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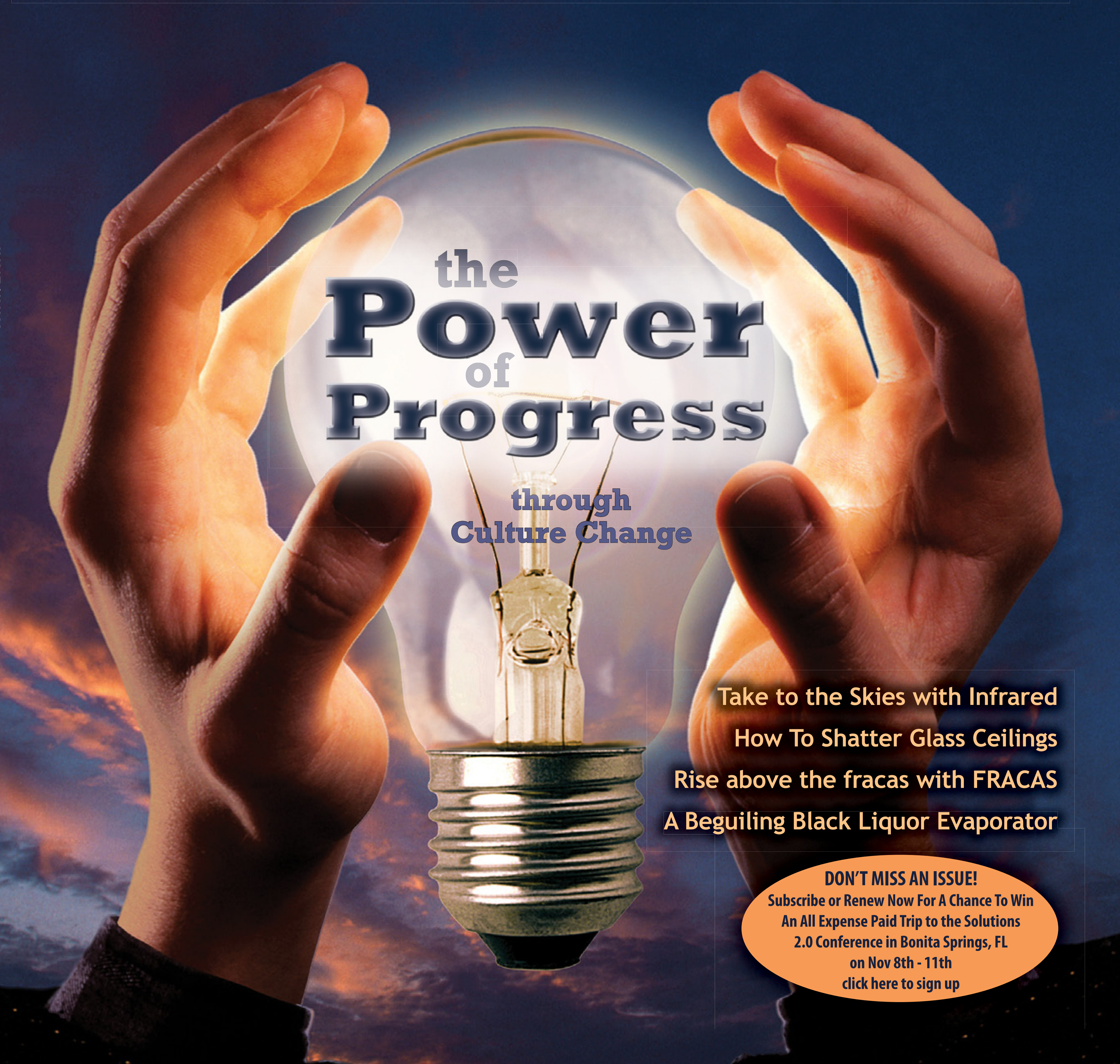

## the Power of Progress

through Culture Change

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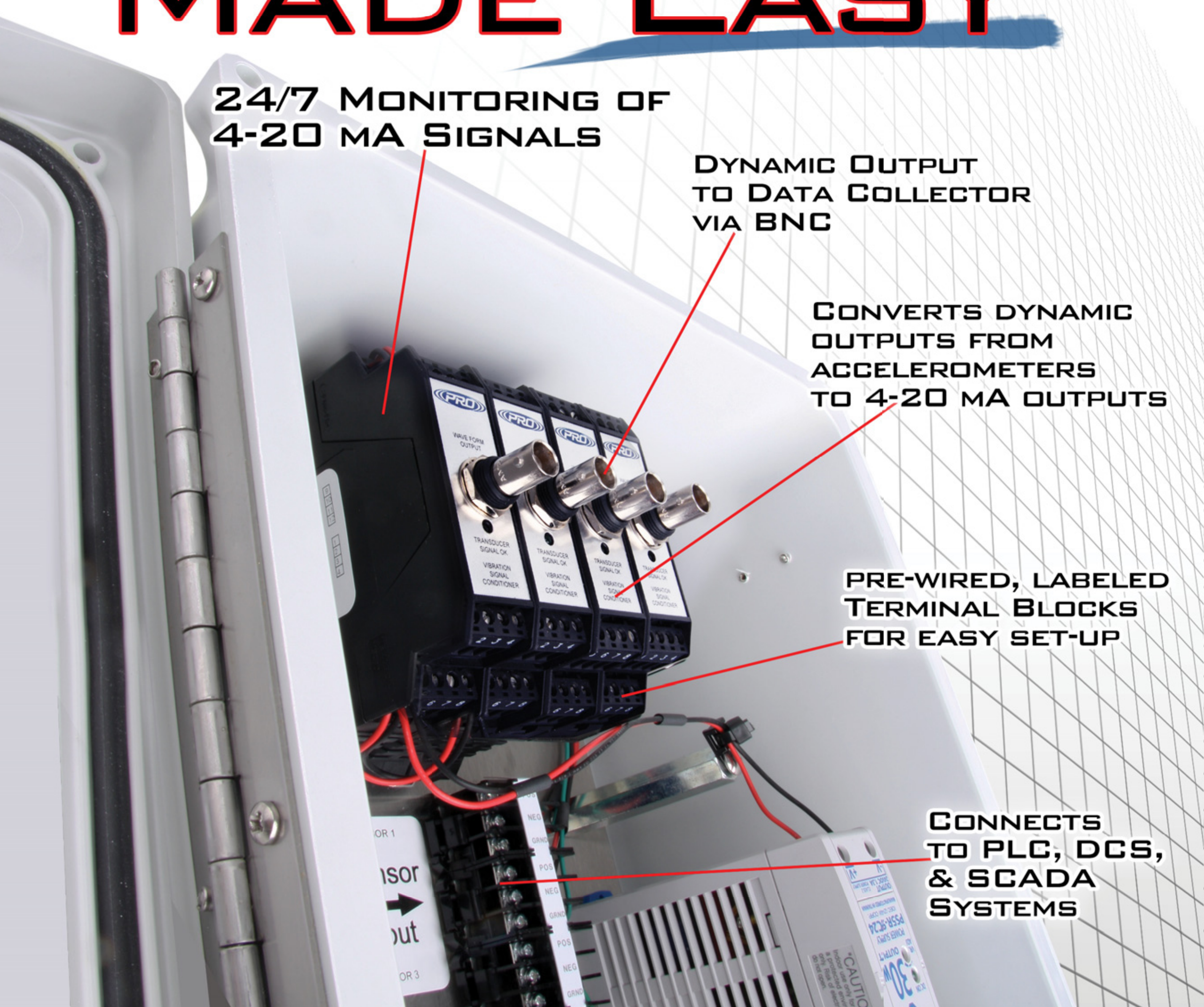
# XE150 Signal Conditioner Enclosure

# 4-20 mA Vibration Monitoring Made Easy



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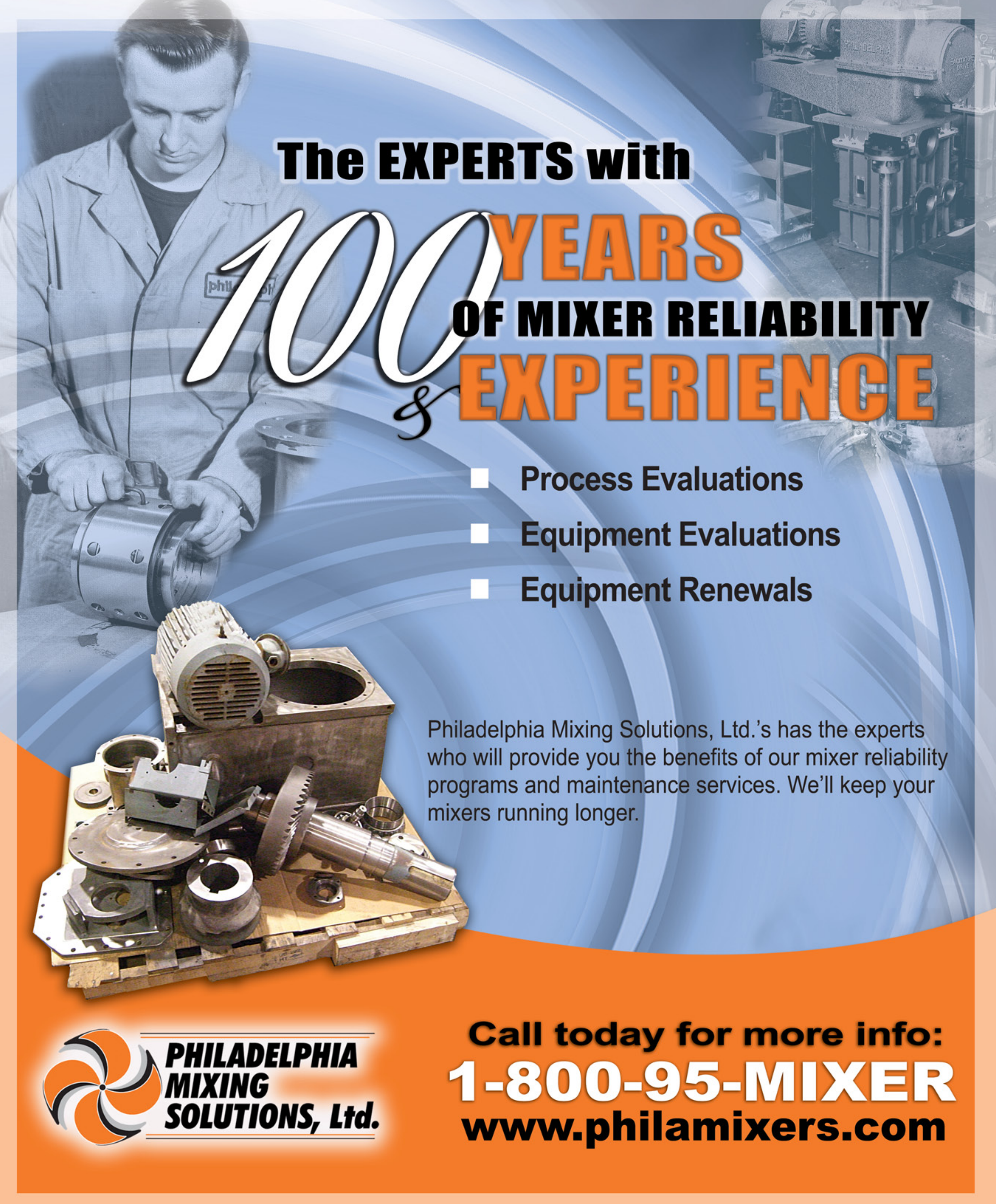
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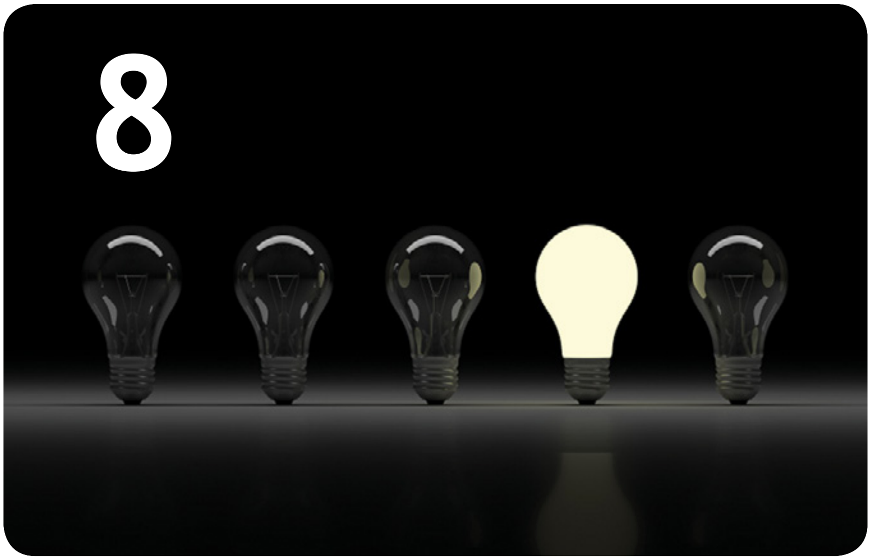
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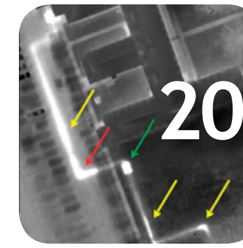
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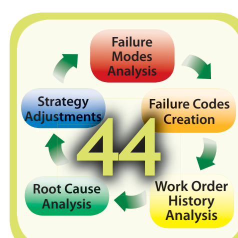
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# Reaching Our Potential

Statistics have been reported by several studies, and can be corroborated by many experts, that somewhere around 80% of all major improvement and change management efforts fail. I don't know you how feel about that, but to me those are disheartening numbers. Unfortunately, with those kind of statistics staring you in the face, there is a temptation to not even try.

If there is an 80% chance of failure, why even begin?

As those numbers suggest, and as most of us innately know, change is difficult. Especially when you are talking about an entire culture in an organization, which has undoubtedly been established over a number of years.

Well, the good news is that, even in the face of these odds, facilities and companies still undertake improvement efforts, and many succeed. I guess the bad news is that they are compelled to try because they must improve if they want to thrive (or, perhaps even to just survive). Of course, this situation implies that they are functioning under, let's just say, less than ideal work practices or outdated processes. In other words, they are not operating up to their potential.

That's why I am excited to bring you the feature article in this issue. It is the uplifting story of a successful change management initiative that paints a picture of possibilities. A picture of your possibilities.

Thinking about possibilities is a positive act in and of itself, and can immediately lift our spirits. After reading our feature article, you will see that, despite daunting odds, change can be accomplished. Think about the possibilities for improvements, both large and small, in your situation.

I would also like to thank the kind folks at Ludeca, Inc. in Doral, FL, a company specializing in laser alignment and vibration analysis. They were kind enough to recently host a plant tour for about 20 inquisitive Reliability 2.0 Conference attendees, including myself. Their facility, including a state of the art training facility, was most impressive. Equally as impressive is the, shall we say, colorful history of their business. It is a story of human perseverance that began in Nicaragua amid their civil war in the 1970's. It is a very interesting story, and I encourage you to ask about it if you have the chance to talk to the good people at Ludeca.

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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# Building Steam

A Story of Hard Work, Dedication and, ultimately, Transformation.

*by Judith Charlton and Steve Lipscombe*

Sembcorp UK, one of the leading suppliers of utilities to UK industry, is transforming its operations. Steam and power operations are vital to the success of Sembcorp UK and its customers in the petrochemical, power and biofuels sectors. Just five years ago the business was struggling to manage an aging power station and all its associated problems with limited resources. The challenges seemed insurmountable.

This article shows how Sembcorp, in partnership with change management consultants Reliable Manufacturing, rose to the challenge and galvanized its leadership to engage the whole workforce out of narrow workgroups and into delivering outstanding results through proper teamwork. It is a story of 'the blood, sweat and tears' that were shed to overcome a huge range of challenges and legacy issues to restore performance and pride in the operation.

## Background

Sembcorp provides steam, power and other utilities to all of the major manufacturing companies on the Wilton International site in Teesside, United Kingdom. The site was built by ICI in the 1940's, but by the 1990's a change in strategy by ICI brought about the gradual sell off of the ICI bulk chemical businesses on the site. This brought with it the prospect of the ultimate closure of the aging Wilton Power Station. In 1999, Enron bought the power station along with the rest of the site's utilities and services operations, and began a growth strategy which was cut short by the company's global collapse in 2001. After 18 months of operating as a stand-alone business, the business was bought by Singapore-based Sembcorp Industries in the spring of 2003 and it now operates as Sembcorp Utilities (UK) Ltd. Since then, Sembcorp has invested more than £150 million in its assets and further enhanced its reputation as a dependable supplier of high-quality utilities and services.

At the same time, the underlying business has been put on a sound financial footing. However, good business performance has been aided by the ability to import steam from a third party utility. This backup supply was used whenever Sembcorp's own assets were unable to deliver the required steam demand to its customers. Ironically, due to the commercial nature of the contract, the use of third party steam was often more profitable than running Sembcorp assets, a situation which led to a reduced need to maximize the capability of the existing asset base.

With this favorable long term third party contract due to end, by 2005, Sembcorp management had concluded that in order to maintain its business position, strong action was required to turn around the performance of its assets. The company needed to become self sufficient in terms of its ability to supply steam to the Wilton Site. Without this change the business could face an uncertain future.

## The Challenge

The challenge is described by Jane Atkinson, Vice President Utilities Operations, "I joined Sembcorp in late 2004 and quickly became aware of the massive challenge I had inherited. Morale was at an all time low, a "make do and mend" culture had set in, and plant and equipment that was the best available at the time of construction, was aging and unreliable. Although we had large volumes of procedures covering every last detail, they weren't being applied in the same way and many were, frankly, out of date."

"I also became aware that this wasn't the only area of concern. We had neglected some equipment, and our buildings required significant restoration," Jane continued to explain, "But most of all we had neglected our people. With the ICI Divestiture and resulting uncertainty, the work force had become depleted as people secured careers elsewhere. Many of those remaining seeming to accept that they had 'a job for life', and were content that they would be financially secure as they moved into retirement."

"Our whole culture was one of 'run it and fix it'. Departments were working in 'silos' with little obvious co-operation. Maintenance and Operations were content with blaming each other, and were not engaging with other supporting functions such as stores, purchasing, HR and IT," Jane added, "In addition, I personally had to deal with comments like 'What does a manager from outside the power industry know about running a power station?!'". But, with the realization that the outsourced steam contract was to end, there was a desperate need to turn things around".

Jane was tasked with leading and delivering the change.

## Strategy and Change Process

Given such a huge task, where do you start? In 2005 Reliable Manufacturing Ltd, a reliability based change management consulting firm, facilitated a Manufacturing Excellence Master Class for the Utilities Management Team. The Master Class was led by their principal consultant Ron Moore, an internationally recognized expert on Manufacturing. Participating with Jane and her direct reports were first line supervisors and union representatives. The event began the process of engagement and enabled Jane and her co-workers to make an initial benchmark of their practices and performance against world class parameters. The Master Class highlighted the task ahead and the need for urgent action. Above all was the recognition that restoring pride in doing a good job and winning the hearts and minds of those working on the site was a fundamental requirement if the change was to succeed. It was going to be a massive challenge, but one that had to be taken on.

Jane was also keen to expose her team to organizations that had faced similar challenges. One of the visits was to BP Grangemouth to learn about their site-wide Operations Excellence Program. Jane and her boss Tom Davidson were impressed by the stories told by the BP staff of how they had transformed their performance by engaging their first line people in the change process. Following this visit, Reliable Manufacturing was engaged to develop and lead a two year Change Management Process for Sembcorp, which would incorporate the engagement principles as seen at Grangemouth.

At the heart of the Change Process, which was led by Reliable Manufacturing's Andrew Fraser, were two main elements. Andrew described them, "The first element was a 'bottom-up' cultural change process at shop floor level aimed at engaging people and developing cross-functional working throughout the organization. This was followed by a 'top-down' process focused on aligning the management team and analyzing critical plant equipment and work practices."

## From The Bottom Up

The initial, and the biggest, priority was changing the organizational culture. Jane explained, "We needed to communicate the requirement for change to people who, from previous experience, had little trust in management. So, in early 2006, we launched a series of engagement workshops, running two workshops a month, for all of our employees". These workshops featured The Manufacturing Game, which was developed at DuPont Chemical Company in 1991 by Winston Ledet, Ph.D. and others as a tool to facilitate organization change. "The Manufacturing Game was an excellent way of engaging our workforce in the Change Process. The Game demonstrated the complexities of running our assets, how the decisions and actions in one area impacted on other departments, the value of cross functional working and the importance of eliminating thousands of seemingly insignificant defects from our operation."

During the workshops the participants discovered for themselves why there was a need for change and heard directly from Jane her vision for the site. "In addition to Maintenance and Operations staff, we included regular Contractors and staff from HR, Purchasing, Stores, Accounts and even IT. People were generally receptive to what I had to say and actively participated in discussions about the things we collectively needed to change."

Toward the end of each workshop, small cross-functional Action Teams were formed with the purpose of converting the discussions into concrete actions to eliminate defects from equipment and work practices. Since the start of the process, well over 200 Action Teams have been formed (see Figure 1, note data ends Nov 2007).

This approach encouraged a sense of per-

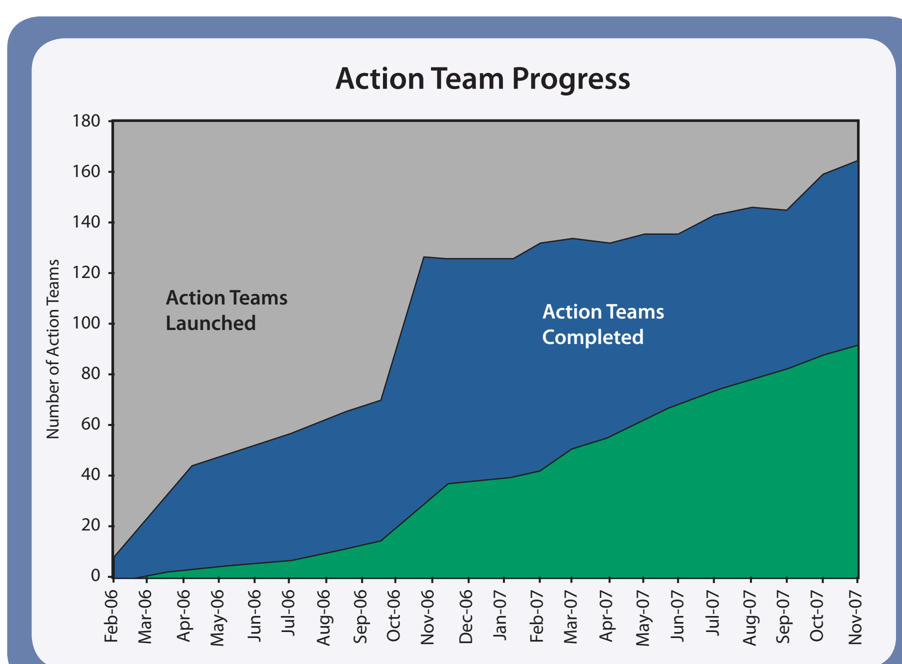


Figure 1 - Rapid involvement of the workforce in 'Action Teams'

sonal responsibility for making the changes, and fostered ownership and pride in the new standards being implemented. These three components - responsibility, ownership and pride – are critical to achieving cultural change in any organization, and Sembcorp proved to be no different.

Many of the teams have successfully tackled repetitive problems, which has delivered improved availability, cost reductions and improved Health, Safety & Environmental (HSE) performance. In addition, the improvements released manpower that had previously been repairing equipment, which now could be redirected to focus on more improvements. For example, An Action Team, led by mechanical fitter Dave Scope met about improving boiler availability by targeting coal mill feeder issues. One of the major causes of feeder failures was the unreliability of the chain tensioning unit.

Dave came up with an innovative re-design of the tensioning unit that addressed the problem, and as a result, reduced boiler downtime by 13 days per annum. Another Action Team, led by E/I Supervisor John Haveron, was frustrated that their daily plans were being disrupted by requests to provide temporary 110-volt supplies for portable tools used by contractors. Only fixed 50-volt supplies were available in the plant. The team purchased 110-volt transformers and positioned these at strategic positions throughout the plant. The result was a saving of over 400 man hours, as well as a reduction in hire costs. These and other Action Team successes required very little up front analysis and enabled Sembcorp to almost instantly put some 'rubber on the road'. Crucially as well, the creativity of the workforce was beginning to be tapped.

Following up on the workshops, a series of bi-monthly Reliability Forums were held. Attendees represented all aspects of the business, including frontline Maintenance and Operations people. The Forums helped to build momentum by providing people with recognition and encouragement as they presented their Action Team success stories. The Forums also provided the opportunity to identify and take action on barriers that needed to be removed to encourage more defect elimination. One such barrier discovered early in the process was the lack of communication regarding Action Team successes to those that were still not engaged in the change. A team set up for this purpose concluded that the best way to publicize successes would be by creating a reliability website. The website was established on the Company intranet and was positioned adjacent to the safety website to emphasise the importance of reliability and defect elimination. People can update progress on their Action Team directly. In addition to reading success stories, all staff can view which defects are being tackled, and who's involved.

