive maintenance program in your storeroom might be affecting your plant performance.

Wally Wilson, CMRP, CPIM, is a Senior Subject Matter Expert specializing in Materials Management with Life Cycle Engineering. He has over 25 years experience in plant management with three Fortune 500 corporations. Wally is a member of the Society for Maintenance & Reliability Professionals (SMRP) and the American Production & Inventory Control Society (APICS). You can reach Wally at wwilson@LCE.com

Taking Care of Business

The Benefits of Implementing Reliability Engineering

by Fernando Vicente

Over the past several years, reliability has become an ever-increasingly important topic and component in the organizational continuous improvement tool box. Higher plant reliability reduces process and equipment failures, and as we all know, failure disruptions decrease production output, which in turn, limits gross margin. Additionally, equipment failures also increase the probability of having a catastrophic environmental accident and the potential for increasing safety related accidents.

Both the strong competitive environment between companies to secure business and the current world financial crisis are forcing organizations to explore ways to reduce operating costs. A popular approach to reduce operating costs is to reduce expenditures on equipment maintenance. While results can be obtained by reducing investments in equipment, this approach is very short sighted. It is not unusual that deferred investments will re-surface and cost 2 to 5 times more than if they were addressed in the early stages of failure development.

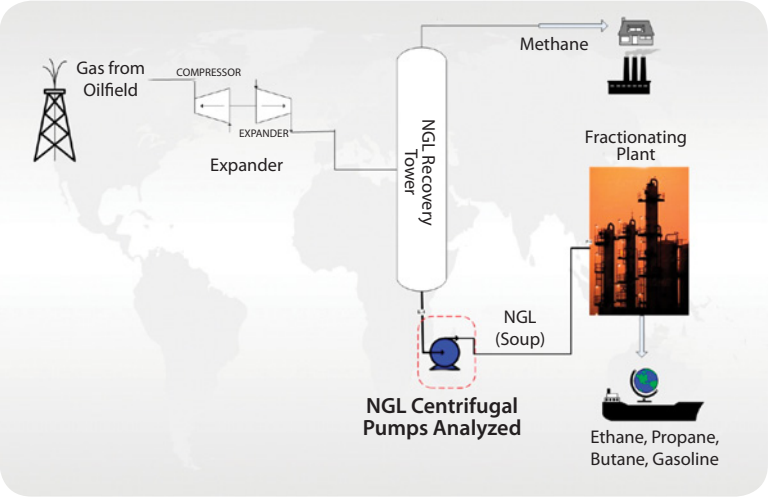


Figure 1 - Typical NGL Recovery Gas Plant Lay Out

The purpose of this article is to objectively demonstrate an approach that focused on reliability, availability and maintainability prediction which helped detect components, equipment and systems that required improvements. These predictions helped maintenance managers make the right decision while analyzing a centrifugal pump system in a gas plant. This process can be applied to many other components and systems across all industries.

Development

The primary function of a NGL Recovery Gas Plant is to recover the rich components of gas (ethane, butane, propane and gasoline) known as "soup". This soup is dispatched to a fractionating plant, where the components are recovered again and then sold to the market.

The centrifugal pump system analyzed is a critical part of the process, and is basically the core of business. The main purpose of the centrifugal pump is to take the soup out of the main recovery tower, and send the NGL (Natural Gas Liquids) to the dispatching area (See Figure 1).

The pump system is composed of two centrifugal pumps arranged in parallel — one pump is operating and the other pump is in standby. For reliability analysis purposes, the system is called "Stand-by redundancy" type 1 of 2, just one pump is in operating mode and the other pump is waiting for failure of the first pump. These are two-stage centrifugal pump type (WTB) and are vertically mounted. They are designed for heavy duty use in refineries, electric centrals and for general services.

The mechanical seal is an important component, due to the possibility of NGL leakage to the atmosphere, which could be dangerous. For this reason, the reliability of the mechanical seal in these types of pumps is a key aspect for the process to maintain the highest levels of both safety and gross margin levels.

Root Cause Failure Analysis (RCFA)

RCFA is a technique that allows us to determine the cause of failure, which could have a physical root or a human root. The purpose of RCFA is to resolve problems that affect plant performance and avoid recurrent problems. There are several techniques used such as FMEA, Failure Tree, Ishikawa, 5 Why's and statistical analysis. In this case study, we have used 5 Why's technique, Weibull analysis (statistical technique) and examined physical evidence to determine the causes of the centrifugal pump system break downs.

Over the last two years, the centrifugal pump system suffered break downs due to leakage through the mechanical seal. During the gas plant start-up, we detected quantities of solid particles in the main gas stream, which made the mechanical seals of the NGL pumps fail, taking down the whole system. Most of these solid particles were sand, which, apparently, was a remnant from the plant's construction, and had remained inside the piping. However, there weren't solid particles in the main gas stream that could affect the seal face lubrication. Figure 2 shows the physical evidence in the mechanical seal, marks indicating it had run dry (lack of fluid for face lubrication). The 5 Why's analysis concluded that gas operating conditions in the NGL centrifugal pump system had changed; pressure and temperature were unstable, affecting the mechanical seal lubrication. For this reason, a Weibull analysis was performed.

Figure 2 - Seal face with marks from lack of lubrication.

Weibull Analysis

The Weibull analysis is a widely used technique for statistical data analysis. In this particular case, this type of analysis permits us to determine the failure behavior of the mechanical seal (early life, random life or wear-out).

The Weibull distribution is widely used because it has a great variety of shapes, enabling it to fit many kinds of data, especially data relating to product life. The Weibull frequency distribution (or probability density function) has two important parameters: β is called the shape parameter because it defines the shape of this distribution and η is the scale parameter, defining the spread of the distribution. The β parameter represents the failure pattern of the component under study, for instance if $\beta < 1$ the piece is failing in the early life, if $\beta = 1$ the failure rate is constant and the piece is failing in the section of useful life of the bath curve (see Figure 3) and if $\beta > 1$ the piece or component analyzed is failing due to wear-out and a scheduled maintenance is justified.

$$\lambda(t) = \frac{\beta}{\eta}\left(\frac{t}{\eta}\right)^{\beta-1}$$

Equation 1

$$R(t) = e^{-\left(\frac{t}{\eta}\right)^{\beta}}$$

Equation 2

Where:

R(t): Reliability value
λ(t): Failure rate
t: Mission time (hours)
β: Shape parameter
η: Scale parameter (hours)

For this particular analysis of mechanical seal failure, data from mechanical seal failures were collected from the CMMS system to determine the time to failure for every mechanical seal and then computed in a specific software for Weibull Analysis (Reliasoft). Table 1 shows the result of Weibull analysis for the mechanical seal of the NGL pumps.

Equipment	BETA	ETA (hours)
NGL Pump A	1.13	4866.5
NGL Pump B	0.84	6513

Table 1 - Weibull Analysis Results

Graphing equations 1 and 2 with Weibull results for running time of 17,520 hours gives us the results shown in Figures 4 and 5 on the following page.

From the Weibull analysis performed on mechanical seals, Pump A is failing in a random way (could be caused due to the variation of process parameters) and Pump B is failing on infant mortality zone of the bath curve (could be caused by a combination of variable process conditions, (i.e. pressure, temperature, lack of maintenance procedures and/or a poor mechanical condition of the shaft seal).

Making a comparison between Weibull parameters from the mechanical seal of both pumps against a typical mechanical seal in Oil & Gas industry, it is clear that the life of the mechanical seal analyzed in this article is significantly lower than a typical mechanical seal (Beta=1.4 and Eta=25,000 hours).

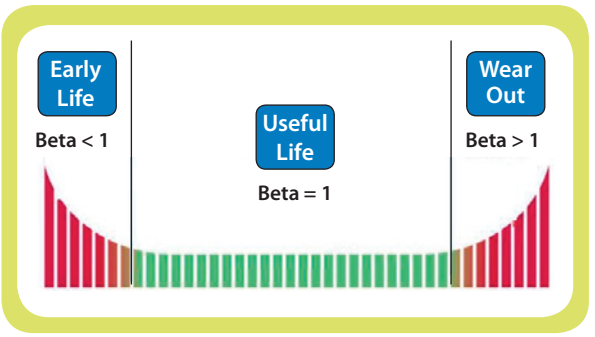


Figure 3 - Bathtub Curve

Calculate MTTF (Mean Time To Failure) for mechanical seal with Equations 3 and 4.

$$MTTF = \int_0^{\infty} R(t).dt$$

Equation 3

$$MTTF = \eta\Gamma\left(1+\frac{1}{\beta}\right)$$

Equation 4

Where:
Γ(1+1/β): Gamma Function
η: Characteristic Life (hours)
β: Weibull Shape parameter
MTTF: Mean Time To Failure (hours)

Use Table 2 to evaluate Gamma function.

β	MTBF/η	β	MTBF/η	β	MTBF/η	β	MTBF/η
0.0	∞	1.0	1.000	2.0	0.886	3.0	0.894
0.1	10!	1.1	0.965	2.1	0.886	3.1	0.894
0.2	5!	1.2	0.941	2.2	0.886	3.2	0.896
0.3	9.261	1.3	0.923	2.3	0.886	3.3	0.897
0.4	3.323	1.4	0.911	2.4	0.886	3.4	0.898
.05	2.000	1.5	0.903	2.5	0.887	3.5	0.900
.06	1.505	1.6	0.897	2.6	0.888	3.6	0.901
.07	1.266	1.7	0.892	2.7	0.889	3.7	0.902
0.8	1.133	1.8	0.889	2.8	0.890	3.8	0.9.4
0.9	1.052	1.9	0.887	2.9	0.892	3.9	0.905

Table 2 - Properties to Evaluate Gamma Function.

