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Editorial

When you think of high performance teams, like our special forces responsible for taking out terrorists like Osama bin Laden, or the teams participating in the NCAA basketball tournament, or the volunteers who show up to clean up after disasters like the recent tornados that affected so many communities, what is it about these teams that makes them so effective? Of course, any high performance team has some specialized knowledge, but when you get a chance to hear members of these teams speak, you get a real sense of the thing they all have in common is a culture that accepts nothing less than high performance. These teams accept nothing less than high performance regardless of the resources that are provided, special unexpected situations they face, unforeseen losses and other negative circumstances.

When you think of your maintenance reliability team, are you reminded of high performance teams like these? Is your team prepared to create stellar results even with a lack of resources and unexpected barriers and challenges? So much of the conversation about achieving high performance maintenance reliability typically centers around the right strategies, techniques, tools and training. Often overlooked are effective plans that account for human behaviors, human attitudes, human engagement and human leadership. I have had the good fortune to come to know of many under-resourced maintenance reliability programs that were able to begin the journey to high performance with nothing more than cleaning supplies and paint. These special programs were led by people of extraordinary vision and passion, and all eventually earned additional resources to support high performance maintenance reliability by proving themselves worthy and effectively communicating that worth to company leadership.

This issue of *Uptime* features what we consider groundbreaking work by Brad Peterson in the area of creating a performance culture. We are very interested in your reaction and comments to this article and would like to begin a conversation with the community to expand awareness of this important aspect. To share your ideas, please email us at crm@reliabilityweb.com or post your comments online at the article's web page at reliabilityweb.com.

The other *Uptime* authors in this issue have contributed many other unique ideas, suggestions and tips that you will not find anywhere but on the pages of *Uptime* magazine. We asked our authors to pay special attention to providing information that you can use immediately, together with ideas to improve your long-range performance. They have delivered that and more. If you recognize your maintenance reliability program as you read this issue of *Uptime*, or if you have a story that you think you could contribute to the maintenance reliability professional community, you are invited to request your own copy of *Uptime* magazine article guidelines by sending an email to *Uptime* Editor Jenny Brunson at jenny@reliabilityweb.com. In many professions, such as nursing for example, the learning cycle includes learning as the first step, doing and demonstrating competence as the second step and then teaching and passing on that knowledge as the third and final step to verifying effective knowledge capture. Use vehicles like *Uptime* magazine or events like The International Maintenance Conference (IMC) for your third and final step of demonstrating effective knowledge capture. We know from experience that our readers and attendees appreciate and value these efforts. Thank you for being an *Uptime* magazine subscriber and reader.

Warmest regards,

Terrence O'Hanlon, CMRP
CEO/Publisher
Uptime® Magazine
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Data, What Data?

Many organizations today spend an enormous amount of time and money purchasing and implementing a Computerized Maintenance Management System (CMMS) or an Enterprise Asset Management (EAM) system. Many are unsure of the difference between them; one is typically associated with maintenance, while the latter is viewed as an all-inclusive system for the entire organization. Regardless of how much you spend, the key to successfully implementing these systems is data. Not necessarily the amount of data, but the quality of the data.

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Consistent Foundational Data Should Begin from Day One

If the foundation isn't built with the proper level of detail, the system will not be able to deliver on its designed value. During implementation, it might be tempting to skip building data because it is a time-consuming and costly endeavor, but taking the time to enter quality data will result in a valuable and sustainable system. Get the most out of your CMMS by building in the details and starting with a solid foundation. Making the investment to do this up front will ultimately save the organization time and money. Examples of foundational data include:

- Master Equipment List
- Specification templates with fully developed specification data
- Bills of Material
- PM Procedures
- Materials records with detailed specification data and descriptions.

It is a good idea to formally document master data and transactional data requirements, and ensure these requirements support the organization's performance measurement metrics. Publicly available standards, such as ISO 14224, provide a good starting point for the development of internal standards.

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Creating the
Performance Culture

Uptime is named after the single most important topic in process manufacturing. Uptime is a result of doing all the right things. Even safety is a byproduct of doing all the things necessary to get uptime.

Brad Peterson

We at SAMI, and others in our field, routinely write and speak about the methods and success stories that have resulted in substantial improvements. These are inspiring stories and give us insights as to which tactics to use, how to deploy them and the kinds of gains we can achieve.

The truth that most of us prefer to hide is that most of these successes *were not sustained over time*. So many of the improvements we make create *anecdotal stories.* One-time events. Sometimes we get bottom-line changes mentioned in our stories (additional production or reduced costs), but mostly we talk about a unit or a line and the changes in availability or another key performance indicator (KPI).

Permanently affecting the bottom line of the company is a far more daunting task than improving the availability of a machine, or improving a KPI. In benchmarking studies, the relative position of the measured plants seldom changes in the long term, looking at a 10-year time horizon. For instance, most refineries are benchmarked by Solomon Associates. The relative position and strengths/weaknesses of these refineries very seldom change.

Why is that? Why is real, measurable, bottom-line change so difficult to get?

It comes down to culture. Cultures resist change like crazy. That's one reason why Toyota and Honda remain so good at what they do. They are so conscious about creating the right culture that they spent years at it before a product ever came off the line. Each new person who joins the company learns expectations, methods and teamwork. You can change out the entire workforce over a period of time, but the values and expectations remain embedded.

This is also true for the low performers. They transmit values and expectations as well as the best companies.

Culture Determines Results

My point in presenting this article is that ***culture determines results***. You can have all the best practices in the world. You can measure 100 KPIs. You can have 15 #1 priority initiatives in a company (and most

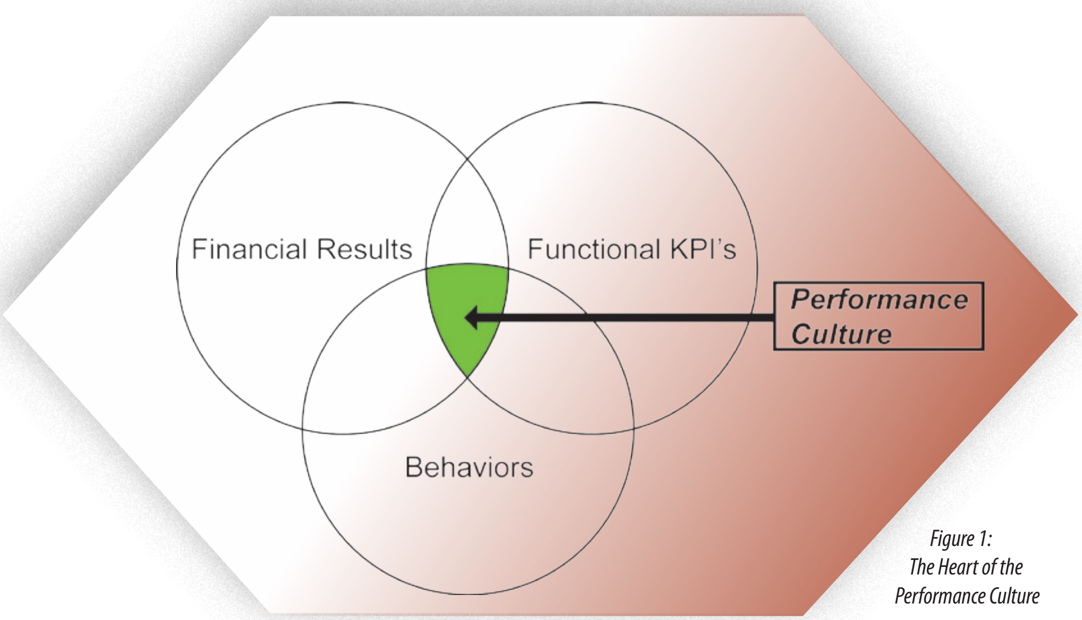


Figure 1: The Heart of the Performance Culture

do). These things are all meant to drive changes in the behaviors of people on the plant floor and the supervision who manage them.

Let's say that again: *All the improvement work we do is trying to change the behaviors of the people in the plant.*

This may be the most important sentence in this article. If you don't understand or agree, I'll give an example or two.

The topic of safety has been prominent in industry for about 25 years. We have seen waves of attempts to improve safety results. At first, we measured incidents. Things got a little better. Then we tried training and awareness, and little jingles that people should remember when they are working. Didn't see much change. We finally saw a breakthrough when behavior-based safety (BBS) became the standard. We gained an understanding that what people habitually do gets predictable results. We began measuring not only lost time incidents (things after the fact), but the behaviors that create the incidents (near-misses). By focusing on safe and unsafe behaviors, our results in safety have improved dramatically.

Behaviors as the core of results are not a new realization:

"We are what we repeatedly do. Excellence then, is not an act, but a habit."

- Aristotle 384 BC – 322 BC

It comes down to this:

1. A culture is the sum of all the behaviors in a group.

2. A culture determines the outcomes in every business.

3. To change the culture, you need to change the behaviors of all the people involved.

We have observed recently that the largest and most sophisticated companies (industrial companies who lead their industries) are observing this:

- All the KPIs are reported as GREEN (everything is working great).
- Results are flat or declining.

If we make sure we have no identified gaps, we cannot change. GAPS are our friends for improvement. Why do we game the KPIs? Try to make them look great? Because they are tied to our compensation! We are smart guys—we know how to make the KPIs look *really* good. (Figure 1)

Articles written in journals like *Uptime* focus on measuring KPIs. We are measuring KPIs because we want to improve our results and comply with company policy and standards.

Executives are measured on results. Results are the *consequence* of what we do.

What's missing is measuring *behaviors*. Change the behaviors sustainably and you get a different *culture* and different results. The ***Performance Culture*** measures all three. (Figure 2)

Behaviors and practices determine uptime and overall production reliability, the holy grail of manufacturing.

With these things in mind, just what is a ***Performance Culture***? How do we know we have one?

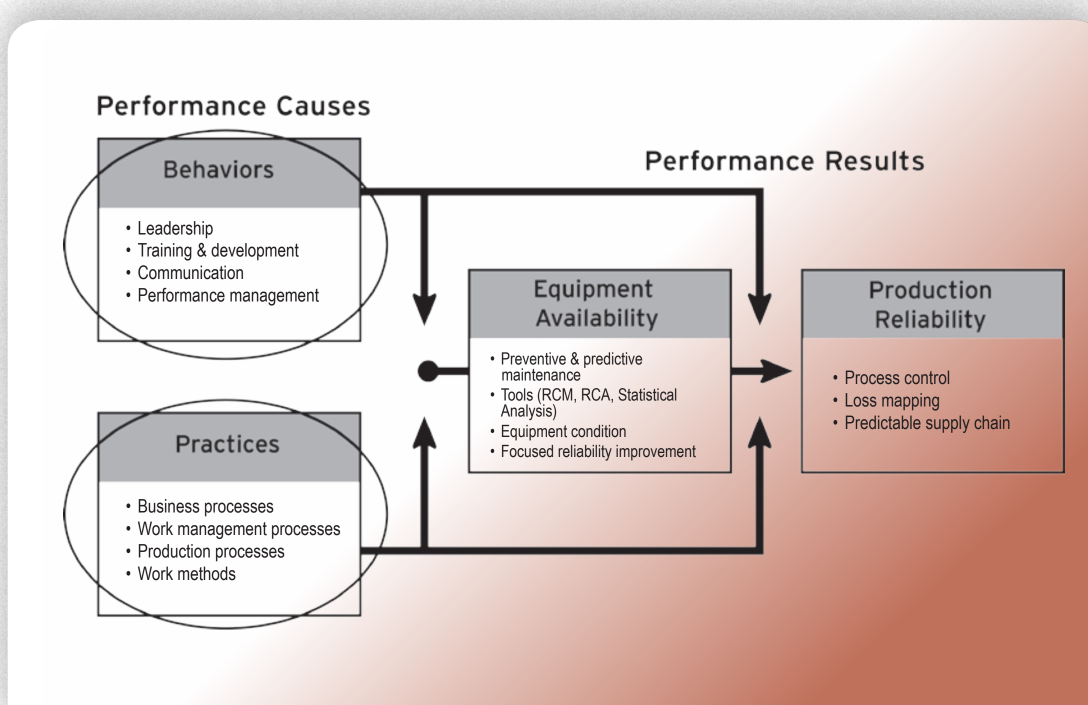
We measure four broad areas. We call them the "**4 P's of the *Performance Culture***": (Figure 3)

1. Performance
2. People
3. Purpose
4. Predictability

1. Performance.

- First and foremost, Performance Culture companies make their numbers. They set realistic targets and achieve the production, safety, expense, revenue, ROI, inventory and pricing targets they set.
- Next, they satisfy their customers. In many cases, they delight their customers, going beyond the agreements.
- Third, you can see that their results trend in the right direction, getting better and better when measured over time. Continuous improvement is part of the fabric of companies like Toyota and Honda.

Figure 2: Performance Culture Drivers



2. **People.**
   - In a *Performance Culture*, managers realize their most important resource is their people. Their selection process assures a fit in values, as well as capability. They develop their staff by formal training, increased responsibilities, coaching to improve, or formal evaluations. And sometimes they have the luxury to learn by failing.
   - One of the things we notice immediately on entering a plant where there's a *Performance Culture* is the type of energy expended by the staff there. Everyone is busy, but it's not a frantic, out-of-control busy. There's intensity, a quiet purpose. When people talk, it's mostly business-related, problem-solving and coordination. I have heard that Google is like this; everyone is intent on keeping Google at the top.
   - A great aspect of working in a performance culture is that people trust each other. Trust has two major pieces: First, am I willing to make everyone successful, do I tell the truth, do I have integrity? Second, am I capable and competent at the tasks to which I have committed? There is so little wasted effort when people meet these conditions of trust.

3. **Purpose.**

In his book *Built to Last*[1], Jim Collins says every successful company has a higher spiritual purpose. A purpose that creates value for society, not just makes money for the shareholders. The fulfilled purpose creates value for their markets and good financial results are an outcome of doing well.

   - A great company focuses on its values. In such an organization, there is no doubt as to what those values are because they form the basis for every decision made. For instance, our highest and clearest value is integrity. In dealing with our clients, ourselves, our contractors, our markets and regulators, there is integrity in all we do and it helps us create the trust we need to be effective. Sometimes it means we don't get business because another firm may promise things they can't deliver. In our case, it means we get a lot of repeat business.
   - A major portion of purpose is knowing the target. What do we want to achieve? What's the "end in mind?" People who know the outcomes they are collectively working to achieve need little supervision. Everything they do is aligned to the company direction, to the extent that the vision and goals have been embedded.
   - Jim Collins's *Good to Great*[2] is a touchstone for me. I keep going back to try to understand what's important. His descriptions of Level 5 and Level 4 leaders set the tone for excellence: Level 5s are humble and know they are part of a vast system of people doing their best for the company. Level 4s are charismatic leaders—when they leave, the company has no North Star to guide them. Everyplace we go we see silos, usually by functional area. The very lack of teamwork and common business processes creates serious issues with results. The issues with results create the need for finding a scapegoat. And everyone is right! Maintenance can't perform because of production not giving them the equipment to maintain. Production can't perform because maintenance doesn't keep the equipment running. Only teamwork can get us out of the catch-22.

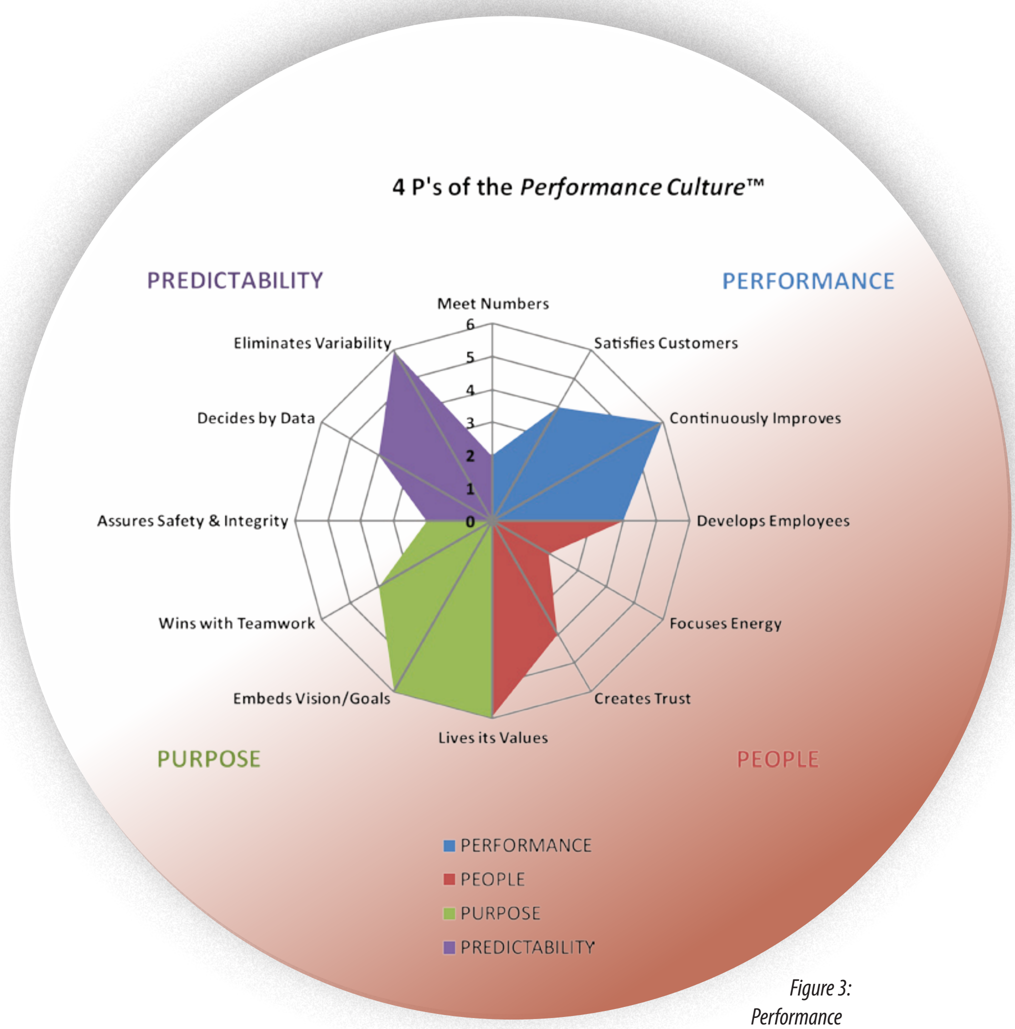


Figure 3: Performance Culture Spider Chart: Sample Data

4. **Predictability.**
   - The *Performance Culture* is all about *predictability*. The point is to be consistent in our results, in our approach to our people, in our values and in our purpose. Making a record one day at the cost of performance the next is not what greatness is about. Greatness is about doing the right things consistently and improving on what we do all the time. It's about understanding what our customers want and need, and exceeding expectations. Consistently, predictably.
   - Safety and integrity are core principles to running any operation. In the past 10 years, behavioral-based safety has made great strides in becoming part of most cultures. At the same time, we see reactive cultures trying to emphasize safety. Based on our observations, we conclude that it's an oxymoron to have a safe work environment that's reactive. Reactive environments by definition aren't in control of the equipment, nor are they able to provide proper equipment care, planning and scheduling of work. Inevitably, this puts pressure on the individual operator or technician to keep an operation running without the proper study, parts, equipment, reaction to alarms, etc. Predictability for safety goes hand-in-hand with predictability of production.
   - Having the right data, knowing what to do with it and operating from data-based decisions will deliver predictability faster than any method. This is a disciplined operation by definition, as it requires analysis of what's important to start with, then having the discipline to enter data that may not seem immediately relevant to the provider. Making the time to analyze data, mix in the proper experience and come to a consen-

sus on action plans will eliminate a lot of false starts. Doing things once, doing them right and eliminating root cause will help assure every other part of the *Performance Culture*.

- Variability in manufacturing operations is a fact of life. It takes many forms, including customer demand, operating speeds, process and equipment parameters, materials and finished product. Variability in any form produces waste, and as variability increases, performance is adversely affected. It affects the operation in one or more of the following ways:
  - ◊ Lost throughput
  - ◊ Wasted capacity
  - ◊ Inflated cycle time
  - ◊ Larger inventory levels
  - ◊ Long lead times and/or poor customer service.

CASE STUDY

We worked with the oil and gas production operations of a European-based oil major to achieve three goals:

1. Improve production output;
2. Reduce costs;
3. Improve asset integrity within the existing operating budget, as opposed to special studies and interventions.

The vehicle was through improved maintenance and controls within their managing system. When we began our work, their *Performance Culture* analysis summary showed the measurements shown in Figure 4.