As the Change Process gathered pace, further workshops were held to build organizational capability. These 'Supervising the Change' workshops were open to leaders and indeed anyone, irrespective of their position, who wanted to get more deeply involved. The workshops were particularly effective in helping to redefine the first line leader's role; moving from just coping with problems to identifying recurring defects and launching further Action Teams.

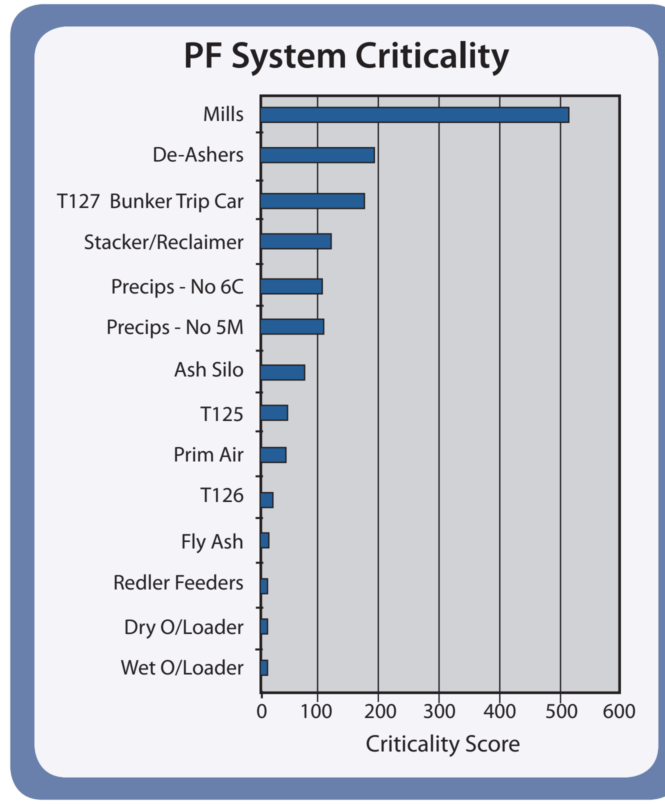


Figure 2 - Pareto Diagram from one of the criticality studies.

## From The Top Down

Once the bottom up cultural change was well underway, the next stage of the Change Process was to align the management team and identify critical systems and practices that needed improvement. Like many businesses, Sembcorp had limited resources to devote to improvement. In fact, many experienced personnel had been lost in a voluntary redundancy exercise in 2000, leaving the business significantly depleted. The current resource base was already stretched as it began to prepare for two back-to-back six yearly overhauls of the main boilers, which were scheduled to take three months each. So it was vital that the limited time that management had at its disposal was not wasted on secondary issues but was directed at addressing critical priorities.

In order to flush out the critical areas, a series of Criticality Studies and Practices reviews were facilitated. First, the site was divided into several areas and criticality studies carried out. The resulting information from one area of the site is shown in Figure 2.

"The criticality studies were a simple and effective method of identifying problematic equipment," Operations Plant Manager Steve Purvis explained, "The studies took into account both past performance and any potential changes to the condition or use of the equipment that could affect future performance. They helped us to allocate resources to the equipment that was having the biggest impact on the business."

In parallel with the criticality studies, a detailed review of Operations and Maintenance practices was conducted. This provided an in-depth understanding of how work was currently being carried out. This was compared to best practice standards, and priorities for action were identified. Unlike the Action Teams that were numerous and relatively small in nature, the improvement tasks emanating from the studies and reviews were larger in scale, typically requiring more management involvement and funding.

A series of Project Improvement Teams (PITs) were formed, each team with a specific

**Reliability PIT Charter**
**Topic - Fuel Oil System from the MS area up to 5 & 6 boiler burner fronts**

**Sponsor** - S. Purvis | **Leader** - S. Lax | **Team Members** - D Baker, R. McQuillan, N Hood, M Bean, E Middleton

**People to be Consulted** - J Atkinson, N Booth, D Heron, J Maclaren

**PURPOSE**

To ensure that the fuel oil system is kept in appropriate state of readiness so that it is available as a reliable fuel whenever it is called upon to be fired on 5 & 6 boilers

**BENEFITS**

1. Operating to a clear fuel oil strategy.
2. Reduced funning costs (parasitic load).
3. Reduced Maintenance costs.

**OBJECTIVES**

1. An agreed business strategy for the ability to burn fuel oil post gas firing ability on 5 & 6 boilers.
2. To rationalize the fuel oil system to reflect the business strategy.
3. To ensure that the fuel oil system is available when called upon to operate.

**Next Key Steps/Dates**

1. Arrange kick-off meeting with PIT members (Oct 07)
2. Review current operation (Oct 07)
3. Develop recommendation for future strategy (Nov 07)
4. Carry out criticality study on rationalized system (Nov 07)
5. Present & gain agreement for strategy from NB/JA (Dec 07)
6. Revise strategy to reflect NB & JA's comments (Dec 07)
7. Specify and deliver any system changes (Mar 08)
8. Review PSOI's, communicate changes (Mar 08)

**WE WILL ACHIEVE THIS BY**

1. Review of the current fuel oil operation.
2. Develop a recommendation for the future operational strategy.
3. Agreeing the future fuel oil operation strategy with the business.
4. Carry out a criticality study on the rationalized fuel oil system.

**RISKS AND ISSUES**

1. Unrealistic expectation of time to change over to oil firing.
2. Quantity of fuel oil held in storage tanks.
3. Aversion to calculated risk taking.

Figure 3 - Example of team charter to ensure clarity of objectives and responsibilities

charter (see Figure 3), sponsor, leader and team members. The teams were required initially to report progress on a monthly basis. However, although some teams made good progress, other teams struggled to balance meeting day-to-day needs and finding time for improvement.

It was recognized that resourcing was a critical issue, and this led to an external recruitment campaign to find additional key resources and skills for the business. However, obtaining new recruits and bringing them up to speed was, at best, going to be a six to nine month process, and in some cases much longer. In the mean time, a short interval control process was introduced to accelerate the delivery of results.

Everyday at 8:00am, Jane held a one-to-one update session with one or more of her direct reports, each of whom was sponsoring a PIT. Initially this commitment added more strain to those that were already fully loaded, but it helped to crystallize issues that were impeding progress and ensured that a documented action plan for the next seven day period was put in place. This proved to be a crucial step in delivering the results. As the bottom-up and top-down processes began to kick in, a Reliability Steering Group was formed to manage the overall improvement process. The steering group provided a key role in monitoring progress, identifying any gaps and ensuring the correct priorities continued to be worked on.

## Improvements

Sembcorp followed the Reliability Model shown in Figure 4 as an underlying core philosophy in tackling its performance issues. The model demonstrates that the root causes of reliability issues can be a result of factors in design, purchasing, stores, installation/start-up, operations or maintenance practices. Sembcorp has made substantial improvements to its operating processes using this model. Described below are a few examples:

**Coal Quality –** Contamination of coal supplies with metal objects and poor quality coal were found to be key root causes affecting mill reliability and boiler performance. Improvements to the coal specification, screening, metal detection and changes in supplier have been made.

**Mill Overhaul Procedure –** The quality of maintenance work on mill overhauls has significantly improved since the introduction of a detailed overhaul procedure complete with digital photos and hold points for engineering verifications and inspections.

**Lubrication –** External expertise was engaged to help make a step change in Lubrication standards. As well as improved quality of lubrication, the number of machines under a supervised lubrication regime has risen from 60 to well over 600.

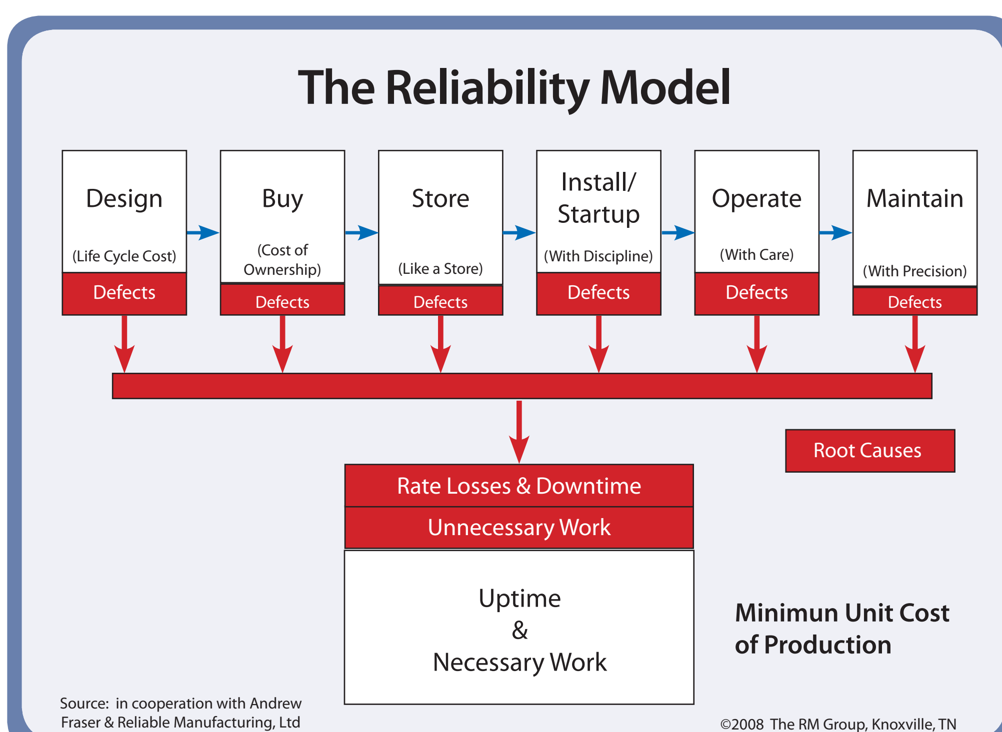


Figure 4 -The reliability model guided the improvement effort.

**Feedpump Operation –** There was a widely held view that the poor performance of boiler feed pumps was wholly due to the age of the pumps. However, upon closer inspection, a PIT team found they were able to improve performance by tightening up the operations procedures, particularly around start up and shutdown of the pumps. The value of cross-functional team working was demonstrated by the quick removal of a long-standing performance issue on one of the pumps. It came from one of the team members, who had not been previously involved, asking "a silly question".

**No defect, no job! –** It was common-place for work to be done on the basis of verbal requests. This often resulted in "who shouted the loudest" getting work done as opposed to what was most important. A key turning point in behavioral change occurred when the decision was made that no work would get done without a properly written and authorized request.

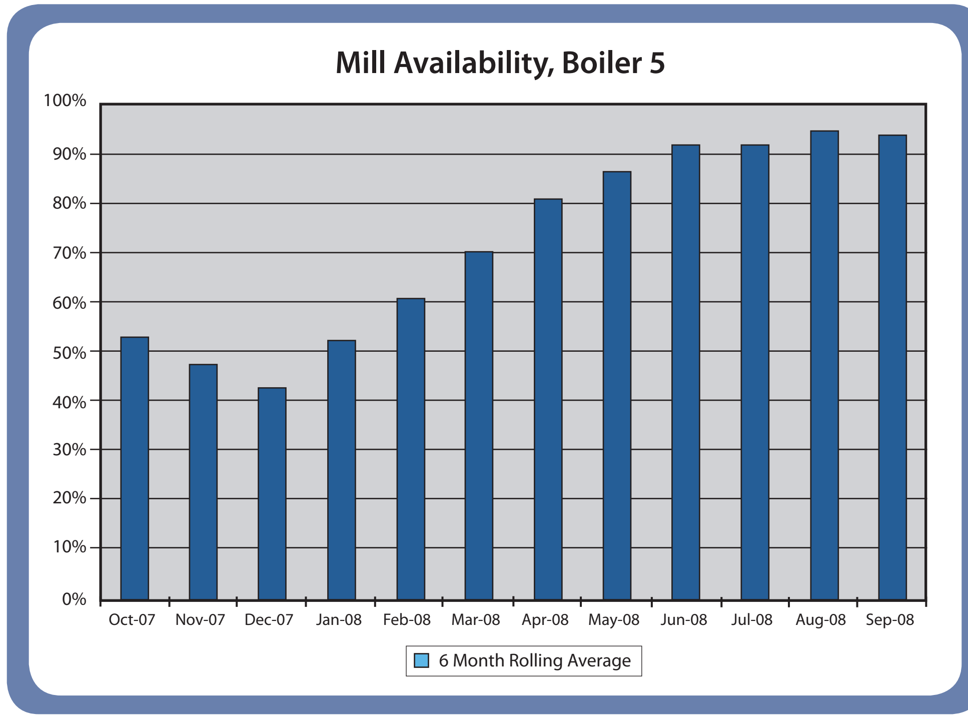

Figure 5 - Coal Mill Availability

**Defect Tagging –** Many people were frustrated that repairs, particularly to steam and water leaks, were not getting fixed as quickly as expected. The fact that it wasn't obvious whether a leak had been reported to maintenance was part of the problem. Following a visit to INEOS CHLOR, one of the major chlor-alkali producers in Europe, a visual defect tagging system was introduced. In addition to raising an electronic request for maintenance, the operator would tie a defect tag on the equipment. The tag description includes date, brief statement of the problem and name of the person who raised the request.

**Problem Solving Skills –** A standard system for root cause analysis was adopted across Utilities to provide a common language and process for problem solving. Criteria have been established which trigger when an investigation is required.

Figure 6 - Sembcorp, UK's Biomass Power Station uses wood (40% of which is recycled) from a variety of sustainable sources in the UK, to generate around 30 MW of electricity.

## The Results

Three years into the process and the huge effort expended by all of the team members, and other personnel, is more than paying off.

The culture has now changed, with everyone recognizing that they have a part to play. "At the beginning of the journey, we had a 30/70 split between people who were involved and supportive of the change and those that were not," Jane said, "Now the split is around 70/30, which not only makes my job easier, but is helping us to make much faster progress than we were in the early days."

Mick Trodden, a shift manager who left the company for a year, saw a definite change when he returned. "Things had certainly improved, there was a more positive atmosphere and pride seemed to have returned. You could tell that some serious work had been done on the reliability of the plant and equipment," said Mick, "The way it was operated and maintained had improved and procedures were once again being followed. Many areas had become cleaner and tidy work areas had returned."

Plant performance has also been transformed. Coal mill availability on one of the two main steam boilers increased by over fifty percent in a year (See Figure 5), along with a commensurate reduction in maintenance costs. At the plant level, overall steamboiler availability has increased by thirty percent. The process has also recently been applied to Sembcorp's new Biomass Power Station (Figure 6) - with spectacular results. In less than six months after applying the process, availability of plant more than doubled. (See Figure 7.)

With the combined bottom-up and top-down approaches to improvement, the application of the reliability model and a massive amount of effort by all staff involved, Sembcorp has taken a monumental step forward toward their overall goal of becoming self sufficient in steam supply to its Wilton Site customers. And almost as impressively, in spite of undertaking a huge amount of change, Sembcorp has continued to improve its excellent service levels to customers.

## People Perspectives

This major transformation effort has centred on the involvement of people. Here are some of the perspectives of key individuals who were involved in the change:

**Ron Moore**, Reliable Manufacturing's principal consultant, describes his initial impressions in 2005. "It was like 'stepping into a void'. There was a lack of drive, energy and leadership. There were huge challenges to deal with, which were compounded by the use of multiple power generation technologies, and multiple fuels including oil, gas, coal and wood chips. There were leaks of air, water and steam everywhere and a seemingly general acceptance of the chaos that was the normal day; many people were actually enjoying 'firefighting.'"

**Jane Atkinson** remembers shedding "blood, sweat and tears" during the process. She could see the major challenge they had in

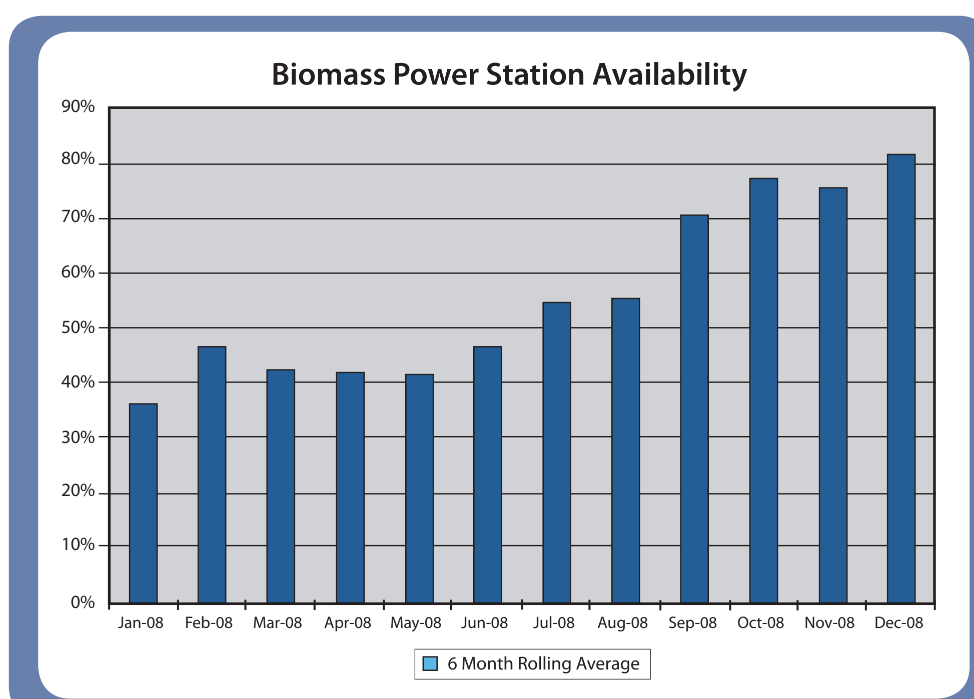

Figure 7 - Biomass Power Station Availability

front of them. Although she was confident it could be achieved, it was going to take a huge amount of dedication and hard work. And time was pressing. They were fast approaching the cut-off date for the end of the contract for importing steam. Her days were full – opening and closing workshops, followed by de-briefing and dealing with resistance from those who didn't understand the benefits and the process. She also had to cope with the skeptics who thought it was all a waste of time and it was probably only a 'flavor of the month' initiative. Sheer determination, and the fact that the alternative was neither acceptable to her, nor to the business, kept her going. She knew she had to make changes in the culture in order to move forward.

"As people were given responsibilities to lead key improvements, it became clear that the ability and enthusiasm of some people had been overestimated and so had the support of some of the senior management team, whom I needed to lean heavily upon in order to deliver the objective," she said, "As we learned more about people we made adjustments in the process to compensate." It was important to keep focusing on the positives. Seeing people change, and the way they were embracing the change, gave Jane and the team much needed encouragement.

**Andrew Fraser**, Reliable Manufacturing's Change Manager, reflects on the complexity of the challenge. "The strategy we developed for the project essentially remained the same throughout the change process. A key element of the implementation, however, was the discipline to review progress at regular intervals and take into account new information that had emerged since the last review. Some of this learning related to a better understanding of individual capability and some of it was the discovery of new and sometimes surprising supporters of the process throughout the organization. We took advantage of this new knowledge to modify our tactical plans as the implementation gathered pace."

**John Haveron**, I/E Supervisor, and **Andy Fisher**, I/E Planner, express how the process impacted them: "We got our Friday nights back! We used to hate Friday's. When everybody else wants to go home and start the weekend, we were often left trying to sort something out. This is the exception now, which is how it should be. If the business hadn't changed direction in the way it did we don't think we would be here today, we would have 'walked' or have been off sick. We were over-worked and battle weary from fighting to keep things going."

John and Andy also found value from getting to know people from other parts of the organization. "We met people like Paul McCann from purchasing who helped us sort out some problems we were having with gas bottles. Meeting people from other parts of the organization and sharing our issues made it easier to find solutions to our problems."

**Paul McCann**, Senior Buyer, shares his perspective, "The approach taken by Reliable Manufacturing was familiar to me, as this is an area I had studied at University. The Manufacturing Game got people involved and helped them realize how they were working and how this could improve. They became aware of the need for enhanced reliability at the plant and the impact of what they do on the business. Generally, they just became aware of the bigger picture and how they could make a difference. From my point of view, the forums opened up a huge internal network of people who I had not had the opportunity to meet previously."

Technical Plant Manager **Chris Plews** describes how they are having success in applying the reliability model to Sembcorp's New Biomass plant, commissioned in 2007. "When we saw the effect the process was having on our mature assets, we decided to adopt the process on our £64 million Biomass plant. Within months we were seeing dramatic improvements and it has helped us achieve record performance from the plant. We want to see reliability and defect elimination become second nature and part of the natural way we work. I only wish we had done this earlier, the benefits make me wonder why we didn't do this three or four years before we did".

The heart of the change process is empowering people to do a better job and contribute to the business. **Dave Scope**, Mechanical Maintenance Fitter, describes the change for him, "The whole process has been enlightening for me personally. It has made me aware, for the first time, that I am empowered to make a difference. I now know that I am empowered to turn my ideas into practice and make things happen. I have been exposed to methods of solving problems, flagging them up and having an input into the solution. I have seen the benefits brought about from mixing everyone together from across the different disciplines within the business to deliver benefit. "

"Through the forum, I have been able to show others what is possible and I am determined to keep on "picking fault" and challenging things with a view to pushing forward improvements continuously".

## The Future

The pride and enthusiasm is back in the business, but the journey is not over and will continue well into the future. The emphasis on reliability and defect elimination continues to have a high focus. Sembcorp is committed to strengthening their team at all levels by engaging people with expertise and enthusiasm to drive change. The recent recruitment of new people has brought fresh energy and helped to spread the load. The future is looking bright and Sembcorp UK is looking forward to expanding the use of this improvement philosophy in all of its operations. They have demonstrated how, in partnership with external expertise, they are able to bring an aging, run-down, heading for closure site, back to life. Sembcorp is currently looking at expanding its business by acquiring other major utilities sites in the UK and Europe. Reliable Manufacturing and Sembcorp look forward to using this proven strategy to help transform these sites too.

*Judith Charlton is the owner of Judith Charlton Consulting, an independent PR consultancy based in Cheshire, England. She has over 25 years experience in public relations working for high profile blue chip companies, including BNFL and Airtours Holiday. You can visit www.charlton-consulting.co.uk for more information.*

*Steve Lipscombe is managing director of marketing consultancy firm RONIN Marketing, based in London, England. More information is available at www.roninmarketing.co.uk.*

*Judith and Steve would like to acknowledge the generous contributions of time and effort of the following folks: Jane Atkinson, Terry Waldron, Steve Bishop from Sembcorp, and Andrew Fraser of Reliable Manufacturing (www.reliable-manufacturing.com).*

# Cloudy with a 100% Chance

## ....of Enhanced Operational Efficiency

*by Jonathan Hakim*

Software as a Service (SaaS), also commonly referred to as "cloud computing" or "on-demand services," is sweeping through enterprises in just about every industry. With SaaS, a customer licenses an application for use as a service on demand, either through a time subscription or a "pay-as-you-go" model, rather than purchase the hardware and software to run a standalone application on their own. In a SaaS model, customers need only a computer or a server to download the application and Internet access to run the software. While there is a considerable amount of hype around on-demand services, there are some very real advantages plants can leverage to enhance operational efficiencies, improve reliability and drive ROI up from their predictive maintenance and condition monitoring programs.

The catalyst behind increasing interest in on-demand services in manufacturing is plants' requirements for services that deliver reliable information and analysis, accessible anywhere in the world 24 hours a day, 7 days a week. SaaS technology enables this "always on" business culture and removes the responsibility of implementing and maintaining IT infrastructure, which require hardware investments, software licensing and support costs. Rather than spending time managing an IT network, plant managers are free to take on critical projects that will help them reach their reliability and uptime goals.

### The Cloud is Accessible to Everyone

One of the primary benefits of cloud computing is that only minimal PC and technical components are necessary because cloud computing resources remain on the remote data center site. In many cases, the web services deliver content to a thin client machine via a web browser. The client computer resource requirements are low, needing only a decent Internet connection to the data center and basic Windows components such as a Remote Desktop client and a modern web browser.

The first question many manufacturing companies have when it comes to adopting a new technology like SaaS is whether it will require major up-front capital investments. Oftentimes, even if the application or operating systems themselves aren't expensive, plants will need to prepare their current infrastructure for the new product's integration, which can lead to unforeseen costs. SaaS, however, is not one of those technologies.