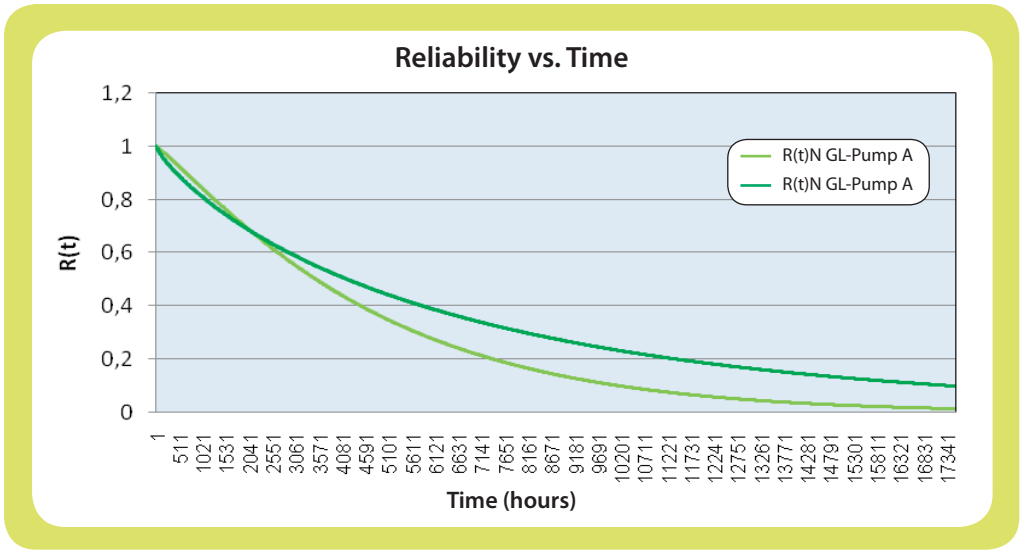


Figure 4 - Mechanical Seal Reliability Curve at 17520 Hours

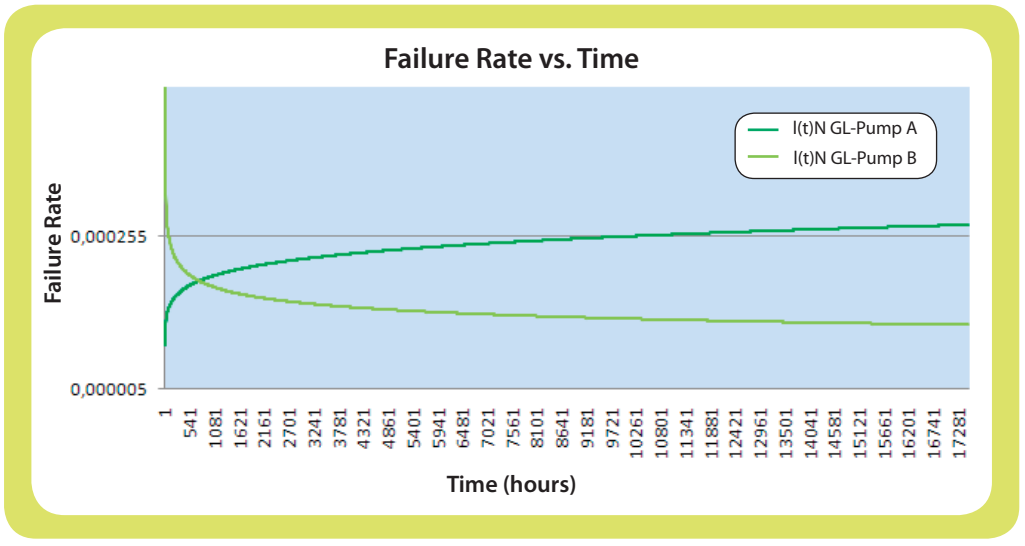


Figure 5 - Mechanical Seal Failure Rate Curve at 17520 Hours

See Figure 6 for example calculations for NGL Pump A.

$$MTTF_{PumpA} = \eta\Gamma\left(1+\frac{1}{\beta}\right)$$

$$\beta = 1.13$$

$$\eta = 4866.5 \text{ hours}$$

$$\frac{MTTF_{PumpA}}{\eta} = 0.9578 \text{ » table Gamma Function}$$

$$MTTF_{PumpA} = 0.9578 * 4866.5 = 4661 \text{ hours}$$

Figure 6 - Example Calculation for NGL Pump A

Reliability Analysis for the NGL Pumps System

Because the NGL recovery gas plant would not shut down for the next two years, it was necessary to get the reliability parameters of the NGL centrifugal pump system. Our objective was to know the risk of continuing operation of the pump system under these conditions.

Again, the NGL centrifugal pump units are arranged in parallel mode, being part of a Standby system with passive redundancy. More specifically, the system contains a total of k+1 units, and as soon as the operating unit fails, the operator replaces the failed unit with one of the standby units. Figure 7 shows the simple block diagram of the standby system.

Pump	NGL Pump A	NGL Pump B
MTTF/η	0.9578	1.1
MTTF hours)	4661.134	7164.3
η	4866.5	6513
β	1.13	0.84

Table 3 - MTTF Values for Mechanical Seals

For a system with two pumps with two different failure rates, the equation to calculate the reliability value is Equation 5:
Where:

$$R_{SB} = e^{-\lambda 1 t} + R_{sw}\left(\frac{\lambda 1}{\lambda 2 - \lambda 1}\right)\left(e^{-\lambda 1 t} - e^{-\lambda 2 t}\right)$$

Equation 5

RSB: Reliability Standby system
RSW: Reliability of switch mechanism (100%)
λ1 = Global Failure rate operating unit 1
λ2 = Global Failure rate operating unit 2
t = Mission time (hours)

Many times, failure rates on some pieces of equipment are not available because they have never failed. Because of this, to establish the global failure rates, the use of an international standards database like API, OREDA or others is required. The failure tree for the NGL centrifugal pump is shown in Figure 8.

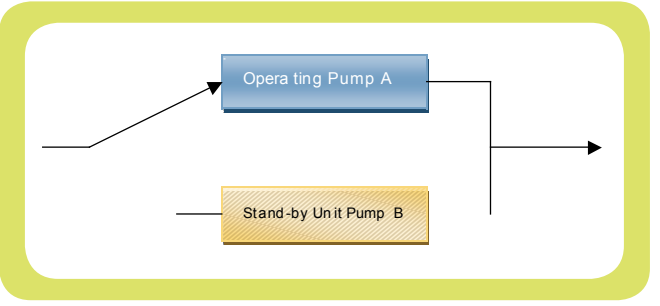


Figure 7 - Standby System Design

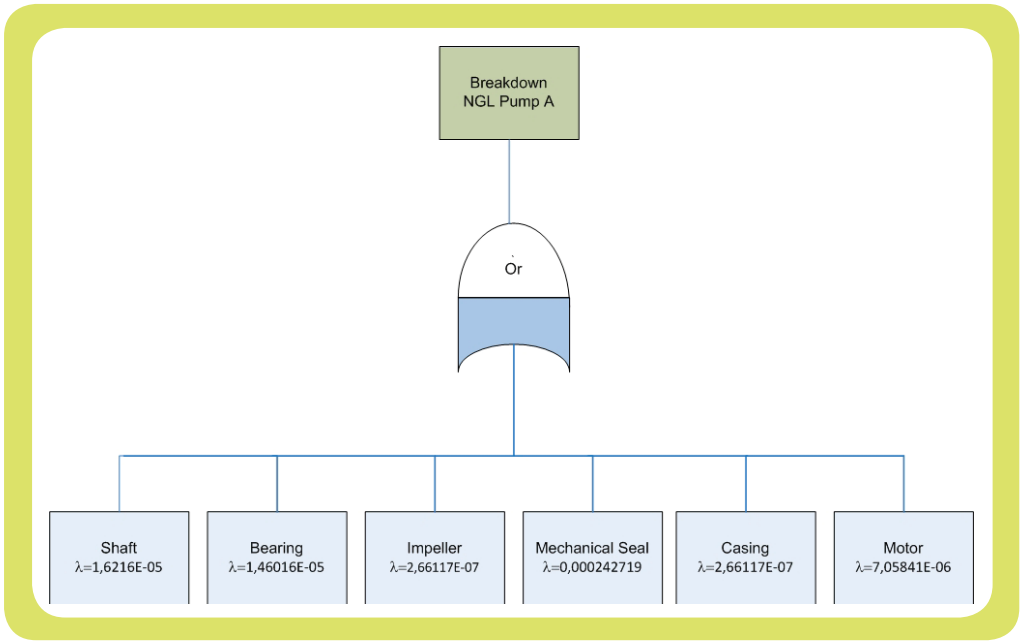


Figure 8 - Failure Tree for NGL Pump A

$$R_{SB\ System} = e^{-\lambda At} + \left(\frac{\lambda A}{\lambda B - \lambda A}\right)\left(e^{-\lambda At} - e^{-\lambda Bt}\right)$$

$$R_{SB\ System} = e^{-0,000169*17.520} + \left(\frac{0,000169}{0,000281 - 0,000169}\right) * \left(e^{-0,000169*17.520} - e^{-0,000281*17,520}\right) = 0,122$$

Figure 9 - Calculations of the reliability value for the NGL centrifugal pump system at 2 years of service.

$$\lambda(global) = \lambda_{Shaft} + \lambda_{Bearing} + \lambda_{Seal} + \lambda_{impeller} + \lambda_{Casing} + \lambda_{Motor}$$

Equation 6

Equipment	Failure Rate (f/h)
Pump A	0.000281128
Pump B	0.000169465

Table 4 - Global Failure Rate

Considering all failure modes are statistically independent and a failure of any component breaks down the pump, the global failure rate is the sum of all independent failure rates (see Equation 6). For Pump A and B, it is the same procedure, the great difference in the failure rate is the value for the mechanical seal (calculated in Weibull Analysis). In table 4 the failure rate is shown for both pumps.

