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Lessons We Can Learn from Australian Companies in Their Journey Toward Reliability and Operational Excellence

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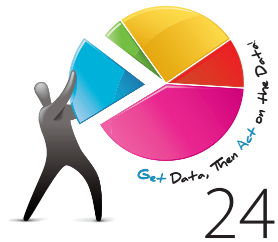

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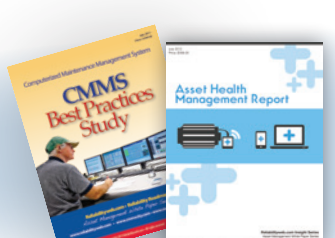

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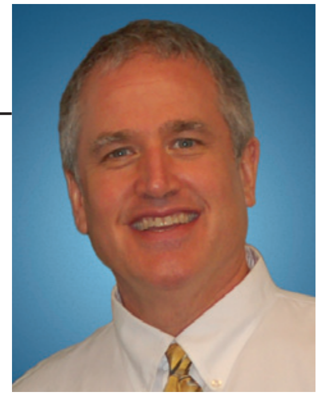
Editorial



Is This As Good As It Gets?

The human body is an amazing thing. Just six months ago, I could barely walk due to Guillain-Barre Syndrome (GBS). Once the condition was diagnosed, of course I got treatment that stopped the antibodies from doing any further damage to the myelin sheath in my peripheral nervous system.

Half a year later, my recovery is at a very high level and 99% of my practical functions have returned. Yes, practical functions. That is the term the physical therapists use for walking, lifting etc….

The statistical outcome for GBS patients is 5% of them die, 20% never recover the functions that they lost and the other 75% recover most or all of their functions within one year. There is very little active research being done in the area due to the low number of people it affects (1:100,000), so those numbers are pretty stable.

They tell me there is nothing that can be done to speed the progress of myelin regrowth, which is a mere 1 millimeter per day. As a result, I still have some small lingering issues with numbness or grip and I sometimes ask myself, "is this as good as it gets?"

The physical therapists do not share my concern for two reasons. One is that chances are these issues will disappear over the next six months and two, I am functioning at a very high level – especially compared to where I started. As long as I have function, they are not concerned about any small sensory lingering issues that do not impede function, even though they bother me.

For me, the answer to "is this as good as it gets?" is a resounding NO. I educate myself and do research on innovations for myelin sheath regrowth. I do physical workouts to ensure my muscles are in good shape. I do yoga to ensure I have balance and flexibility. I eat right. I meditate to ensure my mind is right for more rapid healing and I take herbal supplements that claim too many things for this short editorial. I also have strong faith and surround myself with a wonderful support system.

Does all that make any difference? I say yes, but a skeptic could make a good argument for no. Should I share the physical therapists' view that I should be happy with the return of all practical functions?

No, I am the asset owner and I have added complete sensory feeling and adequate grip strength to the list of functions I want.

In addition, I find that by doing everything possible that I can do, I am practicing good Asset Health Management for the body and life I have been blessed with. I owe that to my Creator and the people who love and support me.

As maintenance reliability leaders, you know that conventional reliability-centered maintenance theory tells us that our job is to ensure function of the system and no more. Just remember though: It is the asset owner who defines the function, not you.

Can you and should you find innovation to enhance asset function that goes beyond traditional reliability-centered maintenance or is this "as good as it gets?"

My advice is you should read everything you can on the subject. Do research, do training, do simulations and exercises, and even consider "reliability meditation" to get your mind right for high performance.

Do not listen to any "expert" who tells you about the ONE WAY to do things. There is no such thing. If I would have listened to my first neurologist, I may have had a much worse outcome. I got other opinions and thankfully, that saved my life.

It is my hope and it is the shared goal of the entire *Uptime* magazine team that we bring you a broad range of innovative ideas to use as you develop and refine your Asset Health Management system with each and every issue.

Look for even more innovation at IMC-2012 The 27th International Maintenance Conference as we think this event will change the world one maintenance reliability leader at a time. Maybe today it is you.

Warmest regards

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Rel

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Lessons We Can Learn from Australian Companies in Their Journey Toward Reliability and Operational Excellence

Ron Moore

IMC2012! Conference Speaker

Introduction

My first trip to Australia was in May 1995. It was exciting and rewarding. I found Australians to be friendly, fun loving, open to new ideas and very interested in reliability. And still do. We have much in common with Australians. I've been going there now three to four times per year ever since then, making four trips per year most years and have now been there more than 60 times. It's a long trip, but every single trip has been very gratifying and rewarding. If ever I were kicked out of the United States for some bizarre reason, I would go to Australia first and ask if they would let me in. More importantly, while all the companies there continue to have considerable opportunity for improvement, their industrial operations have made remarkable progress in their journey toward reliability and operational excellence.

Then – 1995

My first encounter with Australians was in making a presentation to a group called the IMRt of SIRF Rt, that is, the Industry Maintenance Roundtable of the Strategic Industry Research Foundation Roundtables. You can see why it's abbreviated. If you have a keen sense for the obvious, you can guess that it is a group of maintenance managers and engineers, all of whom are very interested in reliability. There are very few, if any, operations managers, no executives, no capital projects managers, no purchasing managers…just maintenance managers. Giving my presentation was a wonderful experience. Everyone (that I know of) was quite enthused to see that the process being presented and discussed required the inclusion of several other functions, among them design, operations and procurement, in order to assure reliability and operational excellence.

In my early trips to Australia, as with most places I've traveled, workshops were attended mostly by maintenance personnel. When the word reliability was mentioned, it was viewed as a maintenance thing, so the nearly automatic response to "reliability workshop" was to send a group of maintenance people. At the time, it was typical for maintenance managers, engineers and others in attendance to report the following:

- Reactive maintenance made up ~50% of the total maintenance work, the balance being heavily focused on PM/planned maintenance, with a small amount of predictive/condition-based and even smaller being proactive or root-cause based.
- Operations had little or no role in assuring reliability.
- Capital projects and purchasing had little or no role in reliability; stores were an afterthought most of the time.
- Overall equipment effectiveness (OEE) or asset utilization (AU) was very often not measured, but when it was, it was reported as ~ 50%-60% for discrete/batch plants and ~ 70%-80% for process plants; it was often not even used to determine asset performance. If the production schedule was met, all was good with the world.
- Most plants were mediocre relative to unit cost of production.

As the Aussies say, it was all pretty ordinary. (Beware of an Aussie saying, "Oh, that's pretty ordinary" – they don't mean average, rather far from it). Maintenance and reliability were, in essence, big **M** and little **r**, very little **r**. My experience, however, has found that if you don't have strong operations leadership and ownership for reliability, along with a strong philosophy for lifecycle costs in the design and total cost of ownership in purchasing, plus excellence in leadership, teamwork and alignment to these principles, you will not have reliability and operational excellence.

Far more executives attend reliability and operational excellence workshops in Australia than any other country.

Now – 2012

Over the past many years, however, Australian companies have made a great deal of progress in most industries. Progress has been slow and gradual, but continuing. There is far greater realization of the leadership role that operations must play to assure reliability; of the fact that most production losses and equipment failures are typically ***not*** controlled by maintenance, but rather by operations and design, and to a lesser extent procurement; and of some simple ratios – there are typically two to 10 times more operators than maintainers in a given operation, so operators plays a critical role in reliability. A simple way of thinking about this is that maintenance can't fix things faster than operations can break them. Alternatively, expecting maintenance to own reliability of a plant is like expecting the mechanic at the garage to own the reliability of your car. Most of us need a good mechanic, but if we don't operate the car properly and take good care of it, the mechanic cannot make up for that.

Today in Australia, there is still a heavy emphasis on maintenance as a key contributor, but there is far more emphasis on operations' leadership role for assuring reliability and a far greater appreciation of the need for reliability to be led from the top, i.e., site manager, VP of operations and COO or CEO.

- Reactive maintenance is now typically in the range ~35% and often less, with the rest being more "balanced," that is having a larger dose of PM/planned maintenance, of predictive/condition-based maintenance and a reasonable dose of proactive or root-cause maintenance.
- Operations has an increasing, and often leadership role, in assuring reliability, except in many mining operations.
- Capital projects, purchasing and stores still need considerable work, but improvements have been made.
- Overall equipment effectiveness (OEE) or asset utilization (AU) is commonly measured and used to develop improvements. It's uncommon for an operation not to be measuring this in some form. While I don't have as much data on this, anecdotally, OEE is routinely measured and seems to be somewhere in the range of ~ 55%-65% for discrete/batch plants and ~ 75%-85% for process plants. A few even report significantly better performance. OEE still needs more attention in terms of how it is used to **manage the losses** from ideal.
- Reliability, much like safety, is a business imperative for many more Australian companies. This is because plant operating data strongly indicate that a reliable plant is a safe plant, a cost effective plant and an environmentally sound plant. To have all these simultaneously, you must be applying reliability principles across the company.
- There is simply a greater overall awareness in Australia of the need for a more holistic approach to reliability.
- Finally, and perhaps most importantly, far more executives, GMs and operations managers are focused on leading the reliability improvement effort, and far more executives attend reliability and operational excellence workshops than any in other countries. Klaus Blache, who heads the Reliability and Maintainability Center (RMC) at the University of Tennessee, points out, "Executives won't come to a course on reliability in the U.S." That has been my experience in the U.S., but not so in Australia. It is ***not*** extraordinary to have a CEO or COO in a session and quite common to have a site GM or VP in a session. In turn, they lead and drive reliability improvement using a more holistic approach.

Why?

While there are many good companies in the U.S., I don't think the overall progress has been as good as it has been in Australia. Why has Australia made more progress, at least from my, perhaps isolated,

perspective? The reasons are numerous and discussed below. I should note that my opinions are not based on any exhaustive research or compelling analysis, but rather impressions from working there for many years. Perhaps we could learn something from them, and indeed, I'm writing this article to share some of what I observed as a frequent traveler to Australia with the hope that the United States and others can benefit from these observations and lessons.

First, and as noted above, more Australian executives have come to realize that reliability is a business imperative, much like safety, and is closely linked to safety. The data from operating plants demonstrate that a reliable plant is a safe and cost effective plant. Though there are many exceptions, Australian companies are more active in reliability and operational excellence than their American counterparts. I believe the reason for this is three-fold: 1) American executives associate reliability with maintenance, and in many cases consider the two synonymous; 2) maintenance is not considered a strategic issue, and therefore of lesser importance (though they complain loudly about the costs); and 3) American executives typically do not understand reliability principles, or maintenance for that matter.

Another reason could be that while Australia is large in land mass (nearly the size of the U.S.), it is a relatively small country in population, with some 20 million people. Furthermore, a larger proportion of industries there, in most states except Victoria, are focused on natural resources – like mining, ore processing and related industries. Because of more common problems, systems and issues, this appears to make networking easier among the different companies in the same industries. A good process for networking is available in Australia and we'll discuss more on that later. This networking process encourages greater sharing of reliability/best practices for operating and maintaining the plant, and more often includes integrating design, procurement and employee development practices. Bill Holmes, Managing Director of SIRF Rt, has suggested that this may not be the case since most mining operations are remote, making networking more difficult, not easier. While it is true that these sites are often quite remote, and having spent several nights in tin huts at these sites, I can certainly relate. The big issue seems to be having the opportunity to network among similar operations. This is where SIRF Rt has played a critical role, which is also discussed below.

Holmes also suggested that this perception may make it easier for others, and particularly Americans, to say, "We're different, so this doesn't apply." While they may actually do that, my opinion is that taking that view is utter nonsense, hogwash. American companies are not all that different. It's just that their leadership is not as involved in reliability and operational excellence as a business imperative. Peter Drucker, famed management consultant, said 90% of all organizational problems are common. Indeed, that has been my experience. W. Edwards Deming said that 85% of all organizational problems are because of poor management and just before he died, he said he was wrong, it was 95 percent. One could argue the percentages, but even if they are anywhere close, the issue is management and leadership. Australia is truly a resource-rich country, and they have the managerial systems, rule of law, infrastructure and technology to take advantage of this.

In a bit of a paradox, however, the same factors that make it essential for Australian resource industries to have reliable operations also make it possible for most of them to make money ***without*** having reliable operations. If you're sitting on a high concentration ore body, reliability is not necessary to be successful – you can be reactive and still make plenty of money. As one person observed, "Excellent ore bodies make bad miners."

More Australian executives have come to realize that reliability is a business imperative, much like safety, and is closely linked to safety.

Granted, the poorer operators soon find themselves in difficulty, particularly if they have no structural advantage, such as a high concentration ore body. The more enlightened companies however, and not just resource-based companies, want to achieve the maximum business performance, and are thus giving a lot of energy to a holistic approach to reliability to assure optimal performance.

One of the major reasons why Australia has made really good progress, in my opinion, is the networking company, SIRF Rt. There are other companies in Australia doing similar things, but I'm most familiar with SIRF Rt. It began with support from the Victorian state government in conjunction with the Commonwealth Scientific and Industrial Research Organization (CSIRO) and the Australian Academy of Technological Sciences and Engineering (ATSE). Its original focus was to bring technology and best practices from around the world into practice in Australian industries, that is, to learn, use and build upon what others have developed, rather than reinventing things that already exist. Its foundation as an organization in the sciences encouraged working from a basis of fact and learning.

According to Bill Holmes, a member of SIRF Rt from its early days and now its managing director, from the beginning, focus was given to learning with an open mind and with no particular agenda except to facilitate the gathering of knowledge ***for its members***. This was crucial to its long-term success. It provided a compass so that emphasis was given to the strategies and tactics that led to success ***for its members***. SIRF Rt was not driven to rollout a particular tool or ideology, but instead its first few years were really a journey of inquiry with a growing number of members benefiting from learning along the way. Knowledge and understanding was sought from around the world. From this, early benchmarking studies showed SIRF Rt that two themes in particular were critical:

1. The principle that maintenance is not about "putting it back together to be as good as new," but rather about understanding why things fail and changing "the system" so they don't fail again. Hence, a more holistic approach to reliability and problem-solving was taken, particularly a focus on other issues, such as operating and design practices. Other issues that came to the forefront were leadership, alignment, teamwork and human resource management. And, of course, attention was given to improvement in traditional maintenance practices, such as planning and scheduling, preventive and predictive maintenance, stores management and contracts management. All these are critical to understand, but are meaningless without a clear direction from the leadership of the organization. Thus, a greater emphasis was placed on the executive role in reliability and operational excellence.
2. The principle that eliminating waste, in all its forms, is critical, as is recognizing the importance of operator ownership and responsibility for outcomes, something which is fundamental, for example, to the Toyota Production System.

In fact both points are really the same, but use words and concepts that are meaningful to different people. Fundamentally, both are about truly understanding what is causing the many forms of waste (another name for defects in the reliability model) and then providing systems that eliminate the waste and defects.

According to Holmes, the early influencing factors were:

- The Fraunhofer Institute for Terotechnology concepts from Manchester University by Dr. Tony Kelly, which gave insights into the European perspective.
- Vince Flynn of DuPont and a paper he delivered at the 1991 TPM World Congress in Tokyo, which, among other things, reported a $200 million a year savings through a focus on reliability. This was an astonishing claim. A $200 million savings to a company might be equivalent to an extra billion dollars in sales, but without all of the capital and logistical costs in achieving the business improvement without growth. This also led to meeting Ed Jones and Winston Ledet, who offered exceptional insight into manufacturing excellence and how to influence a large audience, e.g., 150 or so sites across DuPont, and provided a roadmap to success. Of special note was Winston Ledet's insight on how to change the culture of an organization and address the systemic issues that can be corrosive to success. His workshop, called The Manufacturing Game, is an outstanding example of how to engage people at all levels in understanding the key issues within an organization and in aligning the functional groups within the organization to solve problems and eliminate defects.
- Insights from the Toyota Production System (TPS) were profound. TPS, which applied total productive maintenance, gave insight into the importance of the operator in a reliable plant and prompted the creation of networks focused on manufacturing excellence.
- Various benchmarking studies across some 130 sites were particularly beneficial. However, an important side benefit was that SIRF Rt developed a strong insight into what is important in delivering the best results within an organization. This fed back into the design of its networking activities. SIRF Rt did not randomly present opportunities for learning, but instead focused on the more important messages and the strongest approaches.

Over time, SIRF Rt has "morphed" into a pure networking company, with over 250 members from various companies and industries. This networking approach facilitated the sharing of best practices – operating, maintenance, stores and other practices – among members so as to lift each industry to a highly competitive level on a global scale. Vendors and consultants participate by invitation only, and generally are not permitted in networking meetings. At the request of members, vendors and consultants can present information or do workshops for their benefit. However, the key driver is members sharing among each other how they have addressed particular problems and issues successfully. This gives the practice or approach far more credibility in the eyes of companies considering the practice since there is no bias toward pushing any commercial product or outcome by members as there might be with a consultant. To facilitate this, a regional facilitator takes on several tasks:

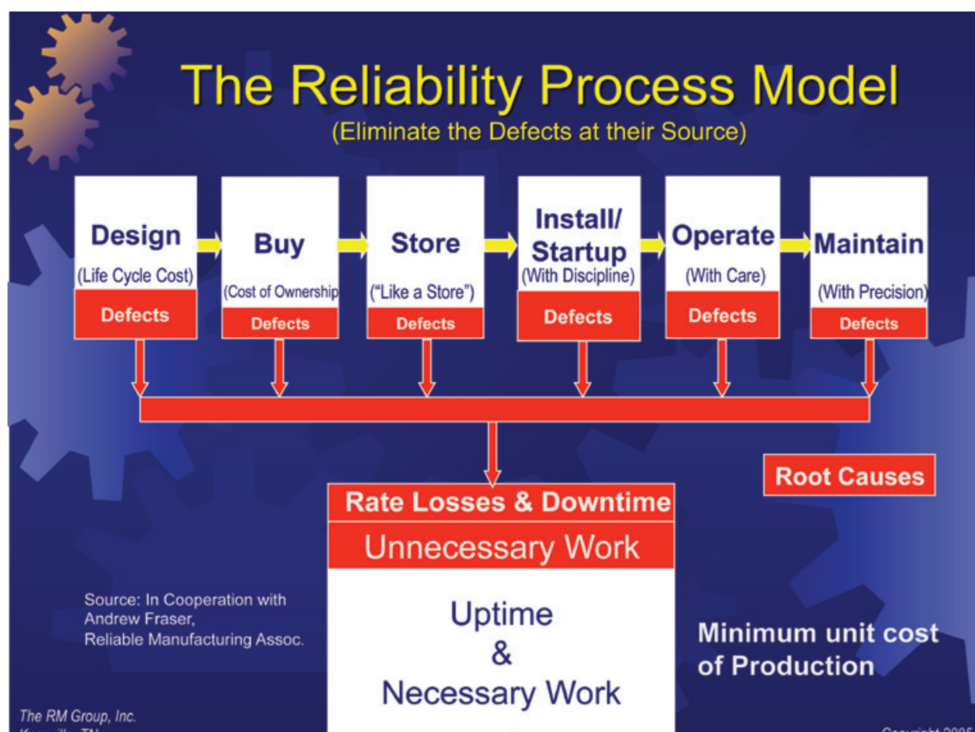


Figure 1: The Reliability Process Model

- Organizes monthly and quarterly meetings for members to share with each other certain practices that have been successful.
- Arranges specific so-called common interest workgroups (CIWGs), wherein a specific issue or practice is reviewed and developed by a subcommittee of members who may have a special interest or expertise in this area, for example, performance measurement, electrical or rotating equipment reliability, operator care, contractor management, developing supplier alliances, and so on.
- Organizes annual conferences for the sharing of specific information around reliability and operational excellence. Different topics are

covered at each conference, e.g., applying lean manufacturing principles, equipment condition monitoring, planning and scheduling, and so on.

- Coordinates external thought leaders to provide specific seminars and workshops targeted at a particular purpose, e.g., lean manufacturing, fleet maintenance, operating practices, reliability and operational excellence, and so on.
- Provides easy access to basic ingredients for success in the areas of problem-solving and waste elimination.

There are 13 SIRF Rt networks and their regional facilitators run more than 300 one- and two-day activities designed to expose and share some aspect of best practices.

It is critical to note that these topics, while facilitated by SIRF Rt staff, are driven by the members and their needs. The focus is on helping members work together to solve common problems and improve performance. As such, they have a much greater sense of ownership and, therefore, focus on implementation of the practices that are developed and shared among the members.

There are many examples of similar concepts around the world, but there seems to be an intensity and clarity of focus and purpose that is different in Australia. To put all this in perspective, remember that Australia's land area is similar to the contiguous United States, but the U.S. population is 15 times greater. If the numbers are simply scaled up by a factor of 15, then SIRF-Rt networks would be similar to a U.S. organization:

- Running 180 regional networks around the U.S.;
- Engaging more than 3,500 companies and sites;
- Conducting more than 4,000 one- and two-day activities per year, all designed at sharing and improving practices in operations. That consistency and drive makes a difference.

Yet to Be

The reliability model often being used in Australia is provided on the opposite page.

While Australian companies have made considerable progress, there is still much to be done. Not withstanding the considerable executive attention being given to reliability as a business imperative, there is still much convincing to be done among executives. There are still too many executives who, when they hear the word reliability, think of it as a maintenance-driven activity. ***It is not***. You will never have good reliability by only doing good maintenance. You will be doing more efficient work that you should ***not*** have to do in the first place. Even worse are those executives who hear the word maintenance and immediately think of costs and breakdowns, something to be viewed very negatively. Clearly, maintenance excellence is required to manage the defects and failures, no matter the cause, but the critical effort for ensuring reliability is to eliminate the defects upstream of maintenance that are causing the failures, and particularly in improving operating and design practices. Reliability must be operations led.

Similarly, much progress has been made in involving operations in taking a stronger, even lead role, in assuring reliability, but much remains to be done. For example, the development of strong, disciplined operator care routines, including look, listen, feel and smell, to ensure operators take care of the place where they make their living so it will take care of them; a greater focus on consistency of operation to specific standards across all shifts; better practice in startup and shutdown efforts since the greatest risk of failure and defect creation is during startup and shutdown; and just generally greater process consistency and conformance to specific standards. My experience has been that about two-thirds of production losses have nothing to do with the equipment. It's because of things like changeovers, rate and quality losses, production planning problems, etc. Of the one-third that is equipment-related, some *two-thirds of that* is typically because of poor operating practices. This leaves maintenance in control of only about 10% of the total production losses. Reliability is about an operation's ability to reliably produce quality product. Maintenance controls very little of that.

There are many examples of similar concepts around the world, but there seems to be an intensity and clarity of focus and purpose that is different in Australia.

In my view, only a little progress has been made in design and purchasing, specifically getting these two functions to think longer term than the initial price or the installed cost, that is, to focus on lifecycle cost and total cost of ownership. Some progress has been made in managing the stores operation, but this area typically reports to purchasing and one of its primary drivers is often reducing inventory since this is working capital not working parts. Reducing inventory and parts availability without improving related operating and maintenance practices will only increase the risk of loss and waste to the business.

And of course, there is still considerable work to be done in maintenance, including better condition monitoring to detect problems early so the risk of loss can be minimized through better planning and scheduling, including integrating the maintenance plan with the production plan so there is one plan for the site; optimization of PM routines for more effective and efficient use of labor; better lubricating practices – some 40% of machinery failures are due to poor lubrication; and greater precision in the work done to put reliability into the equipment.

Training and employee development is also lagging in many companies. Most companies spend millions each year operating and maintaining their plant, but very little to improve their employees' ability to better operate and maintain. As someone once said, "If you think education is expensive, try ignorance."

Conclusion

With all this said, I've observed that Australia has made remarkable progress over the past 17 or so years, for the reasons discussed above, and particularly with executives playing a much stronger role in reliability and operational excellence. Yet, much remains to be done. I'm hoping I'll have another 17 good years to help in their development. However, the more important question is, "What can the United States and other manufacturers learn from the Australians that will help them be more competitive?" Hint – executives must take the leadership role.

Ron Moore is the Managing Partner of The RM Group, Inc. Ron is the author of Making Common Sense Common Practice: Models for Manufacturing Excellence (now in its 4th edition) and What Tool? When? - A Management Guide for Selecting the Right Improvement Tools (now in its 2nd edition), both from the MRO-Zone.com, and Our Transplant Journey: A Caregiver's Story from Amazon.com, as well as over 50 journal articles. He holds a BSME, MSME, MBA and CMRP.

"Wrench Time"

Why the "FEAR" to Measure Maintenance Productivity?

IMC 2012! Conference Speaker

José Wagner Braidotti Jr.

The best results of maintenance practices carried out in enterprises critically depend on the efforts of maintenance staff to ensure their day-to-day actions comply with the schedule of services in order to avoid unwanted failures, correctly diagnose the behavior of active production processes, and ensure quality information recorded in the work orders.

