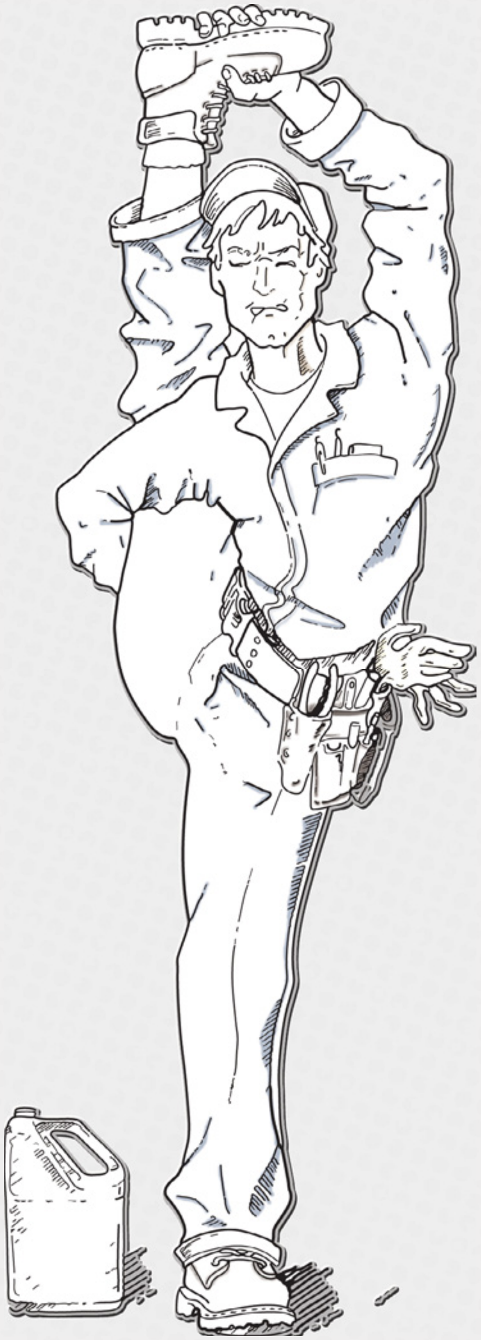

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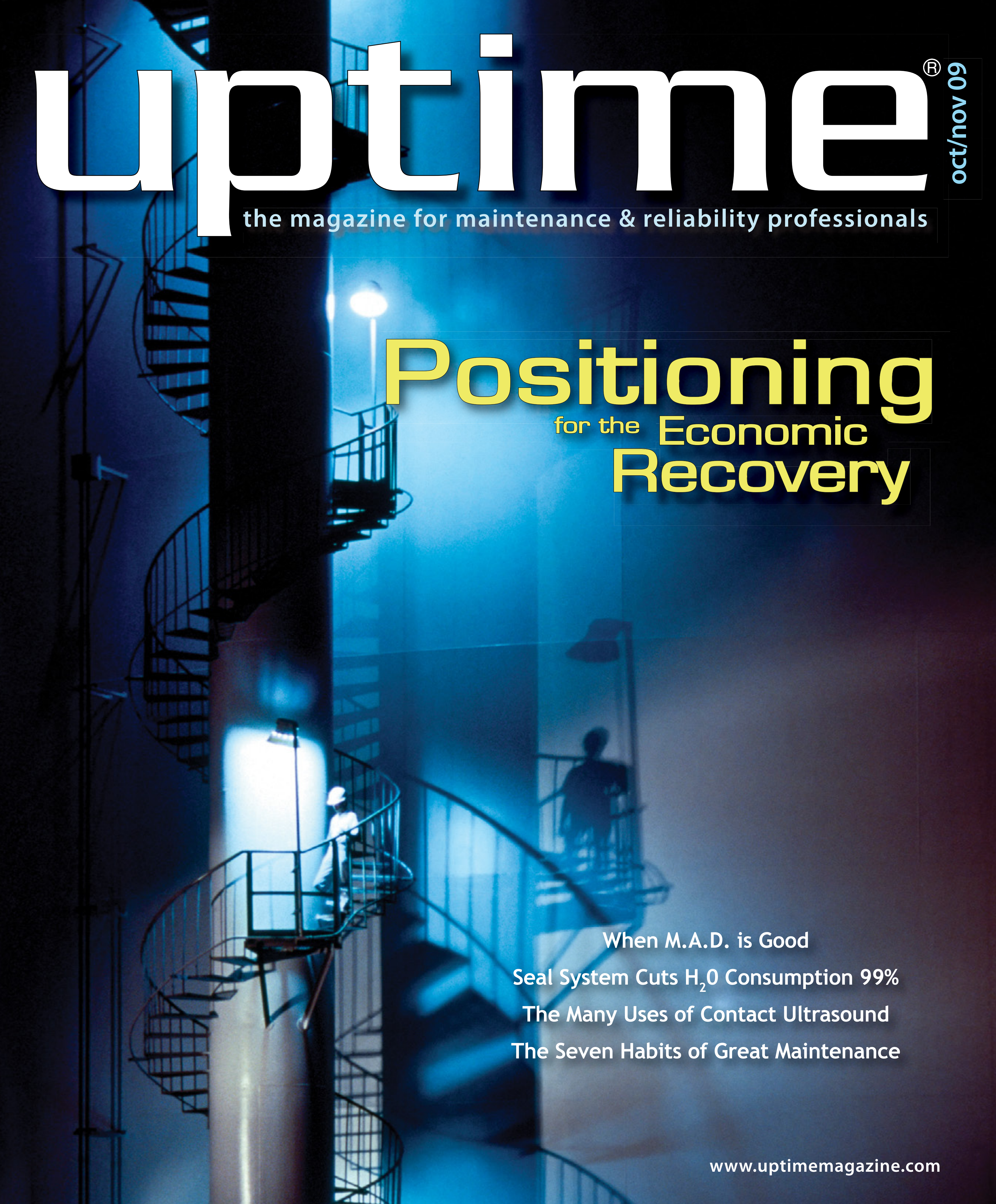

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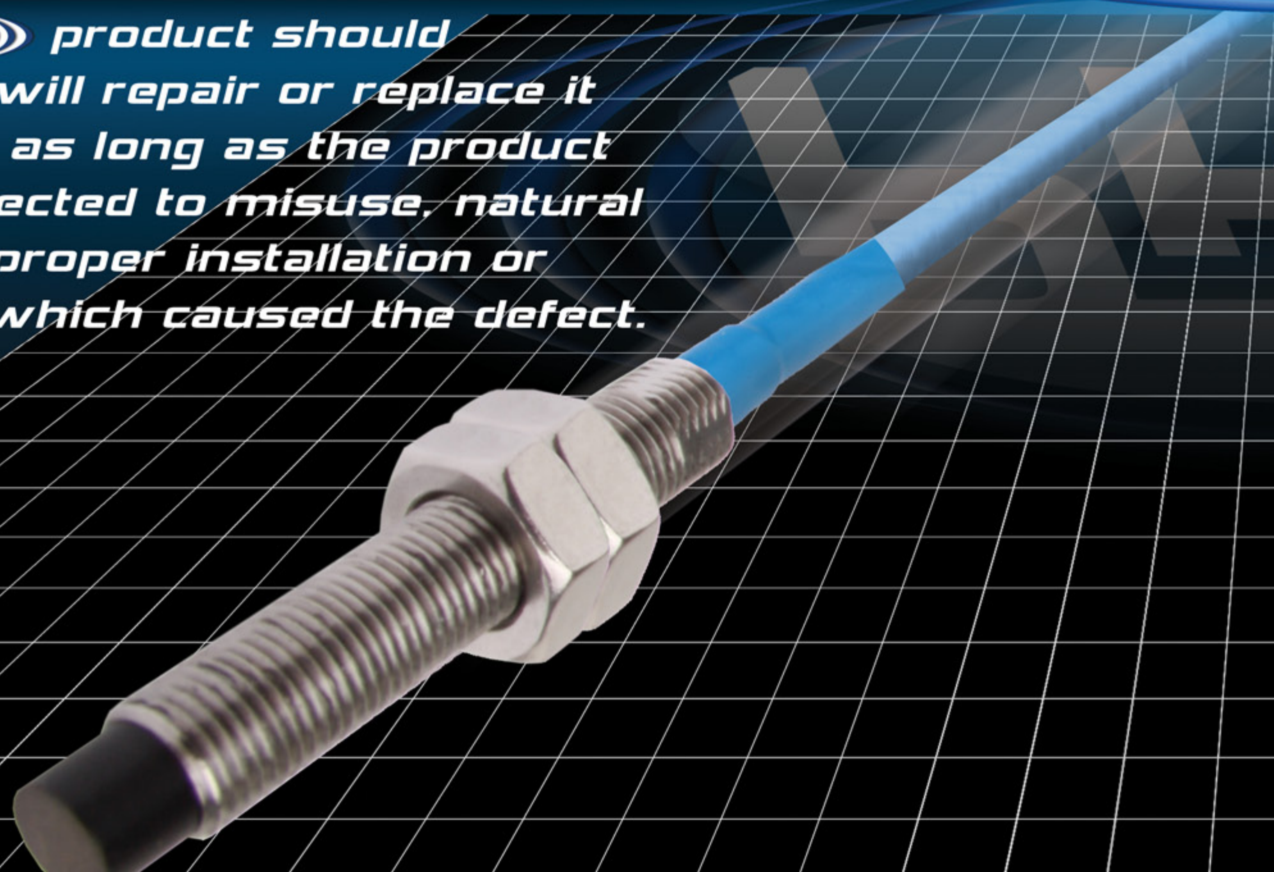

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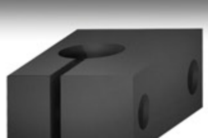

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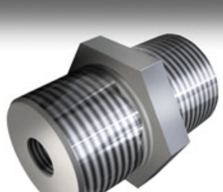

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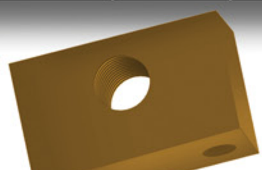

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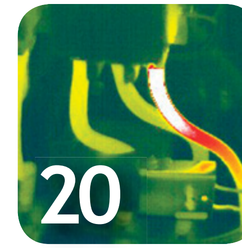
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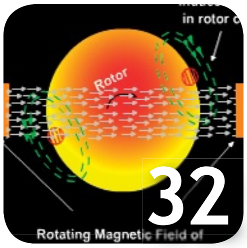
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Recovering

It is not the strongest of the species that survive, not the most intelligent, but the one most responsive to change.

Charles Darwin

These are turbulent times. While the economic outlook remains unstable now, one thing is certain... there will be a recovery. It's not a question of if, but a matter of when. Yes, we are living in a volatile economic environment, which only magnifies the need for patience, perseverance and a plan for the future.

In this issue, we decided to bring you a few articles that focus on finding opportunities in the economic slowdown. When sales are high and production is up, there is little time to tweak processes, implement culture change, and perhaps, little inclination to revisit or revamp long term strategy.

But, as you will find in the pages that follow, it's possible to turn slower economic times into a competitive advantage. Many adaptable companies are using this time to reassess long term strategies, strengthen work processes, streamline storerooms and train employees. These proactive companies will be positioned to prosper when the economy rebounds.

Implementing technology to better manage resources, both economic and natural, is another way to strengthen your company's outlook. I love it when a product comes along that creates a win-win situation for both corporate and environmental health. With this in mind, I'd like to bring your attention to the article on page 22, which is about a product that can extend the mean time between failure of your pumps and save millions of gallons of water doing it.

I also want to congratulate not only the Uptime Magazine PdM Program of the Year award winners (see facing page), but all the impressive programs that entered. This year the competition was fierce, and there were many very strong programs that didn't win. The companies that did win are truly deserving, and we look forward to highlighting these fine PdM programs in future issues.

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
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UPTIME'S PdM PROGRAM OF THE YEAR

This 2009 award goes to...

Pfizer Inc.
Best Overall PdM Program

San Antonio Water Systems
Best Emerging PdM Program

Alcoa, Mt Holly Facility
Best Green PdM Program

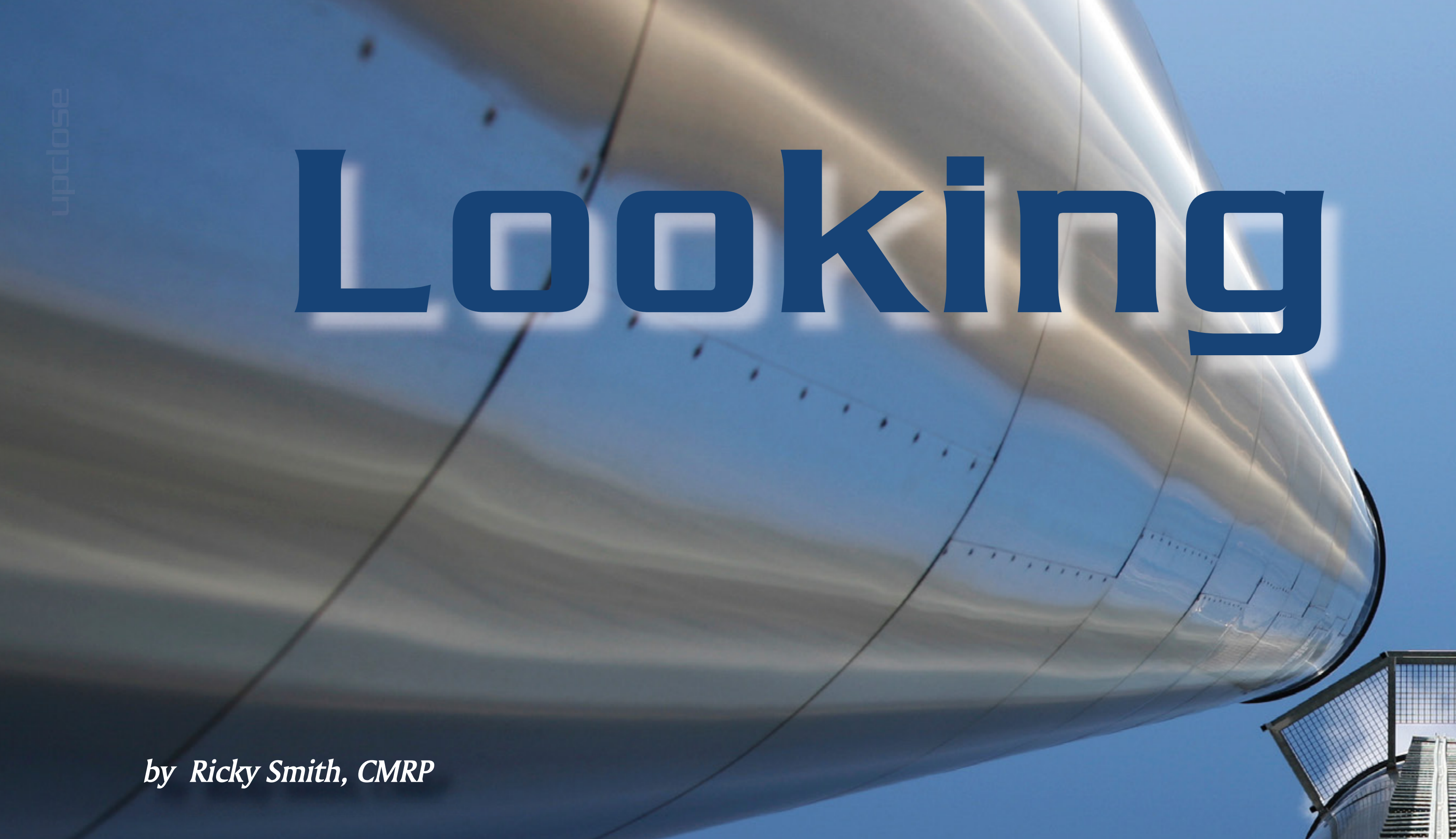
Calpine Corp
Best Oil Analysis and Lubrication Program

EG&G Technical Services (NASA/Kennedy Space Center)
Best Precision Maintenance Program

DMax Ltd.
Best Ultrasound Program

Powder River Coal Company
Best Specialized Vibration Program

Uptime® congratulates these outstanding programs for their commitment to and execution of high-quality Predictive Maintenance and Condition Based Monitoring programs.



Looking

by Ricky Smith, CMRP

Most companies have reduced costs during these tough economic times in order to survive – shutting down equipment, laying off or furloughing staff, extending time between rebuilds and preventive maintenance – without thinking about the preparation they should be taking in order to take advantage of the economic turnaround. There will be winners and losers once the world economy turns around. Companies that are prepared will win by shutting down their competition and demonstrating even higher profits than before the economic downturn. This can be accomplished by focusing on "optimizing asset integrity at optimal cost".

Do you Want to be a Leader or a Laggard When the Economy Turns Around?

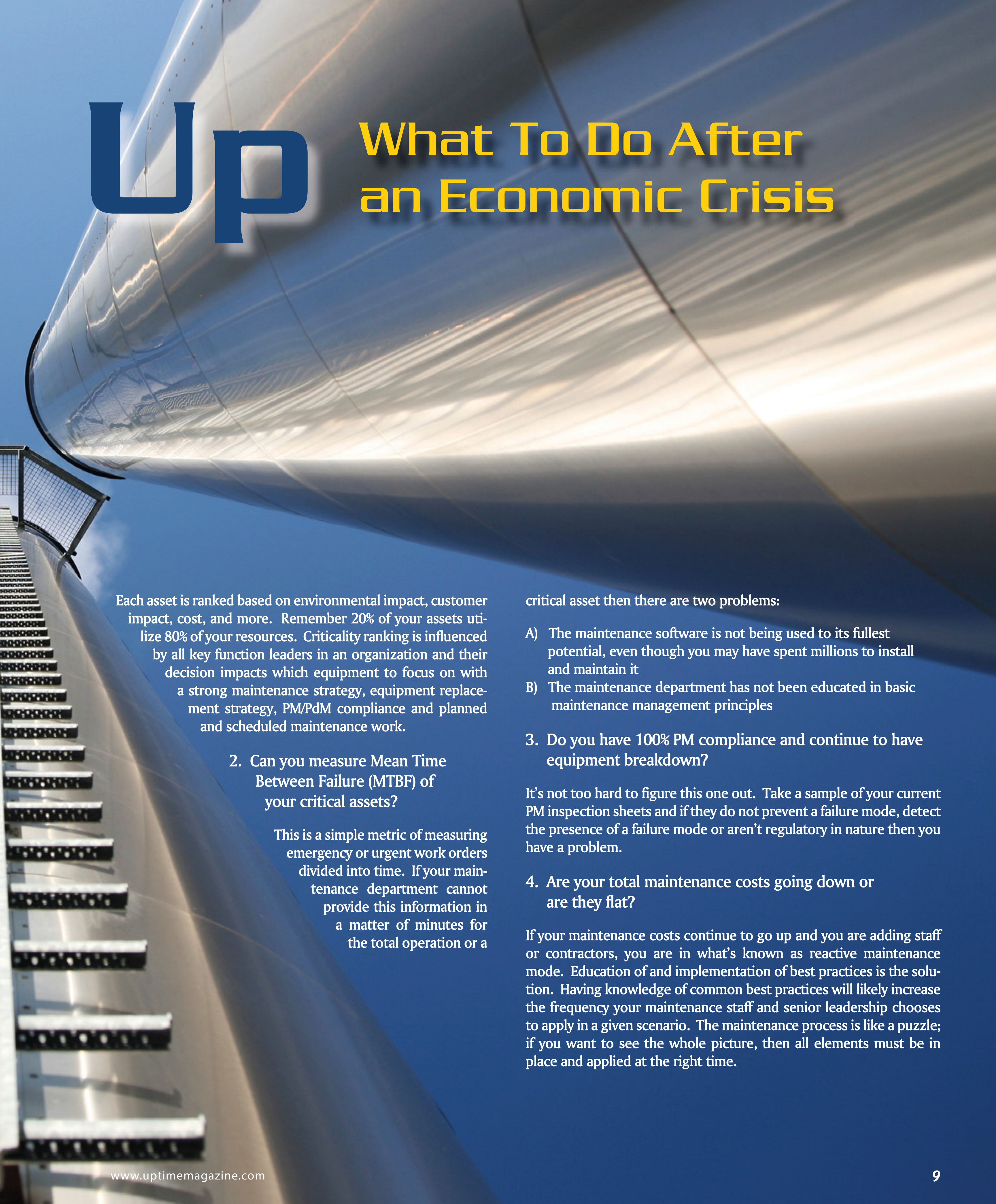
Many industries have advanced maintenance and reliability in their operation and have taken great strides toward managing asset integrity. By applying known maintenance and reliability best practices, they have been able to optimize asset integrity, reduce total cost and, at the same time, reducing overall risk. But, most organizations are still trapped in the old way of thinking, and do not follow the true definition of asset integrity. One good way to know where your organization stands is to answer these questions:

1. Have your assets been ranked based on criticality?

The definition of critical equipment may vary from organization to organization. In fact, if it is not formalized, there may be several interpretations of equipment criticality within a single organization. The assumptions used to assess what equipment is critical are not technically based. As a result, when different individuals are asked to identify their critical equipment, they will likely select different pieces of equipment. Often we are told, "all of our equipment is critical!" Selections are based on individual opinions, lacking consensus or even basis in functional relevance to achieving business goals. The potential for equipment failure having significant safety, environmental or economic consequences may be overlooked.

A consistent definition for equipment criticality needs to be adopted. The definition used in the context of this article is:

"Critical equipment is that equipment whose failure has the highest potential impact on the business goals of the company"



Up

What To Do After an Economic Crisis

Each asset is ranked based on environmental impact, customer impact, cost, and more. Remember 20% of your assets utilize 80% of your resources. Criticality ranking is influenced by all key function leaders in an organization and their decision impacts which equipment to focus on with a strong maintenance strategy, equipment replacement strategy, PM/PdM compliance and planned and scheduled maintenance work.

2. Can you measure Mean Time Between Failure (MTBF) of your critical assets?

This is a simple metric of measuring emergency or urgent work orders divided into time. If your maintenance department cannot provide this information in a matter of minutes for the total operation or a critical asset then there are two problems:

A) The maintenance software is not being used to its fullest potential, even though you may have spent millions to install and maintain it

B) The maintenance department has not been educated in basic maintenance management principles

3. Do you have 100% PM compliance and continue to have equipment breakdown?

It's not too hard to figure this one out. Take a sample of your current PM inspection sheets and if they do not prevent a failure mode, detect the presence of a failure mode or aren't regulatory in nature then you have a problem.

4. Are your total maintenance costs going down or are they flat?

If your maintenance costs continue to go up and you are adding staff or contractors, you are in what's known as reactive maintenance mode. Education of and implementation of best practices is the solution. Having knowledge of common best practices will likely increase the frequency your maintenance staff and senior leadership chooses to apply in a given scenario. The maintenance process is like a puzzle; if you want to see the whole picture, then all elements must be in place and applied at the right time.

In this article, we will discuss what are known as best practices in Asset Integrity and how they are applied to prepare an organization for the economic turn around.

Let's look at Shell's Asset Integrity and Risk Management Statement:

Asset integrity and process safety standards. We are committed to preventing incidents that put our people, neighbors, the environment and our facilities at risk. Asset integrity and process safety means making sure our facilities are well designed, safely operated and properly maintained.

Webster's Dictionary contains the following definitions: **Asset:** anything of value that a corporation owns; and **Integrity:** firm adherence to a code. So, it follows that the definition of **Asset Integrity** is: anything of value that a corporation owns that is held in firm adherence to a code.

The Codes can be defined as ISO, ASQ, etc. The question is to what level of adherence is your company meeting these codes? Of course, you can say we satisfy environmental or safety codes by meeting PM compliance every month. However, is this the intent of a true PM Program? A preventive maintenance program is to prevent or predict a specific failure mode. All PM compliance tells us is that the PM is completed within some schedule, but it does not tell us if the PM is effective or not. If something is of value then a corporation should want to ensure it is well protected from failure, especially if the failure results in unacceptable costs.

Let's look at how this entire Asset Integrity process works. Asset Integrity impacts safety, cost, and service to the customer. It also impacts your competition. If we look at the Market Survivor Model in Figure 1, it tells us a lot.

Any company will own a certain portion of market share. The market price drives profits and your future. With company "A" their market share is high, costs are low, and Asset Integrity is high, thus, they are prepared for economic turn around. Company "B" has a large part of market share, however, their cost is higher than Company "A" and this puts them at some risk. Their Asset Integrity is not optimized and thus their cost, along with risk, is higher. Company "C" has the smallest market share and the largest cost. A good example of a Company "C" would be Alcatel Telecommunications in 1999. The fiber optic cable business was growing at a rapid rate. By assessing the current level of their Asset Integrity program, we found key areas of improvement and closed the gap quickly. They went from being a "C" Company to an "A" Company within 6 months with a Return on Investment (ROI) of 8:1. This involved the application of known best practices in maintenance and reliability. Best practices are measurable and do impact the customer's need in quality, delivery and price as seen in Figure 2.

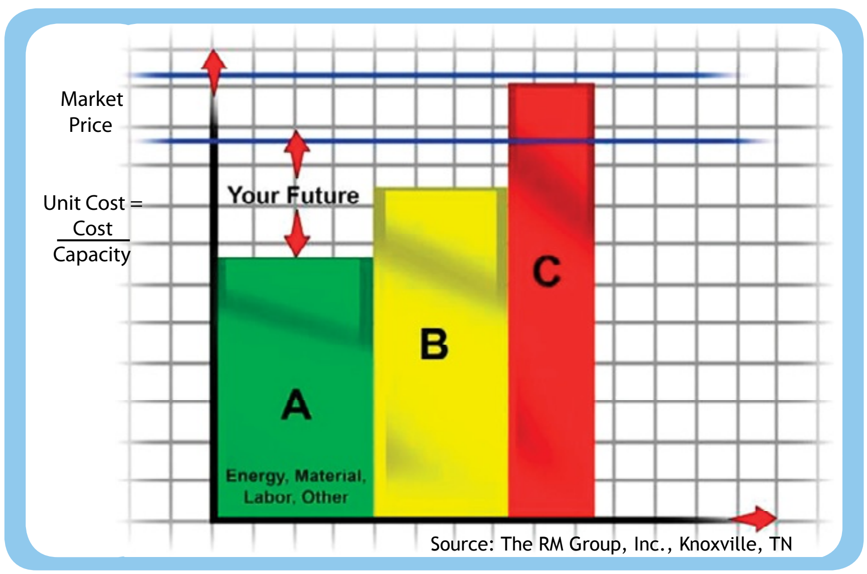


Figure 1 - Market Survivor Model

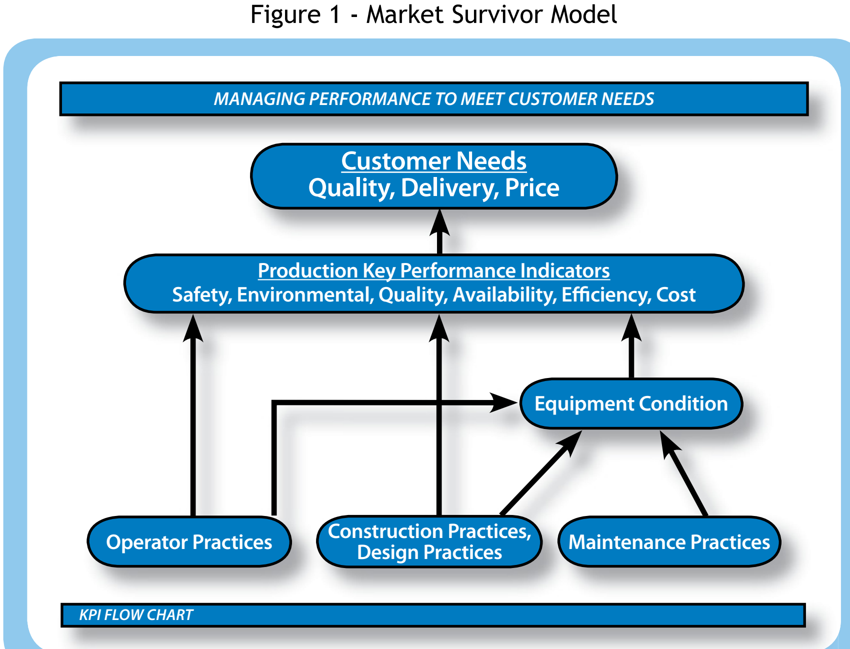


Figure 2 - KPI Flow Chart

Some of the Known Best Practices are:

Using the right metrics or Key Performance Indicators (KPIs) to manage asset health effectively and efficiently – such as:

1. **Mean Time Between Failures**: Most companies don't measure Mean Time Between Failures (MTBF), even though it's the most basic measurement that quantifies reliability. MTBF is the average time an asset functions before it fails. MTBF should be used for:

- Overall Operation
  - Area
  - Asset Type

So, why don't they measure MTBF? We will discuss those reasons a little later.