Applying equation 5 to calculate the reliability value for the NGL centrifugal pump system at two years for non interrupted operation (17,520 hours), considering Rsw=1, gives us Figure 9.

$$MTTF = \int_0^\infty R(t).dt$$

$$MTTF = \int_0^\infty e^{-\lambda t}.dt$$

$$A = \frac{MTTF}{MTTR + MTTF}$$

Figure 10 - Calculating MTTF

Calculating MTTF using equation 3 and the Availability (A) of the Pump System gives us Figure 10.

Where:

λA: Failure rate for Pump A
λB: Failure rate for Pump B
MTTF: Mean Time To Failure (hours)
MTTR: Mean Time To Repair (hours)
A: Availability

Table 5 summarizes the reliability analysis for the NGL pump system.

Parameter	NGL Pump System
$R_{(17520)}$	0.1220
Average Failure Rate	0.000120
Expected Failure in 2 Years	2.1035
MTTF	8329.0194
MTTR	21.0349
A (availability)	0.9975

Table 5 - Reliability Analysis for NGL Pump System

It is well appreciated that the reliability value for the system at 17,520 hours is too low, leading to a high probability of suffering a failure. However, the availability value remains high (that is typical in the Oil & Gas industry, due to the high redundancy on equipment). The cost of unreliability is the main cause of losing gross margin in most industries, due to a high frequency of failure, wasted time, labor hours and money spent on spare parts. High availability provides the opportunity to make money because the plant is ready to respond. Low reliability provides the opportunity to incur outages, which cost money.

Cost Analysis

Cost analysis is the most important section of any reliability analysis. The main goal of this section is to turn the reliability numbers into money — money that will be used by the Plant Maintenance Manager to justify improvements or to make the right decisions, and thus, avoid losses to the gross margin of the company. Clearly it is the responsibility of engineering departments to define the equipment failure rates and the consequences of engineering practices on the life of the

$$COU = Cost_{Spareparts} + Cost_{labor} + Cost_{lossproduction}$$

Equation 7 - Cost of Unreliability

$$\mathbf{COU} = \$56{,}000 + \$3{,}360 + \$531{,}000 = \mathbf{\$590{,}450}$$

Equation 8 - Calculating the Actual Cost of Unreliability

equipment. It is also the responsibility of engineers to convert the results of equipment life and failures into a financial format for clearly communicating within the organization. Equation 7 shows how to calculate the cost of unreliability (COU).

This NGL pump system expects 2.1 failures for the next two years which causes a COU of $590,450 US. The cost of unreliability is divided into these categories:

- Cost of spare parts
- Cost of labor hours per repair
- Cost of lost production
- Cost of mechanical seal failures = $7,000 US (per seal) x 8 (number of mechanical seal failures in both pumps A and B) = $56,000 US
- Cost per mechanical seal repair: MTTR= 10 hr * 2 technician * $21 US (cost of labor hour) *8 (number of mechanical seal failures)= $3,360 US
- Cost of lost production = 2.1 (number of failures) * 90 NGL Tons/h * $281 US/Ton * 10 hours = $531,090 US

So, the total cost of unreliability is $590,450 US. The RCFA (The Root Cause Failure Analysis) and Weibull analysis have demonstrated that the mechanical seal of the centrifugal pumps is the main reason of high value of COU.

Technical Proposal

With financial figures calculated, the technical proposal to make improvements in the NGL pumps system included:

1. Purchasing one new pump.
2. Replacing the less reliable pump (pump A) with a new one and send it to the factory to obtain the original shaft size.
3. Modifying the currently API plan to become independent of process variables.

Table 6 summarizes the total cost of the technical proposal to improve reliability figures and reduce the COU.

Proposal	Cost in US $
Purchase New Pump	220,000
Repair Old Pump	15,000
API Plan Modification	82,000
Total Cost	317,000

Table 6 - Technical Proposal Cost

Since the cost of unreliability for the NGL pumps system is $590,450, an investment of $317,000 is clearly well justified to improve reliability figures, and increase the gross margin of the company.

Conclusions

From the failure analysis of mechanical seals, we glean that several factors are causing pumps to break down. One is a process condition variable that makes the seal face run dry, another cause is the poor mechanical condition (wear) on the pump shaft due to the bad condition of the start up of the plant (sand in pipes). The Weibull analysis has confirmed the early failures of the seal due to the causes mentioned before. An API plan modification is required to isolate the seal face lubrication from the process condition, and the shaft pump restoration is required as well.

The reliability analysis shows that an improvement in the NGL centrifugal pump system is required. If immediate action is not taken, the gross margin is going to go down year by year. The cost analysis indicates that an investment in this system is well justified to improve the reliability figures.

Tracking the reliability values and keeping the availability indicator in the monthly report is an action requiring implementation as soon as possible. In the Oil & Gas industry, it is very common to find high availability numbers but low reliability figures. For this reason, most companies do not publicize the loss of money due to unreliability (high frequency failures). The cost of unreliability index is a simple and practical reliability tool for converting failure data into cost, helping managers and the entire the organization to understand the problem within a single report.

This article shows the importance of Reliability Engineering and its application to both individual components and to systems. Those companies that start to implement this kind of tool in their facilities will create advantages in increased uptime, decreased maintenance and capital costs, and an increase in the bottom line of the business. In the competitive world of industry, these advantages can make all the difference.

Fernando Vicente is a Maintenance, Reliability and Integrity engineer at ABB Full Service in Neuquén, Loma La Lata, Argentina, and has been there since 2005. He holds a Mechanical Engineering degree (2003) from Universidad Tecnológica Nacional - Regional General Pacheco-Argentina. Fernando also holds a Reliability Engineering posgrade (2009). He is a member of the ABB Global Reliability group and has 10 years experience in the areas of supervision and maintenance management of industrial plants.

Fernando can be reached via phone at +540299 4893943 ext 115 or by email at Fernando.vicente@ar.abb.com

Bibliography

1. Eugene A.Avallone, Mark's Standard Handbook for Mechanical Engineers, 10th edn. Mc Graw-Hill, New York, 1999, p.61.
2. A.Birollini, Reliability Engineering - Theory and Practice, Washington, D.C, April 1999.
3. Weibull Database-Barringer & Associates Inc
4. Dr. David J Smith, Reliability, Maintainability and Risk,7th edn. Elseiver Butterworth-Heinemann, Oxford, 2005.

Pick It Up and Use It

Savings Are Just Waiting for You With Ultrasound

by James Hall

It's not rocket science, it doesn't require extensive training and you don't need a $10k dollar instrument to perform ultrasonic inspections in your plant. In other words, the low hanging fruit can be found by almost anyone. However, you may want to gain an understanding of the technology to routinely find leaks, diagnose bearings, inspect steam traps and perform electrical inspections. But with most of today's instruments, virtually anyone can simply pick it up and scan for air leaks, or use an accompanying sensor to listen to motor bearings, gear boxes or steam traps.

Ultrasound can certainly be a stand alone program. Today's instruments give the end-user the ability to perform the duties described above and more. For instance, some of the manufacturers include waveform analysis software and have features such as an RPM sensor, infrared temperature sensor and onboard recording chips to store and play wave files for diagnostics.

Figure 1 - Using an SDT170 to scan for energy savings.

Would you believe that during a recent maintenance conference, 60-65% of the maintenance professionals polled did not use ultrasound? Most of the same group that was polled do have vibration, oil analysis and infrared programs, but no ultrasound. I find this incredible. Can you imagine all that low hanging fruit? Why are there so many plants and businesses that rely on vibration or infrared technology but do not have ultrasound? Is it that ultrasonic technology is not considered technical or objective enough? That's only a guess. But whatever the reason, many companies are simply losing out on a quick and easy way to save good money for a relatively small investment. And with a little more investment in training, they could be realizing tremendous returns.

How much training is needed to use an ultrasound instrument? It simply depends on what you want to accomplish with your ultrasound program. Do you want a world class predictive maintenance program or simply a program to locate compressed air leaks or to listen to a bearing or two? Certification is a noble pursuit (particularly if you are compensated financially) because it expands the user's knowledge and capabilities. But, otherwise a 2-3 day ultrasound workshop is all that is needed to start saving a company money.

You may be reading this article and thinking that all you need is a little familiarization with the technology. So, I have written a few briefs in this article to help you locate the leaks, listen to a motor bearing, diagnose a steam trap, and possibly hear corona tracking and arcing.

Air Leaks — Over the years I have had technicians say that their work environment is too loud for ultrasound to be effective. Nonsense! I have been in some of the loudest environments, everything from being next to a 650MW turbine set (low & high pressure) running in a power plant looking for leaks to being under a Boeing 737 jet aircraft trying to locate control air leaks (25-30psig) while the aircraft's auxiliary power unit (APU) is turning within 3 feet of me.