### Look Beyond Cost-Savings to Business Benefits from the Cloud

Though SaaS has considerable cost benefits, plants that rely on the cloud solely for that reason are selling the technology short. The first, and most important, reason plants should evaluate SaaS for their IT infrastructure is because it enables managers and employees to better share the results of their maintenance and reliability efforts. Rather than sharing information amongst a small group in the engineering department, general machine condition health information can be accessed by all stakeholders in the enterprise or local plant. This way, the condition monitoring program does not operate in a bubble and is accessible to personnel from operations, management, maintenance and engineering who are then in a position to make informed decisions that affect plant production and outage planning. This sharing of information can ensure that the plant runs smoothly, and managers outside of the condition monitoring program always have the most current machine condition information.

For example, Air Liquide offers industrial gases and related services to a variety of customers including those in large industry, industrial manufacturing, electronics and healthcare marketplaces. With over 100 industrial locations in the U.S., Air Liquide benefits from cloud computing to integrate its plants with Azima DLI machine condition analysts via Azima DLI's WATCHMAN Reliability Portal. Rather than collect data from individual field engineers and compile it into reports, information is uploaded to the cloud where the information can be accessed and acted upon by both Air Liquide and Azima DLI expert analysts.

Remote access greatly enhances condition monitoring data analysis practices. Cost-cutting and lean manufacturing have led to a more distributed workforce including many remote employees. In this scenario, SaaS can have great benefits because isolated employees need only an Internet connection to perform a review or analyze work. For instance, ordinarily a technician would collect machinery health information on a data collector and download information at the end of the day to a terminal where it would then be stored for analysis. In a cloud computing environment, the worker can upload the information using a wireless network so remote engineers can review the data in near real-time, as well as store and retrieve data history and reports. This gives them the ability to accurately assess the situation on the ground rather than having to re-deploy a technician to fix a problem after they have come back from the field.

## Tackling Fear of the Cloud

Fear of cloud computing has been widely publicized within the media. In fact, according to the ISACA IT Risk/Reward Barometer survey, nearly half of the 1,809 US IT professionals surveyed said that the potential risks associated with cloud computing outweigh its benefits and that 25 percent of respondents do not plan to use the cloud for any IT services. This data is misleading because SaaS is a relatively new technology for the manufacturing industry, and the benefits and risks have not been clearly defined as of yet. The technology is maturing, but is still in its relative infancy and many companies are currently evaluating the technology to see how it fits within their IT infrastructure. Many of the claims made against SaaS are groundless and rooted in a fear of the unknown. With the right education and partner, a plant can easily become more comfortable about the safety, security and reliability of its data in the cloud.

The key to alleviating cloud fears is to evaluate the potential SaaS partner's network and security model and see how well it maps to the plant's infrastructure. The customer's IT department should be directly involved in these discussions from the start. They are truly the experts and have a specific set of criteria for their own enterprise network. Here is a quick list of questions you should be asking that are helpful in appraising a cloud vendor's security model:

- Do you clearly understand how the cloud computing offering works from the SaaS vendor?
- Does the vendor meet the IT security model of your plant?
- Does your plant have the delegated ability to control access to their system?
- Will your plant have clear lines of communication with the vendor for sales and technical support needs? Does the vendor have a structured change management and patch management process?
- Can I obtain a copy of my data if I need to?

## Flexible Cloud Deployment Models

An under-reported benefit to deploying cloud computing within your IT infrastructure is the flexibility it offers. While many companies wring their hands when thinking about sharing their sensitive information with a third party, SaaS technology has matured to the point where manufacturing organizations can put as much, or as little, data in the cloud as they are comfortable with at any one time.

ACME Industrial Services is an integrated plant reliability maintenance company that uses the cloud to centralize all of its field engineers, who are stationed all over the world. ACME's central facility in Hyderabad, India is fully integrated with the field engineers by using a predictive maintenance SaaS solution hosted by Azima DLI on the other side of the globe in Tukwila, Washington. At the central facility, engineers provide machine condition analysis support and the results are published within the cloud. Customers can then view detailed condition information for their machines within their local plants, rather than relying on spreadsheets delivered by email or other analog channels. In this example, the cloud provides an infrastructure that allows an Indian services company to streamline its workflow and better serve its clients from a central location.

An Australian premium provider of bearings, Continental Bearing Company (CBC), also leverages the cloud in a customer-facing application. CBC utilizes the cloud to connect their customers and field services technicians to analysts located throughout the United States. The analysis is executed on servers in the cloud allowing the results to be published instantly via Azima DLI's WATCHMAN Reliability Portal. This value added is branded with CBC's logo so the service is transparent to the Australian industrial market and helps establish CBC as a one-stop shop for Australia's bearings market.

Admittedly, cloud computing is still at nascent stages of adoption for predictive maintenance and condition monitoring initiatives, so we strongly recommend "doing your homework" along with implementing a thorough evaluation of a potential SaaS partner. Customer support, uptime and security protocols should be at the forefront of your discussions when evaluating vendors, especially if this is your first foray into the cloud. A good SaaS partner is critical as it will be the key in helping your plant achieve the performance and budget goals that will catch the eye of senior management and keep your predictive maintenance and condition monitoring programs running smoothly.

*Jonathan brings an extensive background in finance, business, and technology to Azima. He co-founded wireless bandwidth company A2Q and has advised many wireless and telecom start-ups. His previous positions include Director of the International Finance Corporation, as well as Managing Director at Lehman Brothers, where he was responsible for arranging financings for companies in Europe, the United States, and Latin America. Prior to that, he was Banking Editor of The Economist, interviewing many notable figures in banking and finance. He holds a Master's Degree from the London School of Economics and a Bachelor's Degree from Oxford University.*

# Up, Up and Away

## Taking Off with Aerial Infrared Surveys

*by Gregory R. Stockton*

The imagery (IR) from aerial infrared thermal surveys of facilities, complexes, campuses, military bases and cities can be used for many purposes. Systems like supply steam and condensate return lines, hot water lines, chilled water lines, supply water mains, distribution piping, storm water drains and sewer lines can be monitored by looking at surface temperatures/patterns. In the case of district heating systems, the distribution system can be flown rapidly and inexpensively to provide thermal data for asset management planning and predictive maintenance (PdM). As a result of finding and repairing leaks in the steam system, energy usage can be reduced with all the related benefits.

Leaks and insulation failure in overhead steam lines and underground steam lines (direct-bury lines and in steam tunnels), can result in less than optimal energy efficiency, especially when the steam leaks and line heat losses (see Figure 1), are undetected, inaccessible or difficult to find given the vast acreage at some facilities. The longer that a steam leak or excessive heat loss on a line and/or undetected draining of fluids (see Figure 2) goes undetected; the greater the energy loss, the more make-up chemicals have to be added and the more potential there is for negative environmental impact.

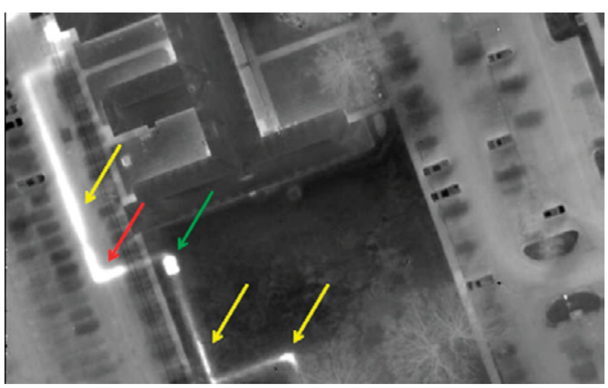

Figure 1 - Typical steam system heat losses. (Red is more heat loss than yellow and green is normally operating apparatus.)

Figure 2 - Steam line leaking onto the ground surface.

### Understanding Aerial Infrared

Aerial infrared can help monitor the steam distribution system so that those charged with the task, can better manage the assets. Checking the boilers, lines and steam traps inside buildings and inside steam tunnels are jobs best accomplished on the ground, but the distribution and condensate return lines are best surveyed from the air. Thermal contrast between active lines and the surrounding ground are usually good, depending on the depth of the line, temperature, flow and the materials covering the lines. The entire system can be flown, a mosaic thermal image produced and the areas with suspected problems can be pinpointed and documented. On-ground, hand-held IR surveys on all but very small areas within a system are time-consuming, labor intensive and produce small field of vision imagery and/or paint on the ground. Owing to recent developments in infrared technology and the availability of high thermal sensitivity/high spatial resolution (large format) thermal imaging systems mounted on an aerial platform, the on-ground survey has become outdated.

The methodology for taking aerial infrared thermographs is similar in many ways to taking aerial photographs. To collect the data, the aircraft flies over a given area with a camera mounted to the airframe and oriented looking straight-down to the ground (NADIR). The imagery is stored on a computer hard drive and later post-processed. Where aerial infrared thermography differs from aerial visible photography is the time of day when the survey occurs and the wavelength of the imagery that the detector collects. IR thermography of ground objects is performed at night. Thermography reveals sources of heat and the relative differences in heat from one object to another.


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# Background IR Imagery Info

Infrared imagery is a grayscale picture whose scales (or shades of gray) represent the differences in temperature and emissivity of objects in the image. Typically, objects in the image that look lighter are warmer, and those that look darker are cooler…bright white objects being the warmest and black objects, the coolest.

Any object with a temperature above absolute zero (0 Kelvin or –273 degrees Celsius) emits infrared radiation. An infrared picture only shows objects which emit infrared wavelengths in the 3000-5000 nanometer (mid-wave) range or 8000-14000 (long-wave) range. Objects in visible light wavelengths of 400 to 700 nanometers are detected, but only because they also emit heat. An example of this would be a street light that can be seen in the IR imagery because the ballast and bulb are warm.

Infrared imagery is usually recorded on digital media and later copied to DVD-Video, videotape and/or captured as digital image files. The images may then be modified in a number of ways to enhance their value to the end-user, such as creating false-color images and/or adjusting the brightness and contrast of a grayscale image to be used in a report.

## Steam Leak Infrared Surveying

Steam and condensate return lines are almost always readily visible with infrared imaging, even when no notable problems exist. This is due to the fact that no matter how good the insulation, there is always heat loss from the lines which makes its way to the surface. Problem areas are generally quite evident, having brighter infrared signatures (see Figure 3) that exceed the norm.

Steam line faults normally appear as an overheated line or as a large hotspot in the form of a bulge or balloon along the line. Overheated lines often occur when the steam line is located in a conduit or tunnel. If there is a leak in the line, it will heat up the conduit with escaping steam. If a steam line is buried directly in the ground with an insulating jacket, a leak will usually saturate the insulation, rendering it largely ineffective and begin to transfer heat into the ground around the leak, producing the classic bulge or balloon-like hot area straddling the line.

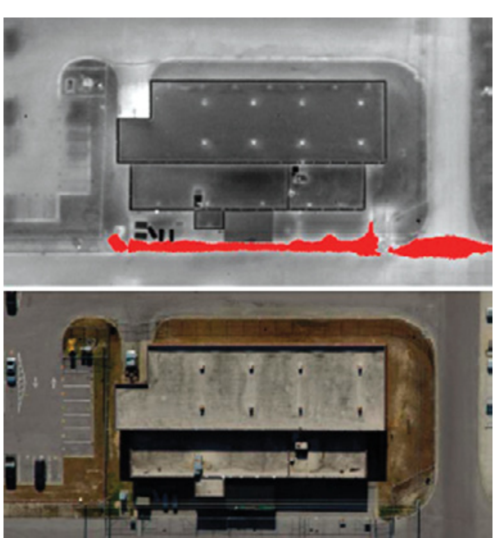


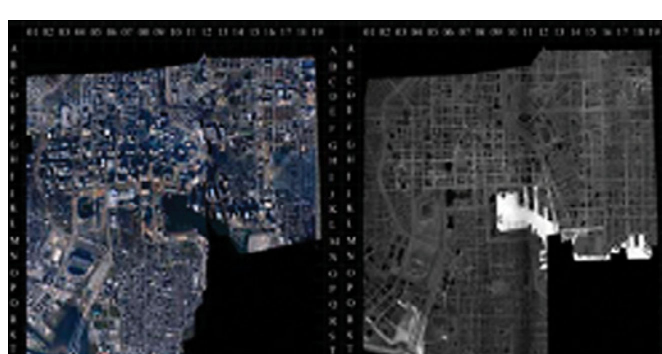
Figure 3a (top) and 3b (bottom) - IR and visual image of a steam line with leak colorized red.

Some leaks show up as an overheated manhole or vault cover. Manholes or vaults that contain steam system control apparatus which are leaking, will often heat the covers to warmer than normal temperatures. Unless these leaks are severe enough to significantly raise the manhole temperature above their normally slightly elevated temperatures, these leaks can be difficult to identify.

In fact, steam line infrared imagery can be a little misleading, unless one understands and interprets the relative brightness and temperature of a given line correctly. For instance, a steam line that is the same temperature from one end to the other that passes under different surfaces and materials can exhibit a variety of real and perceived temperature variations. Five different apparent temperatures will result from the same temperature line that runs under a grass-covered field, an asphalt roadway, a concrete loading dock, a gravel-covered parking lot and a bare earth pathway.

## Thermal Mapping, Ortho-Rectification and Post-Processing

Using a non fixed-mounted high-resolution thermal imager to survey a couple of buildings or a few thousand feet of underground lines can be done by flying over and locating the target(s) in the imagery, saving the data and putting it together into a report. This works for very small areas, but it is not possible to make precise thermal maps of a whole complex, campus, military base or city (see Figures 4) without ortho-rectification of the imagery. In order to produce ortho-rectified thermal maps, much more information must be gathered and tagged to the IR imagery. During the flight, the aircraft flies straight, smooth lines on a pre-planned grid, allowing overlap and sidelap of the imagery. The IR operator manages the sensor data-acquisition following a structured checklist for orderly data file management. The imagery must be collected with a precise direct-digital timing system, a 3-axis ring-laser-gyro and an inertial navigation system (INS), which is tightly-coupled to a real-time differential GPS satellite positioning system that provides x, y, z positioning of the sensor at all times.



Figures 4a and 4b - Mosaic visual and infrared imagery of a city steam distribution system.

After data is collected, the digital infrared imagery is processed into a series of ortho-rectified image tiles, which are then stitched together to create a giant mosaic image. A computer system puts all this information together using a digital elevation model (DEM) of the scene that consists of a uniform grid of point elevation values and the position and orientation of the camera with respect to a three-dimensional coordinate

Figure 5 - Mosaic infrared image (geo-TIFF) of a small college.

system output. The result is presented as a high-resolution thermal image in the form of a geo-TIFF (see Figure 5), which is compatible with any GIS software such as ESRI ArcView™, AutoCAD® Map 3D, Global Mapper, MapInfo™, etc. Once high quality digital thermal and photographic ortho-rectified maps are created, they can be added as layers of other data sets, to existing or new CAD and GIS systems. Digital data can also be post-processed in other ways, such as creating false color imagery to highlight areas of interest, adding temperature data and/or creating graphic reports (see Figure 6).

## Qualitative v. Quantitative Evaluations

The imagery approach described above is qualitative. It identifies and locates problems in steam systems based on their anomalous heat signatures. This is low-hanging fruit with regard to return on investment. Now, this method does not quantify the amount of heat loss. In order to develop quantitative information, if desired, some additional work is needed in the form of additional field effort in the infrared data acquisition phase combined with heat transfer analysis of the steam distribution system.

To understand the quantitative approach, it is necessary to understand how heat moves and the factors affecting its transfer, as well as the physics involved in determining the infrared signature. In order to know exactly what the radiated energy of any object is, the characteristics of the sensor, atmosphere and the target must be taken into consideration and one must know the transmission, emissivity and reflectivity of the target. There are big differences in the emissive qualities of concrete, asphalt, grass, dirt, etc. The ability to obtain quantitative measurements is built into a radiometric imaging system, so one must use a radiometric infrared camera to collect the imagery, and in a form that can be post-processed.

Heat energy moves by conduction, convection and radiation. In order to make meaningful quantitative thermal calculations, the pipe's or pipe's content's temperature, insulation properties and the complete thermal properties of all the materials in the ground (specifically heat capacity, thermal conductivity, and density) must all be known and made part of the calculation. As-built drawings and the thermal properties are not always readily available, if available at all. This generally means that estimates of the heat loss, implications of temperature values obtained, and quantitative evaluation of the pipe's performance can only be developed as estimates.

Even though some large format thermal imaging systems are fully capable of accurate radiometric measurements and rapid frame-by-frame digital temperature data acquisition of every pixel of every IR image, the cost of quantitatively gathering measurements and using steady-state and transient heat transfer analysis calculations (typically done with FEA or finite element analysis), make quantitative measurement a more expensive step, than simply using the image data to make judgments based on experience of the person analyzing thermal data. Most of the time, identifying leaks and excessive line heat loss is straightforward, but making calculations regarding insulation effectiveness and other qualities is an additional step that adds cost, which may add value, but also could offer a lower return on investment. In other words, grab the low-

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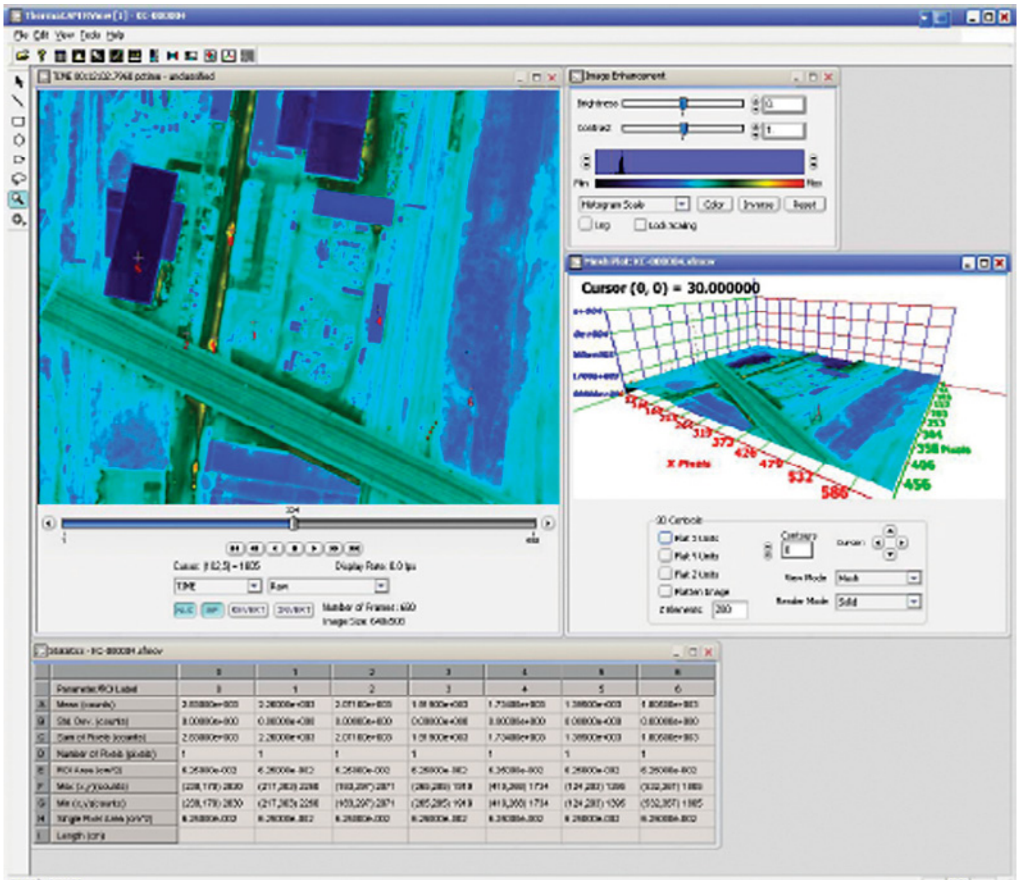
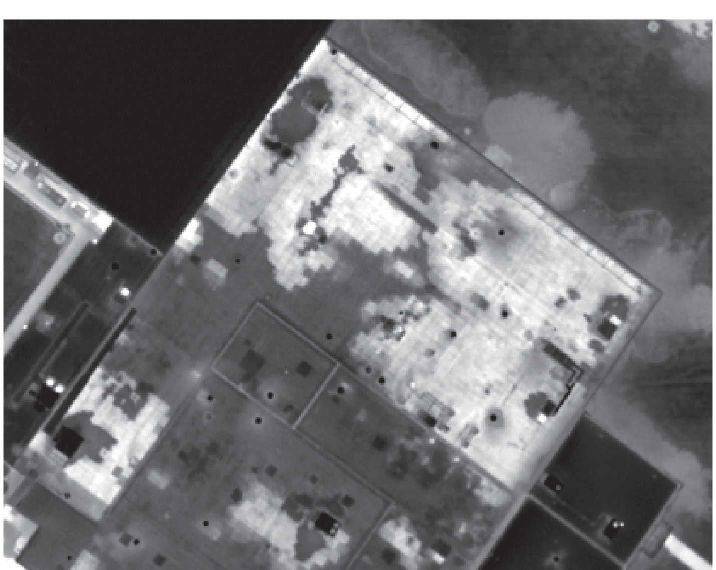



Figure 6 - Colorized thermal imagery and post-processing example.

hanging fruit first by identifying leaks, and if you have a known issue (or find one) requiring quantification, then post-process the thermal data. If you expect to need quantification, it is wise to plan it ahead of time since it will slightly affect the methods used for IR image acquisition.



Figures 7 - Thermal image of a flat roof (wet areas are lighter).

## Ancillary Benefits

Safety is improved, asset reliability by condition monitoring can be achieved and wasted energy can be saved by aerial IR imaging, analysis and repairing the steam distribution system. Creating a 'thermal map' of a given area has benefits far beyond that of just steam. A thermal map helps asset managers in the analysis of many other types of systems, such as HTHW (high temperature hot water) lines, MTHW (medium temperature hot water) lines, LTHW (low temperature hot water) lines, CHWS (chilled water supply), CHWR (chilled water return), supply water mains, storm water drains, sewer lines and any other distribution piping. Also, Electric power lines and substations can be surveyed to point maintenance personnel at the facility to electrical problems.

Drawing the entrained moisture in flat and low-sloped roofs on a CAD drawing with surgical precision provides a significant predictive maintenance benefit. Roofs are an expensive and onerous asset to maintain. Entrained moisture (see Figure 7) in the insulation and other roof substrates is indicative of leaks into the roof substrates, seam and flashing failures.

However unfortunate, 'wholesale' building heat loss surveys cannot be accomplished with a NADIR thermal survey, primarily because most building roofs are decoupled from the heat loss of the building, either with ventilation, with insulation or by being so reflective that they are immeasurable with IR sensors. Oblique aerial or on-ground, right-angle infrared surveying of the walls will be necessary to accomplish building heat loss surveys.

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# The Effectiveness of Quality Filtration

**Focusing on In-Situ Filtration and Filtration of Stored Lubricants**

*by Paul Dufresne, CLS, CMRP*

In the current global economic market companies are trying to find new and innovative ways to reinvent themselves to run more efficiently and increase production while minimizing equipment downtime. Now more than ever, plant managers, and maintenance and reliability leaders are looking for ways to improve equipment reliability, optimize maintenance and reduce energy consumption. Many are doing so by challenging current methods and experimenting with new ideas. While many focus on the obvious lubrication techniques (5 R's), many are missing key opportunities when it comes to the quality of their plant filtration program.

Prior to tackling any kind of filtration opportunities, you must first develop a plant filtration standard that addresses the individual needs of your equipment, and ultimately, tie into your plant reliability strategy. Many plants fail to address the need for a plant filtration strategy and take a one size fits all approach when it comes to filtration.

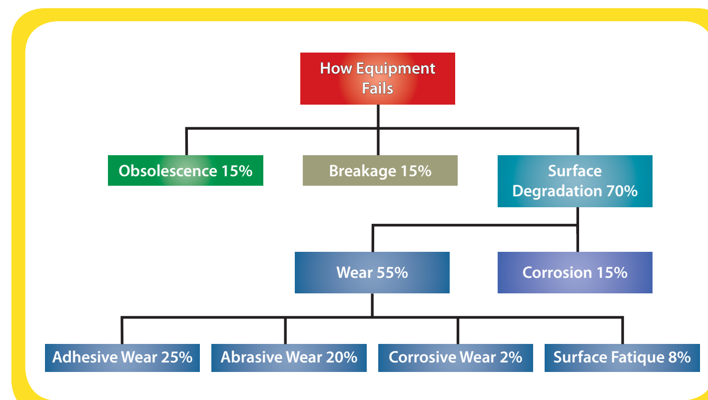


Figure 1 - How Equipment Fails Flow Chart
Rabinowicz, 1981.

## Fluid Cleanliness

As we start discussing the effectiveness of a quality filtration program we need to start with what is "Fluid Cleanliness". Fluid cleanliness or lubricant cleanliness refers to the absences of contamination. Microscopic particles are the most harmful form of contamination in lubricants. They can irreversibly damage bearing surfaces, shorten life of equipment and cause early unexpected equipment failure. The saying "New Oil is not Clean Oil" is correct in most cases. The concentration of particles in "new drums" and in bulk deliveries can be extremely high, and if not monitored and addressed, will ultimately lead to premature equipment failure.