2. **Percentage of assets with No Identifiable Defects –** This means you can Identify a component defect early enough in the failure cycle where work can be planned and scheduled effectively and without interrupting operations or customers

In this case everyone must understand the P-F Curve and how it impacts asset reliability (Figure 3).

"P" on the P-F Curve is the point at which failure begins on a specific component which will lead to catastrophic failure of an asset. Once a failure begins, we call this a defect and the severity of the defect and criticality of the asset determines how quickly we respond to the problem. If the defect severity is low and asset criticality is low, then there is no panic.

Tracking the percent of assets with "NO Identifiable Defect" is key to knowing the current health of your assets. When the percentage of Assets with No Identifiable Defect is over 80%, there is no longer a need

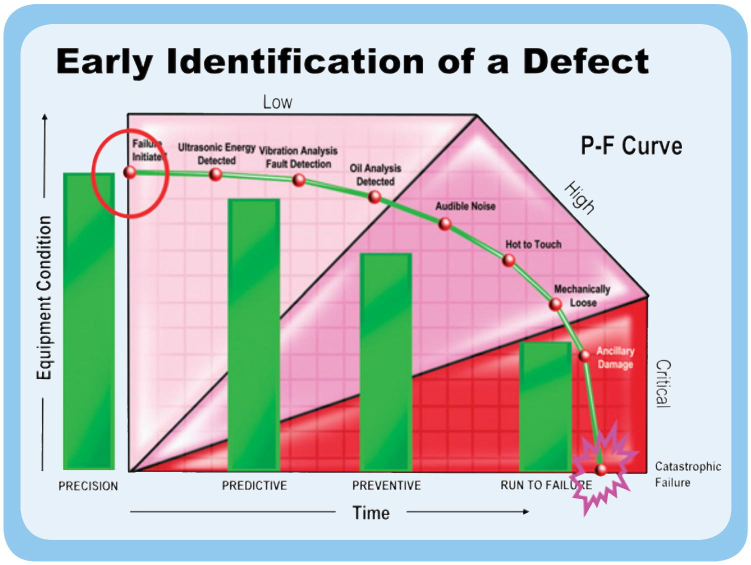


Figure 3 - The P-F Curve

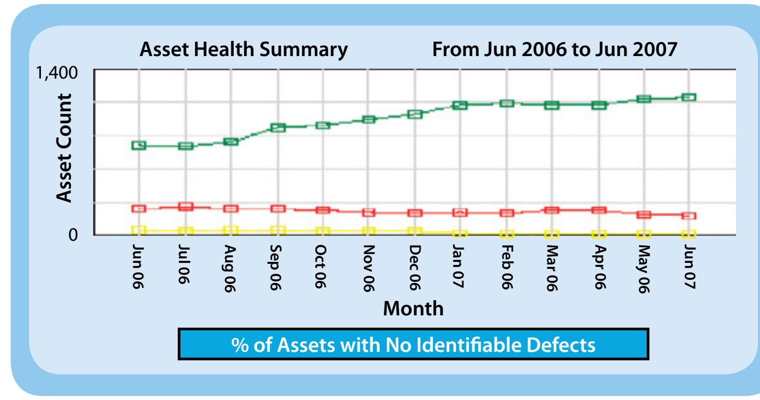


Figure 4 - Summary of Assets with No Identifiable Defects

to track Mean Time Between Failure (MTBF) because we are now in a proactive, not reactive mode.

An asset that has an identifiable defect is said to be in a condition RED. An asset that does not have an identifiable defect is said to be in condition GREEN. That is it. It is that simple! There are no other "but's", "what if's" or "if then's". Yellow is an unknown and must be determined to be either Green or Red within 72 hours. Figure 4 is an example of this metric.

Applying the right maintenance strategy at the right time – When an organization is focused on preventing and predicting failure modes, they can "Optimize Asset Integrity at an Optimal Cost" along with managing associated risks. My question to you is…

"Do you know the failure modes of your critical assets, and if so, are you applying the right maintenance strategy at the right time?"

An example of a failure mode would be pump bearing failure which could have been caused by poor alignment practices. If an inspection checklist for alignment had been followed, the problem would have been found. A failure modes analysis would identify Vibration Analysis as the most cost effective maintenance strategy for detecting alignment problems. Vibration Analysis will indicate if the shafts are in alignment, if a bolt is loose on the motor, if the pump has bearing stress, etc.

Failure of critical assets is unacceptable, as is spending too much money on reliability. The focus should be on applying the maintenance strategy, which predicts or prevents a failure mode in the most cost effective manner.

Identifying the Most Dominant Failure Pattern in your Operation – Many organizations today are focusing their resources on the most dominant failure pattern in their operation instead of reacting to problems. Identifying the most dominant failure pattern allows a company to focus on the common thread which has the largest impact on Asset Integrity. The US Navy conducted a study of their assets and found the most dominant failure pattern was infant mortality and considered the findings to be unacceptable. They put forth an effort to reduce infant mortality of their assets. Focusing on the dominant failure pattern allowed them to identify commonalities between different types of assets. They were successful in doing so as the percentage of Infant Failures dropped from 69% to 6%, which had a significant impact on their overall Asset Integrity.

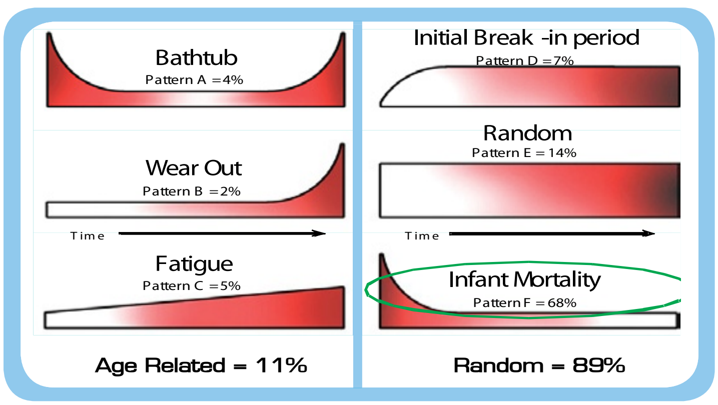


Figure 5 - Failure Patterns - Which is your most dominant one?

The failure patterns shown in Figure 5 were conducted back in the 1960s by United Airlines. These failure patterns have been found to be the same across different industry verticals.

Causes of Infant Mortality has been found to be the same in most industries. Here are a few examples of Infant Mortality:

Number 1: Lack of effective preventive, corrective and lubrication work procedures.

Number 2: Employees fail to follow the steps for a given procedure because either they do not agree with them or there is a lack of leadership follow-up.

Number 3: No contamination control – personnel apply grease into perfectly good bearings with contaminated grease on the end of lube fittings on the motors or the lube guns.

Number 4: Not removing the relief plug on large motors to relieve oil grease to purge out of the motor. Walk out to a 30-100 HP motor and look for a plug under the motor bearing and see if the plug has ever been removed. My guess is that is hasn't.


Figure 6 - Motor that was Over-Lubricated

Number 5: Welding on equipment without attaching the ground lead within 6" of the weld. Most construction and maintenance personnel attach the ground for welding as close to the welding machine as possible, thus allowing current to flow to the path of least resistance (aluminum conduit, etc.). We do not want arcing between bearings, motor stators, electrical circuits, etc.

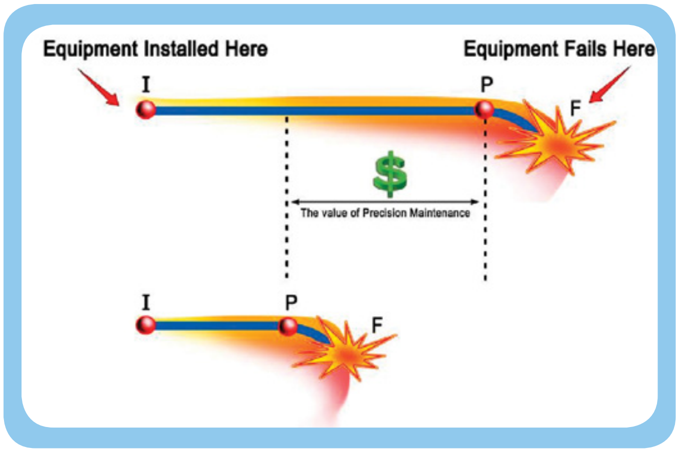


Figure 7 - The I-P Curve and the Value of Precision Maintenance

If the welding lead and ground lead on your (or your contractor's) welding machine is not the same length, then it will cause either infant mortality or random failures.

This list could go on and on. Just remember that if you could reduce the occurrence of this failure pattern by 50%, you will make a large impact on both asset reliability and cost.

The ultimate goal is to extend the life of the equipment without seeing "P" on the P-F Curve. You can accomplish this by applying Precision Maintenance, which includes training craft personnel, effective work procedures, etc. Look at the I-P Curve in Figure 7, and decide on which curve your maintenance staff is currently working. This is exactly what the US Navy did, and their results speak for themselves.

I am sure that some people will say, "we do not have infant mortality". Well, I hope that after reading this article, you actually investigate for yourself. If you would like a longer list, send me an e-mail and tell me which industry you are in, and I will share industry specific issues which cause infant mortality. The long I-P will never be obtained as long as the focus is not on the reduction of infant mortality by everyone from Project Engineering to Operators.

What a Successful Asset Integrity Manager Does

A successful Asset Integrity Manager focuses on providing reliability to an operation at the rate which its customers demand. However, we know this is not easy. Many organizations have spent millions of dollars performing Reliability Centered Maintenance (RCM) on their assets with what seems like very little Return on the Investment (ROI).

Doug Plucknette, a noted RCM expert and author states in his book *Reliability Centered Maintenance using RCM Blitz*, "The key to RCM was abandoning the philosophy of "preserve-equipment" in favor of "preserve-function". Simply put, equipment became the means to an end, not the end in itself." Doug has performed RCM on thousands of assets world wide and is noted among the best in the business.

Past studies have concluded that a maintenance policy based on operating age would have little, if any, impact on failure rates. Thus, applying time-based maintenance on equipment which has no "wear-out" pattern is futile. This conclusion forced a change in philosophy from, "It wasn't broken, but we fixed it anyway" to "If it isn't broken, don't fix it". These studies also concluded that:

1. Time-based maintenance works only for a small percentage of components, and then only when there is solid information on their "wear-out" characteristics.

2. Condition Based Maintenance (CBM) is the preferred option. That means monitoring, observing and taking non-intrusive actions, such as lubricating and cleaning, until a condition signals that corrective action is necessary. This means striking the balance between PM and Condition Monitoring (CBM) / Predictive Maintenance (PdM).

We know it to be a fact that the cost to repair increases the longer we wait to correct a known defect, and that the time in the x-axis on the P-F Curve is an unknown. We can't determine how long that interval is, nor can we tell when something is going to fail.

If you hear people say, "I think it will last a little longer," when a defect has been identified using one of the Condition Monitoring technologies (IR, UE, Vibe etc.), then you are taking a great risk if you leave that equipment in service. You should be using asset criticality and defect severity to determine when to make the repair. Have you ever seen a large pump fail after the bearing defect has been identified 6 months earlier? It is all about risk and the consequence of that risk.

3. Run-to-failure is a viable tactic in situations where there is little economic and no safety or environmental impact.

4. In a significant number of situations, the very act of maintenance itself causes subsequent failure of the equipment. This should be more clearly defined. This suggests that even if we do maintenance correctly, we still cause problems.

5. Non-intrusive maintenance tasks should be used instead of intrusive maintenance whenever possible. In other words, don't do any maintenance, except monitoring and non-intrusive sustaining actions, until condition directs intrusive corrective action.

A simple example is v-belt tension. The PM states "Check tension of Belt". The equipment is stopped, the belt checked and found to be "loose", so the mechanic tensions the belt using his hand as the tension gauge. It is highly probable he has over tensioned the belt because if he under-tensioned it you would hear the belt squeal when it returns to full speed and load. Over-tensioning of the belt will cause bearing failure. Why not use Infrared Inspection and look for belt slippage while the equipment is running (Figure 9)?

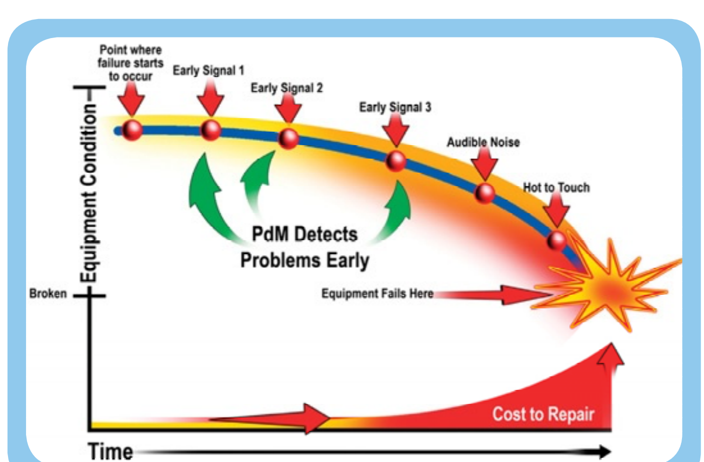


Figure 8 - Time in x-axis of P-F Curve is an unknown.

You must move from being a PM Centric organization to a truly PdM Centric organization if you ever want to obtain "Optimal Asset Integrity at Optimal Cost". PdM is the most non-intrusive and precise method for conducting inspections while the machine is running under full load.

In his book, *Plant Engineer's Handbook*, Keith Mobley links the following benefits to PdM:

- Maintenance costs - down by 50%

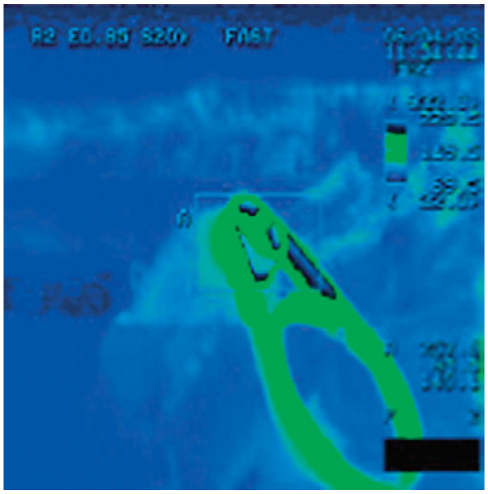


Figure 9 - V-Belt Slipping Identified with Infrared Technology

- Unexpected failures - reduced by 55%
- Repair and overhaul time - down by 60%
- Spare parts inventory - reduced by 30%
- 30% increase in machinery Mean Time Between Failures (MTBF)
- 30% increase in uptime

Now these numbers may seem high. But even if you take only a fraction of these benefits the financial impact of an effective PdM program at most organizations can easily reach into millions of dollars.

Despite what you may have heard, the foundation of a successful, comprehensive inspection program is simple: a detailed equipment list.

Why? Because your equipment list is the foundation for all of the key steps that follow. For example, a good list is essential for:

- Identifying how your equipment can fail (identifying failure modes)
- Choosing the right PdM technologies to apply to the asset
- Determining the ideal amount of PdM coverage for your operation
- Ranking the criticality of each piece of equipment
- Building databases for each PdM technology
- Determining PdM staffing levels

Equipment Type Vs. Technology Application(s)	Mechanical				Electrical				Stationary			
	Vibration	Ultrasound	Infrared	Oil Analysis	MCA Online	MCA Offline	Infrared	Ultrasound	Visual Inspection	Ultrasonic Thickness	Dye Penetrant Testing	Eddy Current
Chiller	X	X	X	X	X	X		X	X			X
Centrifugal Pumps	X	X	X	X	X	X	X		X	X	X	
Air Compressor	X	X	X	X	X	X	X	X	X			
Tank		X							X	X		
Evaporator		x					x		x			

Figure 10 - Recommended Technologies for Equipment Type

So if your list is incomplete or incorrect, everything that's built from it will be flawed. Any shortcuts or inaccuracies will be exposed as big problems later.

Figure 10 illustrates a sample of recommended technologies by equipment type for a specified environment.

In the last 40 years, no better method than RCM has been found for determining what maintenance should be performed to increase asset integrity. Four statistically significant studies have confirmed the validity of RCM.

In a survey conducted by Reliabilityweb.com in 2005, many companies offered the following excuses for the failure of their Reliability Centered Maintenance Implementations.

"Organizations want results right away, not in 6 months or a year. The classical RCM process is too time and resource intense."

"RCM is a great tool but very resource intensive."

"100% reliability is extremely expensive, difficult to attain, and not necessarily the right answer."

"RCM is misunderstood to be software."

"In the beginning, it was hard. And, it is still a challenge to steer the mind-set toward more condition-based maintenance than time-based."

"We always ran into the problem with implementation. In the few places where we implemented it successfully, it was at the maintenance level. And recognition for it was non-existent."

"The system is very strong but too high level"

The truth is, there are many pitfalls in RCM. But few get revealed when an RCM project fails. You see, nobody wants to write an article or present a paper at a conference that reveals how money was wasted or about great visions that were never realized.

In order to ensure RCM works in an organization, you must focus on the systems that will give you the best Return on Investment (ROI).

Simply put, RCM is a slam dunk when it comes to ROI for critical assets. Begin your RCM effort by identifying the top 10% of your most critical assets. Once this list has been identified, you should now begin to measure Reliability on these assets; performing RCM analysis on those critical assets that have equipment-based operational, speed and throughput losses and thus reducing total cost of maintaining these assets by reducing contractors, overtime, maintenance parts, and fines. If you have selected a critical asset, your implemented RCM maintenance strategy will show measurable improvements with added improvements in Health, Safety and Environmental performance as well.

As a general rule, the success of your first RCM analysis will build the business case to complete RCM analysis on the remainder of your critical assets.

In the simplest terms, RCM is a decision-making process which calls for answers to questions such as:

- What is this system supposed to do?
- How can it fail to do that?
- What causes it to fail?
- What happens when it does fail?
- Can we predict or prevent that from happening?

Getting the Tools in place - Funding, Staffing, Practices, and Reporting

Step 1 – Do not accept excuses for why you cannot transition an organization to the optimal maintenance model. Steven Covey once stated the following: "Your sphere of influence is very small, your area of concern is very large, focus on your sphere of influence and not on your area of concern and you will find your sphere of influence will grow."

When an organization transitions from their current maintenance model to a more proactive one, you will find staffing is not a problem, costs are lower, and emergencies become a rare occurrence, however, you must take it one step at a time and follow the industry proven best practices. There are no excuses for following the wrong path.

Step 2 – Develop a business case for the reliability improvement process. Identify costs and Return on Investment based on known data. Involve senior leadership and the financial team in the business case development. You must have everyone sold on this idea of change or it will never happen. Too many organizations have had many false starts. You should never start a journey without everyone knowing success is the only option.

Step 3 – Develop a master plan that focuses on results and moving an organization to having a balanced PM and PdM program using the Proactive Work Flow Model (Figure 11). In this plan you want financial targets and metrics to ensure you are receiving the benefits expected. You want short term results with long term gains. Note the Work Flow includes Management of Change (MOC) procedures to ensure consistency of processes and data. In addition, a process for a Failure Report Analy-

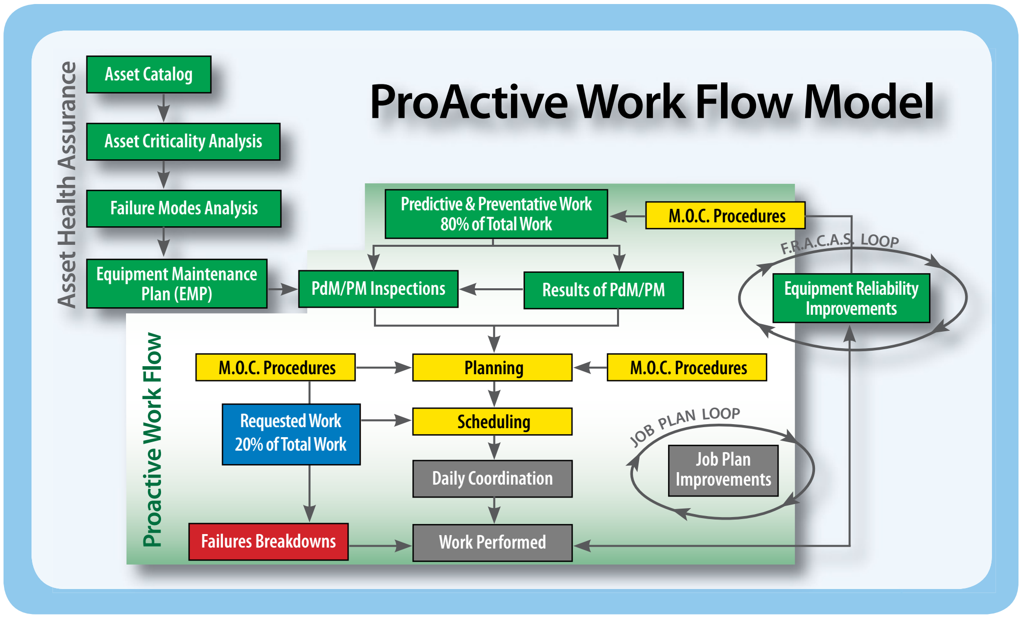


Figure 11 - ProActive Work Flow Model

sis and Corrective Active System (FRACAS) is identified for ensuring failure data is analyzed and used for decision making. This means implementing known best practices at the right time and not trying "new ideas" which are not proven.

Step 4 – Ensure you have identified Key Performance Indicators (KPIs) and financial targets. Make sure you have leading KPIs and lagging KPIs developed which equal the expected financial Return on Investment (ROI). These metrics and financial targets must be aligned with the process changes being made. In financial targets we want "hard dollar" savings and not "soft dollars". Here is an example of what I mean: While working at the Pentagon with the US Army I was in a meeting and a Lean Six Sigma Director was reporting to his General officer (3 star General) and he stated they he had exceeded their expected goal of $70 Million Dollar savings and the General looked at his comptroller and ask if he had seen the savings and, if so, he wanted to use this money for a critical project. The comptroller stated he had not seen any monetary savings. Needless to say, the General was not too happy about this situation. Remember only "hard dollar", verifiable savings can reported.

Figure 12 shows some known benchmarks in the chemical processing industry.

Benchmarking can be deceiving, but it is a great way to know where you stand in relation to other companies. The metric is the amount of money spent annually maintaining assets, divided by the Replacement Asset Value (RAV) of the assets being maintained, expressed as a percentage. This metric allows one to compare the expenditures for maintenance with other plants of varying size and value, as well as to benchmarks. The RAV as the denominator is used to normalize the measurement given that different plants vary in size and value. Here is what we know:

- Companies who are leaders have an RAV of less than 3.5% for Maintenance
- Companies who are in a reactive state have an RAV between 3.6-14%

Where does your organization you stack up?

The definition has been defined by the Society for Maintenance and Reliability Professionals (SMRP) after years of research. Here is SMRP's definition:

Guidelines provide additional information or further clarification on component terms used in SMRP Best Practice Metrics. This guideline is for Replacement Asset Value (RAV).

A. Definition: The Replacement Asset Value (RAV) is defined as the cost that would be incurred, in today's dollars, to replace the facility and equipment in its current configuration. It is intended to represent the realistic value to replace the existing assets at new value.

B. Purpose: RAV is used as the denominator in a number of calculations to normalize cost performance of facilities of various sizes within a given industry. These calculations are used to determine the performance of the maintenance and reliability function relative to other facilities within its industry.

C. Inclusions:

- Building envelope
- All physical assets (equipment) that must be maintained on an ongoing basis
- The value of improvements to grounds (provided these must be maintained on an ongoing basis)
- Capitalized engineering costs

D. Exclusions:

- Value of land on which the facility is situated
- The value of working capital:
  - Raw material inventory
  - Work-in-process inventory
  - Finished goods inventory
  - Spare parts inventory
- Capitalized interest
- Pre-operational expense
- Investments included in construction of the facility that are not part of the facility assets
- Mine development

Chemical Processing Industry Benchmarking Results

Average Return on Investment 16:1

Technology Credit for Return	
Vibration	35%
Infrared	9%
Electrical	1%
Oil Analysis	13%
Ultrasonic Leak Detection	5%
Traditional NDT	41%
Savings Result of	
Increased Uptime	33%
Increased Production	2%
Avoided Costs	6%
Reduced Parts	23%
Reduced Labor Costs	16%
Scrap Reduction	2%
Other	18%

Maintenance Strategies by %	
Proactive Strategy	9%
Predictive Strategy	55%
Preventative Strategy	29%
Run to Failure Strategy	7%
Other Benchmark Data	
Maintenance Staff as % of total site	19%
Maintenance as % of Plant Investment Production	3.3%
Plant Investment per Mechanic	$6.1 Million
Contractor Costs as % of Total Maint Cost	27%
Maint Dollars as % of Sales Dollars	5.4%
Uptime	95%

This data is information on maintenance savngs that the top quartile performers realized.

Figure 12 - Chemical Processing Industry Benchmarking Results

Replacement Asset Value Formula:

$$\text{Annual Maintenance Cost per RAV (\%)} = \frac{\text{Annual Maintenance Cost (\$) X 100}}{\text{Replacement Asset Value (\$)}}$$

Best Practice Leaders typically have an Annual Maintenance Cost per RAV in the 2%-3.5% range, while Reactive Organizations tend to run anywhere from 4%-14%.

Look at this example of the cost a company incurs by not following codes and standards identified to optimize Asset Integrity.

Type of Company	Maint Cost/RAV	Cost
Typical company in a reactive state	9%	$45,000,000
Maintenance Cost Leaders following Best Practices	3%	$15,000,000
Difference (losses)	**6%**	**$30,000,000**

This is not including increase equipment performance and output which can be 2-10 times these losses.

Step 5 – Educate everyone from top leadership to operators on your plan and what your organization's future state looks like. You want operations to understand they own reliability integrity as an equal partner with maintenance and of course engineering. This is a three legged stool which will fall if not supported properly.

Step 6 – Execute the plan and always meet targets and goals set by the plan. Ensure everyone sees the KPIs and financial targets which were established, and thus always knows the "score in the game".

In summary, organizations can be successful if they apply best practices at the right time and tie all changes to "hard savings". Remember, the ultimate goal is "optimal asset integrity at optimal cost" by following best practices.

Ricky has been involved with maintenance for over 30 years as a maintenance manager, maintenance supervisor, maintenance engineer, maintenance training specialist, maintenance consultant and is a well known published author. Today he is a Principal Advisor at GPAllied, LLC. Ricky has worked with maintenance organizations in hundreds of facilities, industrial plants, etc, world wide in developing reliability, maintenance and technical training strategies. He has worked for Exxon Company USA, Alumax (this plant was rated the best in the world for over 18 years), Kendall Company, and Hercules Chemical providing the foundation for his reliability and maintenance experience. Ricky Smith is Vice Chairman of the Oil, Gas, and Petrochemical SIG for the Society of Maintenance and Reliability Professionals (SMRP), is the Reliability Engineering Discipline Manager for PetroSkills and is well known as a Reliability Advocate in Asset Reliability and Process Integrity in the Middle East and around the world. Ricky is the co-author of "Rules of Thumb for Maintenance and Reliability Engineers", "Lean Maintenance" and "Industrial Repair, Best Maintenance Repair Practices" and "Planning and Scheduling Made Simple". Ricky holds certification as Certified Maintenance and Reliability Professional (CMRP) from the Society for Maintenance and Reliability Professionals (SMRP) as well as a Certified Plant Maintenance Manager (CPMM) from the Association of Facilities Engineering (AFE) and is also a Six Sigma Black Belt. Ricky lives in Charleston, SC with his wife. Aside form spending time with his 3 children and 3 grandchildren, Ricky enjoys kayaking, fishing, hiking and archaeology. He can be reached at rsmith@gpallied.com

Control Your CMMS to Cut Costs

Optimizing Planning and Scheduling

by Dave Koelzer

For asset-intensive operations, maximizing the use of maintenance dollars is critical. Put simply, planned and scheduled maintenance costs less than unscheduled and reactive maintenance. How much does it cost your organization for unplanned, reactive work? How much for emergency work? We'll explore how a small reduction in unplanned and emergency work can lead to significant cost reductions and improvement in real-world resource availability and productivity.

A common challenge experienced throughout asset-intensive industries is figuring out how to drive efficient work execution management practices in order to push valuable data back across the enterprise so that more informed decisions can be made at the executive level.

A reduction of reactive maintenance is achieved through the implementation of a single point of entry for the Scheduler/Supervisor, which gives control of the work execution back to the Supervisor. A reduction in the time that the Supervisor takes to manage the work execution results in better maintenance and production planning. When an organization can get to a single version of the truth, the information becomes a business driver and a leading indicator of the overall health of the enterprise. So, the ideal scenario is to get to a single process. Gray areas lead to poor data, and poor data leads to uninformed or under-informed management decisions.