Ultrasound is truly remarkable for finding air or gas leaks. Yet, many people still think of it as snake oil. I can't tell you how many technicians would rather take a bottle of soap and water into a plant, hitting every single pipe joint or potential leak site looking for bubbles rather than take an ultrasonic instrument into the plant and find the leaks. These same individuals will have to use a man-lift or climb up a ladder to get to a leak with the soap and water technique. This is not only dangerous but a waste of time. If you have an ultrasound receiver and the right accessories, you don't need to climb or reach for the ceiling.

In a previous article, I used an illustration of a technician who needed to find a leak that was creating a terrible hissing in his plant. No one had been able to locate this leak. The fact is low-frequency sound (which you and I hear) is high energy, but is omni-directional. Who knows what direction its coming from? This part of the plant had a small office and above that office next to an air compressor was a mezzanine in which several nylon

3/8" and 1/4" tubes were routed for control air. When measured with an "A" weighted db sensor attached to the SDT170, this noise measured 110 db's! Wow…this sound was deafening. (What if this sound had been related to a potential production stopper?) After using ultrasound he was able to locate the leak hidden high above the mezzanine. A knife and a repair union was all that was needed to remedy the problem.

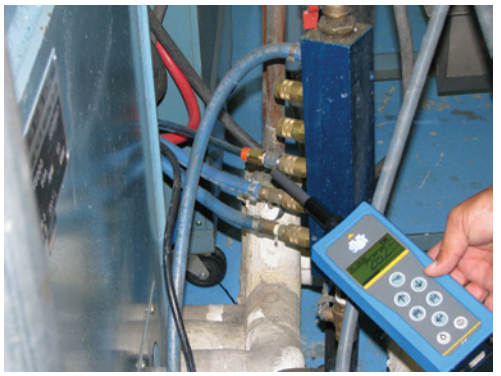


Figure 2 - Find the low hanging fruit quickly. Just a wrench secured this leak on a manifold.

That leads me to another point. When using ultrasound for surveying air leaks, let your eyes have time to coordinate where you are pointing the instrument. Simply walking into a plant and swinging the instrument back and forth is not the most effective way to survey your plant, and many air leaks will simply be missed.

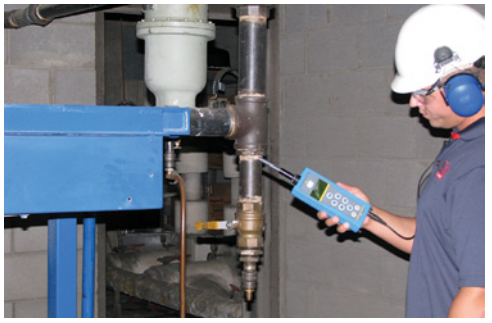


Figure 3 - SDT170 locating a leak (heard 15-20 feet away with ultrasound) at the base of the tee fitting.

I prefer my "X" pattern survey (see Figure 4). That is to survey in front of you with a slow and deliberate "X" pattern. Whether you are using a parabolic dish or a close or long range horn attachment, aim the ultrasonic receiver high and to the right of your filed-of-view, then slowly and deliberately bring the receiver to the left of your body and downwardly to the far left, making one leg of the X. Then bring the receiver up and to the far left of your field of view and bring the receiver down and across your body to the lower right, completing the 'X' pattern. I have performed countless demonstrations and air leak audits and found this method less tiring. My arms do not feel so sore after a survey and I could probably survey for several hours instead of just a couple of hours.

When it comes down to measuring leaks, you can either use one of the many manufacturers' charts for converting decibels to cubic feet per minute, or, my favorite is to simply note the leak as either a small, medium, or large leak on the survey sheet.

Since many of the ultrasound instruments are not repeatable among instruments of the same model, you might want to reevaluate the idea of putting a cost on the readings you get. Some of the earlier ultrasound instruments manufactured could differ from as little as 2 to as much as 40 decibels between units of the same model, from the same manufacturer.

I should point out that there are many variables that can apply to every leak. For instance, the material, the size and the configuration of the leak site (well-rounded or a jagged opening) can determine how quickly the leaking air can exit the leak site.

Today with "Cap and Trade", and other environmental and energy reduction programs, plants have to be accountable for their reports of savings through audits or studies by an independent lab. I think that the "decibel to cfm charts" can lead to plants claiming inaccurate energy savings. Fair and accurate reporting of savings is needed, with clear documentation of those savings.

There is little more embarrassing than a technician who has documented 1200 cfm's of leaks in his plant on a system that can only supply 1100 cfm of air. I have heard about reports like this over the past 15 years. Ultrasound can contribute to significant savings, but some numbers I've seen seem just too large to be true.

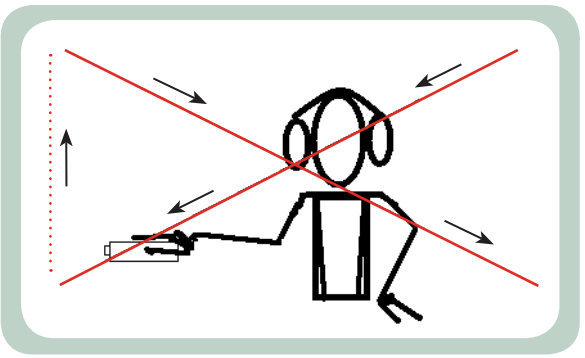


Figure 4 - The 'X' Pattern. Performing this pattern during an air leak audit will save you time and energy.

Mechanical Survey — When performing mechanical surveys, you should remember that sound travels faster in solids. This is because the particles (atoms or molecules) in a solid are touching each other and rather fixed together. Since the particles are bonded together, a sound wave moving one particle can immediately transfer the motion to another particle touching it. However, temperature, material, and frequency can affect the outcome. Generally speaking, the speed at which sound travels is fastest through solids, then liquids and, finally, gases. Sound waves travel faster (velocity) through harder materials of a lower density. For instance, titanium has about half the density of steel and aluminum is about one-third (Table 1). Therefore sound travels faster (velocity) through titanium at 6100 than it does through steel at 5800 and aluminum at 6300.

Aluminum	2.70	Copper	8.96
Lead	11.35	Steel	7.90
Magnesium	1.74	Titanium	4.50

Table 1 - Densities of some metals (g/cm^3)

So keep this in mind when using the contact probe on motors with different materials that house the bearing and motor. Use of the contact probe to diagnose bearings is preferred. Most companies have a contact probe with a rod or stinger to touch the surface of the motor. Using the rod or stinger, simply touch the bearing housing. If there is a zerk fitting atop the bearing housing, I like to seat the rod end or point in the threads at the base of the zerk fitting. If there is not a zerk fitting, but there is a plug where the zerk would have been, use this location (see Figure 5). Whichever location is used, care must be taken on subsequent readings to come back to the exact location.

If you were to take a reading at a point were the metal was thicker between the housing and the bearing vs. the distance from the previous read, you may end-up with a reading of less decibels than previously read.

Magnetic sensors are great too. If you have one that has the power to hold to the surface (vertically or horizontally) no matter what, than you have the correct strength magnet.

I am not a big fan of listening to a bearing purely on the sounds I hear, unless I am using an analog ultrasonic receiver. Today's instruments are mostly digital instruments. For me, using an analog instrument may be

Figure 5 - Use the contact probe at the base of a zerk fitting or atop a plug for the zerk. Always come back to the same spot for repeatability.

the difference between hearing a ball out-of-round or not hearing it, or hearing the sound of a defect on a race or not hearing it.

Many of today's instruments offer waveform analysis to help you diagnose a condition or defect. Still, unless you're qualified in vibration analysis, many of us cannot define what we are seeing.

In general, first establish a "baseline." This may be accomplished by two methods, comparison and historical. Comparisons can be done by comparing one motor to another motor of the same rpm, loads, etc. It must be performed using the same location, i.e. the drive end of one motor to another motor's drive end, non-drive end to another motors non-drive end, etc. If you have several motors that are alike, take readings and compare all the readings of the drive ends. The bearing with the lowest decibel reading becomes the baseline for the others (do the same for the non-drive end bearings). However, if a bearing is removed and replaced it is important to give the motor some "run-in" time before taking a new reading to be used as a baseline.

Figure 6 - Here the technician uses the Ultraprobe 9000 with the 31-inch rod extension to listen to the bearing.

I prefer creating a baseline and then watching the bearing over a period of time. When the bearing decibels rise in the 8-10 db range over the baseline, I would lubricate the bearing, either acoustically using an ultrasound instrument, or, manually using a grease gun and following local standards or procedures called for by the plant.

When bearings reach a preset (pre-decided) decibel level that warrants removal and replacement, I might then (if applicable) invite a vibration analyst to analyze the bearing. Sometimes, integrating other technologies like vibration, oil analysis, infrared imaging and ultrasound may allow the bearing to continue running for several more weeks or months.

What decibel range would be considered a failure? Who really knows? A failure rate or decibel that represents failure can be made up from many different factors. A very small bearing or a very large bearing may have the same decibel range for failure.

So, how do you determine a failure rate? By first taking several readings and comparing them to acquire a baseline. After a baseline decibel is established, you can then set a decibel level as a "failure." One manufacturer says that when a bearing exceeds the baseline by 12 decibels, it's in an "incipient stage" of failure. Incipient simply means the beginning or to become apparent. So, once it enters this stage you are to make a determination as to what would constitute a catastrophic failure or a reason to remove and replace. Which manufacturer's instrument you are using will determine what decibel range you consider failure and/or a catastrophic failure.

NOTE: Always consult with the manufacturer of your instrument directly about what decibel range above baseline may be considered a catastrophic range.

I have searched many owners/user manuals available on-line for the top instruments and cannot find a definitive answer in any of them. A pre-failure, incipient failure, but nothing saying what decibel range indicates a failure and when a bearing should be removed and replaced.