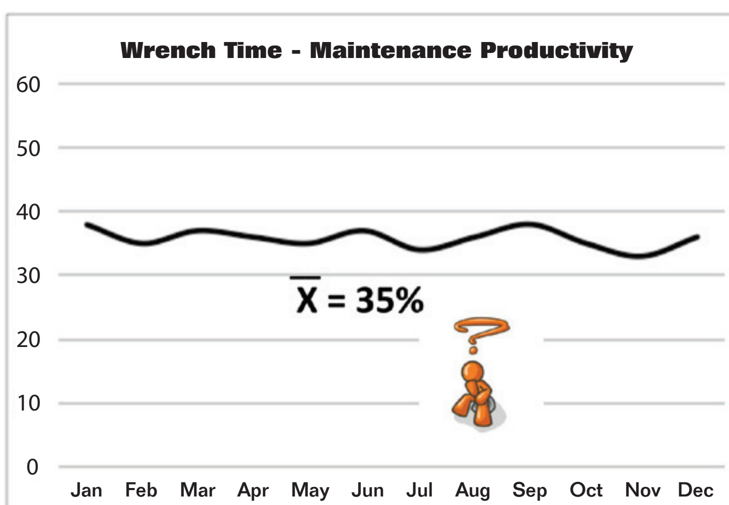


Figure 1: Wrench Time Chart

Because results depend largely on employees, it is of fundamental importance to know the manner in which these same employees conduct all activities related to the total time they are in the company daily.

On the other hand, there is a great paradigm in business that is represented by the fear of employees to report and record in detail their activities on a day-to-day basis. This fear exists even though these same employees were hired with the understanding that they are responsible for performing the daily tasks that are planned, scheduled and necessary for reliably ensuring the stability of the production process.

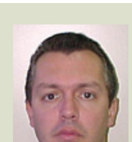
The method that enables identification and distribution of activities by employee time is called **"productivity maintenance,"** which is also known in the international market as **"wrench time."**

Applying this method does not, at any time, involve checking the individual behavior of each employee during their daily practices. Their vices in their work routines would reflect in the analysis of the results as a comparison of individual productivity. The wrench time method has as its central focus direct identification of all negative interference that occurs day-to-day so issues can be properly treated. This ensures that a sustainable process is implemented, thereby providing a continuous improvement factor in the use of maintenance employees.

It should be noted that the demand for improvements to be made is not always directly related to maintenance, or maintenance employees participating in this process. Some examples of this are the time waiting for the release of an asset to deliver the service, the time waiting for the material in the warehouse, the time used for daily shifts in the company, the time waiting for the orientation of supervision, etc.

By recognizing the dynamics represented by maintenance activities in the company and understanding the particularities of the various types of tasks performed daily, the better you can understand and know the parameters that lead to loss of productivity. This knowledge will allow you to make the performance of maintenance more assertive and increase the degree of utilization of employees to maintain productivity in the required service so results can be better, both in terms of fulfillment in what is scheduled and in meeting the economic viability of the maintenance department.

Depending on the opportunity for continuous improvement on actions related to processes identified as deviations from performance by direct interference in daily services performed by service technicians, it is possible to identify a dynamic and flexible result, one that is designed through a staggered target in search of the best possible productivity for each analyzed maintenance team.



José Wagner Braidotti Jr. has more than 28 years of experience in the technical area, working for JWB Engineering and Consultancy as Director, in the SIEMENS Technical Service as Maintenance Engineering Manager, in the ABB Service as Maintenance Engineering Manager of MMC (Maintenance Methodology Center) and in the Indústrias Votorantim - Cement as Senior Mechanical Engineer.

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Converting Reliability Initiatives into Measurable Returns

Darrin J. Wikoff

Today's economic climate brings with it the challenge of accessing credit for capital investment. In *The Ernst & Young Business Risk Report 2010*, as shown in Figure 1, access to credit hit number two on the top 10 list of business risks across 14 sectors evaluated in the study. Internationally, asset management professionals are working collaboratively to define new standards that shift the focus away from capital replacement and instead bring visibility to asset performance.

Return on assets (ROA) is a leading financial and asset performance indicator used by investors and executives when making decisions that impact the long-term viability of a business. ROA allows for a comparison of like-industry organizations to determine which is the most cost effective at producing a particular product. Typically, in today's competitive and credit-constrained economy, ROA is a first-pass differentiator between those companies that receive capital investment and those that do not.

ROA is calculated by dividing the company's net income by the average asset value for a specific fiscal period. Net income refers to the total revenue gained from the sale of goods produced minus the cost of goods sold. Asset value is the average value of all of the company's assets throughout the fiscal period, as asset value may vary due to capital increases and depreciation. ROA is usually expressed as a percentage, however, some organizations report it as a multiplier of net profit margin to illustrate asset turns.

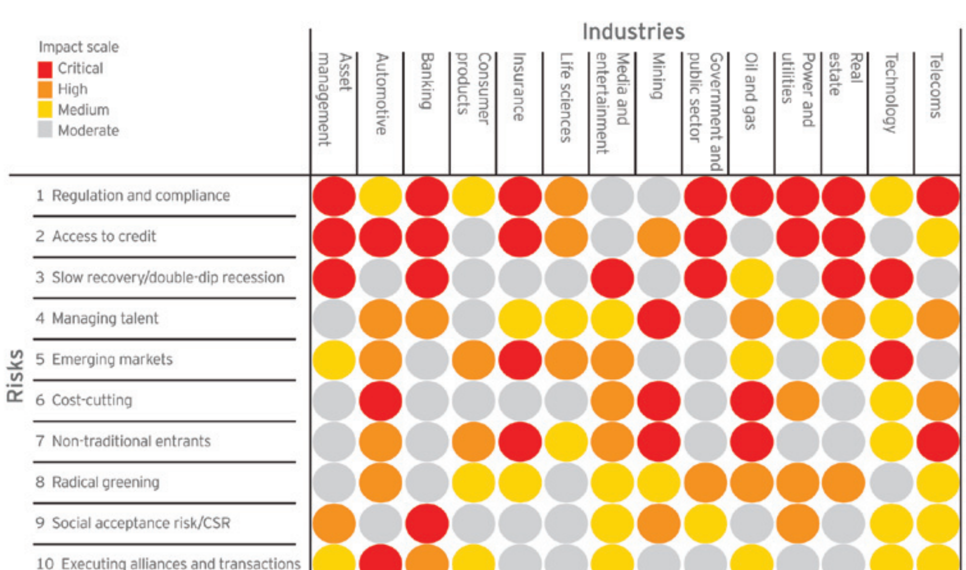

Figure 1 – Ernst & Young Top 10 Business Risks, Risk Impact Matrix

Stepping Away from Capital Replacement

Over the past 20 years, capital replacement has been the predominant solution used by asset management professionals to address suboptimal asset performance. As a cost consolidation tactic, maintenance of physical assets is often held to a minimum until capital resources are available to replace the perceived to be "old" asset. In many cases, once the asset is scheduled for capital replacement, preventive maintenance strategies are postponed. Even after capital replacement, some organizations forego maintenance activities until the asset shows signs of "aging." In the reliability engineering community, we know these practices are reactive, and although they may have a short-term financial benefit to the organization, these practices have a negative long-term impact on ROA.

There are two fatal flaws associated with the capital replacement philosophy as it relates to ROA. First, when we replace a fully depreciated asset, our asset value goes up, causing the company's ROA to go down. If the organization is impacted by a loss in production volume during the installation of the new asset or incurs extraordinary costs after installation, ROA is doubly affected. The second fatal flaw, and one that is commonly made in pharmaceutical and food and beverage industries, is upgrading technology at the time of replacement. Reliability professionals agree that, in the event that capital replacement is necessary, the organization should strive to utilize 80% of existing technology. With regards to ROA, upgrading technology will inevitably result in an increase in costs, with as much as 60% of that increase accruing in the first two years after installation. When an organization upgrades technology, the cost of maintaining and operating the asset increases as a result of:

1) the need for additional spare parts that are not currently provisioned for under the old technology, 2) the need for training operators and maintainers on the new asset, and 3) inefficiencies experienced as operators and maintainers are becoming familiar with the new asset. While the first two cost factors can be estimated during the final design phase of the capital project, the third is more difficult, and often the most costly. Even though the loss of performance caused by an "old" asset will likely be resolved by the capital replacement, new and even greater process losses will be experienced in the first year after installation in this scenario.

Identifying Performance Losses

ROA, like any other business metric, is a numbers game, one which is poorly played in many manufacturing settings because of the lack of available data for decision making. At the executive level, data is only presented as net income and a financial valuation of assets, with little visibility of what makes up the company's asset portfolio or how those assets are performing compared to the efficiency of the operating process itself.

Decisions made at this level can have a significant and sometimes adverse impact on physical assets in order to reposition the company's ROA rating. Even when executives are looking at the assets side of the equation, they are generally focused on reducing the number of assets to compensate for a less than favorable net income. This only creates more pressure on the remaining assets to perform at higher levels. It's a chaotic cycle. When an organization chooses to consolidate assets, they are forced to run harder and longer with the remaining assets and maintenance strategies are cut short, which further reinforces the perception that assets are aging because they are failing more often. The company finds itself again looking to capital replacement as the only option, undoing the financial gains from the original decision to reduce asset value.

In turn, senior management at the local level tends to be narrowly focused on reducing costs or maximizing production. Obviously, this behavior is created by the focus of executive leaders; however, as a result of inadequate process-related data, the effects of their decisions are similar in that they seldom aim to resolve non-asset related issues. Transforming your company's ROA valuation today means business leaders will need to have a better understanding of how assets are performing. Cost is just the tip of the iceberg.

When the question arises on how to improve performance, it is important to understand the characteristics of performance. Over the past few years, researchers have analyzed specific industries to better understand these characteristics. Figure 2 illustrates the contributors to less than ideal performance within the food and beverage industry as an example.

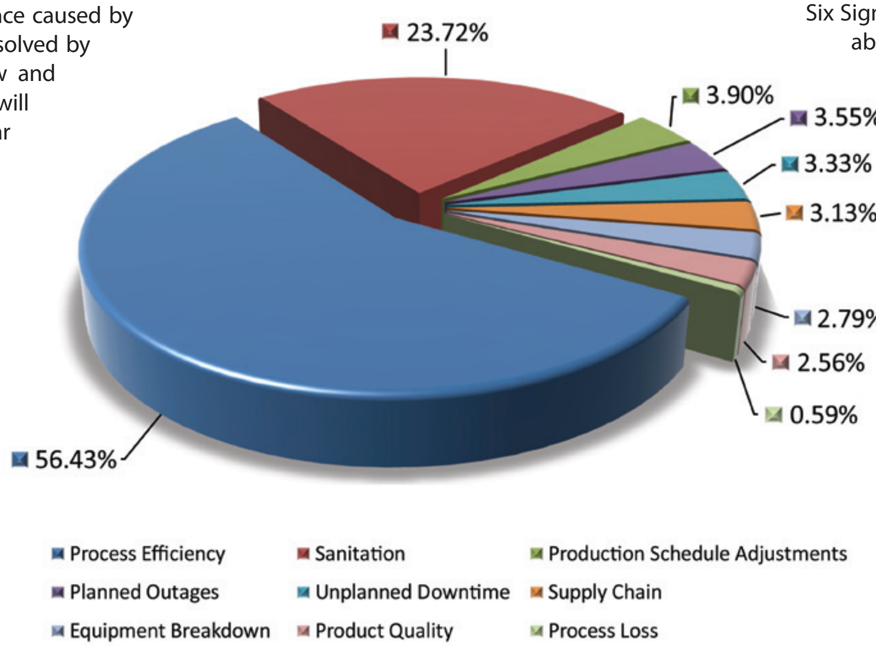

Figure 2 – Food and Beverage Industry Study of Performance Losses

To begin your reliability improvement journey, you will need to identify the performance losses and monetize the impact that reliability improvements will have on the company in order to obtain sponsorship.

Here we see that just over 56% of the total losses that impact net income are the result of process inefficiency. Also notable is the fact that equipment or asset-related downtime losses are less than 3 percent.

If we were to continue our examination of process efficiency losses within a food and beverage company using Weibull analysis, we would most certainly discover that variation over an annual fiscal period (e.g. 365 days) is *not* normally distributed. Using Barringer's process reliability analysis model, as shown in Figure 3, we can determine the rate of variation, known as the Beta, and the number of production units lost when compared to a "nameplate" value that defines the acceptable level of variation. In Six Sigma terms, a Beta of 50 is acceptable. In the example provided, a Three Sigma target of 25 has been selected as the comparator for this food and beverage company.

In Figure 3, we have two categories of losses, asset-related "special cause" losses and non-asset related "common cause" losses, which are the result of human error, speed reductions and minor process interruptions. Notice that, despite the misleading areas under each category resulting from the varying scale on the X-axis, common cause losses account for 54% of the total process inefficiency.

From these two examples, we can conclude that the company is not receiving optimum earned value from its assets due to both asset-related and non-asset related causes, and that replacing assets as the only improvement strategy will account for less than 28% of the total causes of less than ideal performance, an insignificant figure in the ROA calculation.

Return On Asset Reliability

Fewer and fewer companies in 2012 will have the luxury of using capital resources to recover from performance losses, which means your organization will need an alternative strategy to be competitive. Reliability improvement strategies focused on eliminating performance losses are a viable alternative and can have a more favorable affect on the overall financial health of the company. To begin your reliability improvement journey, you will need to identify the performance losses and monetize the impact that reliability improvements will have on the company in order to obtain sponsorship. Instead of focusing your reliability improvement business case solely on cost reduction, tune in to the language of executives and communicate the opportunity in terms of ROA.

Return On Asset Reliability™ (ROAR™), developed by GP*Allied*, is the practice of maximizing

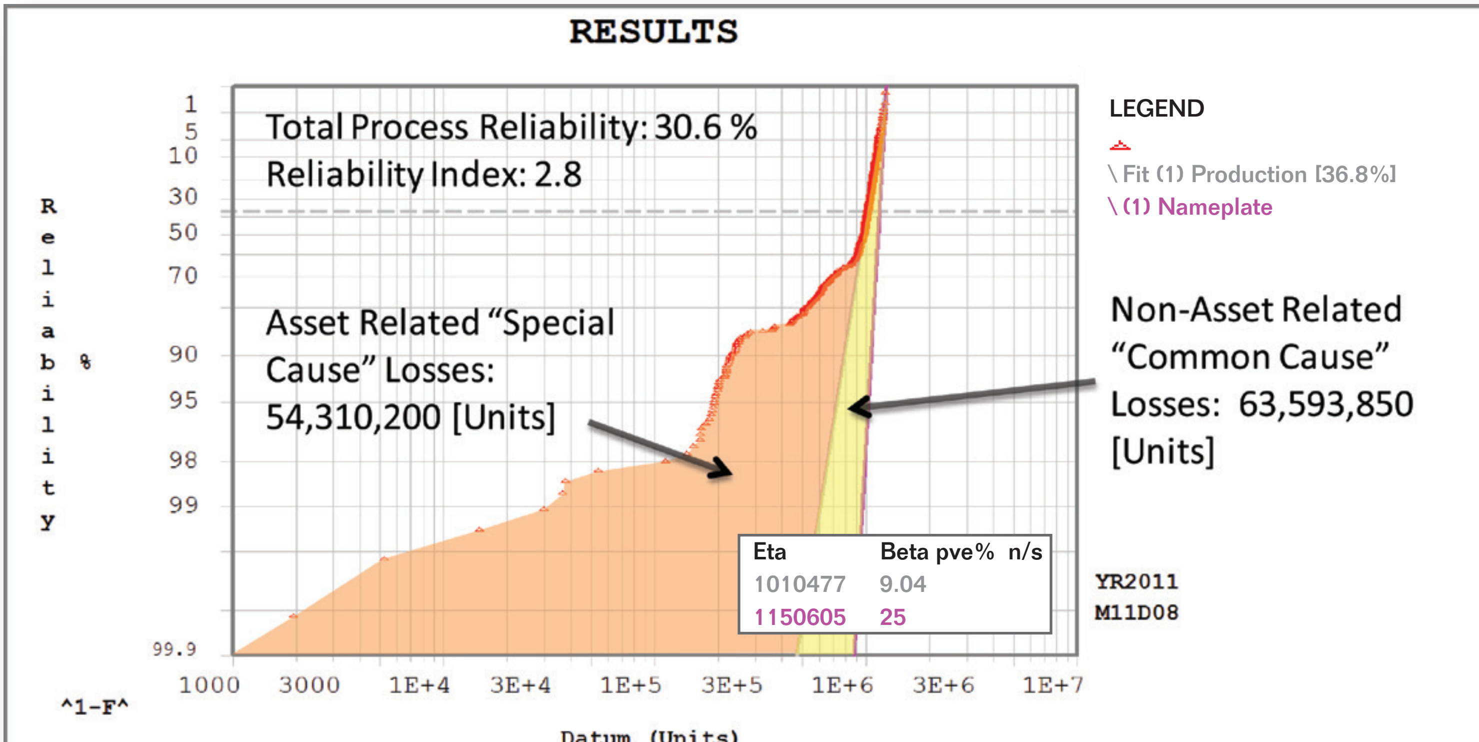

Figure 3 – Barringer Process Reliability Analysis of Losses

the earned value of each asset by analyzing both asset and non-asset related losses from ideal process performance. Instead of using ROA as a lagging indicator to evaluate how viable one organization is over another, ROAR can be used as a leading indicator to better inform business leaders of potential opportunities for improvement without capital investment, and assist in long-term decision making. ROAR illustrates the potential of your reliability improvement strategy by re-forecasting net income gained by minimizing process variation. The ROAR calculation is as follows:

ROAR = (Recovered Net Income + Net Income)/Average Asset Value

Recovered net income in the ROAR calculation is the net sum of the revenue gained by removing variation and producing at the desired level, and the variable cost associated with the production of the additional units since the fixed costs are already captured in the existing net income reports.

Table 1 is an example of how to calculate ROAR in order to define the impact your reliability strategy will have on your organization. In the first line of the table, we see that the average asset value is $1B, from which $350M of revenue is earned. If we assume that the cost of goods sold (COGS) is 65% of revenue, as is typical in many industries, then the net income is $122.5M. Divided by the average asset value for the fiscal period, the result is an ROA of 12 percent.

In this scenario, 20% of the projected units produced were lost due to process inefficiency, equating to $70M. Your reliability strategy is focused on recovering these losses by addressing causes of variation at the process level and maintenance practices that have been ineffective in preventing equipment breakdowns at the asset level. At an estimated variable cost per unit of 30%, the recovered net income is $49M. When we add this recovered value back to the net income and divide again by the average asset value, we get a five point increase in ROA.

Table 1 – ROAR Calculation example

Average Asset Value	$1,000,000,000	Average value of all assets during the fiscal period
Income	$350,000,000	Revenue from products produced during period
COGS	$227,500,000	Cost of goods sold during period
Net Income	$122,500,000	Income minus COGS for fiscal period
ROA	**12%**	Net Income/Average Asset Value
Losses	$70,000,000	Total units not produced due to process inefficiency
Recovered Net Income	49,000,000	Revenue from additional units minus 30% variable cost/unit
ROAR	**17%**	(Recovered Net Income + Net Income)/Average Asset Value

Table 2 – ROA Calculation with CAPEX example

Average Asset Value	$1,000,000,000	Average value of all assets during the fiscal period
Income	$350,000,000	Revenue from products produced during period
COGS	$227,500,000	Cost of goods sold during period
Net Income	$122,500,000	Income minus COGS for fiscal period
ROA	**12%**	Net Income/Average Asset Value
Capital Replacement	$50,000,000	Capital replacement of 5% of asset base
Estimated Net Income	$136,000,000	Forecasted net income after CAPEX
Adjusted Average Asset Value	$1,025,000,000	Average of beginning and end of fiscal year asset values
ROA after CAPEX	**13%**	Estimated Net Income/Adjusted Average Asset Value

However, a five point increase in ROA does not mean much without something to compare it to. Therefore, using the same scenario, Table 2 provides a comparison using a capital expenditures (CAPEX) strategy that is aimed at overcoming performance issues by replacing 5% of the asset base. Here we have to consider that we are increasing the asset value by $50M during the fiscal period, so our average asset value is going to change. Remember, it is an average between the beginning and end of the period. In the CAPEX strategy, we also have to estimate the change to net income. Besides hopefully generating an increase in revenue, there most likely will be an increase in operating and maintenance costs. In this example, we have conservatively estimated the cost increase to be 8% of the CAPEX asset value. With both the average asset value and net income adjusted, we repeat the ROA calculation. The result is only a one point increase, less favorable than the reliability strategy due to the fact that both asset value and cost increased without a sufficient gain in revenue.

Moving Forward

The laws of global competition are in a state of flux and every company is challenged with the crude reality that survivability lies in the hands of financial analysts. The days of proving financial health with an ability to invest capital and build asset portfolios are over. This article demonstrates the danger of a one-dimensional, capital intensive asset performance improvement philosophy and provides an alternative approach to gaining executive interest in your reliability improvement strategy through ROAR™. Today's high-growth company is required to be more innovative in how it addresses performance. Those companies that are focused on eliminating variation and improving the reliability of people, processes and technology are pushing the boundaries of competition. Don't be left behind waiting on others to invest in the future of your business. Be proactive, communicate the overall company benefits of reliability to top management and take charge of the losses that are within your control.

Darrin J. Wikoff, CMRP, is a Senior Instructor/Change Management Professional with GPAllied. He specializes in Organizational Change Leadership, Business Process Re-Engineering, Reliability Engineering and Work Execution Management. Darrin has nearly 20 years of experience in maintenance and reliability engineering best practices and over 14 years of business leadership experience as both a consultant and small business owner. www.gpallied.com

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decision support
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CMMS Best Practices Study

Selected graphs are taken from the CMMS Best Practices Study and are consistent with report's figure reference.

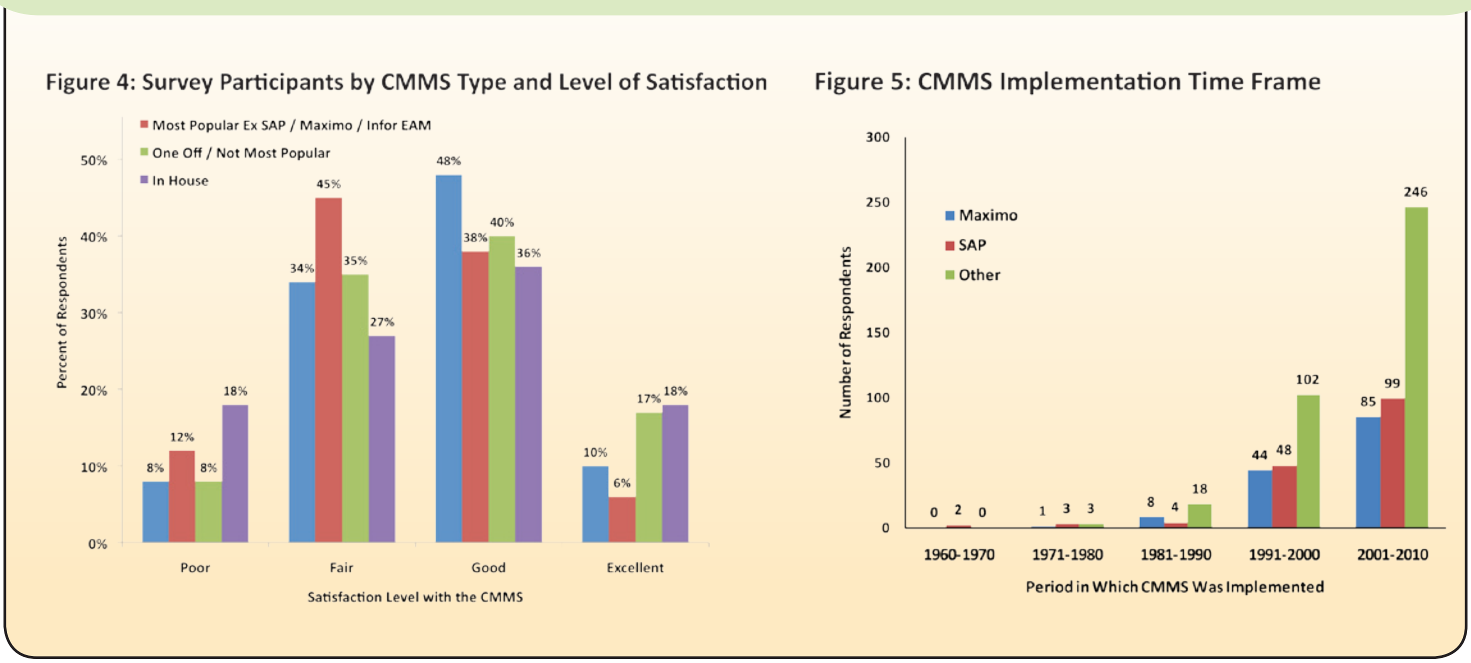
A Perspective

Julie Rampello

Are Capabilities Being Fully Utilized Despite Aggressive Growth?

The importance of CMMS has been growing exponentially since 1990. Maximo and SAP achieved 100% growth between the 1990s and the 2001 and 2010 timeframes. Reliability-centered maintenance is a serious topic today and I am not surprised with the continued growth!

Yet with that growth, the satisfaction levels are not as high as I anticipated. Generally speaking, I am surprised to see the sub-excellent satisfaction levels for all CMMS categories, from the most popular SAP, Maximo and Infor EAM systems to in-house and one-off systems. This raises two questions: Do users fully understand the capabilities of a CMMS system and are they utilizing those capabilities? And do users feel their CMMS systems do enough for them or do their CMMS systems cause more headaches in addressing their needs?



Reliabilityweb.com produced a CMMS Best Practices Study in July 2011 demonstrating the value computerized maintenance management systems add, as well as areas for future growth and improvement. The report was based on a survey of users conducted earlier that year which focused on implementation, use and sustainability.