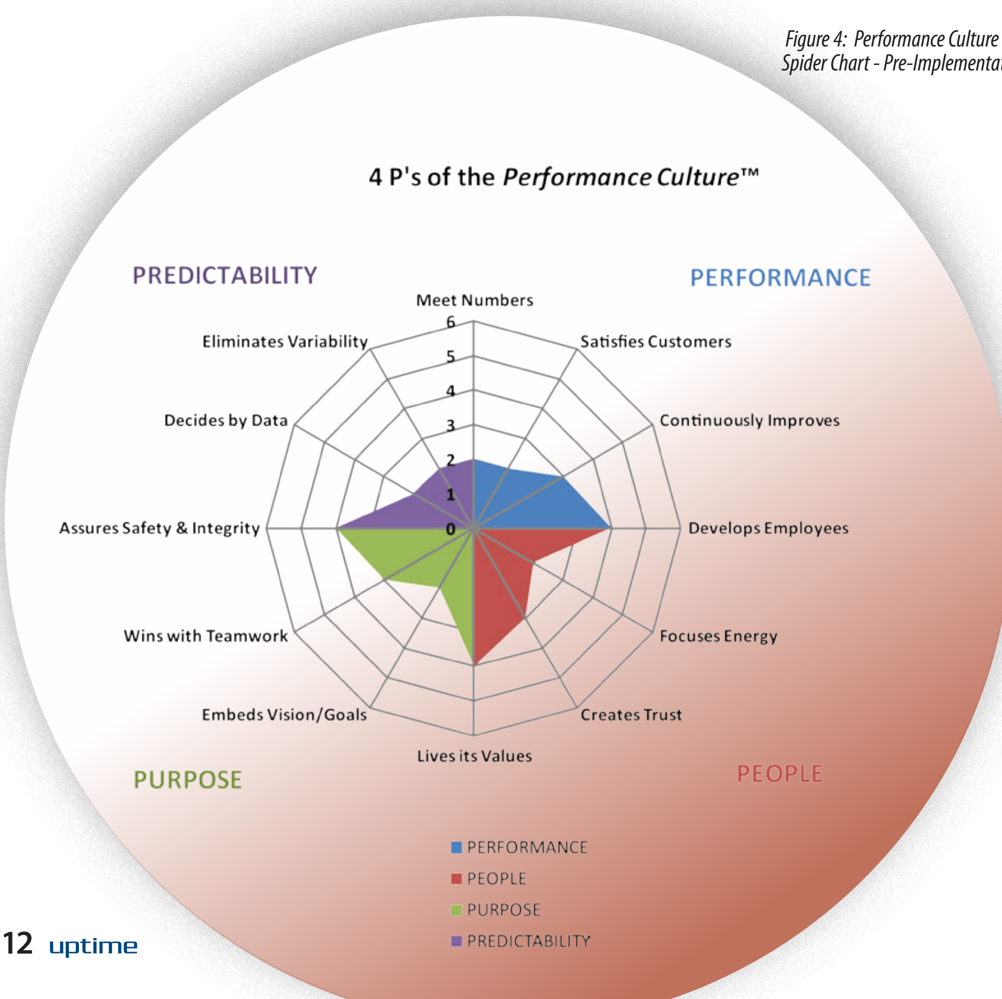
There was no understanding of the value of implementing these practices and disciplines. Was SAP PM implementation an exercise of some administrative mandate, or was this a business imperative, leaving hundreds of millions of dollars on the table?

The company was regarded as a first quartile operator in its industry—demonstrating how low the bar is for this industry when you see the huge opportunity for improvement demonstrated by this "spider-diagram."

The issues demonstrated in the 12 elements of the *Performance Culture* were:

1. Meets Its Numbers - Despite being a top quartile performer in the categories of production loss and operating expense, both of these highly important metrics were trending in the wrong direction.

Figure 4: Performance Culture Spider Chart - Pre-Implementation



2. Satisfies Customers - Increasing unplanned production losses were causing occasionally missed customer nominations at export points.
3. Continuously Improves – The organization had ongoing improvement initiatives, but these projects required a substantial "push" effort from the staff to engage the field. There were far too many to attend to and most showed no progress at all.
4. Develops Employees – Individual and position developmental plans existed along with significant training resources. Although these were in place, there was a high level of under-utilization of training and personal development resources.
5. Focuses Energy – The organization was data and information rich. However, there was insufficient focus on the critical few parameters that were driving production and expense.
6. Creates Trust – A low level of trust existed between the field staff and office staff. This was primarily the result of multiple "high" priority initiatives that would start/stop, were chronically under resourced and usually had little follow through and no accountability.
7. Lives Its Values – The organizational values were clearly communicated and largely exhibited with occasional exceptions.
8. Embeds Vision and Goals – Goals and objectives were communicated in the organization from the top down. However, goals were not uniformly cascaded down into the organization. This created misalignment on the asset and regional levels with top-level goals.
9. Wins with Teamwork – Although subtle, the organization was "siloed" in several ways. Territorial divisions existed between functional organizations (i.e., operations, maintenance, logistics, procurement, etc.), as well as the field versus the office staff. Some teamwork was exhibited at the asset level within functional organizations.
10. Assures Safety and Integrity – There was a high focus on safety, health and environmental issues. Safety-critical work always received the highest priority and safety performance was high.

11. Decides by Data – As mentioned previously, the organization was data rich and monitored many parameters. It was not effectively using the data and reporting system as management tools to guide the decision-making process. The result was a lot of cost to measure and little application of the information.
12. Eliminates Variability – Due to increasing unplanned outages, production and expense budgets were being missed. With the lack of data-driven decisions, waste was being introduced by emotional and "gut feeling" actions to address issues. The variability trends were consistently in the wrong direction.

What We Did:

The presenting problem was their failure to implement SAP PM, in spite of several attempts. The underlying cause was identified as "optionality." The culture of oil and gas exploration was entrepreneurial and lacked discipline. Managers felt they had the "option" of following best practices.

Perhaps a better cause of optionality would be lack of clear leadership. There was no understanding of the value of implementing these practices and disciplines.

Was SAP PM implementation an exercise of some administrative mandate, or was this a business imperative, leaving hundreds of millions of dollars on the table? The magnitude of the opportunity was never quantified, the implementation plan had little field input and there was no plan to coach for sustained performance of excellent practices. Without these methods in place, the implementation was doomed, as indeed it is throughout the SAP implementation universe.

We began with a strategic plan for operations. Everyone has a strategic plan for the business, but improving operations seems to be a series of overlapping initiatives, all well-meaning, yet overwhelming in their resource demands, leading to frustration and very little progress. We worked with a team of people in the organization to clearly delineate:

1. Where they were now;
2. The future state of where they envisioned they wanted to be;
3. The strategies to bridge these gaps, and the projects and sequence to implement the strategies;
4. The overall implementation plan for all 28 properties, which varied dramatically in size and geography;
5. The business case, cost and benefits for the overall plan implementation.

This plan was the vehicle to implement all 12 elements of the *Performance Culture*. It got leadership's attention because the value of the plan was a result of over $1 billion dollars per year in

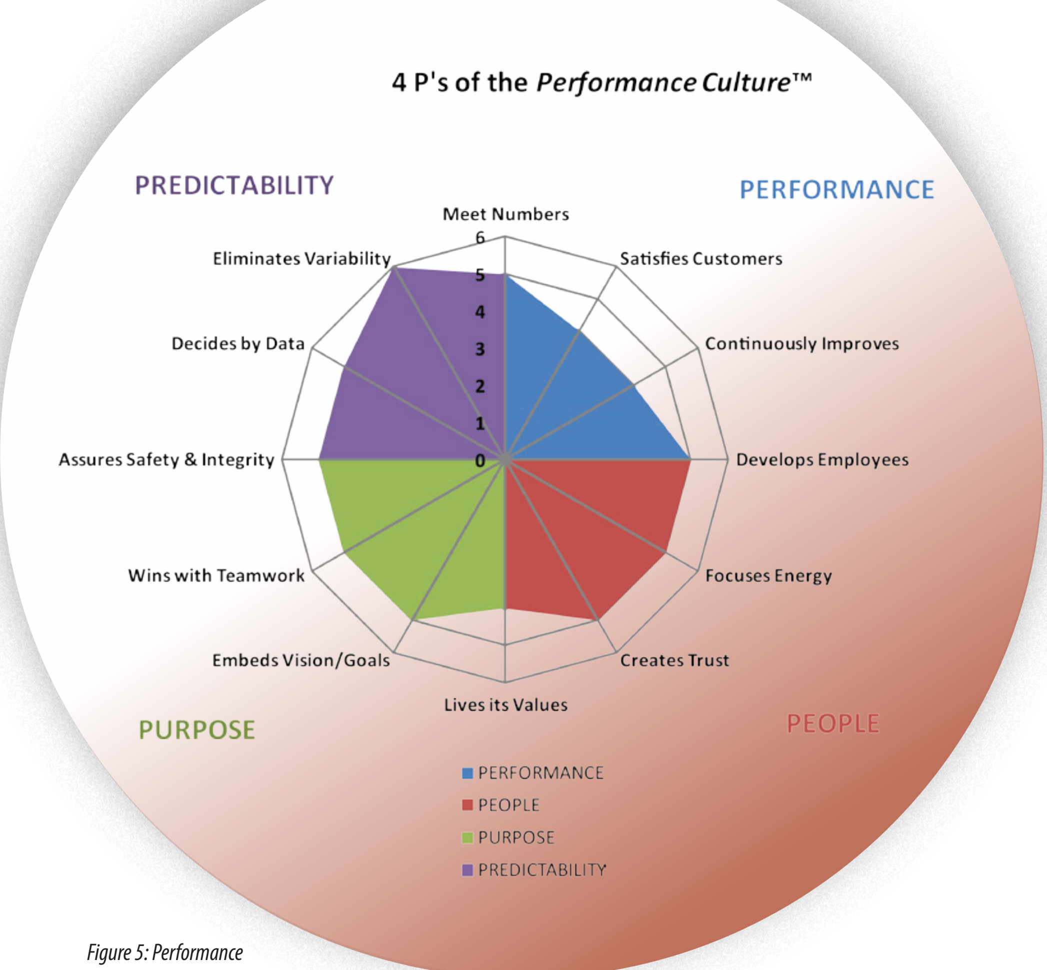


Figure 5: Performance Culture Spider Chart - Post-Implementation

additional cash flow. The future state described how the organization would work, what the work would be, how it would achieve its numbers and what data would drive decision making. The organization structure, the cross-functional teamwork required, the job development and gaps in personnel and skills were all laid out. A result of the implementation would be to measure and reduce variability, including the operators' job descriptions, roles and responsibilities, and planning all work to eliminate most opportunities for safety lapses.

The implementation was laid out to develop more than 100 subject matter experts; this was in no way a "SAMI Project," but fully owned by our client. We put part of our fees at risk and acted as a partner in the implementation and results, not simply as a consultant. We could veto changes in the project plan when we knew they would compromise results. We moved resources around to make sure every property met with maximum success. We had a planned implementation period of two years. However, we finished in 18 months. Everyone knew the change was coming. It wasn't *optional.* And everyone was prepared in advance to get ahead of the curve.

The results were spectacular: Unplanned downtime went from 6% to 1% and planned downtime was reduced by one-third. Platforms that were experiencing a trip a day moved to a trip per month or less. Productivity increased by 50% and safety critical backlog went to nearly zero. Total operating costs were reduced by $25,000,000 annually, or 20%.

Culture determines results. Until you understand and embrace that, your professional life will be like Sisyphus, rolling a rock up a hill, only to have it roll down again and having to start all over.

The resulting measure of the *Performance Culture* is shown in Figure 5.

We did an audit of the business processes in 2011. We found that 85% of what was implemented was still being used many years later.

Conclusion

"We are what we repeatedly do. Excellence then, is not an act, but a habit."

Culture determines results. Until you understand and embrace that, your professional life will be like Sisyphus, rolling a rock up a hill, only to have it roll down again and having to start all over. (In Greek mythology, Sisyphus was a king punished by being compelled to roll an immense boulder up a hill, only to watch it roll back down, and to repeat this throughout eternity.)

Changing results requires changing behaviors for the long haul. A project, a computer system, all the initiatives in the world will not change a culture.

We understand and agree that technical and tactical competence is important, but the sustainability of such approaches is totally dependent upon the behaviors supporting the *Performance Culture*.

Over the course of our professional lives, SAMI has made a study on the *Keys to Sustainability.* If the keys to sustained performance stem from the *culture,* then how do we change the culture?

Our findings are conclusive and in agreement with Jim Collins's in *Built to Last*[1], Stephen R. Covey's in *7 Habits*[3] and Stephen M.R. Covey's in *The Speed of Trust*[4]. Performance is an outcome of doing all the right things, which are embedded in the ***Performance Culture*.** The right things involve having the right elements for:

- Performance (meets numbers, satisfies clients, continuously improves)
- People (develops employees, focuses energy, creates trust)
- Purpose (lives its values, embeds vision and goals, wins with teamwork)
- Predictability (assures safety and integrity, decides by data, eliminates variability).

We know how to measure these items. We know how to correct them and we know how to engage our clients to make these permanent behaviors. The ***Performance Culture*** is not a mystery, but a path towards excellence.

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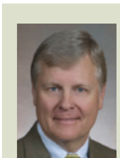


Brad Peterson is the Chief Executive Officer of SAMI. As the founder and principal owner of SAMI, Brad is sought after as a speaker and advisor to companies around the world. Prior to founding SAMI, Brad's experience has included practice leadership in two major management consulting firms. His education includes an undergraduate (Phi Beta Kappa) and Masters degrees in Physics and a Masters degree in Counseling Psychology. www.samicorp.com

Part 2 of a 2 part series

Stress: The Silent Killer

John Lambert

What if…? You were installing a very large motor just back from repair onto a base and let's say the motor weighs one ton and the distance between the front and back feet is 38 inches. If the base frame was twisted by 0.010 inches, would you expect to find this twist using the traditional feeler gauge method, i.e. tightening and loosening the hold down bolts?

Would the foot spring up? This is a twisted base frame not a short or distorted foot. Remember, a motor is a hollow casing with a stator attached to it. The end bearings support the heavy armature suspended in it.

I believe that on large (heavy) motors with lightweight casings, the foot will not spring up when measuring a small amount of twist. If it doesn't spring up, it is natural to assume that nothing is wrong and no other action is taken. I also believe, although motors (machinery) are designed to be mounted on flat surfaces, many of them are clamped down on twisted or uneven bases. (Figure 1)

Figure 1

The question is, Where is the problem? Is it the foot or the base? We use the term soft foot to describe foot problems, but this is incorrect. The word is actually a description of the feeling you get when you are tightening a machine's foot. Although the foot appears to be down, you can still tighten it and pull it down some more. It feels soft or spongy. If you feel this, the foot is distorted and flexing as you tighten it. To find and correct this problem, we can quite easily measure it with a feeler gauge (Figure 2). We have to make sure we measure under each corner of the foot so we can make the proper correction. We can do this as a rough measurement with the bolts loose and then tighten them and redo each foot tightening and loosening.


Figure 2


Figure 3: Base Measurement Case Study: Using Easy-Laser's D525 Laser Shaft Alignment System and D22 Swivelling Laser

My point is you can't find distorted, twisted bases using a feeler gauge under the foot in the old traditional way. I think new large motors are more flexible than in the past. I think they will sag and conform to the base on which they are mounted. Obviously, if it is severe enough, there will be a gap under the foot. But are you measuring all of it? Even a small amount can make a difference.

If the motor casing is distorted because it is bolted to an uneven base, you now have an offset between the bearings. The offset tolerance for shaft alignment on an 1800 RPM motor is 0.002 inches to 0.004 inches, bearing in mind that you do have some flexibility from the coupling in this area. Now think about the offset tolerance between the two bearings in the motor. What should that be? Is the base creating internal misalignment of the bearings and motor shaft? A small amount of twist, say 0.010 inches, can give you a 0.005 inch of offset between the two bearings, which is too much.

This isn't angle or slope, as some say, where we are allowed so many thou per inch. This is offset. One company specification that I have seen says the base mounting pads shall be flat within 0.001 inches (yes, one thou of offset!).

The motor pictured in Figure 1 has a high vibration reading, indicating an electrical fault. The motor was sent out for repair and after reinstallation, including a soft foot check and shaft alignment, the same problem existed. A stress test was performed and the vibration level went down. A decision was made to remove the motor and measure the base.

Before revealing the results, let's first explain how measurements were taken. (Figure 3)

Although the base appears to be two long rails, the motor sits only on the shim packs positioned under the mounting pads on the motor. This means we only have to measure around each of the bolt holes. If we measure at each corner of every bolt hole, we would have about a 5″ x 5″ square area.

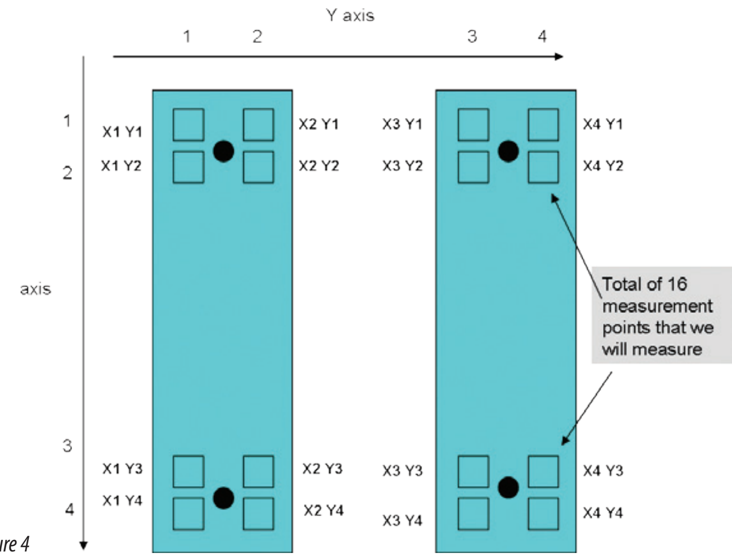


Figure 4

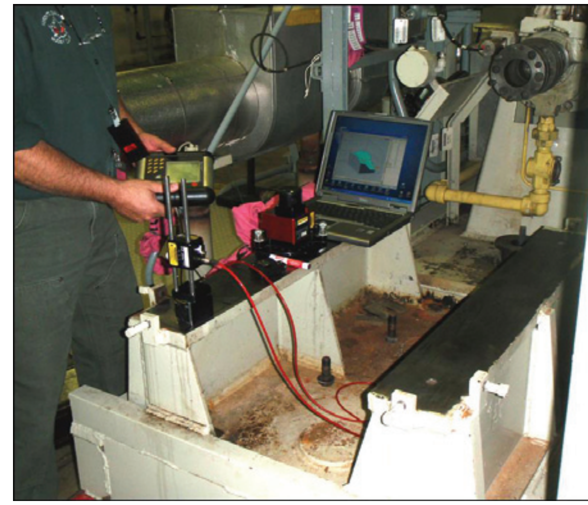


Figure 5

So first we set up a grid. Starting at the top left, the X axis goes down and the Y axis goes across. This makes the top left side X1-Y1 and each square box is where we place the laser detector. (Figure 4)

After the measurements were taken, the information was transferred to the EasyLink software program (Figure 5) and a line graph was produced. (Figure 6)

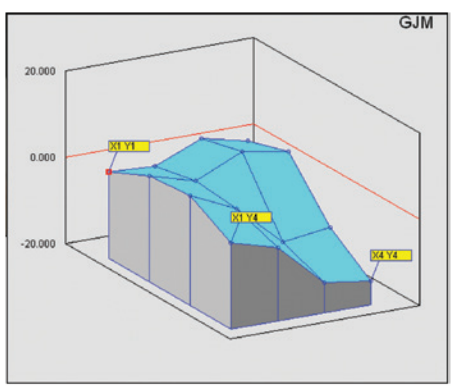


Figure 6

Figure 6 represents the wire diagram the software uses to display a picture of the measurement results. The center is colored, but you can still see the two rails down each side indicating that the #2 foot is high and the #4 foot is low. Figure 7 shows the full report in mils (1.0 mil = 0.001 inch.). The feet are numbered and the reference point where the highest and lowest measurements were taken is highlighted in red.

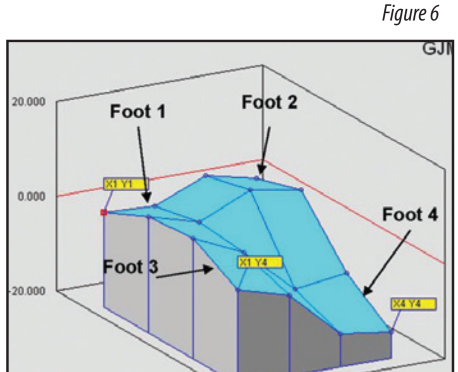


Figure 7

Based on these results, we were able to cut up shim stock and create a shim pack at each foot, thus making the base flat again so the motor now sits on a flat base.

This base issue is not as uncommon as many would think. I shared this information with a friend who is the vibration technician at a local plant. He recently e-mailed and wrote:

"We have recently (and still are) dealing with a very similar issue on a motor/base combination at our plant. In our case, it's a 250 hp (3600 rpm) motor driving a multi-stage boiler feed water pump. The motor was 'emergency' sourced from China when our in-service unit died in early February (severe stator damage). After spending a lot of time with coupling fit issues and alignment, we ended up having to run the motor with 3 feet/base bolts tight, one foot loose - we call it our 'tripod motor.'"

I have not seen this machine base as yet, but my guess is it was fabricated on site during the construction of the plant. I also think it's a large-sized base because a 250 horse power motor would be a good size. Again, my guess is the base was never stress relieved, so over 25 years of operation, it has become distorted and has a twist. The reason I think this is because the new lightweight motor is telling me so.

Measurements for Figure 7	
X1 Y1 Ref 0.0	
X1 Y2 4.5	
X1 Y3 5.5	
X1 Y4 0.0	
X2 Y1 -0.5	Max 6.5
X2 Y2 1.5	Min -14.5
X2 Y3 0.5	
X2 Y4 -3.0	Peak - Peak 21.0
X3 Y1 4.0	Average level -1.2
X3 Y2 6.5	
X3 Y3 -9.0	Standard dev 5.1
X3 Y4 -13.0	Flatness Rms 4.4
X4 Y1 1.5	
X4 Y2 4.5	
X4 Y3 -7.5	
X4 Y4 -14.5	

You might say the fix would be to add shim under the foot, but what if you try this and the vibration level is still high? Or, what if the motor is sitting high and you would actually like to lower it for a better alignment? You also might be adding shim under the wrong foot. The best way is to measure the base and make the correct call based on knowledge. This means you have to measure the base.