If you start a trend of reading your bearings and you see the decibels steadily rise, then you can assume a problem is occurring. For example, let's say you have a two year trend of a bearing that was reported for several months with readings between 25-30 decibels, yet slowly over three to four more months the level continues to climb steadily,

You might say a 30-35 decibel increase over the original baseline would warrant removing the bearing at the next convenient opportunity. A "catastrophic failure" may be 45-50 decibels over the baseline, which means remove and replace now rather than later. Due to its early warning (there is actually ultrasonic energy before there is vibration and heat), ultrasound can be very subjective.

Personally, I believe the number of decibels is just a reference point anyway. Watching the decibel level climb over a period of time means the bearing has a problem. It's either degrading or there is a lack of lubrication. Simply graph the readings over a period of time and, as the decibels reach a previously decided level or range, you can move the inspections closer together. For instance, instead of every 90 days, now you might inspect every 60 or 30 days. Depending upon the criticality of the bearing or motor you may take a reading weekly or even daily.

Many of today's manufacturers have some very good trending software as well as waveform analysis software. But, even the basic pen and paper will allow you to monitor motor bearings. Once you start, who knows, maybe you'll be buying a bearing trend phone application for your Blackberry or IPhone.

Electrical Inspections — These applications are still among the most under-utilized of all the capabilities of ultrasound. I think the main reason is because most technicians are unfamiliar with the application, and don't understand what they are supposed to hear.

Unlike listening to bearings and watching decibels climb, when scanning electrical switchgear one must listen to the sounds and try to identify what he/she is hearing. Is it arcing, tracking and/or corona (either destructive or nuisance)? Fortunately, there is software out there with which a technician can record the sounds and play them back through FFT's or in Time Waveform (see Figure 7.)

Sounds to Remember:

- Arcing, an abrupt start and stop popping sound.
- Tracking, this sounds like baby arcing, climbing then discharging and starts all over again.
- Corona or nuisance corona has an egg frying or bacon sizzling sound.
  It may not require attention now, but left unchecked could find a path to ground.

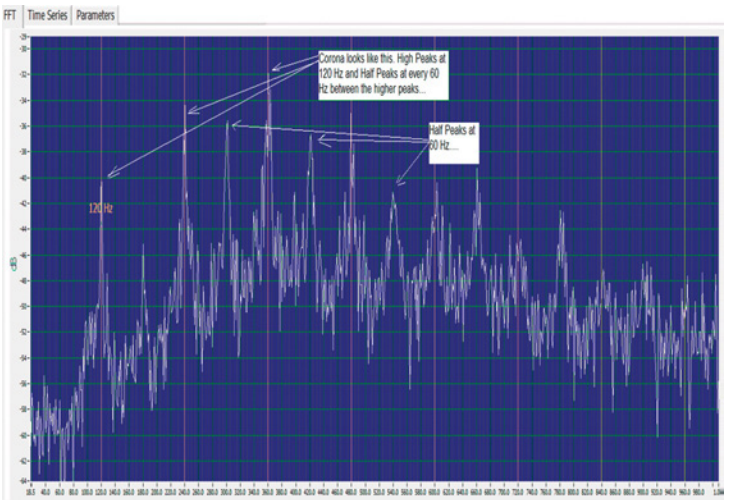


Figure 7 - Here you have the classic corona discharge. High peaks at 60 cycles with half-peaks between cycles.

- Corona or destructive corona exists to find ground. Corona should be removed and a remedy to prevent corona should be put into place.

Ultrasound should be used to scan any and all electrical panels or doors for arcing, tracking or corona discharge prior to opening. If you don't learn anything more from this article regarding electrical inspections than the prior sentence, you have still gained a lot.

If you are an infrared user and do not use ultrasound in tandem with your electrical inspections, or your third party inspector does not use ultrasound, you are missing out! Accidents, downtime, and possibly saving a life can be attributed to those that use ultrasound during electrical inspections. Unlike infrared thermography and corona camera inspections, ultrasound does not require line-of-sight, so it is effective when some other technologies might not be.

Steam Traps — These are defined as either working or not working. Ultrasound, along with infrared, is a sure fire method of determining the condition of a steam trap. The three more common traps are the Dish Trap, Inverted Bucket Trap and Thermostatic Trap.

All traps make a particular sound of distress. Motor boating or quick popping sounds could describe the disk trap when the disc is badly worn. If the trap has failed you will not hear it open and close.

The inverted bucket trap has a bucket and linkage. Condensate and air enter under the bell or inverted bucket and air flows through the discharge orifice. After all the condensate and air are removed, steam reaches the trap and floats the bucket, closing the valve. When condensate and air enter the trap, the bucket loses its buoyancy and drops. This opens the valve and the condensate and air are discharged until the steam again floats the bucket, closing the valve. Normal failure may be either open or closed. The thermostatic traps are designed with a float inside that is raised by condensate. When released, steam can be heard escaping through the vents with ultrasound.

Simply listening to any steam trap is not enough, knowledge of the cycle, temperature and load is very important to know. Start listening now, as the more you listen to, the better you will become at diagnosis.

So, no matter what your skill level is, pick up your ultrasound instrument and use it. Using this instrument can easily improve your troubleshooting skills, and who knows, it may locate that anomaly early enough to avoid some real headaches or downtime. If you do not have an instrument, contact the different manufacturers and ask for demonstrations. Do your research, buy an ultrasound instrument and start using it. Believe me, the savings will add up in no time at all.

Unless noted otherwise, all photos courtesy of Ultrasound Technologies, Inc.

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

The Challenges of Safety

Permanently Mounted Sensors Key to Gathering Quality Vibration Data

by Tim Hunt and Tom LaRocque

Over the past several years, safety has experienced an increase in focus at manufacturing facilities. And sometimes, that increased emphasis on safety provides challenges to vibration measurement, many of which require creative solutions in order to obtain the valuable vibration data that ensures the maximum life out of our (now much safer) equipment and machines.

Logan Aluminum, Inc., located in Russellville, Kentucky, is a world class manufacturer of Aluminum sheet products. Since 1983, they have been involved in the fabrication of rigid container sheet, building products, automotive sheet, distributor sheet, and food can stock markets since 1983. Logan Aluminum is a premier manufacturing facility with modern, high-speed equipment and technology available in the operational areas of ingot casting, hot rolling, cold rolling and finishing.

Logan Aluminum is an industry leader in terms of safety performance, product quality, customer service and cost performance, and receives broad based recognition for its progressive management concepts. Logan Aluminum is proud to be a part of the Commonwealth of Kentucky and the community of Logan County.

Figure 1 - The Logan Aluminum Facility in Russellville, KY.

New Equipment – New Monitoring Requirements

A new tab stock line was installed in the fall of 2007 (see Figure 2). The Level Clean Line is designed to a safety level that reaches Category 3, which is European Standard EN954-1. Many US companies have adopted this standard in order to meet safety requirements. The line is completely surrounded by fencing (see Figure 3)

Figure 2 - Tab Stock Line

which meets ANSI standards for height, opening size, and distance from hazards. There are a total of 17 gate entrances around the line that are safety interlocked using Fortress Interlocks. Each interlock requires that the operator press a button which acts as a request to enter. Once pressed, the safety PLC will put everything into a safe state and then release the solenoid on the interlock allowing the gate to open. Each gate is equipped with at least 2 safety keys which the person entering the gated area is required to take with them. By having the key on their person, it keeps the machine in a safe state, prevents the line from running, and prevents personnel from being locked inside the area.

Figure 3 - Machine Inside Safety Caging

The Challenge

The safety system posed a challenge due to the difficulty of gathering real-time critical information. Critical machine components, such as the unwind mandrels, rewind mandrels, and pass-line rolls, could not be accessed in order to gather vibration data in support of the Finishing Department. They were at risk of not being monitored, which left the line open to failure without prior warning.

The Planning

Due to the criticality of obtaining good information in order to have effective maintenance planning and long-term reliability, an initiative was presented to members of the management team, which included permanently mounting sensors inside the safe areas and utilizing junction boxes to access the vibration data. The Finishing PdM department was given the green light to develop a solution and provide a cost to implement this solution.

The Solution

There were many options available for the components necessary for the installation. The ideal installation would be three axis accelerometer on each bearing. However, that was not economically feasible, so critical areas were identified, and the selected pieces of equipment to monitor were high rpm rolls, gearboxes and motors.

Since the main requirement was to access the vibration measurement points without having to enter the safe area, permanently mounted sensors were determined to be the best option.

Placing sensors permanently on the measurement points allowed for consistent measurement data with the ideal mounting method (direct mount to the bearing housings), which allowed the full utilization of the frequency response of the sensors.