Increasing spares utilization reduces the demand purchasing and allows the configured EAM/ERP system to utilize the data provided, delivering that data up the chain to executive decision makers. The utilization of standard purchasing processes and inventory can reduce the operating expense, not only in regard to the reduction in inventory valuation, but there can also be considerable savings realized by reducing the amount of materials and repair parts that have to be expedited.

On the shop floor, when the process is streamlined, there is less time and energy wasted looking for the right part the first time, and thus there is less confusion around who is doing what and when. Imagine the crew productivity that is possible if your technicians could go straight to the job and straight to work, rather than spend the first hour or two searching for a plan of action.

For the maintenance and operations professional, the issue isn't what they want to do. They know that the work ahead of them comes in many different forms—RCM, PDM, PM, Corrective, operator requests— the list goes on and on. Today's managers and supervisors need help with the amount of data that they have to sift through. From the maintenance manager to the technician, they need to be able to acquire skills through easy to use tools and easy to navigate processes. The process improvement initiative has to attainable. We see over and over that there is a desire to improve... but these people are being left hanging, trying to implement.

Today's Managers are cut from one of several cloths — odds are that they are one of the following:

1. An engineer — in which case management assumes that since they have an engineering background, that they must be qualified to manage a department.

2. They may have an operations background — and since they know what is required to run the plant or the operation they're assumed be able to manage a maintenance department.

3. They're the guy who's moved up from the hourly workforce to a supervisory role — because in management's view, they're technically very competent so they must be qualified to manage a maintenance department.

Many surveys exist that indicate a surprisingly low number of managers using any type of advanced planning, scheduling, and project management software. There is also a very low percentage of managers and front line supervisors that are using even basic desktop software on a regular, repeatable basis. When they do use their desktop software, it is usually reserved for the 'big job' and it's not integrated with their backend EAM/ERP. There are significant numbers of the same groups that are using a simple spreadsheet into which they have to manually load the work orders to manipulate the work and somehow get a "schedule" of the day's events. Following these outdated practices usually means that the ability to measure resource productivity and effectiveness goes out the window. If they are manipulating any of the data in the spreadsheet, it almost never gets back to the EAM/ERP.

So, right away we have gray areas and the 'one version of truth' is out the window, along with the crew productivity. If you're not getting all of your work order data back into your EAM/ERP, the data quality is diminished and suspect as being flawed to the point that you can't use it to make management decisions. In other words, you can't use your own data to make your day-to-day decisions.

Due to the 'fire fighting' nature of the business, there are cultural paradigms that need to be overcome in most maintenance organizations. When a Technician moves up through the ranks into the role of Supervisor or Foreman, then on to some other role on the management team, that person usually brings with them the desire to be the Hero and put out the fire of the day. Many organizations struggle with changing the culture from being reactive (the 'hero culture' – saving something everyday) to having a standard, repeatable process for planning, scheduling and execution that embodies foresight. To this end, the organization has to not only want to move forward with their process and continuous improvement initiatives, but they also have to provide a framework (aided by technology) to institutionalize the desired improvement initiative. The people on the plant floor need some support, and, ultimately, more than a recommendation that they 'do more with what they have' and/or a directive to change their work habits.

Five Steps to Adding Value

Take back your process. Don't let the ERP/EAM/CMMS consultants tell you how to run your business.

Drive more value out of your existing EAM/ERP/CMMS systems by concentrating on the following five objectives.

1. Improving Planning Performance

Most EAM/ERP systems provide comprehensive planning and scheduling capabilities. It is generally accepted that proactive (i.e. planned), maintenance costs roughly 50% of reactive maintenance. Our experience is that companies tend to overestimate the level of planned maintenance they actually perform. These organizations are also generally not able to accurately report some of the key performance indicators that measure maintenance planning. Given that maintenance can comprise 30% to 50% of the total expenses in an asset intensive industry, improving the amount of planned maintenance can quickly result in significant ROI.

2. Reducing Training Time

Many companies do annual refresher training to try to improve the data quality and user abilities within the EAM systems that they utilize. By reducing the amount of time an MMP (Maintenance Performing Persons), Planner, Supervisor, or Technician spends in training, you can improve your labor efficiency and increase ROI.

3. Reducing Computer Screen Time for Maintenance Personnel

Time wasted navigating through multiple screens and multitudes of fields can lead to hours of inefficient time sitting in front of a computer. Look at how to calculate what it really costs you to get the information that you need into your systems, and the value of reducing that infamous screen-time.

4. Optimizing (Reducing) the Time to Return Assets to Production

There is a widely held consensus that the primary goal of every maintenance department is to keep its assets running at optimum capacity, and when they're down, returning them to the operation or production groups as soon as possible. While the value of the collective assets varies, there is a value for each individual asset, and as such, the value of returning that asset to service can be calculated. That number can provide helpful insight to your operation.

5. Optimizing Return of Assets to Support the Mission of Your Organization

Is the lack of reliability or predictability in your planning and scheduling systems / processes affecting your ability to accomplish your mission? It may not be possible to put a dollar figure on improved reliability or improved performance within your Planning and Scheduling departments, but you can calculate how returning assets to service faster can affect your mission. By increasing the utilization of your existing workforce and systems you'll maximize resources, increase uptime, and support your mission through better reliability and availability.

As President of Dimension Technology Solutions (DTS), Dave Koelzer is responsible for day to day operations, new product development and customer and partner services and engagements. Prior to joining DTS, Dave held a wide variety positions in gold, copper, and coal mining as well as the transportation industries. He started his career as a maintenance apprentice in the gold fields of Nevada for Newmont Gold (formerly Carlin Gold) where he was promoted from Mechanic-Welder to Maintenance Supervisor, Maintenance Planner, Maintenance Manager and finally as IT Project Manager. He also held a position as the GEM Coordinator-Manager in a process reengineering initiative to redesign all maintenance and operations process and technologies for the mineral and coal divisions. Koelzer held the position of Maintenance/Operations General Coordinator-Manager at the Belle Ayr Mine, and finally corporate IT Manager for the entire company with responsibilities for all corporate applications and networks.

Koelzer has designed, implemented, and managed a wide spectrum of IT applications including eMESA™, MIMS/Ellipse, Lawson, Cybershift, SAP, Coal and Mineral Production Systems as well managing numerous IT initiatives for both surface and underground mining in the Financial, Sales-Transportation, Materials, Operations-Production, and Maintenance areas.

Tap Into Infrared

Successful Programs Can Be Outsourced or Run In-House

by Jeffrey L. Gadd

Infrared thermography is emphatically embraced by those who have realized the benefits. Equally, infrared is dismissed by those who aren't quite sure what it is or whether it has value. "I've been here twenty years and we never needed infrared" are words on the lips of more than one old salt. Well, things change, and this is an exciting time for those of us who are involved in the IR technology. When evaluating this technology for your operation there are two methods to consider, specifically; should you develop an in-house program or outsource the work? Training and experience of the thermographer and the quality of the infrared (IR) camera used on the job are both a critical part of the equation. Figuring out which camera is the best value can be tricky, so proper research on the subject and some due-diligence are required for you to be able to "tap into infrared".

In-House vs. Outsourced

This is simple: unplanned downtime = lost money. For companies with critical operations, 24/7 manufacturing and a proactive mindset, an in-house program makes good business sense. Many companies have successfully implemented in-house programs; for example, 2006 Uptime PdM Program of the Year Infrared winners Johns Manville in Kansas, and 2007 Infrared winners Aerospace Testing Alliance (ATA) at Arnold Air Force Base in Tennessee, to name a couple. These are examples of world class in-house P/PM programs. Many companies must outsource this type of work as it is not economically feasible to have an in-house program. The biggest benefit to outsourcing is that there is no long term commitment and the costs are generally lower –but so are the returns on investment. Not having an on-site IR camera system makes troubleshooting using IR impossible.

Training and Education (In-House)

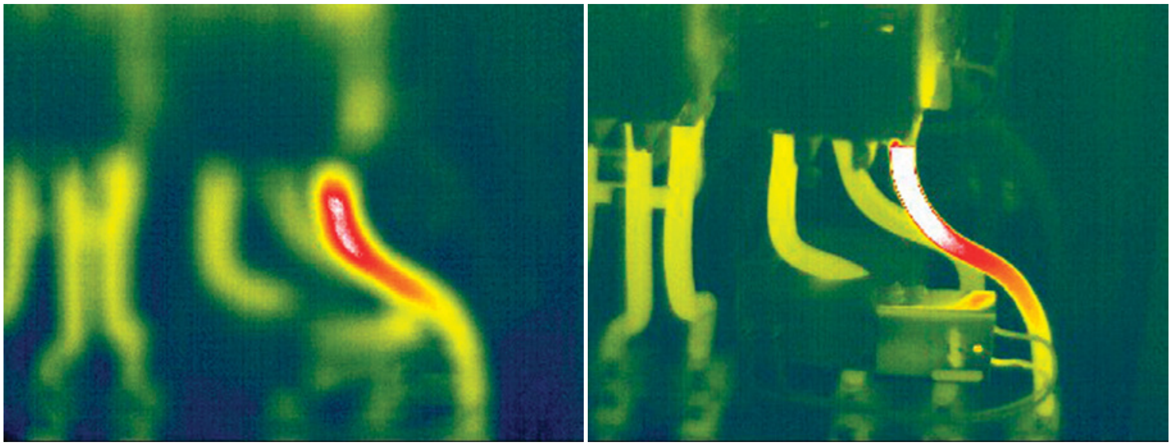
Training is a critical step if you have an in-house program or are planning to start one. In the case of electrical infrared inspections, a person with an electrical background is the ideal person to train on infrared if they have the right personality. Someone that is timid is not a good candidate. While performing electrical inspections, there are a lot of considerations. Safety is the first, but you also need a person who understands the equipment, i.e., switchgear, buss ducts, fuse clips, control transformers, etc., so that they can identify what they are looking at.

Next, never make the thermographer responsible for the repairs when he or she finds problems, even if they are capable of accomplishing, them because it is not efficient. Infrared thermography has not quite progressed into a science, so it is still somewhat of an art form. This leads to wild variances in the number of reportable findings. Training and mentoring by an experienced thermographer is key. There are other personality factors to consider. Some people will over-report even if this creates more work for them. Others will not report all the problems because they don't want to repair them, or they think maybe it will be OK until the next scan or the classic "I'm quitting soon, so I don't really care" attitude.

Training and Experience (Outsourced)

Training and experience of the thermographer are the two factors that should drive the purchase of any service. A technician from a professional infrared service company has most likely [but not certainly] had some sort of formal training and on the job training. However, the more important component is to find someone with a considerable amount of experience. No one wants an untrained thermographer with a low-resolution IR camera learning how to do electrical infrared surveys at their facility. You must qualify the contractor by inquiring as to what type of training they have had, what references they have and what experience they have accumulated.

Many companies that we have dealt with in the past (even ones that have eventually hired us), at first, judge the company solely by the cost of my service –which is not the right way to buy any service, and certainly not infrared services. Recently a company brought me in for what seemed to be an "interview" and plant tour. Both the maintenance manager and plant manager had prepared questions to find out what we could and could not do. It was refreshing



Figures 1a and 1b - The left image shows an IR image that is out of focus. The clear image on the right is correctly focused.

to see people take a genuine interest in evaluating my skills, my company's capabilities and the cost of the services. This is one of few companies in recent years that have taken the time to find out what they are really paying for.

Evaluating samples of past IR projects by the thermographer is important and effective. When someone prepares a sample project, they will naturally use some of their more impressive imagery. If the thermographer shows you images that look like the ones on the left in Figures 1 or the left in Figures 2, it should let you know that you definitely do not want to hire them since you are probably looking at their "best" work.

Infrared Cameras (In-House and Outsourced)

To effectively contract IR services, one needs to evaluate not only the thermographer's capabilities, but also the equipment specified. The specification should be based on performance and not brand-specific. In other words, the specification should not read: "the IR camera used shall be a Brand-X, Model-Y". Instead the spec should be about the technical characteristics of the camera, such as the minimum spatial resolution and the minimum thermal sensitivity.

Other considerations when specifying IR cameras are:

- Proprietary infrared software compatibility and usability
- Lens options (telephoto, wide-angle)
- Built-in visual camera
- Built-in voice recording & data-logging
- Built-in laser pointer
- Extra (and standard!) batteries
- Adaptability to infrared windows (to increase safety and lower PPE requirements)

Once you have narrowed down your selection of cameras to a couple, ask for demonstrations of the units and the software for each. Bear in mind that the newest trend on the lower end cameras is for the manufacturers to sell through distributors instead of reps. Distributors don't have the margins to sell by demonstration, so they will resist. Now, if you want a demo of a $35K camera, I promise a representative will make time for you.

Conclusions

When evaluating what infrared technology can do for your operation, there are many considerations. In-house programs can be very successful, but are highly prone to failure if you select the wrong personnel and if the program is not given full support by management. If you outsource your infrared services, set up an "interview" with the contractors and have lots of questions ready. At the end of the interview, you should know if this contractor will not meet, meet or probably exceed your expectations. When specifying an IR camera purchase, consider hiring a thermographer who knows the IR market to be your consultant. Many cameras have features that are not necessary and overpriced. Do your homework each step of the way and you will see positive results and a positive impact to your company's bottom line.

Jeffrey L. Gadd is the owner of Vision Infrared Services (www.visioninfrared.com) in Cleveland, OH. He is a Level II Infrared Thermographer and has an AAS in Industrial Electricity along with 12 years experience as a electrician and maintenance technician. You can contact Jeff with questions at 440-554-3620 or e-mail to: jeff@visioninfrared.com

Figures 2a and 2b - The left image shows an IR image that is not properly thermally tuned. The much clearer image on the right is correctly thermally tuned.

Reduce the Red by Going Green

Increase Pump Uptime, Decrease Costs With Water Management System For Mechanical Seals

by Chris Rehmann

Rising cost and shrinking availability of clean water for operating industrial pumps are of concern to many plant managers, as is as the high cost of treating this water for disposal. For over a half-century, the accepted method of providing cooling and flush water for mechanical seals and packing has been to pipe plant water through the seal or packing, and then to drain. Under this scenario, the normal consumption of water is 1.7 million gallons of water per pump, per year.

A water management system that cools and re-circulates the water can reduce this water consumption to just a few gallons per year. This water management system also increases the pump reliability and mean time between failures (MTBF) significantly, with a return on investment (ROI) that is usually around 6-12 months. Additionally, significant energy savings is documented through the use of this system, by greatly reducing or eliminating the amount of energy needed to heat the flush water up to process temperatures, and then to boil/evaporate this water from the product.

Water, Water Everywhere…

"Almost 3 billion people will face severe shortages of water by 2025 if the world keeps consuming water at current rates…" United Nations Report

"Even where supplies are sufficient or plentiful, they are increasingly at risk from pollution and rising demand. Fierce national competition over water resources has prompted fears that water issues contain the seeds of violent conflict…" Kofi Annan, UN Secretary General

"The simple fact is that there is a limited amount of water on the planet, and we cannot afford to be negligent in its use. We cannot keep treating it as if it will never run out…" Mohammed El Baradei, Head of the International Atomic Energy Agency

Of all the world's water, 97.4% is salt water, 2% is frozen in glaciers and ice caps, and only 0.6% is available for human consumption and industrial use. As the above quotes illustrate, our water supplies are finite; the sources of supply are becoming increasingly polluted, and are asked to supply ever-larger volumes. The United States is struggling with long-term water shortages in California and the Southeast, shortages which will not be overcome by one or two good years of rainfall. We have also heard about the serious drop in the water level of the Ogallala Aquifer which underlies 8 central states, from North Dakota to Texas, due to over-pumping of this water resource for crop irrigation.

Clean, fresh water is a limited resource which is under increasing pressure on our planet. There are compelling reasons to actively pursue water conservation measures that are both proven and economically justified.

The Impact of Industry

The 2nd most common machine in industry (after the electric motor) is the pump (Figure 1). It is estimated that there are about 600 million industrial pumps in the world (not counting about one billion pumps in domestic use, such as dishwashers, clothes washers, automobile water pumps, etc). These industrial pumps rely on a mechanical seal (Figure 2) or packing to seal the rotating shaft and contain the pressurized liquid within. Mechanical seals and packing require clean fluid, usually water, and lots of it, for cooling and lubrication. As our world has become more industrialized, the population of pumps has grown accordingly, and so has our demand for clean water to service these pumps.

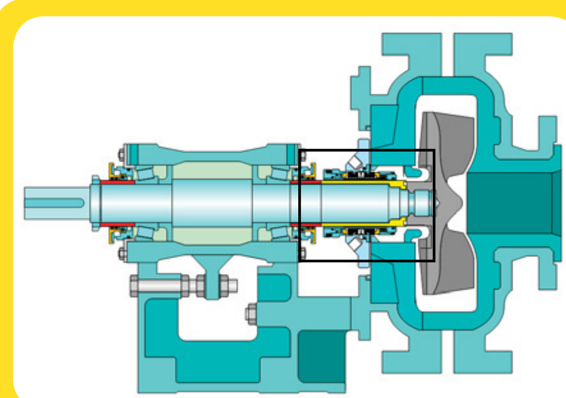


Figure 1 - Cutaway view of a typical industrial centrifugal pump, with the mechanical seal inside the black square (see Figure 2 for detail).

However, the rising cost of water, along with increasing awareness of the long-term consequences of unrestricted water use, has caused many forward-thinking companies to reconsider their traditional, wasteful water use

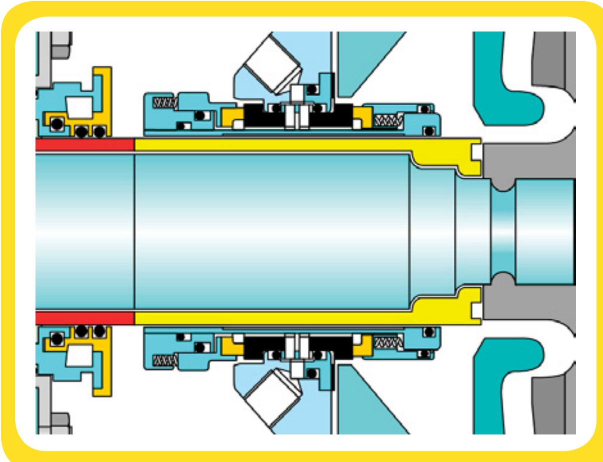


Figure 2 - Enlargement of area inside black square of Figure 1, to show detail of double mechanical seal.

practices. Moderate investments in proven new water-conserving technology can achieve financial payback within the first year, while also having beneficial effects on our global water supply that will last for decades.

> Environmental protection and sustainability efforts have been an important focus for Cargill. Efforts to reduce our companies' environmental footprint and usage of natural resources have been underway for many years. AESSEAL's innovative solutions for our pump applications have been one avenue in which our plants have reduced water consumption, in addition to the reliability and cost benefits achieved.
>
> Timothy Goshert, Worldwide Reliability and Maintenance Manager, Cargill

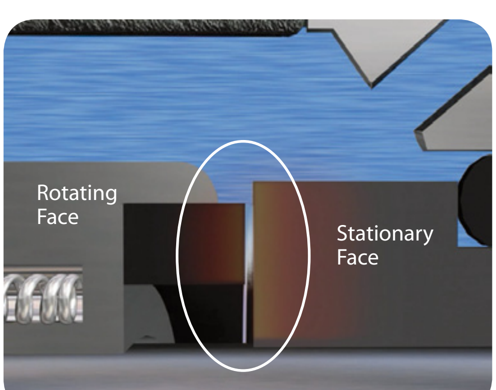


Figure 3 - Mechanical seal faces with a fluid film of fresh, clean water will run cooler and longer

The Importance of a Fluid Film

Process pumps usually use a mechanical seal to contain the pressurized fluid by creating a sliding seal between the rotating shaft and the pump housing. This mechanical seal is engineered to operate with a thin fluid film separating the highly-polished rotating and stationary seal faces (Figure 3). The face materials and seal design are selected specifically for the particular pump application parameters and fluid properties (pressure, temperature, viscosity, etc.). The fluid film may consist of either the pumped process fluid, or a special fluid such as clean water may be introduced under pressure if the process fluid is not suitable (e.g., if it is too hot, too high solids content, tends to crystallize, etc.)

If this fluid film is not stable or not present, the two faces will contact, overheat, and damage each other and the mechanical seal will fail, causing the pump to fail (see Figure 4). When the seal fails, the entire pump unit is removed and repaired, at an average cost of $2,500 per repair. This is the maintenance cost (parts and labor) only and does not include the value of lost production, which can be thousands of dollars per hour.

The fluid film can be adversely affected by process upsets that lead to dry-running of the seal, which can include:

- Process changes upstream that lead to no liquid product at the pump.

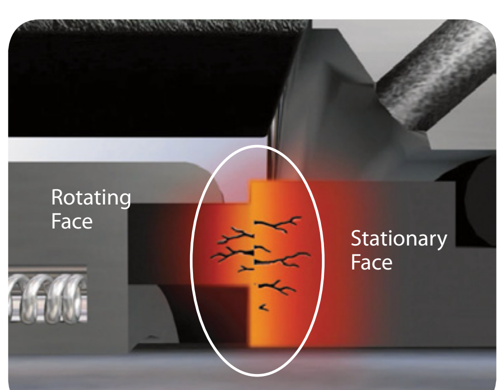


Figure 4. Dry-running of mechanical seal faces destroys the fluid film, resulting in overheating and failure.

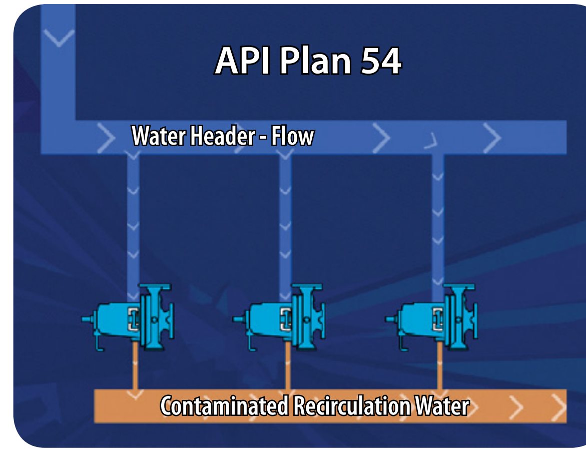


Figure 5. Typical "water-to-drain" method of cooling mechanical seals on pumps.

- Operator error (opening or closing a valve which stops product flow to the pump, etc.)
- Cavitation, where there is inadequate net-positive suction head to the pump and the liquid product changes into a vapor state at the impeller.

Mechanical seal faces can also be damaged by product crystallization due to temperature and pressure changes across the face. Suspended solids in the pumped liquid are another major cause of seal damage, and these solids must be kept away from the faces with a supply of clean water to form the fluid film or the seal will fail prematurely.

Old "Water-to-Drain" Plan

Many industrial plants supply their double mechanical seals with a fresh supply of barrier water using the "water-to-drain" method, or API Plan 54 (shown in Figure 5).

In the water-to-drain plan, plant water is supplied to all of the double mechanical seals in parallel from a water header main. This plan can work satisfactorily if all conditions start out perfectly and stay perfect, but as we know, this level of perfection is rarely found or maintained in a real, operating, industrial plant. The water-to-drain plan is prone to process upsets that cause seals and pumps to fail, for example:

1. Water will take the path of least resistance. If the pressure and flow rates of each branch of the piping are not set exactly right at startup, most of the water will selectively flow through the pipe with the least resistance, leaving the other seals to starve for water and seal failures can result.

2. If one mechanical seal fails and allows process fluid to enter the water supply line, All of the seals can be cross-contaminated and thus lead to multiple seal failures.
3. If an alternative flow path is created, for example by an operator turning on a large water line for wash-down, the pressure and flow of water to the seals will drop and this could lead to seal failures.
4. If the quality of the water being supplied by this system is poor, it will lead to solids being delivered to, and collecting on, the seal faces; this will lead to premature seal failure.

In addition to these failure modes, water-to-drain has the following cost considerations:

- If the supply water is being purchased from a municipal supply, the cost of the water can be very high, as can be the cost of treatment and disposal of the waste water.
- The typical water flow rate on a water-to-drain plan runs an average of 3.2 gallons per minute to drain. Running 24/7, this amounts to a staggering 1.7 million gallons of water per year, per pump, running to the drain.

Figure 6. Closed-loop water management system tank connected by tubing to a mechanical seal.

New Water Saving Solution

The solution to the shortcomings of the water-to-drain plan is to install a water management system tank above each pump (shown in Figure 6). Recall that the sliding faces of the mechanical seal (at lower left in Figure 6) create frictional heat in the seal. Heat is also added to the seal by the hot pumpage. Hot barrier water from the double seal rises up to the tank via the upper tube, where the heat is radiated to the atmosphere; the cooled barrier water is then returned to the seal through the lower tube. Circulation of the barrier water from the seal to the tank, and back to the seal, is maintained by the thermo-syphon effect (basically, hot water rises and cool water falls), with no moving parts. In cases where more flow of the barrier fluid is required, pumping assistance can be obtained from an optional bi-directional pumping ring in the seal itself.

The tank is connected to the plant water main and automatically tops up with water to replace the very small amount (about 30 gallons per year) of barrier water that is lost at the seal faces during normal operation. The tank is maintained at a pre-set pressure that is one bar (15 psi) above the pump's stuffing-box pressure, to maintain a positive pressure differential across the seal faces that ensures clean barrier water is forming the fluid film (as opposed to process liquid). Additional cooling can be accomplished, where necessary, by adding fins to the tubing, adding a cooling coil to the tank, and/or using a larger tank.

A diagram of a typical multi-pump layout is shown in Figure 7. Each tank system serves just one seal/pump set, and is isolated from all other tanks. (Note that only 3 tanks/pumps are shown in the figure, but many hundreds of tanks/pumps are often connected in practice.)

The advantages of this system include:

- The waste water-to-drain is completely eliminated, with huge savings in water resources, the cost of water, and the cost of treating waste water. A single tank/seal combination typically uses only about 30 gallons of water per year, thus typically saving 1.7 million gallons per pump per year.
- Water from the plant main line passes through a check valve which prevents contamination caused by a seal failure from passing back into the main, so each pump and seal is isolated; one seal failure does not adversely affect other pumps.
- A pressure regulator on the water feed line into each tank sets the tank pressure at the correct pressure for that pump, so each pump can operate at a different pressure and have a fluid film that is maintained at 1 bar (15 psi) over its stuffing box pressure. Note that the maximum pressure possible in each tank is equal to the plant's main water line pressure.
- Each tank/seal/pump is a stand-alone system; changes in the operating conditions of one pump or the water flow to one seal do not affect the water flow to the seals of any other pump.
- Changes in the main line pressure, such as turning on a wash-down hose, do not affect the operation or the pressure in the tank systems, as each tank is isolated by its own check valve.
- The water quality is greatly improved by installing a filter on the incoming line to each tank. Since only about 30 gallons of water are used per tank per year, the filter will last a long time before plugging. Cleaner water leads to longer seal life.

> We have installed numerous AESSEAL water management systems in our plants globally. In these cases we have seen improved reliability of our pumping systems due to increased MTBF. These installations and activities have reduced our maintenance costs and helped reduce water consumption.
>
> Timothy Goshert, Worldwide Reliability and Maintenance Manager, Cargill

Additional Savings

In addition to eliminating water-to-drain and the pump seal life extension, there is one more way that water management systems save plants large sums of money, in those instances where the plant is using single mechanical seals. Figure 8 (following page) shows an API Plan 32 on a single mechanical seal, where clean water is used to flush and cool the seal faces. Cold water passes from the incoming line at upper left in the figure, into the stuffing box, and directly into the hot product. As much as 3 million gallons of water per year can be injected into the process liquid by a single pump using API Plan 32. In many processes this water must be heated up to the process temperature and ultimately evaporated out of the product, using large amounts of additional energy.

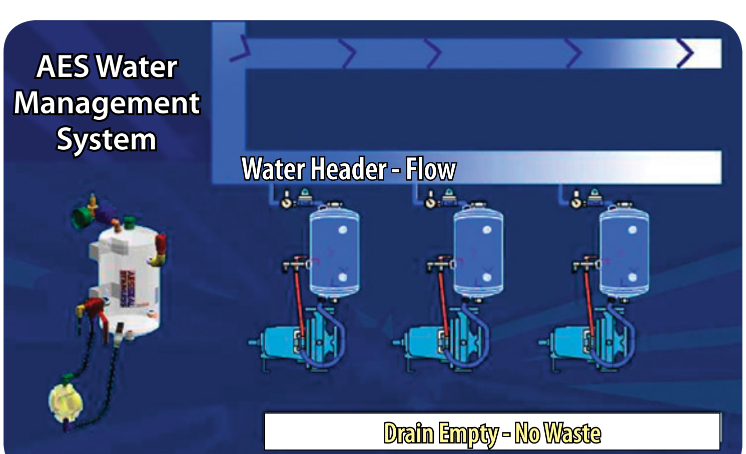


Figure 7 - Typical industrial plant layout of pumps, seals, and tank systems.