Understanding how equipment fails is the first step in establishing a quality filtration program as part of the overall plant lubrication program. Internal surface degradation is the cause of over 70% of equipment failures (Figure 1), according to one study conducted by Rabinowicz of M.I.T.

There are four basic types of wear: adhesive, abrasive, corrosive, and surface-fatigue.

The most common type, adhesive wear, arises from the strong adhesive forces that are generated at the interface of two solid materials. When solid surfaces are pressed together, intimate contact is made over a number of small patches or junctions. During sliding, these junctions continue to be made and broken, and, if a junction does not break along the original interface, a wear particle is formed. These particles eventually break away. Adhesive wear is undesirable for two reasons: first, the loss of material will eventually lead to deterioration in the performance of the mechanism; and second, the formation of large wear particles in closely fitted sliding members may cause the mechanism to seize at an early stage in its productive life. Adhesive wear is many times greater for un-lubricated than for effectively lubricated metal surfaces (Fig 2 and Fig 3).

Abrasive wear occurs when a hard, rough surface slides over a softer one, producing grooves on the latter. It also can be caused by loose, abrasive particles rolling between two soft sliding surfaces or by particles embedded in one of the opposing surfaces. Abrasive fragments borne by a stream of liquid or gas may wear down a surface if they strike the surface at high speeds. Since abrasive wear takes place when the abrading material is rough and harder than the surface to be abraded, it can be prevented either by eliminating the hard, rough constituent or by making the surface to be protected harder still (Figure 4).

Corrosive wear occurs whenever a gas or liquid chemically attacks a surface left exposed by the sliding process. Normally, when a surface corrodes, the products of corrosion (such as patina) tend to stay on the surface, thus slowing down further corrosion. But, if continuous sliding takes place, the sliding action removes the surface deposits that would otherwise protect against further corrosion, which thus takes place more rapidly. A surface that has experienced corrosive wear generally has a matte, relatively smooth appearance.

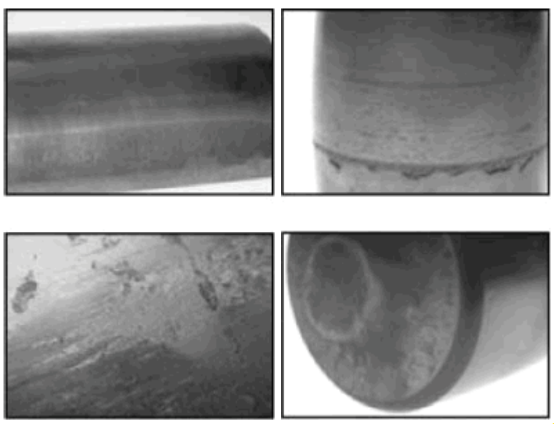

Figure 2 - Damage to bearings due to adhesive wear.

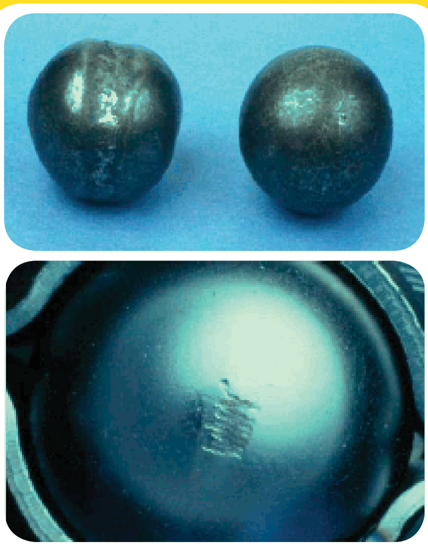

Figure 3 - Damage to bearings due to particulate within lubricating oil.

Figure 4 - Damage to bearings due to abrasive wear.

Surface-fatigue wear is produced by repeated high stress attendant on a rolling motion, such as that of metal wheels on tracks or a ball bearing rolling in a machine. The stress causes subsurface cracks to form in either the moving or the stationary component. As these cracks grow, large particles separate from the surface and pitting ensues. Surface-fatigue wear is the most common form of wear affecting rolling elements such as bearings or gears. For sliding surfaces, adhesive wear usually proceeds rapidly enough that there is no time for surface-fatigue wear to occur (See Figure 5).

By understanding what the four basic types of wear are, and how they originate, we can then start to address the proper filtration requirements needed to maintain proper equipment life. If we address new oil delivery, proper storage and handling practices, ventilation and breathers, sealing issues, service and built-in debris and clean reservoirs before filling with new oil we can combat contamination ingression. It is important recognize and understand that the cost of excluding a gram of dirt is approximately 10% of what it will cost to remove it once it gets into the oil.

## Examples of Fluid Cleanliness

As part of your plant reliability program you must address the proper fluid cleanliness targets for each family of equipment such as pumps, gears, hydraulic systems, turbines, etc. Hydraulic fluid is normally cleaner than gear oil since the dynamic clearances in hydraulic systems components is much tighter than those in a gear case (See Figure 6).

Following the ISO (Solids Contamination) cleanliness code test ISO 4406:99, targets the particle size of 4$\mu$m, 6$\mu$m, and 14$\mu$m micron. This is usually presented as a three part series of numbers like 18/16/14. The lower this number the cleaner the overall oil is. A typical cleanliness code for new oil delivered to a facility can range from as high as 19/17/15 or higher down to 16/14/12 depending on the manufacturer. Based on the dynamic clearances of your equipment this "New Oil" being delivered to the plant, although it may meet the test criteria to be called the specific oil, in most cases, will it not meet the cleanliness criteria based on the dynamic clearances of your equipment. The best way to identify the initial cleanliness of your "New Oil" is to pull a sample of oil from one drum of each brand of oil when it comes into the plant. You don't have to sample every drum of oil, but you should pull random samples from each family type of oil you use. By understanding this you can now start to identify the proper filtration level you want to attain per family of equipment.

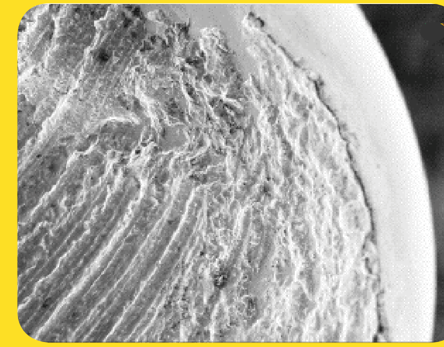

Figure 5 - Damage to bearing due to surface Fatigue.

| Component | Clearance |
|---|---|
| Roller Element Bearings | 0.1 to 3 microns |
| Journal Bearings | 0.5 to 100 microns |
| Gears | 0.1 to 1 micron |
| **Engines** | |
| Ring/Cylinder | 0.3 to 7 microns |
| Rod Bearing | 0.5 to 20 microns |
| Main Bearings | 0.8 to 50 microns |
| Piston Pin Bushing | 0.5 to 15 microns |
| Valve Train | 0.0 to 1 microns |
| Gearing | 0.0 to 1.5 microns |
| **Pump, Gear** | |
| Tooth to Side Plate | 0.5 to 5 microns |
| Tooth Tip to Case | 0.5 to 5 microns |
| **Pump, Vane** | |
| Vane Sides | 0.5 to 13 microns |
| Vane Tip | 0.5 to 1 micron |
| **Pump Piston** | |
| Piston to Bore | 5 to 40 microns |
| Valve Plate to Cylinder | 0.5 to 5 microns |
| **Servo Valves** | |
| Orifice | 130 to 450 microns |
| Flapper Wall | 18 to 63 microns |
| Spool to Sleeve | 1 to 4 microns |

Figure 6 - Dynamic Clearances in Design of Components

## Bearing Life and the Effects of Contamination

Like we already know, bearing life is greatly reduced in the presence of contaminated lubricants. However, if we want to improve bearing life and equipment reliability, we must understand the relationship between lubricant contamination and bearing life. Many factors can impact the overall life of a bearing, for example: speed, load, and contaminated lubricant. The basic life or L10 life as defined in ISO and ABMA standards, which is typically given in years, is the life expectancy of the bearing with a probability of 90 percent under given stressing conditions (load, speed, etc.), before the bearing fails due to fatigue. In other words, out of a population of 100 bearings, at least 90 of those bearings should reach their L10 life.

Let's address how one of the most common contaminants, water, affects bearing life. Many studies have been conducted over the years to address how water contamination has a drastic impact on the life of a lubricant. First, where does the water come from? The majority of moisture that enters the oil comes from the following:

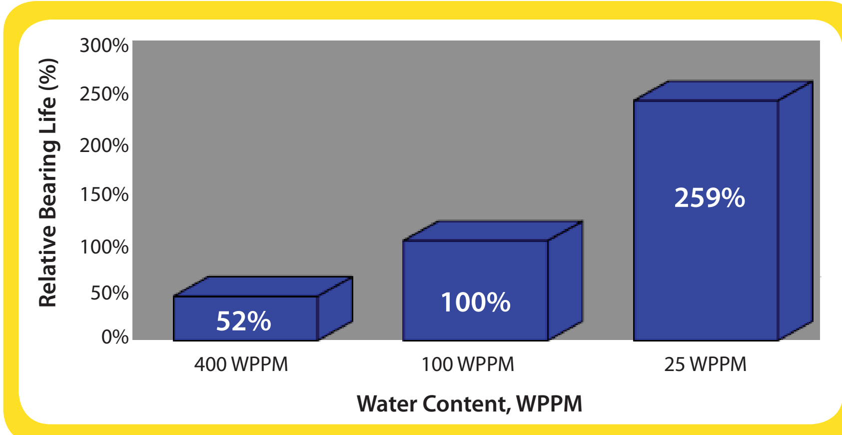


**Figure 7 - Relative Bearing Life vs. Water Content**

- Pressure differential between the equipment housing and surrounding environment
  - » Housing temperature fluctuations
    - – Frequent on/off conditions
    - – Process fluid temperature changes
    - – Outdoor use
    - – Air flow over the equipment/reservoir
- Through system vents and breathers
- From coolers and heat exchangers
- Precipitation
- Introduction of contaminated top up fluids
- Rain entering outside storage reservoirs
- Rain entering into barrels stored incorrectly

Water effects on the life of a bearing are as follows. Many bearing manufacturers recognize that if you have 100 ppm water concentration in your oil that you're bearing life ration is 1%. If you increase the water concentration to 400 ppm, you just reduced the bearing life to .52%, cutting the life of the bearing in half. On the other hand if your water concentration is 25 ppm your bearing life is approximately 2.59%, increasing the bearing life to over 2 ½ times (See Figure 7).

By understanding how water contamination happens and the effects it can have on your equipment, strategies can be developed and implemented to combat these issues. By using proper storage & handling techniques and sound filtration principles and standards, you can keep you oil in pristine condition. By doing this you will not only reduce equipment failure but also increase your equipment uptime. Remember, if you keep your oil clean, cool and dry it will last for a lot longer period of time.

## Implementing a Filtration Program

As you start to develop your plant filtration program you must decide first what level of filtration you want to achieve and then develop your plant filtration standard operating procedure (SOP). The reason for this is you need a roadmap for success for your plant filtration program. In most plants, there are a variety of both low and high viscosity fluids. What what filtration standards and practices are necessary will depend on the type of fluid and the application for which it is used.

The first priority in your program should be the identification of your major family types. Next, you determine to what level of filtration you want to pre-filter the oil and to what level of filtration you want to maintain on your system. In developing this you must go back to the dynamic clearance chart for your equipment. Once you have identified the dynamic clearances for that family of equipment, you can then look for the correct filter for that application.

The next priority in developing your program is to identify the necessary equipment needed to execute your program. The main item needed in your program is a filtration unit. The most common type of these is a portable filter cart. The versatility of these units is second to none, but their downfall is they too are a piece of equipment that must be maintained. All too often they are a forgotten part of the program and are only remembered once an issue has been identified. These units are available for filtering low viscosity oils as well as high viscosity oils. The key is to pick the correct unit for your specific application. This step is your greatest opportunity to remove contamination particulate (Silica, Water, Metal Catalysts, etc.) before it gets into your equipment. Again, the cost per gram of removal before entry to equipment is approximately 10% of the cost once it gets into your system. Once the contamination ingression has occurred the cost for removal can be staggering. These units also give you the ability to filter lubricants that have been stored for extended period of time. These units may also be used on oil that is already in service. By using portable filtration you can easily address your In-Situ filtration requirements. These are usually identified from an oil analysis report, system issues, etc. By using a portable filter unit you can address your lubrication filtration needs and continue to operate your equipment. This will also allow you to take proactive measures to maintain lubricant health.

The next issue you must address is the ability to minimize the potential for cross contamination. This happens when there is only one unit that is available and improper flushing procedures are followed. The optimum is to have a low viscosity unit available for each family type of lubricant you maintain in your facility. Of course, I understand that we all do not operate in a in an optimum environment and we all have budget constraints. If that is your situation, and you still have the desire and drive to improve your program, make sure that you purchase the equipment that will meet all your needs. Then make sure you not only have very detailed flushing procedures, but that they are followed to the letter.

Once you have developed your program based on the needs of your equipment and identified and purchased the equipment necessary to implement your program, the final piece is training for your lubrication technicians. Not only should the training be on the equipment in your program, but also on your standards and practices; for it is these documents that are the foundation for your program.

## The Move to Proactive Maintenance

Now that you have your filtration equipment in place and your plant personnel trained, the last step is your move to a Proactive Maintenance Strategy. By applying oil analysis technology in your program, sampling new oils, sampling lubricants already in use, etc., you now have the ability to let your oil analysis direct your future maintenance activities. Once you have qualified your equipment into your oil analysis program based on criticality of assets and identified the correct test slates per family of equipment, you can start the move to the proactive approach. Ensure that you identify both upper and lower caution and critical limits for trending.

Do not fall into the traps of having a poor strategy when it comes to oil analysis. Do not wait until you have a problem with a machine and then decide you need to get oil analysis involved. Ensure you avoid the following:

- Too infrequent analysis intervals
- Improper Sampling Techniques
- Poor data sent to the Lab
- Delay in getting samples to the lab
- Incorrect test slates per family of equipment
- Lack of knowledge reviewing oil sample reports
- Failure to integrate oil analysis with other PdM technologies

By doing these things you can grow your program into a "Best Class" lubrication program. Although lubrication is only one pillar of the program, it is critical that you get it right if you want to have success in your overall program.

## Conclusion

By understanding the four common wear modes and how and why your equipment fails, it is easy to see the importance of having a quality plant filtration program. In order to achieve a world class program it is important that the groundwork is laid by first developing the standards and procedures for your program, and second, identifying and purchasing the necessary equipment needed to implement it. Last, it is paramount that a solid training program is implemented to train technicians, not only on the equipment, but also on the new policies and procedures. Once this training has been completed, the technicians will have the tools, training and the confidence to go out and execute solid lubrication fundamentals that you can build a quality filtration program on. Following these steps will also ultimately catapult your company to what should be the ultimate goal, that is, to move your plant to a Proactive Maintenance posture.

*Paul Dufresne is an industry leading expert in the area of plant lubrication and equipment reliability. Paul is a Distinguished Military Graduate from the University of Central Florida and holds a Certified Lubrication Specialist (CLS) rating from the Society of Tribologists and Lubrication Engineers; Certified Maintenance Reliability Professional (CMRP) rating from the Society of Maintenance and Reliability Professionals. Paul can be reached at paul.dufresne@hotmail.com*

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# Guidelines to a Good Motor Repair

## A Good Motor Repair is a Two-Way Street

*created through a collaborative effort led by Advanced Energy*

In the late 1990s a group of industry experts worked collaboratively to produce a document that any facility can use to better understand and communicate with their motor repair vendors. This group consisted of utilities, government, motor manufacturers, and the motor repair industry and energy efficiency advocates. Each participating company is noted in the resulting document "Guidelines to a Good Motor Repair."

Good motor repairs should maintain the efficiency level of the motor before its failure and last for a significant amount of time when placed back into operation. While this may seem obvious to many, the steps required in the repair process and the information needed to be shared between the motor service center and the motor user requesting the repair may not be as obvious. The document below provides a framework for motor users to consider when requesting repairs, and for motor service centers to execute when repairing electric motors.

## Guidelines To A Good Motor Repair

Having a clear understanding between you and the motor service center will produce a much more satisfactory experience.

It will help if you can provide the following information or answer the following questions:

1. Complete nameplate information including manufacturer, horsepower, speed, voltage, phase, enclosure, catalog, part and/or model number, frame size and serial number.
2. What does the motor operate (a fan, blower, conveyor belt, pump)?
3. How does the motor drive the load (direct drive, belted)?
4. Is there auxiliary equipment attached like a clutch, gearbox or brake?
5. Why do you think the motor needs repair (it smokes, it doesn't run, it needs preventive maintenance)?
6. What is the motor's past repair history? Is it a "problem motor"?
7. How is the motor started (across the line, soft start, adjustable speed drive (ASD), part winding start, wye start, delta run)?
8. What is the operating environment (indoors, out doors, subject to hazardous fumes or dusts, water spray)?
9. When do you need the motor back? Will you authorize overtime work if necessary?
10. Is the motor still under manufacturer's warranty?

You should expect the motor service center you select to provide answers to these questions:

**1. What are my repair/replacement options?**

In the case of standard motors, repair may not always be the best option. The motor service center should be able to offer premium efficiency replacement alternatives to repair which may save you operating dollars. Bear in mind, however, that many motors are special and not readily available off the shelf. This may make repair the best option. Discuss this with your service center.

**2. Do you have experience in repairing this type and size of motor? Do you have access to similar replacement motors?**

The motor service center probably specializes in certain sizes and types of motors (AC and/or DC, vertical pump motors, single or three phase motors, gear motors). If the motor is an ordinary one, they should be able to offer replacement models to meet your needs in a timely manner.

**3. How can we get the motor in for repair?**

Most service centers will pick up the motor. In some cases you will have to deliver it to them. In the case of a very large motor or a motor that is located at a remote site, some coordination with a crane or other material handling equipment may be necessary. Some service centers are also licensed contractors and will install and/or remove the motors for you. If not, they may be able to suggest a qualified contractor who can perform these services, if you need them.

**4. What standards will you use when repairing my motor? What is your warranty?**

Many motor service centers are members of the Electrical Apparatus Service Association (EASA) and perform repairs to the EASA Recommended Practice for the Repair of Rotating Electrical Apparatus. A clear understanding of the warranty offered will help avoid disagreements later. Remember that a warranty is only as good as the company behind it.

**5. Are you an authorized warranty shop for this motor?**

If the motor is under warranty, be sure the shop is authorized to perform warranty work.

After the motor has been inspected, you should expect to be told:

**1. What is involved in the repair.**

The service center should tell you if the motor needs rewinding or just bearing replacement and clean up. They should tell you what tests they performed to substantiate these findings.

**2. How long it will take to complete the repair.**

Remember, a good repair, including rewind, can take several days or more. Cutting corners on repair can cost you money and even result in premature motor failure.

**3. What the repair will cost.**

You should expect to receive an accurate cost estimate for the repair. Remember, however, that repair costs can vary once the shop actually starts the repair because they may find hidden problems that were not readily apparent on their first inspection. Be prepared to work with them to obtain the best repair possible.

**4. What your options are.**

Many service centers can offer repair/replacement options. In some cases the motor — because of its age or type — may not be readily or economically replaced. In other cases, a new motor may be the best way to go. If the motor was designed specifically for an OEM, the replacement may have to come from the OEM. Work with your service center to find the best solution for you.

### A good motor service center **SHOULD**:

1. Conduct a stator core test before and after winding removal. This will assure that the core has not been damaged during repair.
2. Repair or replace defective stator core laminations.
3. Calibrate all test equipment and measuring devices at least annually against standards traceable to the National Institute of Standards and Technology (NIST) or an equivalent standards laboratory. This will insure the accuracy of the readings taken during repair.
4. Measure and record winding resistance and room temperature. The resistance measured in all three phases should be balanced. If it is unbalanced by more than 5 percent, the motor should be tested further. It may need rewinding.
5. Have the appropriate power supply for running the motor at rated voltage. Measure and record no-load amps and voltage during the final test. Tests at reduced voltage may not reveal certain motor problems.
6. Have a quality assurance program. This will ensure that you get the same quality of repair each time.
7. Have and use, at a minimum, the following test equipment: ammeter, voltmeter, wattmeter, ohmmeter, megohmmeter, high potential tester. Other useful test instruments include surge testers, core loss testers, dynamometers, tachometers, vibration meters and milliohmmeters.
8. Balance the rotor. Out-of-balance rotors can cause vibration, which wears out bearings prematurely and increases friction losses, resulting in loss of motor efficiency and higher operating costs.
9. Repair or replace all broken or worn parts and fits. Bearing fits should be measured and, if worn, should be restored to manufacturer's specifications. In the absence of manufacturer's guidelines, The Electrical Apparatus Service Association (EASA) has published bearing fit charts to aid the motor service center.

A good motor service center **SHOULD NOT**:

1. Overheat the stator. The safe limit for organic lamination insulation is 680°F and 750°F for inorganic material measured at the core. Most service centers use heat to soften the old windings for removal. Overheating the stator during stripping can cause core damage.
2. Sandblast the core iron. Blasting with sand or other hard materials can cause short circuits between laminations.
3. Knurl, peen or paint bearing fits. Knurling, peening or painting these fits could cause them to become loose in service.
4. Use an open flame for stripping. Using uncontrolled heat causes loss of core plating and can warp the core.
5. Short the laminations when grinding or filing. Excessive grinding and filing can increase core losses resulting in decreased motor efficiency.
6. Increase the air gap. Increased air gap produces higher magnetizing current, which increases stator and rotor copper losses and decreases power factor.
7. Increase the resistance of the stator windings. Increased resistance results in increased stator copper losses and decreased motor efficiency.
8. Make mechanical modifications without your prior approval. This includes, among other things, changing fans, types of bearings, shaft material and seals. Making changes in the manufacturer's original design can decrease motor efficiency.
9. Change the winding design without your prior approval. This change can affect the overall efficiency, torque and other characteristics of the motor.

Reference: EASA Tech Note 16 Guidelines for Maintaining Motor Efficiency During Rebuilding and the EASA Recommended Practice for the Repair of Rotating Electrical Apparatus

Decreased motor efficiency translates into higher electricity use and higher energy bills.


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In short, don't cut corners in the repair of your motor. A good motor repair takes time. Cutting corners can result in a poor repair which can cause higher operating costs and premature motor failure.

In addition you should expect that the motor service center will:

1. Maintain an inventory of motors and parts to service your needs.
2. Maintain a stable, knowledgeable and well trained work force to service your needs.
3. Maintain a sound financial condition.
4. Be environmentally responsible.
5. Utilize the best available technology in the repair of your motor.
6. Provide complete documentation of the cause of failure, before and after tests and measurements, and the repairs made.
7. Provide prompt and accurate quotations.
8. Provide repair/replacement alternatives.
9. Provide prompt and courteous service.
10. Treat your motor problems with concern.

Remember, the best way to ensure that you will always get the best repair/replacement advice is to know and have a good two-way relationship with your Motor Service Center. *This guide was prepared with assistance from the following organizations:*

Baldor • Brithinee Electric • California Energy Commission • Diagnostic Solutions ITT Flygt • Imperial Irrigation District • Pacific Gas & Electric • Sacramento Municipal Utility District • San Diego Gas & Electric • Southern California Edison • U.S. DOE • U.S. Electrical Motors

Today, there are more resources motor users can employ to ensure high-quality repairs maintain efficiency. Advanced Energy offers a quality assurance program called Proven Efficiency Verification (PEV) that ensures motor repair is done to industry standards, resulting in improved operating costs and increased uptime in motor driven processes. During this program, the motor repair center is required to perform before and after re-wind testing in Advanced Energy's motor test lab – the only independent motor testing lab in North America accredited by the National Voluntary Laboratory Accreditation Program (NVLAP) through the National Institute of Standards and Technology (NIST). In our August/September issue we will examine the PEV program further and highlight the benefits for both the motor service centers in the program and the customers receiving repairs from these centers.

*With expertise in motors and drives and industrial process technologies, Advanced Energy provides solutions through consulting, testing, and training for motor manufacturers, original equipment manufacturers, distributors, importers, motor service centers, utilities and government agencies. At its Motors and Drives Lab, Advanced Energy provides access to cutting edge state-of-the-art testing of motors, drives and industrial process technologies. For more information, visit www.advancedenergy.org/md or contact Kitt Butler, director, Motors and Drives, Advanced Energy, at kbutler@advancedenergy.org.*

# Breaking Through Glass Ceilings

## Thoughts on Implementing Organizational Change

*by R. Keith Mobley, MBB, CMRP*

Have you ever been involved in an attempt to improve the performance of your department or one function, such as maintenance or quality, in your plant or corporation? Ever wonder why the attempt did not work at all or failed to reach its full potential? If you have, the reason was probably a list of deficiencies or omissions, or perhaps it was because cosmic forces preordained that improvement is not possible. Sound familiar?