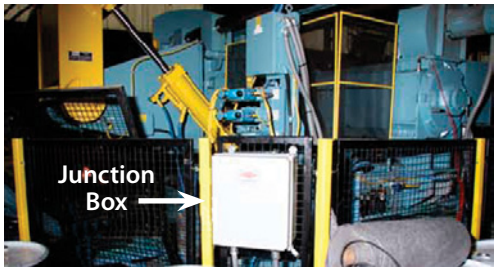


Figure 4 - Junction Box Mounting

Mounting the junction boxes in a convenient location allowed direct access to multiple measurement points without having to move to each sensor location, allowing for more efficient data collection. (see Figure 4)

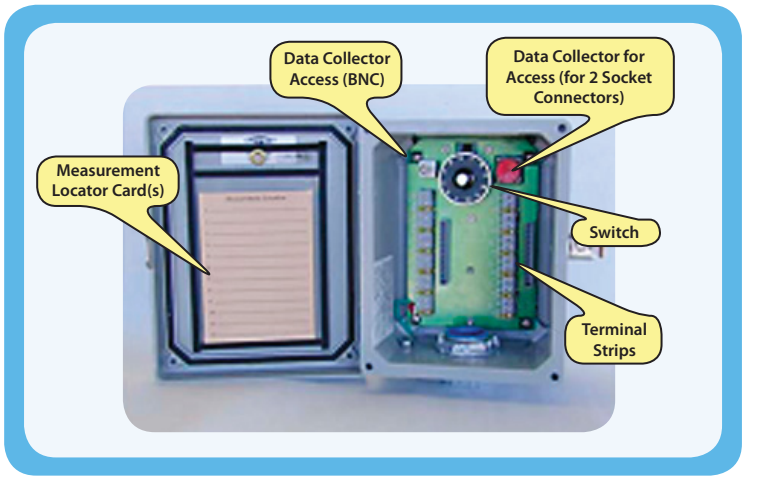


Figure 6 - Key Features of Switch Box

The wet section pumps and motors were the only pieces of equipment that didn't have the safety cages installed around them. For those measurement points, a portable measurement mounting system was used, which consisted of a triaxial sensor and a magnet.

Hardware Selection

Figure 5 - Top Exit Sensor

Sensors – Most of the vibration measurements taken were targeting many types of faults, from chipped gear teeth to all bearing faults and motor failures. Top exit, multipurpose accelerometers (see Figure 5) were selected for this application due the general frequency range of the sensors (.5 – 15,000 Hz); enabling data collection that would encompass the required frequency ranges, and also provide a low cost solution.

Cabling & Connectors – Although there were no environmental chemical concerns, a red Teflon jacketed cable with permanent polycarbonate connectors using stainless steel locking rings, ensured proper connectivity from the cable to the sensor.

Junction Box – A vibration switch box was selected for the termination of the sensors and for access to the vibration data at a centralized location. The switch box (see Figure 6) assured further efficiencies because the measurement points were accessible through the turn of a switch.

Upon receipt of the costs, the decision to proceed with the purchase and installation of the remote system was granted. CTC was selected as the supplier for the accelerometers, cables, and boxes.

Installation

There were a few installation challenges that were required to be evaluated. Placement of the accelerometers required careful site

Figure 7 - Installing Junction Box

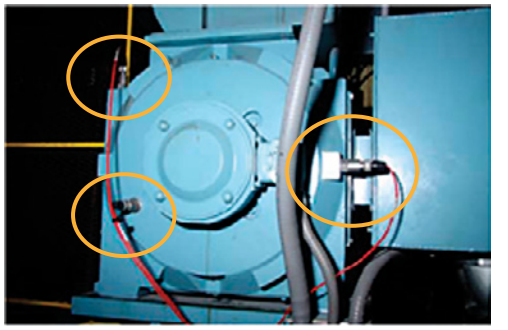


Figure 8 - Sensor Mounting Locations

planning to determine the best installation location of the sensors (see Figure 8). They had to be mounted in the load zone, while avoiding areas where they would be used as a foot peg (see Figures 9 and 10). Special consideration was also required when running the cables – they needed to be placed where they would not be a tripping hazard. The junction boxes were mounted on the back side of the line, out of high traffic areas.

The installation of the project took 160 hours to do 215 points. The project came in under budget because no contractors were needed, which was critical, as the only time the points were accessible was on outage days or coming in on days the line wasn't running.

Data Collection

Logan Aluminum has two manufacturers of data collectors that can be used to collect data - Azima/DLI, and CSI. The boxes were set up to be able to use either of these data collectors. The most popular data collector in the Finishing Department is the Azima/DLI. This data collector can take a tri-axial reading by attaching a custom cable connector plug equipped with six BNC connectors, allowing multiple data collection for three simultaneous readings.

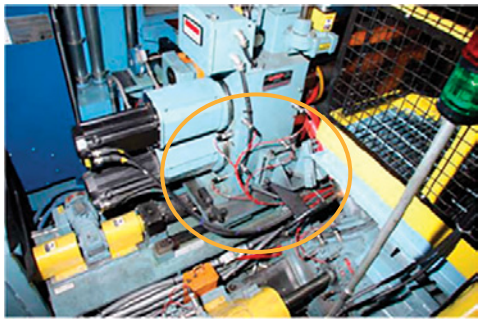


Figure 9 - Measurement Location Points

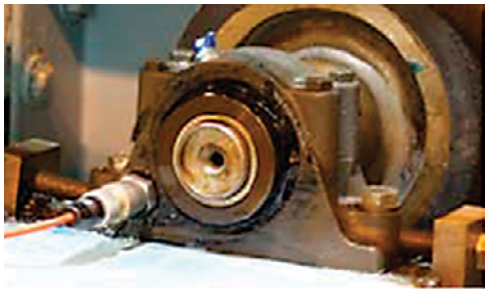


Figure 10 - Mounted Sensor on Bearing Housing

Figure 11 - Collecting Data

Figure 12 - Some Final Collection!

Other Technologies

Ultrasonic analysis and oil sampling are two other predictive technologies that are employed in combination with vibration analysis for condition monitoring. With the use of these three technologies, breakdowns are at a minimum.

Since Installation

Prior to installation, the complete line was prone to failures because there were no vibration sensors mounted on the equipment to monitor the condition of the machine. Since these permanently mounted sensors have been installed, the monitored points increased to over 200 measurement points. Several vibration related issues have already been identified, avoiding machine failure and down time.

Based on these successes, more permanently mounted sensors will be added to the other lines to continue to increase the efficiencies, solve the issue of being blocked out due to safety, and continue to avoid costly unplanned down-time.

Figure 13 - Final Product

Conclusion

The enclosed safety system does exactly what it was designed for, which is to keep employees away from moving equipment. The challenge that the safety system presents is that it doesn't allow you to feel, hear, or in some cases, even see the equipment. The costs of the remote vibration monitoring equipment are generally justified in cost avoidance of damaged or down equipment and the safety avoidance of injuries, minor or severe, for all those involved.

Tim Hunt works at Logan Aluminum and has been in the maintenance field for 18 years. He holds a Fluor Daniel millwright certification, as well as being a Level 1 Certified Vibration Analyst from Technical Associates and a Level 1 Certified Ultrasonic Analyst from UE. He has an associate's degree from Mid Continent University.

Tom LaRocque is an engineer at Connection Technology Center, Inc. (CTC), and has been involved with the vibration industry for over 11 years. He is a Certified Vibration Analyst: Category III from the Vibration Institute, and has a Bachelor of Science in Engineering from Clarkson University. Tom can be contacted by phone at 585-924-5900 Ext. 817 or by e-mail at tlarocque@ctconline.com

The latest vibration analyzer has now hit the streets. It's fast, it's powerful and it's lovely to look at with its full color, high definition display. Say hello to the....

VIBXPERT II

This new instrument has all the bells and whistles. But it is much more than just a pretty face with fancy makeup. The VIBXPERT II's capabilities are impressive, and will help vibration analysts be more productive and vibration analysis programs to perform better. That means higher uptime and lower maintenance costs. It is also fully scalable, so you can start a vibration program with it, and as your program grows, you can open more of its capabilities, so it grows with you.

We asked Trent Phillips, the Condition Monitoring Manager for LUDCEA, INC, to give us more of the scoop on this powerful new instrument. Trent has over 15 years of experience in the design, implementation and use of vibration monitoring equipment and other condition monitoring technologies. Here is what Trent had to say about the VIBXPERT II...

The VIBXPERT has been a stalwart performing vibration analyzer for years. Tell us about the improvements that the VIBXPERT II brings to the table?

The VIBXPERT II provides superior state-of-the-art processors and electronics that outperform all others. The VIBXPERT II has extremely fast data acquisition speed, which increases operator performance and productivity and reduces data collection time. The VIBXPERT II features a very high resolution color display that is viewable from different angles and in bright sunlight. As a result, this display technology allows very detailed analysis of equipment faults right on the instrument in the field. The memory can be very easily upgraded to 8 GB by the customer. VIBXPERT II is rugged and lightweight — weighing only 2-1/2 pounds. An advanced battery allows an astonishing 8 hours of continuous data acquisition in the field. The enhanced battery life creates a new standard for data collectors and analyzers. The VIBXPERT II provides all of the functions required for the routine identification of equipment faults as well as all of the advanced functions required to determine the root causes of equipment failures. The VIBXPERT II incorporates all of these standards and creates a new platform for exciting features to come in the future.

Give us an idea of all the types of applications that the VIBXPERT II can be used for.

The VIBXPERT II can be applied to almost any type of rotating equipment such as motors, gearboxes, pumps, fans, etc. and more specialized equipment like wind turbines. The VIBXPERT II can provide fault analysis for many different types of equipment such as: ball mills, coal mills, crushers, kilns, cranes, drilling machines, escalators, complex gearboxes and many more. Really, the applications are almost endless.

VIBXPERT II, A New Portable Vibration Analyzer — with Full Color Display, Fast Data Acquisition and Powerful Vibration Diagnostic Tools

The VIBXPERT II has many available options. Please tell us about the different configurations and options you can equip the instrument with.

The VIBXPERT II was developed to support a facility that is just starting a vibration monitoring program as well as one that already has an advanced vibration monitoring program (root cause identification and more) in place. The VIBXPERT II can be easily upgraded to provide additional capabilities as the needs of the facility grow. This can be achieved without the replacement of the device.