On a typical pulp and paper mill sealing application, with the incoming flush water at 60° F, and mixing with process fluid at 140° F, the cost of energy for heating the flush water to process temperature costs $4,000 per year. The energy to evaporate this water at the end of the process costs an additional $9,000 per year. Ironically, this API Plan

32 water addition is not easily visible and so this huge water usage, and resulting waste of energy, is often not even recognized as such by the plant operator.

A water management tank system used with a double mechanical seal to replace the single mechanical seal in Figure 8, eliminates both the wasted water and energy by re-circulating and cooling the barrier water to the seal faces.

CASE HISTORY #1
Tanks, Double Seal and Flow Fuse on Agitator

Guinness/Diageo, a major beer brewery in Dublin, Ireland, was experiencing failures of the single mechanical seals on their hot wort agitators about every 6 months. The vessels on which the agitators are mounted contain about 25,000 gallons each and must be drained completely for an overhaul, leading to a great deal of down time and lost production. When the seals failed, the wort leaked straight onto the floor, causing a loss of valuable product, as well as a safety hazard. Any proposed remedy had to also prevent the addition of water into the vessel, since dilution of the product was not allowed at this point in the process.

The proposed solution was a double mechanical seal with a water management system. Because the hot wort could not withstand dilution, the system includes the Flow Fuse automatic valve shown in Figures 9 and 10 below, which detects an abnormally high water flow rate and shuts off the plant water main supply to the tank system. This action protects the hot wort product by preventing water entry into the agitator in the event of an inboard mechanical seal failure.

The water management system package has been in place for 2 years with no seal failures (recall that the previous MTBF was six months). The payback period based only on the cost of repairs (not including lost production) was only 180 days.

CASE HISTORY #2
Tanks & Double Seals Replace API Plan 32 Single Seals

A pulp & paper mill in the USA uses API Plan 32 (Figure 8) to flush their single seals, with considerable energy required to (a) heat this flush water up to process temperatures, and (b) evaporate this excess water off at the end of the process. Five bleach filter pumps were fitted with water management tank systems and double seals in October 2008, and monitored over the following 9 months. First year savings (from energy, water, wastewater, and reliability) were calculated at $41,800, with an ROI payback on the investment cost (parts and labor) of the new tanks and seals of 1.2 years.

Spurred on by these excellent results, the paper mill has now completed a comprehensive mill survey to look for additional savings opportunities. A total of 604 pumps/seals were surveyed, and 144 pumps (24% of total) were deemed to be "highly energy inefficient". A capital project is being considered to convert these 144 pumps to double seals and tanks. Annual savings are conservatively estimated to be $473,000 per year, with water savings of 174 million gallons per year.

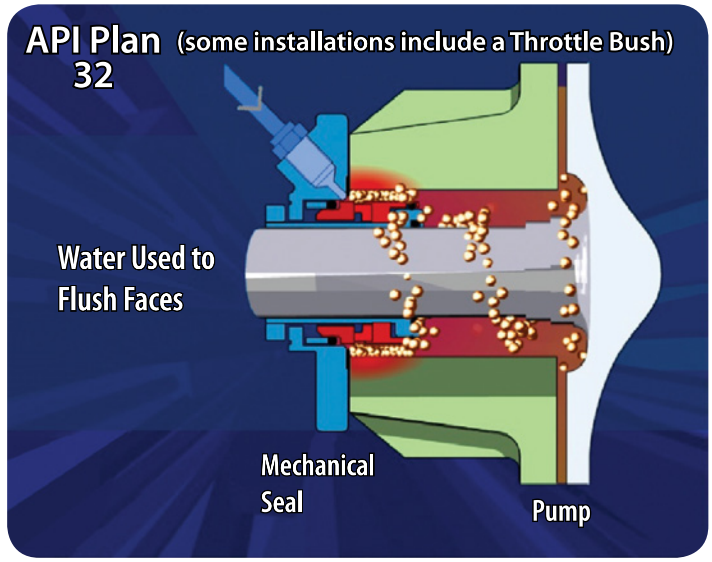


Figure 8 - API Plan 32 showing water used to flush seal faces entering the product, where it must then be heated and evaporated with additional energy input.

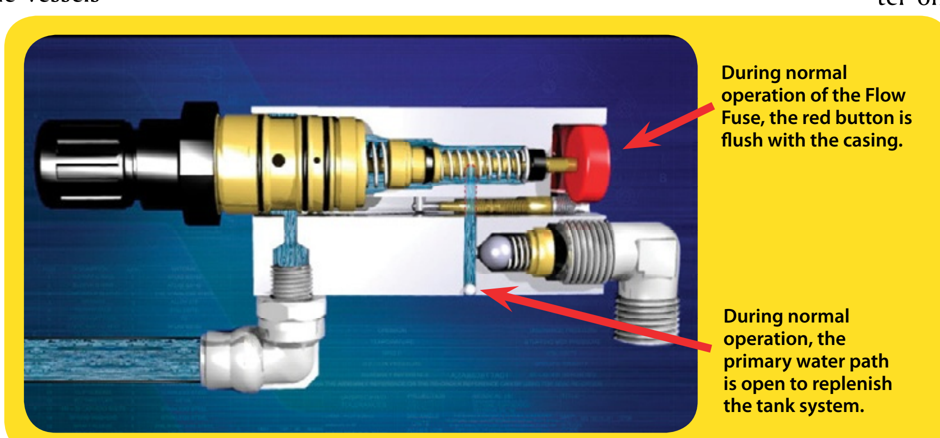


Figure 9 - Flow Fuse in normal operation. Water from the plant main line is allowed to flow at very low flow rates to the water management system tank, making up small amounts of water lost to normal seal operation.

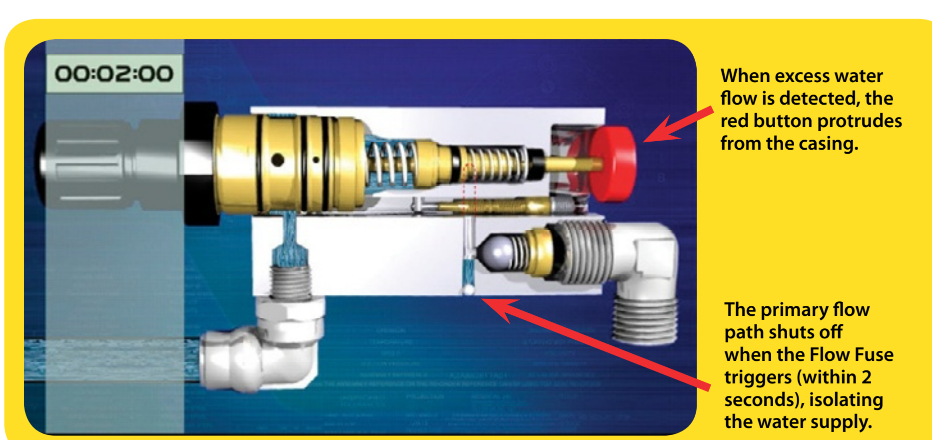


Figure 10. Flow Fuse detects excessive water flow into the water management system tank (possibly due to an inboard mechanical seal failure), and shuts off the water supply to the tank within 2 seconds.

CASE HISTORY #3
Tanks Replace API Plan 54 Water-to-Drain

At a food processing operation with a total of 6,300 pumps, water management tank systems have been installed on 1,310 (20% of total) of the most arduous "bad actor" pumps over a six year period. Of the 1,310 upgrades, 750 (57%) are running with no failures since the upgrades began in 2001. Prior to the upgrades the seal life for the population of 1,310 pumps was 2.58 years. After the water management systems were installed, the seal life improved to 3.42 years.

The upgraded population of pumps had 2,127 failures prior to the upgrade, and only 1,059 failures after the upgrade (during the six year period). Using an average cost of a pump repair of $2,500, we find the following savings in avoided repair costs:

Cost of repairs prior to Upgrade: 2,127 failures X $2,500/repair =	$5,317,500
Cost of repairs after Upgrade: 1,059 failures X $2,500/repair =	$2,647,500
Repair Costs Avoided:	$2,670,000
Total cost of the 1,310 water management systems:	$1,345,000

The savings to the equipment owner, based on equipment life alone, resulting from the upgrade to water management systems is thus $2,670,000 - $1,345,000 = $1,325,000. Additional savings have been realized from the 1,310 pumps X 1.7 million gallons per pump per year = 2.2 Billion gallons of water saved per year.

Summary

Water management tank systems, used in conjunction with double mechanical seals on pumps, agitators, and mixers, will generate significant cost savings due to:

- Virtually no water usage and no associated costs for either buying city water or treatment of pond water. Savings of 1.7 million gallons of water per pump, per year have been frequently documented when used on API Plan 54.
- No waste water treatment and disposal; again, as much as 1.7 million gallons per pump per year on API Plan 54.
- No energy needed to heat the flush water introduced into the process up to process temperatures using an API Plan 32.
- No energy needed to boil/evaporate added flush water from the product (Plan 32).
- Increased pump lifetime and reduced pump overhaul costs.
- Less downtime and associated lost production.

These tank systems are pressurized by the plant water main to 1 bar (15 psi) above the pump stuffing box pressure. The tanks use no moving parts, simply relying on the "thermosyphon" process to circulate hot water away from the mechanical seal, release the heat to atmosphere, and return cool water to the mechanical seal. This clean, re-circulated water extends the life of the mechanical seal and the uptime of the pump by flushing solids away from the seal faces, as well as cooling the seal faces. The systems are maintenance-friendly, requiring no external compressed air for pressurization, and do not require any manual intervention for refilling.

The standard flow indicator gives a quick visual indication of an inboard seal failure, which is difficult and costly to identify otherwise. An optional Flow Fuse will shut off the plant water supply when it detects an abnormally high flow of water, such as that caused by an inboard seal failure.

ROI payback periods for water management tank systems with double mechanical seals are typically 6 to 12 months, after which the tank systems continue to generate large savings for the remainder of their 10 to 20 year lifetimes.

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Maintenance and Steven Covey

The 7 Habits of Highly Effective Maintenance Organizations

by Paul Swatkowski

Through his books and audio programs, Steven Covey, author of The 7 Habits of Highly Effective People and other works, has been a great influence on me and many of my colleagues. Over the years I've noticed a direct correlation of the practices of successful maintenance organizations and Dr. Covey's seven habits. This article is based directly on Dr. Covey's seven habits. It is drawn habit-by-habit from his book but with the examples modified to fit the maintenance world.

Covey first published his book in 1990. More than 14 million copies have since been sold and it's been translated into over a dozen languages. In his book, Dr. Steven Covey breaks success in life down to the everyday practice of these seven habits:

Habit 1 – Be Proactive
Habit 2 – Begin with the end in mind
Habit 3 – Put first things first
Habit 4 – Seek Win/Win
Habit 5 – Seek first to understand, then to be understood
Habit 6 – Synergize
Habit 7 – Sharpen the Saw

These Habits not only apply to personal productivity, but to organizational productivity as well.

Each of these—and how they relate to maintenance organizations—are covered in detail in this article. Here is the "Seven Habits" story and how it can be applied to any Maintenance Organization:

In his teachings, Dr. Covey strongly encourages his students to go out and teach what they've learned as soon as possible after learning his material. There are three reasons for this. One, it reinforces the concepts for the person putting the teaching together. Next, it spreads these concepts to others who might not be familiar with them, and third, it's likely that many people hearing these ideas will be interested enough in what's taught to pursue their education in these matters more fully.

The above scenario is what Covey refers to as a "win/win," which is Habit 4. The idea is you don't stop here. Reading or listening to these concepts once is great, but for them to really become "Habits" one must revisit the material over and over again—i.e. buy the book. As more people in your maintenance department, and throughout your organization, adopt these habits, the culture will transform from the inside out. Reliability based maintenance, and all the benefits that come with it, can become a way of life.

Habit 1 – Be Proactive

Being proactive is the ability to control one's own environment, rather than have it control you. It's self determination. It's choice. It's the power to decide your response to stimulus, conditions, and circumstances.

The title of the first habit, and our frequent use of the same term in the maintenance and reliability field, is what originally drew my attention to the correlation between Dr. Covey's 7 Habits and successful maintenance organizations. Reactive maintenance organizations have a tendency to jump or react when a piece of equipment fails. Proactive organizations respond based on a predetermined strategy.

Embracing Habit 1 means you are in the driver's seat, and you can decide which actions to take.

Take Charge: In a ranked list of companies in any industry, there is one at the top and one at the bottom. Your organization is likely somewhere in-between. Companies move up that list when they realize that doing things the way they have always been done continually yields the same results. Organizations have the power to make the necessary changes to move up the ranks by choosing to take initiative, and embrace proactive change.

Realize That We Are Responsible: Being responsible is often viewed as being the person who should accept the blame when something goes wrong. Accepting that, we can then identify all the necessary things that should be done to ensure that things don't go wrong. In other words, create the steps for success.

Step Down the Path of the Effective Organization: The organizations at the top of that list we mentioned have come to these realizations. They've decided what works in their organization, and they have learned and reinforced the habits of doing it effectively.

Rule Your Equipment: When you are proactive you rule your equipment, it doesn't rule you. Successful organizations have found that the best way to do this is by moving up the F/PF (Failure/Potential Failure) Curve. That move is accomplished primarily through the use of predictive methodologies (PdM) and quantifiable PMs integrated with

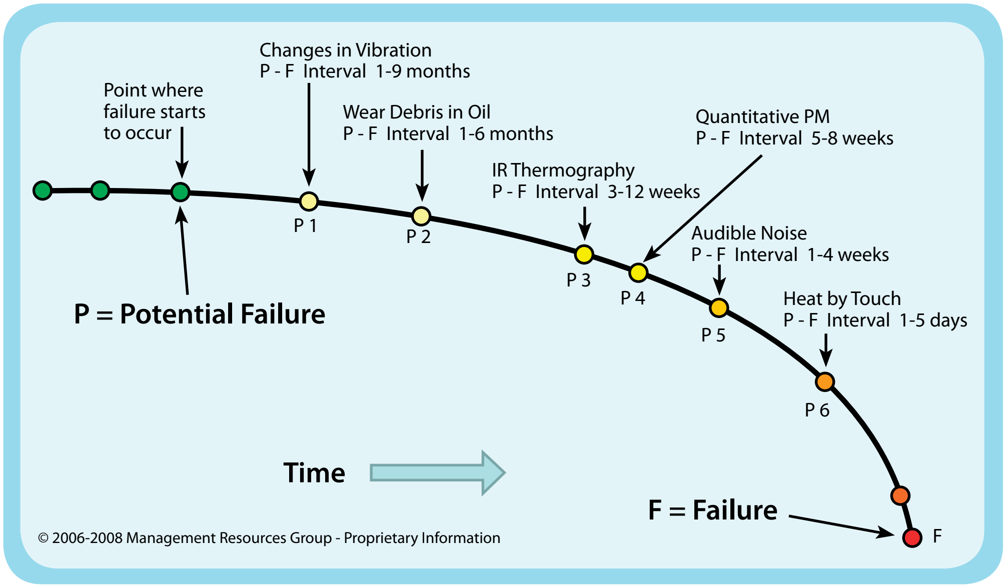

Figure 1 - Understanding the P-F Curve allows you and your organization to implement the 7 Habits of HIghly Effective Maintenance Organizations.

good Planning and Scheduling.

Decide to Make a Plan: Then, do it. Successful organizations design and build highly effective maintenance departments. You have the power! Deciding to make a plan segues us to Habit 2…

Habit 2 – Begin with the End in Mind

This is the habit of leadership—both personal and organizational—and leading yourself and the organization toward your goals. Dr. Covey professes that everything is created twice—once in the mental realm and then a second time in the physical realm. By first developing a clear mental vision of our desired results, we will be able to create the necessary steps to achieve that vision. Habit two is all about creating that vision.

Effective maintenance organizations have taken the time to create strategy plans for various aspects of their organizations. They make sure to include a good cross representation of the stakeholders in the formation of these plans. The output is always a document that can then be referred to and adhered to. Here are some areas in which strategy plans should be created and questions that should be asked:

Maintenance Strategy: Does a run-to-failure or a reactive strategy make sense to your organization? Do you want your jobs planned and scheduled in advance? Who in your organization should decide which equipment gets repaired first? What should the decision be based on—criticality of the equipment and job priority, or the squeaky wheel supervisor?

Reliability Strategy: Are you going to use predictive methodologies on all of your equipment to which it applies? Or, are you going to apply it only to certain systems? Will you use on-line monitoring, or route-based monitoring? Are quantitative PMs being utilized now, and if not, do you plan to apply the resources to scrub your PMs and make them better? Do you use/will you use reliability engineers?

Material Strategy: Will you have a lean storeroom, or a storeroom that never suffers stock outs? What will you base that decision on? Will you enter bill-of-material (BOM) data into your computerized maintenance management system (CMMS) ahead of time, or as you make entries for equipment as it's repaired? Who'll enter that data? What about kitting, or vendor managed inventories (VMI)?

Employee Strategy: Have you identified the skills your employees need to perform their jobs well? Do you know which employees have those skills and which don't? Are you going to hire for new skills, use contractors, or train your existing employees in the new skills they need? It's obvious that having the answers to these questions in advance, can head off major issues in the future.

In the graph shown in Figure 2, the top line is representative of companies that don't have an end in mind. They adopt reliability tools and strategies on an ad-hoc basis without ever reaping the synergistic benefits of a good reliability program. Without a plan, you're planning to fail. When you begin with the end in mind—an end that entails an efficient and effective maintenance organization, that utilizes its CMMS to the fullest, that plans and schedules jobs in advance, and engineers the root cause of failures out of their equipment—you will see the earliest rewards for your efforts and investments. Keep in mind, those rewards are not only financial as shown by the green line in the graph, but are also quality-of-life issues, i.e., no more calls in the middle of the night on a weekend. A well run Maintenance department should be boring.

Habit 3 – Put First Things First

This is the habit of personal management. But, it applies to organizations as well. It's about organizing and implementing activities in line with the aims established in Habit 2. If Habit 2 is the first, or mental creation of a vision, then Habit 3 is the second, or physical creation of that vision via the creation of, and adherence to, an organized implementation plan.

Having a documented plan allows important activities (urgent or not) to never be at the mercy of the unimportant activities (urgent or not).

The steps of a successful organization's implementation plan are determined through the assessment of their maintenance and reliability practices. This is usually best accomplished when done by an outside, or objective, set of eyes. The improvement steps resulting from these assessments include, but are not limited to, the following areas:

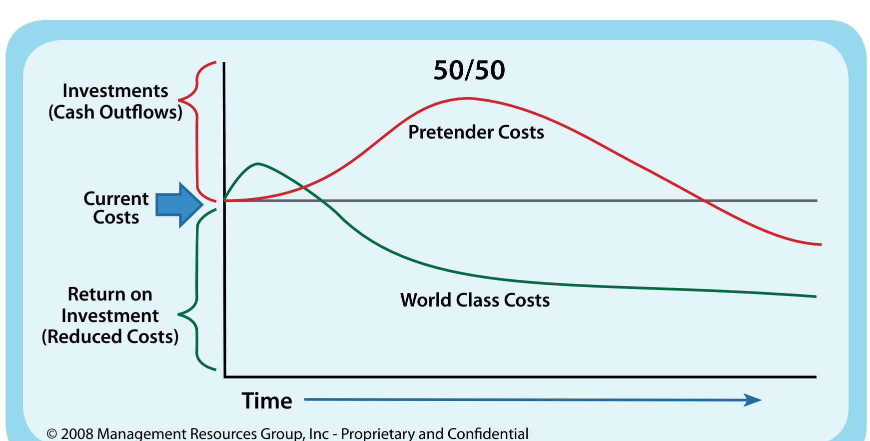

Figure 2 - Beginning with the end in mind reduces both costs and problems.

Business Processes:
- Instituting a cultural change management program
- Developing key performance indicators (KPIs)
- Developing workflows for all key processes

Foundational Elements:
- Verifying/scrubbing of the Master Equipment List (MEL)
- Criticality ranking of equipment

Inventory Strategy:
- Standardization of inventory content/ taxonomy
- BOM development
- Storeroom design & kitting integration
- Stock optimization

Reliability:
- Determination of PdM baseline
- Performance of RCM and FMEA on applicable systems and equipment
- Root Cause Failure Analysis (RCMA)
- Application of appropriate PdM
- PM development and/or optimization

Training:
- Skills needs analysis
- Skills assessments
- Training Plan & Schedule

Steps Should be included to ensure the plans are tracked, measured, adjusted if necessary, and adhered to.

Focus Efforts Where They Count: In Dr. Covey's words, "Is your ladder against the right wall?" I've often asked maintenance organizations, "If two pieces of equipment go down at the same time, and you only have one crew to repair them, which one do you send the crew to first? Some of the answers are amazing. There should be no hesitation. Crews should be assigned according to equipment criticality and job priority. Following the seven habits eliminates this dilemma because during Habit 2, such rules were constructed with input from the appropriate parties. Everyone is aware of the strategy, and is on the same page.

Using Dr. Covey's time management matrix, reproduced in Figure 3, allows us to identify where our time is being spent.

Quadrant I is where reactive organizations spend most of their time. Emergency breakdowns and fire fighting take place in Quadrant I. These are things that are usually both important and urgent.

Quadrant II is where activities that are impor-

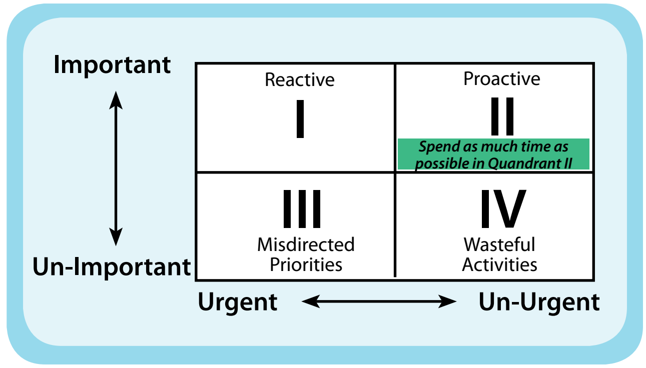

Figure 3 - Dr. Covey's Time Management Matrix

tant, but not urgent, take place. It's activities in this quadrant that keep us out of Quadrant I. Reactive organizations have not yet made this realization.

In our personal life, these are activities such as exercising, eating right, and going for medical and dental checkups. Maintenance-related Quadrant II activities include: equipment inspections, quantitative PMs, implementing and using predictive methodologies, creation of workflows, training to workflows, and entering foundational data into the Computerized Maintenance Management System (CMMS). By living in Quadrant II, we proactively head off the causes that have us work in Quadrant I. Remember, Quadrant I activities are more expensive because they are unplanned, and unplanned activities are always more expensive than planned activities.

Habit 4 – Think Win-Win

Dr. Covey calls this the habit of interpersonal leadership, necessary because achievements are largely dependent on cooperative efforts with others. He says that win-win is based on the assumption that there is plenty for everyone, and that success follows a cooperative approach more naturally than the confrontation of win/ lose situations.

When a successful organization finds a solution to a situation they always ask, "How is this going to affect the processes before and after this one?" If it's going to help one area but hurt another, then in the long run it's not going to work. All solutions have to help all the parties concerned. Some groups to consider: finance, purchasing, operations, marketing, human resources, employees, stockholders, the neighboring community, even the local business owner down the street. We're all on the same team.

An example of a win/win can be found in organizations that practice full integration between maintenance and operations. Communicating with operations to schedule planned maintenance activities within a reasonable timeframe allows both parties to better utilize their resources and adhere to their schedules.

Habit 5 – Seek First to Understand, Then to be Understood

One of the great maxims of the modern age, this is Covey's habit of communication, and it's extremely powerful. Covey helps to explain this in his simple analogy "diagnose before you prescribe", which is simple, effective, and essential for developing and maintaining positive relationships in all aspects. Habit 5 is about communication and listening to the customer—in this case operations, employees, and management.

What do they mean when they say no? In presentations, I've often used the story of a production supervisor who refused to let a maintenance department have a piece of equipment for as long as they said they needed it.

What did the supervisor really mean when he said they couldn't have the equipment for eight hours? Did he mean that if maintenance had the equipment for eight hours he wouldn't make his production for the month? Did he mean he believed the equipment may be down longer? Maybe he felt that if it was down eight hours he'd have to go over his overtime targets for the month. Did he mean he'd rather have the job done partially or incorrectly? It's possible that any or all of the first three may be true, but it's highly unlikely that he'd want the job done partially or incorrectly only to have it fail again later, especially if that meant he wouldn't make his targets under any possible recovery plan. Until we know what exactly his concerns are, how do we know how to find the win-win in that situation?

In dealing with any party, a highly effective maintenance organization should seek to find out what the concerns of the party are before formulating a response.

"If you want to interact effectively with me, to influence me, you first need to understand me" – Steven Covey

Habit 6 – Synergy

Covey says this is the habit of creative cooperation. The principle is that the whole is greater than the sum of its parts, which implicitly lays down the challenge to see the benefits and potential in another person's contribution.

In our example earlier, operations didn't want to have the machine down at all, and maintenance felt they needed it for a full eight hours to repair the equipment properly. What if they compromised and agreed to repairing the equipment in four hours? In that case, neither party would get what they wanted. In reality, that's a lose-lose situation, the worst of the four possible outcomes in Habit 4.

Compromise should be a red flag that things aren't right. Instead, to find the win-win, one must proactively seek first to understand what it is that operations really needs. It might turn out that it's just not a good time for the equipment to be down. It's possible that it wasn't a good time for maintenance either. Maybe maintenance needed eight hours because the welder was out, or a necessary part wasn't in-house, so a part would have to be fabricated. During the conversation, it may be discovered that a combination of a temporary repair and a reduced load would allow operations to get their production out and allow maintenance to order the part and align all the necessary resources to fix the job right.

Now, instead of a lose-lose, there is a win-win. Seeking to understand the other group's needs is key in establishing trust between departments. Some common activities during which synergy takes place in highly successful organizations are: Reliability Centered Maintenance Analysis (RCMA) sessions, Root Cause Failure Analysis (RCFA), Criticality Ranking sessions, and through Planner's reviews of feedback forms completed by craftsmen at the close of Planned Maintenance activities.

Habit 7 – Sharpen the Saw

Habit 7 is the law of continuous improvement. It's about personal development and the development of personnel. We read articles like this one and attend seminars and conferences because we want to develop our skills, and that's very admirable. Part of our employee strategy mentioned in Habit 2 may revolve around training or Sharpening the Saw. Effective organizations recognize that employees can't be held responsible to do something in a certain way, if they haven't been properly trained. They commonly use workflows as the preferred method of mapping out organizational activities that can then be easily followed and adhered to. They also recognize that precision maintenance skills and predictive maintenance skills are not always skills craftspeople bring to the company with them.

When companies proactively train personnel, they must first establish the end goal. For example, an end goal might be for employees to perform the tasks as outlined in the job plans. Some necessary first steps would be to find out what skills are needed to accomplish that and what skills they already possess. Doing so allows for targeted training, which is less expensive than blanket training and is also more palatable to the student—another win/win. Learning additional skills often leads to job enhancement, which usually leads to job enrichment for the employee.

Conclusion

This is an extremely high overview of the 7 Habits and how they apply to successful maintenance organizations. Dr. Covey is listed as one of Time Magazine's 25 Most Influential People for good reason. Practicing the 7 Habits has increased the productivity and quality of life of countless people. Read and re-read these 7 Habits looking for more ways in which they can apply in your life and in your organization. Research the topic more by reading or listening to the original works by Dr. Steven Covey or by contacting the author of this article.