John Lambert served his apprenticeship in Mechanical Maintenance in Liverpool, England. After emigrating to Canada in 1973, he worked in the Aero Industry and Fiberglass manufacturing. In 1994, he started his own business, Benchmark Maintenance Services Inc., specializing in rotating machinery installation, training, service and equipment sales. He has conducted training on offshore oil rigs, paper mills, at chemical plants, cement plants and gold mines. www.benchmarkpdm.com management PaM physical asset management

Smartphones & QR Codes Are Changing Physical Asset Management

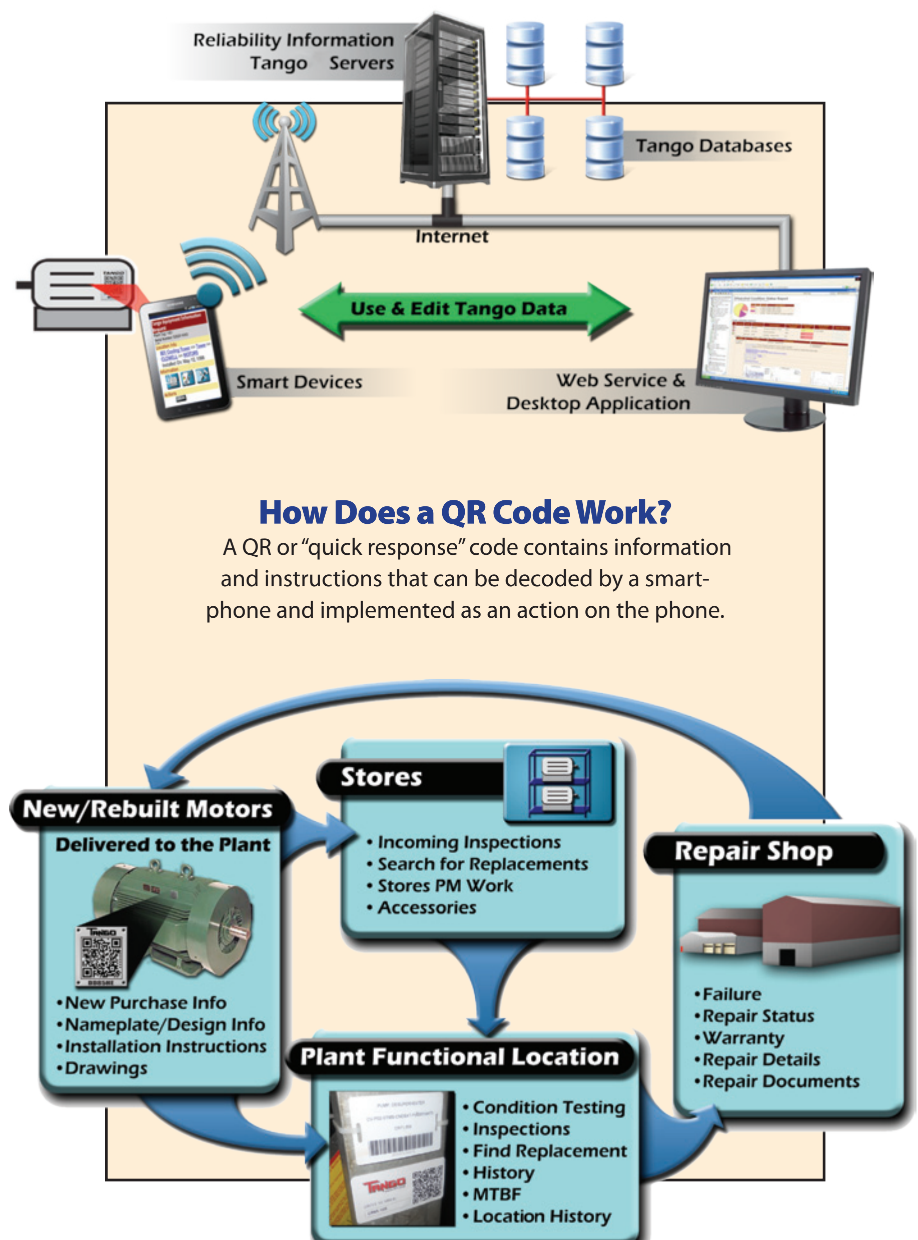
Forrest Pardue and Chris Tyler

Smart devices and QR code technology offer an opportunity to simplify asset management by putting usable information into the hands of more plant employees needing the information.

In general, smart devices allow plant employees to easily check equipment condition, inspections, or the status of repairs and send equipment action requests, like condition entry, request for condition testing and disconnects.

Some Uses for QR Codes and Smart Devices in Reliability Information Management

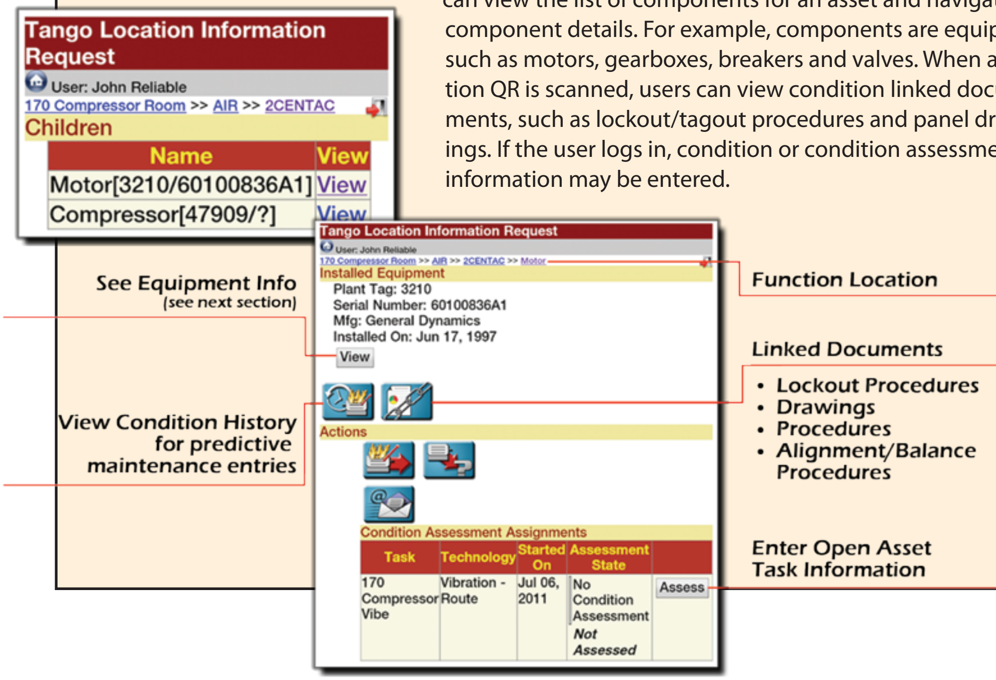
1. Enter immediate problem notification
2. Display installed equipment name plate and design information, such as bearing ID, brush data, breaker settings
3. Display documents like manuals, installation procedures, lube procedures, lockout/tagout
4. Search for replacements in stores
5. Display previous and current condition entries
6. Define an action for selected equipment, such as disconnect, test, clean
7. Display previous repair shop results
8. Send email about equipment/location
9. Update equipment state > install, stores, send to repair
10. Initiate an inspection route



Location QR Tags:

Display and enter asset or component functional location information

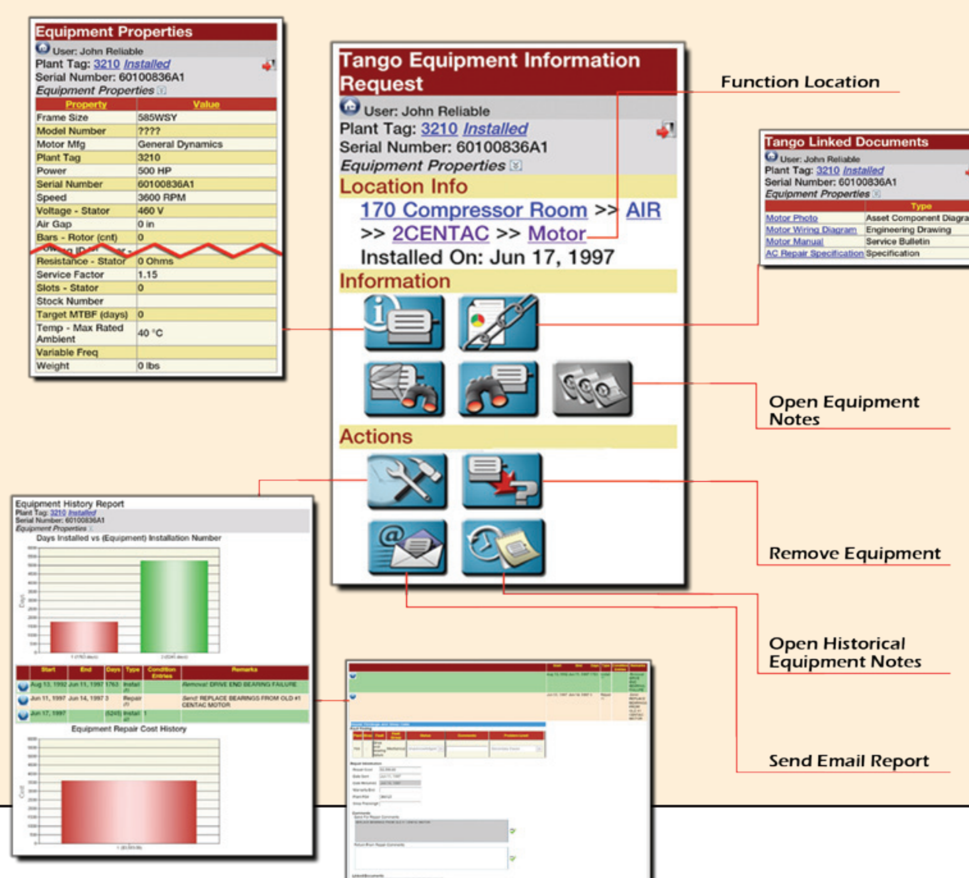
By assigning a QR code to the asset functional location, you can view the list of components for an asset and navigate to component details. For example, components are equipment, such as motors, gearboxes, breakers and valves. When a location QR is scanned, users can view condition linked documents, such as lockout/tagout procedures and panel drawings. If the user logs in, condition or condition assessment information may be entered.

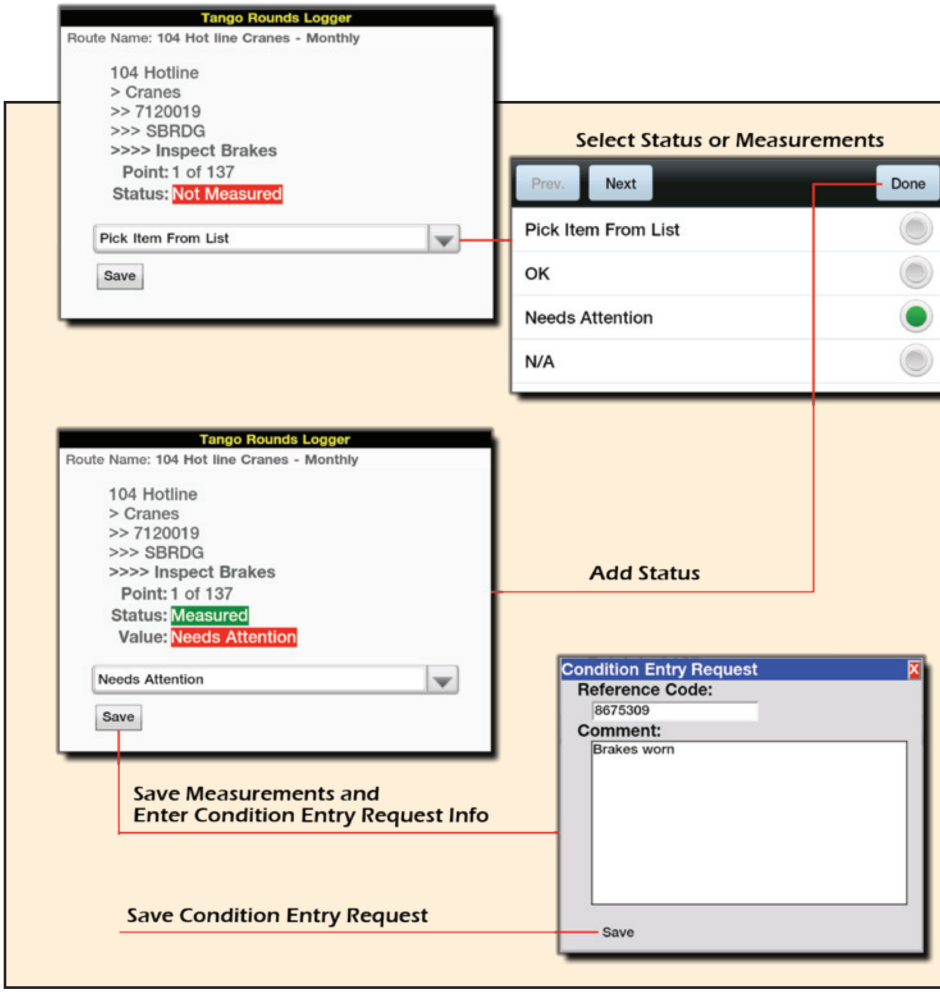


Equipment QR Tags:

Display and enter specific asset information and identify replacements in stores

An equipment QR code allows the user to view the equipment nameplate and design parameters, documents and history, and enter actions and movements.

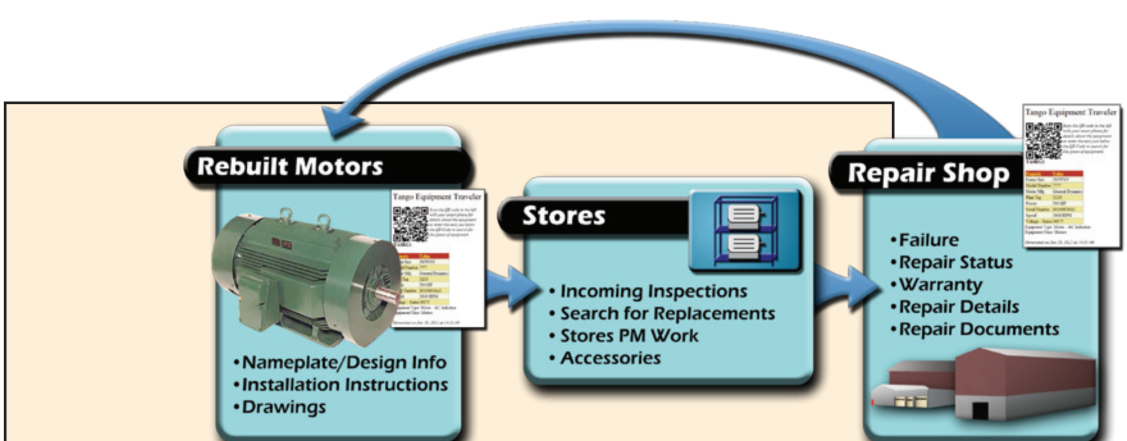




Rounds Logging QR Tags:

Display periodic inspection/lube route or operator rounds tasks

With a rounds logging QR tag, you can collect route-based equipment trends and observations, typically collected with operator rounds, lube routes and PM inspections.



Tango Equipment Traveler

Scan the QR code to the left with your smart phone for details about the equipment or enter the text just below the QR Code to search for this piece of equipment.

TA0RG1

Property	Value
Frame Size	585WSY
Model Number	????
Motor Mfg	General Dynamics
Plant Tag	3210
Power	500 HP
Serial Number	60100836A1
Speed	3600 RPM
Voltage - Stator	460 V

Equipment Type: Motor - AC Induction
Equipment Class: Motors

Generated on Jan 18, 2012 at 14:31:40

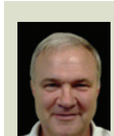
Equipment Traveler:

Provide easy reliability management for critical stores

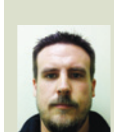
The equipment traveler QR code may be printed by a repair vendor and returned with the repaired component.

At the plant, the user can scan the QR code and:

- View repair/failure information and history
- Assign components into stores
- Remove components from stores
- Enter incoming test and periodic storage PMs.



E. Forrest Pardue, President, 24/7 Systems, Inc. Forrest has worked in the field of vibration analysis and production maintenance for the last 25 years. In 1998 Forrest co-founded 24/7 Systems with his partner, Paul Wolfensberger.



Chris Tyler, Customer Support, 24/7 Systems, Inc. Joining 24/7 Systems in 2011, Chris works with clients to introduce web-based equipment lifecycle management services. www.tf7.com

Tango™ is a registered trade mark

decision support cMms computerized maintenance management system

You Told Us...

Dave Bertolini

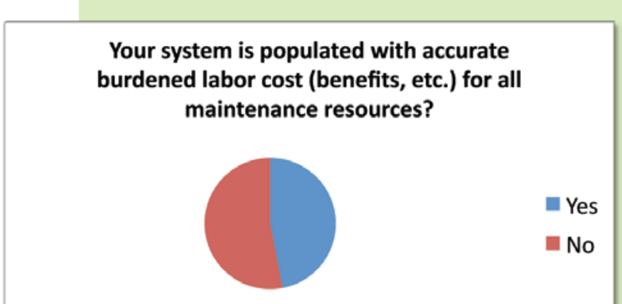
Over the last few months, People and Processes, Inc. has been conducting a survey of computerized maintenance management system (CMMS), enterprise asset management (EAM), or enterprise resource planning (ERP) utilization, understanding, value to the organization and integration in support of maintenance activities.

Eleven poll questions were utilized and respondents were from multiple manufacturing industries, municipalities (government and private sector) and facility environments (again, both government and private sector). These poll questions were collected through ReliabilityWeb.com webinars and publicly- and privately-held training seminars, with approximately 70 unique organizations participating. The selected questions placed emphasis on accurate cost collection and distribution, integration into day-to-day activities, proper training, data utilization and reviews that add value to the organization. Thank you to all who took the time to participate in our survey. For those who didn't have a chance to participate in the study, feel free to poll yourself with the questions provided here.

The questions selected for the survey were straightforward and had no hidden meaning. The only agenda is or was to point out what successful system implementation, integration and utilization should or could provide. Keep in mind that at "go live" time, your system may have "scored" very well, but that was then, so how does it score now? Actually, there really is no score, only the ability to make the right decision utilizing accurate and factual data. This more than likely was one of the driving factors in your decision to purchase your system in the first place. Let's see what everyone had to say:

Poll Question 1

The survey finds that 53% of respondents did not have accurate labor costs within their systems. Is this that important? It is if capturing accurate labor expenses to assets or equipment, departments, areas, activities, etc, is important to you. Ideally, your system should provide you with a real-time picture of your maintenance expenditures. Labor costs are a significant part of those expenditures coming from the maintenance budget. It's an eye-opener, especially when one sees the actual labor expenses to repair, or rebuild low cost items that perhaps should have a run-to-fail strategy. If you want to drive behaviors, start by looking at the labor costs of specific activities or repairs.

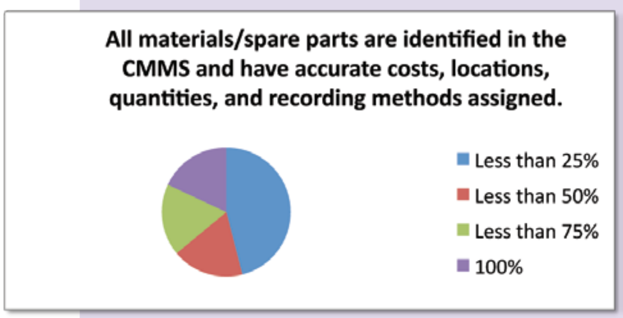


I routinely hear numerous excuses as to why labor is not included within the system. Confidentiality is always a concern, however, if implemented properly, this data is only available at the system administrator level. While averaging of (unburdened) labor rates are utilized by many organizations, this could be misleading if the system is used to track maintenance expenditures since the averages are typically a few years old. Additionally, this will establish inaccurate job plan and backlog labor cost estimates that will impact utilizing your system in developing next year's budget. The correct answer is each maintenance resource should have its burdened labor rate established within the system. It is routinely updated when salary adjustments are made.

Here's What We Heard

Poll Question 2

The overwhelming majority had 25% or less of materials/spare parts identified with costs, locations, accurate quantities and reorder methods assigned. There are a few issues associated with this particular question. How do maintenance resources and stores personnel locate necessary parts efficiently? Ideally, it is all contained within the system and that's the resource used to locate necessary parts or materials. Otherwise, time is spent wandering the storeroom trying to locate items.

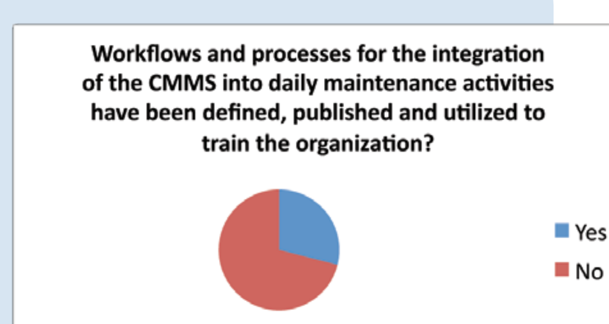


The other major component of costing information is parts or materials used to repair or maintain items. Accurate parts costs must be established to the asset or equipment that used the items to ensure a complete (labor and parts) costing picture. This information is part of the equation to identify when it is no longer cost effective to continue maintaining an asset. Routine-established cycle counting would assist in keeping locations and quantities updated.

Not having this information fully recognized within the system as a bill of materials (BOM) impacts the planning effort. Valuable planning time is spent identifying and obtaining parts information for ordering purposes or establishing them within the system. Ideally, during the maintenance planning phase, pick lists are generated and parts are pulled and kitted to support proactive maintenance. Identification of required reorder points or min/max levels would assist in ensuring necessary items are available when needed. The correct answer is 100% parts or materials are identified with accurate costs, locations, correct quantities and reordering methods assigned.