The VIBXPERT II analyzer can be purchased in different configurations to fit the specific needs of a facility and can be easily upgraded with additional capabilities as needs change over time.

One option is the VIBXPERT II Basic. This basic configuration provides the measurement and analysis capabilities required for routine fault identification in equipment. Another configuration is the VIBXPERT II Advanced, which provides very advanced multi-channel functionality for the identification of the root causes of equipment failures.

Please explain in a little more detail the VIBXPERT II's analysis capabilities.

The VIBXPERT II was developed to be a scalable device that fits the needs of our customers and provides a very cost effective growth path. The VIBXPERT II provides very fast data collection, route-based setup and field analysis capabilities. Alarm conditions, specific equipment faults, changes in equipment condition (trends) and more can be easily displayed in the device during routine data collection. Equipment templates can be used to assist the data collection specialist or vibration analyst with routine tasks and advanced troubleshooting techniques. These equipment templates can be shared between multiple users.

Unbalance is one of the most common faults found in equipment and is easily corrected. This eliminates collateral equipment damage and improves overall equipment reliability. The VIBXPERT II provides functionality that can be used to balance a vast range of equipment from fans to wind turbines.

It is critical to measure enough detail in the acquired vibration data to distinguish between different types of faults (mechanical, electrical, etc.). The VIBXPERT II is a true multi-channel analyzer that provides up to 102,400 lines of resolution for each measurement channel. These capabilities allow very detailed data to be collected for slow speed or high speed equipment, which means that multiple measurements are not required to obtain meaningful data for the analyst. This increases productivity, provides detailed data and accurate analysis of equipment faults.

The VIBXPERT II includes advanced features such as orbit measurements, cross channel phase measurements, start-up/coast-down measurements, bump tests, negative averaging, modal measurements, ODS measurements, FRF, transient functions, and many more advanced capabilities. These capabilities can be used for identifying the root causes of equipment failures. Data acquired with the VIBXPERT II can be exported to other programs for

additional capabilities.

The monitoring of process data such as temperature, pressure, etc can be important indicators of equipment faults. This type of data can be monitored routinely with the VIBXPERT II.

Tell us a little about the OMNITREND software that can be used with the VIBXPERT II.

The OMNITREND software is fully compatible with Windows XP, Windows Vista and Windows 7. Data from the VIBXPERT II or any of our other portable and online vibration devices can be uploaded into the OMNITREND software for trending, analysis, reporting and more.

Oil analysis parameters such as viscosity, water, etc. are very good indicators of equipment health. The OMNITREND software can automatically import and store this type of data from most oil labs. Alarm indicators for oil parameters can be set up in OMNITREND to automatically alert the analyst as required. Oil data can be trended in OMNITREND along with the collected vibration data and other process data for early warning of equipment defects.

OMNITREND can automatically import and store process data and various other data types. Alarm indicators for this data can be created and the OMNITREND software will automatically alert the analyst of alarm conditions. This data can be trended in the OMNITREND software along with oil data, vibration data, alignment data and more, to provide early indications of equipment defects.

Data can be automatically exchanged between OMNITREND and most popular CMMS systems. Monitoring schedules, equipment setups, equipment condition and more can automatically be shared between OMNITREND and the CMMS system at a facility.

Alarm conditions, specific equipment fault conditions and the ability to perform detailed analysis of collected or imported data is provided in the OMNITREND software. The software can store collected or imported data, trend historical data, perform statistical analysis, store drawings, store purchase records, etc.
The OMNITREND software can be used by one user or multiple users across a local area network or wide area network. It is a true multiple user platform with fixed and/or floating user setups.

The OMNITREND software can be configured to provide remote analysis capabilities. The data can be collected at one or multiple locations and the analysis completed at a centralized location or by a contracted resource.

What are the three top reasons a company should consider investing in a VIBXPERT II?

The VIBXPERT II is the next generation of vibration analyzer with extremely powerful processors and state of the art electronics. It provides both the routine functions required by data collection specialists and the highly advanced features required by expert analysts. It allows a facility to get started with a vibration monitoring program and add capabilities as their program advances and their needs change over time. Replacement of the device is not required as features are added.

Support agreements are not required, because product support is always provided free for the VIBXPERT II and the OMNITREND software. Also, firmware and software updates are provided free of charge. All of this for as long as you own the product. This significantly lowers the overall cost of ownership.

LUDECA's service facilities include a NUPIC approved calibration laboratory with NIST certified calibration equipment.

The VIBXPERT II provides a tremendous return on investment and a future growth path for vibration monitoring programs. The VIBXPERT II will allow a facility to reduce equipment maintenance costs, maximize profits and increase reliability.

How can interested people get more information about the VIBXPERT II?

Just contact Ludeca at 305-591-8935 or visit www.ludeca.com/vibxpert

New Fluke TiS Building Diagnostic Thermal Imaging Scanner — Tough, reliable, affordable tool designed for building applications

Fluke Corporation has introduced a new entry level Fluke TiS Thermal Imaging Scanner for Building Diagnostics. Specifically designed for building and home inspectors, electricians, energy auditors, HVAC/R professionals, insulators, roofers and window installers, the Fluke TiS is the perfect tool to identify hidden issues, find moisture intrusion, detect energy losses or missing insulation, and spot overheating in electrical components. Now Fluke quality, durability and performance are available in a thermal imager engineered for the value-conscious building professional. Priced at $2495, the Fluke TiS Building Diagnostic Thermal Imaging Scanner is the top-performing imager in its price class and the most affordable thermal scanner to meet the proposed RESNET infrared standards.

www.fluke.com/thermography 800-760-4523 thermography@fluke.com

Powerful, Multi-LED, Broad-Beam UV-A Lamp Ideal for NDT Inspection

Spectronics Corporation has introduced the powerful Spectroline® TRITAN™ 365 — an ultra-high-intensity, multi-LED, broad-beam UV-A inspection lamp perfect for NDT applications. The TRITAN 365 features three ultra-hi-flux UV-A LEDs for NDT inspection, plus a white light LED to illuminate dark areas. It produces a nominal steady-state 365nm intensity of 5,500 $\mu W/cm^2$ at a distance of 15 inches (38 cm). This versatile lamp meets MIL and ASTM intensity specs for FPI and MPI.

The TRITAN 365 is extremely compact and lightweight, weighing just 16 ounces (454 g). A convenient three-way rocker switch allows easy control of the light sources and a lightweight, angled lamp body ensures fatigue-free inspections. Just a push of a button turns the lamp on instantly at full power!

Spectroline 1-800-274-8888 US/Canada
516-333-4840 Intl.
www.spectroline.com

What's Next in Maintenance and Reliability?

We Want to Know... So We Can Let Our Readers Know

Uptime Magazine and Reliabilityweb.com want to know about your new and innovative products and services designed to improve the Reliability and Maintenance community.

In our continuous effort to keep our readers informed and educated about the latest and greatest in the reliability and maintenance world, we want to help get the word out about your products and services.

Send information about your product or service to:

upgrade@uptimemagazine.com

We will publicize any and all worthy offerings throughout our information network, where it will reach over 50,000 maintenance professionals worldwide. And who knows? We may highlight your offering with a double page spread in Uptime's Upgrade Section as our Featured Product.

INCLINEO High Precision Inclinometer — Ideal for Flatness and Angle Measurement

INCLINEO high precision electronic inclinometer technology with a resolution of 0.0003 degrees. In combination with interchangeable mounting bases INCLINEO measures relative or absolute angularity, flatness, levelness, or parallelism of surfaces; as well as plumbness of vertical shafts, perpendicularity of planes, and straightness along a line. The system features integrated wireless communication technology which transmits the measurements to a PC to quickly and easily generate measurement reports. The surface profile of the measured component is shown in full color 2-D and 3-D graphic display with color coded tolerance levels giving a clear representation of the results.

LUDECA, INC.
305-591-8935
www.ludeca.com/inclineo

Kistler Introduces Type 8640A IEPE PiezoBeam® Accelerometer with TEDS for Multi-channel Modal Analysis of Small Structures

Kistler Instrument Corporation has announced the launch of Type 8640A, a lightweight, miniature single axis IEPE accelerometer family with optional TEDS, designed for the multi-channel modal and structural analysis of small or thin-walled structures and components, as well as other general purpose vibration measurements. Offered in ranges of ±5 g, ±10 g and ±50 g, with sensitivities from 100 to 1000 mV/g, the this is Kistler's dimensionally smallest PiezoBeam® single axis accelerometer model with lowest mass, weighing just 3.5 grams. This design provides outstanding amplitude and phase response over a wide frequency range with low base strain sensitivity and exceptional measurement stability. Sensing elements are housed in a durable and hermetically sealed welded titanium housing.

1-888-KISTLER sales.us@kistler.com
www.kistler.com

Meggitt Sensing Systems Launches New Endevco® Extreme Temperature Piezoelectric Accelerometers

Meggitt Sensing Systems has announced the global market debut of the Endevco® model 2271A series, an accelerometer family designed for high-reliability vibration and acceleration measurements in cryogenic and other extreme environments. Available with either 10-32 side connector (model 2271A) or 10-32 top connector (model 2271AM20), the Endevco® model 2271A series is designed to reliably operate over a very wide operating temperature range of -269°C to +260°C (-452˚F to +500˚F) with unusually flat temperature response. Units exhibit excellent output sensitivity and stability over time, with shock survivability to 10,000 g pk. The piezoelectric sensing elements of the model 2271A series are housed in a corrosion-resistant stainless steel case, which is hermetically sealed for use in demanding environments.

www.meggittsensingsystems.com

Society of Maintenance and Reliability Professionals Certifying Organization (SMRPCO) Attains Approval for Reimbeursemenr of Exam Fees Under the GI Bill

SMRPCO is pleased to announce that the Certified Maintenance and Reliability Professional (CMRP) certification program has been approved by the Department of Veteran's Affairs and will be added to their list of certification exams that military personnel and Veterans can be reimbursed for. "We are very excited about this new opportunity to both expand our certification program and to also offer our internationally recognized program to those who have served our country," said SMRPCO Chairman, Greg Yeager.