Paul Swatkowski, CMRP, is a management/training consultant with 29 years of manufacturing, processing, and consulting experience. Paul has a background as a Trainer at United Technologies' Corporate University, and worked as a Quality Manager and Quality Engineer in the Aviation Industry. He has extensive experience which includes world-wide delivery of; Corporate Gap Analysis Assessments, Total Productive Manufacturing, One Piece Flow, Kanban, 5S-Space consolidation, Value Stream Mapping, Root Cause Analysis, Mistake Proofing, Lean Manufacturing, Inventory Reduction, Reliability Centered Maintenance Analysis, Failure Modes & Effects Analysis, Workflow Development, and Maintenance Planning and Scheduling. A proven problem solver, Paul is highly effective at conveying the necessary information to foster change. He defines, develops, and delivers world-class training in maintenance and reliability best-practices to external MRG customers as well as internal employees. Paul has direct hands-on experience with instructional design methods and has led delivery of over 100 formal customer training courses in both on-site and public venues internationally. He can be reached at SwatkowskiP@MRGinc.net

Tools For The Trade

Diagnosing Rotor Bar Issues with Torque and Current Signature Analysis

by Drew Norman

Over the years rotor bar problems have been a diagnostic challenge for motor maintenance professionals. Now with current signature, spectral torque analysis and automated computer diagnostic software, defining rotor health problems has been made fairly simple. However, problems arise when professionals do not understand the underlying principles of the what's, whys and how's of dynamic rotor testing.

Professionals who maintain motors need to be able to answer the following questions. How can an instrument 100 to 1,000 feet or more away from the motor provide information about the condition of the rotor? What is going on within the motor to produce the peaks and ripples that we see with our instruments? What defines the frequencies of the peaks and causes the amplitude to increase as the rotor bars break? And finally, how do we interpret those signals to make proactive decisions about motor repair scheduling?

In this article we will present the following:

- A conceptual explanation of rotor construction and operation
- An explanation of the effect of a broken rotor bar on this operation
- A review of several techniques for rotor condition analysis
- An explanation of the calculations and where to find the faults frequencies in the spectrum

Maintenance Professional's Challenge with Rotor Bar Analysis

There are several challenges when trying to analyze rotor health with vibration analysis. It is necessary to know the number of rotor bars to identify the frequency of interest in the vibration spectrum. This knowledge is often difficult to obtain without disassembly of the motor. Incipient rotor bar problems in some motors will not contribute significantly to overall vibration. Even though the effect on torque and current is evident, the contribution to vibration is not large enough to be definitive. Contributions to 2x Line frequency and 2x and 4x running speed can be difficult to distinguish, especially in 2-pole motors. The 2x line frequency can have contributions from eccentricity, rotor bar issues, as well as voltage and current imbalance. Distinguishing which forcing frequency is responsible for the amplitude increase at this frequency can be nearly impossible with vibration analysis alone. The analysis methods described in this article will alleviate questionable readings and unclear diagnostics from vibration data.

Rotor Construction & Operation

In its simplest form a three-phase induction motor is comprised of a stator and a rotor. The purpose of the stator is to develop the rotating magnetic field. The stator field induces a voltage into the rotor cage. The rotor cage is made up of parallel conductors shorted together on each end by a shorting ring. This shorting ring is used to complete the circuit and allow current to flow through the rotor bars. Current flow through the rotor bars develops the rotor field. The field of the stator and the generated field in the rotor interact to produce torque.

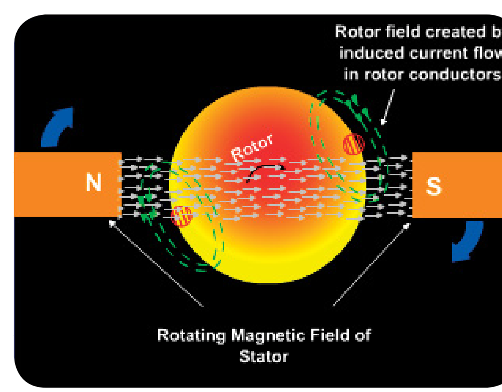

Figure 1 - Stator operation illustration

At startup, the rotor is stationary and the difference in speed between the rotating field and the rotor bars is at its maximum or what is identified as "slip". Slip is defined by the equation:

$$S = \frac{RPM_{synch.} - RPM_{operat.}}{RPM_{synch.}}$$

Figure 2 - Formula to calculate Slip

As the torque is produced, the rotor begins to speed up. The difference in speed is reduced as the rotor speed approaches synchronous speed. In fact, the relative motion between the rotor and stator of an operating motor can vary from 1 to approximately 200 RPM,

$$\text{As slip} \uparrow \rightarrow V_{rtr} \uparrow \rightarrow I_{rtr} \uparrow \rightarrow \text{Torque}_{rtr} \uparrow \rightarrow \text{Speed}_{rtr} \uparrow \rightarrow \text{Slip} \downarrow$$

Figure 3 - Definition of slip

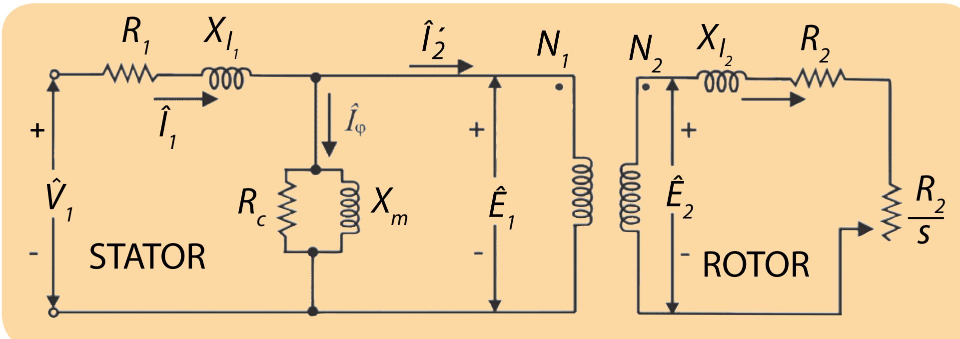

Figure 4 - Equivalent Circuit Drawing

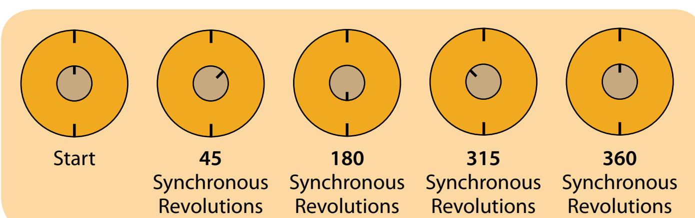

Figure 5 - Synchronous Revolutions

and from no load to full load respectively. These RPM values vary widely from motor design to design.

As the difference in speed between the rotor and the stator begins to decrease, the voltage generated in the rotor is reduced. The resultant current flow will be reduced to some steady state value that is required to maintain steady state torque. During steady state operation of the motor, the torque generated by the motor is equal to the torque being demanded by the load. Changes in load will affect the speed.

For a load increase, the torque demand of the load becomes greater than the torque being supplied by the rotor. This causes the rotor speed to slow and therefore, slip will increase.

Torque will continue to increase at a slower and slower rate until the torque of the rotor is again equal to the torque of the load. As the rotor current increases this causes the stator current to increase during the transient condition until the stator current levels out at its new higher steady state value.

It is important to understand that the motor is, essentially, a transformer with a rotating secondary. As the simplified circuit drawing (Figure 4) illustrates, any current consumed in the rotor will be seen as a load on the primary side of the circuit, which is the stator winding.

With this load current relationship of primary to secondary current, any changes in the rotor current will also be present in the stator current. By monitoring the stator current the effects from the rotor imbedded in the stator signals is seen. Industry software applies the complex algorithms necessary to make these signals more meaningful for analysis.

Before understanding how rotor bar analysis works, it is important to understand how the rotor works with the stator, and the effect a broken rotor bar has on the system. In this explanation some very complex interactions will be generalized to allow for conceptual understanding.

Consider a two-pole motor operating at 60Hz and at some steady state load condition. The field developed in the stator will make one revolution every 1/60th of a second (3600RPM). The rotor is rotating at a speed slightly slower than the synchronous field. Let's say it is rotating at 3590RPM and makes one complete revolution every 1/59.83 of a second. This means that the rotor will slip behind the stator field by one degree for every revolution of the stator field, as seen in Figure 5.

Think of two race cars on a circle track. How many laps does it take for the faster car driven by Steven Synchronous (Stator Field) to over take the slower car driven by Larry Lagging (Rotor)? Well, t will take the Steven Synchronous 360 laps or revolutions to overtake Larry Lagging. It will take the synchronous field six seconds to lap the slower rotor. During this overtake process the point on the rotor will pass under the south and the north magnetic pole, represented by the dashed lines at 6 and 12 o'clock respectively. The calculation of the pulsation frequency associated with bar passing under the poles is:

$$f_{rotorbar} - f_{fund.} * (1-2*s)$$

$$\textbf{Slip} \quad S = \frac{RPM_{synch.} - RPM_{operat.}}{RPM_{synch.}}$$

Figure 6 - Calculations of pulsation frequency associated with rotor bar pass.

In our example, slip is (3600-3590)/3600 and equals .00278. The frequency of any given point passing the poles would be 60Hz x (1-2(.00278)) or 59.667Hz.

The Rotor Bar Effect on the Lower Sideband Amplitude

When a broken bar is present within the rotor, current cannot flow through it, and therefore, it can no longer add its share of torque to the rotors load burden. As the broken bar passes under the pole it will effectively reduce the torque of the rotor for the period of time it is under the field pole, in its torque producing position. Since the torque of the rotor is reduced slip is again introduced. As the rotor slows and the slip is increased, the voltage induced into the rotor is also increased, and therefore, the current in the good rotor bars will have to increase to produce the needed torque. This continues until the torque of the motor is restored to equal the torque of the load. When the broken bar is in a position where its contribution is not relied upon (traveling parallel to the lines of flux), the torque of the motor will go up and the opposite effect will be true. The beating frequency at which this occurs is defined in the equation in Figure 6. This analysis method is referred to in several ways - lower side band analysis, pole pass frequency sideband analysis, rotor bar signature analysis, as well

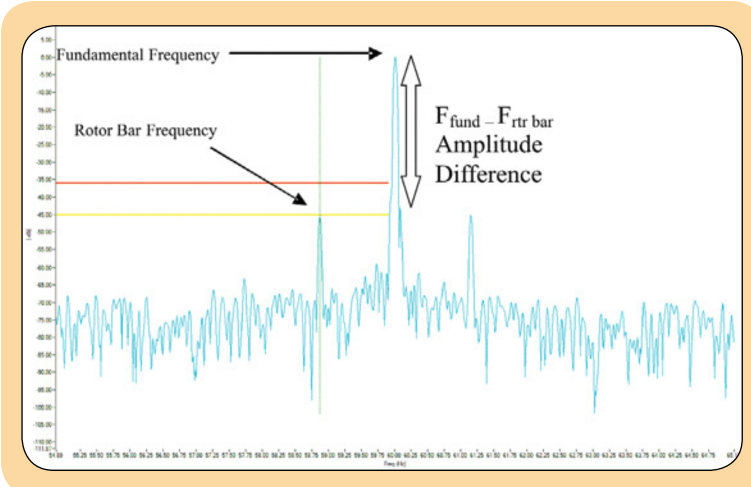

Figure 7 - Frequency Amplitude Difference

as a few others. Regardless of the name, the current spectrum surrounding the fundamental frequency is closely examined (see Figure 7) for the relative amplitude difference between the fundamental and what is referred to as the rotor bar sideband frequency ($F_{rotor\text{-}bar}$). The amplitude increase at the $F_{rotorbar}$ is due to the added current drawn in the rotor and also from the stator as the good bars attempt to make up for the one defective bar.

As the amplitude increases at the rotor sideband frequency, the amplitude difference between the fundamental frequency, and the rotor bar frequency will go down. As the rotor bars break, and the health of the rotor continues to decline, this difference will also decline over time as the sideband frequency becomes more and more dominant in the signal.

Torque Spectrum Analysis

The acquisition of torque ripple and the analysis of the torque spectrum is a relatively new addition in the realm of condition based maintenance technology. By capturing the real components of the current and deriving the flux generated from voltage, a signal equal to air gap torque is developed. Mechanical information buried in a complex modulated current signal can now be easily accessed and interpreted for electrical and mechanical conditions. Mechanical conditions such as faulty bearings, pump cavitations, loose fan belts and even oil whirl have been successfully diagnosed with torque spectrum analysis. Analyzing the torque spectrum is also an effective tool for analyzing rotor bar health. In fact, there are four frequencies of interest that can be used in this regard. Since the torque spectrum is not electrically modulated like the current spectrum, it is not necessary to perform sideband analysis around the fundamental frequency. Instead, the spectrum is analyzed in the same way as a vibration spectrum. Look for frequencies that naturally occur due to the forces that generate them. This is much more intuitive and natural than current spectrum analysis.

The frequencies of interest are:

1. **Slip Frequency –** The difference between synchronous and rotor speed.
2. **Rotational Frequency –** The speed of the rotor.

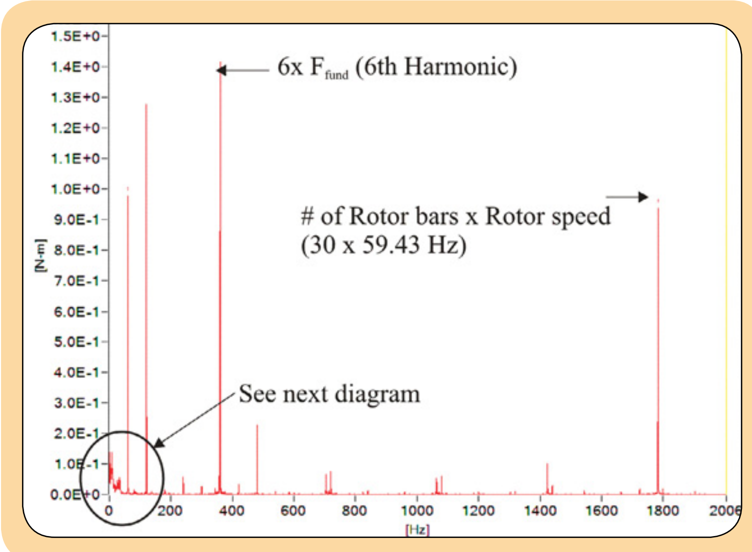

Figure 8 - Frequency Spectra Diagram

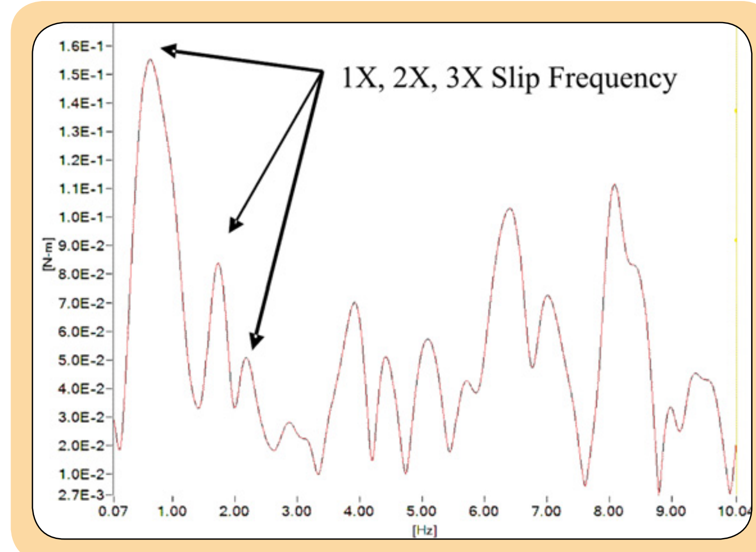

Figure 9 - Expanded Spectra Diagram

3. **6x Fundamental Frequency –** The 6th harmonic of the fundamental.
4. **Rotor Bar Passing Frequency –** The # of rotor bars x Rotational Frequency

Each of these frequencies is identified in the spectra shown in Figures 8 and 9.

Torque Spectrum

A Torque Spectrum Showing Slip Frequency Peak and Two Multiples is shown in Figure 10. The running speed peak for a two pole motor is very close to the fundamental frequency. For this reason increased load and/or increased spectral resolution is required for an accurate analysis (see Figure 10).

Spectrum Analysis of Individual Phase Currents

Analysis of the phase current in the spectrum domain reveals additional peaks of interest apart from the sideband frequencies discussed earlier. Because there is a natural 6x turning speed peak in the torque, there will be a 5th and 7th harmonics present in

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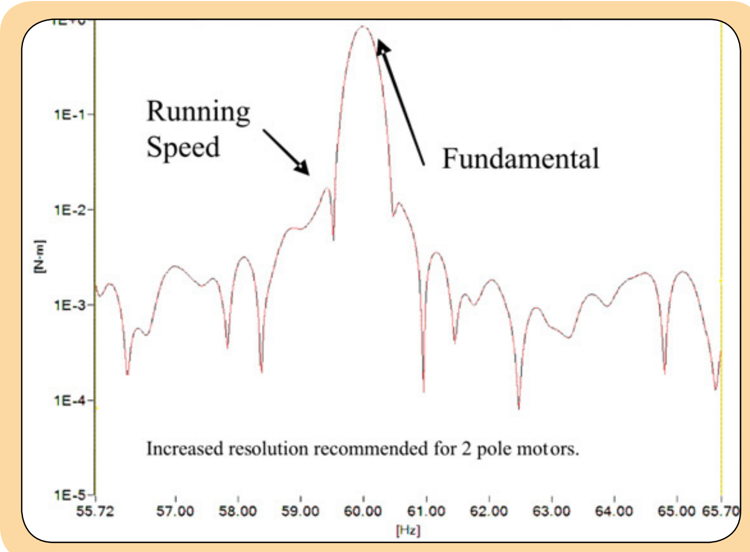

Figure 10 - Increased Resolution for 2-Pole Motors

criticality. The presence of broken bars will cause an increase in overall motor losses and a decrease in motor efficiency. The additional heat generated from the added current will also further increase the rate of insulation degradation in the stator. Taking routine data on your motors, analyzing that data as described above and trending this data over time will allow you the confidence to "make the right the call".

Drew Norman is currently working with Baker Instrument Company, an SKF Group company performing product training in the US and Canada. He worked with General Electric for eight years in a variety of roles including predictive maintenance technician, motor generator specialist and shop operations manager at the Tucson Service Center. He has also worked in the pulp and paper industry as an Equipment Management Program Coordinator, as well as trained and served in the US Navy as a Journeyman Electrician and Nuclear Operator.

the current spectrum. This offset from the 6th harmonic is due to the natural modulation in the current signal. The presence of significant 5th and 7th harmonics, coupled with pole pass frequency sidebands, will indicate the presence of a rotor bar defect as shown in Figure 11. The data imbedded in the modulation signals surrounding the fundamental is valuable, but can be difficult to analyze. Demodulation of the current is a complex method that can be used to make these signals more meaningful. Unfortunately, the demodulation method is typically limited in how far away from the fundamental it can calculate.

Summing it all up

Today many instruments incorporate the use of computer algorithms to automatically identify the frequency peaks of interest and the amplitudes of these peaks to aid in analysis. What appears to be a very challenging task becomes quite simple with the aid of industrial designed software. Of the various methods put forth in this article, no single test will definitively prove the presence of a rotor bar defect. Understanding why these peaks are where they are, and what is actually causing the increases in amplitude, allows us to better analyze the condition of our machines. The use of these methods will also provide additional clarity to the vibration data. Luckily, very few rotor bar defects lead to catastrophic motor failure. All of the data analysis methods described in this article have trendable indicators. Trend the relative amplitudes for motors, compare these results to other motors of the same design, and make a educated decision that is practical concerning motor

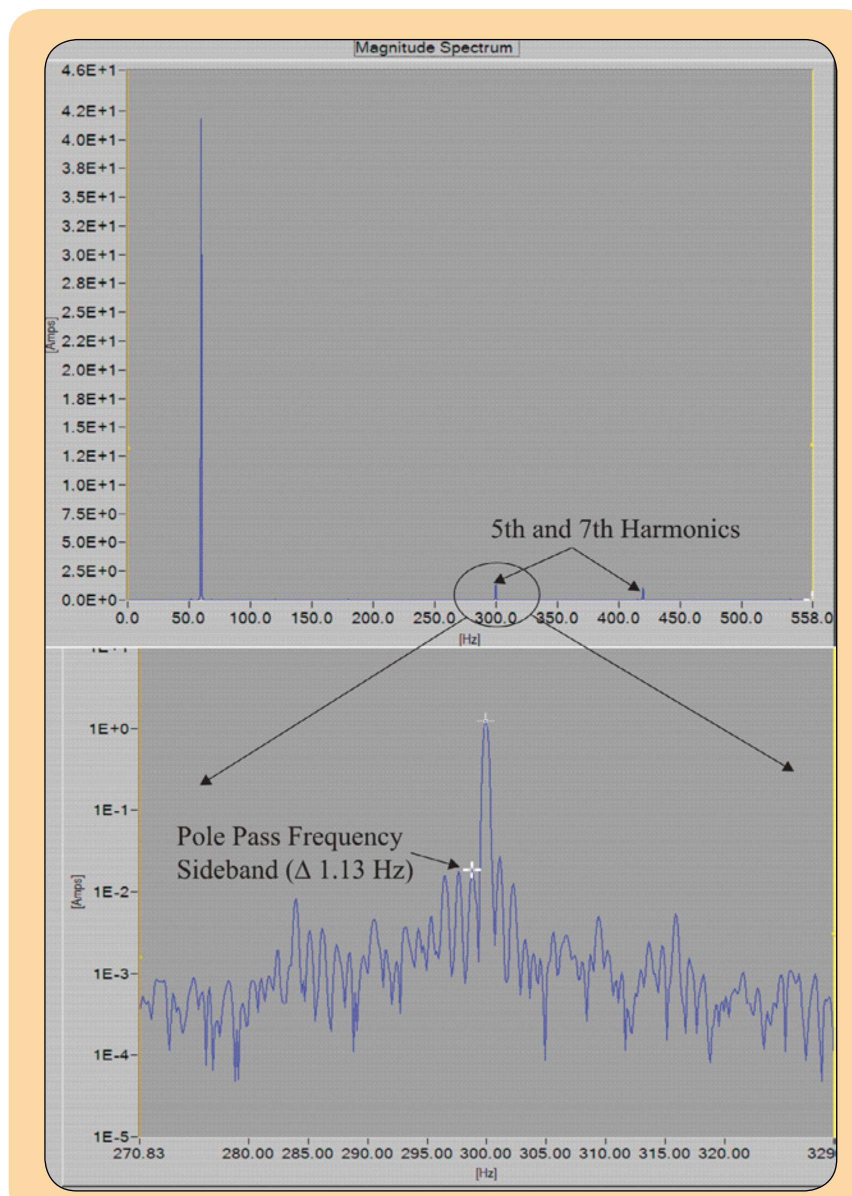

Figure 11 - Pole Pass Frequency Sideband

Don't Get Even, Get M.A.D.

Making the Decision to Make A Difference

by Phillip Slater

The impact of the Global Financial Crisis is being felt far and wide. Millions have lost their jobs, production has been cut, shifts dropped, overtime cancelled and budgets slashed. In this environment it is easy to see how people get frustrated and angry. Angry that they lost their jobs through no fault of their own; angry that their colleagues have been let go; angry that they are left to do the work without the manpower that's really required; angry that their carefully thought out plans are cancelled due to a sudden lack of funding; angry that they are expected to produce results without adequate resources.

One response to this situation is to get even. That is, stay angry, blame the world, work slowly, become mediocre, give up, stop striving for benchmarks, and stop caring. And this is understandable, when it feels like your family, friends and colleagues have been attacked as the result of some Wall Street hubris. But getting even is a vicious cycle. If things are bad, getting angry and not caring can only make things worse.

A wise man once said, "It's not what happens to you that counts, it's how you respond." With the Global Financial Crisis, rather than getting even, a better response is to get M.A.D. That is, to Make A Difference. In fact, this is exactly what is required now as we work our way out of the current financial mess. While our hearts go out to those families, friends and colleagues that have lost their jobs, the rest of us must now work to ensure that they have something to return to. We are, in effect, the guardians of the future employment of our families, friends, colleagues, and especially our kids.

Like many activities in management, maintenance and engineering, Making A Difference is simple but not easy. It requires action and courage. It requires us to look forward and demonstrate leadership. It requires your involvement and commitment.

To help you get started, let's go over five key elements for Making A Difference:

1. Be Optimistic
2. Think Long Term
3. Expand Your Sphere of Influence
4. Be Active Not Passive
5. Demonstrate Leadership

Be Optimistic

OK, so we all know that things have been pretty bad. The credit crunch has led to the near collapse of many industries and governments all over the world have been injecting many hundreds of billions of dollars into economies through stimulus packages. But there is one thing of which I am certain, and that is that we will recover.

Optimism is defined[1] as 'a tendency to look on the favorable side of events and to expect the most favorable outcome' and if you want to Make A Difference then you need to be optimistic. Winston Churchill, the famous British war time Prime Minister, said, 'For myself, I am an optimist, it doesn't seem to be much use being anything else' and I agree with him. You don't need to be optimistic in a Pollyanna[2] way, but you do need to 'expect the most favorable outcome'. If you are going to get M.A.D, then you need to be motivated and there is nothing less motivating than the gloom and doom of the pessimist.

So, what is the basis of my optimism? Let's look at Figure 1 on the following page. This chart shows the annual change in the growth in world trade between 1970 and 2009 and has several notable attributes.

Firstly, all the pessimists will notice that the dip in 2009 is the lowest point in nearly 30 years – by a long way. But we already knew that. The interesting thing is that there are three other major dips – 1975, 1982, and 2001- and each is followed by periods of growth. The boom times that we have been enjoying for the past seven or eight years were preceded by the lowest growth for nearly 20 years. Another interesting point is that the chart continually goes up and down, there is a cycle at work here.

My conclusion: times are tough, but they will get better.

In preparation for that recovery we need to start Making A Difference right now and that starts with being optimistic, not pessimistic or complacent.

Think Long Term

Obviously the recovery won't happen tomorrow, and even if it did, we probably wouldn't recognize it for a number of months (maybe it's already started!). This means that we need to think long term. In any case with no budget or resources, it may be hard to have a short term impact. So, you may not be able to get that new CMMS or vibration unit or inventory software. But what

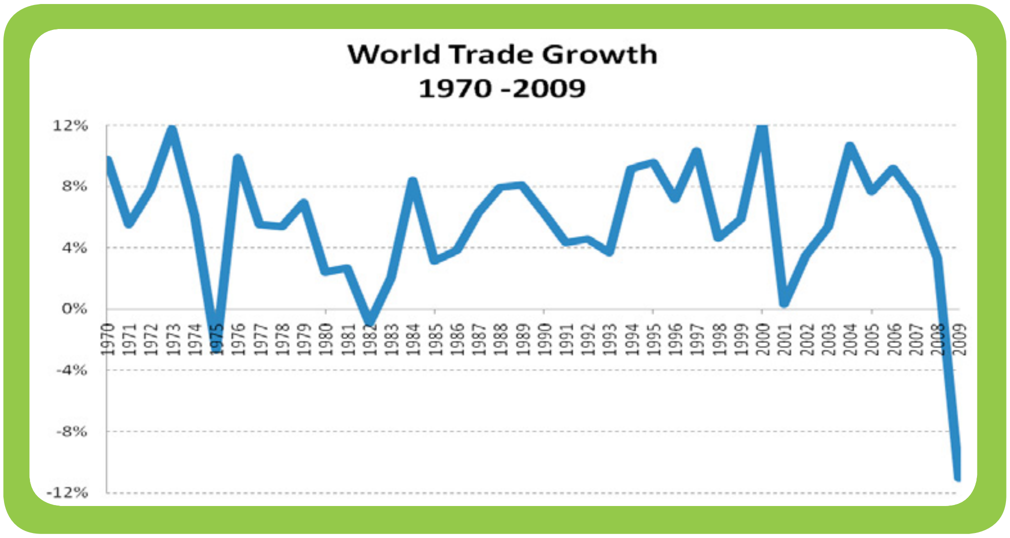

Figure 1 - World Trade Growth Chart[3]

can you do? What is your plan B to improve your operational results?

Thinking long term gives us a sense of purpose, it gives us something to work towards, one step at a time. During a downturn it's about working on those things that we can influence without money – culture, systems, procedures, measures, reporting and the discipline of application.

Many people have been quoted as saying 'why waste a good recession?' (I'm not sure who said it first) and it's hard to argue with that sentiment. The best time to change is when change is happening anyway, and that is right now.

To Make A Difference think long term, and look at the small things that you can change in the way you and your company go about things.

For example, in the area of engineering spares management, here are a few 'small things' that you can do to make a difference:

- Ensure that the storeroom locations are labeled so the items can be found.
- Ensure that items are labeled and segregated so that they can be identified.
- Work on ensuring that records are maintained accurately so that they can be managed with some degree of science.
- Identify your spares categories (e.g. critical spares) so that everyone knows which ones are important.
- Review your policies and procedures; are they still relevant and are they actually followed?
- Review the maintenance of your spares – will they perform when you need them?

Sure, these actions need time and energy but they don't need much money. Better still, they can be worked on a little bit at a time. None of these actions require a major project if you are prepared to do the work gradually. What they do need is some focus.