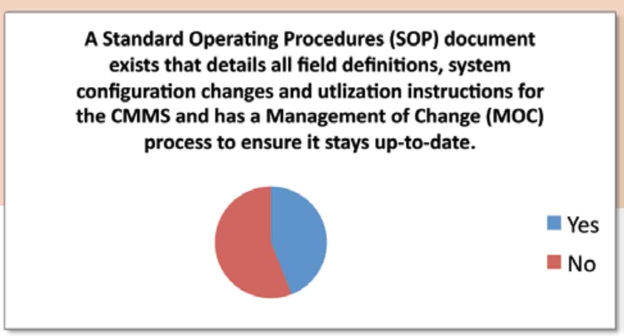
Poll Question 3

Approximately 75% of respondents had no workflows, no integration, or no training on the desired way to ensure the system captures accurate data. Unfortunately, this is extremely common and the worst part is these tools are designed to automate workflows and processes. So basically, 75% of the responders have automated nothing. To fully integrate these tools, workflows must be developed and utilized to identify numerous key system enablers that collect accurate data, such as work order types, work order statuses, approval levels, etc. Once developed, they must be documented and utilized to train the organization to ensure the tool becomes integrated into all activities. The goal is everyone following the flows and collecting accurate information as a result of system utilization. The correct answer would be all workflows and processes for the integration of the system into daily maintenance activities have been defined, published and utilized to train the organization.



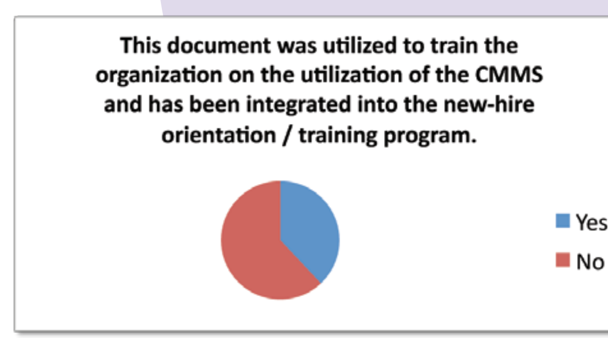
Poll Question 4

Approximately 60% of respondents had no standard operating procedures document to use as a system management and future training tool. Numerous configuration decisions were made during the implementation of the system and these must be documented to ensure meaningful system training can be provided while staying current with future configuration changes. As part of a continuous improvement culture, this document is typically "owned" by the system administrator and has a management of change (MOC) process or procedure. To ensure the system evolves with the changing environment of the facility and changing data needs, there should be routine auditing and changes made when necessary to ensure the system and the resident data continuously meet the needs of the facility. Within the document, detailed flows or procedures for requesting, approving and implementing changes by any system user should be found.



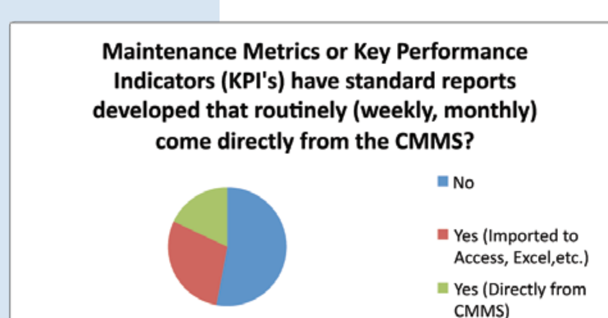
Poll Question 5

Again, since 60% of the respondents did not have a standard operating procedures document, they did not utilize it for training. How were individuals trained on the system? How was standardization applied in the utilization of the system to achieve standardized data collection? What about new employees and their system training needs? This critical phase puts the tool in the hands of the users and must be reinforced with training materials. What better training material than a document that contains all information about the system, its configuration and its intended utilization? Ideally, this document and the developed workflows and processes are both trained together so everyone understands the flow and the system to ensure standardized data collection. Once developed and kept current through the assigned management of change process, it also becomes the training for future employees.



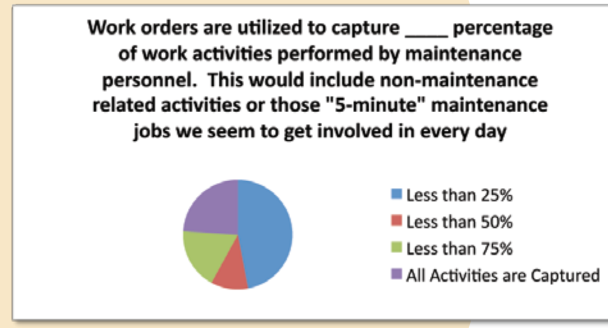
Poll Question 6

The survey shows that 55% of respondents had no established metrics or key performance indicators and no standard reports developed. Only 20% obtained the information directly from their system. The number one reason most organizations purchase a system is to establish routine reporting information and metrics or indicators to guide them in driving appropriate behaviors. These metrics or indicators must be established, trained to the organization, posted for all to see and utilized to drive behaviors. Routine reports should be developed for numerous roles throughout the organization (e.g., maintenance, materials, purchasing, operations, etc.) to ensure these roles utilize accurate data in their day-to-day decision making. In an ideal system dependent environment, all reporting information and metrics or indicators come directly from the system, reducing any possibility of data manipulation errors.



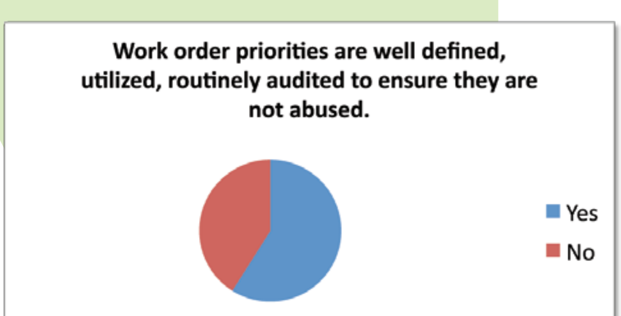
Poll Question 7

According to the poll, 47% of respondents capture 25% or less of the actual work activities performed by maintenance. I like to think of these systems as a communications tool, with communication performed through the utilization of work orders. Once a work order is established within the system, it becomes the collection point of all expenditures, the starting point of all necessary metrics or indicators and, ultimately, the authorization to perform activities. Too many organizations routinely conduct maintenance activities without work orders. When this happens, these activities are considered non-events and necessary maintenance management information and historically valuable information are never captured. Those 5-minute jobs that are routinely performed are, in most circumstances, the most problematic pieces of equipment or assets, yet we know nothing about them. The correct answer is all work is captured to a work order that identifies the equipment or asset where the time and materials were spent.



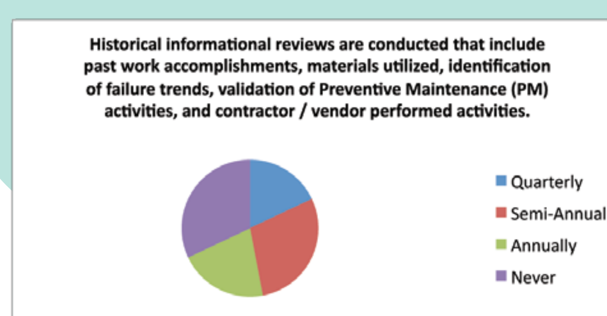
Poll Question 8

Poll results show that 41% of respondents do not have defined work priorities. Defined work order priorities are critical for ensuring available maintenance resources are utilized on important work first. Most organizations approach this from a passionate approach with who yells the loudest getting responded to first. Work order priorities are developed to assist in identifying the mean time to plan and mean time to execute. These priorities work hand-in-hand with equipment or asset criticality. We must work on the important assets and the highest priority work first. There should be a routine auditing process to ensure priorities are not abused and maintenance resources are deployed to meet the needs of the facility, not individuals.



Poll Question 9

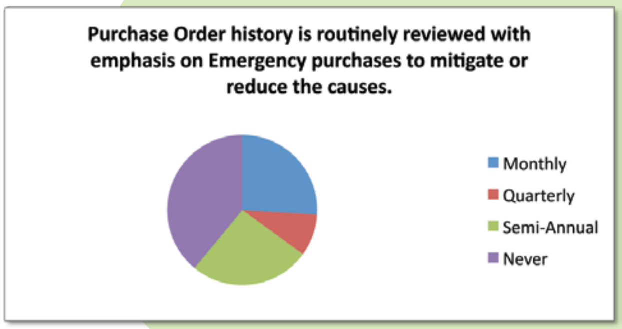
The survey finds that 33% of the respondents never conduct historical reviews of their data. Fortunately or unfortunately, maintenance is a very repetitive business, meaning the failures and activities we do today, we will do again in the future. Quarterly reviews of historical data should be conducted and include identification of repetitive failures, detection for patterns or trends and development of a Top 10 list of problematic equipment or assets. Materials utilized also should be reviewed to understand where the parts are being consumed. Through these historical reviews, enhancements to the preventive maintenance (PM) program and the frequencies of performance should be examined to keep the PM program dynamic within the changing operating environment of the equipment or assets.



Continued

You Told Us... Here's What We Heard

Poll Question 10

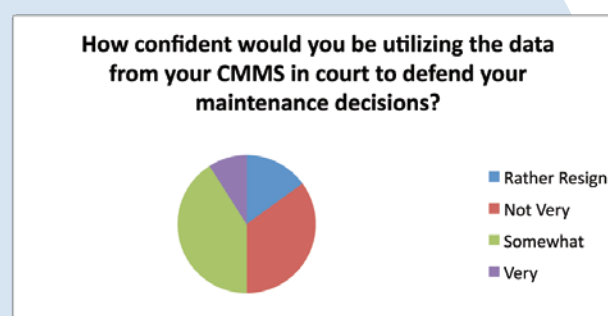


This poll question reveals that 38% of respondents never review their purchase history. Much like the work order history review, this review will identify what is bought, where it was used and how many were purchased. Typical things to look for are parts utilization to equipment or assets and a Top 10 list of where the items are going. Additionally, emergency purchases must be understood. These types of purchases are your most expensive and mitigating them is necessary. As with the work order, historical review trends can be seen through the expenditures of parts and where they were utilized.

Poll Question 11

This question, although it may seem farfetched to some, is very real. One of the more interesting jobs where I have worked was a law firm. Ten years of historical data was used to determine the outcome of a multi-million dollar lawsuit. Much to the disappointment of one of the parties, the results were not favorable. The answers everyone sought were contained within the system. As can be seen by the responses, a very small number would be comfortable in the courtroom.

If you address the first 10 items in this article and you're faced with poll question #11 in your future, you'll be able to respond with "very confident."



Dave Bertolini is a Managing Principal with People and Processes, Inc., a firm that specializes in changing cultures from reactive to proactive through the optimization of people and processes. He has over 30 years experience in improvement initiatives and has led more than 300 improvement initiatives and implementations for facilities, municipalities and manufacturing environments. He is recognized as an industry expert in the implementation and utilization of computerized maintenance management systems (CMMS). In addition, he routinely conducts educational seminars on best practices, CMMS selection, implementation and utilization. www.peopleandprocesses.com

reliability

Kpi

reliability performance metrics

The PUZZLE

Don't expect good results from bad practices

Guess: What is the value of backlog?

Tarek Atout

The maintenance manager in a manufacturing organization asked two different maintenance supervisors to report on the work orders backlog up to the current date. The two supervisors reported two different values for the backlog, while both seemed to use the same data sources to produce the report.

Why did this happen? Is the backlog value a puzzle where everyone tries to guess an answer? It must be a straightforward job to get the backlog value, but sometimes the work practices make it a PUZZLE.

What happened here initiated many key questions for key performance indicator (KPI) calculations.

1. What is the definition of a specific KPI? Meaning and characterization included.
2. What are the prerequisites before calculating a specific KPI? Specific preparations in the work processes, flow, practices, or computerized maintenance management system (CMMS) to be ready to measure.
3. Why are we calculating this KPI? What is the value added to the business if we know this value and what will we miss if we don't?
4. What is the calculation methodology? Parameters and equation explained.
5. What are the precise sources for obtaining the accurate data? Persons, CMMS, log files, etc.
6. Who are the contributors and owners of a specific KPI? Stakeholders whose work affects the value.
7. In what stage of the process and how frequently should a specific KPI be measured? Daily, weekly, monthly?
8. What is the relation between a specific KPI and other indicators?
9. What is the plan for overcoming out-of-range values of this KPI? Remedy actions required to reverse the trend, if any.

Let's go back to the maintenance orders backlog example and try to find out how it became a puzzle, guess a solution and review what other puzzles can be found in a maintenance workshop.

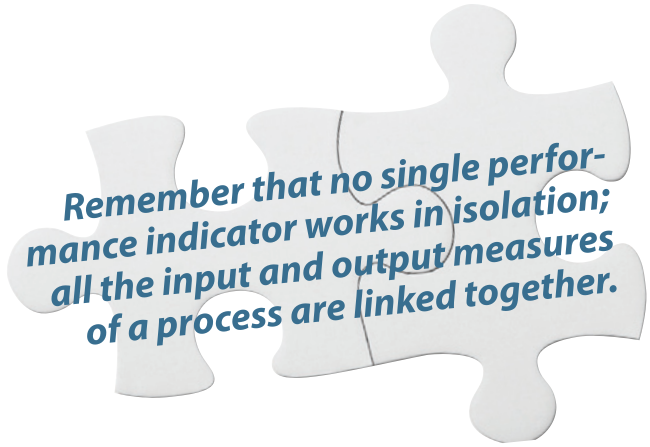
- The primary key in a KPI development is that everyone in the organization must have the same understanding. It must be well communicated so everyone is working to achieve the targeted value according to a common shared definition.

  For example, let's say we have two categories of backlog: ready and total. The *ready backlog* includes the jobs that are planned and all job requirements are available, in other words, *jobs are ready to be inserted in the schedule*. The *total backlog* includes the ready jobs plus other jobs that are in planning or planned, but still miss some of the required resources (spares not available, awaiting vendor, etc.), in other words, *all approved maintenance requests*.

What creates the puzzle?

The main reasons that created the differences in the reported values of backlog between the two supervisors are:

- Not all the staff has the same understanding of what the backlog is because it was not well communicated or explained to them. One supervisor calculated the ready backlog and the other calculated the total, regardless of the accuracy of calculations, which will be covered later in this article.
- While it seems both supervisors used the same source of data, the data source is not reliable enough to produce an accurate report.
- Having multiple data sources can misinform the parties and lead them the wrong way. These sources are within CMMS, private Excel or Access data sheets, private log books and the memory of each person. Imagine if each staff member has all these data sources, what type of accuracy, quality, or integrity can you expect?
- Data corruption factors that created the puzzle, among them:
  - One of the supervisors considered the preventive maintenance records and the other did not. This reflects a poor understanding of what exactly is required about reporting.
  - Job is done, but the work order is not closed in the CMMS. If both supervisors used the CMMS record as is, the backlog is not accurate. If one used the CMMS and the other knows from his Excel data sheet or logbook that the job is already done and excluded this work order from the value, this makes it worse.
  - One of the supervisors downloaded the backlog work from the CMMS to an Excel sheet and made some changes in the planned



man-hours and durations because he didn't believe in the estimates of the CMMS. The other supervisor used the data as is; the puzzle started becoming tricky.

- Some duplicate jobs with different descriptions for the same equipment or the same description used for the equipment and its children.
- Same preventive maintenance jobs that are issued before completing the previous ones (fixed plan) are included many times by one supervisor, while the other supervisor considered only one event; the puzzle now is a difficult challenge.
- Some long-pending jobs that are no longer required were considered by one supervisor and ignored by the other; the puzzle becomes more complicated.

- Some jobs still in the request phase, not yet approved for planning were totally counted by one supervisor and partially by the other; more confusion is added to the puzzle.
- One of the supervisors had purposely done some data manipulating to either:
  - Reduce the backlog value to show maintenance performance was in good shape in order to get personal advantages or avoid blaming.
  - Increase the backlog value to give justification for overtime or additional resources.
- Many jobs with unclear status are lost in the two versions of the backlog report.
- Non-official jobs are in progress in the site, but there is no record in the CMMS, making the puzzle cloudier.
- You can imagine many more scenarios to add mystery to the backlog from the four data sources mentioned above. Try it and see what you find.

At this stage, the big question that comes to mind is this: Is there a maintenance organization that knows what the exact value of backlog is at the end of any working day? I have great doubt about this, but you can obtain a closer to real value backlog using some controls. I've used the backlog as a clear example of the inaccuracies of performance measures in the maintenance function due to poor practices, lack of control and unaccountability on the part of the staff.

The puzzle can be easily expanded to many performance indicators; the inaccuracy of the backlog itself is a symptom of inaccuracies in most of the indicators tied to the work management process.

Add to the previous scenarios other corruption factors as described below:

- Jobs in progress are not the jobs in the approved schedule
- Inaccurate man-hour estimates and durations
- Actual work hours are a "copy and paste" from the planned hours
- Detailed work done is not recorded
- Failure codes and reasons are not entered in the work order
- Materials used from hidden stock are not recorded in the order
- Unused materials are not returned to the store
- Inaccurate dates of order closing and material transactions
- Blanket work orders that contain a mix of data for different jobs.

You can then forecast that most of the work management indicators or cost indicators are not functioning to your expectations. Samples of these suspected KPIs are:

- PM compliance/schedule compliance/planning accuracy
- Maintenance costs (for all cost elements and maintenance types)
- Failure and reliability reports

Remember that no single performance indicator works in isolation; all the input and output measures of a process are linked together. Keeping in mind that all maintenance internal processes are interrelated, you can't skip the accuracy in one process because it will pull down all the others. As such, no right decisions can be taken to improve any of the maintenance functions. Imagine the impact of these decisions using these suspected values.

How to solve the puzzle?

Whatever the complexity of the puzzle may be; there are always solutions. I recommend adopting a two-prong approach to solve the puzzle and avoid its re-creation.

1. One focus is on the cultural change of the staff. They need to realize the value of the measures and be accountable when working with the maintenance data. They have to understand that achieving the true target of indicators will impact not only the organization, but

its individuals also. Cultural change must also extend to managers so they understand that measures are not a blaming tool. Everyone has to know that work measurements are used to promote improvements in the maintenance process and practices.

2. The second focus is on introducing controls to your work process and data management. Start with *KILLING* all other data sources and make the CMMS the official and only data source. Then work to improve data accuracy and completeness in the CMMS.
   a. Enhance your CMMS configuration so it is able to receive and restore the specific data you need. Confirm full implementation with full capacity of the CMMS.
   b. Build standard reports in the CMMS for all your KPIs, with customized selection criteria that prevents different interpretations of the indicator and individual tailoring. The goal is for everyone to do the same clicks to get the same report.
   c. Implement regular data audits and validation. They are key to ensuring data integrity of the CMMS and verifying that no maintenance, procurement, or inventory transactions are executed outside CMMS.
   d. Schedule refresher training for the staff to fill gaps in system utilization.
   e. Introduce some controls of access and authorization to the system and enforce some mandatory data fields. Too many optional fields sometimes lead to blank records. Automated work order flow is also useful for imposing accountability.
   f. Consider applying some incentives or enforcement rules; sometimes they are necessary.

Whatever the case may be, one aspect remains constant. All the puzzles in maintenance are from one root and all the solutions are also from one root.

Working in these two directions will definitely help to solve the puzzle. Start now by taking count of how many puzzles are in your maintenance function. Perhaps one solution is valid for all, or it may be that each puzzle requires its own solution.

Whatever the case may be, one aspect remains constant. All the puzzles in maintenance are from one root and all the solutions are also from one root. One puzzle will lead to another and one solution will lead to another. ENJOY SOLVING!

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Quarterly Profits or Machine Production
Which Comes First?

David F. Piangerelli

Companies invest millions of dollars in revenue producing assets, specifically, machines of all types. These machines, ranging from trucks to wheel loaders, cooling towers to crushers, paper machines, injection molding machines, blowers, mixers, food processing equipment and so on, depend upon proper maintenance protocol with qualified personnel using quality products to insure the longest possible reliability and production.

While we are seeing a general upward trend in organizations that understand that a reliability centered maintenance (RCM) approach can impact the profitability of the company, they are unfortunately, few and far between. Too many organizations resist change and insist on doing things as they have always been done, relying on tribal knowledge of stakeholders within the organization who may not have the company's best interests as a priority. These stakeholders, often entrenched within their own system of working with key vendor partners, willingly resist exposure to new concepts or products and services that can provide game changing strategy, and in fact impact the organization's profitability with ramifications that are largely unknown or not even considered by management.

As a professional involved in the business of lubrication management, I am often times directed to the maintenance supervisor, mechanic or lube technician. While conversations with these individuals are generally enlightening and instructive as to the present methodology and philosophy practiced by the organization in maintaining their equipment, these same individuals, in many instances, are powerless in effecting any real change within the organization. To do so they must become salespersons who take on the task of convincing their supervisors that there may be better ways of doing things. Veteran maintenance persons, tired of fighting the fight, often don't even try, as management simply tells them they are not interested, as from their perspective, it isn't broke, so there is no need to fix it.

Injection Molding Machines- Sizeable investment typically using low price fluids.

Management and Vendor are Aligned–Neither Cares!

A successful plastics and metal manufacturing company several decades old, with six locations in four states, and a world class (appearing) manufacturing facility, has millions of dollars invested in over 30 injection molding machines. The maintenance of these machines is lacking severely causing unnecessary expense and lost production. Worse yet, it is evident that management does not see any issues with their present situation as after having replaced a hydraulic pump on a machine, the fourth one in 12 years, management or (lack thereof) thought it was acceptable to do so *without changing the highly contaminated oil* that was determined to cause the failure of these pumps! It was also determined that this oil apparently has never been filtered or changed. The pump cost was $5,000, the cost of 3 days lost production was not provided, but I am confident it was several thousands of dollars.