As a marketer, this report is important as it provides an opportunity to better understand the user experience with CMMS in general and, for the Maximo brand specifically, the CMMS that Projetech provides. From this report, we see there is much that is changing in CMMS and the details summarized in the report provide us with opportunities to address the evolving needs of our customers. It is my pleasure to provide a perspective on the results of the survey and report.

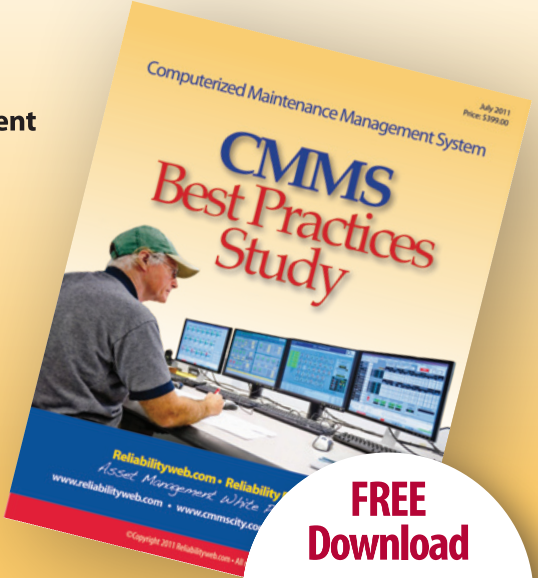


Figure 7: CMMS Hosted Location vs. CMMS Satisfaction Level

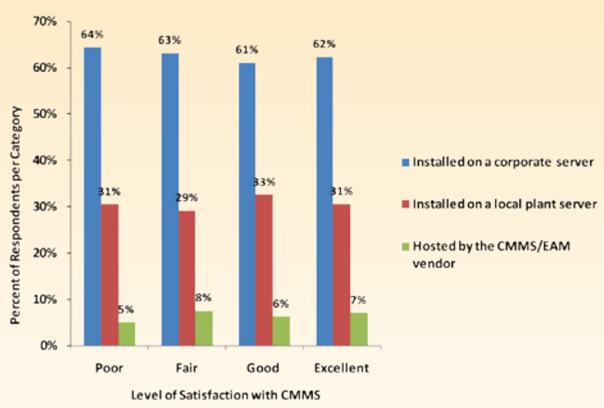
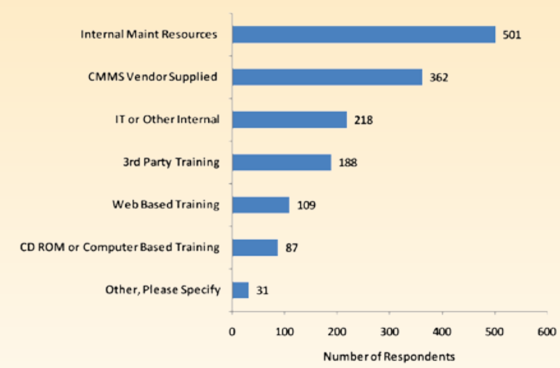


Figure 11: Resources Used for Implementation by Respondent Count



Note – Many respondents used multiple sources and as a result the total of all responses on this chart is in excess of the total survey population.

A Strong Implementation Foundation Leads to Sound Business Decisions

As stated in the report, "How the CMMS is implemented has far-reaching effects on the organization far into the future. A good implementation provides a strong foundation on which to build value-added processes, procedures and an asset information system upon which sound business decisions can be made by all levels of management." There are a couple of areas to be noted regarding implementation. One area I've noticed in the marketplace is that users love to be able to touch their servers. Looking at Figure 7, it's no surprise that for any given satisfaction level, the majority of respondents have a corporate server environment. However, due to resource constraints in the future, I do expect that more organizations will switch to outsourcing the hosting and maintenance of their CMMS. And with the increasing frequency of outsourcing, I would expect satisfaction levels to be high, perhaps outperforming the current corporate server satisfaction numbers.

In the near future, I expect Web-based training to surpass third-party training, as noted in Figure 11. Internal maintenance resources as a resource for implementation will always be the most important as in-house experts understand the system more fully and completely. In general, as applications for knowledge tend to become more cloud- or Internet-based, Web training will slowly become more important.

Use: Value Increases When Used to Improve Effectiveness and Efficiency

The next section of the report focused on how CMMS is used and the value it delivers to the users to drive improved effectiveness and efficiency. Consistent with the findings in Figure 17, my studies in the past have also shown that work order management, reporting and inventory functions are very important to users. Figures 19 and 20 show the Top 50% and the Bottom 50% of CMMS features. With the proliferation of smartphones today, it is surprising that wireless functions are not very important to respondents. That number should rise in coming years, especially as wireless functionality becomes more available in all systems. Perhaps the lower ranking of the wireless feature is due to the lack of availability on some of the lesser known systems. In Figure 21, respondents indicated the Top 10 features of CMMS versus satisfaction with CMMS. This area requires additional analysis; satisfaction numbers cross-referenced to each CMMS system would be helpful in further understanding the opportunity to improve the differences between feature/function level of need and user satisfaction.

Figure 17: Features of Importance – Top 50%

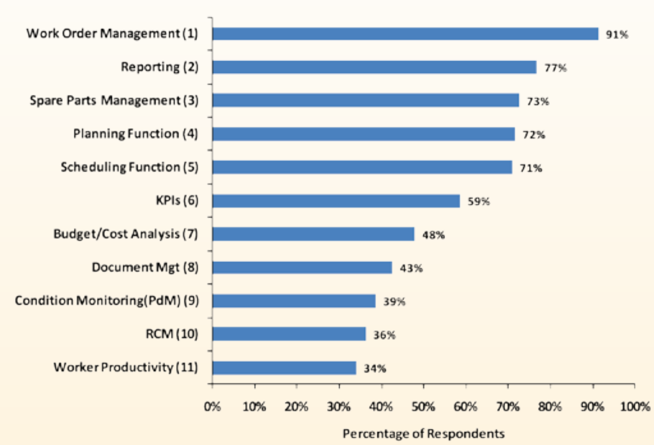


Figure 19: Excellent Performance Level – Top 50% of Features

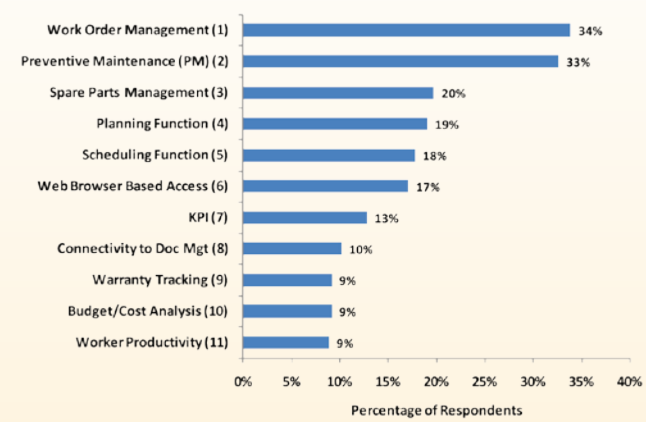


Figure 20: Excellent Performance Level – Bottom 50% of Features

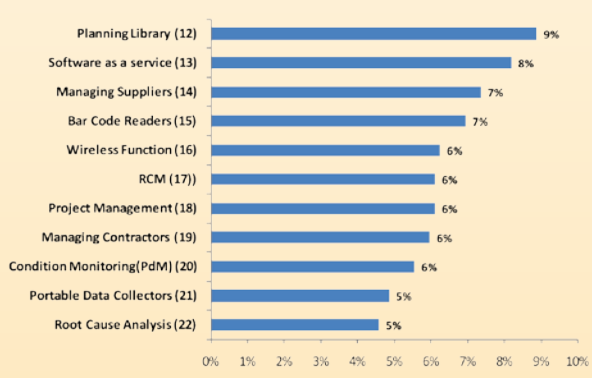


Figure 21: Top Ten Features vs. Satisfaction Level of CMMS

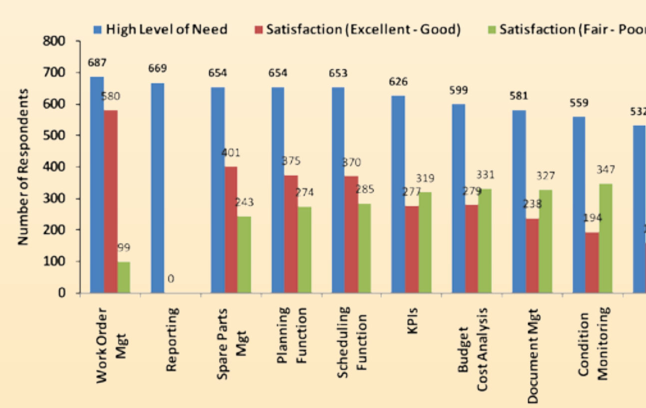
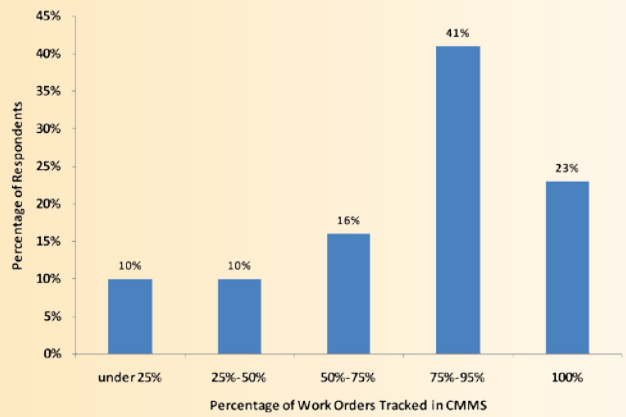


Figure 22: Work Orders Tracked in CMMS by Percent



Continued.....

Use: Value Increases When Used to Improve Effectiveness and Efficiency

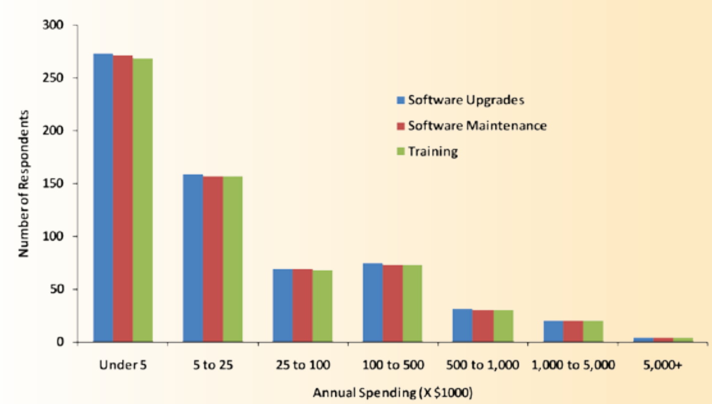
As previously mentioned, increased satisfaction comes with complete adoption. Only 23% of respondents are logging 100% of their work orders in the CMMS as noted in Figure 22. I'd be curious to see if satisfaction and adoption are closely correlated and the impact of those numbers.

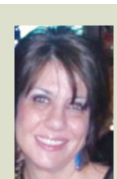
Sustainability: Good Implementation Sets the Stage for Optimum CMMS Use

One area of concern in terms of optimizing the use of CMMS is the level of complacency among users. The annual spend by company is fairly low, as shown in Figure 26. With low spending levels, companies are failing to see the opportunity to better utilize the system and benefit from the latest features, often developed at users' requests. In many cases, they feel the system is just good enough and may not seek any new knowledge to improve implementation. Continued communication from CMMS providers should be improved to reinforce the importance, as well as the sustainable and effective use, of CMMS in the 21st century.

Overall, satisfaction levels would be higher with greater corporate investment. Not only would users gain more knowledge of the effective use of the system, the investment would also show the importance in the product and increase user buy-in and satisfaction. This investment, according to the report, includes post-implementation training and upgrades, all critical components of high satisfaction levels.

Figure 26: Annual Spending on Software, Hardware and Training





Julie Rampello has worked for Projetech for eighteen years with three years serving as Director of Sales and Marketing and previously as a Maximo Project Manager and Trainer. Julie was awarded the IBM Champion designation earlier this year for her role in the education of the Maximo user community using Social Media. Projetech was awarded the prestigious IBM Application Specific License Partner Award in 2012 in recognition of its best-in-class Maximo hosting bundled solutions. www.Projetech.com

Operations-Led Reliability: Continuously Improving

David Landry and Joe Mikes

Executive Summary

Downtime tracking can leave a leadership group with fractured data that makes decision making difficult. By shifting the emphasis from which equipment is "down" to "the reasons why we are not performing well," the data at the end of the cycle becomes much more meaningful. By fixing the top causes of production losses, businesses are steadily achieving better results. This article details how Joe Mikes, Production Loss Elimination SME, and David Landry, Chief Production Engineer at a uranium processing facility, led the change from downtime tracking to a robust production loss elimination process that is delivering monthly improvements to the facility's operation.

Introduction

Since 2002, the Cameco Port Hope Conversion Facility (PHCF) in Ontario, Canada, has been striving to improve its downtime tracking system. Past attempts have been made, but ultimately the gains were short term. Since then, a whole new philosophy that engages employees' input has been put in place and results are already evident from this effort.

The past practice was based on a "downtime" approach, where data was routinely collected and entered into a simple spreadsheet template. The concept was to highlight process equipment or areas in the process that were effectively recording zero production. This information was intended to be used as a rationale to explain monthly production target misses and to identify areas for improvement.

For each downtime event, engineers working Monday to Friday collected and entered data into the spreadsheet for each process area. Because of multiple, duplicate processing streams, each process area was broken down by area, then further by process stream. To collect this data, the engineers reviewed operational trends for periods in which a process stream was not in operation or recording zero production. Further effort

Get Data, Then Act on the Data!

was conducted by the engineer to determine the specific equipment involved and the underlying cause of each downtime event. To determine the reasons for the downtime, engineers had to review log book entries, conduct field observations and communicate with operations personnel to identify and/or support these observations.

Several inefficiencies existed with this approach. Firstly, engineers were not always present when downtime events occurred. Secondly, reasons for events were not always recorded in operational log books, so engineers spent time and effort to determine a reasonable cause. Because of these inefficiencies, monthly compiled results were often inconclusive. In many occasions, reason codes, such as “miscellaneous” or “unknown,” were recorded as the highest causes or reasons for downtime for the month.

Setting up a production loss elimination program requires getting the right information at the right time and then taking action on that information. It sounds really simple – get data, then act on the data. But it is challenging to shift old habits. In September 2010, PHCF began preparing for, and has since started, a full loss elimination program. The goal of the program is to focus attention on production loss opportunities to improve throughput and reduce operating costs. A key element of operations-led reliability is establishing a program where front-line operators are given a voice to share their top concerns about how the production process is running. The culture change is a big deal. Deciding how it is going to work and who will be accountable for the processes are key to a successful change. Because the culture change is so important to success, a systematic approach to change management is required.

To manage the culture aspect, several things happened to prepare the site for the change. Management had to understand the value of the new approach. Employees at many levels had to be educated and engaged to design how the new process would work.

At PHCF, one key task was to prepare employees to work within the new process. It was important to address concerns around individuals’ roles and how they may change. Overall, there was a temporary cloud of doubt that had to be addressed in order to drive the new process forward. This was to be expected because previous efforts to reduce downtime had been unsuccessful. Cameco leadership recognized that a new direction was necessary and downtime tracking alone was not going to result in measurable improvements.

It is common for organizations to be overly focused on downtime versus all production losses. Unfortunately, that approach leaves about 60% of the problem undetected. Operations-type problems are the bulk of what needs to be fixed. After the data is collected for a month, items like start-up procedures, standard operating guidelines, incoming raw material, shift to shift communications, etc., will surface as some of the top causes for lost production. There may be a piece of equipment that keeps acting up, but more than half of the time it is because of how it is being operated or maintained, not an actual functional failure of the equipment itself.

After educating the stakeholders at PHCF, the next step was to begin collecting the right data at the right frequency. Loss time or reason codes were defined and the frequency at which they would be recorded was set. When setting up the reason codes for operators to use, it’s important to set the expectation that these codes would not be recording root causes of failures. Operators will only be capturing symptoms they can detect from their perspective on how things are running. The actual root causes are determined after a symptom surfaces as a top issue. When establishing this effort, a spreadsheet program is recommended to keep responses from operators written in a consistent manner.

Setting up a production loss elimination program requires getting the right information at the right time and then taking action on that information. It sounds really simple – get data, then act on the data. But it is challenging to shift old habits.

Operators are expected to record an issue when production for any given period is below target. This is best done on a short interval, usually every hour. Recording primary issues every hour when they do not meet the target rate is a significant responsibility for operators. The benefit for the operators is that they have been given control of the data that goes to the senior manager at the end of each month.

Basic ground rules were set in order to convert monthly data into real actions with measurable results. At PHCF, operators and process engineers are responsible for compiling the data at the end of each month, conducting some preliminary research on the top issues and presenting this to the production and maintenance/engineering leaders. Collectively, they decide on which actions to pursue that month to make improvements. These decisions are then presented to the senior manager of the site. Once the action plans are agreed upon, the operators get feedback on the top issues and what is being done about them.

At PHCF, the tracking tool has been rolled out in four different areas of the site. All areas are reporting reasons for their losses when the hourly production target isn't met. Over 45 highly-skilled operators have been trained to load information into the tracker. Operators and process engineers, as well as several layers of management, have been trained to address the results with the focus on removing barriers that operators face.

Keeping it simple is key. Employees need to be able to understand the issues during each period they are below the target, then fill in the loss tracker tool with appropriate data and return to running their area quickly. To keep it quick and simple, drop-down lists in the spreadsheets should be used.

Software solutions were considered by the site before implementation. In combination with the spreadsheet and a database, the site's current needs were met. Perhaps in the future, a software solution could help take the performance to a new level, but for now, PHCF has everything it needs to get to the reasons for production losses.

As the first month's data was compiled, it became clear that one shift wasn't producing the same as another shift. As the root causes were investigated, it was due to a gap in standard operating procedures. Steps have been taken to improve these procedures, thereby removing it as the primary issue requiring a resolution. The plant is now focused on a specific operating area that was always known to be a problem, and operators, engineers and maintenance employees are working together to permanently resolve it. The ROI for this effort is accumulating.

Summary

Production losses of many types keep us all from performing at our very best. Don't allow past failed attempts at downtime tracking stop you from putting this into action. Education of employees at all levels is required to launch the process effectively. Setting up the actual tracking tool to be user-friendly is one key to success. The next key is to have management committed to support the solutions. Expect the program to grow and mature. It will not be perfect the first time out of the block. However, if employees see their ideas for improvement being put into play, the program will grow and achieve sustainable results.

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Joe Mikes, CMRP, Senior Consultant at Life Cycle Engineering (LCE) in Charleston, S.C., has helped organizations from multiple industries successfully organize programs in order to improve reliability and reduce operational costs. As a project leader, Joe helps companies drive the necessary corrections to improve equipment utilization and work processes. www.LCE.com

Fundamentals for Successful Field Balancing

IMC 2012! Conference Speaker

Dennis Shreve

Field balancing today with its modern portable instruments is fairly simple and doesn't require much formal training since all the complex vector calculations and trigonometry functions are performed behind the scenes with fast digital signal processing. Long gone are the needs for taking out polar paper and plotting vector vibration displacement readings of amplitude and phase on initial, calibration, correction and trim balancing runs.

Before we dismiss all these details so quickly, it is probably a good idea to understand the basics of the technology and its practical application. As with other automatic analysis and corrective recommendations from handheld instruments, a basic knowledge of what is going on behind the scenes and the physics of the measurements will instill a bit of confidence in arriving at the problem solution.

The first assumption that is made in most field balancing work is that we are dealing with a "rigid" rotor. A rotor is considered rigid if it shows no flexure throughout its operating speeds. A rigid rotor typically operates at a maximum running speed that is below 70% of what is called its first critical frequency, where it shows flexure in the middle of the shaft length. Next, we need to decide if we can balance the rotor in a single plane or whether we need to balance in two or more planes. Rigid rotors can be balanced in two planes, with two-plane balancing usually necessary when the length of the rotor exceeds three times its diameter. Most applications will utilize rolling-element bearings, where infinite stiffness is assumed in the support structure.

Before we begin our work on a machine, we should first establish our goals. We need to decide the balance criteria for the job and establish the maximum allowed amplitude for rotational vibration. There are several possible references, with the most common ones listed below. These are listed in no particular order, and depending on the customer (the requirements set forth by your facility or your client), one should be selected as your target.

- Manufacturer's recommended balance criteria
- ANSI S2.19-1989/ISO 1940 balance grades
- Machine average baseline + 1 sigma (standard deviation)
- MIL-STD 167; API 610
- Work experiences

Next, we need to be certain that we are really correcting a fundamental balancing issue. This is a very important step because we have to rule out any other related issues that might give us a false indication that we have an unbalance problem or could prevent us from improving the balance condition of the rotor. In the end, you don't want to try to "balance out" some other underlying vibration problem. This can prove to be a very frustrating and futile exercise. This is the time to perform further measurements and analyses to rule out other possible causes of a high 1X vibration level. Some of these potential problems are stated below:

- Dirt build-up,
- Rotating shaft instability,
- Looseness or excessive clearances,
- Bent shaft,
- Resonance,
- Cracked shaft,
- Structural or foundation looseness,
- Pulley/sheave eccentricity,
- Misalignment.

Our process is fairly straightforward. Unbalance can be represented by a spinning mass at a particular location outside the center of rotation. What we don't know when we start out with balancing is the magnitude of the mass and its location. If we did know, we could put an equal mass opposite the unbalance mass to cancel out its effects. The task of balancing a machine consists of finding the amount of unbalance mass and its location, and then affixing one or more correction masses at appropriate places to cancel the effect of the unbalance mass. The machine will need to be started and stopped several times throughout the process. At a minimum, you will need to perform the following five steps:

1. Original Run,
2. Trial (Calibration) Run,
3. Correction Run,
4. Trim Runs (if required),
5. Final Run (for before and after assessment).

We start out with an initial reading of vibration on the rotor. Since there most certainly will be a residual unbalance condition contributing to vibration at the 1X turning speed, we need to assess its magnitude as compared to the overall level and other vibratory forces present. If the overall amplitude of vibration exceeds published industry standards for the class of machine and a 1X component exceeds 80% of the overall value, then an unbalance condition is most likely the root of the problem. However, as discussed earlier, a 1X high component also could be due to structural looseness and a number of other root causes. Phase and amplitude measurements in two or more radial locations will help to pinpoint unbalance issues. Amplitude values will be close and phase will be 90 degrees from vertical to horizontal, showing a true radial force.

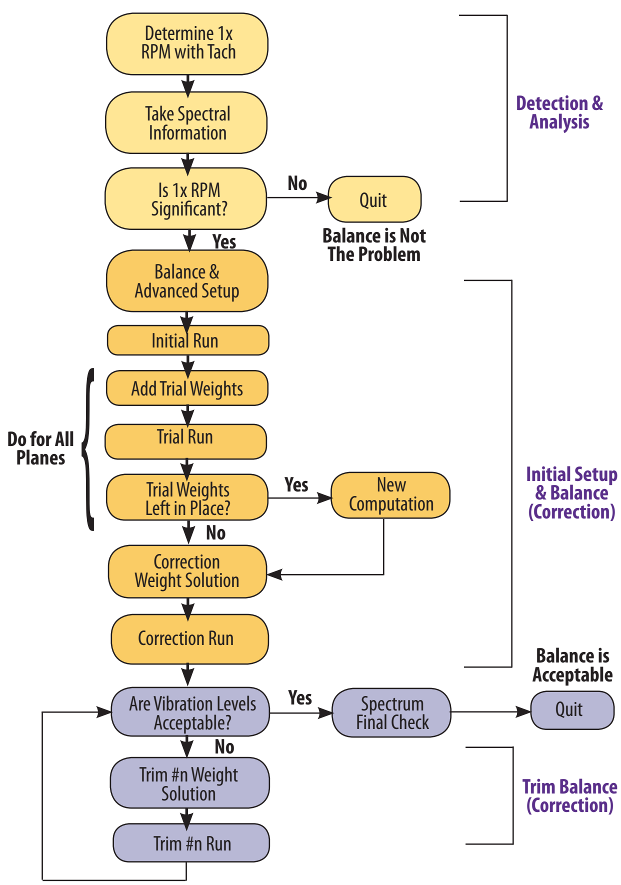


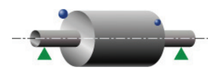
Figure 1: A flowchart for a typical field balancing procedure

Once we are convinced that unbalance is the machine's real problem and that it must be corrected, we need to look at the physical makeup of the machine and where we can make any weight modifications – both at the radius and the positions. We also need to look at where we place our transducer to see the most effects of the unbalance forces within the machine. For machines with the running shaft parallel to the floor, we typically see the most effect of movement in the horizontal plane, where there is a higher degree of freedom. The vertical movement is generally suppressed a bit by the gravity effect of the weight of the machine, the supporting structure and the hold-down bolts.

Next, we need to consider safety factors for our work. We need to make certain electrical lock-outs exist during our steps for balancing and that we are running at safe speeds with safe trial (calibration) weights. Making sure of safety with lock-outs and appropriate notification and tagging, we need to estimate safe trial weights to be used.

Sometimes this will come from field experience or a simple calculation. For normal running speeds between 1200 RPM and 3600 RPM, this is a simple estimate of trial weight in ounces given by 0.004*rotor weight (lbs.)/radius of weight (in.). It is important to note that the value of the trial weight is based on calculating a safe amount of weight to meet the so-called 30/30 rule (30% vibration change and/or a 30-degree angle shift.) To be more precise with actual running speed, the recommended trial weight (Wt) value in ounces is calculated as follows: Wt = 56,375 WR/(N2*r), where rotor weight (WR) is in pounds, speed (N) is in RPM and radius (r) is in inches.