Expand Your Sphere of Influence

Now I can hear the gloom and doom merchants saying 'I am just one person, what can I do?' What you can do is expand your sphere of influence. Henry Ford is reported to have said 'if you think you can do something or you think you can't, in either case you're probably right' so expanding your sphere of influence starts with you believing that you can do it. Let's break that down.

Influence can be defined[4] as 'the capacity of power of a person to be a compelling force on or produce effects on the actions, behavior and opinions of others'. Your sphere of influence is how far your influence stretches beyond yourself. This is shown diagrammatically in Figure 2.

While this figure shows concentric circles you can think of your sphere of influence as a bubble all around you. Think above, below, beside, in front, behind. Who do you influence? Your peers, your department, your company, your industry, and, of course, yourself.

As a starting point, you influence your own behavior. You decide if you want to Make A Difference and how you will go about it. Next you should be looking at how to stretch that sphere to other areas. And remember that influence can be positive or negative but if you are optimistic and thinking long term then your influence needs to be positive.

Some people have influence as a result of their position. Presidents, CEOs, VPs all have influence because of their organizational roles but that is not the sort of influence that I am talking about. I am talking about behavior and actions. You see, people love to mimic other people's actions, but most of us don't realize it. So, if you consistently do the right thing others will notice and you will influence their behavior. If you consistently put up good, positive ideas people will start coming to you for good, positive ideas. It's that simple.

There are plenty of high profile examples of people that have exerted influence way beyond their organizational roles. Think of Gandhi peacefully protesting against the British in India. Think of Erin Brockovich bringing a chemical company to account in the US. Think of Joanna Lumley influencing the British Parliament to change its immigration laws. But there are many, many more examples of people influencing your industry, your company, your department and right now, you – you just may not have recognized them.

Stop and think right now about things that have changed around you. They could be

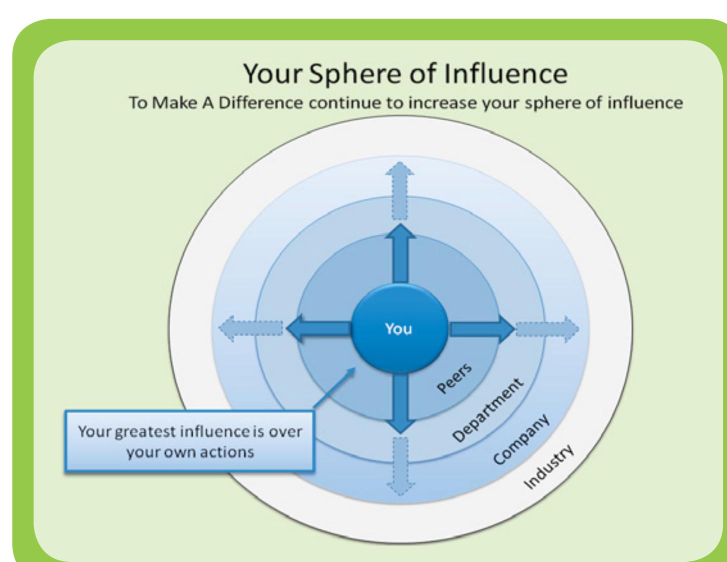

Figure 2 - Your Sphere of Influence


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health and safety initiatives that have saved lives or minimized injuries. They could be maintenance activities that have saved downtime and improved profitability. They could be spares management initiatives that have improved spares performance and saved millions in working capital. They could be any number of things. The key is that each of them will have started with one person asking 'how can I get this done better' and then influencing others to that way of thinking.

Be Active not Passive

Too often people understand all the theory and ideas, they agree with the sentiment, they agree that something should be done and then they wait for someone else to do it. Making A Difference is all about being active, not passive.

By now, I am sure that you can see that if you are optimistic, thinking long term and expanding your sphere of influence then you need to be doing something. This means being vocal, talking with your peers, contributing in meetings, doing the research, getting the numbers together – whatever needs to be done.

It also means having the courage to be vocal with nay sayers and doom merchants. It means catching people doing the right thing and encouraging them further. It means correcting the people doing the wrong thing rather than just talking behind their backs or muttering as they walk away.

One of my favorite quotes is from George Bernhard Shaw who said 'The reasonable man shapes himself to the world around him; the unreasonable man shapes the world to suit his needs. All progress therefore relies on the unreasonable man.' So, yes, sometimes being active and Making A Difference means being unreasonable. And, yes, sometimes being unreasonable means being the odd man out. But maybe that's the whole idea of Making A Difference, if you are doing the same as everyone else then are you really changing things?

People that make a difference do so by being active, not passive. So don't just sit there, do something!

Demonstrate Leadership

All of the above actions really are the actions of a leader, so Making A Difference is all about leadership. Not the leadership that comes from a position on an organization chart but the kind of leadership that comes from a person doing the right thing, showing the way forward, guiding and directing. Much of this is the informal leadership that comes from what you do rather than who you are. Perhaps John Quincy Adams said it best when he said, 'If your actions inspire others to dream more, learn more, do more, and become more, you are a leader'.

Conclusion

The Global Financial Crisis has given many people a reason to complain, after all, the circumstances were not of their making. But we have a choice to make about the way we respond to those circumstances. We can take revenge by being resigned to our 'fate' or we can take fate into our own hands and do something to influence our outcomes. Follow the advice of American entrepreneur, Jimmy Dean who said, 'I can't change the direction of the wind but I can adjust my sails to always reach my destination.'

Ultimately the choice is yours: how will you 'adjust your sails?' Do you want to get even or do you want to get M.A.D?

Phillip Slater is a Materials and Engineering Spares Management Specialist and the developer of Inventory Process Optimization™. He is the author of a number of management books, including Smart Inventory Solutions, A New Strategy for Continuous Improvement and The Optimization Trap. Phillip utilizes the expertise and experiences built up through nearly 25 years involvement in maintenance and operations management to assist select clients achieve significant improvements in operations management and inventory optimization. Contact Phillip directly at pslater@InitiateAction.com or visit the website www.InitiateAction.com

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Don't Work Harder, Work Smarter

Making Operational Excellence a Reality

by Mike Bresko

Has your company struggled to sustain its Lean, Six Sigma, or other initiative? Even if the initiative appears successful, does a closer look reveal that standard work is often not followed, front-line supervisors don't exhibit the behaviors required to sustain the improvements, and the culture hasn't really changed? This article aims squarely at understanding the root cause of these problems, and providing a solution that builds a culture of ongoing operational excellence.

Competition is fierce, especially during these challenging economic times, and companies have to improve performance of their processes.

Most companies adopt, or attempt to adopt, methods such as Lean Manufacturing, Six Sigma, Total Quality Management, Total Productive Maintenance, and a host of others. Unfortunately, studies show a poor record of success of sustaining reliable operations. Often, serious backsliding occurs. Or, if the implementation appears successful, a deeper look reveals that employees don't always follow standard work, supervisors don't know how to reinforce standard routines, and managers seem to prefer to move onto the next initiative. The forces against sustaining process improvements are strong and relentless. The result is cost and quality well below process potential.

This article describes the Work-Harder Syndrome, the root cause of backsliding. It then introduces the Pathway to Operational Excellence and the Business System; which together can create quantum-leap improvement in key operating parameters, assure quality and productivity daily, enhance the capabilities of front-line supervision and associates, and build a culture of operational excellence.

The Importance of Process Improvement

All industries are under intense financial pressure right now. Press releases frequently announce red ink, bankruptcies, and industry consolidation. Which companies will survive? Will the survivors' return on shareholders' equity actually exceed the return from a money market fund?

Today, perhaps more than ever, companies must improve safety, reduce total cost, meet shorter delivery cycles, and meet more stringent quality requirements. Even the more-competitive companies must improve. As Will Rogers said, "Even if you are on the right track, you'll eventually get run over if you sit there."

In today's economic environment, companies adopt various approaches to balance the books. One approach is to downsize via slashing headcount, divesting non-strategic assets and closing plants. A second approach hopes to achieve cost and competitiveness improvement via merging or acquiring. A third approach is to become more competitive by improving the efficiency and effectiveness of the company's processes.

While each approach has its place, the one that most improves a company's ability to compete is the third – improving the company's processes. Why is this? First, a company that operates its processes most efficiently has a clear advantage. For example, Southwest Airlines has simplified its processes for maintenance, spare parts management, training, and gate turnaround, allowing it to earn money while its competitors lose billions of dollars. Second, a company that has well-managed and understood processes can transfer its production and maintenance knowledge quickly to companies that it might acquire. For example, Alcoa applies its Business System to companies that it acquires to quickly improve their performance. Third, the downsizing approach is, at best, an effort to retrench. It buys time, and may even stop the red ink, but it doesn't fundamentally strengthen the company.

The Challenge

Management of operating, maintenance, and office processes to achieve world-class levels of excellence is the best way for companies to compete. Recognizing this, many companies embark on various process improvement initiatives. They adopt methods such as Business Process Re-engineering, Total Quality Management (TQM), Small Group Activities, Total Productive Maintenance (TPM), Lean Manufacturing, Six Sigma, Open Book Management, Enterprise Resource Planning, Computerized Maintenance Management Systems, and a host of others.

As previously mentioned, there is a poor record of success. An Arthur D. Little survey indicated that only one-third of managers felt that their programs had any competitive impact. A McKinsey study found that two-thirds of corporate improvement programs grind to a halt because they failed to produce the hoped-for results. Research at MIT by Nelson P. Repenning and John D. Sterman discovered that despite spending nearly $100 billion during 1997 on implementing these types of methods, and notwithstanding dramatic success in a few companies, efforts to implement such methods generally failed to produce significant results.[1, 2]

It seems that research now proves what people in many, maybe most, companies have experienced. Each new method that comes around will soon pass – it's just the flavor of the month. Many employees think that if they just keep their heads down and do what they've been doing, they'll be all right – this too will pass.

There are problems with this type of thinking. First, if companies keep doing what they've been doing, they'll get what they've been getting – and that is insufficient in this competitive environment. Second, it is wrong. Although it is true that many companies fail to achieve expected results, a number of careful studies now demonstrate that companies making a serious commitment to the disciplines and methods associated with what we call Sustained Reliable Operations, outperform their competitors.[2, 3]

Companies have at their disposal a host of methods that will improve performance. However, performance doesn't improve. What is happening? Repenning and Sterman conclude that the ability to learn about these methods is not a barrier. There are a number of books, articles, and consultants available to help companies understand any of these methods. People in companies know what to do; they just can't get it done. Or, if they can get it done, they can't get it to last. The challenge is implementing these methods to create lasting improvement.

The Root of the Challenge – The Work Harder Syndrome

Why are methods to improve performance so difficult to implement; and why, if implemented, are the results so difficult to sustain? Solve this problem and unlock the key to sustainable competitive advantage.

Performance of a process depends on two factors: time spent working and the capability of the process to do that work. Process output can be improved by dedicating additional effort to work or to improvement — work harder or work smarter. Working harder produces immediate results; however, learning to work smarter produces the more sustainable improvement in output, and increases the capability of that process to produce higher output into the future. Working smarter requires time to study the process, understand problems, and implement changes. Studies show that achieving results on improving a relatively simple process, such as the yield of machines in a job shop, is on the order of a few months, while improving complex processes such as product development can take several years.[4]

Working harder to achieve the same improvement in output requires cutting back on planned maintenance, training, and other activities. Working harder actually causes capability to slowly deteriorate. Given competitive pressures and the need for quick results, pressure to work harder is immense, leaving little or no time to invest in working smarter.

How Successful Companies Beat the Challenge

As we noted above, the forces working against successful process improvement are strong and relentless. Still, some companies have produced dramatic results. How?

To combat these forces, successful companies must have equally strong countermeasures. Our study indicates that successful companies have a system. Let's consider two companies that are voted among the most highly admired in business:

- GE's Annual Report states that GE's Operating System is its learning culture – in essence the operating software of the company. Although GE is famous for Six Sigma, what most people don't realize is that the rest of the operating system was a key ingredient for the success of Six Sigma at GE is.
- Toyota's well-known Toyota Production System is the benchmark for manufacturing operations. It includes tools such as Kanban and Single Minute Exchange of Dies, but also includes less-noticed elements that engage employees and turn them into problem-solvers who continually improve process performance.[5]
- Baldrige National Quality Award winners outperform the S&P 500 threefold. To win, each of the companies had to demonstrate an interlocking set of processes from understanding customer needs to engaging employees to operating practices. In short, they had a system.

These companies organize and integrate various tools and methods into their own system. The tools and methods that make up these systems interact in a harmonious, orderly way.

A Recipe for Success

In this section, we describe key ingredients for establishing and operating a successful system, and apply them to a selected process. These ingredients help to break the forces resisting change. The first ingredient is a clear pathway to achieve excellence; the second is a system for managing and operating the business.

Pathway to Excellence

Companies need a roadmap to guide their managers and associates during the implementation of a methodology. Our experience suggests that following four key stages for implementing a major process improvement initiative.

Define the Opportunity — This stage defines the gap between current performance and industry benchmarks and company potential. Quantifying this gap provides the motivation for change. Benchmarking is a key method for defining the gap; however, comparisons to criteria such as Baldrige, Shingo, and others also provide useful insight.

Develop Leadership and Set Priorities — This stage starts with educating leadership on the approach and benefits of the methodology, be it TPM, Lean, Six Sigma, or something else. Then, leaders can determine the best plan for implementation and set goals for results. As the rollout begins, the leaders must take an active role in the application of the methodology and build their depth of knowledge. Eventually, all employees must achieve competency with the methodology. Employee competency is often overlooked, or cut short, due to the work-harder syndrome.

Mobilize the Organization and Create the Infrastructure for Change — This stage provides the horsepower to implement the change. The most effective approach is to assign employees full time to an improvement office. Ideally, these employees will represent a cross section of the organization. A full-time assignment assures that they will not be pulled into the urgent requirements of daily operations. Members of the improvement office become highly skilled with the technical aspects of the methodology and become skilled facilitators of change. They develop material to communicate and educate all employees and provide hands-on resources for implementing productivity improvements.

Implement the Methodologies and Sustain Results — Education and infrastructure are meaningless without results. An excellent approach to implementation is to select an initial application area. An initial application area is a critical process for the business that will serve as a model of the methodology's application. The application must be thorough, not half way.

During this phase, apply the appropriate tools of Lean, Six Sigma, Maintenance and Reliability Systems (TPM), the Quality System, and exploit technology. Also during this phase, make the cultural changes necessary to sustain improved process performance. Later in this article, we describe Goal Deployment and Daily Management, systems that are important success factors during this phase.

Strive for Excellence — Many hurdles occur along this pathway. The root of these hurdles is the work-harder syndrome. Companies don't have time to clearly define the opportunity, resulting in weak goals, little drive, and no "what's in it for me." Leaders don't have time to develop their knowledge and skills, resulting in uncertain leadership. Companies don't invest in an improvement office, resulting in too little energy available for improvement. Organizations within the companies do the minimum possible during the implementation (just enough to appear "on board" and to stay out of trouble), resulting in inadequate standardization and education on the improved procedures.

Remember, good is the enemy of great — being good enough is not good enough in today's competitive environment. Make sure that all employees understand the best-in-class performance for their processes. Create a culture that strives to become world class.

The Business System

The second ingredient to break the work-harder syndrome is a clear, well-articulated Business System. This is often missed, and is the secret ingredient. There are three subsystems in the Business System. Although they are described separately, there is considerable interrelationship among them.

Leadership and Goal Deployment System — This system sets the direction for the company's strategy, establishes and deploys goals and means to achieve the goals via an annual action plan, and assures accomplishment of the plan. Recognizing that resources for process improvement are at a premium, this system demands focus on only a very few critical objectives and unleashes resources to accomplish those objectives. This system is aimed at quantum-leap improvement.

Daily Management System — This system assures that daily output requirements are met and that process output reliably meets quality requirements. A core practice of the Daily Management System is the Standard Work Process. Recognizing the tendency for processes to go out of control or for performance to deteriorate, this process sets standards, assures the standards are followed, takes countermeasures when deviations occur, and learns from those mistakes. This system is aimed at standardization and incremental improvement.

Operating System

This system begins with an operating philosophy, such as Lean Manufacturing, and applies the principles of the philosophy to the company's operations. Companies choose to produce in large batches or with minimal inventory. Companies choose to run to failure or to assure equipment reliability via autonomous maintenance and planned maintenance. The Daily Management System is what managers, supervisors, and team leaders do to assure that the operating system runs as expected. The operating system is how the operations are accomplished.

Many companies practice some parts of these three subsystems. Companies do set goals (or at least budgets), they do assure daily output requirements are met, and they have a way of operating even if it is poorly defined. However, few companies have consciously developed their Business System.

In our experience, three gaps are common:

- Goal deployment is diffused, with too many goals spreading resources too thinly.
- Daily management is only focused on meeting output requirements, and little or no effort is placed on assuring that standards are followed.
- Operating system implementation is only surface deep.

As an example, how these gaps apply to maintenance processes is explored in the next section. However, the example could just as easily be for manufacturing or service operations.

An Example – The Reality for Maintenance Processes

Maintenance is often considered a necessary evil. Product has to be produced and delivery promises kept. Planned downtime for maintenance clearly decreases output while the equipment is down, but does it really result in more total output? Given the pressure to produce, the work-harder syndrome takes effect. The simple solution is to let equipment problems set priorities. The machine isn't working so fix it — fast. If it isn't broken, don't mess with it. Unfortunately, maintenance costs are too high and equipment is unreliable. Something has to be done.

Imagine one manager in a company deciding to implement TPM. He or she can turn to many sources to learn about the 12-step process for implementation.[6] The first steps prepare the company for TPM by educating, creating an organizational structure for promotion, setting goals, and developing a master plan. The next step begins implementation with a kick off. The remaining steps implement practices such as autonomous maintenance and planned maintenance, and improve critical equipment effectiveness. Learning about TPM is easy enough, just like Repenning and Sterman said it would be.

This manager learns that the first year of a typical TPM master-implementation plan is consumed by preparation such as establishing a committee, benchmarking, assigning coordinators, providing overview training, and developing a strategy. The work-harder syndrome and the urgent need to do something take control, and the manager decides to shortcut preparation. Now, let's jump ahead in time and look at progress on one of the 12 steps — set up and implementation of autonomous maintenance. Some areas have accomplished an initial cleaning, placed autonomous maintenance boards, established inspection checklists and routes, and placed visual controls. Good job — even a casual observer can see the difference.

Now, move ahead six months and look into the same area. If our manager is from a typical company, you'll still see some evidence of the autonomous maintenance effort such as the autonomous maintenance boards and the checklists. However, looking closer reveals that the inspection forms haven't been completed for several months and the equipment condition is just about what it was before the initiative.

What caused this to happen? First, top management hadn't aligned to use autonomous maintenance as a means to accomplish their business plans, specifically equipment reliability improvement. There was no real focus and no management follow up. In short, a goal deployment system wasn't used. Next, we might observe that the supervisors in the area didn't really understand autonomous maintenance other than that there were checklists that had to be completed. They didn't know what to do to help assure that the operators followed the autonomous maintenance procedures. When another operator was assigned to the area, the supervisor didn't have the time or the knowledge to provide training. In short, a daily management system wasn't in place to assure sustainability.

Competitive pressures drive managers to press for immediate results that are most easily achieved by working harder. Little time is given to fundamentally changing the culture and establishing the new method as the way that work is accomplished. The result is a splashy rollout, some initial and visible results, and little else. Maybe they'll try again in another year.

Why are methods to improve performance so difficult to implement; and why, if implemented, are the results so difficult to sustain? Solve this problem and unlock the key to sustainable competitive advantage.

Conclusions

Making process improvement is challenging. The pressure to do more with less engages the work-harder syndrome. In spite of the challenges, performance has to improve or the company's survival is at risk. Here's a guide for successful process improvement:

- Understand that the work-harder syndrome places powerful forces against process improvement.
- Recognize the work-harder syndrome, believe that working smarter is better than working harder, and focus on a precious few improvement goals.
- Follow the Pathway to Excellence. Each phase is necessary. However, don't complete each phase perfectly before moving onto the next. Instead, iterate by adopting and repeating a learn-do-check cycle.
- Begin building a Business System. Start by setting and clearly deploying very few goals for improvement and establishing methods for setting and sustaining standard practices.
- Apply a methodology (e.g., 5S, Lean, Six Sigma, TPM) to make improvements, but be absolutely certain to set clear standards during implementation of new procedures.
- Put follow-up audits in place to review progress on the plan and to assure that standards are followed.
- Develop competency in the front-line associates and supervisors so that the system becomes self-sustaining.
- Expect to work incredibly hard.

Keep the payoff in sight – an operation where things gone wrong are a distant memory and the operations run smoothly.

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There's Something In The Air

Part 2: The Many Uses of Contact Ultrasound

by Thomas J Murphy, C.Eng

The use of ultrasound as a predictive tool has been with us for over 35 years. Yet, despite its vintage, the use – and, indeed the understanding – of this technology is still not widespread. This article continues an exploration of airborne ultrasound applications that we started in the June/July issue. In this article, I will explain how, just by changing from an airborne sensor to a contact probe, we can use ultrasonic inspection in a myriad of mechanical applications.

Things To Keep In Mind

Ultrasound listens to frequencies above the range of human hearing – most frequently in the region between 30-40kHz. Ultrasound is great for listening to friction and to impacting. If I carry out an FMEA exercise and determine that friction or impacting are likely indicators of failure, then ultrasound is the ideal detection tool.

Clearly, the detection of these types of behavior is not limited to rotating equipment, and so, neither is ultrasound. It should be equally clear that some defects will be trendable, in other words there will be a progressive deterioration, and some will be binary, the defect is either there or not.

The dBμV scale continues to be misunderstood. The depth of this misunderstanding is best indicated when people talk about trending. Only a few weeks ago, I heard about a presentation where, to paraphrase, it was stated that 72dB was 20% higher than 60dB. This is probably incorrect. In the case of an instrument using a dBμV scale and a decibel calculation of 20log10 (V1/V0), this 12dB difference would correspond to a factor of 4, which is 300% not 20%.

When we look at a trend we automatically perform these ratio calculations between the new reading and the previous reading. This ratio calculation is invalid when using a decibel scale. It is the absolute dB change which is important. When using a 20log scale, the difference between 20 and 26 is the same as the difference between 60 and 66, namely 6dB which is a doubling of amplitude.

To make matters worse, only a few suppliers in the world of ultrasound actually quote the reference value upon which their dB scale is based. This allows for a significant amount of confusion – a confusion which has, sadly, been exploited by some salesmen. It goes like this: take a reading with two instruments and the one with the higher reading must be more sensitive. Not necessarily so. If I were to take a measurement with an instrument measuring in dBμV and then re-scaled the instrument to read in dBnV, my voltage reading would increase by a factor of 1,000 which is 60dB. Have I changed the sensitivity? No, I haven't. All I have done is re-scale my reading. So if one system is measuring in dBμV and the other is measuring in dBbananas, how can you possibly conclude that one is more sensitive than the other, just because the reading is higher? Neat trick, but it really is just that – a trick.

Another thing to keep in mind is variable frequency ranges. Lots of manufacturers allow the user to change the mixer frequency setting in the heterodyning circuitry (read Part 1 if that meant nothing to you). This was, and still is, most useful for trying to tune out the narrow frequency range of a parasitic airborne noise that is drowning out the broader frequency range generated by an air leak. The air leak will have energy of this much broader region, so my moving away from the parasitic noise, you should still be able to pick up the air leak.

To apply the same approach to a contact measurement is much more dangerous. First, the frequency response of the typical contact sensor is not as wide as the typical airborne sensor – in fact some designs these days are resonant giving a stable, high sensitivity of a fixed and narrow bandwidth. Secondly, the transmission of the high frequency ultrasound can vary with frequency and, lastly, the frequency range of the ultrasound source is unknown. This all means that comparison of measurements taken at different frequencies is not a good idea. Some ultrasound systems allow you to change the frequency range in a discovery mode only while others allow you to store data captured at these uncontrolled frequencies. Combine this lack of control with multiple users and you have recipe for confusion.

Ultrasound is evolving. There is considerable interest these days in the diagnostic capabilities of ultrasound. Apply signal processing principles to ultrasound and you have a very powerful analysis tool which will complement vibration analysis.

Applications

Valves (Blockage, Leakage and Cavitation) — Valves play an important part in plants and valves come in all sorts of shapes and sizes. There are some common failure modes in valves which are detectable using contact ultrasound - namely, blockage, leakage and cavitation.

Ultrasound is great for listening to friction, turbulence and impacting. When fluid flows in a pipe or through a valve, the fluid molecules rub against the side wall of the pipe or valve. This rubbing, synonymous with flow, generates ultrasound.

By applying a contact ultrasound sensor to a pipe, and depending upon the material that pipe is made of, it is possible to hear fluid flow in that pipe. By implication therefore, the absence of flow – a blockage – is also audible (or not, if you see what I mean).

The ability to detect very low levels of flow, leaks, depends upon many factors. The material of the pipe or valve, the true sensitivity of the ultrasound system, the pressure in the fluid and the type of valve will all have an impact upon the audibility of an internal valve leak.

Cavitation in valves, just as in pumps, can be devastatingly destructive. Cavitation is associated with the formation and then collapse of vapor bubbles in a flowing fluid. It is the collapse of the bubbles which is destructive. Physicists tell us that when a bubble collapse it creates a jet. These jets can have velocities of 100m/s (over 200mph) which will generate pressures at the impact surface in excess of 1,000N/mm². These events take place in fractions of a second. The cumulative effect is damaging to the impact surface, the valve or the impellor of a pump. These events however do generate quite large ultrasonic signatures, probably making valve cavitation the easiest of the three defects to detect.

Internal Leaks in Cylinders — Following on from valve leakage, comes internal leakage in hydraulic and pneumatic cylinders. Operational failure of cylinders can range from being a nuisance to being the cause of catastrophic failure and perhaps even the loss of life.

Cylinder inspections in situ, in operation, is therefore highly desirable, but in many cases, access is limited, or the plant is noisy. So there is no easy way of knowing if a cylinder is passing.

An ultrasonic detector with a contact sensor does not pick up the ambient audible noise. It if focused purely on a narrow range of inaudible ultrasound. The hissing sound of a passing cylinder is quite distinct against this background noise.

Some companies have become so successful using contact ultrasound in this way that they have prepared detailed written procedures for their maintenance people to follow. Their test procedures not only cover troubleshooting methods, but also recommendations for routine data collection on cylinders which allows the maintenance team to build up that all-important sensitivity to change. In this way, the onset of a leaking cylinder is handled within their predictive maintenance regime in much the same way as they would look after their bearings.

Steam Traps — Steam traps are a commonly used automatic valve. Steam systems have a very important role to play in the operation of many plants as well. Despite this important role, so many organizations have little in-house maintenance in place to maintain these assets.

Frequently, the only care the steam system gets is an annual inspection by an outside contractor or supplier. Of course, this is better than nothing, but routine inspection of steam traps by your own maintenance people can save a fortune in terms of steam loss, water consumption, chemical consumption and energy.

It is not uncommon to find production processes faltering because the steam heating or cooking system cannot reach or maintain a required temperature. Once again, the same ultrasonic inspection tool with the same contact sensor comes to the rescue.

Contact ultrasound, in conjunction with temperature measurement, is the industry standard method of inspecting steam traps. Listening to the ultrasound signal generated by a healthy steam trap, you will hear the trap collect some mixture of condensate and air and then you will hear the steam trap discharge. The amount of time it takes for an individual trap to collect and to purge varies widely. Some traps will cycle more than once per minute while other traps may take over 10 minutes to collect. A detailed knowledge of the steam system being tested is, therefore, vital to the success of this inspection procedure.