Equally sharing responsibility is the present lubricant vendor who is content to sell their customer the lowest priced hydraulic oil in their product offering, (most likely because someone in the organization demanded a better price) and do nothing proactive to assist their customer. Oftentimes vendors take the path of least resistance as well, as it is always easy to sell goods at the lowest price, there will always be plenty of takers

What should the lubricant vendor be doing? Well, at the very least, they should be taking an active role as opposed to simply taking orders. Here are a few ideas;

1. Implementing an oil analysis program to monitor the condition of the fluid as well as machine health.
2. Training personnel and sharing knowledge regarding contamination control and its importance and relationship to component life.

3. Investigating the root cause of routine hydraulic pump failures which result in lost productivity as well as unnecessary labor and components costs.
4. Investigating the excessive leakage exhibited by all of the machines and determining the root cause and recommending corrective action.
5. Monitoring the improvements gained and moving the client towards a best practices approach that best suits their needs, i.e. putting the customer needs first.

Perfect Marriage- Customer gets Lowest Price, Vendor Sells More Stuff!

Another example of wasted resources and unnecessary expense is provided by the low bidder policy of many organizations. A quasi-governmental organization operates 400 school buses. The buses represent a capital cost of several million dollars. Oil changes on these buses are performed at 4,000 mile intervals. Each year, the organization puts its lube oil contract out to bid, with the winning bidder always being the lowest priced product. Buses used to be turned over at a ten year interval; however, experience has demonstrated that the potential for engine failures rose exponentially during the 8th through 10th year of ownership. Consequently, buses are now turned over at about the 7th or 8th year. When the prospect was shown clear verifiable documentation suggesting that engine oil drains could safely be extended at least 5 times the present interval and that engine life would not only not be compromised but would be extended further, he dismissed it out of hand stating that the only thing that matters is the price per gallon. This individual cannot understand the difference between price and cost and is perfectly content to ignore industry trends, while simultaneously contributing to needless generation of waste oil. This scenario repeats itself thousands of times throughout the country.

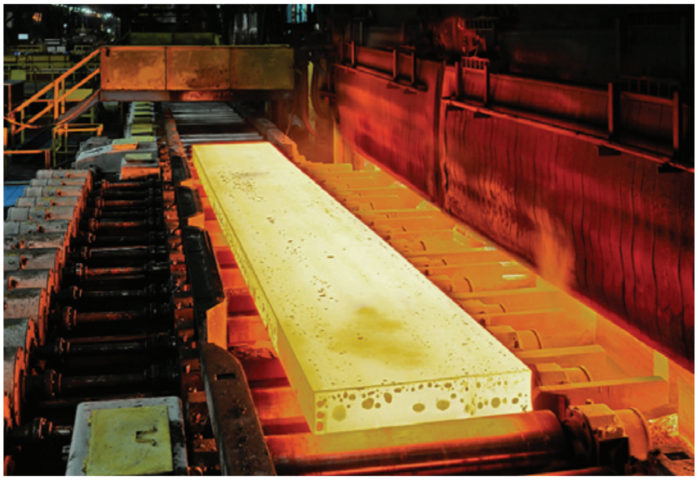
In many ways this vendor/customer/low bid relationship is a perfect one. Customer wants goods at the lowest possible price; vendor wants to sell as much goods (in this case gallonage) at a price he can live with. There is no incentive for the vendor to reduce the volume of product sold to the customer.

Hence the relationship continues, as the game never changes, only the players. With organizations adopting a green initiative, this example represents a prime candidate to reduce the carbon footprint of the organization by effectively reducing the volume of oil purchased to one fifth that presently consumed. Unless and until someone in the organization either has an epiphany or somehow learns about the potential savings, reduced waste and increased efficiency potential, it continues, ad nauseam.

Don't Sell Me What I Need, Sell Me What I Want

A worldwide steel manufacturer requests a quotation for several automatic lubrication system stations at their hot strip mill facility. The incumbent lubrication systems vendor, one who formerly represented a quality manufacturer of lubrication system components, now handles a "knockoff" line manufactured offshore. This vendor enjoys much of the lubrication system business at this and other mills because of their ability to come in consistently as the low bidder. When my organization was asked to quote on a replacement of an existing system, we examined the application issues and determined that several production losses were directly due to the fact that the lubrication system design was deficient. We added certain key components to the design which would address this deficiency, provide a more robust and reliable system, and more importantly, eliminate the root cause of the loss of production. When our solution oriented concept was presented to the prospect, the price was the primary concern. We were requested to re-quote including the same component mix provided by the competitor so the buyers could compare "apples to apples". Interestingly enough, this solution had already been implemented by our partner distributor at a sister plant that had experienced the same issues as this plant, but no one was interested in verifying the results (which was as simple as a phone call). We have decided to not invest any more time with this prospect that is not interested in our solution oriented approach or

School buses-although many maintainers are on extended drains-many still adhere to old school practices



Downtime costs in a Hot Strip Mill can exceed $250,000 per hour

aligned with our philosophy and have declined the request to re-quote.

These three examples represent a microcosm of experience in our world. I am confident that many other vendors have experienced similar situations regardless of the product line. Why these situations occur and how we may collectively work to improve upon the status quo, is, in my opinion, all about communication and priorities.

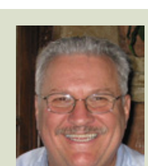
Continuous Improvement Starts with Communication

The predominant use of voicemail, coupled with an increasing trend of organizations that prohibit name sharing of key players serves to isolate decision makers from ideas, products and services that can help them operate more efficiently. Some organizations now actually refuse to receive business cards or product collateral. Vendors must share the blame as they often waste prime time and don't know how to get in, do their business, and get out. Worse yet, they do not bring any value, further supporting managements' decision to isolate themselves. Organizations contracted out to provide MRO materials to the customer, add more layers of insularity. So the question becomes how to screen out those who bring no value and qualify those (or at least communicate with them) who may bring value to an organization. Those who are on the "customer/prospect" side of this discussion may have more to gain than lose in the time dedicated to engaging potential vendors in a conversation or meeting. Unfortunately they cannot easily qualify those that can bring value. The inability of the value added vendor to talk to management who has the power to make the decisions impacting their business is the largest obstacle to moving forward.

So the question becomes, How do we screen out those vendors who bring no value and qualify those (or at least communicate with them) who may bring value to an organization?

If your organization has a sales team, you wouldn't want them to be roundly dismissed as you would hope that they are able to engage your prospects in a meaningful way. If you are an organization that gets called on by sales people in the field, you may wish to extend to them the same courtesy you'd like to have your sales team experience. By encouraging cross department communication; i.e. sales with production, maintenance with management etc. all will be enlightened to each others' challenges.

In the final analysis, we all "profile" each other in some way shape or form. I seek out progressive individuals who are open minded, do not prematurely judge, are interested in learning, vested in continuous improvement, and understand the difference between price and cost. I hope that prospects would seek out and welcome vendors who willingly share knowledge, provide timely well researched responses to their questions or inquiries, have demonstrated self improvement in educating themselves in their respective chosen fields, aspire to become the expert in their field(s) and are willing to do what it takes to show a higher level of professionalism than lesser salespersons' who would reduce our value, tarnish our chosen profession and waste their precious time. By selecting vendors who have your interests as their number one priority, you effectively choose to grow and be better. And that is a worthy goal for all of us.



David Piangerelli, CLS, MLT II, is the President of Lubrication Technologies, Inc., a New England-based company serving industries of all types for 35 years. www.lubetechnologies.com.

RCM Implementation

Douglas Plucknette

Recently, I have been exchanging phone calls and emails with a client we worked with who planned, analyzed, implemented and is now performing tasks from nearly a dozen RCM Blitz analyses we started less than one year ago.

To a lot of people, the fact that over 1,200 failure modes were analyzed and over 1,600 tasks were implemented in less than 11 months would sound impressive and, based on an industry survey conducted in 2005 by Reliability-Web.com and Jack Nicholas Jr., these results would seem impossible.

According to the survey of more than 250 companies, over 85% of the reliability-centered maintenance (RCM) analyses completed are never implemented. As we all know, if your RCM tasks are not implemented, your company will never see any results from the time and money invested in performing the analysis.

I found the reasons/excuses for not completing the RCM tasks to be somewhat amusing. After all, the job of a good RCM facilitator is to uncover failure modes (Why did we fail?) and to then develop tasks to mitigate each failure (How can we prevent these failures?). This list of reasons included:

- We didn't have enough resources to implement.
- We ran out of funding.
- Management did not support the effort.
- It was too difficult.

Before I get into the details of what it really takes to implement an RCM analysis, look again at the four bullets listed above and think of your own company. If this was your company and someone came to you and said we were unable to implement our RCM tasks for any of these reasons, wouldn't you ask that person why?

- Why didn't we have enough resources or funding?
- Why didn't our management support the effort?
- Why was it so difficult?

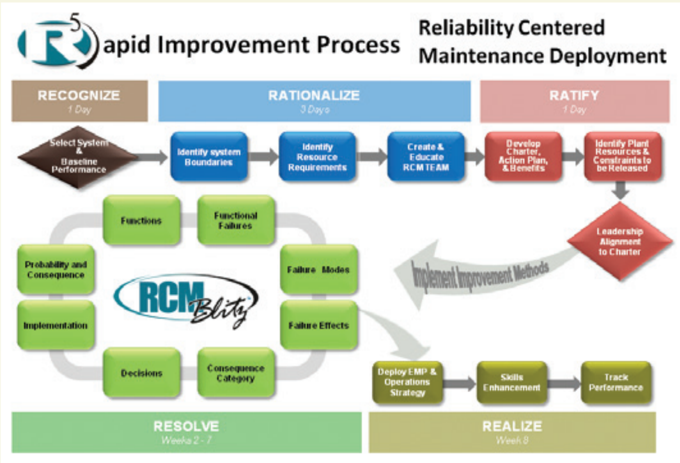


Figure 1: R^5 Rapid Improvement Process

The principles of tools, such as RCM and root cause analysis (RCA) that deal with understanding the relationship between cause and effect and mitigating failure effects, can be applied to any type of failure including the cause or causes of why your RCM effort failed!

The task of implementing the results of your RCM analysis can be somewhat overwhelming for some. I find it is a bit easier to digest if I share with my customers some facts I have gathered over the years regarding RCM Blitz implementation. While some companies have labeled RCM as a "resource consuming monster," the information we share, which comes directly from our customers, clearly indicates that with some good planning up front, implementing your RCM tasks is not at all difficult, nor should it consume an overwhelming amount of resources.

For companies who are just beginning their RCM effort with a newly-trained team, one should expect the following with regards to analyzing and implementing RCM tasks:

1. A new team should be able to complete an RCM analysis of 85 to 100 components, assessing 120 to 140 failure modes, in five days.
2. This analysis should produce 140 to 160 mitigating tasks and, as part of your implementation plan, each task should be assigned to a specific individual, along with a due date.
3. One person should be named the RCM implementation manager, with the responsibility of assigning, tracking and reporting the progress of your implementation effort.
4. Expect your first several RCM implementations to require 100 to 120 labor hours to complete.
5. The companies who have been the most successful at implementing analysis tasks dedicate:

While successful implementation begins with planning in the RATIONALIZE phase, it is executed and verified in the REALIZE phase. As we assign and begin to perform the tasks identified in the analysis, it is extremely important to communicate both the progress of the implementation and the results that have come from performing the new maintenance strategy.

- 1 person to write PMs and job plans;
- 1 person to write operator checklists; and
- 1 person to manage redesigns.

Looking at the above listed items, do any of these things seem overwhelming, unmanageable or impossible?

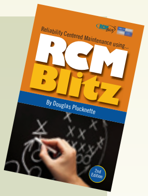
The key to successful RCM implementation begins in the planning stages of the process. Using our R^5 process (Figure 1), which lists the key steps to completing an RCM analysis, resources for performing the analysis and completing the tasks should be identified in the *Rationalize* phase of the process. Quite simply, if you do not dedicate the resources required to implement the tasks before you start your analysis, do not expect money or people to magically appear and volunteer to help on the day your analysis is completed.

The *Ratify* phase is where you build a team you can rely on. It is here where a contract is developed that identifies the resources by name and the time required to complete both the analysis and task implementation. The roster of a successful RCM effort often mirrors that of a championship team, a list of seasoned experts each having the reputation for follow through and results.

While successful implementation begins with planning in the *Rationalize* phase, it is executed and verified in the *Realize* phase. As we assign and begin to perform the tasks identified in the analysis, it is extremely important to communicate both the progress of the implementation and the results that have come from performing the new maintenance strategy. Communication from the RCM implementation manager in this phase of the process is crucial. Without a weekly progress report, the people who participated on the team and the managers who sponsored the effort will assume nothing is being done, when in fact, your implementation may be nearly complete.

One of the reasons I made a career out of RCM was a strong belief in the process. I have always been confident in the results RCM can deliver IF IT IS IMPLEMENTED! To this day, nothing bothers me more than to hear someone say they tried RCM and it didn't work. Immediately following this statement, the excuses previously listed start and I wait for a pause. It is at this moment I make the statement, "We have been tracking our RCM implementations after we refocused our model to include the entire RCM cycle; our customers now complete the implementation for over 85% of the analyses performed each year." For those RCM analyses that were fully implemented, every single one has provided a return on investment.

The remaining RCMs that were not implemented could still provide the same benefits, however today they sit on a shelf and wait for a leader.



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Couples That Play Together, Stay Together

Creating a value stream-based plant organization structure

Drew D. Troyer

We've all heard the saying, "couples that play together stay together." But does this concept have any bearing on the management of plant reliability? I think it does. In this article, we'll explore a reorganization of the plant maintenance structure to focus on what's really important, creating value for the shareholders and other stakeholders of the organization.

Plants have a value stream. In general, raw materials arrive at one end of the plant and finished goods exit at the other end of the plant. The plant's production process is in the middle. The process may be continuous, such as in a power generating or chemical processing plant, or it might be batch and queue, such as an automotive manufacturing or food preparation plant. In all cases, there is a series of sequential processes that must be accomplished. It's crucial for the reliability of the value stream to be managed because, in most plants, process "A" feeds process "B," which, in turn, feeds process "C" to deliver finished goods to the customer. If we're managing reliability along the value stream, why then are most plants and factories organized into functional groups, in particular operations and maintenance, the focus of this article?

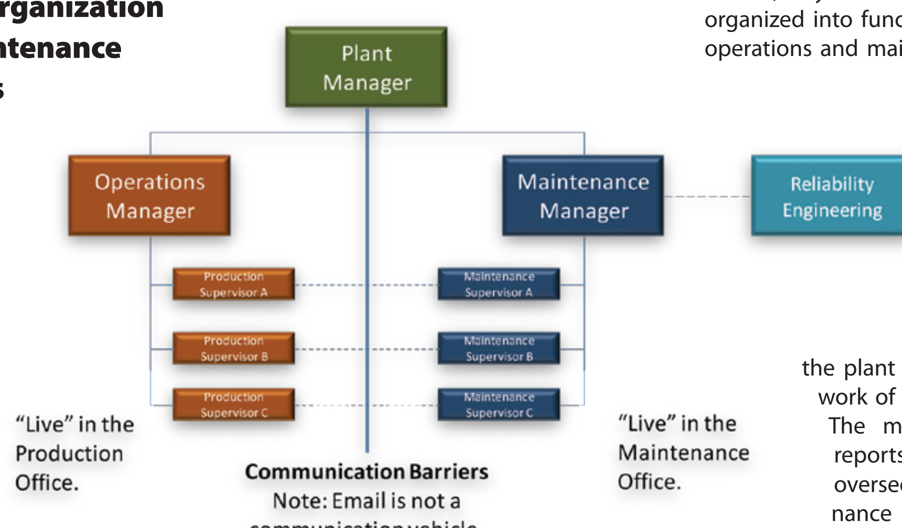


Figure 1: The traditional plant management structure creates barriers to communication.

Figure 1 represents the typical organizational structure of a plant or factory. The plant manager is in charge. The operations manager reports to the plant manager and oversees the work of the operations supervisors. The maintenance manager also reports to the plant manager and oversees the work of the maintenance supervisors. Reliability engineering is, strangely, a dotted line

connection to maintenance, which has always baffled me since reliability engineering is and always has been focused on assuring safe and effective production.

Under the typical, functional organization structure, communication, apart from meetings which are usually formal gatherings, occurs via email. While email is a great way to convey facts, it's not a real form of communication. This organizational structure, while common and convenient from an administrative perspective, usually fails. It fails because it's functionally-focused, not value stream focused. Your value stream and the problems that interrupt it are cross-functional. If you hope to solve cross-functional problems, you need to organize accordingly.

While not exhaustive, some symptoms of the failed organization policy include the following:

- Operations team members believe that the only thing maintenance people want to do is shut down the machines to work on them.
- Maintenance team members believe operations people don't care about the equipment and are happy to run it into the ground to get another ton, megawatt hour, etc.
- A high percentage of maintenance work is reactive.
- When equipment fails, either shutting down or slowing down the line, operations people call maintenance and then vacate the scene.
- Maintenance teams plan work without input from operations.
- Operations managers routinely cancel or move a scheduled shutdown, sending the maintenance team back to square one in the planning process.
- Operations teams don't participate in the reliability process by inspecting, cleaning and creating maintenance or basic care work requests.
- Maintenance team members don't communicate and educate about how and why failures occur, and how minor changes in the operation of machines can avoid a lot of failures without compromising throughput or speed.
- When something goes wrong, whether it's equipment-related or operations-related, the "blame game" is afoot and the incendiary com-

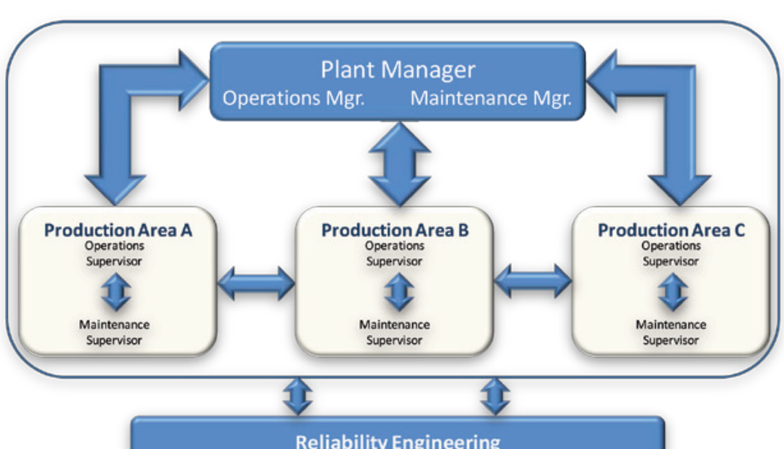


Figure 2: Organizing for success by focusing on the value stream.

Operations Supervisor	Goal Area	Maintenance Supervisor
10%	Plant Profitability	10%
20%	Performance of Up/Downstream Process	20%
40%	Process Operations	30%
30%	Process Maintenance	40%

Figure 3: Example of a balanced scorecard for process area supervisors

ments about the affecting functional group are made by the effected functional group.

If you're experiencing some of these symptoms, you probably need to reorganize your plant, changing from functional-focused to value stream focused.

Creating a Value Stream Focused Organizational Structure

It's really quite simple to reorganize your plant to reflect your real goal of creating value (Figure 2). Let's start at the top, with the senior plant management team. Typically, in a functionally organized plant, the operations manager and the maintenance manager are in separate areas, have separate, function-oriented metrics, and only communicate via formal meetings, email and on an ad hoc basis when something goes wrong. Here are some simple steps to align your senior plant management team to focus on creating value.

1. Geographically, locate your senior management team together – at the same place in the plant. Ideally, the senior plant team will be placed in the same room, or at least in a management module. The objective is to facilitate routine, ad hoc communication. Meetings are too formal, too infrequent and usually problem-focused – they fail to facilitate proactive cross-functional communication.
2. Create value stream focused goals, metrics and rewards. Typically, the production team's metrics and reward systems (both extrinsic and intrinsic) are based on maximizing tons, megawatt hours, or some other production volume metric. The maintenance team's metrics and reward systems are usually based on minimizing parts, materials and labor costs. Neither goal, in-and-of-itself, can maximize value creation. Maximizing value creation requires that the plant optimize production volume and costs. To facilitate this, create a balanced scorecard of metrics that spans the value stream and facilitates cross-functional cooperation. For example, a balanced scorecard and associated rewards for the operations manager might include 30% for overall plant profitability, 40% for typical operations goals (production yield and quality) and 30% for typical maintenance goals (availability and maintenance cost). For the maintenance manager, the balanced scorecard would be exactly the same, except it would be 40% focused on typical maintenance goals and 30% focused on typical operations goals. It's important to note here that the common elements of overall equipment effectiveness (OEE) – availability, yield and quality – aren't independent. Increasing yield (speed or throughput) can detrimentally affect availability, quality and cost. This mutually-dependent relationship between goals sets the organization up for conflict and failure if we don't manage cross-functionally to focus on the value stream. The balanced scorecard gets everyone on the same page.

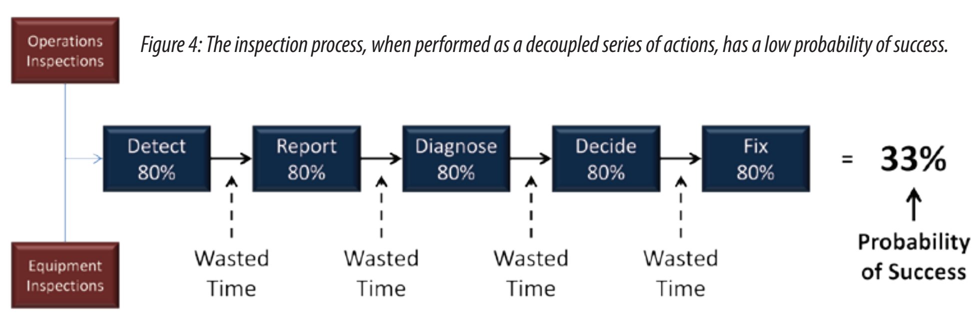


Figure 4: The inspection process, when performed as a decoupled series of actions, has a low probability of success.