One assumption for a rigid rotor is it can be balanced at any speed. A safe speed can be chosen below the actual running speed, all the way down to about 500 RPM. Unbalance forces are not linear with speed; they are proportional to the square of the running speed. Hence, an unbalanced rotor at one speed will have four times the unbalance force when the speed is doubled! Keep this factor in mind for safety.



An unbalanced rotor at one speed will have four times the unbalance force when the speed is doubled! Keep this factor in mind for safety.

After making the initial run and deciding to perform a balancing correction, the next step is to place a known trial (calibration) weight on the rotor at a known location and make another set of amplitude and phase readings. This step is used to determine the rotor characteristics, locate the heavy spot and calculate the corrective weight to minimize the original unbalance force. This weight location will always be 180 degrees opposite of the heavy spot on the rotor.

It is important to note here that we are typically dealing with displacement as our measurement of vibration. We are not measuring the heavy spot, but we are seeing the high spot. However, for a rigid rotor running at 70% below critical, the high spot and the heavy spot are one and the same.

It is also important to note that we will see linearity in our placement of weight with a rigid rotor. As we place a weight at a known angle location, we will see a linear corresponding change in phase reading in the opposite direction. For example, if displacement phase is reading 165 degrees with a weight placement at 135 degrees, then moving that same weight to 180 degrees will result in a new phase reading at 120.

The trial weight (or calibration) step is where we determine the so-called "influence coefficients" of the rotor. The next step is to make some correction callouts. There are five critical parameters here that must be adhered to for effective field balancing:

1. The exact same speed must be used on each run.
2. The same radius must be used each time.
3. Direction of placement must be consistent (against rotation-AR or with rotation-WR).
4. Magnitude of readings must be stable within 5%.
5. Phase readings must be stable within three to five degrees.

If any of these conditions show variation, then the system is not linear or there are outside influences, and any attempts to balance will be futile. Sometimes, this will appear to be a "chasing your tail" exercise, where things just don't seem to make any sense!

Once a correction is made, then the resulting vibration reading must be compared to an acceptable standard for the class of machine. It could be that the exact weight or position could not be met, so a trim run might be necessary. Each subsequent run should get to a convergence, i.e., where weight callouts are getting smaller and smaller and vibration levels are decreasing as well. If excessive weights are being called out and unbalance is getting worse with each run – the so-called "chasing your tail" scenario – it is time to stop and look for other machine conditions that are not associated with unbalance. Oftentimes, major outside influences like looseness, resonance and misalignment can impede the process.

Fundamental requirements for field balancing include three key elements: linear response in the system, accurate/repeatable test measurements and consistent weight placement.

So far, we have been dealing with a simple single-plane balance. Performing a procedure like this in two planes becomes an iterative process in determining the influence coefficients. It involves a couple of extra steps. First, we perform an initial run with two simultaneous unbalance readings – one in each plane. Next, we place a known trial weight at a known location in one plane and read its influence on the two planes. We remove that weight and place it (or a similar weight) at a known position in the second plane and read its influence on the two planes. At this point, we are done with calibrating and determining influence coefficients. The next steps follow recommended correction and trim weights in the two planes with weight callouts and locations. The same five rules stated earlier apply to step-by-step consistency and the stability of readings.

There are truly some elements of art and science involved in performing successful field balancing work. While microprocessor-based instruments with built-in software perform the required vector mathematics and geometry calculations, it really helps with the process to have a basic understanding of the tools and techniques involved. It also helps to benefit from others' field experiences in performing some tricks in arriving at an acceptable solution in a reasonable amount of time and number of trials.

Fundamental requirements for field balancing include three key elements: linear response in the system, accurate/repeatable test measurements and consistent weight placement. These might sound like simple assumptions, but any variations on these can produce significant problems in getting to an acceptable residual unbalance level on a machine component.

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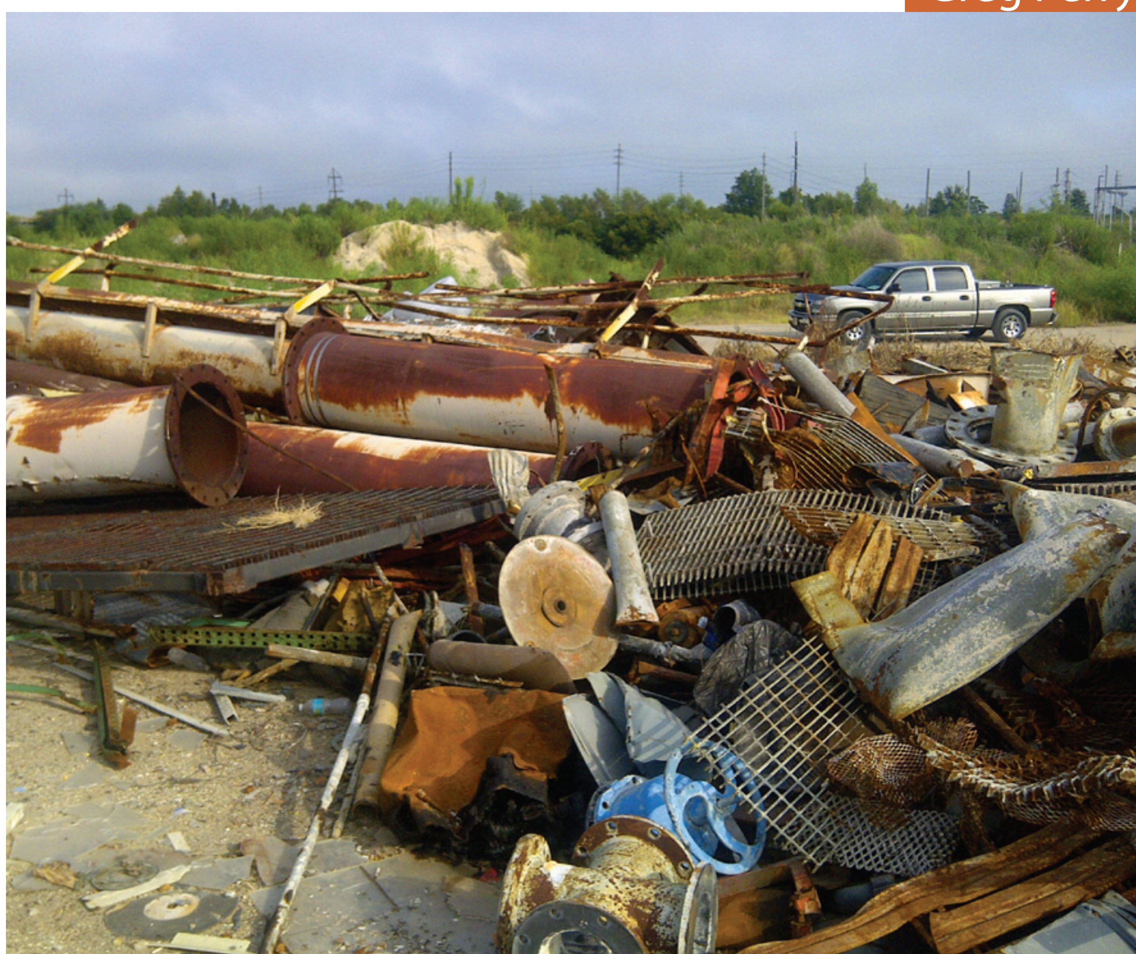
Materials sine qua non

So why keep inferior material items?

Greg Perry

According to Merriam-Webster, the origin of sine qua non is from late Latin meaning: "without which not." The more modern and appropriate definition is stated as: *"something absolutely indispensable or essential."*



Do you have spare parts laying around for machinery or equipment that is no longer in service? Of the material items that are available, are they useable or reliable? In short, do you really need them and if not, why are you keeping them?

Although these questions sound simple in nature, they are often overlooked in industry. But wait, there's more………

What material items have you deemed as *essential*? Of these, which material items can be discarded?

With no surprise, the quick answers are always a resounding "all of them" and "none of them." So you may ask, "If it is an essential material item, why discard it?" At one time, the general consensus might have been: Those material items are all deemed as *necessary and essential* or we wouldn't have them to begin with. Ultimately, this practice over time leads to a collection of duplicate, overstocked, obsolete and eventually, orphaned items.

Sine Quo Non

In a recent material reorganization project to help bring about *sine quo non* (an essential part of the whole) in support of opportunities to improve reliability, several hurdles had to be overcome. The first of many hurdles was to moderate and control the unnecessary collection of material items that were obsolete, deteriorated, non-repairable and/or just unidentified. The conundrum of "hoarding" was (at no surprise) rampant with unaccounted for stock squirreled and strewn throughout the site. Worse yet was evidence of cannibalized equipment/material/parts salted away in and sometimes under material "bone yards." Obviously, this proves to be a compounding problem. Proper attention devoted towards realizing when a material item's *necessary* expiration date has arrived was long past due (no pun intended).

Definition of ESSENTIAL: **of the utmost importance - basic, indispensable and NECESSARY.**

In order to fast-track the material reorganization project, the metrics of "essential" and/or "necessary" were inclusionary measurements that determined whether or not a material item was a candidate for discard.

Clean House

To tackle this impediment, a campaign called **Operation Red Rampage** was initiated, with a follow-up campaign of **Operation Green.** Here, **red** signifies discard and **green** signifies a material item's return to stock (RTS) or simply capturing the material as a non-stock item for location purposes within the computerized maintenance management system (CMMS). The sole reason for the **red rampage** campaign was to identify excess material items that are questionable in terms of use, utilization and reliability. These material items were in need of discard to make room for needed items.

In order to fast-track the material reorganization project, the metrics of "essential" and/or "necessary" were inclusionary measurements that determined whether or not a material item was a candidate for discard. The following questions were utilized to help identify which material items were not a discard candidate, but more importantly, what material items were ready for discard.

Discard Criteria

1. Criticality of Importance
2. Identity of Use
3. Availability
4. Restore
5. Locality of Use

Criticality of Importance:

Criticality can be defined as being crucial to the business and requires a decisive decision. Applied to the potential discard of a material item, the importance and relevance of the item had to be closely examined to make a decisive decision as to its validity and/or need. In other words, the item may be obsolete and therefore not needed. Or the item is deemed *critical and* can be *reliably used* (either through reconditioning or in its current state), so it is not a candidate for discard.

If a material item's criticality is not immediately decisive, the next two inclusionary measurements can help to determine its criticality of importance.

Identity of Use:

Identity of Use can be defined as a process where a material item has a defined role or use. It is here where the answer to "what" and/or "where" the utilization of the material item is determined.

Is the item used on a *critical asset* or assembly?

If so, the material item is deemed *critical* and is not a candidate for discard. But with a "no" answer, the material item can be a potential candidate for discard. Simply put, if we do not know where or what the material item is utilized for, we don't need it.

Availability:

Availability is, in other words, lead time to acquisition.

What is the amount of time it would take to replace the material item in the cases of run to failure (RTF), just in time (JIT), or planned maintenance scenarios?

The material item may or may not be of critical nature, but the lead time to replace the material item may be in excess of multiple weeks or even months. In this case, the material item could be listed as a *critical spare* in your EAM/CMMS. Best practice here is being proactive with the use of your ERP system in replacing the critical spare item upon its initial need.

From a discard perspective, the questions to ask are:

How many of the items do I reliably need on hand? What is an appropriate number of items to be stocked based on average turnaround time? Is it admissible to have only one critical spare on hand? What is the shelf life versus the average turn of the material item? Has it expired?

Restore:

Can the material item be reconditioned back to its original "like-new" condition? If not, discard. With this criterion, a material item may or may not be classified as critical, but the cost of replacing the item far outweighs the restoration cost. If this is true, the material item should be discarded before it can be mistakenly used, or worse yet, used again.

Locality of Use:

Up until now, an item's decision for discard can be justified during any of the above means. But with Locality of Use, or simply put, logistics, the decision to not discard the material item can be based on where the material item is located in respect to the equipment it serves. Consider the case where the nearest material store is not close by or the equipment is located in a remote area of a site.

The qualifying question of, "where is the most efficient yet reliable storage area with regards to the location of the asset it supports?" becomes, in and of itself, necessary to the uptime of the machinery. The material item may not be critical or has a short availability factor, but it has been deemed as essential based on logistics.

Figure 1: Sampling of discarded items

From a discard perspective, if the location of the material item does not carry a logistical value, it can then become a discard candidate.

The Collection

At the conclusion of **Operation Red Rampage**, an excess of 489 metric tons of scrap metal parts/pieces/material items were collected. It involved looking back over multiple decades of various obsolete parts, materials, discarded equipment (both in asset and support types) to account for such a collection of scrap metal. In addition to the investment recovery from scrap material as an added benefit, the move to abrogate excess, inferior and duplicate material items will prove in the long run to help and support the sine qua non of achieving sustainable yet reliable materials management best practices. Perhaps it's time to start your own **Operation Red Rampage.**

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Operator-Driven Reliability Best Practices Series:

Mobilized Technology Distinguishes the Leaders

IMC 2012! Conference Speaker

Dave Staples

Technology is critical to automating ODR. It opens the door to immediate operator feedback, decision support and information sharing.

Technology for ODR typically has two components: a handheld mobile device that assists the operator in making inspections and corrective actions, and a host application that stores the inspection results, manages exceptions and the ODR collection process. The technology can also assist with identifying the potential source of problems and determining how fast a company needs to react to avoid undesirable consequences.

Electronic inspection data enables people to make faster and better decisions and creates consistent verifiable information. Electronic inspection data also makes information accessible to other systems, like computerized maintenance management systems (CMMS) and data historians. Electronically logged inspections eliminate errors that can occur with paper logs due to illegibility, damage from precipitation or inherently damp manufacturing conditions, or loss of data caused by misplaced logs.

There are challenges when dealing with operators who have a wide range of experience and skills. Technology helps maintain consistency by retaining inspection process knowledge. For example, ask five different operators the color of a lubricant and you might get five different answers. By using the technology to drive the operator to make a choice, e.g., black, grey or green, you eliminate most potential differences in opinions.

Probably the strongest case supporting the use of technology is its ability to provide operator feedback. It's like putting a reliability engineer in the operator's pocket. The technology alerts the user when an entry is out of range or an abnormal condition exists. When abnormal conditions exist, the device can immediately prompt the operator to corrective action, like changing a dirty filter, adding lubrication, cleaning the end bell, removing debris, or requesting a work order be created. If more information to perform the inspection is needed, documents, text, graphics, photos and videos can be accessed by the operator from the mobile device.

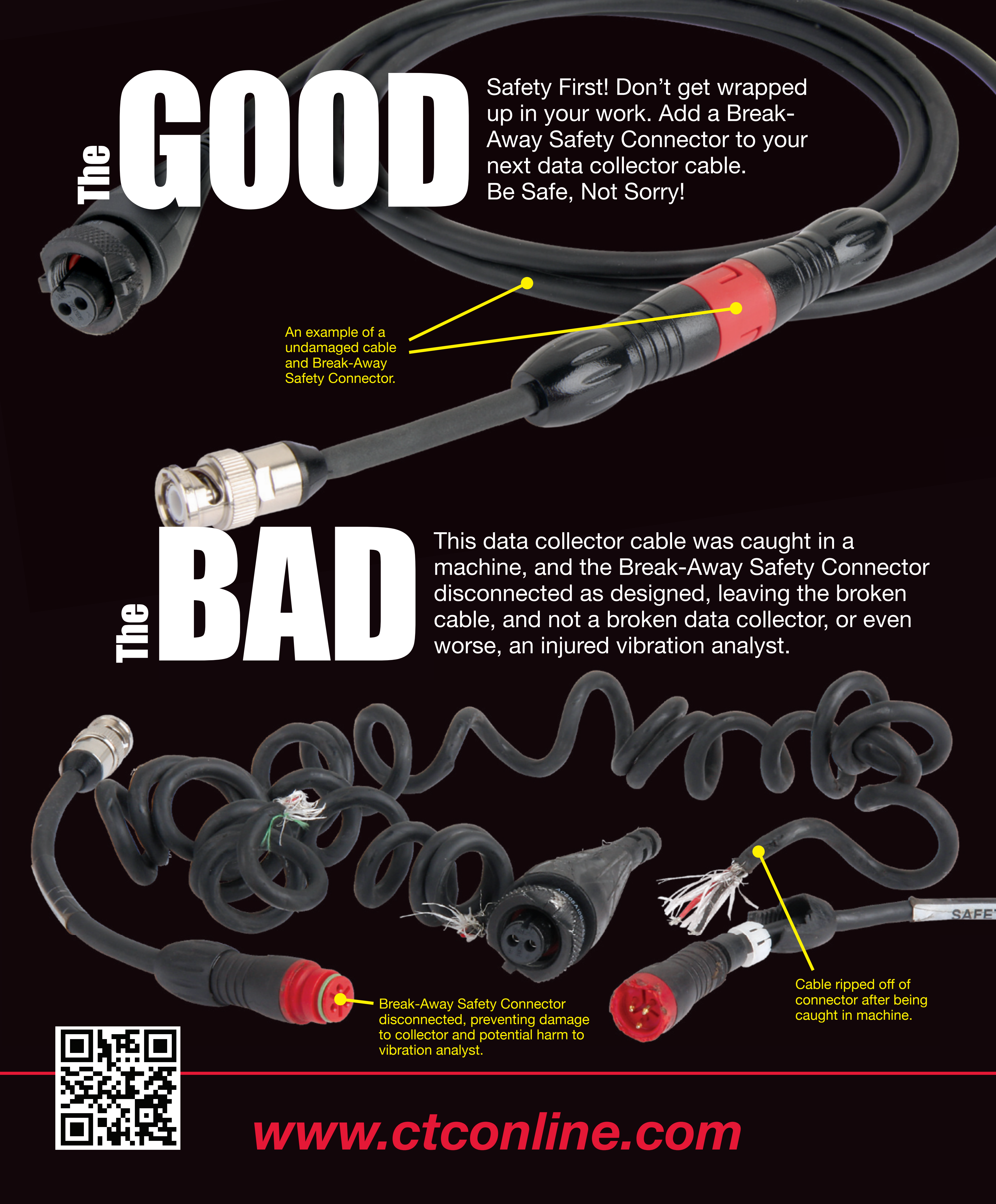
Technology is about enabling processes and driving actions. In addition to automating the ODR process, it automates the fault diagnosis process. By prompting the user to collect additional measurements or inspections, technology narrows down the root cause possibilities. A great example of this is an abnormally high electric motor temperature measurement. The handheld device can prompt to inspect for end bell obstructed ventilation or check the lube line feeding the motor bearings. This information can be included in a work request created by the user so the maintenance team brings the right tools to fix the problem.

Technology can make calculations. A simple example is calculating delta pressure, the pressure differential between inlet and outlet of a pump, valve, or filter. Information like this can be used to indicate a filter change, a valve obstruction, or a pump running off its curve. Equations can be used to calculate compressors or pumps efficiencies, or costs associated with air leaks.

Using technology should be transparent and trouble free. It should be flexible to automate your process. Don't change your process to accommodate technology limitations.

Dave

Dave Staples, Business Development Manager, SKF Reliability Systems, has over 20 years of industrial experience specializing in asset reliability technologies and asset management services. For the past six years, Dave has been focused on helping customers implement and sustain Operator Driven Reliability programs. www.skf.com


The GOOD
Safety First! Don't get wrapped up in your work. Add a Break-Away Safety Connector to your next data collector cable.
Be Safe, Not Sorry!
An example of a undamaged cable and Break-Away Safety Connector.
The BAD
This data collector cable was caught in a machine, and the Break-Away Safety Connector disconnected as designed, leaving the broken cable, and not a broken data collector, or even worse, an injured vibration analyst.
Break-Away Safety Connector disconnected, preventing damage to collector and potential harm to vibration analyst.
Cable ripped off of connector after being caught in machine.
www.ctconline.com

Uptime Awards
Teck Coal 2011 Winner

Mining Haul Road Maintenance

David Hengen

Open-pit mining poses many challenges that need to be overcome to effectively maintain critical equipment fleets.

Similar to the airline industry, where the reliability approach was first defined, maintenance professionals in the mining industry often do not have the privilege of observing their equipment while it is operating. This is changing. Thanks to the introduction of wireless technology worldwide, mobile maintenance crews can observe how their equipment operates better than ever before. At Teck's Fording River operations, an open-pit coal mine in southeast British Columbia, the mobile maintenance crews are using wireless technology to proactively address some of the worst contributors to equipment failures.

If you boil maintenance reliability strategies down to their essence, the primary goal is to efficiently and effectively manage the P-F curve for all equipment failure modes. Whether this involves upfront reliability design, supply chain management, planning and scheduling, or predictive and preventative maintenance tasks, the focus is on the P-F interval with the goal of lowering the costs to the product user.

Figure 1: Example of a haul road

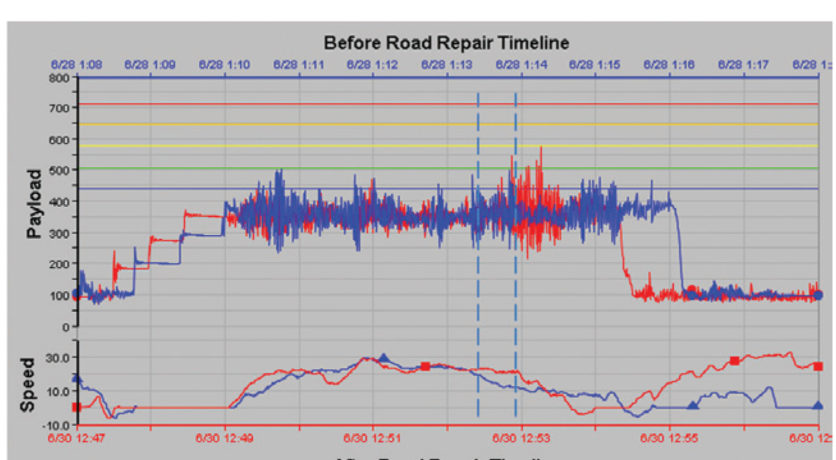


Figure 2: Before and After cycle times/speeds/payload readings

At Fording River, we are trying to move as far up the failure curve as possible to eliminate secondary damage that our highest impact failure modes incur. Following the introduction of wireless technology, we began using a software application called mobile equipment monitor developed by Honeywell Process Solutions, a third-party automation control solutions provider. The mobile equipment monitor sends equipment data to our desktops in real-time, across all equipment types, ranging from haul trucks to shovels and drills. Throughout the past eight months, we have been testing this software to see if it can help us move up the P-F curve.

For our haul truck fleets, one of the major causes of equipment downtime is frame cracking. With the freeze/thaw cycle that can occur in the Canadian Rocky Mountains almost year-round, the haul roads are continually heaving up and down. This creates large potholes that have the potential to cause significant damage to the trucks' frames and other major components. Repairs can take several days to complete and often require the removal of other components to perform the work. Effective work identification, planning, scheduling and execution can significantly lessen the impact these failures have on the bottom line. Eliminating these failures from happening in the first place – true predictive maintenance – would have the largest positive impact on our bottom line.

The root cause of impact failures is a combination of truck speed, payload and road conditions. If you remove any one of these three, the problem goes away. Obviously, stopping production isn't a viable option, so the focus has shifted to road conditions. With the real-time strut pressure data and overall payload readings we receive from the mobile monitor, combined with GPS coordinates, we have been able to successfully pinpoint the locations of our "bad actor" sections of roads. This has allowed us to intelligently provide our road maintenance crews with a priority list of which sections of haul roads are costing our operations the most lost production.

Some in the industry say real-time strut data and payload readings are not necessary to maintain haul roads, and as Figure 1 shows, they are correct. I would argue, however, that the benefit of strut data and payload readings is their value as informational tools that enable the operations foreman to **effectively prioritize and dispatch** road crews to strategically tackle daily road repairs.

The benefits to this approach are threefold. First, production is obvious, as you can see from the before and after information in Figure 2. In this example, haul trucks passing through a section of road after it was repaired were averaging almost five seconds faster travel times through the repaired section while maintaining a similar strut pressure reading. This means trucks can travel through the haul road section at a greater – but still safe – speed without causing damage to the frame and other components. Using time stamps that correlate to physical observations, the dashed lines in Figure 2 represent the start and end of the haul road in question. Throughout the course of a year and a large fleet of trucks, this results in millions of dollars of increased production.

Cycle times through the poor section of road were measured across several units, both before and after the repair work, in order to gain statistical significance. With poor road sections, operators have to slow down in advance of a pothole and then speed up again afterwards. In our test, data was collected from 100 metres before to 100 metres after an identified rough section to account for the loss in production.

The second benefit is decreased maintenance costs. As the frame spikes are lessened by the smoother roads, the truck's frame and other components are not overstressed. This decreases welding time on maintenance days and increases the life of other major components, such as suspension, steering and the sensitive onboard electronics.