One thing that I have learned the hard way is that attempting to improve one segment or one function of a plant or corporation is virtually impossible. It would be so simple if one could do so, but the interdependence of plant and corporate functions precludes a simple solution to what is always a complex problem. In my early career—yes we had industrial plants back then—we attempted time after time to improve our maintenance organization. (After all everyone knows that poor maintenance causes all of our problems.) I was a freshly vetted engineer and had all of the answers; I had just spent four years learning them. We applied all of the latest management methods and tools. We hired and trained planners, retrained supervisors and did everything we knew or could find to improve our effectiveness and efficiency. Through hard work and perseverance our performance did improve, our crafts worked almost at optimum efficiency and controllable wrench-time was nearly perfect. We had arrived! Or had we?

Our joy was short-lived. After a few months of tracking the overall impact of our hard work; we dejectedly had to acknowledge that it had not had any real impact on the plant's performance. Yes, maintenance, at least those parts that were within our span of control, was at world-class levels, but the plant was not. Even parts of the maintenance function were still well below acceptable levels. Lack of spare parts, poorly designed equipment and operator errors continued to limit our ability to maintain the plant's installed capacity.

I did not recognize it at the time, but we had hit a "glass ceiling." We had improved the maintenance organization but in a vacuum—nothing outside the maintenance organization had changed. Production, supply chain, procurement and all of our partners in the plant continued to perform as before—nothing had changed. It took too long for this realization to finally sink in, but once acknowledged, it was logical and clear to me that maintenance improvement was not possible without also improving all of the outside factors that directly or indirectly affected its performance.

In later years as I progressed up the corporate ladder, there were numerous opportunities to implement continuous improvement programs in various functional areas of the plant. I must be a really slow learner, because much of this time we used the same techniques and methods used in my initial attempt to improve the maintenance function. We adopted the latest management techniques, tools, and techniques; attended all the conferences; and read all the books. I even became a founding member of the Japanese Total Productive Maintenance Institute (JITPM) and became an advocate of its approach to production-maintenance improvement. That's right—TPM is a production improvement process that happens to include maintenance. We did it by the book, calisthenics every morning, knocked down office walls, nothing was left out. What do you think the results were?

Well, although we did achieve marginal improvements within the production and maintenance functions, the plant did not improve to the expected level of performance. We still had problems meeting market demands, sustaining a competitive position in the marketplace and the myriad of other performance indicators that define a successful company. Any idea why?

There is a definition of insanity floating around out there that states, "Insanity is continuing to do the same thing over and over again and expecting different results." That is so true. Every time we attempted to isolate one department, one functional group or even one plant from the whole corporation, all attempts at sustainable improvement failed. We kept hitting a glass ceiling. We could only go so far with continuous improvement and no further, and we could never sustain the modest improvements that were achieved.

Rather than prolong the agony of this story, let me go directly to the answer of how you remove the glass ceiling that prevents sustainable, real continuous improvement. Once I finally found the answer, it was so simple. You must include everything and everyone in the change. Please believe me when I tell you that we have tried every possible combination: maintenance and production; procurement and supply chain; human resources and operations; and no matter what the combination, we were never able to achieve and sustain desired goals—not until we holistically tried to improve the entire corporation. Imagine my shock when it actually worked.

For me, this epiphany occurred over twenty years ago, and since then, I have had many, many opportunities to verify and validate this simple, yet complex solution. If you want to improve your plant or corporate performance, then you have to include everything and everyone. Pockets of excellence, improving select functions or focusing on a single factor, such as quality, simply do not work.

### What are the Glass Ceilings?

All plant, company and corporate functions are interdependent and cannot effectively operate in a vacuum. In most cases, the functions are isolated into vertical silos, each with its own view of the way business and work should be conducted. The interdependency of functions creates a series of glass ceilings that preclude individual functions or areas of the plant or corporation from achieving or sustaining acceptable performance levels. These external, or non-controllable factors, severely limit if not prohibit continuous improvement efforts.

### Functional Isolation (Vertical Silos)

The first glass ceilings that must be broken are these vertical silos. The interdependence of the functional groups that make up all plants demands that these functions work seamlessly together as a single, focused team. This simple fact is the primary reason that any attempts to improve maintenance or quality or safety or any other single-function or single-focus continuous improvement program are doomed to failure. If we use maintenance as an example, the glass ceiling is fixed by the engineering, procurement, materials handling and production functions. Without the direct support and active involvement of these outside functions, maintenance cannot achieve and sustain best-in-class performance.

For this discussion, let us assume that we can create a uniform, plant-wide team that includes all of the plant's functional groups. Working together, we create standard processes, procedures and practices that will enable us to effectively plan, schedule, manage and execute all of the day-to-day activities required to operate and maintain the plant's installed capacity. Have we broken through? Are we now capable of achieving and sustaining best-in-class performance? Are there any more glass ceilings that limit our ability to be the best we can be?

Unfortunately, there is another category of glass ceilings that must be broken – those created by the corporate or corporate-level functions that determine or create the tactical and strategic direction for the company. This category includes the following functions:

### Plant Management and Business Philosophies

One obstacle that we see all too often is preconceived or in-grained philosophies that govern the planning, management and execution of business and work within the individual plant or plants that make up the company. In too many cases, the philosophies are diametrically opposed to effective performance and represent an almost insurmountable glass ceiling. Too many corporations are run based on the instincts of its executives rather than on data that define a true picture of the market and operating performance of the plants.

A recent client is a prime example of "running the company on our stomach"—their way of saying instinct—and the mismatch between market demand and installed capacity. For years, their plants have been operating at less than 30% asset utilization and with an average of 500 SKUs per plant. Because their "stomachs" told them they were effectively utilizing their assets, nothing changed. Our first recommendation after evaluating their eleven plants was to consolidate. They were able to reduce the number of plants and average number of SKUs, and as a result, reduce their cost of goods sold by tens of millions annually.

In addition, the corporate reward and promotion criteria compounds the obstacle that must be overcome before the functional groups within the plant can excel. These criteria are short-term—generally two years or less—and arbitrary in nature. They are rarely tied to true performance measures or to sustainable growth and survivability. As a result, too many decisions are made to assure the next promotion or next bonus, and not on achieving a sustainable level of best-in-class performance. For example, if I were to become a new plant manager or vice president of marketing, none of the processes, systems or methods that precede my appointment will be considered in my performance review. Only those policies, processes and procedures that I put in place will be considered. As a result, the only way that I can get my next promotion is to remove everything and start over. And, the new processes only have to work until I get that promotion. After that, it's someone else's problem.

### Marketing

Marketing is the corporate function charged with interpreting the short- and long-term market demands that will dictate the products and services that the plant or plants must provide to assure company survival. The ability of the marketing group to accurately anticipate market demand is essential, and clearly defines one of the glass ceilings that must be overcome before any plant or function within the plant can achieve and sustain best-in-class performance.

In addition, the marketing function directly drives the research, development and innovations that are an integral part of all companies. Individually, and in combination, these functions create one or more glass ceilings that must be broken or resolved before the individual plants, and certainly the company, can be successful.

The vision of the future, and specific product and other market data, provided by the marketing function is essential at the plant level. This data provides plant management with a clear definition of market demand that is essential before the plant can be configured to meet the anticipated demand. This process of matching the plant's installed capacity to market demand is critical for survival and long-term success. For the few plants that are in a "sold-out" situation, e.g. where the market demands for their standard products exceeds their capacity; this is not a major problem. Unfortunately, fewer and fewer plants are in a "sold-out" situation. More and more plants find themselves with excess capacity and struggle each year to effectively utilize their assets. Today, you are more likely to find plants that are utilizing less than 50% of their installed capacity, and many are below 30%. In these situations, the partnership between an effective marketing function and plant management is essential—without it, the plant cannot survive.

A recent example of the impact that a disconnected marketing function can have on plant performance is from a chocolate and confectionery company. For the past ten years, the marketing forecasts have dictated that the plant produce more than 500 different products (SKUs) grouped roughly into five families of products. To compound this demand, the marketing function also forces an average of 200 new products or innovations on the plant each year. To do so effectively, the plant must be able to consistently make quick changeovers, minimize CIP and be near best-in-class in flexibility. The problem is that the plant was designed to make large volumes of a few families of products. The plant's physical layout, as well as material flow through the plant, preclude the ability to be flexible—quick changeovers and short-duration CIP are just not possible.

Obviously, there is no logical reason for a situation like this. All it takes is a little communication and cooperation between the marketing, plant and production management. This is a real example of a glass ceiling that is prevalent in far too many corporations.

## Business Planning

I readily admit to being old and on the downhill side of my business career, and perhaps out of step with today's popular management philosophies, but how do you run a plant, company or corporation without a tactical and strategic business plan? To me, this is as natural as breathing, but few companies, including major corporations, have an effective business planning process. This absence is perhaps the most serious glass ceiling that limits performance. To me, it seems so simple. One must have a plan that defines what, where, when and how the company will achieve its goals and objectives.

The strategic (e.g. three to five year) and tactical (e.g. one year) plans provide the focus and direction that each functional group within the plant or corporation needs in order to define their roles and responsibilities as an integral part of the corporate team. Without a unifying plan, each of these functional groups is free to define its role without any concern for the integrated team. Typically, the result is vertical silos where each group operates totally independently of its neighbors. The result is a dysfunctional organization that cannot function as a cost-effective or value-added plant or company.

## Supply Chain

The supply chain includes procurement, logistics, transportation and distribution of the raw materials, MRO parts, work-in-process, material handling, warehousing and distribution of finished goods. Deficiencies within the extended supply chain are a major glass ceiling that must be overcome before individual plants or plant functions can achieve and sustain best-in-class performance. In addition, failure to seamlessly integrate the supply chain into the corporate and plant team is a certain guarantee of poor overall performance. After all, without the timely availability of proper materials, few plants can operate at any level.

Because of the extended supply chain's complexity, it is difficult to effectively plan, schedule, manage and execute the requisite functions needed to effectively support plant operations and meet market demands. Our experience has shown that the only successful approach is to value-stream map the entire process and develop standard policies, processes and procedures that govern and seamlessly integrate each of the individual functions and actions into a single focus effort. This process is identical to the reengineering processes that have proven successful at the plant function level, but applied to a very complex corporate-wide function.

## How do You Break Through the Glass Ceilings?

If you have read carefully so far, the answer should be clear, or at least beginning to form in your mind. The solution to true best-in-class performance and the ability to compete and survive in today's market is simple—or is it? While there is no absolute guarantee that all of the glass ceilings you face can be broken, the following steps will greatly improve your chances:

## Lead from the Top

One absolute that I have learned is that sustainable change must be led from the top of the organization. There must be a visionary, a strong leader committed to creating a learning organization that embraces continuous improvement and the culture change that is integral to it.

Effective leadership is the key to Reliability Excellence and world-class performance. Without it, there is little chance of success. Simply stated, change must be led from the top and implemented from the bottom. Leadership's central role is to set values and directions, creating and balancing value for all stakeholders as well as driving performance. This role must be the focus of world-class organizations. Success requires a strong orientation to the future and a commitment to both improvement and innovation. Increasingly, this requires creating an environment for empowerment and agility, as well as the means for rapid and effective application of knowledge.

## Change Management

Continuous change is not optional for companies that want to survive in the global market that all industries face today. Just sustaining status quo is an almost guaranteed course to failure; but how do you create and sustain continuous change? Here are some proven ideas that will improve your chance of success:

**Create a Sense of Urgency –** With the possible exception of companies that are operating at a severe loss, the first hurdle that must be overcome is simply convincing the workforce that there is a real need for change. This is not simply a problem of hourly workers' failure to understand the need for change; too many managers even at the highest level also suffer from this problem. The old adage that "profit hides inefficiency and ineffectiveness" is alive and well. No one in a profitable company, even when the profit is marginal, ever asks how much profit we are leaving on the table. Instead, they ignore complacency and inefficiency. To overcome complacency, senior management must create a sense of urgency throughout the workforce. In extreme cases, they may have to create a crisis just to get the workforce involved and focused on improvement.

**Create a Guiding Coalition –** Continuous improvement or change must be led from the top, implemented from the bottom of an organization and involve the entire workforce. The primary keys to success are to find the natural leaders within the company and harness their strengths to help you lead the change effort. Finding the right people is critical and should not be hampered by emotions, titles, or position. The use of cross-functional teams that include all levels of the organization is a proven method for building coalitions that are essential for long-term success. Each of these teams should include all stakeholders, e.g. functions directly involved in the focus area, as well as those that influence or are influenced by the focus area.

**Develop a Vision –** Senior management must provide a clear, concise vision of the future. The focus team concept can resolve the details of what and how to implement and sustain change, but they must have a clear vision of what the future should look like. Without a clear vision, each of the focus teams will create solutions for their individual focus area, but the composite results of all focus teams may not lead the company to improved profitability.

**Communicate the Vision –** In too many cases, developing a vision or mission statement is a short-term process. Senior management or a cross-functional team comprised of stakeholders in the organization will spend a few days or a few months developing a statement, but once developed, the vision is not pursued. Senior management must "sell" the vision, and that means they must continuously communicate and reinforce their view of the future state of the company.

**Empower the Employees –** Change cannot be dictated — it must evolve through a combined effort of the workforce. To be successful, senior management must empower the workforce. Give them the responsibility and authority to determine what needs to be changed and how those changes should be implemented. The final step in the empowerment process is for senior management to hold the employees accountable for success.

**Generate Short-term Wins –** It is difficult to sustain the level of concentration and effort required to develop and implement positive change. Too often, the workforce will lose momentum and interest without some indication that their efforts are generating the desired results. Senior management must ensure that objectives, goals and targets are constructed in a way that will assure measurable, short-term gains that are clearly visible to the entire workforce. It is desirable to "stretch" the workforce, but you must ensure that the stretch is limited to achievable goals.

Breaking old habits and creating an environment that is conducive to continuous improvement, e.g. change, is neither easy nor quick. My final word of advice is to follow through. The dynamics of change are well defined and should be your guide. It will take between 18 and 24 months of focused effort to change the work culture in your company. If you become distracted, too busy, or for any other reason remove the pressure to change before this interval, the workforce will revert to its natural stage, e.g. its old way of doing things.

Change dynamics also show that at least 28% of the workforce must be directly and actively involved in the change process to assure success. This critical mass, if they become advocates of the process, will expand the processes throughout the workforce.

Successful continuous change is possible; but it is an evolutionary process that takes time and your focused effort. Always remember old habits: even yours, are hard to break. But if you think positively, it can be done.

## Holistic not Functional Change

As I hope this article has pointed out, partial change or partial improvement is difficult to achieve and impossible to sustain. There is only one sure way to become a best-in-class survivor in today's marketplace and that is to improve the entire company—not just select parts or functions. Whether we admit it or not, all plants, companies and corporations rely on individual functions and groups, which must be effectively integrated before they can perform at an acceptable level. Choosing to undertake only a portion of the change is not an option—success dictates that everything must be changed and that everyone must be a part of the change.

Do not forget, ignore or omit corporate functions such as business planning, marketing, sales, supply chain, or innovations. These functions are literally the "tail that wags the dog"; they determine the boundary conditions for the plants and without careful coordination and integration of the conditions and plant capabilities, acceptable performance levels are not possible.

### Phased Implementation

While holistic is the only viable solution, there are options that can be applied to the implementation of change. Attempting to simultaneously eliminate all of the waste and losses that have developed over years (or decades) from all of the functional areas of your plant or corporation would be difficult and cost-prohibitive. Therefore, the most cost-effective approach is to implement change in discrete steps that are designed to first build a strong foundation, and over time, develop and implement the necessary changes throughout the organization.

The sequence selected should be predicated on a thorough analysis and evaluation of the entire organization, e.g. company or corporation, and prioritized by the return-on-investment and impact of change in the selected areas or functions.

### Success Takes Time

Correcting the deficiencies that have taken years, and in many cases decades, to form will also take time to correct. The change process cannot— and should not—be rushed. You must have the discipline and patience to follow best practices throughout the design, preparation, implementation and institutionalization stages of the process or it will all be for naught.

Remember that in addition to evaluating the myriad of policies, processes, procedures and practices that make up every aspect of business life, you are also changing the way your workforce thinks, makes decisions and performs their day-to-day tasks. Just this transformation will take time. As a general rule, transformational change will take a minimum of 18 months and is likely to require 24 to 36 months to become completely entrenched—institutionalized—in the culture—to become the norm.

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# The Expected and the Unexpected

## The Ever Increasing Benefits of Modern PdM Technologies

*by Bill Hillman, CMRP*

When dial indicators, straight edges, and taper gauges were the only tools available for doing shaft-to-shaft alignment, machines were often left in a rough alignment condition. This happened because either too much time would need to be invested in order to obtain the required degree of precision or human error entered into the calculations. With the introduction of laser alignment tools, it has become standard operating procedure to perform precision shaft-to-shaft alignment when machines are installed or reinstalled after a rebuild. Before the introduction of laser alignment tools, harmful soft foot conditions were often not addressed.

There are two reasons for this. One was that before laser tools, the soft foot condition was more difficult to measure precisely, and secondly, many did not fully understand the consequences of an uncorrected soft foot condition.

Today, the standard tolerance calls for correcting any soft foot in excess of .002 inches. Since this is smaller than the diameter of a human hair, it is difficult to realize how such a small error could cause a problem. Suppose that a soft foot of .004 inches (in terms of shaft movement as extrapolated to foot movement) is present in a motor foot. This is two times the standard, and if we tighten the motor foot down without correcting the soft foot, the motor foot will not be damaged. In fact, if we were to loosen the foot after a year, it would return to its original position because .004 inches deflection will not exceed the elasticity of the foot material. So, why is the standard for soft foot a maximum of .002 inches? We have learned that the damage is not usually to the machine foot but to the interior of the machine. Power is induced from the stationary part of a motor across an air gap into the rotating part in order to produce torque on the rotating part. The air gap is kept as small as practical in order to make the motor as efficient as possible. The induced forces are magnetic (electromagnetic and electrostatic), and any variance in the air gap causes changes in the magnetic forces. If the distance between two magnets is reduced by half, the forces are quadrupled. In other words, the magnetic forces become four times greater. Only a slight variance in the air gap can result in substantial differences in magnetic forces and current flow in the area of the variance. The uncorrected soft foot may distort the motor housing which, in turn, may distort the stator iron, resulting in reducing the air gap. The stronger magnetic forces in the area of the smaller air gap produce an increase in localized currents that generate heat. For every 10 degrees centigrade temperature rise in a motor, insulation life is cut in half. Infrared technology may be used to detect the heat resulting from an uncorrected soft foot condition. Figure 1 displays an exaggeration of this condition.

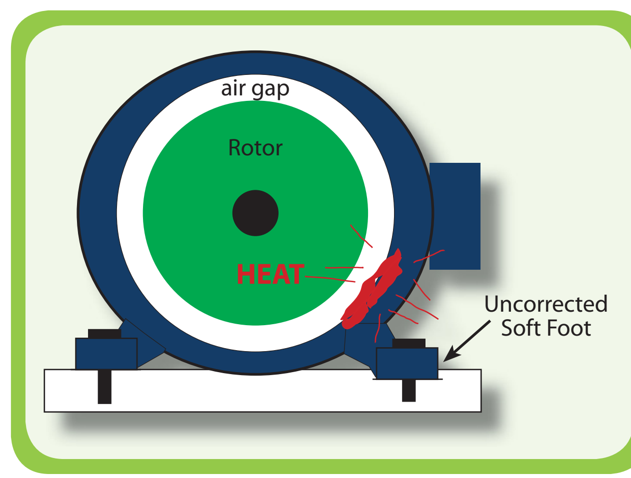


Figure 1 - Heat Generation from Soft Foot-Induced Air Gap Variance.

When laser alignment tools were first introduced, they were used only as corrective tools. Meaning that machines were precision aligned when installed, and the alignment was not considered again until problems arose or until vibration measurements indicated misalignment. However, we soon learned that the laser tools could also be used as mechanical detectives. Their speed and ease of use made it possible for us to write procedures for performing alignment checks on machinery. Once aligned, a machine should remain in alignment and these checks help to ensure that precision alignments endure. If a scheduled check indicates misalignment, we have detected other problems that were previously hidden. A fault is present, or the machine would have remained in alignment. Causes for the machine becoming misaligned must be determined and corrected. The alignment check can also be used to verify vibration measurements that may confuse misalignment with other problems. The combined technologies provide definitive answers.

Ralph Buscarello, founder of Update International, deserves credit as the father of precision in industrial maintenance. Mr. Buscarello advocated precision in machine balancing and parts fitting before most of us fully understood the true value of precision. We were slow to embrace precision concepts because we had difficulty measuring the benefits of precision.

With regard to precision, let's discuss "the point of no return." This is where the effort or investment in achieving a better level of precision costs more than the value gained from the greater precision. This point will always exist, but knowing when we reach this point can be difficult to determine. However, new advances in condition monitoring technologies have helped us push "the point of no return" toward higher precision. PdM technologies provide us with the ability to better measure the value of precision and make greater precision easier to obtain. Before these tools came onto the market many of the available tools for detecting and correcting machine faults were either difficult to use, required too much time or training, or provided minimal results.

the rolling elements pass over the area of separation. These stress waves can be detected with vibration transducers. Signals from the transducers are used for generating plots or displays that are essential for analyzing various types of faults.

Why would we even want to detect faults in equipment that are invisible to the eye or undetectable by our other senses? Because the earlier a fault or potential failure can be detected, the more time one has to take action to prevent the fault from progressing to a failure, which may result in loss of production or collateral damage. Fault detection is only worthwhile if there is time to take action before the fault results in failure. Figure 2 shows a typical failure curve. The "P" point on the curve represents the time when the fault or potential failure is first detected. The "F" point represents the time of failure. Precision maintenance practices delay the onset of the fault and hence move both the "P" and "F" points farther out in time. The effect of higher precision in fault detection is to put more distance between the "P" and "F" points because the "P" point is detected earlier in time. This provides more time to take action after a fault is detected. Combining PdM or condition monitoring technologies can greatly enhance the likelihood of earlier fault detection.

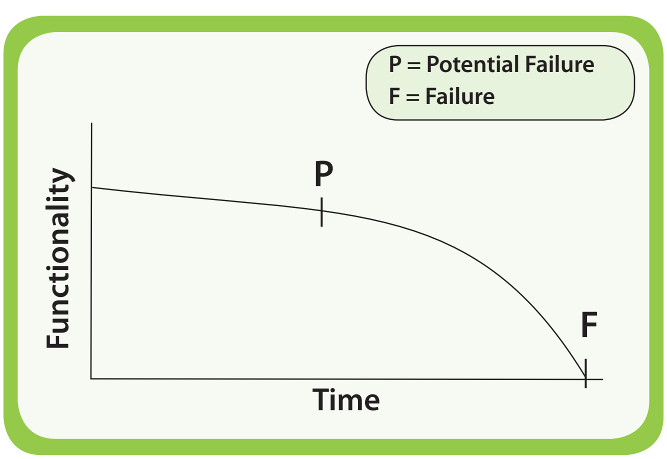


Figure 2 - Fault Detection/Failure Curve

Early vibration measuring tools detected only overall vibration amplitudes and were very limited in diagnostic capabilities. Even their detecting abilities were limited to finding faults or potential failures in advanced stages. Today's technologies make it possible to detect sub-surface flaws in bearings — flaws not even visible in a magnified view of the bearing surface. How is it possible to detect bearing faults that aren't visible even when magnified? Let's first consider one possible way that bearings fail. When a ball or roller passes through the load zone of a bearing raceway, the raceway deflects under the pressure of the rolling element. After millions of such cycles, the crystalline material of the metal race will begin to separate due to fatigue wear. When the metal molecules separate, they rub against one another, producing small stress waves. This happens each time

Problems with low speed machines were very difficult to detect, and even more difficult to analyze, when the available vibration tools measured only overall vibration amplitude levels. Through the use of high frequency technologies, it is now possible to detect problems in rotors that have fractional rotation speeds. Detecting problems buried deep inside complex gear units is also made much easier by these same technologies.

Modern PdM technologies have also greatly improved our ability to establish root cause. Before the advent of modern PdM technologies, most machine faults were undetected, resulting in complete and sometimes catastrophic failure. Finding the cause of these failures was often very difficult because much of the evidence was destroyed during the failure. An example would be bearing failures. Bearings that are removed from service in an early stage of failure due to a PdM alarm can easily be inspected to determine fault causes. If bearing faults are allowed to progress to stages where the metal is plasticized by heat and the rolling elements are deformed or welded to the races, the cause of failure is much more difficult to determine because much of the evidence of the early fault has been obliterated. Establishing root cause is critical to preventing repeat failures, and early fault detection preserves the data on which we base our preventive maintenance decisions.