Director of Certification, Ramesh Gulati, said, "SMRP is really going to be taking a hard look over the next year at how we can reach out to those who serve as we feel they could be the future of the maintenance and reliability workforce."

The CMRP exam is accredited by the American National Standards Institute (ANSI) under the ISO 17024 standards for a Personnel Certification Program and is taken by over 1,000 candidates every year and there are currently close to 3,000 CMRPs in over 40 countries world wide.

SPM Instrument Launches Revolutionary Measuring Technique for Condition Monitoring

In conjunction with the company's 40th anniversary, SPM Instrument AB now presents the next generation of its well-known shock pulse method. SPM®HD is an advanced and patent pending measuring technique suitable for all types of applications and particularly well suited for low speed machinery.

Condition monitoring is all about optimizing operations and maintenance for the purpose of lowering costs. The difficulties of getting reliable results when measuring on low speed applications are a well known problem. These applications create signals with low energy content, where earlier vibration technologies made it difficult to measure such signals with satisfactory results. The SPM®HD measuring technique combines the well-known and reliable True SPM® method with a highly advanced digital technique. Thanks to its high dynamics, SPM®HD can distinguish the weaker yet relevant signals, which are typically hidden among stronger signals caused by mechanical shock phenomena or electronic noise. The ability to detect very weak signals therefore gives decisive advantages when measuring at low speeds. Real world testing has provided up to six months' forewarning, leaving ample time to plan maintenance and repairs.

The name SPM®HD (High Definition) hints at the extraordinary signal quality as well as a very clear picture of machine condition resulting from the measurements. SPM®HD is built around sophisticated and patent pending signal processing in several steps. The technique works with digital enveloping of the analog shock pulse transducer signal. The sampling frequency is very high, resulting in a crisp and distinct signal. A 24-bit A/D converter provides razor-sharp resolution and exceptional detail in spectrums and time signals.

For a full picture of bearing condition, the measuring cycle is based on number of revolutions rather than time. This maximizes the chances of capturing relevant signals in the course of one measuring cycle. By adjusting the sampling frequency to rpm, spectrums are clear and concise.

The measuring technique looks for recurring patterns and uses newly developed and ingenious algorithms to enhance repetitive signals and eliminate randomly occuring high readings. Thanks to the pattern recognition, spectrums and time signals are excellent tools for analysis. The source of the signal is simple to identify, as every component has its own, distinct damage signature. The time signals are easily interpreted, making the type and extent of the damage simple to determine. The benefit of this is no trending is required; occasional measurements provide a reliable diagnosis.

In addition to spectrum and time signal, the measuring technique also generates two scalar values, HDm and HDc. HDm represents the highest value measured during the measuring cycle, while HDc is a measure of bearing lubrication condition. Both values are suitable as the basis for setting alarm limits, regardless of machine type. Automatic evaluation of measuring results, presented on a green – yellow – red scale, provides a quick overview of machine condition.

This sophisticated and complete measuring technique is the result of an intense development effort by SPM Instrument and close cooperation with customers in industry. SPM®HD has been tested successfully on low speed applications such as twin wire presses, screw presses, drying cylinders and wind turbines, some running at speeds as low as 5 rpm, for many months.

Mikael Lindfors, Manager of Business Solutions at SPM, comments: "SPM®HD is the unique solution to the problems involving condition measurement on low speed applications. It sets a new standard for modern condition monitoring and can be used successfully on all types of applications. With SPM®HD, we consolidate our position as a leading supplier of innovative solutions for condition monitoring and predictive maintenance, and we now supplement our successful Intellinova online system with an SPM®HD monitoring unit."

For further information, please contact:

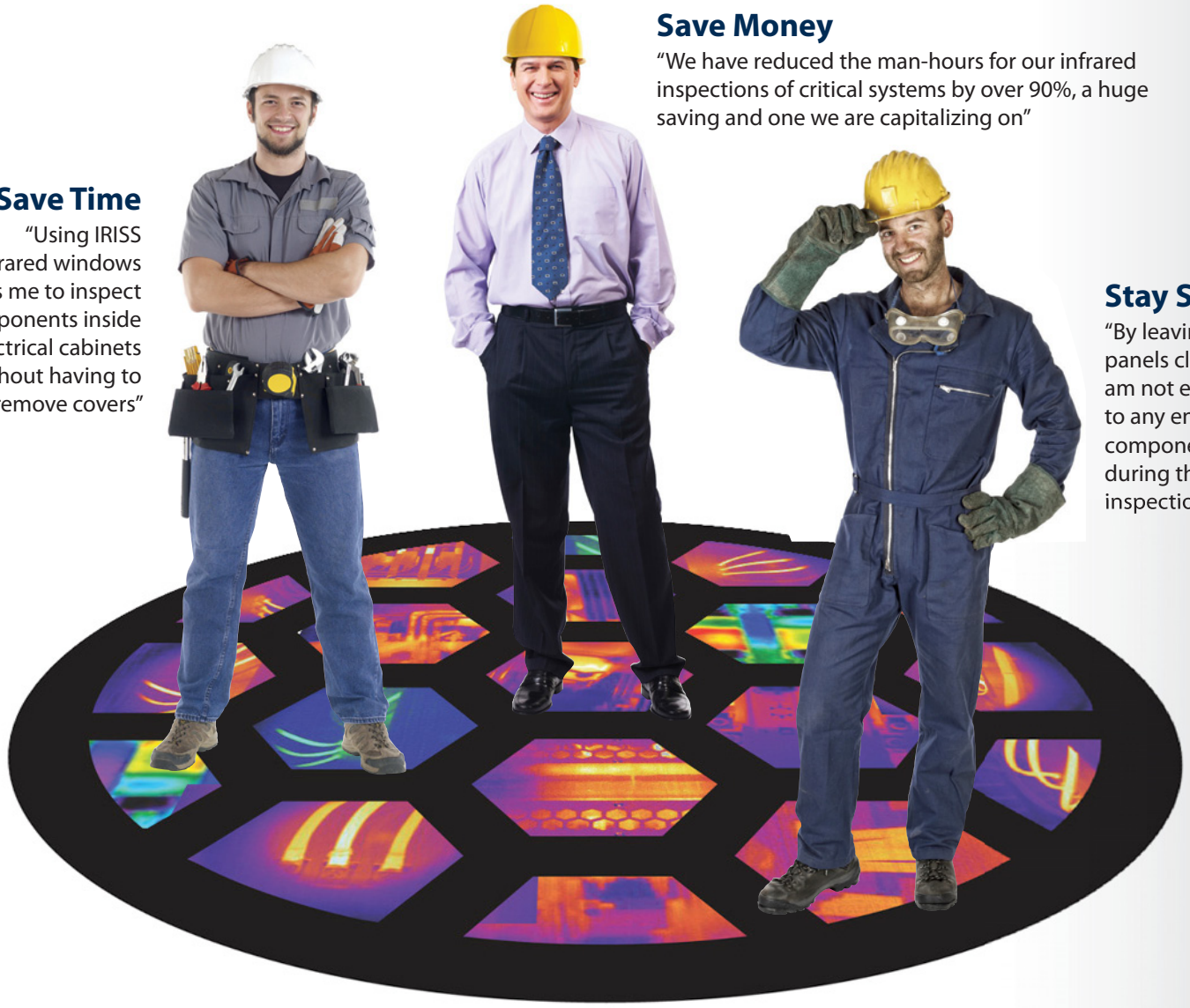
Mikael Lindfors

Manager of Business Solutions, SPM Instrument AB, Sweden

+46 (0)152-225 00 mikael.lindfors@spminstrument.se

www.spminstrument.se

Who says Infared Windows have to be Round?



Save Money

"We have reduced the man-hours for our infrared inspections of critical systems by over 90%, a huge saving and one we are capitalizing on"

Save Time

"Using IRISS Infrared windows allows me to inspect components inside electrical cabinets without having to remove covers"

Stay Safe

"By leaving the panels closed I am not exposed to any energized components during the infrared inspection"

IRISS, Inc. introduces you to the future of infrared windows.

IRISS uses the unique properties of the IRISS VPFR series, "The World's Only Industrial-Grade Infrared Window" as the cornerstone for innovation in the IRISS CAP Series.

IRISS CAP Series, engineered and manufactured in the USA, is available in standard sizes of 6, 12 and 24 inches. The entire IRISS CAP Series allows more freedom to inspect multiple components through one infrared window, reducing the number of IR windows required as well as the installation time and costs associated with them.

- IRISS CAP has IR window only
- IRISS CAP-V offers visual inspection pane with IR inspection
- IRISS CAP-VC offers visual inspection pane with IR inspection plus a cover for the IR window
- CAP-VCH offers protective covers for both the IR inspection and visual viewing panes with a single door

Need a different size or have a Custom Application?
Contact IRISS today: phone **877-704-7477** or **sales@iriss.com**.

Visit our website for more information on CAP Series and Custom Applications Today!

4914 Lena Rd., Suites 105-106 Bradenton, FL 34211
877-704-7477 | sales@iriss.com | www.iriss.com

IRISS®
See What You've Been Missing!