Before Times (sec)	After Times (sec)
29	31
32	23
28	21
35	27
31	30
32	29
30	24
30	23
25	21
40	29
34	22
30	25
34	28
32	26
28	32
	27
	30
	34
	22
	23
	29
	26
31.3	**26.5**

Table 1: Cycle times through poor section of haul road

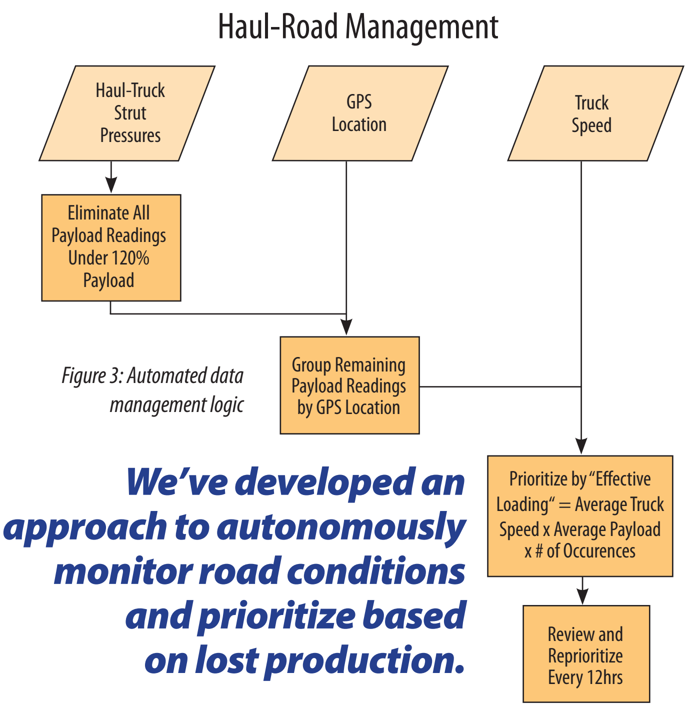


Figure 3: Automated data management logic

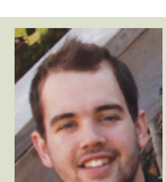
We've developed an approach to autonomously monitor road conditions and prioritize based on lost production.

The third benefit is improved operator health, safety and morale, as repeatedly driving over rough roads can take a physical toll on operators. Although instructed to always drive to conditions, operators can still be exposed to jarring while driving over rough roads. Reducing these occurrences would certainly benefit our operators' health and wellness.

Since the data and examples noted in this article were from a pilot test of the software, the road prioritization was done manually, but with considerations made for a production environment. The key challenge was how to properly manage and respond in a timely manner to the large amount of data collected. Recognizing this, the Honeywell system allows the user to build logic sets that run continuously against all streaming data. As you can see in Figure 3, we've developed an approach to autonomously monitor road conditions and prioritize based on lost production.

We start by eliminating all of the strut pressures that are less than 120% of the haul truck's accepted payload. Then we split the mine site into a large grid, made up of 100 metre X 100 metre sections. The payload readings that are more than the specifications are then clumped together by grid location. The last step is to apply a formula combining the frequency and severity to filter the worst road locations to the top of the road work "to-do" list. Road crews are then dispatched at the beginning of every 12-hour shift to work on the areas that are most impacting the site. The road criticality is then recalculated daily to ensure high-impact areas are addressed.

In summary, by adopting the strategy of monitoring strut data and payload readings to effectively prioritize and dispatch road crews to strategically tackle daily road repairs, we have seen quantifiable improvements across production, maintenance and operator health. This strategy will continue to be developed and enhanced at Fording River so we can expand upon these gains. As we move forward, continuous improvement should drive the application of this system into areas yet unforeseen.



David Hengen, CMRP, was a reliability engineer for Teck Resources and has since moved to Australia to work as a reliability engineer with a multinational mining company. In his current position, he collaborates with Operations and Maintenance personnel to reduce chronic failures and ensure the most cost-effective maintenance strategy is being utilized. He holds a B.Sc degree in Mechanical Engineering from the University of Alberta in Canada.

Case: Weibull-based Method for Failure Mode Characterization and Remaining Life Expectancy Estimation

Jorge Kalocai

1. Situation

Figure 1 shows a couple of process equipment, in order, a secondary reformer and a heat exchanger (heat recovery HPS boiler). Due to the shelling of the internal refractory wall surface into the reformer (in which hot output gases are used as hot draught at the heat exchanger), the heat exchange efficiency on the boiler was affected. Considering the existence of an internal bypass valve (final element of a PID output temperature controller) that regulates the hot draught bypass proportion, its progressive positioning to no bypass condition (to compensate for the heat exchanger efficiency loss) was considered a symptom of the failure mode degradation ("fouling" increasing).

This approach was failure mode based, so even when the potential failure mechanism was suspected, it dealt with it from a black box perspective.

Chronologically, this heat exchanger was opened two times for cleaning from the first evaluated functional degradation in a total period of 16 months. So, considering the first degradation period, there were three other ones in the whole term. This is shown in Figure 2.

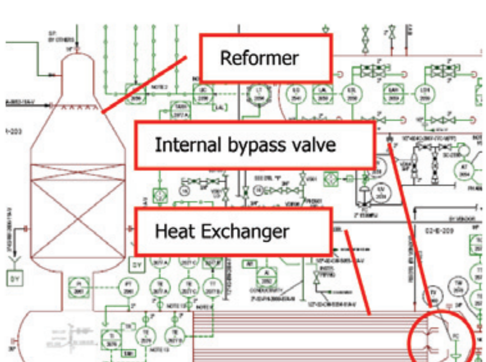


Figure 1 - Process Equipment System

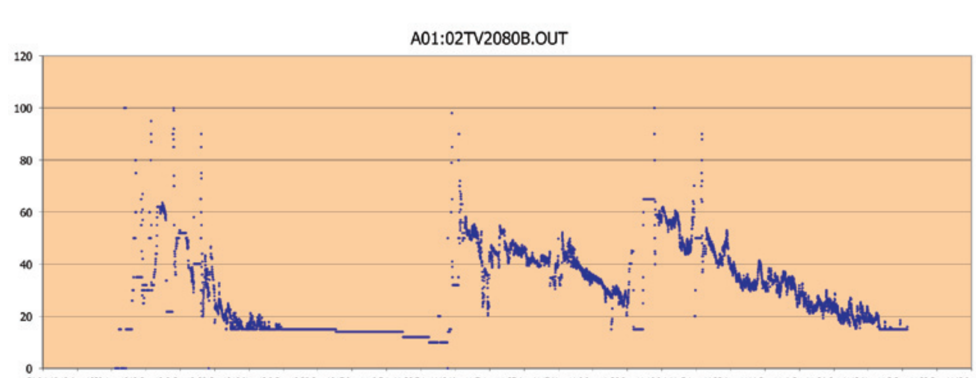


Figure 2 - Historical trend of the internal bypass valve position (electronic limit at 12%)

2. Objectives

2.1. To characterize the failure mode according to the internal bypass valve behavior.

2.2. To estimate the remaining life expectancy due to the failure mechanism progress according to another related process variable behavior.

3. Development

3.1. Objective 2.1.

3.1.1. The first step, according to the proposed approach, was to collect the historical real time positioning of the internal bypass valve (discrete values each hour) at three different periods (see Figure 3 example):

11/8/10 8:39	16.0607
11/8/10 9:39	16.5006
11/8/10 10:39	15.0625
11/8/10 11:39	15.063
11/8/10 12:39	15.063
11/8/10 13:39	15.063
11/8/10 14:39	15.063
11/8/10 15:39	16.6375
11/8/10 16:39	16.1339
11/8/10 17:39	17.5995
11/8/10 18:39	18.7409
11/8/10 19:39	20.1959
11/8/10 20:39	17.6331
11/8/10 21:39	15.6651
11/8/10 22:39	17.924
11/8/10 23:39	20.3438
11/9/10 0:39	19.8258
11/9/10 1:39	20.0188
11/9/10 2:39	20.6449
11/9/10 3:39	21.0885
11/9/10 4:39	21.3415
11/9/10 5:39	21.3202
11/9/10 6:39	19.6565
11/9/10 7:39	19.5645
11/9/10 8:39	20.5977
11/9/10 9:39	17.8093
11/9/10 10:39	15.0494
11/9/10 11:39	15.0494
11/9/10 12:39	15.0494
11/9/10 13:39	15.0494
11/9/10 14:39	15.0494
11/9/10 15:39	15.0494
11/9/10 16:39	15.0494
11/9/10 17:39	15.0494

Figure 3 - Example of discrete values for the internal bypass valve position

3.1.2. The second one was to build histograms for the three sets of historical data, valve position based. The idea behind this was that each time the bypass valve adopted a new position, supposed surrounding process "stable" conditions was due to the need of compensating a heat exchanging characteristic variation, an issue associated to a failure on a Weibull approach (no new position, good and stable condition, no failure).

The amount of times the bypass valve kept a single position (that means amount of hours) was considered as representing the survival period for this failure mode occurrence (this sample).

Every other non-adopted positions within the 0% to 100% range for the considered period were taken as suspensions.

On heat exchanging stable conditions, the histogram should show an array of concentrated tall bars around its typical control position.

As long as this heat exchanging characteristic varies, the histogram should show a set of dispersed shorter bars.

Figures 4, 5 and 6 show the specific histograms.

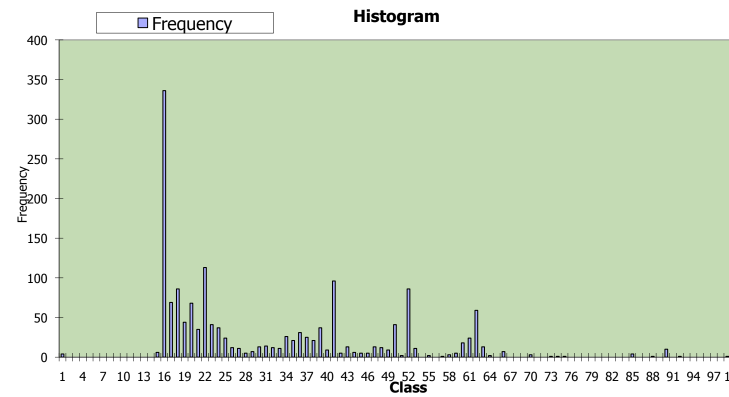


Figure 4 - Histogram of positions for the internal bypass valve on period #1

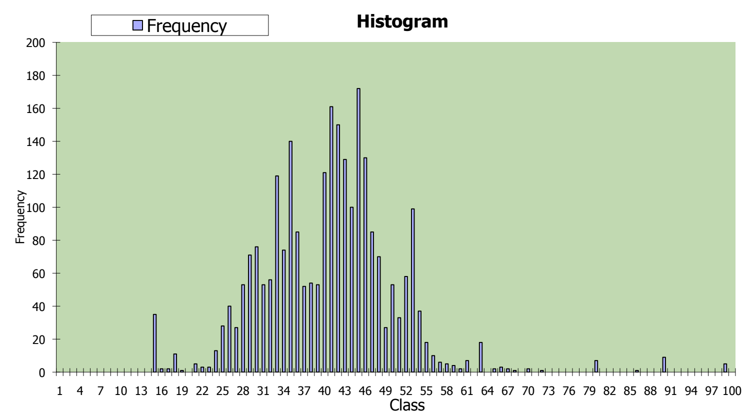


Figure 5 - Histogram of positions for the internal bypass valve on period #2

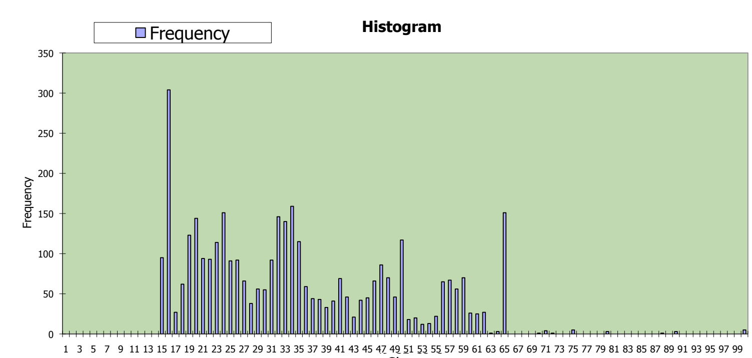


Figure 6 - Histogram of positions for the internal bypass valve on period #3

3.1.3. The third step was to arrange the discrete positioning data by period in order to calculate the dot coordinates for the Weibull graphs.

A previous task was to state a criteria for identifying, on the whole data set, failures and suspensions. To do this, two aspects were taken into account:

- The maximum and minimum values for the valve positioning to be considered.
- The minimum amount of occurrences for each period to be considered, as a stated percentage of the maximum frequency at the histogram.

Every single histogram data satisfying these criteria was considered as failure, while every other as suspension.

From this, the whole data set for each period was arranged and the dot coordinates calculated using the Auth/Johnson adjusted rank[1] and the Benard's median rank[2] expressions.

Two different sets of failure/suspensions selection parameters were used to evaluate sensitivity on results.

3.1.3.1. In the first trial (named raw f/s filtering criteria), no filtering parameters were stated other than the histogram bars height greater than zero. Then, the following was obtained:

- Period #1:

Beta (shape) =	0.818194178
Eta (characteristic freq) =	20.61269207

- Period #2:

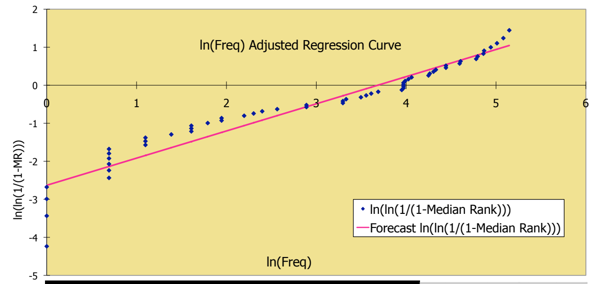
Beta (shape) =	0.71423917
Eta (characteristic freq) =	39.79739697

- Period #3:

Beta (shape) =	0.821925171
Eta (characteristic freq) =	66.75586479

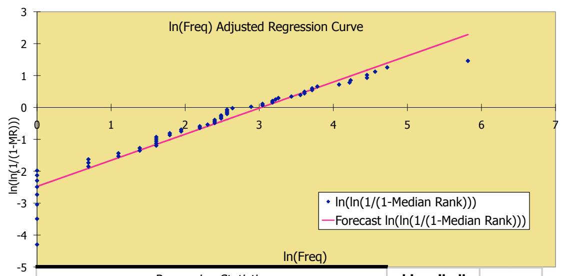
The critical correlation coefficient[3] and the critical coefficient of determination r2[4] were used to verify the goodness of fit for the calculated regression lines for each data set, estimated by means of the minimum squares method. Figures 7, 8 and 9 show the regression lines.

Now, the early conclusions regarding 2.1 objectives were:



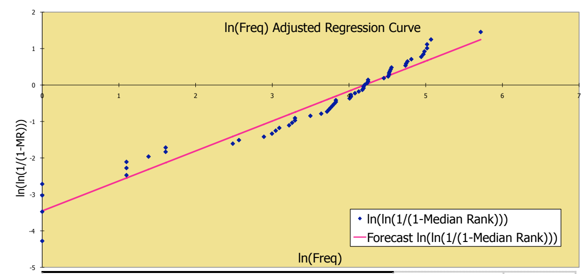
Regression Statistics		bi-weibull	
Multiple Correlation Coefficient	**0.96144633**	**CCC ≈ 0.97**	**Bad Fit**
Determination Coefficient R^2	**0.92437905**	**CCD ≈ 0.94**	**Bad Fit**
Adjusted R^2	0.923004125		
Typical Error	0.334603022		
Samples	**57**		

Figure 8 - Regression line for data set #2 (period #2) - raw f/s filtering criteria



Regression Statistics		bi-weibull	
Multiple Correlation Coefficient	**0.959433199**	**CCC ≈ 0.97**	**Bad Fit**
Determination Coefficient R^2	**0.920512063**	**CCD ≈ 0.94**	**Bad Fit**
Adjusted R^2	0.919141581		
Typical Error	0.34399418		
Samples	**60**		

Figure 7 - Regression line for data set #1 (period #1) - raw f/s filtering criteria



Regression Statistics		bi-weibull	
Multiple Correlation Coefficient	**0.973365776**	**CCC ≈ 0.97**	**Good Fit**
Determination Coefficient R^2	**0.947440933**	**CCD ≈ 0.94**	**Good Fit**
Adjusted R^2	0.946518844		
Typical Error	0.279470716		
Samples	**59**		

Figure 9 - Regression line for data set #3 (period #3) - raw f/s filtering criteria

- The three periods showed Beta values <1 (with very little differences), consistently implying run-in conditions (at the bathtub curve)[5]. These results are consistent with the real behavior, as degradation started each time from the very beginning after each restoration (see Figure 2).
- The Eta values consistently increased at each period, representing a deterioration process deceleration. These results are also consistent with reality as the characteristic life increased after each restoration (see Figure 2).
- The dot distributions at the regression line graphs (concavities at Figures 7, 8 and 9) may imply the presence of more than one failure mode and also increasing (in amount) at each new restoration.

3.1.3.2. In the second trial (named good fit f/s filtering criteria), the valve limits for each period were set according to each observed trend and the minimum amount of occurrences at 5% of the maximum. Then, the following was obtained:

- Period #1:

Beta (shape) =	1.495201059
Eta (characteristic freq) =	91.16688721

- Period #2:

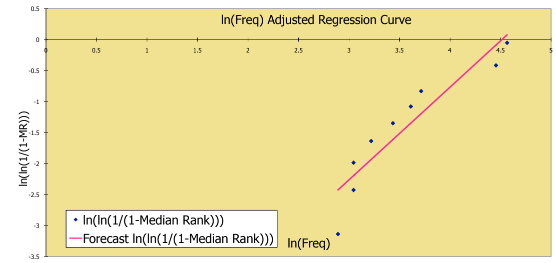
Beta (shape) =	1.636153759
Eta (characteristic freq) =	84.87618883

- Period #3:

Beta (shape) =	1.782388298
Eta (characteristic freq) =	86.13722785

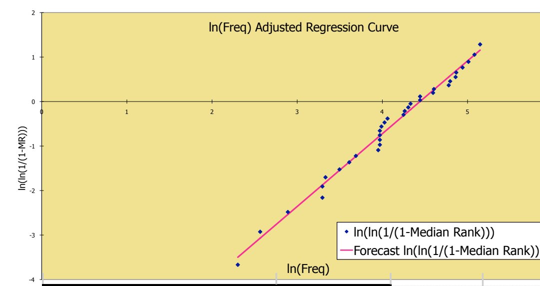
Figures 10, 11 and 12 show the regression lines for each data set.

At these other conditions, the early conclusions regarding 2.1 objectives were:



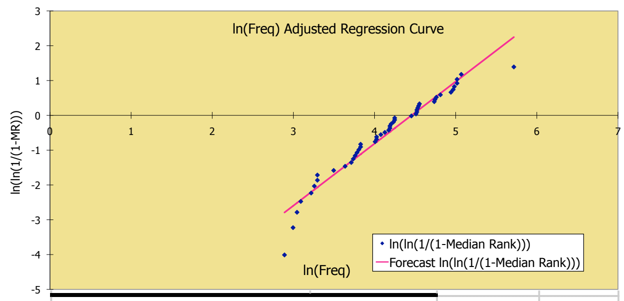
Regression Statistics		bi-weibull	
Multiple Correlation Coefficient	**0.92617058**	**CCC ≈ 0.925**	**Good Fit**
Determination Coefficient R^2	**0.857791943**	**CCD ≈ 0.855**	**Good Fit**
Adjusted R^2	0.837476506		
Typical Error	0.394970969		
Samples	**9**		

Figure 10 - Regression line for data set #1 (period #1) - good fit f/s filtering criteria



Regression Statistics		bi-weibull	
Multiple Correlation Coefficient	**0.993590025**	**CCC ≈ 0.96**	**Good Fit**
Determination Coefficient R^2	**0.987221138**	**CCD ≈ 0.92**	**Good Fit**
Adjusted R^2	0.986808917		
Typical Error	0.135401976		
Samples	**33**		

Figure 11 - Regression line for data set #2 (period #2) - good fit f/s filtering criteria



Regression Statistics		bi-weibull	
Multiple Correlation Coefficient	**0.972390572**	**CCC ≈ 0.97**	Good Fit
Determination Coefficient R^2	**0.945543424**	**CCD ≈ 0.94**	Good Fit
Adjusted R^2	0.944333278		
Typical Error	0.280894172		
Samples	**47**		

Figure 12 - Regression line for data set #3 (period #3) - good f/s filtering criteria

- The three periods showed Beta values >1, consistently implying wear out period (at the bathtub curve) and slightly increasing from period #1 to period #3, suggesting slight increasing deterioration in progress after each restoration.
- The Eta values showed very little variation, but chaotic somehow (no interpretation).
- The dot distributions at the regression line graphs (Figures 10, 11 and 12) may imply the presence of more than one failure mode.

3.1.3.3. Comparing the two previous items (3.1.3.1 and 3.1.3.2), it can be seen that even when the 3.1.3.1 data set filtering criteria do not consistently obtain good fits for the regression lines (while 3.1.3.2 do), it better represents the real behavior so, due to engineering judgment, the conclusion was to adopt this (3.1.3.1) data set filtering criteria that implies not to discard any sample, at least, for the histogram shapes showed at Figures 4, 5 and 6 (dispersed data). In these cases, the observed bad goodness of fit meaning could be that Weibull distribution was probably not the better one to represent the analyzed physical phenomena (may be log-normal adjusted better[6]).

3.2. Objective 2.2

7/14/11 0:39	380.926
7/14/11 1:39	380.926
7/14/11 2:39	380.926
7/14/11 3:39	380.424
7/14/11 4:39	379.923
7/14/11 5:39	378.917
7/14/11 6:39	378.917
7/14/11 7:39	378.389
7/14/11 8:39	378.885
7/14/11 9:39	378.378
7/14/11 10:39	379.882
7/14/11 11:39	381.387
7/14/11 12:39	382.388
7/14/11 13:39	382.391
7/14/11 14:39	381.889
7/14/11 15:39	382.39
7/14/11 16:39	382.39
7/14/11 17:39	381.886
7/14/11 18:39	382.388
7/14/11 19:39	382.388
7/14/11 20:39	381.894
7/14/11 21:39	381.893
7/14/11 22:39	381.393
7/14/11 23:39	380.893

Figure 13 - Example of discrete values for the output temperature

3.2.1. As shown in Figure 2, the final condition for the internal bypass valve is at its limit, so it doesn't represent any more physical degradation process. In order to estimate the remaining life expectancy for this system, another border condition was chosen (as limit), which was its output temperature, now expected to slowly but consistently increase (as no final control element is available at the present condition for the heat exchanger).

Again, the same histogram based method was used for this variable, so the same three steps were followed. For the first one (real time data collection), an example is shown in Figures 13 and 14.

3.2.2. For the second histogram, again the idea behind it was that each time the output temperature adopted a new value, it was due to some change at the heat exchanging condition, an issue associated to a failure (in absence of the final control element), according to a Weibull approach (no new value, good and stable condition, no failure).

The number of times the output temperature kept a single value (that means amount of hours) was considered as representing the survival period for this failure mode occurrence (failure mode sample).

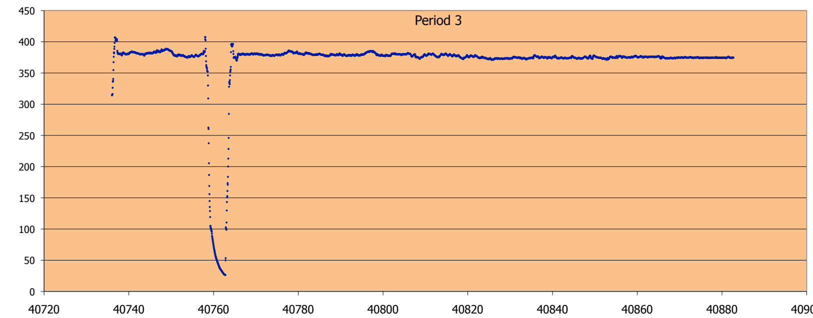


Figure 14 - Graphical trend for the output temperature

Every other non-adopted values within the 0 to 450 °C range for the considered period were taken as suspensions. The specific histogram is shown in Figure 15.

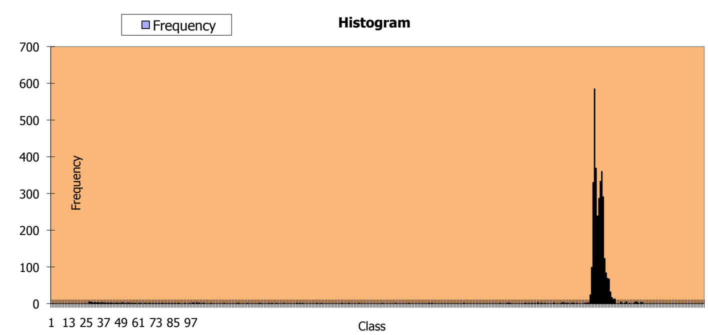


Figure 15 - Histogram of output temperatures

3.2.3. For the third one (failures/suspensions), the filtering criteria were:

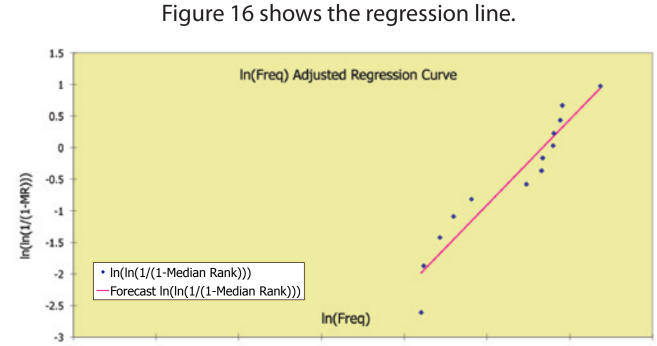
- Maximum and minimum values for the temperature to be considered.
- Minimum amount of occurrences to be considered in terms of a stated percentage of the maximum frequency at the histogram.