Lubrication is another area where PdM technologies improve the precision of the process. The science of lubricants is well-founded in many years of experiment that have helped to continually improve products. We have developed lubrication procedures that use formulas to precisely measure how much lubricant to inject into various bearings. But, the science of applying lubricants to bearings has remained mostly an art because we rarely know how much lubricant is already in bearings when we lubricate. Many factors can enter into the calculations for how much lubricant to apply to a specific bearing, including, bearing size, speed, load, environment, bearing type, vibration levels, and temperature. The calculations can also be quite confusing. After making calculations, we apply what we hope is the proper amount. Yet without knowing how much lubricant is already present in the bearing, we are never quite sure, so we give the bearing what we think it needs. But, now by using modern ultrasonic (sound above human hearing range) lubrication techniques, the bearing now tells us how much lubricant it needs. Different lubricant film conditions emit different frequencies in the ultrasonic range. Ultrasonic probes process the ultrasonic frequency into frequencies that are audible. They also provide indications of the signals' power levels. By applying lubricant as we listen to the bearing's ultrasonic emissions, we let the bearing tell us when it has received the proper amount of lubricant. Ultrasonic lubrication changes lubrication from a time-based task to a condition-based task.

We have explored some of the authentic and positive benefits of modern PdM technologies, as well as some of the less apparent benefits. Learning about these benefits results in increased maintenance knowledge leading to improved machine reliability. Increased knowledge and greater reliability produce increased plant profitability.

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IT TAKES A TEAM TO
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# What's the FRACAS?

## Failure Elimination Made Simple

*by Ricky Smith, CPMM, CMRP and Bill Keeter, CMRP*

"Your system is perfectly designed to give you the results that you get."
W. Edwards Deming PhD

How good is your organization at identifying failures? Of course you see failures when they occur, but can you identify when recurring failures are creating serious equipment reliability issues? Most companies begin applying RCA or RCFA to "high value failures". While this is not wrong, I prefer to either not see the failure in the first place, or at the least, to reduce the failures to a controllable level.

Failure Reporting Analysis and Corrective Action System (FRACAS) is an excellent process that can be used to control or eliminate failures. This is a process in which you identify any reports from your CMMS/EAM or a specialized Reliability Software that can help you to eliminate, mitigate or control failures. These reports could include cost variance, Mean Time Between Failure, Mean Time Between Repair, dominant failure patterns in your operation, common threads between failures such as "lack of lubrication" (perhaps due to lubricator not using known industry standards). One poll was conducted recently covering 80 large companies. Shockingly, none of these companies were capturing the data required to understand and control equipment failures.

Answer the following questions honestly before you go any further to see if you have any problems with identifying failures and effectively eliminating or mitigating their effects on total process and asset reliability.

1. Can you identify the top 10 assets which had the most losses due to a partial or total functional failure by running a report on your maintenance software?
2. Can you identify the total losses in your organization and separate them into process and asset losses for the past 365 days?
3. Can you identify components with a common thread due to a specific failure pattern, such as the one shown in Figure 1?

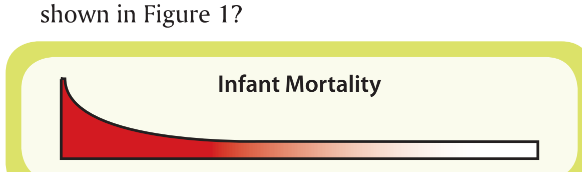


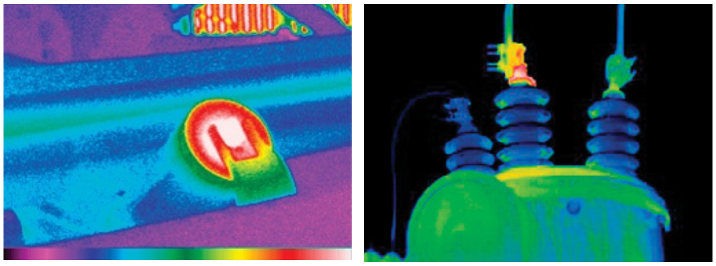

Figure 1 - Failure Pattern from Nowlan and Heap Study

Many times, the cost of unreliability remains unknown because the causes of unreliability are so many. Whether you want to point the finger at maintenance, production (operations) or engineering, each functional area plays a role in unreliability. Here are a few examples of those losses:

1. Equipment Breakdown (total functional failure)
   A. Causes of Equipment Breakdown
      1. No Repeatable Effective Repair, Preventive Maintenance, Lubrication, or Predictive Maintenance Procedure
      2. No one following effective procedures
2 Equipment not running to rate (partial functional failure)
   A. Causes of Equipment not Running to Rate
      1. Operator not having an effective procedure to follow
      2. Operator not trained to operate or troubleshoot equipment
      3. Management thinking this is the best rate at which the equipment can operate because of age or condition
3. Off-Quality Product that is identified as "first pass quality" (could be a partial or total functional failure)
   A. Causes of Quality Issues
      1. Acceptance by management that "first pass quality" is not a loss because the product can be recycled
4. Premature Equipment Breakdown
   A. Ineffective or no commissioning procedures. We are talking about maintenance replacement of parts or equipment and engineering/contractor that fails prematurely because no one has identified if a defect is present after the equipment has been installed, repaired, serviced, etc. See Figures 2 and 3.

(If you have ever seen equipment break down or not running to rate immediately after a shutdown, you know what we are talking about.)

**The Proactive Workflow Model –** Eliminating unreliability is a continuous improvement process much like the Proactive Work Flow Model in Figure 4. The Proactive Workflow Model illustrates the steps required in order to move from a reactive to a proactive maintenance program.



Figures 2 and 3 - Defects Identified

**What the Proactive Work Flow Model really means to your organization –** Implementing the Proactive Work Flow Model is the key to eliminating failures. The built-in continuous improvement processes of Job Plan Improvement and the Failure Reporting, Analysis, and Corrective Action System (FRACAS) help ensure that maintainability and reliability are always improving. All of the steps and processes have to be implemented in a well managed and controlled fashion to get full value out of the model.

The foundational elements of Asset Health Assurance are keys because they ensure that all of the organization's assets are covered by a complete and correct Equipment Maintenance Plan (EM). These are requirements (not options) to ensure that you have a sustainable proactive workflow model.

**You cannot have continuous improvement until you have a repeatable, disciplined process.**

The objective of the Proactive Work Flow Model is to provide discipline and repeatability to your maintenance process. The inclusion of the FRACAS provides continuous improvement for your maintenance strategies. There are fundamental items you must have in place to insure that you receive the results you expect.

Think of FRACAS this way. As you have failures, you use your CMMS/EAMS failure codes to record the part-defect-cause of each failure. Analyzing part-defect-cause on critical assets helps you begin to make serious improvement in your operation's reliability. Looking at the FRACAS Model in Figure 5, we begin with Work Order History Analysis, and from this analysis we decide whether we need to apply Root Cause Analysis (RCA), Reliability Centered Maintenance, or Failure Modes and Effect Analysis to eliminate or reduce the failures we discover. From the RCA, we determine maintenance strategy adjustments needed to predict or prevent failures. Even the most thorough analysis doesn't uncover every failure mode. Performance monitoring after we make the strategy adjustments may find that new failure modes not covered by your strategy occur. You can now make a new failure code to track the new failure mode so additional failures can be tracked and managed when you review work order history. You can see this is a continuous improvement loop which never ends.

## Steps to Implementing an Effective FRACAS

Let's back up a little. The foundational elements of an effective FRACAS are an effective validated equipment hierarchy, criticality analysis, failure modes analysis, and equipment maintenance plans.

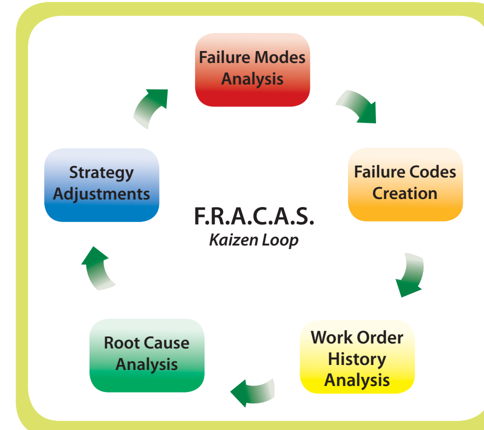



Figure 5 - FRACAS Loop

**FRACAS Checklist:**

Equipment Hierarchy should be built and validated so that similar failures on like equipment can be identified across an organization.

Criticality Analysis is developed and validated so that equipment criticality is ranked based on Production Throughput, Asset Utilization, Cost, Environment, and Safety.

Failure Modes Analysis is completed on all critical equipment using FMA, FMEA, or RCM.

Equipment Maintenance Plans are developed on all critical equipment to prevent or predict a failure.

**Effective Equipment Hierarchy –** Asset Catalog or Equipment Hierarchy must be developed to provide the data required to manage a proactive maintenance program which includes failure reporting or FRACAS (Failure Reporting, Analysis and Corrective Action System). In order to eliminate failures, one needs to ensure this is a successful first step. Figure 6 (on the following page) displays the findings from a plant with 32 total "Part – Bearing" failures from different size electric motors ("Part" is identified from a CMMS/EAM Codes drop down screen). One type "Defect – Wear" occurred in 85% of the failures ("Defect" is identified from a CMMS/EAM Codes drop down screen). In 98% of the cases, "Cause" was found to be "Inadequate Lubrication". Now it is time to perform a Root Cause Failure Analysis on this common thread of failures. ("Cause" as identified on CMMS/EAM Codes drop down screen). Once the hierarchy is established you can find similar failures in one area of an operation or

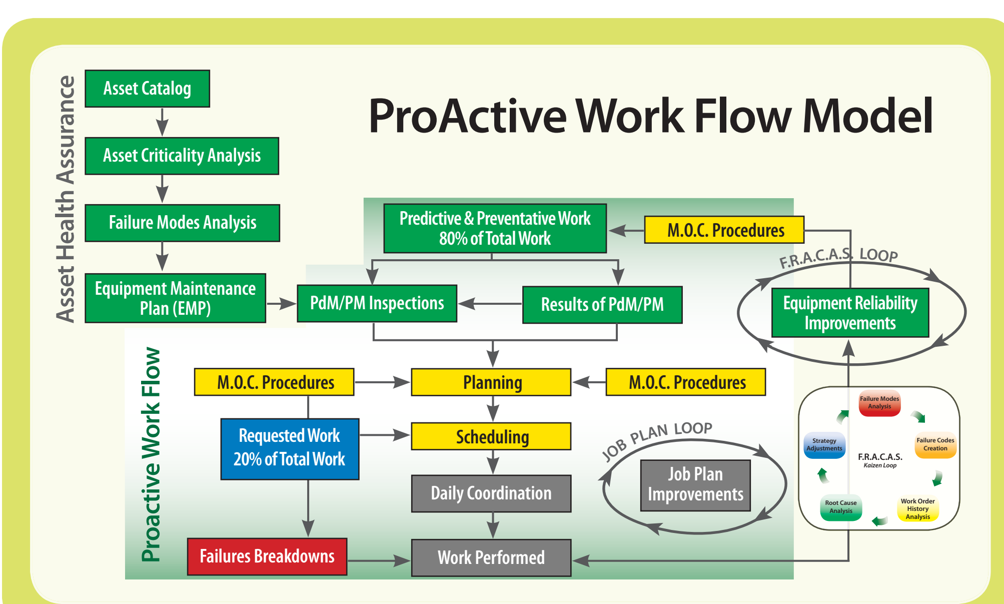



Figure 4 - ProActive Work Flow Model

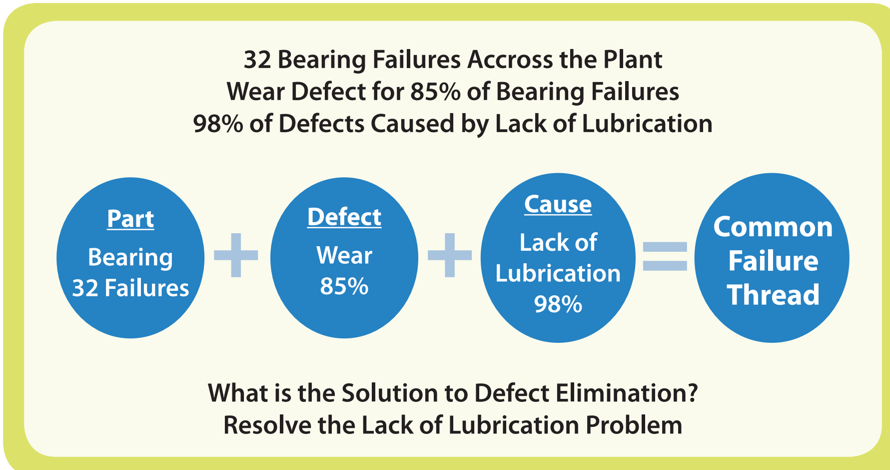



Figure 6 - Reason for Equipment Hierarchy Validated

across the total operation. Validation of the equipment hierarchy is required against the organization's established equipment hierarchy standard. We are looking for "Part" – "Defect" – "Cause". Maintenance personnel may not have the training or ability to determine the "Defect" (Predictive Maintenance Technician could identify Defect) and "Cause" can be typically identified by a maintenance technician, maintenance engineer, reliability engineer, or predictive maintenance technician.

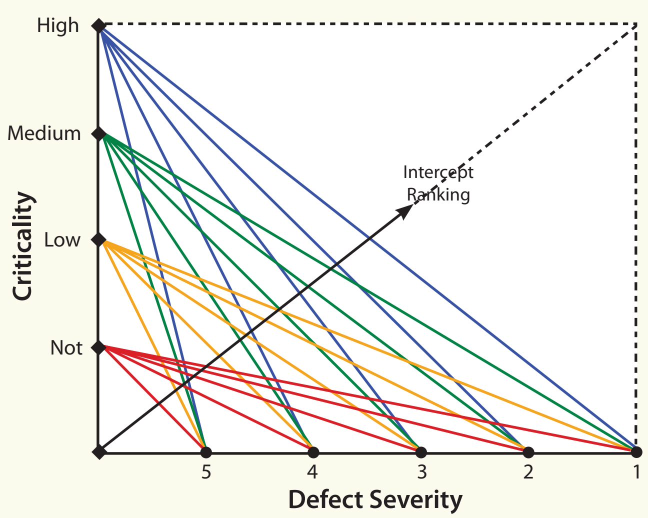
After a thorough analysis you will find that most failures come from a small amount of equipment. The question is, "Which equipment?".

**Asset Criticality Analysis –** Everyone says they have identified their critical equipment. But, in many cases, equipment criticality could change based on how upset people are about an equipment problem or because people are confused about what consequences associate to failure and the probability it will occur if we manage equipment reliability effectively.

The purpose of the Asset Criticality Analysis is to identify which equipment has the most serious potential consequences on business performance, if it fails. Consequences on the business can include:

- Production Throughput or Equipment / Facility Utilization
- Cost due to lost or reduced output
- Environmental Issues
- Safety Issues
- Other

The resulting Equipment Criticality Number is used to prioritize resources performing maintenance work. The Intercept Ranking Model illustrates this process (Figure 7). On the "Y" axis you see the asset criticality is listed from none to high. I like using a scale of 0-1000 because all assets are not necessarily equal. Using the Intercept line which is struck down the middle, a planner or scheduler can define which job should be planned or scheduled first, or at least get close to the best answer, because management has already been involved in determining the most critical asset and the equipment has told you (on the "X" axis) which one has the highest defect severity (in the worst condition).




| Criticality | Severity | Order |
|---|---|---|
| High | 1 | 1st |
| High | 2 | 2nd |
| Medium | 1 | 3rd |
| Medium | 2 | 4th |
| High | 3 | 5th |
| Low | 1 | 6th |
| Medium | 3 | 7th |
| Low | 2 | 8th |
| High | 4 | 9th |
| Low | 3 | 10th |
| Medium | 4 | 11th |
| Low | 4 | 12th |
| Not | 1 | 13th |
| Not | 2 | 14th |
| Not | 3 | 15th |
| High | 5 | 16th |
| Medium | 5 | 17th |
| Not | 4 | 18th |
| Low | 5 | 19th |
| Not | 5 | 20th |



**Figure 7 - Intercept Model**

The only other two factors I would add in determining which job to plan or schedule would be based on work order type (PM, CM, CBM, Rebuild, etc) plus time on back. Figure 8 shows the 4-Way Prioritization Model for planning and scheduling.

Identify what equipment is most likely to negatively impact business performance because it both matters a lot when it fails and it fails too often. The resulting Relative Risk Number is used to identify assets that are candidates for reliability improvement.

A consistent definition for equipment criticality needs to be adopted and validated in order to ensure the right work is completed at the right time. This is the key to the elimination of failures.

**Identification of Failure Modes –** The goal of most maintenance strategies is to prevent or predict equipment failures. Equipment failures are typically caused by the catastrophic failure of an individual part. These parts develop defects, and when left alone, those defects lead to the ultimate catastrophic failure of the part. The defects are, in turn, caused by "something". Eliminating that "something" (the cause) will eliminate the failure.

The primary goal of an effective Preventive (PM) program is to eliminate the cause and prevent the failure from occurring. The primary goal of a Predictive Maintenance (PdM) or Condition Based Monitoring (CBM) Program is to detect the defects and manage the potential failures before they become catastrophic failures.

In addition, many program tasks are designed to maintain regulatory compliance. Many companies have PM programs. However, many of the tasks in them do not address specific failure modes.

For example: An electric motor with roller bearings has specific failure modes which can be prevented with lubrication. The failure mode is "wear" caused by "Inadequate Lubrication". The next question may be why you had Inadequate Lubrication. The Inadequate Lubrication could be identified as a result of no lubrication standard being established for bearings. In other words someone gives the bearing "x" shots of grease even though no one knows the exact amount to prevent the bearing from failure.

The best way to identify failure modes is to use a facilitated process. Put together a small team consisting of people knowledgeable about the equipment, train them thoroughly on the concept of part-defect-cause, and go through the basic equipment types in your facility such as centrifugal pumps, piston pumps, gearboxes, motors, etc.. You will find that a relatively small number of failure codes will cover a lot of failure modes in your facility. The failure modes developed during this exercise can later become the basis for the failure modes, effects, and criticality analysis that takes place during Reliability-Centered Maintenance (RCM) projects. In our book, we focus on failure mode identification as an output of FRACAS (Failure Reporting, Analysis and Corrective Action System), which, again, is a strong continuous improvement process.

If, over a period of one year, the dominant failure mode is "wear" for bearings caused by Inadequate Lubrication then one can change or develop a standard, provide training and thus eliminate a large amount of failures.

The problem is that most companies do not have the data to identify a major problem on multiple assets (No data in equals no effective failure reports out). For example, it isn't the motor that fails; the motor fails because of a specific part's failure mode, which then results in catastrophic damage to the motor. Unless, of course, the defect is identified early enough in the failure mode.

**Maintenance Strategy –** The maintenance strategy should be a result from either a Failure Modes and Effect Analysis, Reliability Centered Maintenance or from failure data collected from your CMMS/EAM.

**Elimination Strategy: The best way to eradicate this deadly waste is get a better understanding of the true nature of the equipment's failure patterns and adjust the Maintenance Strategy to match.**
- Andy Page CMRP

So what is a maintenance strategy? Let's break down the two words: **Maintenance** is to keep

| Asset Criticality | Defect Severity | Time On Backlog | Work Order Type |
|---|---|---|---|
| **500** — Highest Criticality | **5** — Priority 1 (Most Severe) | **4** — Greater than 120 Days | **10** — Emergency |
| | **4** — Priority 2 | **3** — Greater than 90 Days | **9** — Quality Compliance |
| | **3** — Priority 3 | **2** — Greater than 60 Days | **8** — Results of PdM Inspection |
| **1** — Lowest Criticality | **2** — Priority 4 | **1** — Less than 60 Days | **7** — Preventive Maintenance Inspections |
| | **1** — Priority 5 (Least Severe) | | **6** — Working Conditions/Safety |
| | | | **5** — Planned Work Outage |
| | | | **4** — Normal Maintenance |
| | | | **3** — Projects & Experiments |
| | | | **2** — Cost Reductions |
| | | | **1** — Spares Equipment |



**Figure 8 - "4 Way Prioritization Model"**

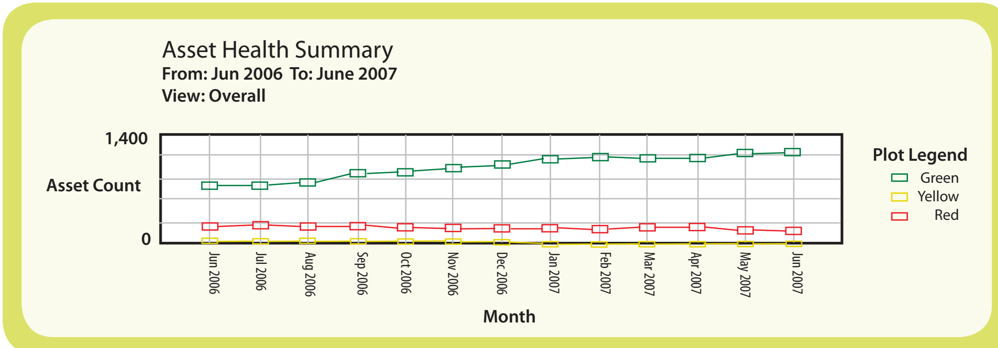



Figure 9 - Percent of Assets with No Identifiable Defect

in an existing condition, or to keep, preserve, protect, while **Strategy** is development of a prescriptive plan toward a specific goal.

So, a Maintenance Strategy is a prescriptive plan to keep, preserve, or protect an asset or assets. Keep in mind that one specific type of maintenance strategy is "run to failure" (RTF). However, RTF is used only if, based on thorough analysis, it is identified as the best solution for specific equipment to optimize reliability at optimal cost. Less invasive maintenance is preferred to more invasive maintenance. This is one of the fundamental concepts of any well-defined maintenance strategy. Specific maintenance strategies are designed to mitigate the consequences of each failure mode. As a result, maintenance is viewed as a reliability function instead of a repair function. Saying this means Predictive Maintenance or Condition Monitoring is the best solution because it is mainly noninvasive.

Knowing that both systemic problems and operating envelope problems produce the same type of defects, a maintenance strategy that merely attempts to discover the defects and correct them will never be able to reach a proactive state. Technicians will be too busy fixing the symptoms of problems instead of addressing the root cause. To reach a truly proactive state, the root cause of the defects will need to be identified and eliminated. Maintenance strategies that accomplish this are able to achieve a step change in performance and achieve incredible cost savings. Maintenance strategies that do not attempt to address the root cause of defects will continue to see lackluster results and struggle with financial performance.

A Maintenance Strategy involves all elements that aim the prescriptive plan toward a common goal. Key parts of a maintenance strategy include Preventive and Predictive Maintenance based on a solid Failure Mode Elimination Strategy, Maintenance Planning consisting of repeatable procedures, work scheduled based on equipment criticality, work executed using precision techniques, proper commissioning of equipment when a new part or equipment is installed, and quality control using Predictive Maintenance Technologies to ensure no defects are present after this event occurs. The very last part of your maintenance strategy is FRACAS, because it drives the continuous improvement portion of this strategy.

## Failure Reporting

Failure reporting can come in many forms. The key is to have a disciplined plan to review failure reports over a specific time period, and then to develop actions to eliminate failure. Following are a few Failure Report examples, which should be included as part of your FRACAS Continuous Improvement and Defect Elimination Process.

**1. Asset Health or Percent of Assets with No Identifiable Defect –** reported by maintenance management to plant and production management on a monthly basis at least (see Figure 9). 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 ifs", "what ifs" or "if then". If there is an identifiable defect the asset is in condition RED. If there is no identifiable defect, it is GREEN. The percentage of machines that are in condition GREEN is the Asset Health (as a percentage) for that plant or area.

The definition for defect is: an abnormality in a part which leads to equipment or asset failure if not corrected in time.

Example: the plant has 1,000 pieces of equipment. Of that number, 750 of them have no identifiable defects. The plant is said to have 75% Asset Health. There is an interesting aspect about Asset Health. Once this change is underway, Asset Health, as a metric, becomes what most maintenance managers and plant managers have wanted for a long time — a leading indicator of maintenance costs and business risk.

**2. Mean Time Between Failures and Mean Time Between Repairs –** reported by maintenance or reliability engineers on a monthly basis on the top 5-20% of critical equipment. The report to management should include recommendations to improve both metrics and should be measured and posted on a line graph for all to see.

**3. Cost Variance by area of the plant –** reported by maintenance and production supervisor area of responsibility. Cost variance must be reported to maintenance and production management on a monthly basis. The report should not be acceptable without a known cause of the variance and a plan to bring it in compliance.