Traps tend to fail in fairly simple modes – stuck open or stuck shut. There are some subtleties of course, but we will save that discussion for another time. The common aspect of both of these failure modes is the lack of change when you are listening. A passing trap will

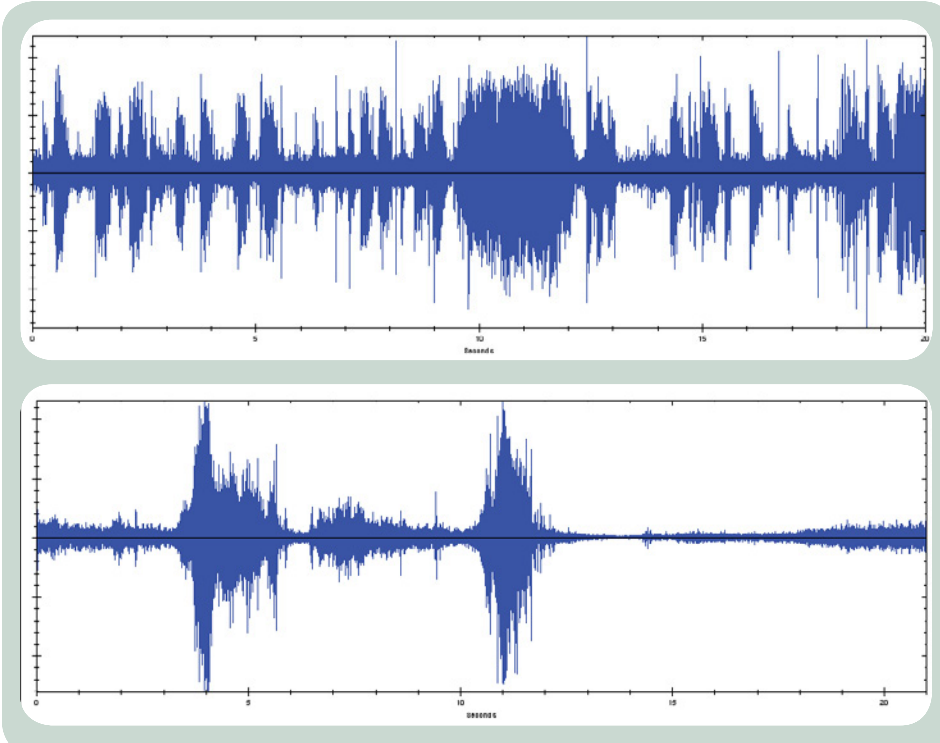

Figure 1 - Signals from two different steam traps. It is clear that the collect and purge cycles of the two are completely different.

generate a constant loud noise caused by the turbulence and noisy steam. A blocked trap will make almost no noise – just the mechanical noises carried in the pipework itself.

As with all predictive processes, success lies in sensitivity to change. The more data there is defining the normal operating condition, the more likely you are to spot a small change indicating the onset of failure.

One common criticism of this inspection procedure is that it is subjective – that it requires an "experienced" ear to discern good and bad operation. There is a small amount of truth to this. The process has been subjective thus far, primarily because of the absence of any methods for objectively recording the dynamic signal associated with the collect and purge cycle. The newest generation of ultrasound technology has evolved to overcome this problem. Using advanced signal processing allows this type of instrument to record events of virtually any desired length. This scalable, digital data acquisition means that an entire cycle, or even multiple cycles, can be recorded and then objectively compared. For example, in Figure 1, you can see that the peak amplitude is virtually the same, but the nature of the collect and purge cycles is totally different. With these measurements, we now have baselines and objective peer comparison to add to just listening.

Bearing Lubrication — In some respects, it seems that bearing lubrication has not altered much in the last two millennia–Roman historians document using animal fat to lubricate cart wheels for instance. Sadly, while lubricant technology has improved quite significantly from animal fats to organic oils to synthetics, via additives on the way, the way we use these highly sophisticated compounds has not really changed at all.

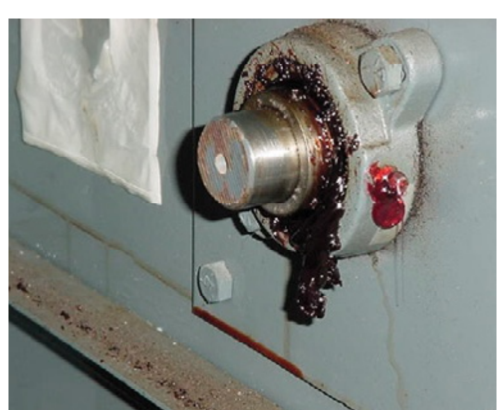

Figure 2 - "When the grease comes out through the side" is still considered an appropriate answer to the age old question, "How much grease?"

Excessive lubrication probably kills more bearings than under lubrication. It certainly increases rather than decreases the friction in the bearing.

For many years now, Ultrasound has been providing a way forward – a means of greasing rolling element bearings on demand and to ensure that the bearing being greased receives only the amount of grease required and no more.

This is an ideal application for trending ultrasound. As friction increases in the bearing, the ultrasound produced will also increase. It is not entirely so simple, because an increase in friction can be caused by too much, just as easily as by too little, lubrication.

Paul Klimuc, a well-known personality in the world of ultrasound, has a wonderful analogy which compares lubrication with walking in a swimming pool. To paraphrase, there are three states:

1. The pool is empty, you can walk up and down but you cannot slide.
2. There is a thin film of water on the bottom, now you slip when you walk – you are aquaplaning, and you might even be able to slide from the shallow end to the deep end
3. The pool is full, you cannot slide on the bottom and the drag caused by the water makes walking very difficult.

This simple analogy beautifully illustrates the difference between a dry bearing, an optimally lubricated bearing and an over lubricated bearing.

There is a need for trending in this application. Where does the myth that all bearings consume grease at the same rate originate? Nobody really knows and yet this myth is continually propagated in industry. If it is a myth, how does time-based lubrication work? How much grease does that specific bearing need? It's an impossible question to answer without measurement. If you have not calibrated your grease guns, how much grease are you putting in? It's starting to look a little bit too random, isn't it?

Consider the ultrasound alternative. Measurement on each bearing, trending the results and only applying grease to those bearings which measurably need it. To go one step further, to answer the big "how much?" question, you can use the same ultrasound system.

By listening to a bearing with an ultrasound system, you can hear and measure the benefit of the grease going into the bearing. With a simple procedure you can follow the improvement down to that optimum point, that sweet

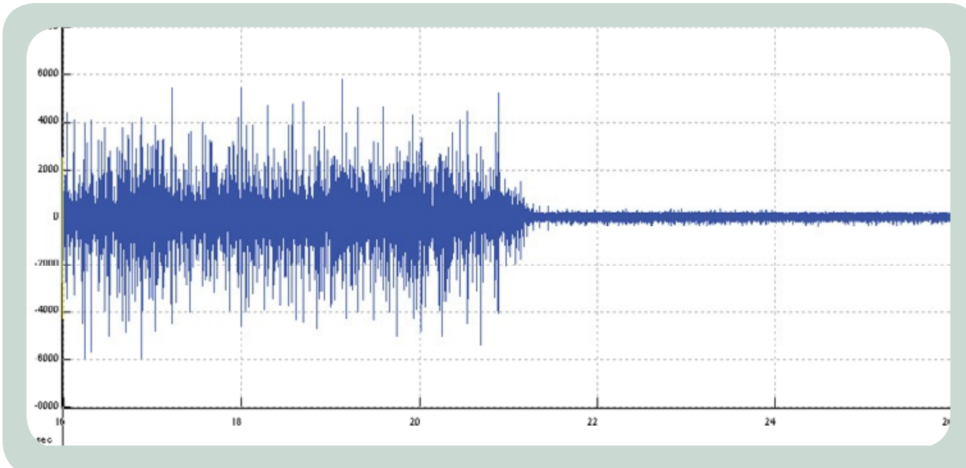

Figure 3 - A classic before and after ultrasound signal when lubricating a bearing.

spot, where you have an optimally lubricated bearing.

Many might say, “It takes too long to do that!” Oh, Really? Consider the time and the cost spent in incorrectly, infrequently and/or sporadically over greasing bearings with the consequent consumption of grease and time spent replacing bearings which have prematurely failed. Compare this with the time spent gathering routine ultrasound data, trending that data and applying the optimum amount of grease only to those bearings that need it.

Does it really take too long? No, not really. You will save time and money with the consequent reduction in grease consumption and the extended bearing life.

Using the signal analysis approach to bearing lubrication allows us to produce time signals like the one shown in Figure 3 that I recorded during one ultrasound lubrication procedure implementation training exercise. How’s that for a before and after?

Slow Speed Bearings — This topic was covered in some depth in the Aug/Sept issue of this magazine. To summarize, since ultrasound is listening to friction and to impacting, the rotational speed of the shaft is not really significant. In my own experience, bearings with rotational speeds below 1rpm can be inspected and defects identified with ultrasound in a matter of minutes, compared with the hours required to do the same with specialized vibration analysis equipment.

Here once again, the use of scalable time signals gives us the opportunity to perform a peer comparison to identify the potential defects.

Motors, pumps, gearboxes, soft foot (before and after) — Apart from the (hopefully now) obvious applications for contact ultrasound, there are many other potential defects which can be identified or investigated.

There is a lot of work underway using ultrasound, particularly using dynamic ultrasound, as an inspection tool for gearboxes. Once again, we are listening for two possible problems – friction (tooth rubbing) and impacting (chipped tooth). The ability of ultrasound to listen only for those high frequency phenomena, while ignoring the rest of the background noise generated in the gearbox, gives this approach a clear advantage over vibration.

I have already discussed cavitation in this article – a common destroyer of pump impellors. In Part 1 (June/July Issue), I also discussed using airborne ultrasound to listen to the rubbing in a misaligned coupling and the chatter of a loose coupling.

The two signals in Figure 4 highlight another advantage to scalable dynamic data – the before and after. This is actually a soft foot problem on a fan bearing. As usual, this boils down to a bad design. The bearing was on a plinth, there was no hole cut in the long side of the plinth, only in the short side underneath the pulley. This was the non-driven bearing, roughly 1 meter away from the front face where the opening was. One man with normal length arms could therefore not reach underneath with a wrench to hold the retaining nut of the bearing housing and at the same time tighten the bolt from above – the result: soft foot.

While performing a contact ultrasound inspection of the fan bearings (again during an implementation training exercise), an abnormal noise could be heard on this bearing – a noise not present on the drive end bearing. It was not the usual hissing or crackling noise associated with poor lubrication. It was a clatter, and obviously a periodic noise. Capturing the time signal and analyzing it showed the repetition frequency related to the shaft rotational speed. Closer inspection with feeler gauges showed that the clatter was caused by impacts of the loose bearing housing either against the bolt head or against the plinth. The repair was a two-man job. But it was only tightening a bolt.

A further scalable time signal and we have

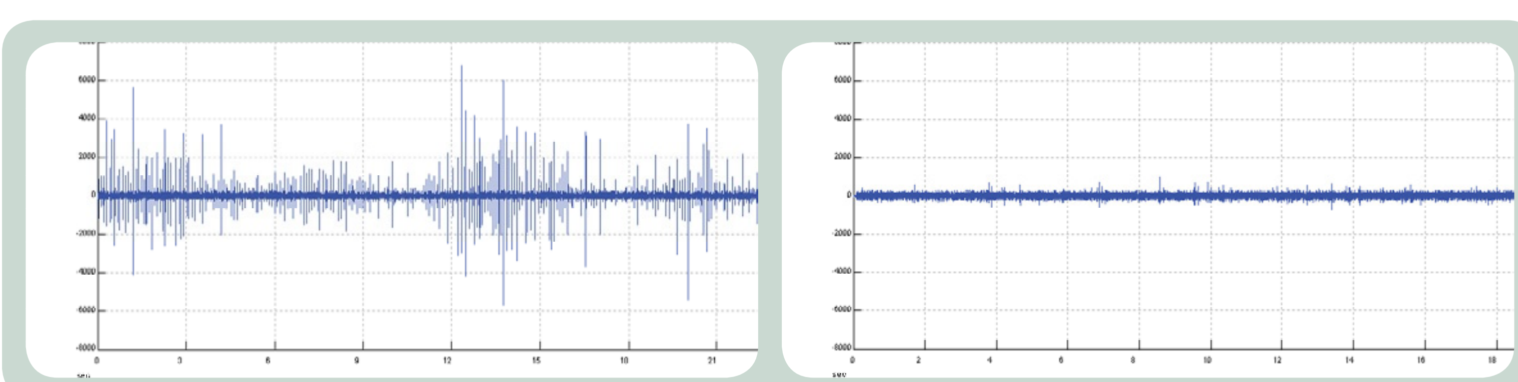

Figure 4 - The signal on the left was measured before corrective procedures on a soft foot defect, and the signal on the right was measured after the fix. Again, contact ultrasound is an effective technology for this type of before and after comparison.

an example of one of the nicest comparisons there is in the predictive world – a before and after comparison of a successful repair.

Electrical Inspections — Even within the electrical distribution world, contact ultrasound has been recognized as a useful tool.

Some years ago, EPRI produced a document which indicated applications for ultrasound in high voltage electrical applications and particularly associated with transformers. One of these applications was incredibly simple – use an ultrasound system with a contact probe to listen for the impacts generated by loose parts in the tank.

Ultrasound has an important role to play in supporting infrared inspections in electrical panels too. Airborne ultrasound is frequently used to listen for arcing or tracking inside a panel or cubicle. If that panel is watertight however, it is unlikely that there will be an air gap through which such an ultrasound signal could escape. In which case, it is recommended to use contact ultrasound either on the door or on the side of the panel to hear what is happening inside.

Procedurally, this is quite simple and akin to a visit with your general family practitioner where a stethoscope is used against your chest to listen to your heart and breathing. For electrical panels, a magnetic contact sensor works perfectly. Position the sensor in the centre of the panel and, with headphones in place, adjust the sensitivity (amplification) of your detector. Ultrasound produced by an electrical fault is typically an airborne phenomenon however we know from acoustics that sound, and ultrasound, can transfer from one medium to another. So tracking or arcing inside a panel starts out as airborne ultrasound, and the direct and reverberant components of this sound inside the panel make it possible for ultrasound sensors to capture part of the signal produced by the electrical fault as these tiny signals induce a corresponding vibration in the door or walls of the panel.

Normally the inside of panels should be quiet, or some behave in a rhythmic manner as contactors come in and out. Listen for tell-tale buzzing, crackling, and popping signals consistent with arcing, tracking, or even corona discharge if the voltage is high enough. Now measure the dBμV of the signal. The SDT170 detector I have used will read anywhere from -5dBμV to +5dBμV for a quiet panel and if there is something unusual going on inside expect readings as high as 15dBμV.

As a brief aside, many people ask me why their SDT devices read a negative value. There is a simple answer to that. The decibel reference for this manufacturer is published and well known as 1μV = 0dB. If the panel is quiet and the sensor were only producing ½μV for example, this would correspond to -6dBμV.

If a high reading is detected and anomalies heard in the headset you may want to capture a dynamic signal and analyze in the time and frequency domain to determine the type and severity of the problem. Since electrical panels are often named and categorized for the purpose of maintenance, why not set up a systematic survey of all panels and capture static (dBμV) data on an interval basis and dynamic (5-10 second signal recording) data for those displaying potential problems?

Conclusion

Contact ultrasound has a wide variety of applications in the world or maintenance. It can be applied at a very simple level - touch a probe to a surface and listen - or it can be applied at a much higher level as a diagnostic tool. Many times I encounter power users of other PdM technologies (Vibration/Infrared/ Oil Analysis), but find a general lack of understanding in the differences between contact ultrasound and contact vibration. My explanation starts by going back to understanding the benefit of FMEA in predictive maintenance programs. What is the point of unfocussed data collection? Why take readings to look for problems that may not be detectable using that particular method?

Vibration accelerometers are capable of measuring acceleration over a huge range of amplitudes and frequencies. In my early years in vibration measurement, I used to work with accelerometers with a mounted resonant frequency of 500kHz and a measurement range of over 100,000g. In the world of predictive maintenance, most people are using an accelerometer on a magnet with a mounted resonant frequency of perhaps 5kHz. How do you measure an event occurring in the 20-50kHz region with such a sensor?

The vibration world is stuck to the spectrum like glue. But Fourier's mathematics were fundamentally based on periodic signals. It is quite common to see vibration measurements where the spectrum has clearly been wrongly applied. So, if your FMEA suggests that defects will be detectable as random, transient events or as high frequency noise, your trusty magmount sensor and FFT are not very likely to find them.

Ultrasound sensors measure sound pressure waves produced in air, liquids and solids. These sound pressure waves are the result of friction and impacting.

Understanding the difference between ultrasound and vibration measurements makes all the difference in the world when it comes to applying the right technology for the right task. Knowing that vibration is normally good for repetitive events, when and where should it be applied? Knowing that ultrasound is normally good for random or transient events, when and where should it be applied?

Are vibration and ultrasound competitors? No, not really. (Who uses a vibration data collector on valves, steam traps, hydraulic cylinders or loose part tests?) Are there problems that I can only find with one or the other? Yes. Are there problems that I can find with either? Also yes. Are they complementary technologies? Absolutely yes.

As the technology continues to evolve, the ability to capture ultrasound signals and analyze them will open up more and more applications in rotating, linear and flow applications. I hope to write Part 3 on this subject in the near future.

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

Transitions

When to Move from Walk-Around to Online Systems for PdM

by Dennis Shreve

Rotating equipment in production facilities offers optimal performance and reliability when properly installed, maintained, and operated. Condition monitoring devices and systems are utilized to keep tabs on the operational performance of key production equipment. All types of tools and technologies exist today in the predictive maintenance field to allow monitoring and assessment of such equipment. In many cases, a structured, portable, walk-around program will suffice. In other situations, where equipment is hard to reach, inaccessible, or located in a dangerous or hazardous area, a permanent installation of sensors and surveillance hardware is necessary. Key objectives for such a maintenance program are to minimize failures, reduce downtime, and to reduce costs.

Condition monitoring tools can improve production uptime, efficiency, and profitability. Candidates for monitoring include motors, pumps, compressors, fans, gearboxes, bearings, and other critical machine elements. As components become worn, dirty, contaminated, loose, misaligned, unbalanced, and improperly lubricated, machines may experience increased vibration levels and higher temperatures, thereby leading to failures and production outages.

The tools for predictive maintenance and condition monitoring must be chosen with consideration given to a planned return on investment. Production personnel should classify machines as "critical", "essential", or "balance of plant", and then decide the right mix in terms of required maintenance expertise and tools.

Careful review of needs and expectations can lead a potential user of these tools down several paths. Popular choices in this area of technology include route-based portable instruments, online continuous monitoring hardware, and predictive analysis software systems. Online systems include options for wireless or hard-wired connectivity. It is important to clearly understand the pros and cons of each offering.

Recent advances in electronics technology have allowed online predictive maintenance systems to be more affordable, reliable, flexible, and modular. These systems have proven to be quite effective in providing early warnings and pinpointing root causes for machinery faults and failures. Online systems can measure and record many process parameters, allowing the user to trend and trigger on alarms so that machine performance and health can be monitored along with vibration-related faults. There has been a natural tendency to integrate some of this data with traditional process instrumentation and control systems.

This article will focus on the recent transition to continuous surveillance systems, the economies of scale, and the distinct advantages relative to implementing a traditional portable, walk-around program. While previous experiences with such systems in this industry have brought out some areas for concern, these will be addressed as well. A specific case history and success story will be cited to show the advantages of increased awareness and improved reliability with online surveillance.

The Transition to "Online" Systems in PdM Practices

Predictive maintenance (PdM) programs have become standard in many plants; and for most corporations, the program is based on vibration analysis technology. In most cases, a company's predictive maintenance system involves maintenance personnel using low-cost portable equipment to record the vibration data on rotating equipment, including electric motors, pumps, fans and blowers, generators, turbines and other plant machinery. This walk-around method is often time-consuming and labor intensive, and also limits personnel in making measurements in hazardous areas - and in other instances, measurements cannot be repeated.

An alternative to this approach is the on-line surveillance system. These continuous, computerized monitoring systems are designed for maintenance of critical and essential equipment, such as key production equipment in continuous processes.

For decades, the portable data collector has served as the cornerstone of many predictive maintenance programs. Capable of gathering vast amounts of data from many areas of the plant and storing it in a central database. Data collectors have been a key tool in many operations. Moreover, advances in integrating a data collector's information with a personal computer - allowing for the data to be displayed and analyzed - have done much to propel the development of more fully automated systems.

With portable analyzers and data collectors, companies of virtually any size can implement a predictive maintenance program. However, manual data collection continues to pose certain challenges. One concern is that it can be a labor-intensive task involving highly skilled personnel. A second concern is that measurements taken with portable instruments may be inconsistent. For example, maintenance personnel may place a sensor on a different part of a machine when periodically taking measurements; or they may take readings inconsistently. On top of this, a plant's walk-around method for collecting data sometimes exposes personnel to hazardous areas.

As an alternative, sensors and system hardware may be placed throughout the plant to obtain continuous, unattended and on-line monitoring of machinery - even equipment located in hot, wet, hard-to-reach and hazardous spots. In this application, the position or the sensor never changes, ensuring that measurements are consistent. Sensors continuously read such parameters as vibration, pressure, flow, temperature, and speed. Another important element of this type of system is the surveillance system hardware, the field-mounted data collectors/information processor, linked to a centralized computer over a local area network. The central computer workstation serves as the focal point for information storage, retrieval and analysis.

The Typical Online System Architecture

On-line systems of today provide an extensive hardware and software platform, including data collection, event monitoring, malfunction diagnostics, and on-line surveillance functions. While these capabilities might sound possible only at an enormous cost, an on-line system's costs are minimized by the physical distribution of hardware as well as lower labor and wiring expenses. The cost of an on-line surveillance system varies from plant to plant, depending upon the total number of points monitored and the physical layout.

Open system architectures are the backbone of most on-line machinery condition surveillance systems. Using standards in communications hardware and protocol and a central database, information on product quality and process performance can be tied together and used for statistical analysis. By connecting an on-line surveillance system to an overall plant information network, potential problem areas may be pinpointed and diagnosed more quickly. And by using a modular, flexible system hardware design, personnel can easily add to the original system later without major equipment replacement or rebuilding.

At the lowest layer in the system, permanent transducers are installed with cables connecting to a central junction box for access by plant personnel. Next, a multi-channel online module is added to provide multiplexed data acquisition and the first level for checking for the effects of sensor fault or failure. Finally, pc-based processor stations are added to select each sensor input automatically and to collect and process the desired data. At this level, the data may be checked against user-defined and statistically-generated alarm levels, as well as signal threshold value, to determine machine operating status conditions. The data collector/processor also provides another layer of protection by adding a data recovery device to the system in the event of unforeseen system power loss. Once the data has been processed, it is typically transmitted to a centralized computer database via the plant data highway. (Wireless technologies can be employed at the various levels in the system hierarchy to minimize typical wiring costs.)

Since information needs vary among the different departments within a plant, predictive maintenance data must be organized so it can be shared with as many departments as necessary. Using an on-line system, acquired data can be presented in various formats, including trend displays, alarm, time to alarm, and action reports. Spectral displays, graphic analysis tools, and machinery diagnostic reports are also available. In many cases, reports are tailored to fit the specific needs of key departments such as maintenance, production, engineering, and management. Using the system connectivity available with an on-line system, individual hardware and software modules can interact with each other for the exchange of information, data reduction, sorting, and presentation.

The sensor interface module allows connectivity to a variety of transducers, such as accelerometers, velocity probes, proximity detectors, and DC inputs. Vibration transducers are selected for the vibration frequency characteristics of the machine being monitored. Generally speaking, velocity probes are designed to detect low- to mid-range vibration frequencies whereas accelerometers are designed to detect mid- to high-range frequencies. Proximity probes are typically used to detect absolute or relative shaft position and serve as an RPM (speed) reference. Other criteria for selecting the proper transducer include: machine type, operating conditions, normal operating load and speeds, environmental factors, etc. The sensor interface provides continuous on-board checks on the input signals to detect either shorts or open-circuit conditions. Multiplexing and processing of the input signals of the connected transducers are performed at this level for presentation to the next level of the system.

A second level of intelligence provides data reduction, surveillance processing, and local area network connectivity for the overall system. It also incorporates a mass storage device for local, short-term data capture. This prevents data from being lost due to hardware failure at the upper level of the system.

The top level of intelligence in the system structure serves as a user-friendly, operator interface "window to the process." Integral HELP screens and interactive prompts arc typically included to promote the ease of system use and ready access to captured data. Along with data presentation, a variety of functions are provided, including system configuration, system diagnostics, data storage, data analysis, and expert system software.

Online System Advantages

An on-line surveillance system offers significant enhancements and an alterative to conventional manual predictive maintenance programs. The system reduces the staff time required to collect pertinent data and improves the ability to complete detailed analysis of machinery condition. Permanently installed sensors provide valuable, high-integrity data from machine locations that are virtually impossible to access with hand-held data collectors. The dedicated system approach also provides more frequency data sampling and faster diagnosis of machinery problems.

Considering the costs of portable instruments and plant labor, a machinery condition surveillance system offers an alternative for obtaining pertinent machinery data on a frequent basis. The resultant predictive maintenance program yields reduced mechanical failure, improved maintenance planning, and increased plant productivity. Providing data acquisition, data storage, data presentation, and data interpretation, on-line surveillance systems help to ensure machinery health. With the "building block" approach design of the system, overall system operation is easy to understand. The upper levels of the system, at the operator interface and surveillance processor, direct the sensor interface to provide information on a machine-mounted sensor. Vibration data is then measured, analyzed, and retained for further action. Scan times and data "freshness" are determined by the system makeup, and the modularity and flexibility of the system allow custom configuration to meet the requirements of the installation. With the intelligence and decision making distributed down to the individual sensor interface cards, hardware failures can be tolerated at the local area network and the upper levels of the system architecture without affecting the monitoring and protection of production process equipment.

Considering the economic pressures of today, having an on-line surveillance system installed on critical and essential plant equipment will be germane to the company's ability to offer cost-effective, quality products.

Ideal Applications and Arguments for Online Systems

Recent surveys among potential users have shown that ideal applications for such a permanently-installed surveillance system include the following:

- A machine that is considered as "critical" to the operation.
- A machine in an area that is very hard to access.
- A machine located in an area that is considered unsafe or uncomfortable.
- A process that requires frequent data collection and system assessment.
- A process that is event-driven or conditional, and not continuous.
- A process that requires immediate alarm notification.
- A process where there is a teaming of operations and maintenance personnel.

Arguments have been presented in considering the pros and cons of a permanent installation versus a portable program. Table1 summarizes typical comments from prospective users.

Practicality of Online Monitoring for Surveillance

A primary consideration for an online monitoring system is to determine which machines warrant surveillance monitoring as compared to what can be accomplished

Pros for Online System		Cons for Online System
Frequent collection of vibration data	Can be imbedded in an OEM system	No "hands-on" assessment, observations
Repeatable measurements	Can be located in remote/hazardous locations	Vulnerable to input/output lines being severed
Less labor intensive in on-going program	Early problem warning via lights/relay outputs	Expense of dedicated sensors and wiring
Safety for making measurement	Only collects on machine condition/criteria	Requires some additional training
Comfort for collection and analysis	Quickly scans for overall alarm checks	Sometimes not easily accessible for check-out
Information tie-in to process variables	Nicely integrates process information for QA	Higher installation and startup costs
Can be easily integrated with process variables	Gives high visibility to the overall program	Sometimes requires NEMA-style enclosure
Ties in nicely with data from portable program	Teams up operations and maintenance folks	

Table 1 - Pros and Cons of an Online Vibration System

with walk around (portable) or protection monitoring systems. Figure 1 provides a good representation of where surveillance monitoring has traditionally fallen in a vibration measurement condition-monitoring program.

As the graph in Figure 1 indicates, on-line surveillance systems are most commonly employed on assets that are costly to maintain and those that negatively impact production efficiency when out of service. Another key consideration is the anticipated time from the first indication of a developing problem to the actual onset of failure. For instance, if the asset is likely to fail in days or weeks, then an on-line surveillance system is the most cost effective approach. Studies have shown that an on-line surveillance system is more cost effective than walk-around (portable) systems when the required data collection interval is shorter than every four weeks. Note, however, that

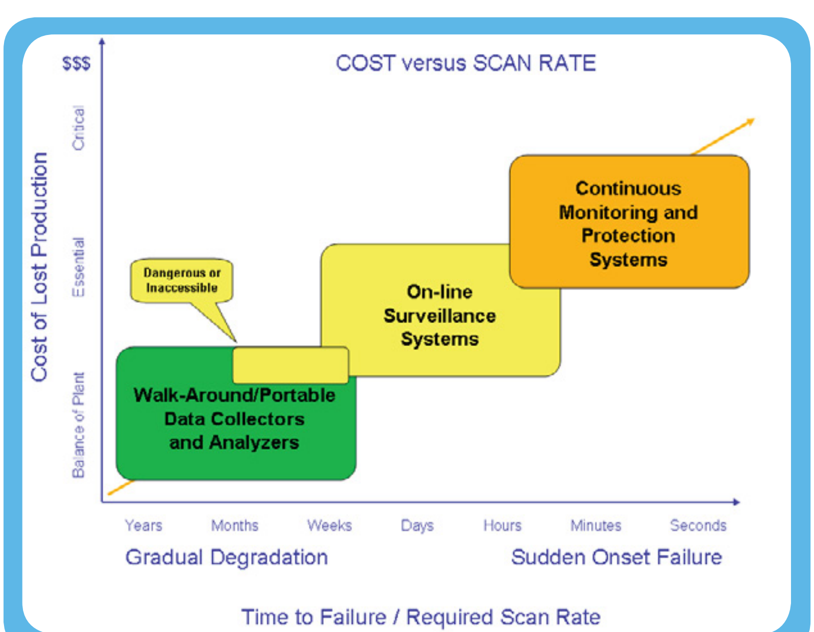

Figure 1 - Cost versus Scan Rate

a typical surveillance system uses polling and input multiplexing; and it is not intended to take the place of a high-speed, quick reacting protection system with shut-down capability. Another excellent application for on-line surveillance is areas that are deemed dangerous or Inaccessible.