Three different sets of failure/suspensions selection parameters were used, although only the selected one according to engineering judgment is shown herein.

3.2.4. Setting the temperature limits for the period according to the observed trend (specifically >370 °C) and the minimum amount of occurrences at 10% of the maximum, the following parameters were obtained:

Beta (shape) =	1.351307844
Eta (characteristic freq) =	290.8241184

Figure 16 shows the regression line.



Regression Statistics		bi-weibull	
Multiple Correlation Coefficient	**0.955635449**	**CCC ≈ 0.93**	Good Fit
Determination Coefficient R^2	**0.913239112**	**CCD ≈ 0.86**	Good Fit
Adjusted R^2	0.905351758		
Typical Error	0.320123426		
Samples	**13**		

Figure 16 - Regression line for the data set

At this data filtering condition, the early conclusions regarding 2.2 objectives were:

- The period showed a Beta value >1, implying a wear out period at the bathtub curve. This was found consistent with the real situation, as the temperature evolution is expected to be due to the final element unavailability, a condition reached after the already shown internal bypass valve full stroke (last period, Figure 2).
- No comment for the calculated Eta value.
- The dot distribution at the regression line graph (Figure 16), may imply the presence of more than one failure mode.
- The goodness of fit for the regression line is quite good, so for this other histogram shape (concentrated data) and considering the previous comment on Beta value, the applied data set filtering criteria seems to be good (the other two were identical, but with the minimum amount of occurrences set at 1% and 25% of the maximum).
- Now, regarding 2.2 objectives and setting a temperature limit of 448 °C and a target date to reach, the corresponding "R" (Reliability) value was calculated for the proposed scenario in Table 1.

As can be seen, it was estimated a 76.7% of success probability in a mission defined as reaching the future date June 15, 2012, with an output temperature no greater than 448 °C.

This estimation is reasonably consistent with a linear extrapolation forecast for this variable.

Additionally, the confidence bounds in the 5% and 95% ranks were also estimated (Beta binomial approach[7]) for each one of the 13 samples filtered as failures from the total of 450 at the histogram (see Figure 17). This estimation indicated an Eta uncertainty between 157.9 hours and 391.9 hours, so the corresponding one for "R" (76.7%) varied between 54.5% and 83.7% (this last calculation only for reference purposes).

		Temp [°C]
Start Date	11-Ago-11	380.03
End Date	15-Jun-12	448.00
days	309	
hours	7416	
req freq	109.10	
R	76.66%	
	54.52%	83.72%

	Beta-Binomial Confidence Bounds			
Rank	5%	95%	Freq [h]	CDF
1	4.838357573	98.15434116	67	12.85%
2	20.87675427	142.2029722	69	13.34%
3	39.92308944	181.2387375	84	17.03%
4	60.38798996	219.2119477	99	20.79%
5	82.1289985	257.8868208	123	26.85%
6	105.345726	298.5795092	239	53.56%
7	130.4197995	342.6554137	287	62.55%
8	157.9264574	391.8776005	291	63.24%
9	188.7405188	448.8992757	330	69.46%
10	224.2782786	518.306841	333	69.91%
11	267.0962266	609.4084252	360	73.66%
12	322.7086933	746.3567297	369	74.83%
13	408.1293245	1031.996929	585	92.36%

Table 1 - Proposed scenario

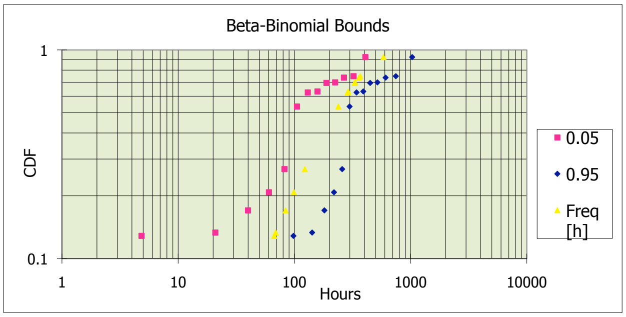


Figure 17 – Beta binomial confidence bounds for the failures population

4. Conclusions

4.1. The exposed histogram-based method for historical process data analysis, combined with the Weibull distribution, seems primarily to be a possible approach for both characterizing failure modes from a black box perspective and predicting remaining life expectancy.

4.2. This approach, particularly regarding remaining life expectancy prediction, is quite different from a linear regression-based extrapolation. As could be seen, it considers not a tendency, but the stability characteristic of a deterioration process in progress, making this method an indirect determination approach. Additionally, every forecast made in terms of "R" calculation for many proposed future scenarios have demonstrated to be conservative when compared against linear extrapolations.

4.3. Particular attention needs to be paid, however, to the basic data set filtering criteria (failures/suspensions), according to the histogram pattern. As a primary view, the more dispersed bars, the more data to be considered as failure in order to obtain reasonably good representing parameters according to reality. The Weibull estimation parameters using the described methodology are pretty sensitive to the data set considered, particularly on extreme values. This also was found consistent with bibliography references,[8] and particularly in regards to keeping the need for engineering judgment.

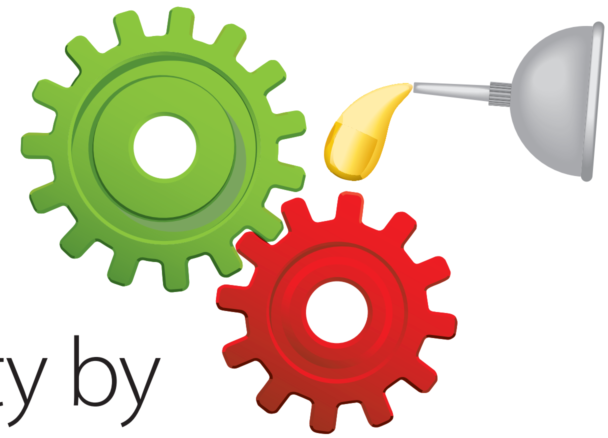
Additionally, a large practical experience was visualized as relevant for building the proper engineering criteria to deal with data beyond any strict statistical perspective.

References

Abernethy, Dr. Robert B. The New Weibull Handbook - Fourth Edition, Houston, TX: Dr Robert Abernethy, 2003

1. 2.9 Suspended Test Items - Pages 2-6.
2. 2.10 Benard's Approximation - Pages 2-7
3. Figure 3.4 - Critical Correlation Coefficient, r and Critical Coefficient of Determination, r^2 - Pages 3-4.
4. Figure 3.4 - Critical Correlation Coefficient, r and Critical Coefficient of Determination, r^2 - Pages 3-4.
5. Figure 2.6 - The Bathtub Curve for a Good Component - Pages 2-8.
6. 3.6 - Curved Weibulls and The Log Normal Distribution - Pages 3-10.
7. 7.3.1 - Beta-Binomial Bounds - Pages 7-2.
8. 3.4 - Suspect Outliers - Pages 3-5.

Jorge Kalocai, Engineer in Electronics, CMRP, TÜV FS Exp, Certified RCM and PMO Facilitator and RCA Analyst, has eight years of applied experience in Asset Management, plus twenty-three years in Instrumentation, Automation and Control on industry. A Tutor for the Reliability Engineering Program since 2008 and Professor for the Risk Engineering Program since 2012, both at Austral University (Argentina), he is currently Reliability Supervisor at Profertil SA (Nitrogen Fertilizer Complex, Argentina).



Maximize Reliability by **Optimizing Your Lubrication PMs**

Jarrod Potteiger

Precision lubrication has several important components that are often summarized in the five "rights" of lubrication. Those being the right lubricant, in the right amount, at the right frequency, in the right place and of the right quality or condition.

When executing a precision lubrication program, these "rights" should be the primary objectives, and ensuring the objectives are met is largely a matter of optimizing lubrication PM activities. Once all lube points have been identified, placed in a proper equipment hierarchy and assigned a proper lubricant specification, the next step is to identify the appropriate lubrication tasks and the optimum frequency for each. The key term here is optimum. Simply doing more lubrication tasks, such as more grease applications or more frequent oil changes, doesn't necessarily equate to better lubrication or better anything. On the contrary, it can actually be harmful in many cases. Over greasing bearings is a common cause of premature failure and performing unnecessary oil changes proportionally increases the chance for errors, such as leaks, improper fill levels, or cross contamination of lubricants.

The term "PM" can be somewhat ambiguous in that it means different things to different people, including preventive, predictive, proactive and even plant maintenance, but for this discussion, it means planned maintenance, which includes all of the above. Most lubrication PMs can be conveniently categorized into four categories: oil changes (drain and fill) or applications, grease applications, oil sampling/analysis, and routine lubrication inspection PMs. Determining the optimum frequency for some of these activities is relatively easy, for others somewhat rigorous, and a few are practically impossible because they require the application of experience and intuition. On the bright side, making most of these decisions is like throwing horseshoes or hand grenades, just getting close is usually good enough.

Oil Changes

There are many factors that affect oil life in lubricated machinery. The lubricant type, quality, relative sump volume, cleanliness, application type and operating temperature all play major roles in determining the useful service life of lubricating oil. These factors are what allow oil

Most lubrication PMs can be conveniently categorized into four categories: oil changes (drain and fill) or applications, grease applications, oil sampling/analysis, and routine lubrication inspection PMs.

to last for many years in some applications, but only a few days in others. This becomes clearer when you consider that oil in a passenger car typically lasts about 50 to 100 operating hours, while oil in a large turbine might last five years or more. The difference is that the internal combustion engines present an extremely harsh operating environment for the oil in terms of temperature and contamination levels, combined with a very small oil sump relative to the circulation rate. The turbine system, on the other hand, has a large sump and provides relatively mild operating conditions.

Oil changes for systems with large volume reservoirs should be almost always performed based on condition as indicated by oil analysis; so in this case, the sampling frequency is the primary concern. For those machines where oil analysis is not available, the optimum frequency must be estimated based on the available information starting with the recommendation of the OEM. When it doubt, the OEM recommendations will normally suffice, but this may not be optimum. Because equipment manufacturers don't normally know the type of service or quality of lubrication provided for a component, they must err on the side of caution and assume poor conditions. Therefore, they will typically recommend a very conservative oil change frequency. A typical OEM recommendation for oil changes on a bath lubricated gearbox is six months, but with good contamination control and oil quality, the actual oil life is usually more like 12 to 24 months. For programs that practice good contamination control and use high quality lubricants, these frequencies should be determined experimentally. A good way to do this for assets not normally included in the oil analysis program is to test a representative sample of similar components to determine the actual useful service life of the oil and make that the standard PM frequency. To be safe, it is a good idea to back off of the experimentally determined value by an appropriate engineering factor. When trying to maximize oil change frequencies, it is important to remember that the penalty for overextending oil drains can be high. Overextended oil drains don't normally lead to catastrophic failure, but the byproducts of oil degradation can lead to ongoing problems with sludge, deposits and curtailed life for subsequent oil changes due to additive depletion caused by the "bad" oil that remains behind. The point is to get most of the life from the oil, not necessarily all of it.

Grease Application

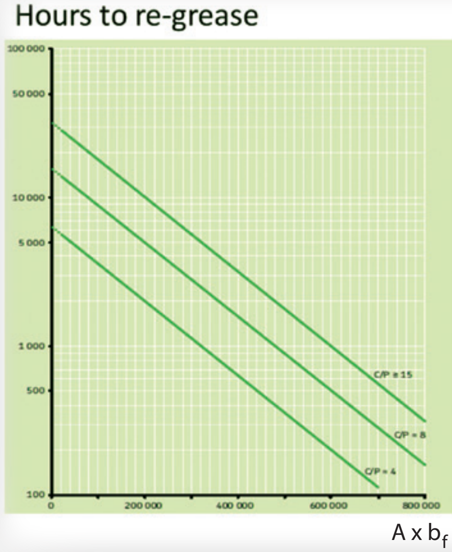
Grease application frequency is an item that many people get wrong. In most cases, they tend to over grease or not grease at all. Just as with oil, useful grease service life can vary tremendously. A bushing on a wheel loader may need to be greased several times a day, while an electric motor bearing in a cool environment may run for many years without needing new grease. Unlike oil life, grease life usually can be predicted fairly accurately using common methods, making this part of the PM optimization process relatively easy. This is fortunate because it is usually difficult to find OEM grease recommendations for most equipment other than electric motors. Because electric motors are particularly sensitive to over greasing, one should almost always follow OEM recommendations, which tend to be more conservative than other bearing re-grease frequency calculators. For all others, calculators like the one published by SKF[1] work well for most applications. Using this method, one needs to know the size, type and speed of the bearings to determine the correct grease replenishment frequency. It is, however, recommended to make adjustments to these values based on the temperature, orientation, vibration levels and the likelihood of particle and moisture contamination. In extreme cases and in slow speed applications, these actually become the predominant factors. For more information on this complex topic, refer to the referenced article by Dr. Mark Barnes[2].

In most cases, this exercise will lead to fewer grease application activities, freeing up time for other PMs that may have previously been neglected.

Oil Sampling and Analysis

All too often, maintenance programs focus on sampling more equipment rather than sampling at the optimum frequency. When optimizing sampling frequencies, the best way to start is to decide which machines should be sampled. It's better to do good oil analysis on the most critical assets than to perform ineffective oil analysis on all of them. There is no universal formula for determining oil sampling frequency, but most experts consider monthly sampling to be optimum for critical machinery.

When making these decisions, it is important to consider the objectives of the oil analysis program. If the only objective is to perform condition-based oil changes, the sampling frequency should be determined relative to the lubricant's expected service life, which goes back to OEM recommended oil change frequencies. In most situations, this is not the only objective, or even the most important one. The real value of oil analysis is its ability to serve as a proactive condition-monitoring tool, allowing for the detection and quantification of particle contamination, moisture, other lubricants or fluids and lubricant condition. In addition to the criticality of the asset, one must consider how the machine would be affected by an unacceptable amount of contamination and the likelihood of a contamination or other abnormal condition. If oil analysis is used as a predictive condition-monitoring tool, the biggest consideration is



The speed factor (A) multiplied by the relevant bearing factor (bf) where:

$$A = N * D_m$$

N = rotational speed (rpm)

D_m = 0.5 x [d(mm) + D(mm)]

b_f = bearing factor depending on bearing type and load condition

	b_f
Ball bearings	1.0
Cylindrical roller bearings (light/no axial load)	1.5
Spherical/tapper roller bearings	2.0
Spherical roller thrust bearings	4.0
Cylindrical roller thrust bearings	10.0

Figure 1: Re-grease interval calculations (Reference SKF Group/Des-Case Corporation Practical Machinery Lubrication Training Course Manual)

Asset	Asset Criticality	Failure Mechanism	Severity Rating	Occurrence Rating	Sampling Criticality Factor (SCF)	Average SCF
Compressor	8	particle contamination	4	7	224	176
	8	wrong lubricant	6	3	144	
	8	water	6	4	192	
	8	lubricant degradation	3	6	144	

Table 1: Sampling Criticality Factor

the likely time period between detection and failure. Obviously, the sampling frequency must be shorter than this period to be successful.

The best approach to this problem may be to employ a formulaic method similar to failure modes and effects analysis (FMEA). This process will allow each of these issues to be pseudo-quantified and gives each asset a numeric score that reflects the importance of sampling more frequently.

Sampling Criticality Factor (SCF)

1. Identify all assets to be sampled and assign a criticality factor from 1 to 10, with 10 being the most critical.
2. Identify all potential failure mechanisms for the lubricant that can be detected with oil analysis, such as wrong lubricant, particle contamination, moisture contamination, etc.
3. Assign a severity rating (1 to 10) for each failure mechanism.
4. Assign an occurrence rating for each failure mechanism.
5. Multiply all three factors to obtain the SCF for the asset (1 to 1,000).

Although the ratings are subjective, this process will at least offer a structured approach to deciding how critical it is to sample an asset at a short interval. The average SCF could be a problem in some cases as it may downgrade a potentially severe failure mechanism. Therefore, it may be preferable to simply use the highest individual SCF for a given asset rather than the average. For various reasons, many plants have a limit on the number of oil samples they are willing to perform each year. When this is the case, methods like this will help to guide the allocation process.

Routine Lubrication Inspection PMs

In a well-designed program, the most common lubrication activity by far should be routine inspections. The very nature of condition-based maintenance is to inspect for conditions that require corrective action. Routine lubrication inspections typically only require a few minutes to perform and include items such as checking the lubricant level and its visible condition, as well as inspecting for other related items, like filters, breathers, seals, etc. Because oil level is so critical for many applications, it is important to perform these tasks at a relatively high frequency. Ideally, these checks would be performed every day, if not every shift. This is an excellent place for operators to be involved in the lubrication process, as their availability is usually much greater than the mechanical staff. With well-documented inspection procedures and a modest amount of training, most individuals can be qualified to perform these tasks. Unfortunately, this is not an option in every situation and if all inspections must be performed by lubrication technicians or mechanics, there may very well be a shortage of resources to perform these checks at the optimum frequency. When this is the case, a FMEA-type process may again be the best solution to allocating resources in the most efficient manner. Just as with the SCF, we can skip machine and lubricant failure modes and go directly to lubrication failure mechanisms that can be detected through typical visual inspections.

In a well-designed program, the most common lubrication activity by far should be routine inspections.

Again, it may be desirable to replace the ICF average with the highest individual factor. A process like this will often show that while a machine may be very critical, the routine PMs are not. Likewise, lubrication inspections for a machine of low criticality may be very critical due to the sensitivity of the machine to an item, such as oil level. Combining a rating system like this with experience and intuition will likely be the optimum approach to optimizing your PM inspection program.

With resources stretched thin in most plants these days, it makes sense to take a critical look at the type and frequency of PMs in the current program. While most plants fall well short of performing all scheduled PMs, studies show that anywhere from 35% to 50% of PM activities essentially have no value. If you haven't done so recently, it may be time to take a big step back and redesign your lubrication program from the ground up to make sure you are using the right lubricants, in the right amount, of the right quality, in the right place and at the right time.

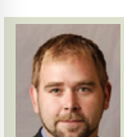
Asset	Asset Criticality	Failure Mechanism	Severity Rating	Occurrence Rating	Inspection Criticality Factor (ICF)	Average ICF
Compressor	8	Low oil level	3	2	48	112
	8	Oil leak	4	3	96	
	8	Breather plugged	1	3	24	
	8	High oil level	6	1	48	
	8	Gross water contamination	7	3	168	
	8	Filter in bypass	6	6	288	

Table 2: Inspection Criticality Factor

References:

1. SKF USA Inc. *Bearing Installation and Maintenance Guide*. USA: SKF Publications, 2008.

2. Barnes, Mark. "Precision Regreasing of Element Bearings." *Uptime Magazine* Feb/March 2012: 28-30.



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condition monitoring

Oa oil analysis

Oil Analysis Techniques as a

CBM Assessment Tool for Plant Critical Equipment

Cary Forgeron and John Underwood

Oil analysis has long been accepted as a valid condition monitoring maintenance technique. The facts show that when properly utilized with a qualified laboratory, proper testing and a full commitment of the user, oil analysis offers the lowest cost of implementation and provides the highest rate of return on investment than any of the predictive maintenance disciplines.

This article will document a complete sampling program at a major industrial manufacturer, the need for full commitment of the user, and the benefits realized when the customer/user understands oil analysis and is fully engaged in the program. A case history will document the decision for a preemptive replacement of a critical gearbox and the resulting cost savings to the customer.

Background

Manufacturing plants with world-class, condition-based maintenance (CBM) or predictive maintenance (PdM) programs use a combination of technologies to determine the mechanical and lubricant health of their equipment. The three most common techniques currently in use are thermography, vibration analysis and oil analysis. When used in combination, they provide maintenance professionals with the information needed to make accurate and informed decisions.

In many cases, equipment critical to plant operations is often "unspared," with no backup unit to replace it when it is not in service. Unspared critical equipment in plants typically have common characteristics:

- They require very high capital investment and are expensive to maintain and repair.
- They are engineered for long service lives when operated within design specifications and in a predictable environment.
- Many are quite large and are made up of several individual components.
- Downtime is quite expensive since production is usually halted when unexpected problems or a system failure is experienced.

Major repairs and overhaul of critical equipment often require a complete plant shutdown, substantial manpower and subsequent loss of production activities. As a result, maintenance managers work to maximize trouble-free equipment operation and ensure repairs are scheduled before a loss of service occurs. Unfortunately, when deciding to remove or repair problem machines from service, the approval process is often difficult. It is not uncommon when engineering and maintenance personnel have evidence of pending problems that a number of meetings must be held with operations management before final action begins.

Of the three primary PdM technologies, oil analysis provides the most information for equipment "end-of-life" decisions and root cause determination. Oil analysis is most effective when samples are analyzed on a regular basis, allowing a trend analysis to be developed.

Of the three primary PdM technologies, oil analysis provides the most information for equipment "end-of-life" decisions and root cause determination. Later in this article, we'll discuss a case study where oil analysis provided the first alert to an impending problem with the findings subsequently confirmed through vibration analysis.

Critical plant equipment requires testing that is broader in scope than the general oil analysis programs provided by oil companies and many laboratories. Appropriate testing should not be derived from a "standard" slate or suite of tests based on a selling price or sample bottle size. Rather, the testing needs to be appropriate to the machine and its application.

Testing should be sufficient to provide an early alert to changes in unit wear, lubricant condition and degradation, and potential sources of contamination to ensure the information needed for an in-depth evaluation is available when problems are indicated. Appropriate testing includes, but is not limited to:

- Wear metal analysis;
- Moisture content;
- Viscosity;
- DR ferrography or PQ Index;
- Acid number;
- Analytical ferrography;
- Particle counting;
- Examination of filter media debris.

Oil analysis is most effective when samples are analyzed on a regular basis, allowing a trend analysis to be developed. Also, results are monitored and measured against not only accepted limits and ranges, but more importantly, against the norms that are established for each particular machine. Accurate trended data permits an experienced laboratory analyst, or the end user, to diagnose and closely monitor the causes and effects of changes within the system.

DuPont, a Fortune 100 chemicals and products manufacturing company, owns and operates over 75 plants worldwide. DuPont USA utilizes all three previously mentioned PdM technologies as part of its corporate predictive maintenance program.

Case Study – Extruder Gearbox Failure Averted

DuPont operates a critical extruder gearbox at one of its chemical manufacturing facilities in the Texas Gulf Coast. The gearbox has an 8000 HP design with a 4:1 service factor – (2000 HP). It has an oil capacity of 2300 liters (600 gallons) and weighs more than 45 tons (100,000 pounds). The unit runs continuously and produces more than 3200 kilos (7000 pounds) of product each hour. The PdM technologies employed at this plant are oil sampling and vibration analysis.

Log Date	Lab No.	Samp. Dt.	WTR. %VOL	WATER %VOL	VIS CS 40°C	TAN D664m	WATER PPM	Particle >4um(c)	Particle >6um(c
10/27/2008	6	10/24/2008		0.30	306.2	0.56			
3/6/2009	4650	3/3/2009		0.50	320.0	0.45			
3/30/2009	221						409		
4/17/2009	5997	4/8/2009		0.50	316.1	0.22			

Table 1 - Water and physical property data

The plant is located in the hurricane zone of the United States. On September 13, 2008, Hurricane Ike made landfall on the Gulf Coast. As part of the company's disaster planning, the plant was shut down in "as is" condition just prior to the arrival of the storm. There was no power or any basic services within the plant during this time and severe flooding due to heavy rainfall and rising sea water from the Gulf of Mexico occurred within the plant.

As part of the company's post-storm disaster recovery plan, all lubricant had been pumped from the unit. It was opened, inspected, wiped clean, then flushed for four to six hours. New oil obtained from storage drums was used to refill the gearbox.

The extruder's lubricant was not contaminated from the storm, however, the drums with the new replacement oil had been stored outside and were heavily contaminated with water. The proactive attempt to prevent problems inadvertently created a problem.

On the first oil sample after the hurricane, Analysts, Inc. laboratory identified .30% water present. Unfortunately, plant personnel were very busy with other problems within the plant and did not react to the report. The next sampling in March 2009 reported .50% water. *(See Table 1)*

DuPont's corporate lubes consultant contacted the plant to discuss the oil analysis results and recommended additional testing of water via the Karl Fischer test, analytical ferrography and a lube filter examination. The Karl Fisher test was to confirm the moisture finding, ferrography was to check for rust and oxides, and the filter exam was to identify collected contaminants.

On May 1, 2009, the ferrogram report revealed moderate rubbing wear (Figure 1), ferrous oxides, a large fatigue particle (Figure 2) and a concentration of spherical particles made of low alloy steel. Antifriction bearings were determined to be the source of the low alloy steel. The spheres and presence of large wear particles were indicators of a potential end-of-life wearing pattern.

The lube filter media examination revealed a large quantity of iron oxides, corrosion products, fibers, seal material and varnish. The filter was removed and replaced on May 1, 2009.