**4. Most Frequent Part-Defect-Cause Report –** reported monthly by maintenance or reliability engineers. If you do not have maintenance or reliability engineers, you may need to appoint a couple of your best maintenance technicians as "Reliability Engineering" Technicians, even if unofficially, and train them to be a key player in this failure elimination process. This one report can identify common failure threads within your operation which, when resolved, can make a quick impact to failure elimination.

There are many more reports that can be used effectively, but will not fit in the space of this article. You will be able to find more reports in the book on "FRACAS" written by Ricky and Bill, which will be published by mid July.

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*Bill has published articles in a variety of internationally recognized maintenance publications, and has presented papers on the practical application of Weibull Analysis at several internationally attended Maintenance and Reliability Conferences. Bill is a Certified Maintenance and Reliability Professional with the Society for Maintenance and Reliability Professionals Certifying Organization. You can contact Bill at bkeeter@gpallied.com*

*Ricky Smith is currently a Senior Technical Advisor with Allied Reliability. Ricky has over 30 years experience in maintenance as a maintenance manager, maintenance supervisor, maintenance engineer, maintenance training specialist, maintenance consultant and is a well known published author. Ricky has worked with maintenance organizations in hundreds of facilities, industrial plants, etc, world wide in developing reliability, maintenance and technical training strategies. Prior to joining Allied Reliability in 2008, Ricky worked as a professional maintenance employee 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 is the co-author of "Rules of Thumb for Maintenance and Reliability Engineers", "Lean Maintenance" and "Industrial Repair, Best Maintenance Repair Practices". Ricky has also written for several magazines during the past 20 years on technical, reliability and maintenance subjects. Ricky holds certification as Certified Maintenance and Reliability Professional from the Society for Maintenance and Reliability Professionals as well as a Certified Plant Maintenance Manager from the Association of Facilities Engineering 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.*

*If you would like to be notified before the release of the new book, or would like to contact Ricky with questions, send him an email at rsmith@gpallied.com.*

# A Better Black Liquor Process

## Finding Vacuum Leaks in a Multi Effect Evaporator

*by Karl Hoffower and Allan Rienstra*

So many industrial processes depend on creating a stable vacuum, but system leaks impair process efficiency and, if left unchecked, will shut it down. Finding these leaks can be challenging in noisy plant environments and reliability engineers must weigh the balance between the costs of downtime versus the cost of continuing production with a leaky, inefficient system. One method of detecting vacuum leaks is to use airborne ultrasound detection, a technology already widely used for positive leak detection in compressed air systems. But finding vacuum leaks is not as straightforward as finding pressure leaks, and often times, the method is abandoned in frustration.

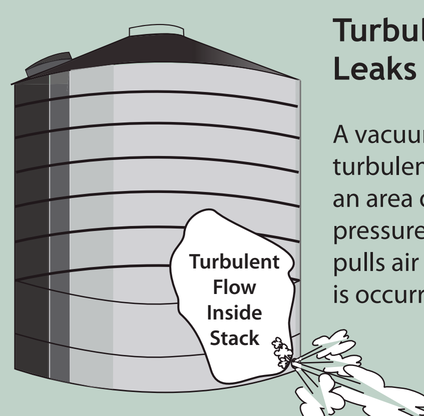
One problem here is the quality of the ultrasonic instrument which can vary significantly from one manufacturer to another. Lesser quality detectors cannot function well in high noise situations. They simply have difficulty differentiating a leak sound from ambient plant noise. Since vacuum pumps already generate a lot of background noise, rarely will an inspector perform vacuum leak inspections in a quiet atmosphere. Another problem is lack of inspector training which really plays a role when searching for vacuum leaks in high noise environments.

Just like positive pressure leaks, vacuum leaks produce a rushing, whooshing ultrasonic signal with peaks around 35-40 kHz. The ultrasound is caused by turbulent flow of air molecules at the leak site. Positive pressure leaks, such as those found in compressed air systems, push the turbulent flow outward making them easily detectable from several feet with a quality ultrasound tool. Vacuum leaks behave quite the opposite, drawing the turbulent flow inward, decreasing the distance of detection as compared with positive pressure leaks. Most of the telltale leak sound is contained within the body which means inspectors must diligently trace an entire installation leaving no stone unturned in the search for ingress.

The amplitude of a vacuum leak is less in comparison to a pressure leak, so proper shielding and positioning techniques are paramount to success. As leading manufacturers of ultrasound equipment continue to innovate, new methods for finding vacuum leaks are resulting in more successful inspections and less frustrating project abandonment.

One such innovation is the improvement of contact sensors. That's right; contact sensors can play a huge role in finding vacuum leaks. When we think of leak detection, most of us draw our point of reference to airborne sensors only. If you only rely on airborne sensors for leak detection you will miss potential wins. Think about it. In a vacuum leak much of the turbulence is contained inside the vessel. A contact sensor that is accurate, repeatable, and super sensitive within a confined bandwidth can be a very effective tool. One area where vacuum leak detection improves efficiency and throughput is applied to multiple effect evaporators used in the processing of sugarcane, the desalination of water, and the production of black liquor in the pulp and paper industry to name just a few applications. The case study focus of this paper addresses significant wins for black liquor production at a large Pacific Northwest pulp and paper maker.

In the pulp and paper industry, vacuum serves a key role in several processes, not the least of which is the production and recovery of black liquor. Black liquor is




### Turbulent Flow From Vacuum Leaks

A vacuum leak generates friction from the turbulent flow of gases being pulled from an area of high pressure into an area of low pressure through a restriction. A vacuum leak pulls air into the vessel so the turbulent flow is occurring inside the vessel. This makes the contact ultrasound probe the best sensor choice.

a by-product of the kraft process which is the stage in the production of paper pulp where wood chips are digested into pulp cellulose. The black liquor contains a majority of the energy potential of the wood so its recovery and reuse has value for pulp mills. They use recovery boilers to burn the black liquor they produce, generating steam while reclaiming spent chemicals that can be re-purposed by the digestion process. During wood digestion chemicals and heat are used to cook the wood into cellulose fibres. Lignin pieces and chemical agents are recovered through evaporation.


Figure 1 - This quintuple-effect evaporator located in Mississippi is a pretty typical congifuration for multi-effect evaporators.

Evaporators are large vessels used to produce black liquor and recover cooking chemicals. Steam is fed through tubes inside the calandria. Water is boiled out of the black liquor and removed as condensate. The condensate is sent to the boiler for re-use after purification. Meanwhile the liquor is further concentrated and becomes more viscous at each stage of the evaporation.

## Multi-Effect Evaporators

In the pulp process, multiple effect evaporators provide more efficiency than single effect for production of black liquor. Multiple Effect Evaporators are more efficient than single-stage evaporators because the energy they consume in the first effect is re-used in the proceeding effects. The temperature in the steam chest is higher in the first effect than the second effect and so on. So, in order for the steam provided by first effect to boil off liquid in the second effect, the boiling temperature point in the second effect must be lower. For this to happen, the second effect must be under lower pressure than the first effect. Each proceeding effect will be at a lower pressure than the previous effect. In some cases, the first effect may be above atmospheric pressure so the second effect could be at atmospheric pressure. Usually the third and later effects must be put under vacuum. In a forward feed evaporator, the vacuum serves two purposes. The first purpose is to keep the boiling temperature of the concentrate lower than the previous effect. The second purpose is to move the concentrate forward in the process without the need for pumping. Backward feeding evaporators work in reverse but require pumping of the viscous concentrate. In either case, adding multiple effects reduces the energy consumption of the evaporator. Adding a second effect reduces energy by 50%. Adding a third effect reduces it to 33%, and each effect thereafter reduces the energy consumption even further.

Of course after a certain number of effects are added, the energy savings is displaced by the capital cost of the additional effects. For pulp and paper, the magic ratio of energy consumption to capital cost equates to seven. So it would be unusual to see more than a seven effect evaporator in any pulping process. Each effect consists of a heat transfer surface, a vapor separator, a vacuum source, and a condenser. Multiple effect evaporators evaporate more water per kg of steam by re-using vapors as heat sources in subsequent effects. They also improve heat transfer due to the viscous effects of the black liquor as it becomes more concentrated. But they also require efficient vacuum to move the liquor on through the process and maintain differential pressure from effect to effect.


Figure 2 - A Seven Effect Black Liquor Evaporator at Dawn.

As explained above, each effect operates at a lower pressure and temperature than the preceding one. The lower pressure creates a temperature difference across each effect. Since vapors are removed from the preceding effect at the boiling temperature of the black liquor, the difference in temperature cannot exist in the proceeding effect without increasing its vacuum. The operating cost of evaporation is relative to the number of effects and the temperature at which they operate, all of which hinges on the tightness of the system, otherwise expressed as its ability to pull and hold a vacuum.

It should be noted here that black liquor, for all its energy potential, is also corrosive. Stress corrosion cracking of stainless steel is more likely to occur in heavy black liquors where the solids contents are above 70%. This is due to the high process temperatures required to both concentrate the liquor solids and to also keep the viscosity of the liquor low enough for pumping. Very high service temperatures combined with corrosive products have been known to impact stainless steel tubes in heat exchangers and are now being replaced with high chromium ferrite stainless steel, which provides better resistance to corrosion from liquors and high temperatures. Herein was the problem on the number four effect stack at our customer.

## Black Liquor Evaporator Vacuum Leak Survey

In November, 2009 SDT Ultrasound Systems received a phone call from a pulp and paper plant in the Pacific Northwest asking if our ultrasound technology could find vacuum leaks on evaporator stacks. Several leak detection service companies had been approached already but none seemed willing to risk the expense of visiting the plant with an uncertain outcome. SDT is lucky enough to have a sound technical representative situated near the Pacific Northwest willing to embrace risk in exchange for providing customer solutions and satisfaction. Karl Hoffower, of Failure Prevention and Condition Monitoring Solutions, Inc took the call and scheduled a visit to the mill. He filed this report.

## Vacuum Leak Inspection on Multiple Effect Evaporator at major Pacific Northwest Pulp & Paper Mill

A report submitted by Karl Hoffower

On December 14th & 15th, 2009, a vacuum leak survey was completed on the black liquor evaporator at a major pulp and paper producer in Idaho. Evaluation of the black liquor process numbers indicated the most likely area of the vacuum leak was somewhere in the 4th effect piping.

Using an SDT170 ultrasound listening device coupled with the new SDT RS-1 (resonant sensor 1) contact needle probe, contact measurements were obtained at various locations along the 4th effect stack. These readings were taken through the insulation and outer steel wrapping. The highest external reading noted was 51db. This location also correlated with the thinnest section of the stack recorded by ultrasonic thickness testing already done by their NDT crew.

Switching to airborne ultrasound detection mode revealed a jump from the ambient levels of 18db to a strong 32dB$\mu$V -33 dB$\mu$V with the tell-tale whooshing sound of a vacuum leak. When the insulation near the bottom of the access door was moved the airborne ultrasound levels rose to 38dB$\mu$V.

Cutting away a large section of the sheet steel and insulation revealed numerous points where the metal had been breached by the corrosive black liquor. The breaches had created a loss of vacuum in the 4th effect stack.

Rubber sheets had been pre-cut in preparation for discovering the locations of the leaks. These sheets were placed over the areas of the holes as a temporary repair and to avoid a complete loss of vacuum on the evaporator system when the insulation was removed.

A repair was carried out to help allow the system to function properly and continue until a planned outage in March 2010 can have the stacks replaced. Gor-tex sheets were wrapped around the stack and sealed with silicone caulking.

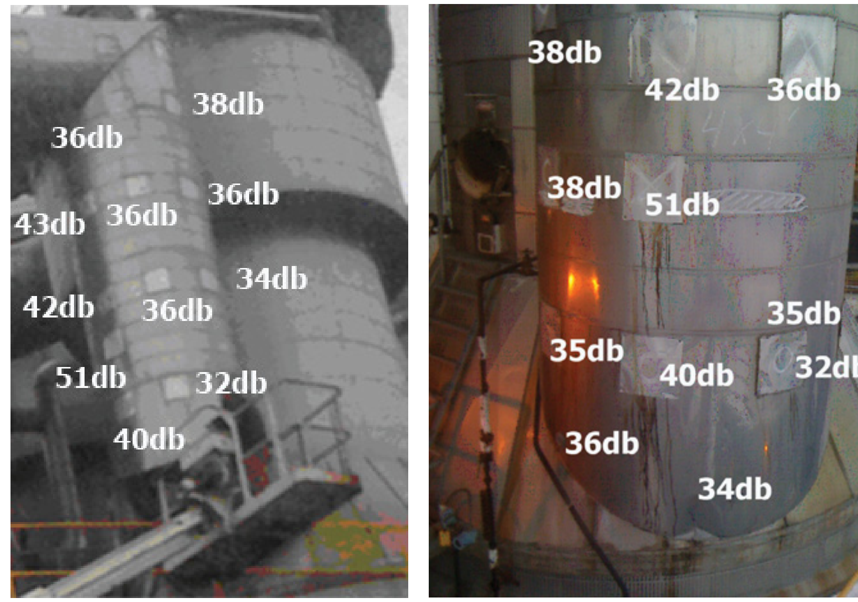



Figure 3 - Diagrams show dB levels mapped out using SDT RS1 Contact Probe. Vacuum leaks detected through 4" insulation and outer sheet steel. Loudest areas were cut away and patched with Gortex patches.

The OSI PI process monitoring software showed an immediate change in the correct direction by the application of the rubber sheets and an even better improvement with the Gore-Tex sheets and silicone caulking.

A "morning report" on 12/17/09 stated: "Vacuum improvements on the evaporators resulted in the best solids throughput tons per day we have achieved on the set in the recent past."

### Testing procedure

Plant personnel explained that the evaporator stacks had several access ports covered by rubber stoppers. These pre-made ports had been constructed to allow easy access for periodic thickness testing. The procedure discussed was to access these ports on the evaporator and contact or "touch" the point with the RS-1 needle probe. The decibel level would be recorded and mapped out.

Maintenance personnel also told us of additional access doors created on the stacks for thickness testing. These access doors were sealed with silicone and screws with 4"-6" of insulation in-between. These additional doors helped make our survey successful.

By mapping the decibel levels at various points around and along the stacks, an area or areas of potential leak could be determined for further investigation. (See Figure 3.)

### Challenges

There were several challenges to completing this survey, access being the primary hurdle. Four rubber access points were easy to get to while standing on the roof of the evaporator building. A man-lift was then employed to gain access to more points (see Figure 4). But if the leak was occurring in a location inaccessible by the man-lift, then staging would have to be employed to gain access to the other stacks. Flow is made more turbulent at twists, angles and bends, like 90 degree elbows. The evaporator stacks had numerous 90 degree elbows. Differentiating between excessive turbulent flow caused by a 90 degree elbow and a vacuum leak was another potential hurdle that was overcome by my extensive inspector training. This training prepared me with the necessary skills to differentiate between internal turbulent flow and turbulent flow that is the result of a leak.

### Survey

The black liquor evaporator uses a 7-effect counter flow method to concentrate the mixture. Using the OSI PI monitoring software, they determined the most likely location was in the 4th effect stack.

Figure 4 - Ultrasound Inspector accesses the 4th Effect Stack from a lift.

Figure 3 shows the maps of decibel levels after we conducted the survey. The decibel levels taken on the inside wall area of the stack (Figure 3, at right) dropped as we moved away from the high of 51db, down to 32db.

The survey required the use of a man-lift to access all of the doors. While the contact ultrasound measurements were made, RCM Tech Jim Storey also conducted contact ultrasound thickness testing. Mr. Storey said that the last thickness survey conducted on this stack had been about 5 years ago.

With airborne ultrasound leaks, a large leak usually registers 65-75db at or around 15' away from the source. Since no other external points had anything higher than 51db we decided to return to that location and investigate further.


Figure 5 - Wall thinning correlated to high dB values.

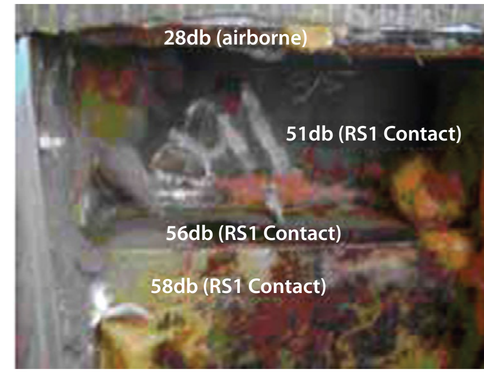
Readings rose when we opened the access door (Figure 5). There was a strong correlation between the locations of the leaks and the thinning of the wall of the stack. At the location of the highest ultrasound, 56db, the wall was found to be 0.091" thin, which was the thinnest area found on our initial survey.

With the ultrasound level increasing as we recorded contacts close to the bottom, I changed from the contact probe to the airborne sensor. Ambient ultrasonic db levels were 18db around the stack. When I brought the airborne sensor near the 51db access door, the airborne sensor jumped to 32db – 33db and gave the whooshing sound of rapidly moving air. When I used my hand to separate some of the insulation away from the metal flange( Figures 6 and 7), readings jumped even further, as the airborne sensor levels rose to 36db.

We decided that we would need to have a larger area opened for inspection. Mr. Storey and I went back to confer with other personnel about how we could gain access to the stack below the retaining ring.

As shown in Figure 8, Mr. Storey marked out the approximate dimensions we wanted to have cut away in chalk.

We went back to the Maintenance shop and were introduced to Mr. Jim Rose. He discussed how he would cut the sheet steel away and remove the insulation to give us better access. We also figured out that we would need to have some type of blocking material to immediately cover the holes we expected to find. If we did not, the probability of losing the vacuum was great, thus potentially causing the entire process to shutdown.





Figures 6 and 7 - Pushing insulation aside allowed further pinpointing of the leaks.

## Corrosion Damage Found

As soon as Mr. Rose removed the sheet steel (see Figure 9) we could see where the insulation had collapsed around the vacuum pull of the stack. As the insulation was peeled away, the holes were immediately visible. We placed two rubber sheets over the large holes

Figure 8 - After ultrasonic inspection determined where vacuum leaks would be found, the area was marked in chalk.

Figure 9 - The marked area was then cut away for better access to leak sites.

Figure 10 - After removing the sheet metal and peeling the insulation back, multiple holes and thinning walls were discovered.

to prevent the loss of vacuum. The sheet on the left covered the largest area of corrosion, about 8” wide. The 2nd major area of damage was about 1½ inches wide.

Several other smaller holes were noticed along the underside of the metal flange area. The exact number of holes were too numerous to count. Also many of the holes had blended together from the corrosion.

Mr. Rose recommended applying Gor-Tex sheets sealed with silicone to effect a strong, yet temporary repair. The decision was to strengthen and seal the holes so that the process could continue until a planned outage in several months later. At that time a complete repair/replacement could be implemented. As they removed more of the sheet metal and insulation for the final repair, additional thickness testing was performed. The areas below where the holes were discovered clearly show how the stack is wearing out. 0.077” was the thinnest area found without actually being a hole.

## Conclusion

After the Gore-Tex sheets were wrapped and sealed, the process monitoring software validated the repair. The amount of vacuum began returning to levels not seen for quite a while. The control valve also moved dramatically into the correct direction right as the repair was being finished. By 4pm on December 15th it was apparent the system had been returned to normal. The survey is considered ended and a success.

I was sent an e-mail that noted, the “morning report” on 12/17/09 stated the following: “Vacuum improvements on the evaporators resulted in the best solids throughput tons per day we have achieved on the set in the recent past.”

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The report filed by Mr. Hoffower illustrates just how complex the job of locating vacuum leaks can be. The complexity in this case was magnified by several conditions, including insulation material wrapping the stack, sheet metal covering the insulation, primary and secondary air gaps between stack, insulation, and sheet metal, high elevations requiring a lift and platform, ambient noise in the ultrasound frequencies related to non-leaking turbulent flow, and of course, the discomfort of high temperatures which also pose a safety risk.

The report also illustrates how rewarding the job can be. The win for this paper company is a reduction in energy costs through more efficient vacuum level maintenance and better thermal transfer from effect to effect. Additionally they have the best throughput of black liquor in years. Make no mistake here; these are trying times for paper makers. The difference between a profitable quarter and a losing quarter may well be decided by the efficiency of a single process such as black liquor production.

Many leak surveys are abandoned due to frustration, which is the product of poor quality equipment ill suited to the task. It is also the product of training. Without ultrasound training, an inspector will be overcome by the hurdles of the task. Your investment in an ultrasound program must be threefold. Invest in quality ultrasound equipment, quality personnel to carry out the inspection, and equally as important, but often overlooked, inspector training. Training must address the unique place ultrasound holds for reliability and plant maintenance, ensure good transfer of knowledge between teacher and inspector, and return the inspector to the field with the confidence to succeed in the most trying inspections.

*Allan Rienstra is the CEO of SDT Ultrasound Systems. He has been involved with airborne ultrasound methods for nearly two decades and has helped thousands of ultrasound inspectors achieve inspection greatness through his unique coaching techniques. He is founder of the SDT certification training and implementation guide and co-author of two certification training manuals, and the newly published book Hear More, a Guide to Using Ultrasound for Leak Detection and Condition Monitoring. His writing appears in maintenance journals around the world. He lives in Cobourg, Ontario Canada with his wife and two sons. Allan can be reached at allan@sdtnorthamerica.com or 905-377-1313 x 221*

*Karl Hoffower is the founder of Failure Prevention Associates, San Jose, CA, which helps Predictive and Condition-based Maintenance programs become a reality for many more companies. When first introduced to the concept of PdM/CBM, Karl realized this was a great marriage between his interest in science and real-world applications. You can reach him at Karlh@failureprevention.net*

# Great Savings for Great River

## Continuous Monitoring Lowers Costs, Boosts Performance

*by Robert Skeirik and Craig Truempi*

The ability of continuous vibration monitoring to provide early detection of potential bearing problems in rotating equipment allows users to plan maintenance work in advance. This maximizes uptime by minimizing the impact of costly machine break downs. For example, Great River Energy, a wholesale electric power cooperative headquartered in Maple Grove, Minnesota, has saved tens of thousands of dollars after initiating continuous vibration monitoring as a means of solving maintenance issues at its Elk River Station power plant. In less than two weeks after installing monitors on the high-speed AVP Anhydro rotary atomizers in the exhaust gas scrubbers, two faulty bearings were identified.

Almost immediately after the first vibration monitor was commissioned, a motor bearing fault was detected in time to prevent an unexpected breakdown, saving the plant at least $40,000 in motor repair costs, not including the value of the unplanned downtime. If an atomizer were to stop operating due to a bearing fault, or any other reason, the plant might have to de-rate to 50 percent production while making repairs.

Within a week, a second transmitter detected an atomizer bearing problem at “maintenance level”, which meant the atomizer could safely be kept in service while operators monitored its condition. With the information that the first atomizer had a severe bearing fault, it was decided to delay the planned maintenance and keep the backup atomizer available. This proved to be a wise decision as the bearing failed several days later. Without the backup atomizer, it could have taken as long as 12 hours to repair the failed bearing, costing approximately $15,000 in lost production. Predictive vibration monitoring prevented any such loss by showing that the second atomizer could continue to operate for some time.

Great River Energy is a not-for-profit cooperative owned by 28 member cooperatives throughout Minnesota. Collectively, these organizations serve about 1.7 million people. As the second largest electric power supplier in the state, Great River Energy owns and operates nine power plants capable of generating more than 2,500 megawatts of electricity.

The Elk River Station, which is located about 25 miles northwest of Minneapolis, converts nearly two million pounds of refuse derived fuel (RDF) every day into enough electricity to power about 30,000 homes. The waste is collected from five surrounding counties, and those materials that can be recycled as well as items that cannot be burned are removed, leaving 1000 tons of RDF to be consumed daily, producing high-pressure steam to turn the station’s three power generators.

Energy is conserved, and the amount of waste entering area landfills is reduced by more than 250,000 tons per year. Emissions of methane, a highly active greenhouse gas, are also greatly reduced. An efficient combustion process is designed to prevent the formation of dioxins as the RDF is burned. Special environmental equipment also treats the smoke and gases formed in the process of incinerating this fuel. Still, despite all these efforts, some undesirable materials must be removed from the burner exhaust gases.

The AVP Anhydro atomizers are commonly used in power plant scrubbers to reduce airborne pollutants before they reach the bag-house. Spinning at 12,000 rpm, they spew a fine lime/slurry mist throughout the scrubber chambers. The spray reacts chemically with the acid gases, forming a fine particulate (dust) that is collected in a


Figure 1 - The Elk River Station is a Waste-to-Energy facility, which creates enough electricity to power about 30,000 homes.

Figure 2 - Keeping tabs on the equipment's condition from the control room at Elk River Station.

hopper below or trapped in the downstream fabric-filter bag-house. This is necessary for the plant to remain in compliance with EPA air quality regulations. Failure to comply can result in fines, but emissions from the station are normally very low.