Surveillance systems have found widespread use in dangerous and inaccessible locations in a factory environment. Machinery that had been left out of programs in the past due to the expense of manual data acquisition in dangerous and inaccessible locations is now being added to these types of systems. This is primarily due to the attractiveness of the installed cost per point and the ease of installation of surveillance systems.

In the past, the prime reason for selecting the location for a surveillance unit was based on the cost per point of the system and the desire to utilize as many of the available channels as possible. When you are considering locations and the number of units, it is important to factor in all costs. Oftentimes, a single centralized unit is more costly than two localized units because the cost of running the signal wires can be higher than adding a second location. It is also important to check with the Information Technology (IT) or Information Services (IS) department on the availability of network drops in the areas where units are planned to be installed.

IT/IS Involvement

Getting your IT/IS department involved during the early planning stage is very important. These folks are usually the owners of the site network and they will have a vested interest in the project. Typically, they will have questions pertaining to how much traffic will be produced, at what speed it will be running at, and what protocols will be used. They will also hold the key to your local area network (LAN), its configuration and limitations. They will be the ones who can help with the connection to the network, and they should be able to answer specific local questions. The IT/IS department will need to help determine if a simple hub is all that is required, if there is an available router, or if it will be necessary for you to create your own LAN for the online system or if an Ethernet switch or bridge will be required. They will also be the ones to provide the static network addresses which are required, such as IP addresses and Subnet Masks. Having the IT/IS department involved up front will better allow you budget the job, be better prepared when the time comes to install the system, promote teamwork involvement, and help to create a smooth running system from the very beginning.

System Input Configuration

Getting the right information from the process is another important consideration. In mounting permanent sensors for the on-line system, there are some key points to note. First of all, you must consider how many sensors to use at each location. Three sensors per bearing (one per axis) would be optimal. However, physical restrictions or

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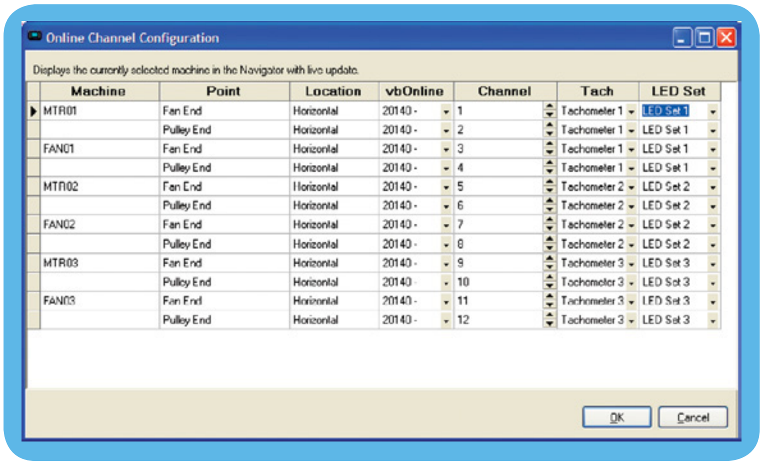


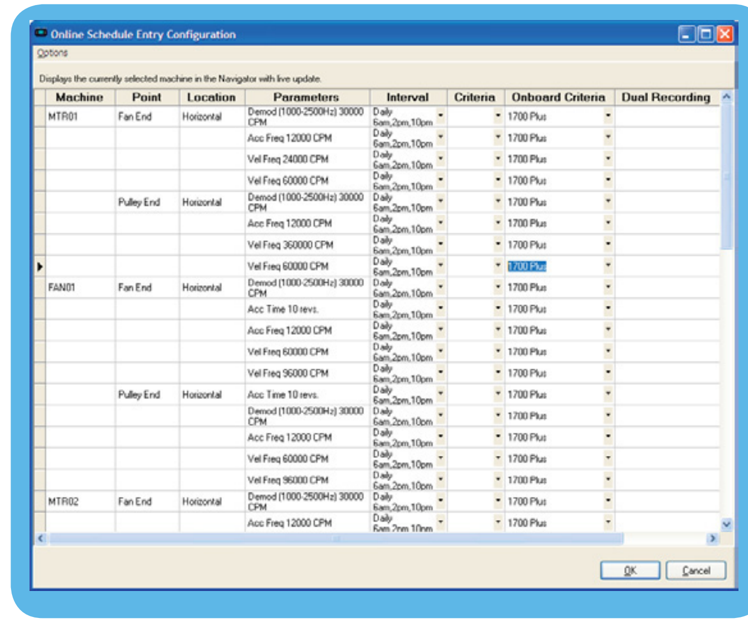
Online Channel Configuration

Displays the currently selected machine in the Navigator with live update.

Machine	Point	Location	vbOnline	Channel	Tach	LED Set
MTR01	Fan End	Horizontal	20140 -	1	Tachometer 1	LED Set 1
	Pulley End	Horizontal	20140 -	2	Tachometer 1	LED Set 1
FAN01	Fan End	Horizontal	20140 -	3	Tachometer 1	LED Set 1
	Pulley End	Horizontal	20140 -	4	Tachometer 1	LED Set 1
MTR02	Fan End	Horizontal	20140 -	5	Tachometer 2	LED Set 2
	Pulley End	Horizontal	20140 -	6	Tachometer 2	LED Set 2
FAN02	Fan End	Horizontal	20140 -	7	Tachometer 2	LED Set 2
	Pulley End	Horizontal	20140 -	8	Tachometer 2	LED Set 2
MTR03	Fan End	Horizontal	20140 -	9	Tachometer 3	LED Set 3
	Pulley End	Horizontal	20140 -	10	Tachometer 3	LED Set 3
FAN03	Fan End	Horizontal	20140 -	11	Tachometer 3	LED Set 3
	Pulley End	Horizontal	20140 -	12	Tachometer 3	LED Set 3

OK Cancel

Figure 2 - Setup Screen



Online Schedule Entry Configuration

Options

Displays the currently selected machine in the Navigator with live update.

Machine	Point	Location	Parameters	Interval	Criteria	Onboard Criteria	Dual Recording
MTR01	Fan End	Horizontal	Demod (1000-2500Hz) 30000 CPM	Daily 6am,2pm,10pm		1700 Plus	
			Acc Freq 12000 CPM	Daily 6am,2pm,10pm		1700 Plus	
			Vel Freq 24000 CPM	Daily 6am,2pm,10pm		1700 Plus	
			Vel Freq 60000 CPM	Daily 6am,2pm,10pm		1700 Plus	
	Pulley End	Horizontal	Demod (1000-2500Hz) 30000 CPM	Daily 6am,2pm,10pm		1700 Plus	
			Acc Freq 12000 CPM	Daily 6am,2pm,10pm		1700 Plus	
			Vel Freq 360000 CPM	Daily 6am,2pm,10pm		1700 Plus	
			Vel Freq 60000 CPM	Daily 6am,2pm,10pm		1700 Plus	
FAN01	Fan End	Horizontal	Demod (1000-2500Hz) 30000 CPM	Daily 6am,2pm,10pm		1700 Plus	
			Acc Time 10 revs.	Daily 6am,2pm,10pm		1700 Plus	
			Acc Freq 12000 CPM	Daily 6am,2pm,10pm		1700 Plus	
			Vel Freq 60000 CPM	Daily 6am,2pm,10pm		1700 Plus	
			Vel Freq 96000 CPM	Daily 6am,2pm,10pm		1700 Plus	
	Pulley End	Horizontal	Acc Time 10 revs.	Daily 6am,2pm,10pm		1700 Plus	
			Demod (1000-2500Hz) 30000 CPM	Daily 6am,2pm,10pm		1700 Plus	
			Acc Freq 12000 CPM	Daily 6am,2pm,10pm		1700 Plus	
			Vel Freq 60000 CPM	Daily 6am,2pm,10pm		1700 Plus	
			Vel Freq 96000 CPM	Daily 6am,2pm,10pm		1700 Plus	
MTR02	Fan End	Horizontal	Demod (1000-2500Hz) 30000 CPM	Daily 6am,2pm,10pm		1700 Plus	
			Acc Freq 12000 CPM	Daily 6am,2pm,10pm		1700 Plus	

OK Cancel

Figure 3 - Polling and Criteria

budgetary limitation sometimes do not allow for this. If you are faced with this issue, here are some key points to address:

- Data should be taken at each bearing,
- If limited to only one radial position per bearing, look at previous data if available or the design of the machine for the direction most likely to give you the first warning of a problem,
- Consider at least one axial sensor per solid shaft to look for problems only identified from energy in that direction.

When permanently mounting sensors, you should mechanically attach them to ensure that they are solid at the point where you want them. (Remember that you are looking for a good transmission path for very small "tell-tale" signals indicating incipient failure.) If physical changes are not allowed, such as drilling and taping, an alternative is to use epoxy and glue the sensors in place. The next consideration is to get the proper wiring for a clean, reliable signal from the sensor to the electronics module. Most new vibration sensors utilize twisted shielded pair cabling to minimize Electro-Magnetic Interference (EMI). The twisted pair is used to carry the signal and are connected from the transducer directly to the input terminal. The shield must only be attached at one end to keep from creating a ground loop, thus allowing it to perform its function of protecting the signal. Other vibration sensors, as well as some process parameter sensors, may only have coaxial cable, which should be wired directly to the input. If you have chosen a central location for your online module to utilize it for several machines, you may want to consider remote junction boxes and multi-pair cable to help minimize cost.

Once the transducers have been mounted, the online unit(s) have been located, and wiring has been pulled, it is time to set up the database - complete with measurement types, channel input assignments, the polling intervals, the conditions and criteria for collecting data, the reading of tachometers and the controlling of output relays.

A typical setup screen appears as shown in Figure 2. Note that measurements have been set up with assigned channels to a specific online unit, along with tachometer inputs and LED sets for showing status relative to preset specified alarm limits.

Database Polling Process

Next, the interval needs to be specified for the polling and any criteria that are necessary for measurement. In this case, we are satisfied to gather 3 measurements daily (6am, 2pm, and 10pm) provided that the equipment is running (say above 1700 RPM). This is shown in Figure 3.

Spectral, time waveform, and demodulation (rolling element bearing defect detection) measurements can be taken on the vibration transducers. Tachometer inputs can be used

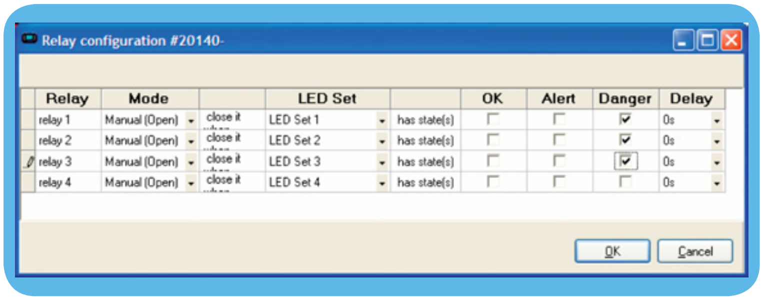


Figure 4 - Relay mapping

to provide speed and relative phase data. DC inputs may also be included to provide key process parameters including pressure, flow, temperature, humidity, line speed, etc.

Next, we need to set up the relays for notifying the operator of alarm threshold in danger, which is shown in Figure 4.

Now that these key pieces have been addressed, we need to set up an online manager to perform the "house-keeping" chores for the data collection and placement into the database. This is a fairly simple piece of software that requires very little setup.

Database Management

As automatic periodic data collection can lead to large database files, online manager systems usually have a thinning process built into them, as shown in Figure 5.

For example, in a system with frequent data acquisition – say once every 5 minutes, we would retain the recordings every hour for all readings older than one week.

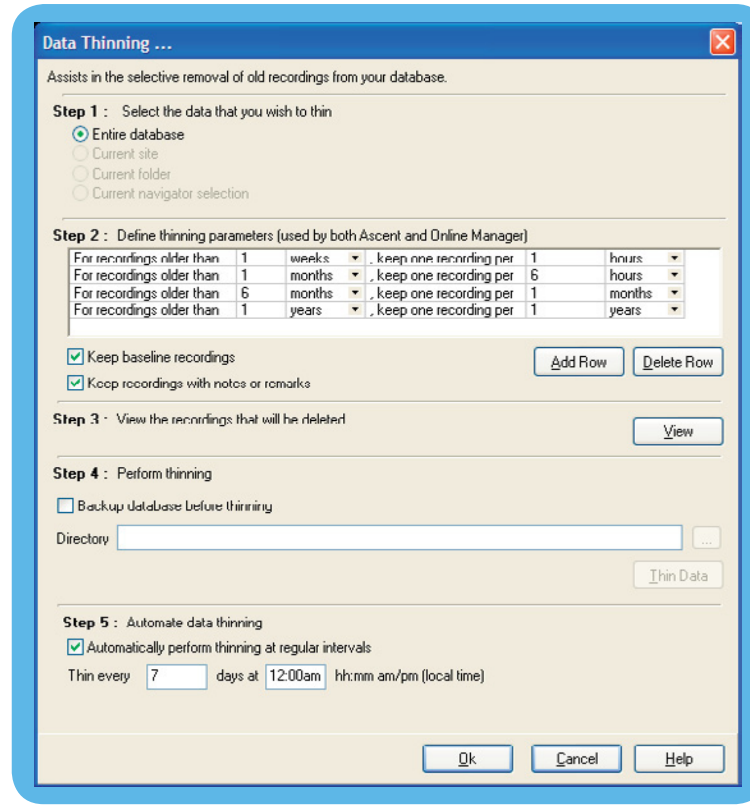


Figure 5 - Database Thinning

Case History Example

With the periodic data collection now all set up and underway, it is often a good idea to go into the software to see if all is set up properly and to do an occasional "Record Now".

In this instance, we will be taking a velocity spectrum on the Fan End bearing on FAN01.

At this point, the automatic data collection process is ready to begin. As data are collected over a 24-hour period, we already start to see alarm conditions occurring, as color-coded labeling shows in the database. See Figure 7.

From this view, we can quickly see that a problem may be present on the Pulley End bearing on FAN02. The velocity reading is quite high at the motor running speed at 1792 RPM. As we also know the bearing at this point is an SKF22218CCK, we can produce a Demodulation chart that shows an inner race defect frequency. See Figure 8.

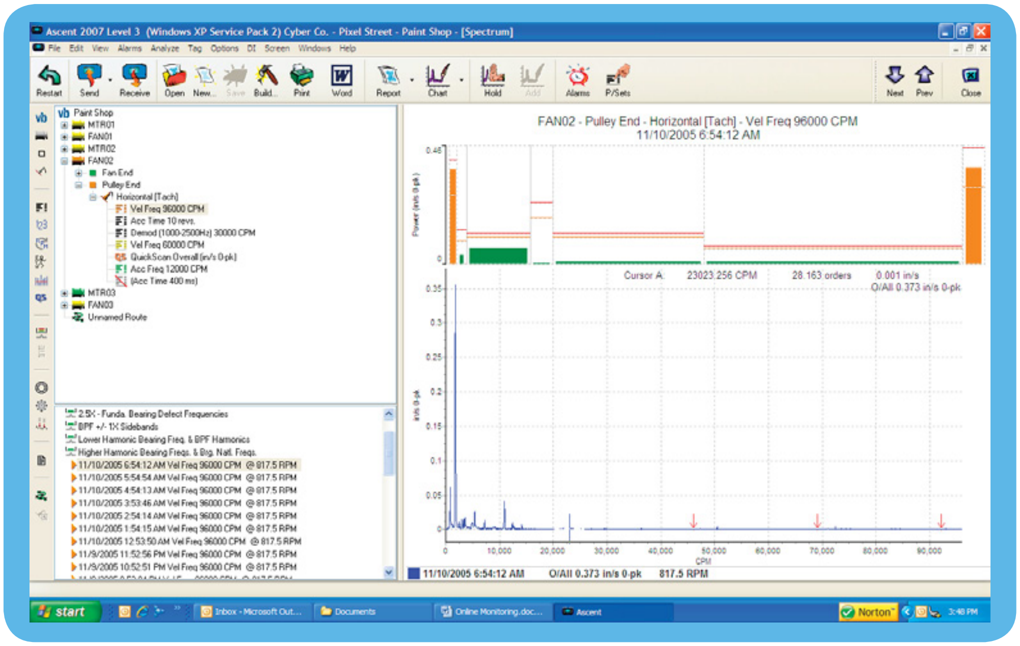


Figure 7 - Database Overview with Color Coding on Alarm Conditions

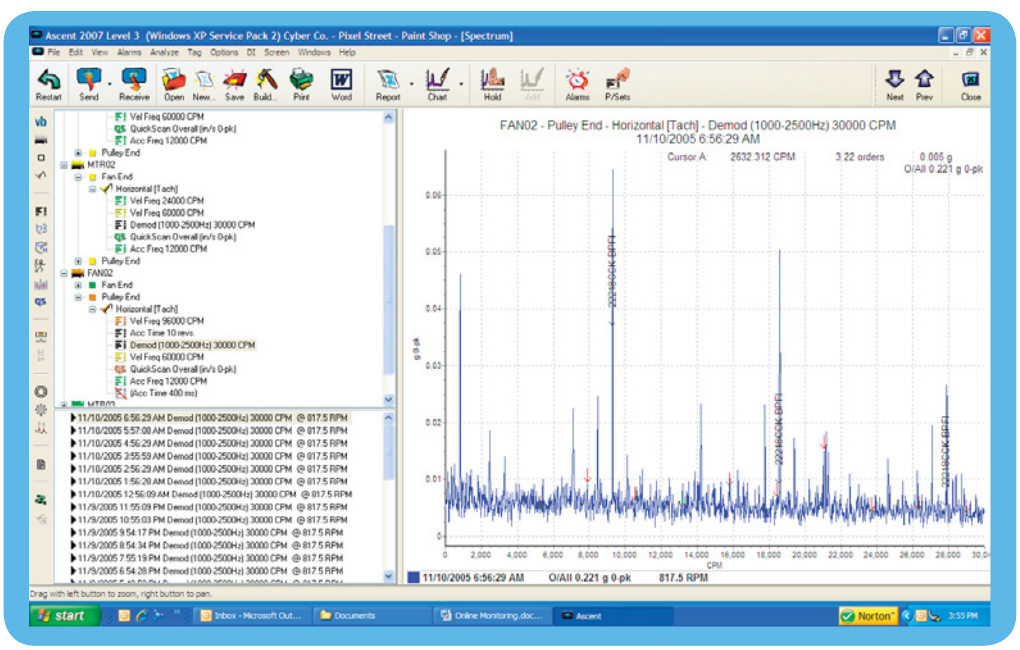


Figure 8 - Demodulation Showing Possible Inner Race Defect on Bearing

Alarming Methods

Another feature that is typically included in online surveillance is automatic alarm monitoring and notification software. Along with local notification, software can be configured to send alarm messages via e-mail addresses and text messages.

Another consideration for installing an online surveillance system for vibration and other related process variables is how it might pass its information to an existing supervisory control and data acquisition (SCADA) system for process variables integration and correlation. OPC is open connectivity in industrial automation and enterprise systems that support industry. Interoperability is assured through the creation and maintenance of open standards specifications. Most online systems conform to OPC, and the vibration database is simply published as "OPC", which is then tied to the proper database.

Overall values of vibration and alarms are typically passed from the vibration monitoring system to the process automation system for display and integration.

Conclusions

With recent advances in technology, online surveillance systems have become very cost effective in relation to the already well-established portable (walk-around) programs. These new systems incorporate multiple input channels and are often viewed as a "data collector on the wall". They have proven themselves to offer reliable, repeatable data for trending and providing an early warning for pinpointing potential failures and catastrophic outages on "critical" rotating equipment for production facilities. More points, more frequent data, and reporting software (virtually at the touch of a button) lead to improved maintenance, less downtime, and higher production efficiency.

Configuring and managing an online surveillance system is no longer viewed as complex and costly. Such a system is no longer earmarked as a tool to be reserved for only the most advanced vibration analyst. The tasks have been simplified considerably and are set up with interactive prompting and navigation, and they typically include self-checking menu structures.

Once a system is configured and powered on, it doesn't take much time to see results and get payback on the investment.

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When we think of maintenance, we usually think of the machinery running within the plants, but the facilities themselves may just be an afterthought. Well, facilities are expensive to operate, so optimizing the building envelope and its systems is important to the bottom line of any company.

Get Smart with BOMI

BOMI works with industry experts who are committed to giving back to an industry that has served them well. With their help, and the application of sound instructional design principles, BOMI delivers high quality education that benefits their students for years to come. The combination of the SMT, SMA, FMA, and RPA designations is unique in that they touch on all aspects of the built environment. With these BOMI designations, students can follow a career path from the boiler room to the board room.

We caught up with the Designation Manager for BOMI, Michael Coleman, who has been with BOMI for 11 years. Michael works to ensure that BOMI's designations and other programs are meeting the needs of the built environment, and that individuals and companies receive maximum benefit from BOMI's offerings. Here is what Michael told us...

Completion of BOMI educational courses can lead to increases in job effectiveness, job security and salary. Companies will benefit from more competent employees which can lower operational costs for their facilities.

First, why don't you briefly explain BOMI International is and what it does?

We are the independent institute for property and facility management education. As the trusted property and facilities educational resource of choice for today's top corporations, government agencies, property management firms, unions, and trade associations, BOMI works across industry sectors to improve the skills of property and facility management professionals. More than 20,000 professionals hold one—or more—BOMI designations and over 80,000 students have turned to BOMI for premier education and training.

Running facilities more efficiently can certainly enhance a company's bottom line. Please explain the benefits of your facility certification and designation programs, to both individuals and companies.

BOMI courses combine well-established best practices with cutting-edge knowledge that will increase your earning potential as you build your current career or branch out into exciting new areas of commercial building and facilities operations and management. According to a recent survey of BOMI graduates, 27 percent received a salary increase or promotion, and 94 percent experienced added job security and responsibility, which means employers also benefit from the value a designation adds to professionals.

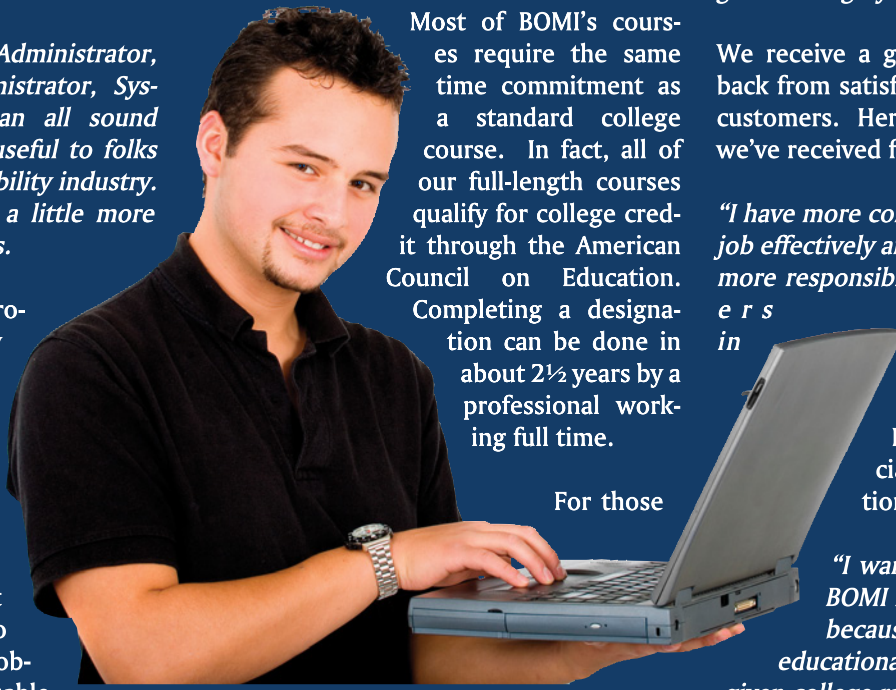
For businesses, an organization is only as successful as its individual team members. The challenge is to give your team the tools they need to advance. BOMI's educational programs enable workers to perform at their best, which means facilities run more efficiently and operating costs are reduced. Some other benefits include improved staff retention, lower recruitment costs, and better communication, teamwork, and decision making. A BOMI-educated staff ensures that an organization will consistently meet high standards of service delivery.

The Facilities Management Administrator, Systems Maintenance Administrator, Systems Maintenance Technician all sound particularly interesting and useful to folks in the Maintenance and Reliability industry. Would you mind explaining a little more about each of those programs.

BOMI's FMA® designation program enhances your career by making you a more effective, knowledgeable facilities professional, thus positioning you as a key strategic professional within your organization. This program teaches you to manage facilities in a way that best supports staff and fits into the organization's overall objectives. You'll develop valuable skills in strategic planning, project management, corporate finance, capital investment, and physical asset management. You'll also learn about new facilities technologies, environmental health and worker safety, and other timely issues. For an organization to incorporate facilities decisions into strategic plans, the Facilities Manager needs to be able to communicate to the C-suite, and the FMA designation helps build the skills necessary to do exactly that.

The SMT® and SMA® designation programs help students increase the operating effectiveness of their buildings. Designed to meet the needs of hands-on technicians and building engineers, the SMT and SMA programs teach best practices, technologies, and trends in the maintenance field that show you how to manage energy-efficient, environmentally sound, cost-effective building systems. SMT and SMA courses detail specific operating systems, while the SMA program includes additional courses covering environmental issues, administration, and building design and maintenance. Through these programs you'll gain career-building skills and knowledge, as well as recognition as an integral part of your facilities team.

What kind of time requirement do the certification and designation programs require?



Most of BOMI's courses require the same time commitment as a standard college course. In fact, all of our full-length courses qualify for college credit through the American Council on Education. Completing a designation can be done in about 2½ years by a professional working full time.

For those who would like to demonstrate progress along the way, we also offer certificate programs that require completion of three BOMI courses. Within one year, students are able to earn a certificate in systems maintenance, facilities management, property administration, or financial proficiency. For a short time, BOMI is offering the third course in our Building Systems Maintenance Certificate program for free when you commit to completing the certificate.

What are the three top reasons a company should consider the educational offerings of BOMI International?

3. Increased professionalism among staff, including best practices applied consistently throughout your facilities.
2. A reduced environmental impact through the reduction of energy and materials usage and prolonged life expectancy of equipment that results in efficient standards of operation and maintenance.
1. An improved bottom line from the cost savings that result from implementing the best practices taught in BOMI's courses.

Would you give us a success story or two from companies or individuals that have gone through your programs.

We receive a great deal of positive feedback from satisfied students and corporate customers. Here are a few comments that we've received from a few of our students:

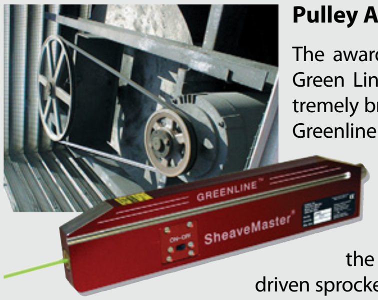
"I have more confidence in myself to do my job effectively and efficiently. I have gained more responsibility in my job and coworkers look to me to help them in their job. Now they want to earn their own designation." Gerald Bergren, Facilities Operations Specialist, Compassion International

"I wanted to complete all of the BOMI International's designations because they provide high quality educational course material, which are given college ratings, and because the designations are internationally recognized. The designations provide a professional identity that is needed in today's market." Ed Paras, RPA®, FMA®, SMA®, Manager School Facilities, Parkland School Division #70

"We chose the BOMI International Facility Manager Administration® designation as a recognized Marriott Certification Program for our Directors of Engineering. The FMA® program both reinforces the skills they have gained in the field and prepares them for new challenges in managing our complex buildings and systems." Claire Kevill, Engineering Program Manager, Marriott International

How can interested people get more information about the programs offered through BOMI International?

If someone has specific questions, or if they'd like to order our course catalog, they can call 800-235-2664, or send an e-mail to service@bomi.org. Our website, www.bomi.org is also a great resource where you can download our catalog and find answers to most of your questions.



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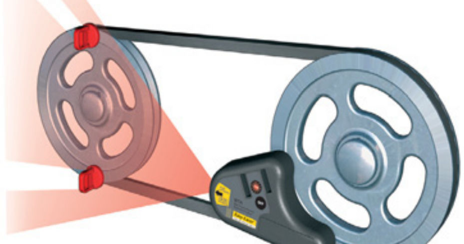

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