As a follow-up after six days of use, the replacement filter was sent to the laboratory for examination. Due to the very short time this fil-

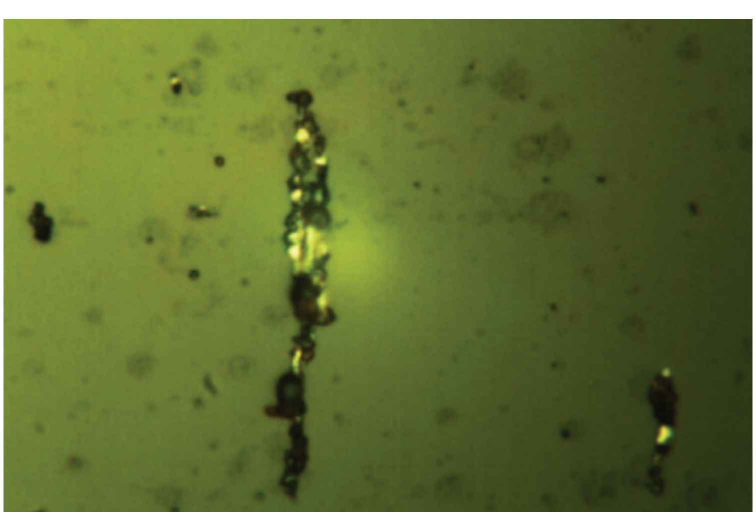


Figure 1 – Rubbing wear and spheres

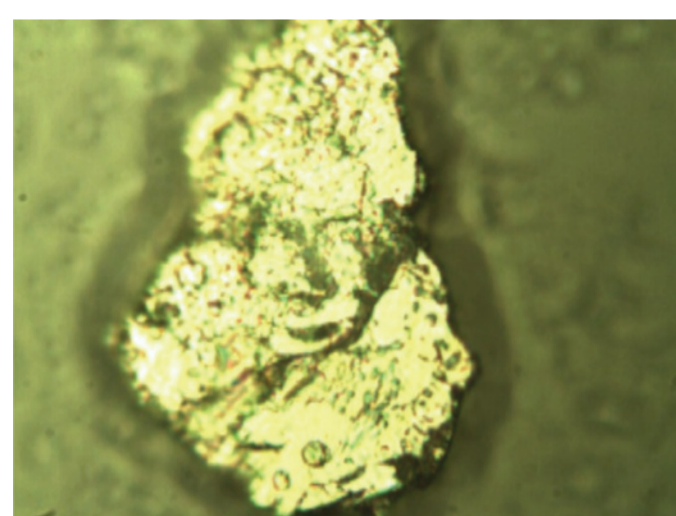


Figure 2 - Large fatigue particle

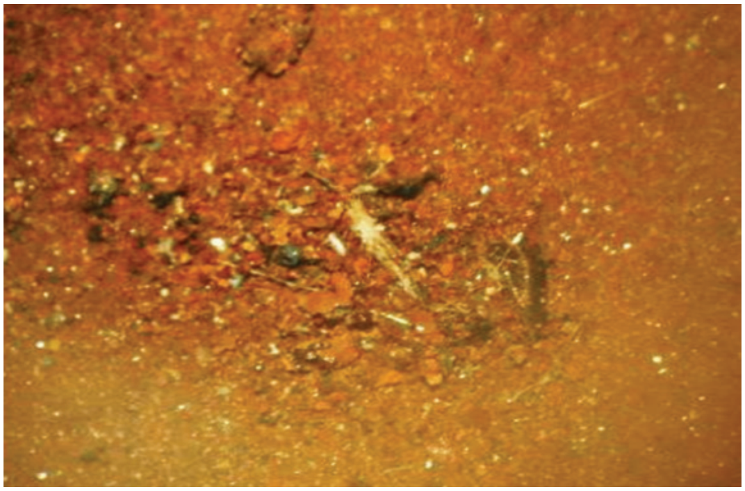


Figure 3 - Debris from initial filter inspection

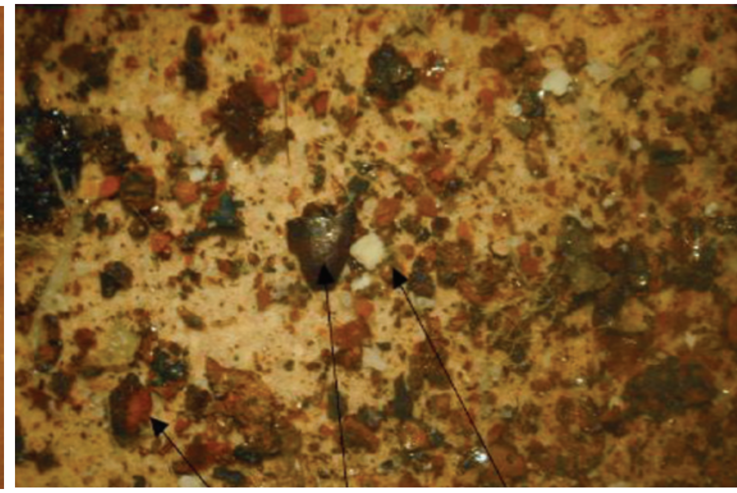


Figure 4 - Debris and large wear particles from second filter

ter was in service, there were lesser amounts of contaminants than found in the first filter. This reduction in contaminants allowed for a better evaluation of the wear material. Sliding wear particles and more spheres were identified. Additionally, the laboratory confirmed the continued presence of iron oxides, corrosion products, fibers, seal material and ferrous scale that were previously observed.

From the data collected and discussions with the lube consultant and plant personnel, it was determined the wear was being caused by a lack of lubrication, high moisture and poor filtration.

On June 1, 2009, the lube consultant, plant personnel and repair vendor met to discuss the available options. Due to business conditions, the unit was to be kept in operation. System monitoring using oil sampling and vibration analysis was done at more frequent intervals, and a kidney loop filtration system was installed. In the short term, spectrochemical analysis results showed a reduction in iron wear. However, after three months, chromium began to appear and after six months, both iron and chromium wear rates increased significantly. Another ferrographic analysis was performed and rated as critical due to the presence of heavy concentrations of ferrous rubbing and laminar wear particles, indications of bearing spalling and oxides.

The decision to remove the extruder gearbox from service and make the necessary repairs was expensive - $2.5 million. An unplanned for failure could have cost the plant as much as three times the money spent, with many weeks of plant shutdown.

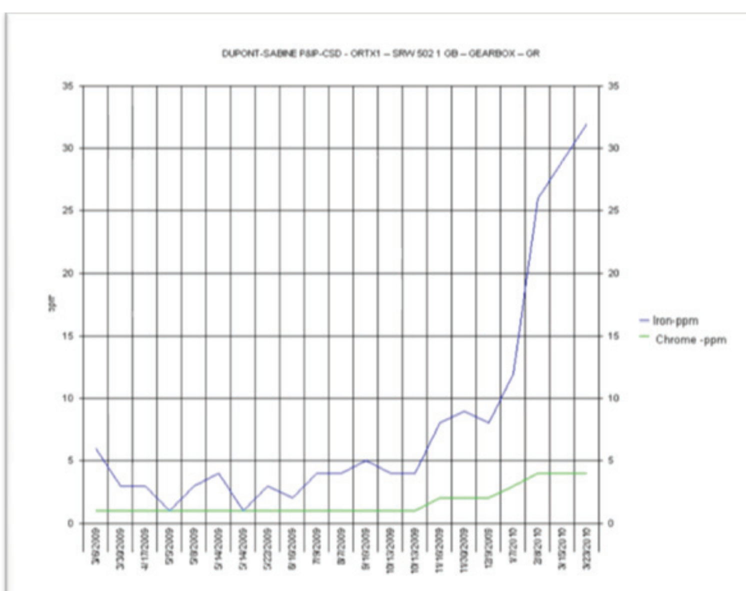


Table 2 - Spectrochemical wear trend data

Based on all the corroborating data, plant operations and maintenance personnel agreed to schedule the proactive removal and repair of the gearbox. Assuming no delays or unexpected problems, this was a 21-day process that impacted plant revenues by $2.5 million (1,909,000 euro).

There was an unexpected discovery that happened two months prior to the removal of the gearbox. The extruder casing was opened so the gear set could be visually inspected. Just before closing the gearbox, the lube oil pump was activated to check the operation of the input pinion gear spray nozzles. It was found that all four nozzles had blockages, two with minor flow restrictions and two completely blocked. The defective nozzles were providing lubrication to the high speed pinion mesh but not to the bearing systems. The nozzles were removed and cleaned than put back into service. The reinstalled nozzles restored proper oil flow to the high speed gear set, but the damage had been done. In the last sample prior to removal of the gearbox, the wear had increased again to its highest level during the life of the gearbox indicating that the unit was entering into an early failure stage.

In addition to the water contamination the gearbox had experienced, it was determined that partial oil starvation caused the increased wear to occur. If the faulty spray nozzles had gone unnoticed, the repair work would have soon been wasted as the wear to the unit would have continued to increase and most likely caused an unexpected failure during production.

After the repairs, the subsequent oil sampling and vibration analysis confirmed that the problems were corrected and the gearbox continues to operate without any detectable problems.

Summary

This case history is an example of a strong and successful CBM/PdM program that utilizes multiple technologies to provide world-class service. In this situation, oil analysis proved to

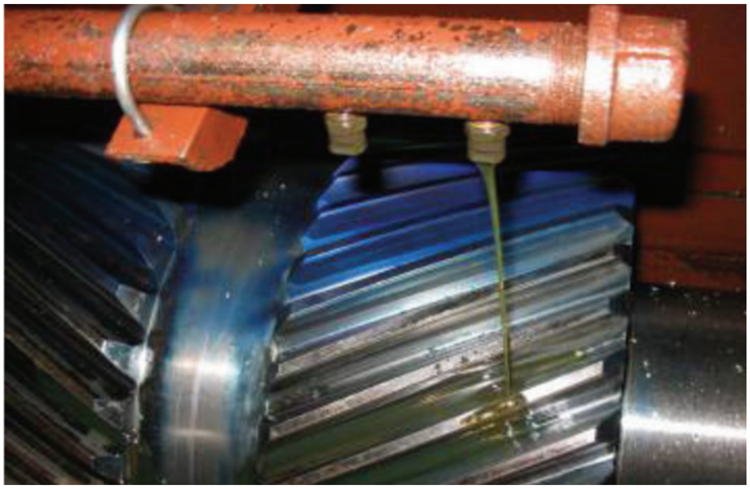


Figure 5 - Plugged nozzles with impaired flow

Figure 6 - Flow from nozzles after maintenance

be the best technology for early warning of the onset of a major problem. It also allowed continual assessment of the machine's condition until repairs were feasible.

The success of the DuPont program is due to the company's commitment to the program and contributions by many departments and personnel. The testing utilized is based upon the various equipment and applications. More in-depth testing is encouraged and supported whenever systemic problems are identified. Decision-making is based on best business practices and practicality.

The decision to remove the extruder gearbox from service and make the necessary repairs was expensive - $2.5 million decisions are not made lightly. However, if the decision had been to continue the unit in operation, it most certainly would have experienced an early end-of-life failure. An unplanned for failure in this case could have cost the plant as much as three times the money spent, with many additional weeks of plant shutdown.

The oil analysis program employed by the plant is a very low cost, high return investment that complements the other technologies utilized.

Cary Forgeron is the National Field Service Manager for Analysts, Inc. Cary has over eight years experience in assisting end-users in developing oil sampling programs to meet their organization's maintenance and reliability goals. His experience in industrial plant facilities has been focused in Power-Generation, Alloy Milling and Chemical Processing markets. www.analystsinc.com

John Underwood is a 30+ year veteran of lubrication. John is currently the Corporate Lubrication consultant for DuPont. He has served in this role for over 15 years, and focused on helping DuPont facilities improve their maintenance and reliability programs through implementation of oil analysis and lubrication programs.

Part 2

WHEN DECIBELS AREN'T ENOUGH

Waterpark Follow-Up

Jim Hall

This article is written as a follow-up to the April/May 2012 Uptime magazine article titled, "When Decibel's Aren't Enough." In the previous issue of Uptime, we told the story of testing eight, 50 hp filtration pump and motors at a local waterpark.

Using the Ultraprobe 15000 instrument from UE Systems Inc., we noted what appeared to be an inner race defect. As you can see from the FFT report (Figure 2) of this motor, the obvious inner race defect was captured.

What was really ground breaking about this particular inspection in June 2011 was the ability to see for the first time a defect with an ultrasonic instrument "in the field." Although recording a WAVE file with an ultrasonic instrument was not new, we had the ability with the same instrument to record a WAVE file, download the file and view it on a computer through spectrum analysis. Again, the big deal was the ability to see in-the-field FFT and/or time waveform in the field. This gives the user an unprecedented look at a motor bearing in the field and opens up a whole new practice of ultrasonic bearing inspections.

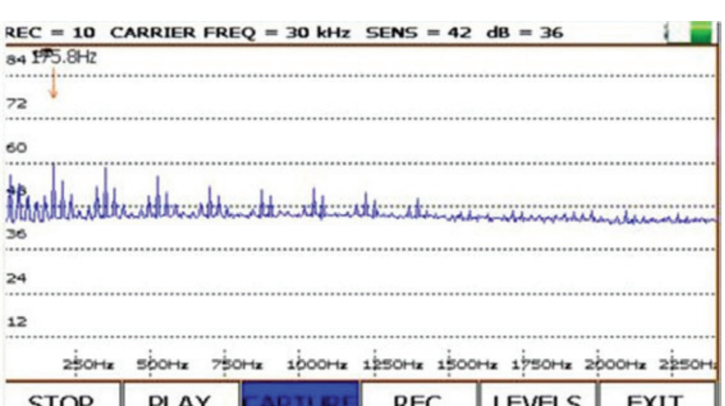


Figure 2 - Motor No. 4 Inboard bearing, June 2011, appears to have an inner race defect (Photo courtesy of Jim Hall, Ultra-Sound Technologies)

Figure 1 - Inspecting the newly-replaced No. 4 motor (Photo courtesy of Jim Hall, Ultra-Sound Technologies, Woodstock, GA)

This particular waterpark, unfortunately, practices a "run-to-failure" maintenance strategy. Other than lubricating the bearings every month with three shots of grease, they have no predictive maintenance. However, allowing our presence to inspect the motors and pumps using airborne ultrasound, the park maintenance personnel are asking questions of upper management. They are requesting equipment to help them maintain the park's filtration pumps and motors.

This same waterpark, during the past year of June 2011 and June 2012, retrofitted all motors with variable frequency drives. To our surprise, we found out from the installers that four of the eight motors had burned up while in the process of installing and adjusting. The motor noted in the April/May 2012 Uptime article that we were to inspect as a follow-up was unfortunately one of those motors replaced.

During the summer season, the waterpark runs the filtration pump motors 24/7, supplying water to the various amusements within the park. In an effort to update the park on a limited budget and reduce downtime, the park decided to install variable speed drive (VSD) controls to vary the speed of the motors with load needs.

Inspection of these motors will now require more data for the ultrasonic inspector than before. The motors are direct drive (no coupling), so for proper inspection of these variable speed motors, a stroboscope or a non-contact tachometer will be required to retrieve and input the actual rpm at the time of the inspection. Since the speed will be determined by hertz, the hertz reading also should be entered into the notes. This is "must have information," especially when using the new bearing fault calculator of the instrument's spectra analysis software. With speeds/hertz changing, care must be taken to assure good results by comparison.

The newly installed motor No. 4 showed no sign of any bearing defects (Figure 3). However, I have often had inquiries about inspecting motors equipped with VSD, and a major concern has always been the annoying whine. Yes, there is a very distinct whine when inspecting VSD motors. Even as I drove within 50 feet of the filtration pumps one afternoon, I had radio interference, lots of interference, through the AM station I was listening to.

Moving on to motor No. 3, its electrical display panel read 50Hz, 47.8 amp and 65.5Vdc. Shortly afterwards, the same motor's hertz reading was ramped up to 53Hz as it was programmed to do. Motor number three after the VSD retrofit is now reading six to eight decibels higher than before.

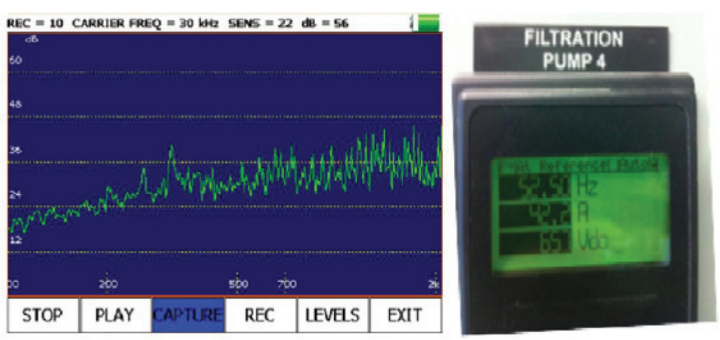


Figure 3 - Motor No. 4 (newer motor) showing no bearing defects

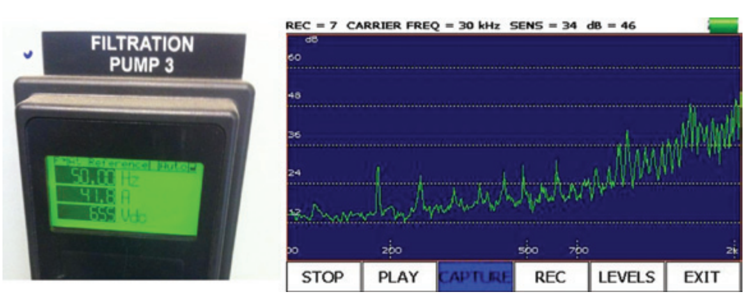


Figure 4 - Outboard bearing, motor No. 3 photo of VSD control panel

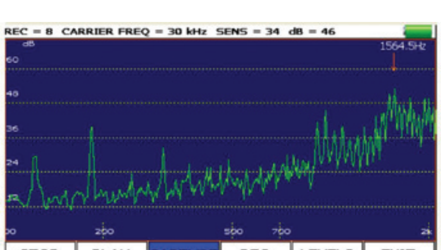


Figure 5a - Motor No. 3 Inboard bearing, as it appeared on the instrument's display of the UE 15000

Four days later, this motor had to be replaced as well with a new motor due to armature problems.

Utilizing an instrument with recording capabilities is key to any inspection, regardless of whether the application is mechanical, electrical, or even leak locating. Having the ability to see defects in the field may reduce costly repairs and/or prevent a shut-down and lost production.

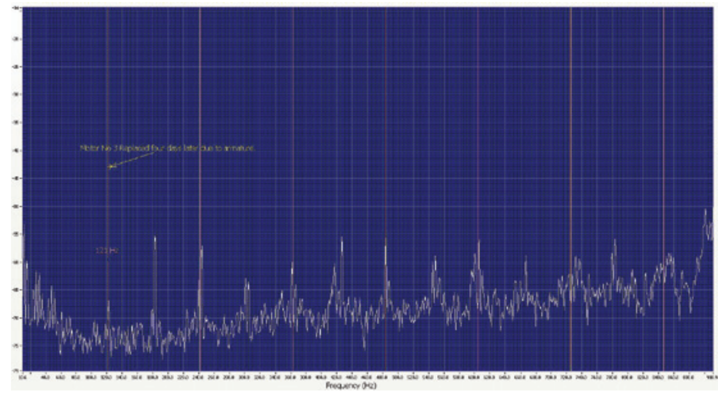


Figure 5b - Motor No. 3 Inboard bearing, four days after this reading the motor was replaced due to armature problems, no other specifics were given

The readings during our follow-up visit were less than expected. We had hoped to reread motor No. 4's inboard bearing. Overall, the inspection did not yield anything of high interest, only that motor No. 3 possibly and motor No. 8 as well were high noise.

Figure 6 - Adrian Messer, UE Systems, inspecting motor No. 3 utilizing an Ultraprobe 15000

It's rather obvious that inspecting motors with VSD is going to be a challenge when utilizing the ultrasound instrument for this inspection. With more and more plants utilizing VSD, it would be helpful to the ultrasound community to discuss the challenges in available online forums, such as ReliabilityWeb.com's Maintenance Forum (online chat). Share with the community your suggestions, thoughts, as well as your experience with ultrasound inspection of motors equipped with VSD.

Figure 7 shows the data logged readings for several of the motors and pumps. Had the VSD not been retrofitted, maybe the decibels would have remained closer to baseline. Some technicians in the past have commented on the higher range of decibels on motors after having been converted to VSD. If you retrofit your existing motors with VSD, you want to take new baselines. Hopefully, a return trip to the waterpark in 90 days will reveal some real changes.

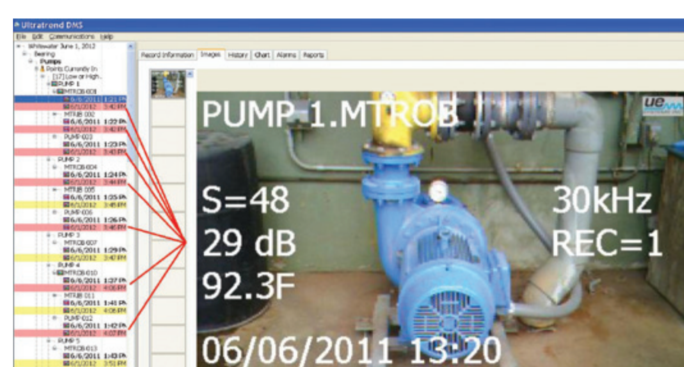
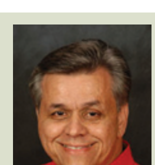


Figure 7 - The DMS software shows a number of the motors with higher decibels than the year before



Jim Hall is the President of Ultrasound Technologies Training Systems (USTTS). He has over 20 years experience and is a "vendor-neutral" company providing on-site ultrasonic training and consultation. USTTS provides an Associate Level, Level I and Level II Airborne Ultrasound Certification. He is also the author of a free, biweekly newsletter called "Ultrasonic War Stories" (visit www.ultra-soundtech.com to sign up).

condition monitoring

ViB vibration

Case Study:

Analysis of Fan Excessive Vibration Using Operating Deflection Shape Analysis

Ken Singleton and Bob Bracher

An unspared process fan had exhibited high vibration levels for several months. A request was received to investigate the root cause of the high vibration. The vibration data indicated high levels of fan bearing housing vibration primarily in the axial direction. Plant operations had concerns about the reliability of the fan since it was unspared and the plant was operating at capacity. An outage was not scheduled for several months.

An inspection of the fan, base and foundation was conducted, as well as collection of vibration data for an operational deflection shape (ODS) model. The test results identified a resonance of the fan pedestal and frame caused by an inadequate number of anchor bolts and deteriorated grout. Installation of additional structural elements and anchor bolts along with grout repair reduced vibration 85 percent. This article describes the analysis process, findings and modifications.

Background

The fan was an AMCA Arrangement #9, see Figures 1 and 2. The fan and motor were mounted on a six-inch channel frame that was grouted using cementitious grout and anchor bolted to a concrete base. Vibration levels at the fan bearing housings, especially in the axial direction, were a concern. The axial vibration levels were high, but slightly different on each bearing. Both axial readings were in phase at running speed as determined by cross-channel phase readings. This vibration pattern is not typical for a belt drive. Most vibration was at the fan shaft rotational frequency. There was concern expressed about possible thrust loading generated by the fan and the potential effect on bearing life reduction.

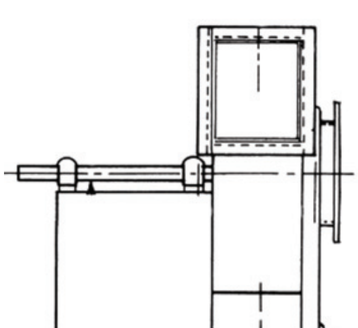


Figure 1

Figure 2

Inspection and Data Collection

The approach typically used when investigating high vibration of a machine or structure is:

1. Perform a visual inspection of the machine foundation, frame or sole plates, the machine itself, attached piping, duct work, etc.;
2. Review process conditions, if available;
3. Review the fan curves and operating point, if available. NOTE: The fan curves and operating point were not readily available for this unit.

The initial inspection of the fan identified movement between the fan frame and the concrete base. No loose bolting was found. Since the fan base was relatively tall, it would tend to be more responsive to the forces generated by unbalance of the overhung fan wheel, sheave run-out and belt vibration. These cyclic loads would be transferred from the bearings and bearing housings to the bearing support plate, the fan pedestal to the frame and then to the anchor bolts in the concrete. Secure attachment of the frame to the concrete and full support of the frame on the grout was important to prevent excessive frame flexure. As shown in the composite photo in Figure 3, there were only two anchor bolts clamping the frame to the concrete near the fan base. It was noted that the anchor bolts were not located close enough to the fan base to effectively restrain the frame and prevent flexure.

Figure 3

After the visual inspection, vibration data was measured on the motor bearing housings, the fan bearing housings and the frame. No bearing defect frequencies were present and belt vibration was very low amplitude. The primary frequency of vibration was the fan running speed as shown by the data in Figure 4. The trend of overall vibration level showed large variations in amplitude, with an excursion to 0.975 in/sec pk. (see trend plot in Figure 4.) The time waveform showed sinusoidal motion. It was concluded that the most likely source of the forcing vibration was fan unbalance. However, the relative flexibility of the frame, lack of adequate number of hold-down bolts and deteriorated grout would allow significant vibration response of the fan base and the supporting frame even at low unbalance force levels.