3. Employ Management By Wandering Around (MBWA) as a team at least once a week. As the name implies, MBWA requires the team to take a look around. Done correctly, it's very effective. Here are some tips for making it work.
   - Senior management makes unannounced MBWA walk-throughs of the plant as a team, which includes the plant manager, operations manager and maintenance manager. Make sure your walk-through is focused on your Top 10 or Top 20 problem or loss areas.
   - Look at equipment, but above all, TALK WITH (not to) PEOPLE – be an active listener. Remember, on the plant floor THEY'RE THE EXPERTS. Ask them:
     - How's it going?
     - How's their family?
     - Are there interesting things going on in their lives? Make note of the personal stuff and ask them about it the next time you see the individuals with whom you spoke.
     - What's working well in the plant?
     - What's not working well in the plant?
     - What problems are imminent?
     - What can you do to make things better and easier for them?
   - Meet with your team to discuss your observations and findings. Summarize your findings into action plans with assignments and timelines.
   - Follow-up on the ideas and suggestions you received from employees. Tell them what you're going to do to address their concerns. If there's nothing you can do in the near term or in the foreseeable future, tell them why. They deserve the respect of honesty.

With this phase complete, you can then start focusing on bringing the value stream concept to the supervisor level in the plant. Rather than situating your operations supervisors together in an office or area and your maintenance supervisors in another separate office or area, create value stream production area teams and locate them together to facilitate the all-important informal communication. Create a balanced scorecard for them that is 10% focused on plant productivity (see Figure 3), 20% focused on the performance of the production area they feed into and/or feeds into the area of their responsibility, 40% focused on the functional performance within their value stream production area (operations or maintenance) and 30% focused on the complementary functional performance within their value stream (operations or maintenance).

The Lean Inspection

How often do inspections fail to lead to actions that are effective and implemented in time? If you analyze inspections, I think you'll be disappointed by your answer to this question. To be successful, the problem must be found in the inspection, then reported, diagnosed properly, assigned a priority, approved by a supervisor or manager and acted upon. If each step in that serial process is 80% effective, as Figure 4 shows, the overall effectiveness of the inspection is only 33%! The problem is the hand off in communication. If the person detecting the problem lacks

As for your reliability engineering team, stop using the word reliability as a synonym for maintenance. Require your reliability engineers to help you analyze, understand and mitigate risks to the value stream.

the skill to diagnose it, further work is required. Likewise, once it's diagnosed, it has to gain approval from a busy supervisor before action can be taken. The traditional approach to inspections is fraught with risk in that hand offs won't occur due to communication problems and time constraints. With every hand off, you must find the next person in the process and then bring that individual up to speed. It's an ineffective and inefficient process. Moreover, operators, mechanical maintenance techs, electrical maintenance techs, instrument and control (I&C) techs, reliability techs, etc. may all be inspecting the same machine, but looking at it from their own narrow perspectives.

What's the answer, then? It's applying the lean cell concept to plant inspections and walk-throughs. As a team, the operations and maintenance supervisors, along with rotating members of their teams to include a lead operator and a lead maintenance technician, should walk through the plant at the start of each day or shift with a Top 10 or Top 20 list of equipment and operations "bad actors" for their respective area. If possible, include lead mechanical, electrical and I&C techs in the walk-through as many of the problems you encounter will have multidisciplinary elements. A team approach facilitates on-the-spot problem detection, creation of diagnostic and prescriptive actions, and approval to execute those actions. All parties are present. Goals for your cross-functional lean inspections should include:

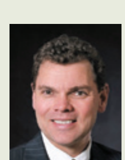
1. Identify problems and opportunities
2. Identify the actual or potential impact on the plant
   - Lost production
   - Increased cost
   - Health, safety and environment concerns
3. Identify and classify causal factors for the undesirable condition
   - Lack of/insufficient procedure
   - Lack of/insufficient training
   - Equipment/material problems
   - Lack of supervision/enforcement
   - Other
4. Identify potential action plans
5. Engage support where required
6. Perform business case analysis
7. Make a decision and act upon it

By incorporating all aspects of the inspection process into a single, multifunctional lean cell action, the likelihood of success increases and time wasted on cumbersome communication and hand-offs is minimized. Lean cells make perfect sense for a manufacturing process. Why not apply the same principles to the inspection - our primary reliability assurance process?

As for your reliability engineering team, stop using the word reliability as a synonym for maintenance. Require your reliability engineers to help you analyze, understand and mitigate risks to the value stream. Focus reliability engineering talent on each production process in the value stream. They should accompany the operations and maintenance supervisors and team members during their structured lean inspections and participate in senior management MBWA walk-throughs.

Conclusion

Gaining a step change in the performance of your plant requires a behavioral change. Continuous improvement isn't enough. Organizing for success is a critical first step. Most plants are organized to get exactly what they're getting – conflict, blaming and non-cooperation. Organize your people, your metrics, your scorecards and your inspection processes to achieve your real goal – creating value for the shareholders and stakeholders of the organization.



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condition monitoring

Oa oil analysis

Understanding the **Limitations** of Oil Analysis

Brian Thorp

It is very important to understand the limitations of test procedures used in oil analysis. If you have been in the business for awhile, you know dark oils can cause problems with laser particle counters.

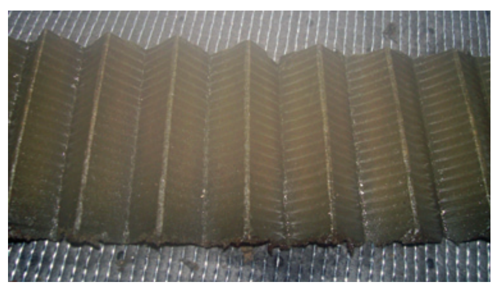


Figure 1: Babbitt flakes on filter media

Some sealants give false positives of silicates and elemental metals measurements with an ICP spectroscopy are limited to a certain range of particle size, usually four to seven microns. Generally, labs will tell you that parts per million (ppm) numbers in the one or two range can be nuisance numbers. But what about when they start trending up to 3 ppm and 4 ppm, still well below most alarm points? This is when knowledge of your equipment and other tests, such as filter debris analysis (FDA), wear debris analysis (WDA), or analytical ferrography, might need to be employed.

A recent oil analysis on a 2000 HP electric motor with sleeve bearings started trending up in tin, a babbitt-bearing component. This motor had a five year inspection/rebuild in March, 2009 with 18,925 hours run time since the rebuild. Oil analysis is done quarterly on this equipment. The tin had been ranging from 0 to 2 ppm since the rebuild baseline sample in six reports spanning 1-1/2 years. The next sample, which occurred after a shutdown, showed the tin increased to 3 ppm, then 4 ppm, 5 ppm, and 7 ppm, consecutively. Normally this wouldn't be of concern, but with low particle counts and this being one of the few large motors with a circulation/filtration system on it, further investigation was initiated.

Figure 2: Babbitt in bearing reservoir

Generally, labs will tell you that parts per million (ppm) numbers in the one or two range can be nuisance numbers. But what about when they start trending up to 3 ppm and 4 ppm, still well below most alarm points? This is when knowledge of your equipment and other tests might need to be employed.

Since there was a filter in this system, a filter debris analysis was done. Several labs have special equipment to perform FDAs, or you can cut open the filter can and remove the filter media for inspection. In a filtered system, the lubrication history of the equipment is at your fingertips for the time the filter has been in service. The filter media indicated a definite problem with one of the motor bearings. The bearing temperatures were not elevated on either bearing, thus indicating possible thrust face damage rather than radial surface damage. This is where knowing your equipment components is very helpful. The coupling guard blocked the view of the motor shaft, preventing a look for the scribe marks of magnetic center, thrust in, or thrust out locations on the shaft. In Figure 1, all of the shiny spots at the bottom of the pleats on the filter media are pieces of babbitt. The human eye can only see about 40 microns in size, so these were fairly large pieces of babbitt.

Since a scheduled shutdown was coming up soon, it was decided to increase oil sample frequency and monitor bearing temperatures closely to see if the motor could make it to the shutdown date. Oil samples were taken every two weeks, with no increase in tin found, and the bearing temperatures remained constant. When the equipment was shutdown, the as-found alignment was checked, indicating it was slightly out of specifications for the RPM, but most likely not the problem. The scribe marks on the shaft for magnetic center, thrust in and thrust out positions had worn off, but the shaft appeared to be thrust in all the way.

The outboard bearing was opened for inspection. Figure 2 shows the amount of babbitt located in the bottom of the bearing reservoir. Since this motor has a circulation/filtration system on it, the bearing reservoirs have a weir in them about three inches above the bottom to maintain proper oil level. This weir prevented most of the babbitt from leaving the reservoir and circulating in the system. Figure 3 shows the as-found condition of the bottom bearing half. The area in the red boxes is the thrust face wear, almost 0.125 inches deep. Most of the other damage to the bottom half is from babbitt roll-over from the thrust face to the radial surface. You can also note the drag out of babbitt in the right side oil relief, as well as babbitt deposited in the left side oil relief. There were slight traces of babbitt smear or buildup on the shaft, which would have caused problems eventually. The bearing temperature indication is located in the bottom center of the bearing, almost three inches from the thrust face. This distance is probably why there was no increase seen in the bearing temperature. A new bearing was fitted and installed in the outboard end. The inboard bearing was inspected and no damage was found.

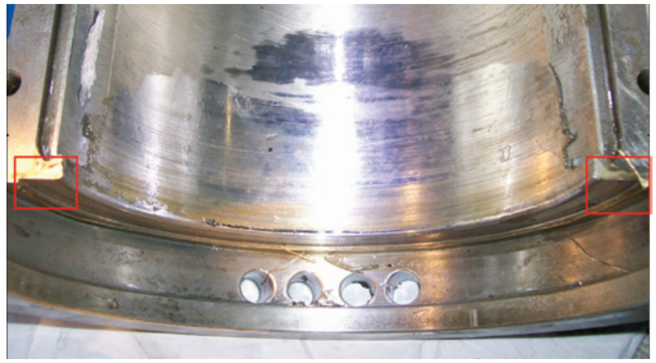
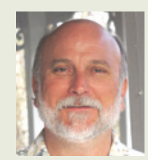


Figure 3: Bottom bearing half

CONCLUSION

This illustrates once again the value of routine oil analysis in identifying potential problems. It also shows a weakness of oil analysis, in this case by the low ppm of tin listed on the report versus the amount of babbitt found in the bearing reservoir. In this circumstance, the trend information was much more valuable than an alarm limit since most programs and labs would not flag this as a problem. Two other major factors in identifying this problem were knowledge and an understanding of the equipment and components within. The root cause analysis (RCA) of this failure was placed on improper greasing of the gear coupling during a prior shutdown. By not allowing excess grease to purge properly, it pushed the motor shaft to the thrust in position against the bearing thrust face of the outboard bearing. This situation reaffirms that if there is a doubt, have your lab run additional tests, such as WDA, ferrography, or in this case where a filtered system was involved, a FDA.



Brian Thorp has been involved with mechanics and maintenance for more than 34 years. In his current position as a Predictive Maintenance Technician with Seminole Electric Cooperative Inc., he is responsible for the lubrication and analysis for a combined total 1300 MW coal-fired power generation plant.

reliability Rca root cause analysis

FAILURE MODES:

A Closer Look at Ductile and Brittle Overload Fractures

Follow up to the article, "Preventing Mechanical Failures - An Introduction to Failure Mode Identification" - Feb/March 2012

Thomas Brown

***Is an overload fracture ductile or brittle?* This question must be answered when analyzing parts. Mitigating factors that can impact the answer to this question should be considered when analyzing a failed component.**

Metals are frequently thought of as ductile or brittle. However, they sometimes behave differently when they fail from an overload. A ductile metal may act as if it were brittle. A brittle metal may behave in a ductile manner.

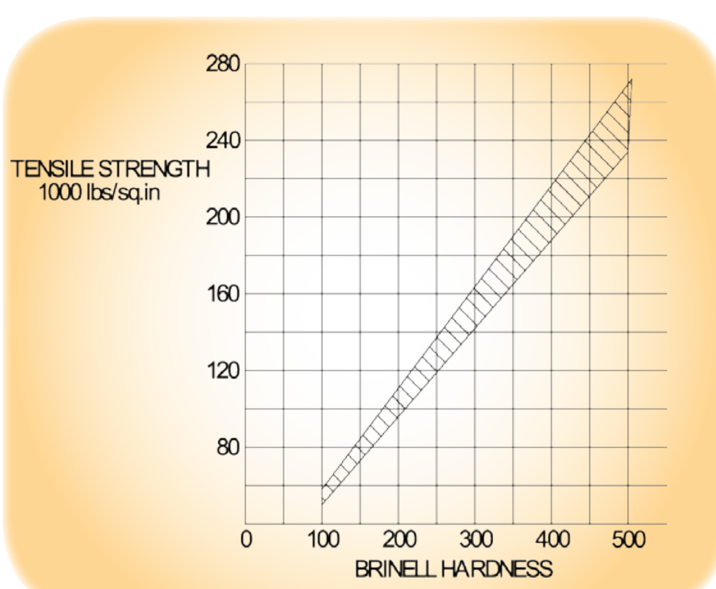


Figure 1: Steel Hardness vs. Strength

Ductile materials frequently undergo brittle fracture. Inherently, brittle materials rarely crack in a ductile mode.

The factors that cause these different behaviors include: strength, temperature, rate of loading, stress concentrations, size and various combinations.

Strength

Strength is the most obvious determinant of a metal's behavior when it is overloaded. In general, soft tough metals will be ductile. Harder, stronger metals tend to be more brittle. The relationship between strength and hardness is a good way to predict behavior. Mild steel (AISI 1020) is soft and ductile; bearing steel, on the other hand, is strong but very brittle. The relationship between strength and hardness of steel is shown in Figure 1.

The elongation (stretch per unit of length) percentage, usually given as % in 2-inch length, is also a means of judging ductility. More ductile metals have greater elongation. For example, the elongation of harder and stronger 4340 quenched and tempered steel is about 16%, while elongation of more ductile hot rolled 1018 steel is about 36%.

There are exceptions to this relationship. The most common exception is grey cast iron, which is quite brittle even though it is fairly soft. Its composition of sharp-edged graphite flakes creates stress concentrations that override the ductility of the iron.

Temperature

Temperature has a significant affect on the ductility of metals. Low temperature decreases ductility, while high temperature increases it. When a part is overloaded at low temperatures, a brittle fracture is more likely to occur. At high temperatures, a more ductile fracture is likely to occur.

Lower strength steel (less carbon and alloys) maintains ductility (toughness) as temperature decreases. When steel strength increases (more carbon and alloys), ductility drops more quickly as temperature decreases.

The dominant factor causing brittle metals to become more ductile is high temperature.

The steels in the Charpy impact test chart (Figure 2) show this change. Higher strength steels with carbon above 0.30% begin to lose ductility (toughness) below room temperature. Low carbon steels (0.20% carbon or less) do not begin to lose ductility until temperatures reach freezing (32°F).

There are exceptions to this relationship. Stainless steels maintain their toughness at low temperatures. However, stainless steels may become work hardened and also lose ductility.

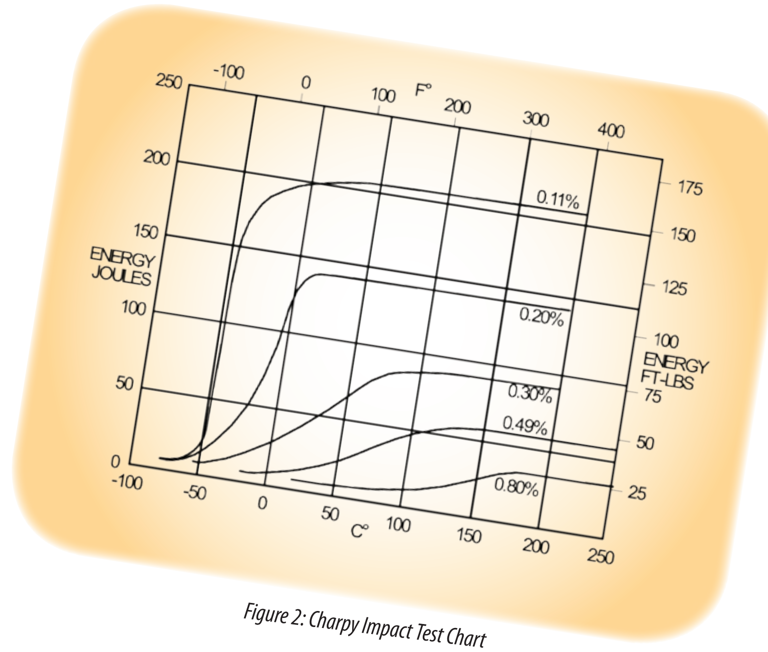


Figure 2: Charpy Impact Test Chart

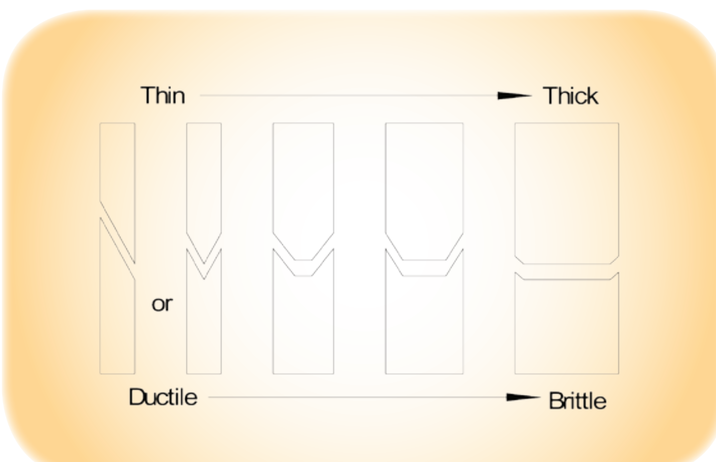


Figure 3: Ductile metals behaving more like a brittle metal

Rate of Loading

When an overload happens slowly, there is enough time for microscopic movements in the metal to occur. The metal deforms plastically before finally breaking. Sudden impact frequently causes a ductile material to behave in a brittle manner. There is not enough time for microscopic movements to take place. Brittle behavior is often seen in a catastrophic failure when the overload is very sudden.

Stress Concentrations

Changes in geometry, such as keyways, diameter changes, notches, grooves, holes and corrosion, result in localized areas where the stress is much higher than in the adjacent region of a part.

In regions where there is no stress concentration, it is easier for microscopic movements to occur. In this case, the metal behaves in a ductile manner. A stress concentration does not allow microscopic movements, so brittle fracture is more likely.

Size

Thin parts are more likely to fail in a ductile manner when overloaded. Large or thicker parts will behave more like a brittle metal when overloaded because the geometry does not allow stress to be evenly distributed. Figure 3 shows the effect of size. Thin parts will usually have a shear lip or fracture at an angle; this is characteristic of a ductile fracture. The shear lip becomes smaller as thickness increases and the fracture becomes more brittle.

Interactions

Figure 4 summarizes the factors that may be present in an overload failure. These frequently occur in many combinations and are subject to many complications in specific applications. If they are recognized as trends, they will help guide the analysis.

Factor	Effect	
	Ductile	Brittle
Strength	Lower	Higher
Temperature	Higher	Lower
Rate of loading	Slow	Fast
Stress Concentrations	None	More/Severe
Size	Small/thin	Large/thick

Figure 4: Summary of factors affecting overload fractures

Figure 5: A brittle fracture of a journal. A piece was cut out for metallurgical analysis.

Figure 6: Broken link from a hoist chain

For example: If a ductile part has severe stress concentrations from corrosion or improper machining and receives an impact, the resulting fracture will have features of a brittle fracture.

The following examples illustrate the importance and interplay of these factors.

Brittle fracture of a ductile material

The roll journal in Figure 5 is made from annealed 4140 steel. Its hardness was about 190 BHN and elongation 26%, characteristic of a more ductile metal. The journal fractured as a fully loaded roll was set into stands using a crane. The brittle fracture happened because three factors were present:

Stress concentrations - severe

- The journal had been repaired; the diameter was decreased and a radius cut at the location of the failure.
- A fatigue crack started in the radius, further increasing the stress concentration.

Rate of loading - high

- When the journal failed, the roll was being lowered into stands.

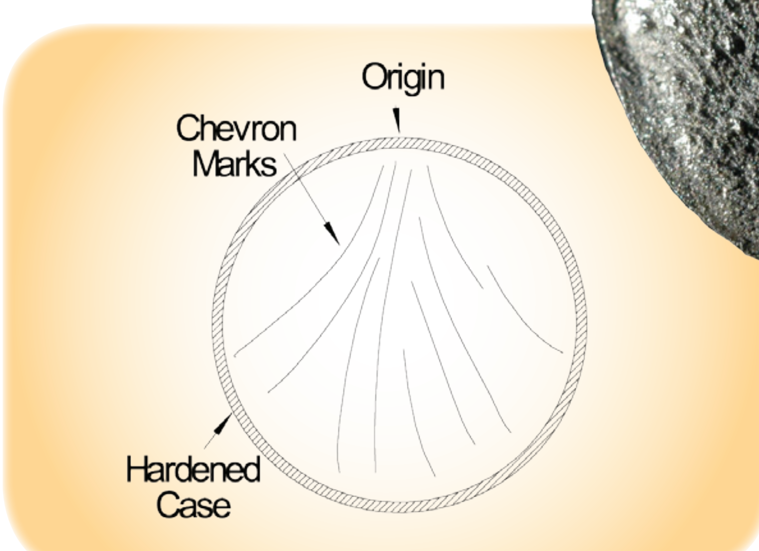
Size - large

- The diameter of the journal was 4 inches.

Remedy

- Reduce the stress concentrations by correctly machining and repairing the journal.