However, the atomizers require a high degree of maintenance. In the past, they were allowed to remain in service only two weeks at a time before being replaced for inspection and repair. The Elk River Station has three atomizer units available for its two scrubbers. Typically, two atomizers were in service while the third received maintenance, and was then held in reserve on a test stand until time to replace one of the other two, after just two weeks in the scrubber. Even then, the expensive precision bearings for these units were replaced quarterly as a matter of preventive maintenance. At $10,000 per atomizer bearing set, this amounted to an operating cost of $120,000 per year plus the skilled labor involved.

Great River Energy management was looking for state-of-the-art predictive monitoring for these atomizers in this critical application. In response, Emerson proposed the CSI 9210 Machinery Health Transmitter, which has enough channels to monitor the drive motor as well as the atomizer bearings. By monitoring vibration, including peak values, with the new transmitters, company officials expected to be able to more accurately predict failures well ahead of time, and make repairs during regular hours when full maintenance support is available.

Almost immediately after the first monitor was installed at the Elk River Station, a warning of excess high-pass vibration in a drive motor was received in the control room (see Figure 2). The information was forwarded to Emerson's Asset Optimization facility in Knoxville, Tennessee, where expert analysts made an initial diagnosis that a bearing was dry and needed lubrication. The operators continued to maintain a close watch on the vibration readings after the bearing was lubricated. Within only a few days, high-pass vibration in that motor suddenly jumped to 30 times the normal level, and the peak waveform topped out at 117 Gs, more than six times the fault alarm level of 18 Gs. The operators on duty immediately shut the motor down, preventing damage to either the motor or atomizer. See Figure 3.

Later investigation showed that no lubricant was reaching the bearing, but piling up inside the motor housing. This dry bearing might have seized up at any time causing severe motor damage. However, by quickly shutting down the unit based on the continuous high-pass vibration readings, the operators saved their company at least $40,000 in motor repairs.

When the second continuous vibration monitor was installed just days later, a high waveform value of 36 Gs was identified in the spindle bearing of the atomizer. Because the backup atomizer had to be kept in a "ready" mode, plans were made to delay replacement of the second atomizer for two weeks, depending on the vibration levels.

Fortunately, the spectrum and waveform readings on this bearing did not change appreciably during the following two weeks, so when it was time to rotate that atomizer out of service, a decision was made not to replace the high precision bearings at a cost of $10,000 per atomizer. Instead, plant per-

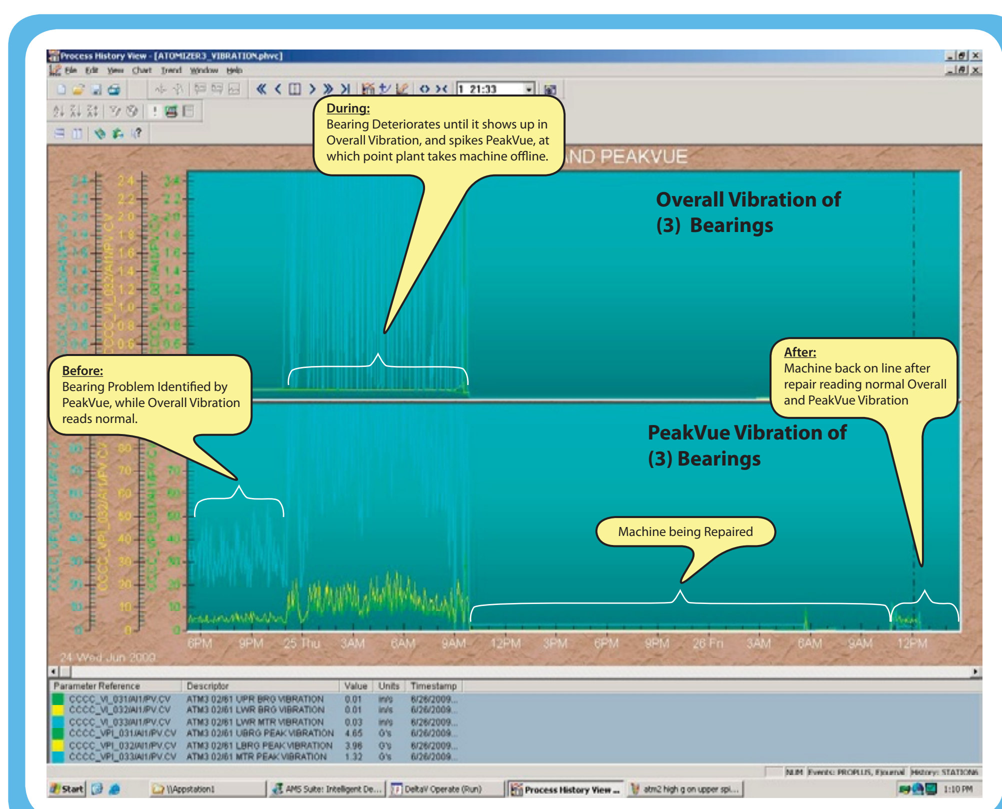


Figure 3 -- Trend Window of Vibration Data on Atomizer #3

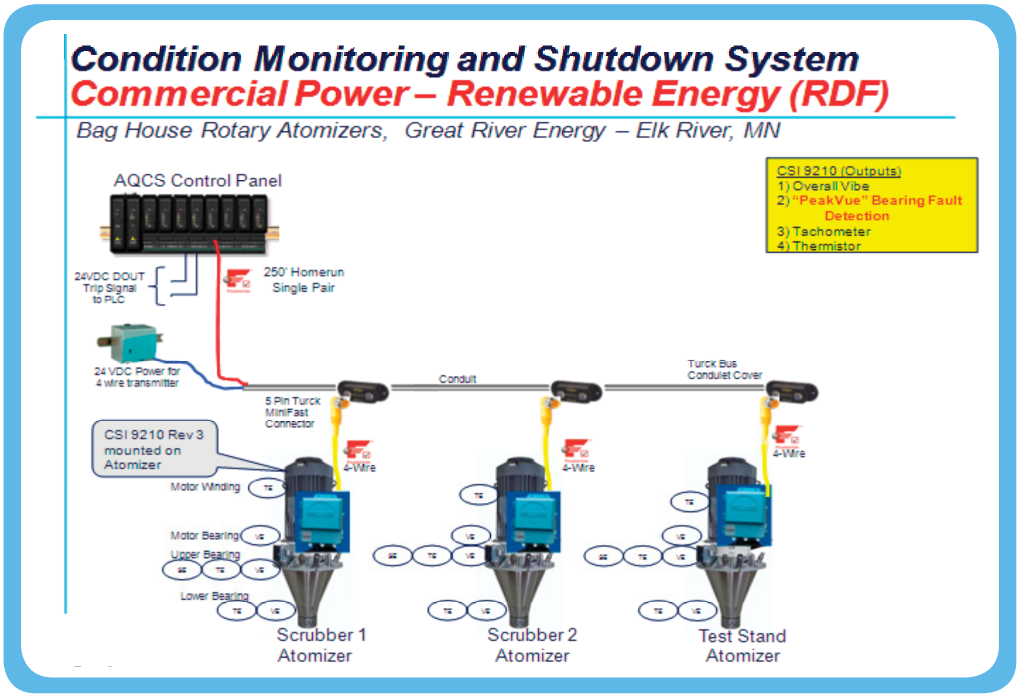


Figure 4 -- Condition Monitoring and Shutdown System

sonnel continued to watch the data with full knowledge of the current condition of the bearings.

## Continuous monitoring

Continuous monitoring of both overall and high-pass vibration provides assurance that essential equipment is always available. Smart transmitters acquire vibration, temperature, and machine speed data on driving and driven rotary equipment and calculate user-defined parameters.

The instruments mounted on the atomizers at Elk River Station each monitor ten parameters (See Figure 4). Outputs include:

- overall vibration velocity ranging from 2 to 2000 Hz on two atomizer bearings and one motor bearing
- maximum waveform energy from 2000 Hz to 20,000 Hz for early fault detection on all three bearings
- two bearing temperatures
- speed (tachometer also used as a belt-break detector)
- one motor surface temperature.

When necessary, alerts are issued and corrective action is recommended and communicated to any host.

The data is passed to the control room, where it is trended and alarmed on the plant's digital automation system. Each atomizer is now allowed to remain in service until the readings indicate it is time for replacement. Since bearing run-time per atomizer has been more than tripled from three to six months and counting, this has extended bearing life and deferred maintenance costs. So far, the plant has saved $90,000 in parts costs over the nine-month period the vibration monitors have been in service.

Since each continuous vibration monitor transmitter utilizes FOUNDATION™ fieldbus communications, it was mounted directly on an atomizer, eliminating a local junction box, field control panel, and associated cabling, so installation and engineering costs were reduced by about $35,000.

## Results of Predictive Maintenance

Never-before-available baseline data generated by continuous monitoring of the atomizer bearings is now used to determine how long they should be able run before bearing replacement is necessary. According to Glenn Hauck of Great River Energy, "Early bearing fault detection allows us to predict bearing failures so we can plan ahead for work on the atomizers and avoid lost production."

The goal at Elk River Station is to extend run-times so atomizer bearings are replaced only when necessary – a direct benefit of predictive maintenance. The vibration data are also helpful in predicting when motor bearings will need replacement to maximize their utility without risking unplanned downtime.

Needless to say, continuous vibration monitoring has already reaped enormous benefits for Elk River Station power plant, and will continue to do so into the future.


*Robert Skeirik has over 20 years of experience in industrial asset management, having served as a product management team leader for Emerson's CSI brand vibration products for the last 15 years. He obtained his Bachelor of Science degree in Mathematics and Physics from Michigan State University and an MBA in international marketing from the University of Pittsburgh. He has written, published and presented numerous papers in multiple languages across six continents. He is now a Senior Product Manager with Emerson's Asset Optimization division based in Knoxville, Tennessee. Robert can be reached at 865-675-2400 Ext. 2245 or by e-mail at Robert.Skeirik@emerson.com.*

*Craig Truempi is a Reliability Group Leader at Novaspect, Inc., as well as, the Chairman of the Upper Midwest Chapter of the Vibration Institute. Craig began his career at Novaspect in 1989, and has been involved in a diverse range of reliability based projects including condition monitoring, troubleshooting, analysis, and equipment upgrades of rotating equipment, pipe vibration, control systems, as well as, data integration to business and maintenance systems. Craig has provided consulting, training, engineering, project management, and field startup services in the power, refining, mining, petrochemical, manufacturing, and food industries. He has managed replacements and upgrades of Bently Nevada, Bruel & Kjaer, and Emerson/CSI vibration monitoring equipment. Most recently, Craig led the development and justification for online condition monitoring using wireless technologies from Emerson/CSI, as well as, supported the re-design of related maintenance work processes. He received his B.S in Electrical and Electronic Engineering from North Dakota State University and a M.B.A. from the University of Minnesota. Craig can be reached at 612 965 1720, or by e-mail this address: CTruempi@novaspect.com*

*The applications for which Ultrasonic technology can be used are nearly limitless. Over the last decade, the technology has grown up. And, with the release of SDT's new instrument, Ultrasound is ready to take its rightful place along side the other predictive technologies. Introducing the....*

# SDT270

It is time for you to move Ultrasound to the front lines of your predictive maintenance defenses. Despite the ease of its use, its wide ranging capabilities and the opportunity for its almost immediate payback, Ultrasound has long been regarded by many as only a bit player in PdM. This instrument could change that type of thinking forever.

We asked Allan Rienstra, general manager of SDT Ultrasound Solutions, to enlighten us about the capabilities of the newly released SDT270. Allan has been involved with specifying ultrasound technology solutions for 18 years, and is the co-author of the newly published book on ultrasound *Hear More, a Guide to Using Ultrasound for Leak Detection and Condition Monitoring.* Here are some of Allan's thoughts...


The SDT270 retains the look and feel of the SDT170, but what is inside is a quantum leap forward.

*The slogan for the new SDT270 is "the evolution of ultrasound". What are some of the reasons you consider the SDT270 is a leap forward in ultrasound?*

The SDT270 moves ultrasound technology from the fringes to the forefront of PdM. Predictive maintenance is all about reliable, repeatable data that is trended. Those trends are what are used to make very important decisions about scheduled uptime. Ultrasound has yet to be accepted as a peer companion to other PdM technologies, such as Vibration Analysis and Infrared Imaging. The SDT270 changes that. It changes the way we look at Ultrasound Testing. It's no longer just a leak detector or another inspection tool. Its a symbiotic partner to other technologies, and can even stand alone as the core of your PdM and Reliability program. The SDT270 is the first ultrasound instrument to incorporate:

- An onboard SQL database for PC/Instrument synchronization
- True Amplitude for collecting accurate and comparable wave files
- A USB or Ethernet IP Addressable connection for remote support/training
- Two channel inputs
- Multi-Functional data collection including (dB$\mu$V, RPM, °C/F, SCFM, dBA, and Acceleration)
- Onboard messaging
- Independent amplification and headphone volume adjustment
- Sensor recognition in Survey Mode to prevent data collection with the wrong sensor
- Powerful database software that is both simple and sophisticated

*The SDT270 can come in a variety of customization packages. Tell us a little about the different configurations and options you can equip the instrument with.*

SDT remains true to its reputation for intelligent instrument design. Like its predecessor, the SDT170, SDT270 is an upgradeable platform with features and functions that can be unlocked with firmware keys. This gives ultrasound inspectors unprecedented customization options when selecting the right ultrasound kit. But they aren't boxed in either. Should their needs change, the ability to increase functionality is only an e-mail away. With six different platforms and 4 additional functions, there are actually 96 different ways to customize your SDT270.

- SDT270SB (static/basic)
- SDT270SD (static/datadump)
- SDT270DD(dynamic/datadump)
- SDT270SS (static/storage)
- SDT270SU) (static/UAS)
- SDT270DU (dynamic/UAS)

From these platforms customers can add internal temperature and RPM sensors, and soon they will have the option of adding acceleration measurements and a remote trigger function.

*Tell us a little about the SDT 'Building Block' concept and the advantages that it brings.*

SDT is an Ultrasound Solutions company, not just an instrument manufacturer. The Building Blocks concept combines options for hardware flexibility (described above), software for powerful data management, sensors that promote ergonomics, ease of use, and inspector safety, and training partnerships that help you define your ultrasound program and map its success every step of the way.

No other company provides as comprehensive a solution as SDT, and the Building Blocks concept is all about that.

*The Ultranalysis Suite software seems like a very nice tool to enhance the capabilities of an ultrasound program. Help us understand some of its important features.*

The most significant advance made by Ultranalysis Suite is its database engine. Factory assets are listed out in Tree Node fashion with up to six nodes possible before a sensor must be defined. But here is where it gets totally cool. The tree is the database, but it's separate from the survey. A survey is a list of defined measurements that must be collected at set intervals. Data points in the tree can belong to as many different surveys as you want, making your day-to-day plant tours extremely customizable. Alarming is done on the SDT270 so you know if something's up right away, not after you've returned to your office.

Perhaps the best part is that the SQL database allows both static (dBμV, RPM, °C/F) and dynamic (time wave files) data to be integrated into one place. That means static values and time wave forms and FFT's are all analyzed in the same window, not in separate software.

But the part I like the best is the ability to build the database in the field, on the SDT270. Measurement points can be added to the Tree Structure from the SDT270 simply by saving a measured value in the field. Afterwards, the new structure is synchronized to the PC. We can do this because the SQL database engine resides on both software and hardware. Very cool.

*Tell us a little about the remote access capabilities of the SDT270…*

The SDT270 is the first ultrasound detector to be IP addressable. That means we can remotely operate a device from any web enabled PC.

This means we can trouble shoot the device for firmware issues. It also means you can connect to the web and download the latest firmware directly to the flash memory. We can control which device serial numbers get updates and which ones do not, based on any criteria we set. This allows us to control bug fixes to a few devices only until we know its ready for the general population.

The SDT270 being used in conjunction with a contact probe.

The coolest advantage of the remote access capabilities of the SDT270 is that we can show you how to use your instrument right over the web. That should help the travel budget for equipment orientation.

*Is there an upgrade program for owners of SDT170s to move up to the SDT270?*

Owners of the SDT170, or any ultrasound instrument for that matter, should contact our sales department to discuss trading up to the SDT270. Some cash allowance incentives are available but they are handled case-by-case. Since the SDT170 was also designed on the Building Blocks concept trade-in values may vary.

One suggestion we make is that the SDT170 be kept as a second instrument used for leak detection and trouble shooting. This valuable technology will serve you better remaining in service.

*What are the three top reasons a company should consider investing in an SDT270?*

1. Those seeking the very best in instrument design in terms of durability, repeatability, and versatility, need not look further than the SDT270. Condition monitoring with ultrasound is fast becoming the go-to technology for PdM Managers. The SDT270 represents the best choice out there, and I suspect it will remain so for a long, long time.
2. Starting an ultrasound inspection program does not begin, nor end, with equipment purchase. Constructing a World Class Program begins with a strategy. SDT has been your strategic partner for more than three decades. Don't choose an ultrasound instrument, choose an ultrasound program partner. SDT is the foundation for your Building Blocks to an effective and enduring ultrasound program.
3. The combination of hardware and software is unmatched by any other manufacturer. SDT is truly an innovator of design.

*Would you give us a success story or two from companies that are using the SDT270 now?*

The instrument has not been on the market for a long time, but it is quickly being adopted. Perhaps the General Mills, in Tennessee is our power user to date. They were frustrated with their old ultrasound equipment and especially the reluctance from that manufacturer to listen to their suggested improvements to the software. They have found SDT's software designers and support people to be extremely receptive to their suggestions. Not to mention that the software already came with most of the features they were asking their previous supplier to integrate. Let's revisit this question in 6 months and see how we've done.

*How can interested people get more information about the SDT270?*

The best way is to visit our new website www.SdtHearMore.com and click on the Products page. Here you will find a lot of details. Be sure to complete the subscriber form on the home page to be included in our monthly newsletter and training updates. The United Nations of Ultrasound Forum is now up and running. Registration is required, but free. And finally, visit the Download/Support section where we are building out a learning centre full of tutorials and tips. Or, you can just call us at 1-800-667-5325. We can schedule a Webinar demonstration of the SDT270 and UAS software.

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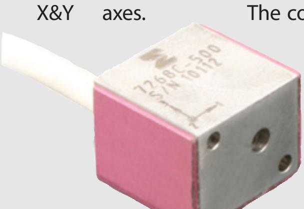
### Turn Existing Accelerometers into 24/7 Vibration Monitoring Sensors

IMI Sensors – a division of PCB Piezotronics, Inc. the industry's No. 1 supplier of 4-20 mA Vibration Transmitters, announces the release of their model 682A09 ICP® In-Line 4-20 mA Vibration Transmitter. Another IMI Sensors industry-first, the model 682A09 installs in line with any industrial accelerometer and converts the vibration signal to a 4-20 mA velocity output that can be trended with today's PLC, DCS or SCADA control room systems. Its sleek design installs right into the cable run, no DIN rails, cabinets or special power required. Now customers can take their existing accelerometers and turn them into 24/7 vibration monitoring devices for their most critical machinery.

For more info about IMI Sensors please call us anytime at 800-959-4464, or visit www.imi-sensors.com

Meggitt Sensing Systems, has announced the global market introduction of the Endevco® model 7268C, a miniature triaxial piezoresistive accelerometer designed for high-reliability measurement of short duration shock across three axes and in three orthogonal directions. Housed within a package size measuring just 12.7 x 10.7 x 13.7 mm (0.5 x 0.42 x 0.54 in.), the Endevco® model 7268C is offered in ranges of 500g, rugged to 5,000g shock with 17k Hz resonant frequency; and 2,000g, rugged to 10,000 g shock with 26k Hz resonant frequency. Sensor frequency response is 0 to 3000 Hz on the Z-axis and 0 to 1500 Hz on the X&Y axes. The combined non-linearity and hysteresis error of the model 7268C is less than 1% FSO, making it one of the most accurate sensors of its kind on the market today.



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### Dreisilker Electric Motors Celebrates 55th Anniversary

Founded May 1, 1955, Dreisilker Electric Motors is celebrating its 55th anniversary at its headquarters in Glen Ellyn, Illinois. When Henry Dreisilker first came to Illinois from Germany in 1954, he found work at an appliance and motor repair business. One year later, he bought the business and founded Dreisilker Electric Motors Inc. His newly established company was dedicated to excellent customer service, highest quality materials, and precision workmanship. Beginning in the late 1960s, the Dreisilker shop adopted their unique Motor-Safe™ Repair method for stripping and rewinding motors. This technique avoids damage to motor components, produces more efficient results, and ensures longer service life than inferior "burnout" methods used by most motor shops. In recent decades, to provide continuous customer support of their products, the DTM2 Program was introduced. This electric motor management service is comprised of a team of experienced motor reliability technicians who perform a wide range of preventive maintenance tests, including motor diagnostics, dynamic balancing, infrared inspection, and vibration analysis.

**http://www.dreisilker.com**

# What's Next in Maintenance and Reliability?

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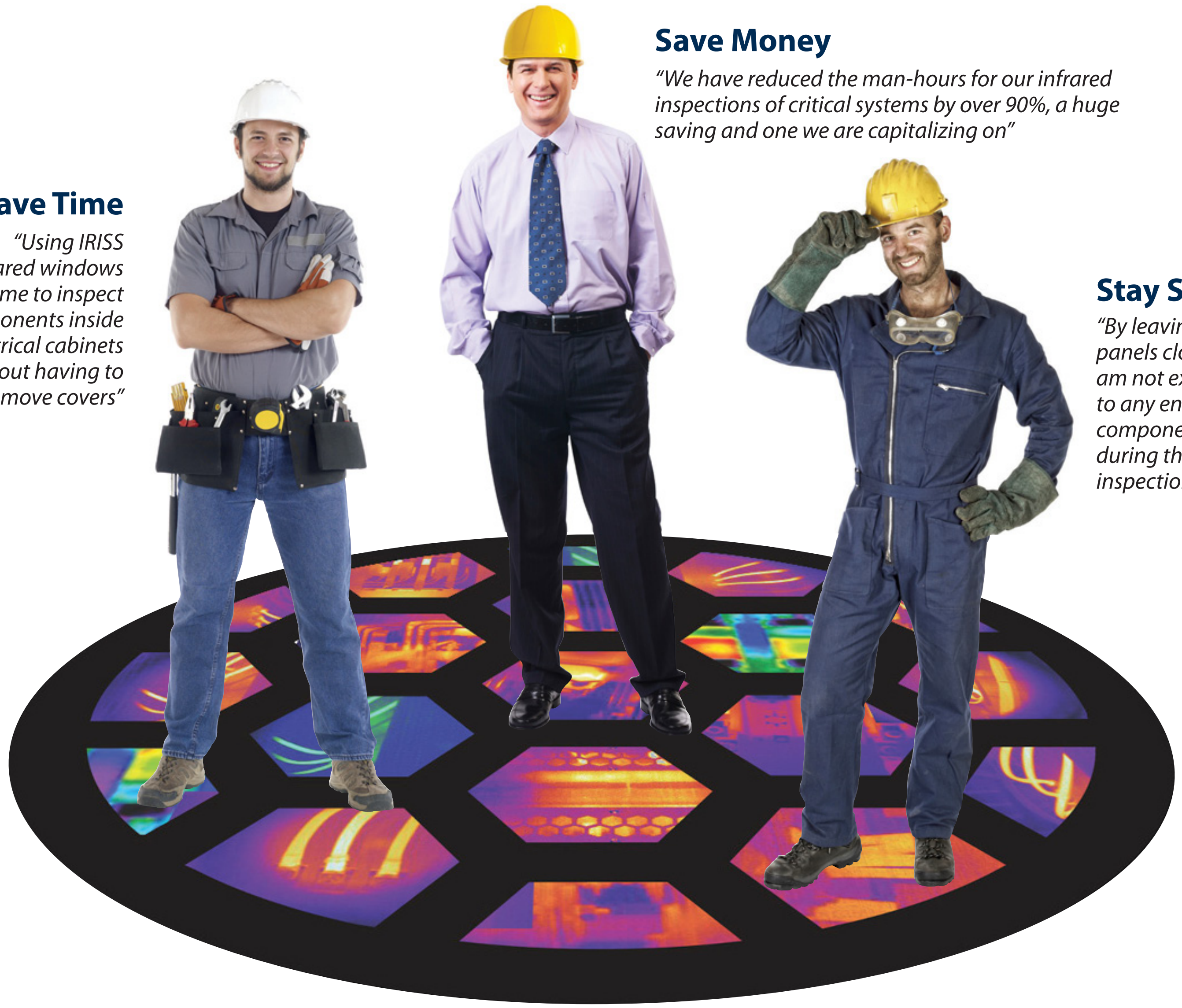

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