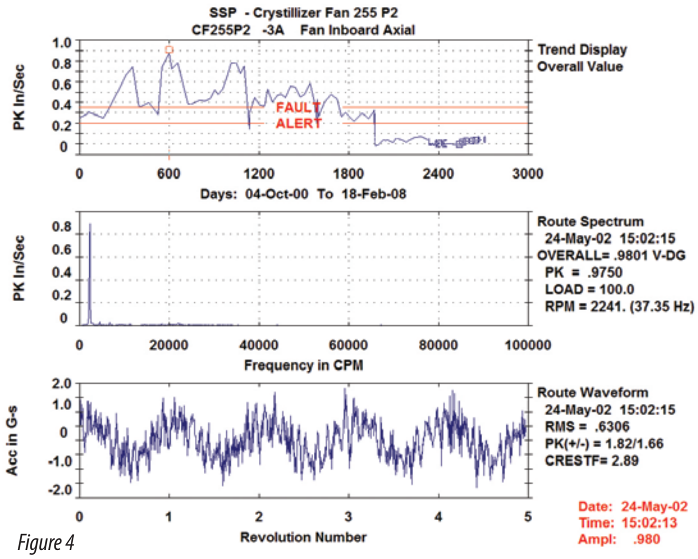


Figure 4

An ODS model would clearly show the movement of the machine's components and also the expected flexure of the frame and the relative movement of the frame to the concrete. Movement of the bearing housings or flexure at the bearing support plate, if any, would be displayed in the ODS animations. Data for the ODS model was measured on the motor, frame, bearing housings and fan base. The 3-D model, shown in Figure 5, was developed in ME'scopeVES. Substructures for the motor, bearing housings, base plate and pedestal, channel frame and concrete were used to develop the model. Cross-channel transmissibility data was then measured using a two-channel CSI 2120 at each degree of freedom (DOF) and imported to ME'scopeVES.

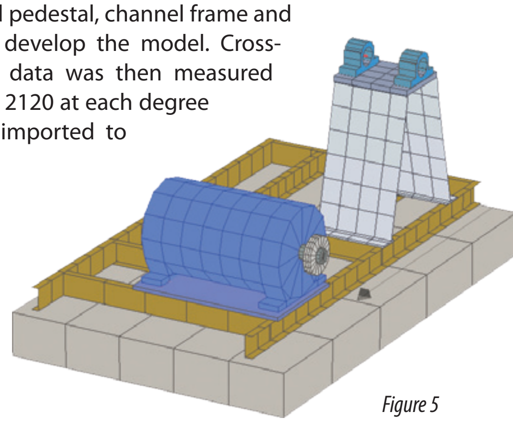


Figure 5

Findings

- Vibration data on the fan bearing housings indicated that most vibration was occurring at one times the fan rotational frequency in the axial direction.
- A bubble of energy at the base of the run speed frequency in the spectrum suggested structural resonance.
- The ODS model showed that the vibratory motion of the fan bearing pedestal and base was rocking in the axial and vertical directions, Figures 6 and 7.
- The channel frame at the sheave end of the fan base was loose at the grout and flexing vertically.
- Only three anchor bolts were installed in the channel frame side rail member. There were two anchor bolts near the fan base on the belt side as seen in Figure 3.
- No looseness of the fan bearing housings to the base plate or flexure of the bearing support plate were indicated by the ODS animations.

Recommendations

The following recommendations were made to management to correct the identified problems:

1. During the next fan shutdown, collect vibration 1X and phase data during coast down at both fan bearing housings in axial, horizontal and vertical. Analyze these data for indication of resonance.
2. After shutdown, perform impact tests at the fan bearing housings in axial, radial and vertical directions. Analyze these data for indications of resonance near operating speed.
3. Review process historical data for fan gas temperature and inlet guide vane settings, if available, to determine if vibration levels are related to changes in gas density or flow rate.
4. Chip grout from beneath the channel frame at the sheave end of the fan base.
5. Replace any carbon steel shims found between the concrete base and channel frame with stainless steel shims.
6. Install additional anchor bolts to secure the fan base and channel frame to the concrete. One method would use Hilti brand two component adhesive anchor bolts (or similar) in the concrete. Anchor bolts should be tightened to securely clamp the fan base and channel frame to the shims and concrete base, then replace the cementitious grout. Care should be taken to avoid changing the position of the channel, which could possibly change alignment of the fan shaft to the mechanical air seal.

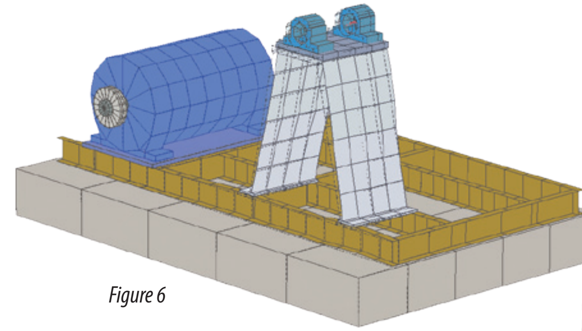


Figure 6

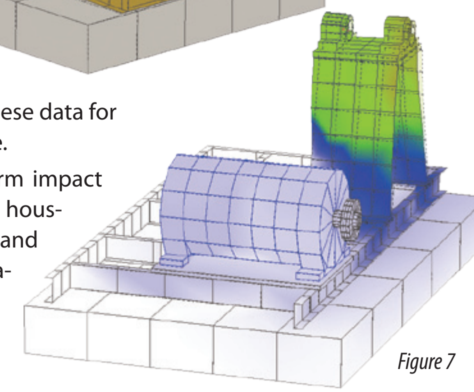


Figure 7

Follow-up

During shutdown of the fan, vibration data was collected using a CSI 2120 two channel analyzer. Normal fan speed was 2247 RPM. The amplitude and phase lag versus rpm plot is shown in Figure 8. The rapid vibration reduction and phase lag angle change from 0.50 to 0.10 in/sec pk with 65 degrees phase lag angle change for the speed range 2247 to 1900 RPM confirmed the presence of a structural resonance.

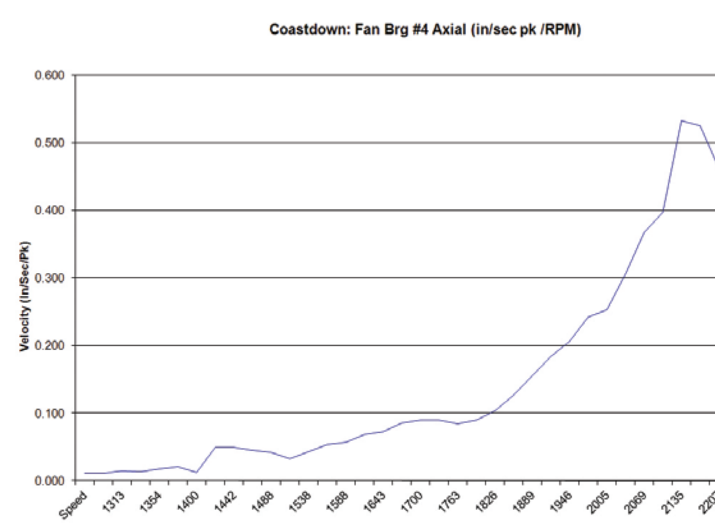


Figure 8

Figure 9

Figure 10

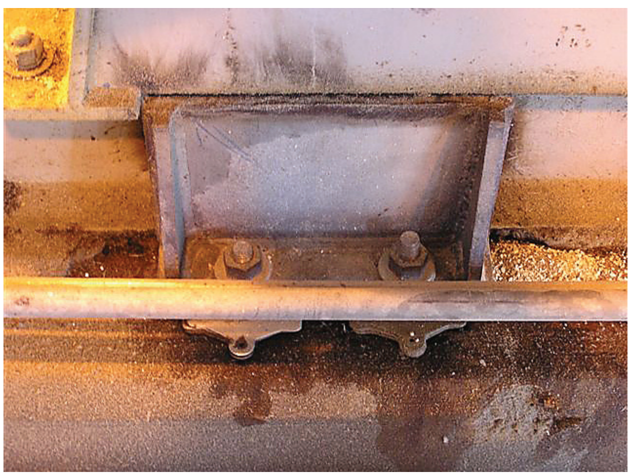


Figure 11

Figure 12

Fabricated structural members were welded to the fan frame and additional anchor bolts installed in the concrete. Stainless shims and grout were used as shown in Figures 9 through 12.

After the modifications, axial vibration at the fan inboard bearing was reduced 85 percent. As shown in Figure 13, the vibration had remained low for over two years.

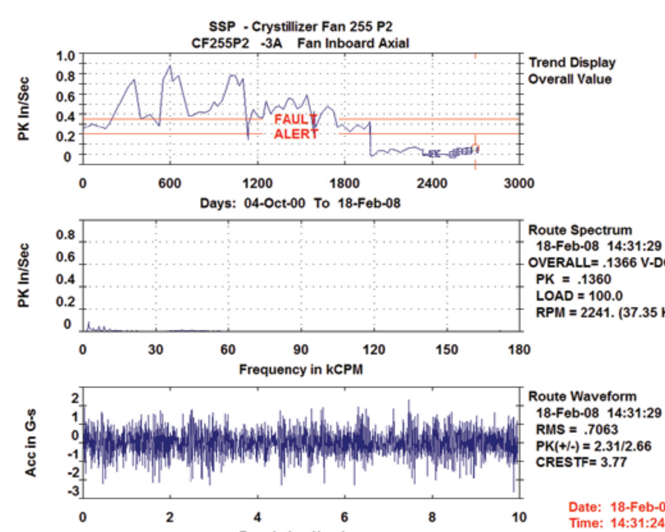
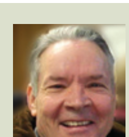


Figure 13

Conclusions

- The installation of the fan on the concrete was probably per the OEM guidelines, but there was not an adequate number of anchor bolts.
- The ODS model was useful to show how the fan base and frame were moving and clearly communicated the problem to management. The ODS also showed that the bearing support plate and pedestal were not flexing.
- The repairs were effective in more securely attaching the fan frame to the concrete pad as evidenced by the dramatic reduction of the vibration amplitude.
- The fan had continued in operation for over two years after repairs with stable vibration levels.

Ken Singleton is Manager of KSC Consulting LLC with over 45 years industrial experience and certified Vibration Analyst Category IV. He retired from Eastman Chemical Company in 1999 as a Senior Engineering Technologist in the Rotating Machinery Technology Group after over 32 years service. www.vibrationconsulting.com



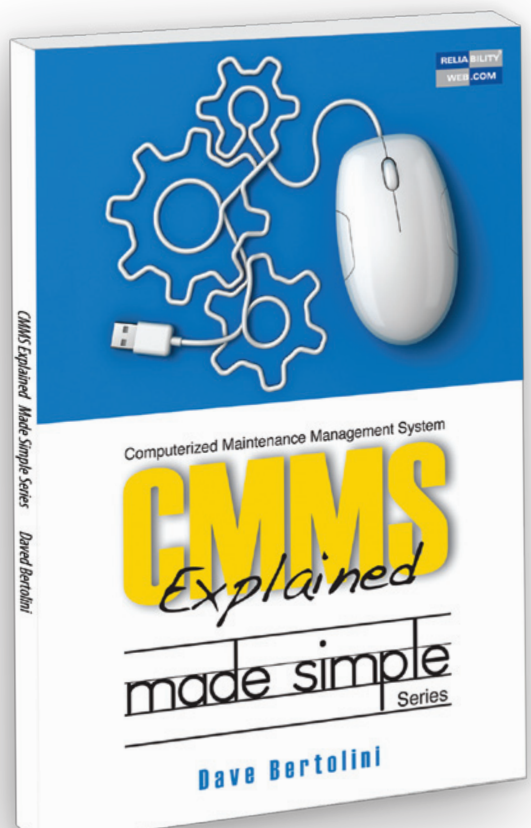
Bob Bracher was the Senior Vibration Analyst at the Wellman Palmetto Plant, Darlington, South Carolina. Bracher has over 41 years of industrial experience and is certified Level III Vibration Analyst. He is currently providing technical support to ATK at the Radford, VA, Army Ammunition Plant. www.ATK.com

CMMS Explained
Made Simple Series

IMC 2012! Conference Speakers

Written by Dave Bertolini • Reviewed by Larry Carver

While working with Dave on our manufacturing reliability initiative (MRI), I learned he was writing a book. Little did I realize he was also figuring out methods to breathe new life into our existing computerized maintenance management system (CMMS).



When I purchased the book and started reading it, I realized all the steps Dave had guided us through regarding our CMMS decisions were all contained in his book. At first, I wondered if we were the test platform or research mechanism for his book.

As I continued reading the book, I realized it contained all the things we as an organization missed when we initially implemented our CMMS. I quickly came to the conclusion that we weren't a test platform for research after all; rather we were not informed of the critical items that had to be defined, documented and implemented when we initially established our system.

CMMS Explained is an easy-to-read book that quickly gets to the point, gives workable examples, and is written from the maintenance perspective rather than the software perspective. Taking one of the quotes from the book, "after all, it is a "Maintenance Management" system and should contain maintenance."

For those that are in the process of implementing a system, I encourage you to read and follow the CMMS Implementation Sequence of Events; it works. For those that are unsure of what these systems are all about, the "Dissecting a Typical System" section does a great job explaining each area of a system and the minimum requirements to gain maximum potential.

Our organization is in the final stages of identifying and implementing a new system. Multiple copies of this book were purchased for the "team" to ensure all were informed and the system gets implemented with maintenance in mind. I only wish this kind of information was available years ago when we initially implemented our CMMS System.

This is a must-read for anyone that plans on implementing a CMMS, currently has one now and wants to maximize the system's potential, or wants to help educate others on what this maintenance tool can provide. Thanks for sharing the knowledge, Dave.

Reviewer: *Larry Carver began his career with Occidental Chemical Corporation, White Springs Phosphate Mining Operations in 1974. He's been employed at this facility for 37 years. His vast mechanical maintenance experiences include all assets of both chemical and mining facilities. Larry is currently the Manufacturing Reliability Facilitator for Potash Corp White Springs to drive and educate the initiative across the site.*

Author: *Dave Bertolini is a Managing Principal with People and Processes, Inc. He has over 30 years experience in improvement initiatives. He is recognized as an industry expert in the implementation and utilization of Computerized Maintenance Management Systems (CMMS). www.peopleandprocesses.com*

Q&A

Uptime Magazine **recently caught up with** ***Leo Pike*****, Administrator for Predictive Maintenance, Norampac-Mississauga. Leo has spent the last two years transforming maintenance at Norampac-Mississauga. Norampac is located near the Toronto International Airport in the city of Mississauga. This mill produces 160,000 metric tons of linerboard from 100% recycled fibers. Leo was charged with implementing ultrasound condition-based monitoring as a legacy project that could be transparently rolled out to other mills. To date, Pike has successfully implemented ultrasound-based trending and infrared thermography inspections on more than 90% of the plant's critical assets.**

***Q** Leo, you recently attended CBM 2012 as a guest speaker and created quite a ripple among attendees. Your presentation, "My Journey with Ultrasound," was inspiring and thought provoking. Can you talk about the products your company produces?*

A Mississauga mill produces linerboard paper from 100% recycled fibers. We produce several grades and they vary from 127 grams to 337 grams per square meter. We also produce a grease-resistant paper that is used for pizza boxes, etc., as well as a product for food and deli containers. There is also a paper produced here for the gypsum board industry. Colors of our products include different shades of brown, as well as white. In my opinion, this is a very universal mill because we can run a product per request to weight according to customer demand.

***Q** There is a lot of emphasis out there for establishing a world-class condition-based maintenance program. What was the driving force for Norampac to get this program off the ground?*

A With the emphasis on establishing a world-class condition-based maintenance program, several factors inspired Norampac to take on this endeavor. One, in particular, that affects Norampac-Mississauga is the opening of a new green pack paper mill in the near future, which will be in direct competition with our product lines.

In addition, the struggling paper industry impacted by new products and high energy costs and raw materials were other factors. Prices escalating have set the stage for an efficient maintenance process. The traditional maintenance programs that replaced equipment on timelines proved to be expensive and often ineffective. In many cases, equipment being changed out were still in excellent condition and did not require replacement. Knowing, understanding and monitoring our equipment has created a maintenance environment that is cost effective and reduces maintenance labor requirements, parts, cost, etc.

***Q** For many people, a journey like yours never moves forward. Can you help our readers take the first step to success by sharing what your first priorities were?*

A My first priority for this journey to be successful was for me to take ownership, be responsible and consider any room for failure not acceptable. The following step was for me to obtain training and knowledge in all fields of predictive maintenance tools that were at my disposal. The next step, and maybe the most important one, I think, was to get myself introduced to each and every piece of equipment and the process perimeters in which it operates. This also would be a definite asset since, coming from a mechanical and electrical trade background, it gave me an advantage for achieving my goals.

***Q** How important was the support of upper management and, ultimately, corporate level sponsorship of your initiatives?*

A The support and understanding from management at the corporate local level cannot be underestimated because without it, the process will fail. Management must clearly set the stage for the initiative and be an active member in the process. In all successful industries, strong leadership creates an environment for evolving and progressive workplaces, allowing these programs to flourish.

Q ***What would you say is the most important thing you did to ensure continued management and corporate support of your efforts?***

A Provide real-time results, proven reliability, lower maintenance costs, decreases in stores inventory, better defined planning and scheduling, and increases in production availability. Quick return on investment from the overall cost of the predictive tools assured continued support.

Q ***Tell us about some of the biggest wins uncovered by your CBM program?***

A Some of the biggest wins uncovered by our CBM program would be:

- Our steam consumption cost reduction;
- Better reliability on over greasing;
- Overall reduced maintenance costs;
- Witnessed a decreased breakdown or urgent work orders.

So to sum it up, the biggest success in my opinion would be that predictive maintenance provided us with the ability to conduct repairs in an organized environment, resulting in equipment life utilized to its maximum potential. As a result, maintenance costs, such as contract labor, parts, etc., were drastically reduced.

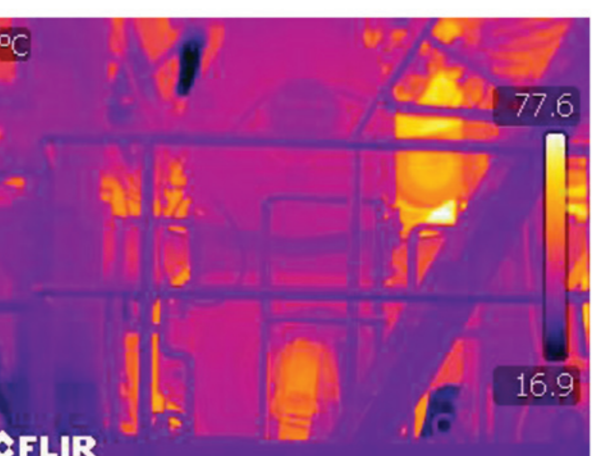
Q ***What condition monitoring technologies do you use at Norampac? Are some more useful than others?***

The results of the first steam trap survey showed that of the 164 steam traps surveyed, 24.2% were either failed closed/failed open or by-passing. The lost revenue was $275,000.

A This is where when you venture into predictive maintenance, to have the ability to make decisions as to how you will measure equipment, you appreciate all the technology at your fingertips. This is where we have the overall advantage. We use all the CMTs: ultrasound, infrared, vibration, motor current analysis and oil analysis.

For which ones are used more fully than others, well we are now two years after conducting surveys and implementing best practices for which tool will give us the best return on value. With regards to knowledge, we now grasp that using these technologies has given us a greater understanding that over-monitoring can easily be applied also, so be cautious. For the best practice, I have found from using these technologies that one might say that a degree of common sense has to be the provider. Let me explain. Early prediction as possible has to be the key to great success in keeping equipment from failing. Ultrasound, in my opinion, would be the first defense in predictive maintenance, and all other tools would be complementary. This strategy has been my greatest ally, while keeping in mind that one cannot or should not exist without the other. I am not being bias, but if the only predictive tool you are using, whether being one or the other, it can and has been proven to be a definite asset to any predictive department.

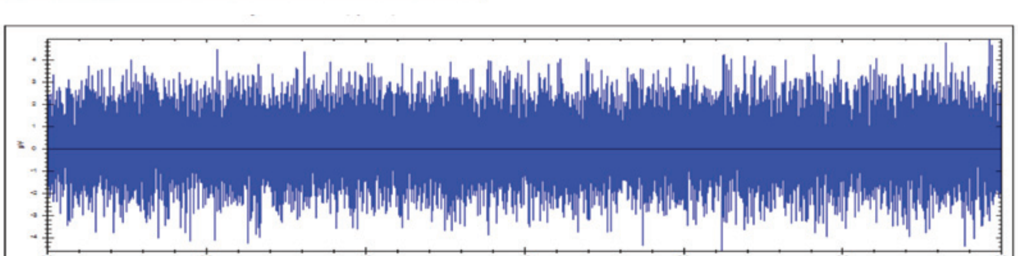
I have learned from years and years of firefighting on the floor; I know what it is like on a hot summer day at four in the afternoon on a Friday when you have a major breakdown and you have to do a changeout, whether it was a motor, bearing, fan, or any other piece of machinery. Then on Monday morning, you're told that this could have been avoided if you were conducting predictive measures and yes, only if we had the tools and the knowledge to do so. This is where I consider myself fortunate that I was introduced to predictive maintenance best practices and given the opportunity to excel.

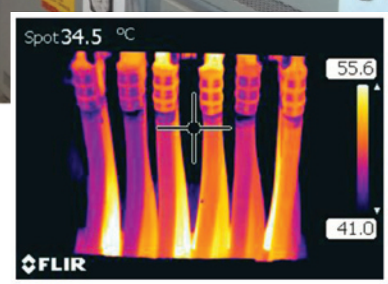


Norampac-Mississauga's 10 million dollar press is monitored by ultrasound analysis, vibration, infrared and oil analysis.

Q ***It seems like you have gotten a ton of mileage out of ultrasound technology. Talk to us about that.***

A Yes, to me, making this statement has to be one of the best learning curves that I encountered. I was introduced to SDT ultrasound, educated by one of the most distinguished, in my opinion, ultrasound and vibration educators, knowing now what I have learned over the last couple of years, I am fortunate to speak about the miles I walked. This educator is Tom Murphy from SDT Ultrasound Solutions, and he first told me that an ultrasound inspector has to create his database, create his routes and survey his equipment. Well, I did just that. I went through the entire mill here and looked at every piece of equipment. Surveyed steam traps, did air loss surveys, monitored bearing and motor deficiencies, and also used the ultrasound to scan electrical rooms before I conducted any infrared scans. I spent two years coming and going, getting data, predicting failures, troubleshooting, and pushing the technology and its database to its limits. Then there is the one thing that Tom told me that I am only now starting to apply.





Safety as a justifier. Electrician using the SDT270 Ultrasound Detector before starting the annual infrared electrical scan.

He said, "When you understand the technology and you adapt to its capabilities, share it!"

To date, we have introduced the technology to all 18 mechanical technicians, to all the electrical personnel and instrumentation users. The ultrasound technology is currently being widely used throughout the mill. Not only one unit, but several units.

***Q** How important has training and certification been to your success?*

A To me, it has been a positive return. But this can be controversial to some since it's one's self achievements that only can be measured from training and certification. I have exceeded in this journey from education, training and learning from the knowledge of others. There is an old saying and where it came from I'm not sure, but it asks, "How can you ask someone to perform a task if first you don't understand how to do it yourself?" Education has always been a positive endeavor for me.

Before revising the grease schedules for the roller bearings, the temperature was 123 deg C. After ultrasound inspection, it was 39 deg C.

All new bearing installations will have a baseline created under the UAS software as a first defense detection against early stage warning defects.

***Q** You told us about vendor certification training, but you also mentioned implementation training from the same vendor. Which would you say provided the biggest value and impact for your team?*

A The biggest value and impact for us was to have a vendor like SDT Ultrasound Solutions to not only sell us a piece of equipment, but to have their continued support as an industry leader. Their knowledge and expertise in this field gave us confidence to venture on in our journey because we knew we were not alone. We were fish out of water and their profound training and support was what contributed to our success. This has to be, as far as I'm concerned, at the front of the table when trying to decide which vendor will be introduced to any facility. Long-term engagement definitely has to be the utmost concern. When things go wrong, and they will I'm sure, having a vendor that will build a relationship not only for sales, but for technology growth, has to be the front-runner for any predictive maintenance success. Vendor implementation will provide a shorter timeframe for achieving your goals. They are subjected to all industries and have the knowledge and feedback that people are searching for.

***Q** Nothing ever goes 100% as planned. Share with us some of the trials and mistakes made along the way.*

A One would think that when we have everything in place, when we balance predictive and preventive maintenance, we would never have another failure. Wrong! There were times when we detected bearing faults, motor deficiencies, etc., and scheduled a planned shutdown to correct these measures, but then we had a premature failure. This is where we learn from our root cause analysis; there are so many variables in the mechanical and electrical components associated with industry that one could only expect to predict early enough to act accordingly to address it before failure. I think one of the greatest assets that would be beneficial to everyone would be to evaluate the effects of improper installation or maintenance. Applying the strongest proactive measures can decrease the amount of time needed for applying predictive measures.

***Q** It would seem you have everything in place at your Norampac mill for continued success. Where will you go from here?*

A We will look at how to balance CBM and our PM inspections in order for us to have a more effective maintenance strategy. We are going to introduce more employee training on the PDM tools, and embrace to our advantage the benefits from this education and training. Education is an equal opportunity for everyone. Learning from each other and evaluating our wins and losses builds for a better team.