Figure 7: Brittle fracture face



Failure of high strength plate at low temperature

High strength plate was substituted for mild steel in a conveyor transfer point. This was done because the mild steel plate was bent by repeated impact of large material pieces hitting it. As winter approached and the temperature dropped, the high strength plate began to fracture. It had to be replaced in the middle of winter.

Strength – high

- High strength steel was substituted for the ductile low strength mild steel.

Temperature – low

- The ability of the high strength steel to absorb energy (ductile to brittle transition) decreased very rapidly as the temperature fell.

Remedy

- Use thicker mild steel that maintains ductility at low temperature.

Sudden overload

The hoist chain in Figure 6 failed in two places. The fracture on the top of Figure 6 is a fatigue fracture caused by repeated loading. The brittle fracture at the bottom of the link in Figure 6 occurred immediately after the fatigue fracture occurred.

The link deformed, indicating it was moderately ductile (344 BHN). The suddenly increased load on the remaining side resulted in the brittle fracture. The chevron marks of the brittle fracture are visible in Figure 7. (opposite page)

Strength – high

- The chain was case hardened with a softer core. Tensile strength was approximately 160,000 psi.

Rate of loading – high

- When the first fracture occurred, the entire load was instantaneously transferred to the remaining side.

Remedy

- Periodically inspect chain for damage caused by improper use or maintenance

Take all the factors into consideration that may influence an overload fracture. An incorrect diagnosis can be hazardous and expensive for all concerned. When looking at a ductile or brittle overload fracture, remember there is frequently more than meets the eye.

Thomas Brown, P.E. is the principal engineer of Reliability Solutions headquartered in Duluth, MN. Tom uses his extensive experience to analyze machinery and component failures, provide vibration analysis and essential reliability skills training. www.reliabilitysolutions.us.

Strong Predictive Maintenance Program Boosts UPTIME to Meet Growing Demand for Recycled Papers

Paul DeHaan and Matthew Schmandt

As the only paper mill in North America dedicated to producing coated mechanical printing papers made from nearly 100 percent recycled materials, FutureMark Paper Company is in the enviable position of having just what customers want – environmentally-friendly products that meet high print-quality standards for magazines, books, catalogs and advertising flyers.

In fact, customer demand was so great that our one paper machine was hard pressed to keep up. We had to turn some customers away, which meant the company was essentially leaving money on the table.

To meet the growing demand for high-recycled printing paper, our plant in Alsip, Illinois, was under pressure to increase production. Investing in additional capacity was not in our budget; the mill had already invested more than $250 million on equipment and processes over the past decade. Instead, the production increase we sought would have to come from boosting our manufacturing efficiency.

In the summer of 2009, FutureMark Paper embarked on a program to improve the time efficiency of our paper machine, i.e., the amount of time we were actually able to make paper. This meant not only improving overall manufacturing performance, but also minimizing unscheduled machine downtime. At that time, FutureMark's maintenance was almost totally reactive, as the workers went from one emergency situation to the next "putting out fires," but never able to sustain planned maintenance for any prolonged period.

> ***During the first six months of 2011, we recorded a production increase of 13 percent versus the same six-month period in 2010 with no change of equipment.***

Recognizing a need for specialized maintenance expertise, mill management contracted with Emerson Process Management's Asset Optimization Services in Nashville, Tennessee, to utilize technology as a means of "predicting" potential failures. Several factors drove the decision to use an outside source rather than develop in-house expertise:

- The time and cost to equip and develop in-house personnel in specialized disciplines, such as vibration analysis, were beyond our budget and would have delayed the start time for a much-needed reliability program by six months or more.
- Vibration signatures are not fully useful without an extensive database documenting observed changes in the vibration signature leading up to failures. We would have had to suffer many failures to build a sufficient history, whereas this knowledge base already existed.
- We were able to combine and enhance the coverage of several preventive maintenance contractors into a single contract, enabling us to get better service for a lower overall cost.

For these reasons, an Emerson employee was assigned full time as an on-site asset manager with instructions to implement a predictive maintenance program based on analyzing vibration data collected from rotating equipment throughout the mill.

The vibration level at thousands of points is measured monthly using a portable analyzer and the daily results are uploaded to a machinery managing software program. The monitoring program now encompasses about 800 pieces of equipment from pumps, compressors, agitators and rolling drums to hundreds of bearings on paper machine rolls.

This software provides the basis for our predictive maintenance program, which is largely responsible for early identification of mechanical faults so corrective action can be taken to avoid machinery failures. As a result, we've seen a 6.8 percent increase in time efficiency on the paper machine and the impact on productivity has been amazing. During the first six months of 2011, we recorded a production increase of 13 percent versus the same six-month period in 2010 with no change of equipment. This productivity boost means FutureMark Paper is now able to meet higher aggregate demand for our high-recycled paper products, and that translates into millions of dollars in additional revenue.

The key to this exceptional about-face, we believe, is technology that enables us to "see into the future" by an on-site asset manager who fits neatly into our organization, working closely with mill management and supervisory personnel. The asset manager provides a variety of reliability services, but they didn't materialize overnight. First, the entire asset database had to be restructured, including a number of pieces of equipment not previously monitored for excessive vibration. Additional resources were brought in to do motor current evaluations and establish vibration signatures on every piece of rotating equipment. These became baselines against which to make predictions using advanced vibration analysis.

The on-site asset manager now spends about 3 1/2 weeks each month gathering data, giving us a unique perspective on every critical point in the mill. By using this information to track trends, it can be predicted how long an asset should continue to run and perform well. The asset manager issues a monthly exception report listing five to 20 pieces of equipment that need attention because of abnormal vibration levels. The maintenance department uses this information to *prioritize and plan* work in order to prevent failures and avoid those debilitating shutdowns.

In case of a rapidly developing fault, the asset manager is free to go straight to any supervisor in any area and discuss the situation. The asset manager is also empowered to initiate immediate action if a failure is highly likely and may happen soon. With more than 800 pieces of machinery being monitored, this actually occurs quite frequently, giving managers time to formulate a plan of action to prevent costly shutdowns.

For example, not long ago, plant personnel noticed severe vibration near a drum pulper, which is a very large rotating cylinder that sits on 10 rollers. Recycled materials go up a conveyor and drop into this machine, where unwanted debris is removed and water is added to begin the pulping process. The floor was shaking, but we didn't know the root cause of the problem or how long it would be before something broke. A one-time, shaft speed abnormal frequency was identified as coming from a specific roller, so we knew exactly where to look. The machine was shut down long enough to make a visual inspection, and after removing the protective shielding, we could see that a piece of metal had broken off the roller and was scraping against the outer surface of the drum. Obviously, the roller had to be changed, but we knew this situation would not cause the machine to stop running. A decision was made to restart the drum and continue to operate until a planned shutdown in about a month. The faulty roller was eventually replaced and the drum restarted with no difficulty.

Issues like that are common, so the ability to control a potential failure is priceless. We're normally able to make timely repairs based on *knowledge,* not guesswork, to avoid unplanned downtime.

On the other hand, in an extreme situation, we will react immediately because a short-term stoppage is better than running all-out into a catastrophic breakdown. It's all about being able to quickly and accurately identify a problem and get to the root cause so it can be fixed once and for all.

Being proactive rather than reactive has meant a great deal to FutureMark. Our efficiency, all our critical factors and our productivity continue to improve.

Predictive maintenance is an effective solution based on technology that delivers actionable information which allows us to prioritize maintenance activities.

Other technologies are also employed to help save money. For example, air leak surveys using an ultrasonic measuring device frequently spot pressurized air system leaks that cannot be heard in the noisy mill, but are the sound of wasted energy. Leaks found in this way are mapped and prioritized, so maintenance crews know exactly where to go to make repairs that will save the most money. In fact, 115 leaks have been identified and fixed since this program's inception. We know this has reduced the load on two very large air compressors and had a direct impact on energy savings. The amount of wear and tear on the equipment has been reduced as well.

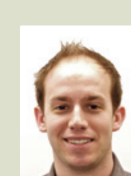
In addition, thermographic surveys help locate "hot spots" that indicate a potential mechanical failure, wasted energy, or both. Motor current analyses can reveal loose electrical connections or a motor going bad. The use of these technologies has also prevented unexpected downtime and saved money on repairs and lost energy.

Being proactive rather than reactive has meant a great deal to FutureMark. Our efficiency, all our critical factors and our productivity continue to improve. The on-site asset manager understands the operation of this mill, responds when necessary and works very well with our personnel. It's a great partnership.

We are now able to run the paper machine the way we want to run it as opposed to reacting to the needs of the machine. It's not just uptime; we now have much greater operating flexibility and have even been able to use our higher production capacity to develop a whole new product line. Our new high-recycled coated book paper has been greeted enthusiastically by a number of book publishers and their customers.

Recycled paper and predictive maintenance are both ideas whose time has come.

Paul DeHaan (left) and Matt Schmandt (right) oversee the predictive maintenance program at FutureMark Paper Company, North America's leading producer of high-recycled coated publication paper. Paul is FutureMark's Director of Maintenance & Operational Excellence. Matt is the company's lead reliability engineer. www.futuremarkpaper.com



Part 1

WHEN DECIBELS AREN'T ENOUGH

Jim Hall

For years, I have preached about trending motor bearing readings when using ultrasound. The most common practice is to acquire a baseline (db reading) and then follow-up at 90-, 60-, or 30-day intervals. I still recommend that you continue to trend your decibels on motor bearings.

If decibels increase over a period of time or continue upwards from a previous read, you should lubricate and if no significant difference is noted, then you must assume the bearing is headed to failure. Watching the decibel levels over time will assist you in determining first or early failure to a catastrophic failure. Ultrasound is the earliest indication of bearing failures, before heat and before vibration.

Figure 1: Taking ultrasonic readings of pump/motor 4.
Photo Courtesy of: Jim Hall, Ultrasound Technologies Training Systems

It's important to remember that the ultrasound instrument is a high-frequency receiver that receives a high frequency shortwave signal measuring from 1/8-inch to 5/8-inch long, is low energy and mostly travels in straight lines, making it directional. If you take a reading at the base of the Zerk fitting, for instance, return to that location for repeatability (Figure 1).

You want consistent readings when trending bearings on a motor. You want to measure "apples to apples" and "oranges to oranges," or non-drive end to non-drive end, etc. Most ultrasound instruments allow the user to set the instrument at the previous sensitivity and frequency settings so the end-user can quickly see any differences from the previous reading.

Are you using multiple instruments from two or more manufacturers or two or more models from the same manufacturer? If so, know your instrument! Be familiar with the instrument's sensitivity or amplitude level. Is the instrument linear across all ranges of sensitivity or amplitude?

Recently, I visited a waterpark where the maintenance superintendent and I are good friends. He explained that they had nothing but hands, fingers and ears to diagnose bearing failures. I told him that ultrasound is the most complete instrument a mechanic can have. It's inexpensive, it has a multitude of applications and the return on investment, in most cases, is immediate.

Figure 2: Locating underground waterline leaks in kiddie pool area of waterpark. Photo Courtesy of: Jim Hall, All Leak Detection & Locate

I've been serving this waterpark for a couple of years now, providing underground leak locating services (Figure 2). Occasionally, I would watch as the technicians listened for bearing sounds and touched the motor with their hand, purposely raising their index finger as if to feel for vibrations, thinking this alone would aid them in determining whether or not they had a bad motor bearing.

Out of the eight pumps and motors of the waterpark's filtration system, five 60 hp motors and three 50 hp motors were coupled by a flex coupling to a pump.

With no real predictive maintenance program and no predictive maintenance equipment, my maintenance superintendent friend was facing the "perfect storm" for failures. Flex couplings between the motor and the pumps are fine, especially when no alignment tools other than a straightedge were used to align the motor and pump. A flex coupling may correct some misalignment, but when the ability of the flex coupling to correct is exceeded, the motor, pump, or both may be headed for failure.

We took several readings of the 60 hp motor bearings (outboard/inboard) using an ultrasonic pistol. Readings were in the mid-range of 35 to 45 decibels. However, one pump was trending at 53 decibels. It also had a loud pitch, an overall loudness that really didn't sound like bearings.

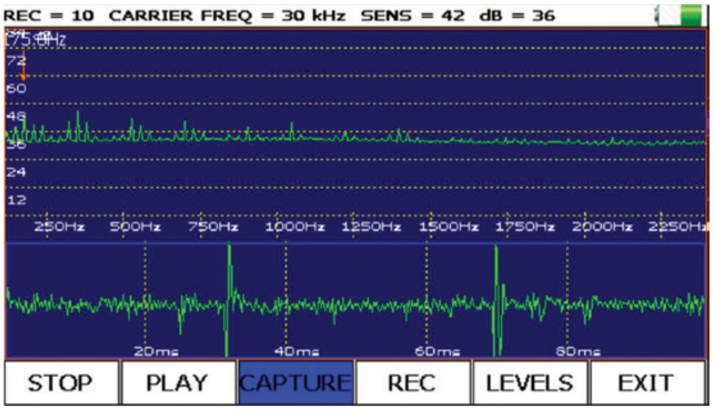
Puzzled by this, we took a reading with a vibration data collector. The vibration analysis indicated an imbalance problem, but not a significant bearing problem as of yet.

Figure 3: Adrian Messer, UE Systems, Inc., ultrasonic inspection of bearings.

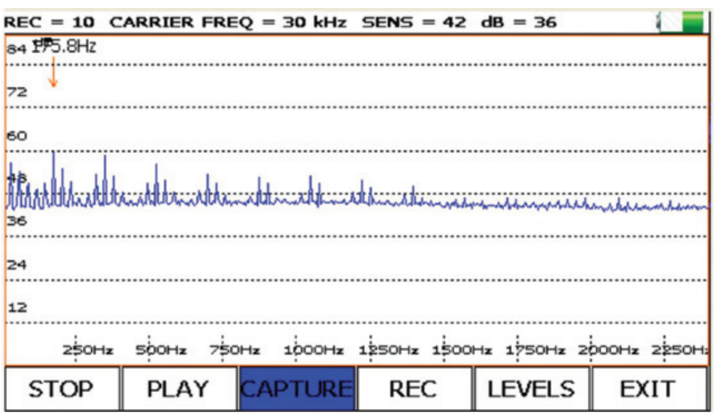
Fast forward a few months. All eight of the filtration motor and pumps were removed, the old motor stands replaced and the flex couplings (motor/pump) replaced with a direct drive setup. Still wanting to engage the waterpark in the idea of trending its pumps, I called once more and proposed taking readings and preparing a database for future readings. This time I was joined by Adrian Messer, Manager of U.S. Operations for UE Systems, Inc. (Figure 3). Adrian brought with him a new state-of-the-art ultrasound instrument. The fairly new instrument has tons of onscreen applications at your fingertips.

With the UE Systems' Ultraprobe 15000 Touch instrument set for dual display of fast fourier transform (FFT) and the time waveform chosen (Figure 4a, next page), we watched and listened. What we saw clearly was significant harmonics. Was it harmonics from the inner, outer, cage, ball pass frequencies? We didn't know right away. Changing the display to just FFT (Figure 4b, next page), we noticed a cursor highlighting a fault frequency of 175.8.

The latest version of advance spectra analysis software has a new on screen bearing calculator. The end-user simply enters the RPM and how many balls or roller elements are in the bearing. You can also select *outer*



Figures 4a & 4b: Dual display of the Ultraprobe 15000® instrument used above, FFT (top) and time waveform (bottom). FFT only below. Users have their choice of views.



race, *inner race*, *ball pass*, or *cage frequencies* (see Figures 5a and 5b). On pump #4, our harmonic cursor indicated the *inner race* bearing frequencies as the problem.

Still not satisfied with the results, I forwarded the findings to Peter Marquardt of Predictive Maintenance LLC in West Point, Virginia. Pete is certified Ultrasound Inspector Level II and Vibration Analyst Level II. He offers services in vibration analysis, thermal imaging, ultrasonic leak detection, ultrasonic bearing analysis, precision laser alignment, field balancing and consulting.

Pete wrote in his reply to me, "Utilizing the ultrasound data collected at the filtration pump/motor number four 'outboard' bearing, from a vibration analysis point of view and without actually having been there to collect this data using my own vibration analyzer, I was able to determine the 6212 bearing has an inner race defect. A normal 6212 bearing has 10 rolling elements. At 1750 rpm, this bearing would produce a vibration at inner race frequency of around 175Hz. The FFT data shown on the image sent has a dominant harmonic of 172Hz. This, along with the running speed sidebands and running speed harmonics, would indicate the most reasonable conclusion for this analysis. Inner race defects will usually produce these running speed harmonics as the race goes in and out the load zone once per revolution. The ultrasonic waveform data in live mode also shows this impacting with a slight ring down."

Trending bearings with decibels alone may sometimes not be enough. Recording a wav file, either with an ultrasound instrument or a simpler digital recorder, and then analyzing the wav file further in a FFT or time waveform diagnostic software may be your next great move. However, I must caution anyone wanting to utilize FFT or time waveform to make a diagnosis that you should first understand how to properly capture repeatable signals for analysis.

Randy Stiver, the Ultrasound Level II Certification Program instructor at Ultrasound Technologies Training Systems (USTTS), demonstrates to Ultrasound Level II (USTTS-II) attendees how to properly capture ultrasonic detector output signals using digital recorders, vibration spectrum analyzers, oscilloscopes and personal computers. The use and understanding of the captured signals are then used for analysis. This better equips even the novice in the fundamentals of sound analysis when using FFTs and time waveform along with ultrasound frequencies to determine faults.

Can ultrasound determine every fault each time? No. Therefore, you should still utilize, if available, vibration analyzers, oil analysis, infrared and ultrasound instruments. Their usage is especially important when you're in doubt or mission critical depends on a motors operation.

**Note: Look for an update on this article late 2012, after another bearing survey of the eight motors and pumps is performed in Summer 2012.*

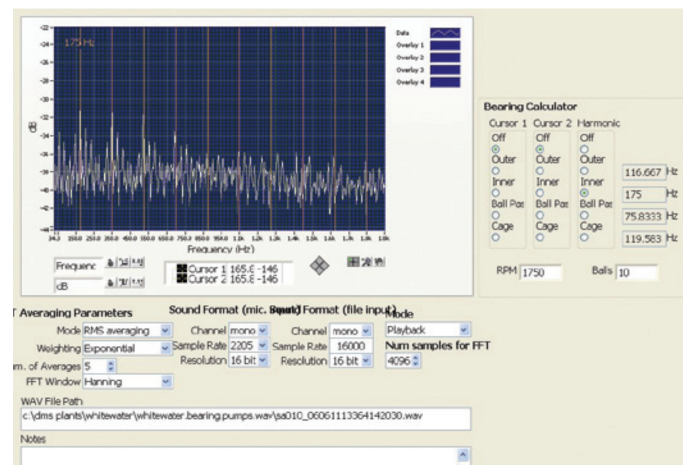


Figure 5a: Pump motor No. 4, played through software identifies inner race problem.
Photo Courtesy of: Jim Hall, Ultrasound Technologies Training Systems

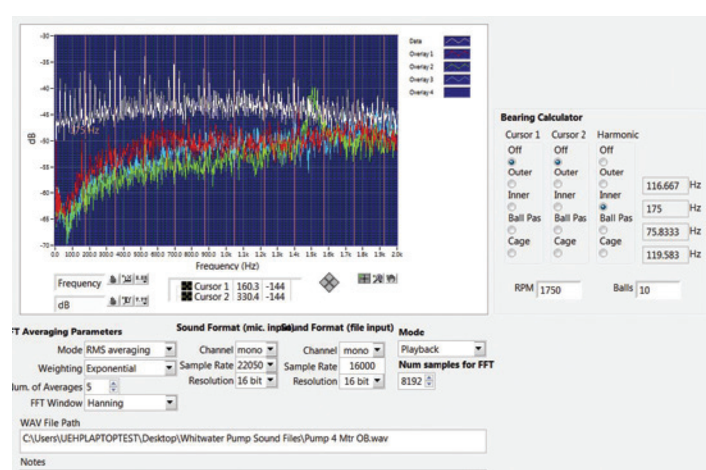
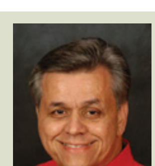


Figure 5b: All five pump motors overlay. Notice No. 4 with inner race in "white" coloring.
Photo Courtesy of: Adrian Messer, UE Systems, Inc.



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).

Operator-Driven Reliability Best Practices Series:

"Leadership Wanted"

Whether leadership is recruited or cultivated within your own organization, successful operator-driven reliability (ODR) programs rely on it. Leadership can come from many places in your organization's structure, from top management to the frontline operators.

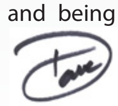
Leaders don't necessarily have to be in a position of authority, but they all have one thing in common - they are excellent at organizing a group of people to achieve a common goal or vision. Therefore, it is imperative to have that vision well defined. Your ODR program has to have a well-articulated vision, preferably in writing, and be well communicated throughout the organization. Defining the ODR vision can be as easy as answering this simple question: How will your operators contribute to the maintenance process and overall reliability of the equipment they operate?

Visions differ from company to company. The answer to the aforementioned question must fit with your business goals and corporate culture. It should also incorporate your current reliability strategies and practices. So don't just adopt some other company's vision. Define your own ODR vision then strive to make it become a reality in your organization.

Top management leadership is critical in the successful implementation of an ODR program. Support must come from the top; they must show commitment to ODR. This gives the program credibility and ensures proper funding and resources are available. This top-level support also ensures the program has good visibility and demonstrates its importance within the company.

But do not stop at the top! It's just as important to garner commitment, ownership and accountability from the operations team. Since ODR is a process that operations will own, it needs to take a leadership role from the start. It is very difficult for operations personnel to adopt and execute operational changes if they do not have a role in leading and designing the program. Identify operations' key supporters as they are a great source for quick wins. Start recruiting ODR sponsors and champions within the operations team and allow them to be leaders throughout the program development and rollout.

Finally, delivering ODR results is an enterprise-wide endeavor. In fact, the best ODR programs rely on leadership from other company areas, like engineering, maintenance, procurement and planning. ODR needs multidisciplinary support to be successful. You need a broad perspective of other departmental disciplines to have an impact on asset and process reliability and performance. For example, oil leaks must get fixed, inferior quality assets need to be upgraded, maintenance practices need to be improved to precision standards – all of these things are important. Great leaders are not always easy to find. However, they are the key to implementing and sustaining ODR by assuring people are doing the right things and being held accountable for producing excellent results.



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 6 years Dave has been focused on helping customers implement and sustain Operator Driven Reliability programs. www.skf.com

Figures in this article were misplaced in the Feb/March 2012 issue. Here is the correct reprint.

Understanding & Comparing Risk

Understanding Risk

In the Oct/Nov11 edition of *Uptime*, a concept of risk was introduced that utilized a Euclidean distance of probability and consequence, mathematically written as Risk^2 = Probability^2 + Consequence^2

The author claimed that "this [method] provides for accurate comparison of relative risk."[1] The purpose of this article is to explain the conflict between traditional risk calculation methods and distance methods, as well as the potential poor business decision that could result from using distance methods. For the purpose of this article, the Euclidean distance for assessing risk as described in the original article will be called the "positional risk."

Brian Y. Webster

The method described in the original article basically assumes that adding a consequence and a probability together will yield a meaningful number. If we add the two numbers together, which do not have the same units of measure, the end result is meaningless. For example, would an electrician add the voltage and the amperage of an electrical motor to determine the wattage? (Hopefully not.) A strong caution about the use of distance methods for risk assessments is probably best stated by Edmund H. Conrow in his book, *Effective Risk Management: Some Keys to Success:*

*"**There are innumerable representations of risk possible, but most do not appear to have a convincing mathematical and probabilistic basis. Computation of risk should generally be performed using a simple multiplicative representation (P * C), assuming the underlying data do not violate any mathematical or probabilistic principle.**"*[2]

Understanding risk is important for making sound business decisions. If the basis for understanding risk is flawed, then businesses are making decisions on flawed information. Unfortunately, the distance method (Euclidean distance or "positional risk") described to calculate risk represents a potentially poor understanding of risk, which could lead to making poor decisions. Prior to looking at an example of how distance methods could lead to poor business decisions, we will first look at risk.

What is Risk?

ISO 31000 and ISO 73 both define risk as the "effect of uncertainty on objectives."[3] This broad definition encompasses: 1) Either a positive or negative effect, 2) Objectives that can reflect one or many different categories, such as safety, environmental, or financial goals, and 3) The uncertainty reflecting the likelihood (probability) of events actually occurring. This broad definition allows for qualitative, semi-quantitative, and quantitative risk analysis of the consequences and associated probabilities.[4]

Correspondingly, risk has been traditionally defined as the likelihood and the consequence of an event where the expected value of the risk is expressed mathematically as:

Risk = Consequence * Probability.[5]

I refer to this as traditional risk. This basic mathematical and probabilistic concept of risk is used for common industry tools, such as event tree analysis, fault tree analysis, Monte Carlo simulations and other tools. In addition, this definition of risk has been used in many industries (insurance, refining, medical research, statistics, banking, etc.) for many years. Furthermore, the mathematics supporting this method also allows cumulative risk to be calculated.[6] Thus, we have strong reasons for using the traditional quantitative risk analysis.

Visual Representation of Risk

Since the positional risk in the original article was applied on a risk matrix, we should discuss risk matrices and how they illustrate risk. There are numerous methods and approaches for risk matrices.[7] A risk matrix can often be developed where the probability and consequence axes have quantitative scales in conjunction with qualitative descriptors.[8] The quantitative scales allow for the calculation of risk using the traditional C * P method, while visually representing the increasing levels of risk by color. An example of a risk matrix is shown in Figure 1. This example risk matrix utilizes qualitative descriptors, associated quantitative scales that have a log-log scale and a color scheme that reflects relative risk that is consistent with the calculated expected value of the risk.

Often, the quantitative scales will use a log-log scale to allow the risk matrix to represent a very wide spectrum of risk. Within some industries, risk matrices that have a range of four to five orders of magnitude are used on a daily basis. For consequences, the matrix could show the progression from a slight injury to a minor injury to a major injury to fatalities to multiple fatalities. For the probability, the matrix could show a 0.1% to a 1% to a 10% to a 100% probability that an event could occur within a year. It is important to keep in mind that risk matrices are typically not linear and represent exponential increases in magnitude along the axes. In general, risk matrices may vary by design, application and color coding, meaning we should be mindful of applying any generalizations.

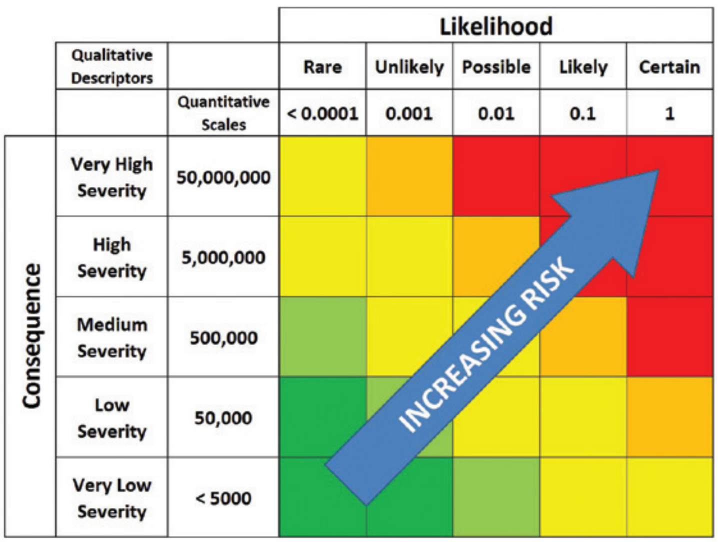


Figure 1: Example of a 5x5 risk matrix using log-log quantitative scales.

Comparing Positional Risk to Traditional Risk Methods

To illustrate the difference between positional risk and traditional risk, we will compare constant risk as defined by each method. The visual representation of constant risk is similar to isolines (lines of constant elevation) on a contour map. Both conflicting definitions (traditional vs. positional) of risk can be represented by lines of constant risk, much like lines of constant elevation on a map. In a contour map, the elevation is set to a constant level and the lines represent the constant elevation using longitude and latitude as the axes. With risk, we can set the risk to be a constant level and chart the constant risk with consequence and probability axes.

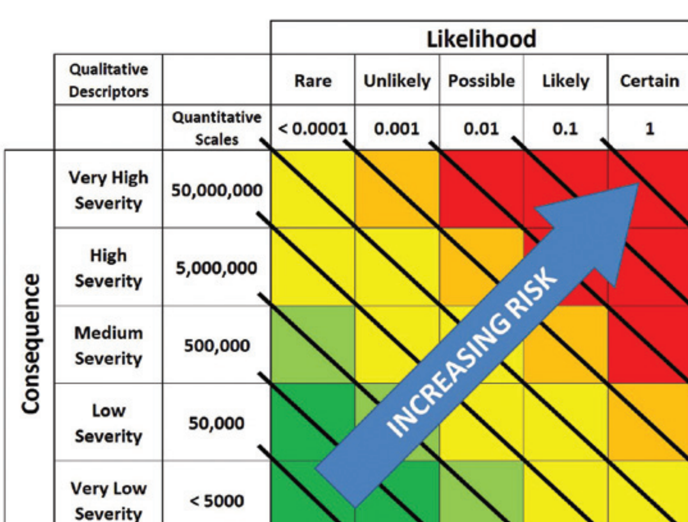


Figure 2: Example risk matrix with superimposed constant risk contour lines as described by the traditional risk definition.

In the traditional risk definition, constant risk appears as straight lines on log-log scale charts (similar to many quantitative risk matrices). An example of constant risk lines using the traditional risk definition are illustrated on a risk matrix with a log-log quantitative scale shown in Figure 2. Also visible in Figure 2, the lines of constant risk run parallel, with the color changes representing increasing risk levels.

In the distance method proposed (positional risk), the constant risk is a fixed distance from the origin point of the graph, which looks like concentric quarter circles. An example of constant risk lines using the positional risk method is shown in Figure 3.

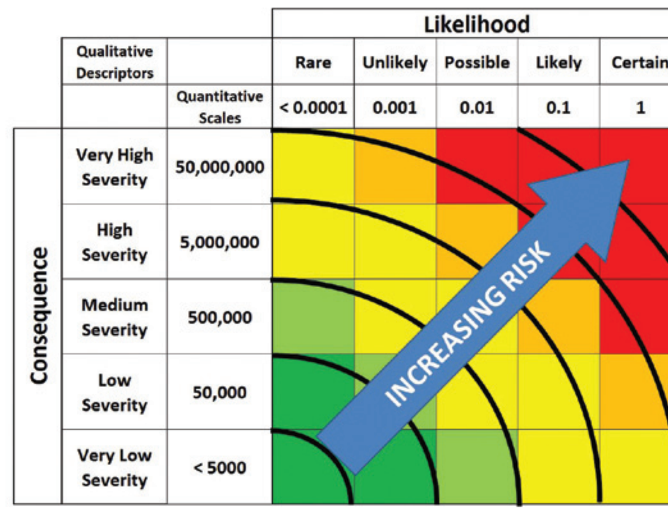


Figure 3: Example risk matrix with superimposed constant risk contour lines as described by a distance method ("positional risk") definition.

A problem becomes immediately clear with the positional risk in Figure 3, whereas the constant risk lines wander through several levels of differing risk. In Figure 3, the constant risk line starting in the upper left moves from yellow to orange to red and back again, which indicates that the risk is not nearly as constant as proposed.

To further illustrate the difference between traditional risk and positional risk, we can compare the two methods, as shown in Figure 4. In the figure, we have superimposed two constant traditional risk lines with

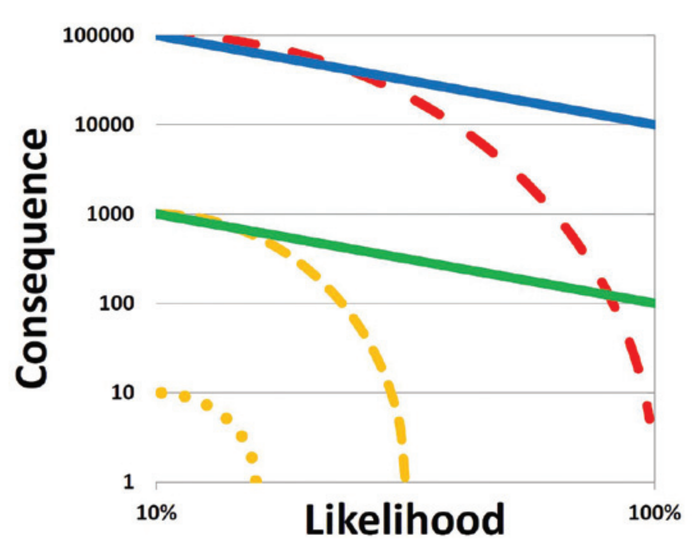


Figure 4: Quantitative comparison of traditional and "positional" risk with a 10% to 100% likelihood scale.

three constant distance lines. The traditional risk is represented by two constant risk lines shown by the blue and green straight lines, while the positional risk is represented by the dashed lines. For the purpose of the example, we are using probabilities from 10% to 100% likelihood and consequences of $1 to $100,000, much like the risk matrix in Figure 1 but with reduced scales on the x-axis. In Figure 4, the perceived slope of the traditional constant risk lines, as compared to Figure 2, has changed due to the x-axis scale, but the underlying mathematics and actual values of the risk have not been affected by the change in scale.

Difference Between Risk Definitions

We can calculate the difference between the traditional risk calculation method and the positional risk method. First, we need a starting point where the two methods agree on the risk. This is a single point where the probability and consequence are the same for both methods, i.e. where lines intersect. In Figure 4, the solid blue line and the dashed red line intersect at a probability of 10% and a consequence of $100,000. By calculating the risk along the paths of the red and blue lines, the differences in risk level can be shown as a percent difference between the two. Figure 5 shows the calculated deviation between the traditional risk calculation method and the positional risk calculation method, which varies from +80% to -100% of the traditional method of evaluating the level of risk.

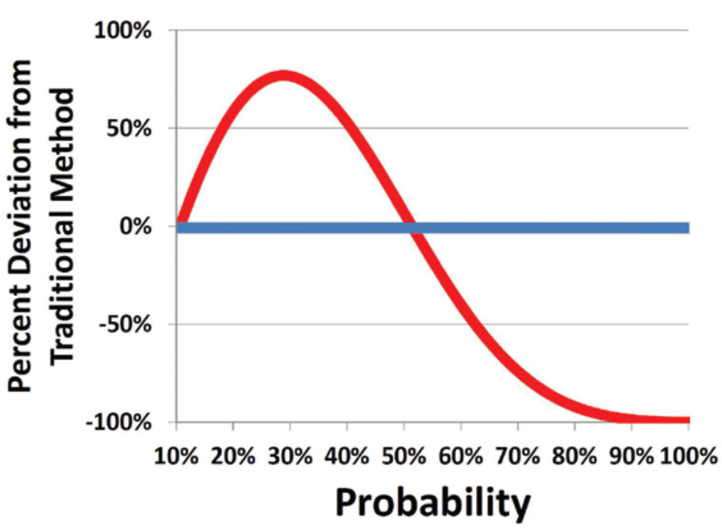


Figure 5: Percent deviation of the "positional risk" method (red line) from the traditional method (blue line) constant risk lines in the Figure 4 example.

Impact from Misunderstandig Risk Example

Given the magnitude of the deviation between the traditional risk and positional risk, we should look at how the difference of risk measurement could impact business decisions. Suppose we have a problem, Option A, within our hypothetical plant that has a 95% probability of occurring with a consequence of roughly $100. We can graphically represent this as arrow "A" in Figure 6. The length of arrow "A" shows the positional risk method for calculating risk. We also see the traditional definition of risk associated with the problem being shown as the green line.

To eliminate this problem, our hypothetical plant underwent an improvement effort to develop a solution. The proposed solution, Option B, resulted in changing the risk, as shown by arrow "B." Using the positional risk method, the risk of Option B was less than arrow "A" because the length of arrow "B" was shorter than arrow "A." If we had used the traditional risk method, we would have understood that both Option A (the original problem) and Option B (the proposed solution) have the same risk level as represented by the green line.

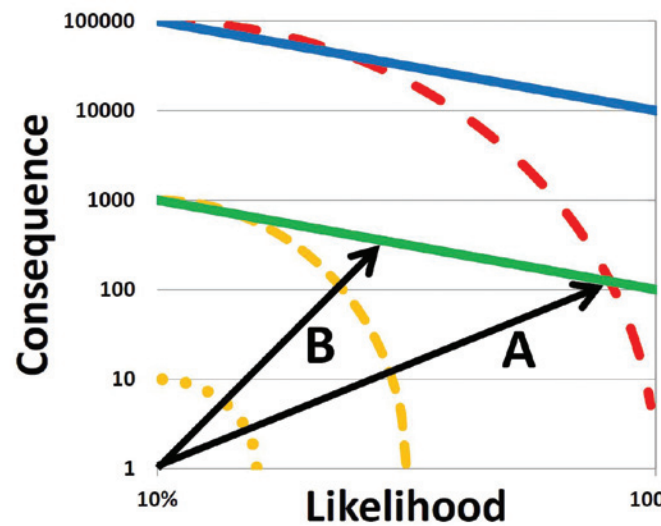


Figure 6: "Positional risk" incorrectly shows improvement from A to B, whereas actual risk has remained constant.

Thus, if we had used the positional risk in our risk assessment for our project screening and approval process, we would have approved and implemented a project that would not have reduced the overall risk of our hypothetical plant. With respect to the project, we would have had a negative return on our investment even though the positional risk clearly (and incorrectly) showed an improvement.

Conclusion

The use of Euclidean distance for comparing and assessing risk is not consistent with the mathematics used in other industry-accepted reliability and risk analysis methods. Without a solid understanding of the risk, we have incomplete information to make sound business decisions. ISO 73 and 31000 may allow for a broad range of risk analysis methods, but the practitioner should be mindful of the limitations of the methods, tools, underlying assumptions, limitations and objectives when using various methods to assess risk. Thus, caution should be used when using Euclidean distance or other distance methods when comparing risk as described in the original article.

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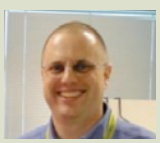


Brian Y. Webster, CRE is currently the Reliability Manager for a refinery in Washington. He has more than 18 years of experience in the Oil and Gas Industry and served as an Ordnance Officer in the U.S. Army.

In response to Brian Webster's article, Terry Nelson requested the opportunity to supply additional information relating to his article in the Oct/Nov 2011 issue of Uptime.

Risk Calculation Methodology

Terry Nelson

I appreciate Mr. Webster bringing risk calculation methodology to the forefront for discussion. The focus of my article was limited to the overall processes of analysis rather than specifics. The very character of risk is an excellent topic in further exploration of these important concepts and principles.

Mr. Webster contrasts positional risk - determined using distance in space as I suggested in my article on traditional risk - calculated using a simple product of consequence and probability (which I will refer to as actuarial risk because it merely expresses risk as cost-over-time).

I first emphasize that both risk calculation methods have value and place. In fact, my intent is to supplement rather than supplant actuarial risk. It is important to understand the value and how each method should be used. There is no correct or incorrect method, rather better and poorer applications for each.

Mr. Webster suggests that using positional risk is synonymous to simply adding voltage and current to get power (wattage) for a motor. In fact, Euclidean distance is more closely related to the product of the components than to the sum and most importantly incorporates the fact that consequence and probability are two very different characterized contributors to risk. Positional risk is a "planer" calculation rather than a linear one. Think of consequence as a north-south value, while probability is an east-west value, with positional risk being distance over the landscape. Figure 1 shows a simplified comparison of constant risk lines using positional risk and actuarial risk calculation methods along with points for many risk events one might encounter within a real system represented as dots.

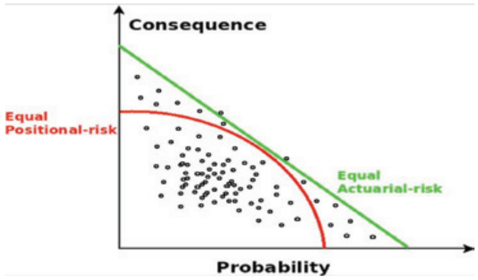


Figure 1: A simplified comparison of positional risk (red) and actuarial risk (green) calculation methods with the dots representing risk events

For an electrical motor, wattage is certainly a limit for the motor in many ways. However, it is not the ONLY limitation. Voltage limits exist that are based on insulation capabilities. On the other hand, amperage limitations are based on heat dissipation capabilities – quite different characteristics and also different from those associated with wattage limits, such as shaft torque, etc. Hypothetically, even with extremely low voltage applied to a motor, high current could damage the motor even though the total wattage is far below acceptable levels. Similarly, extremely high voltage could damage the motor even if far below wattage limits. In a motor (any electrical circuit), we need to be concerned about outliers in respect to ANY of the three aspects: voltage, current, or wattage. Likewise, we need to identify outliers in any of the three aspects of risk: consequence, probability, or actuarial. It is easy to see in Figure 1 that positional risk identifies outliers, while actuarial risk limits outlier identification to only those based on actuarial risk.

This is further demonstrated in chart form. Figure 2 is produced using positional risk calculations. It shows that outliers along each axis (rows one and four) calculate risk values comparable with outliers in actuarial risk (row three) and greater than values for non-outliers, such as row two.

Consequence	Probability	Positional-risk
1	9	9
3	3	4.2
6	6	8.5
9	1	9

Figure 2: Positional risk calculation

Consequence	Probability	Actuarial
1	9	9
3	3	9
6	6	36
9	1	9

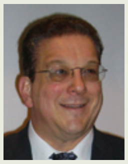
Figure 3: Actuarial risk calculation

Figure 3, with the same four points as Figure 2, shows that actuarial risk calculates very low values for even extreme outliers along the axes (rows one and three) similar in value to non-outlying points such as Row 2. Only the single actuarial risk outlier is identified.

The essential aspects of identifying outliers that are closer to the axes are many, but the two most important are to avoid becoming "bean counter" driven and to find real opportunities for improvement. Actuarial risk methods likely would not have identified significantly major, but rare events, like the Bhopal disaster, the Fukushima nuclear reactor disaster, or the BP oil spill, because their extremely low probability would relegate them to obscurity. Positional risk methodology might have made all three possibilities clear and difficult to downplay. On the other end of the spectrum, extremely frequent but relatively low consequence events would also be ignored by actuarial risk, resulting in "consequence leaks" that might add up to major overall significance and multiple lost opportunities for improvement, known as pound wise and penny foolish.

Once outliers are identified using positional risk, then responsive actions can be evaluated for potential outcomes and compared to as-is or alternative cases. This is where actuarial risk is rightly applied as suggested by Mr. Webster's comparison of his cases A and B. As he suggests, a real and actual improvement in risk profile is necessary to justify making the change. We don't want to just move the problem from one of consequence to one of probability, or the other way around.

Just as actuarial risk is less valid for discriminating and prioritizing opportunities and challenges, positional risk is less valid for evaluating effectiveness of various options to address those opportunities and challenges. In essence, positional risk is the horse and actuarial risk is the cart. We should not use a cart in place of a horse, or the other way around. As we all know, we shouldn't put the cart in front of the horse.



Terry Nelson is a consultant and thought leader in physical asset management. Based in Washougal, Washington, he has decades of experience in nuclear power, water utilities and other industrial processes. www.uberlytics.com.

Integrating Vibration and Temperature Measurements in Condition Monitoring

Jack D. Peters, Sudipta S. Das, Joseph L. Sklepik III

Many industries have adopted permanent vibration monitoring as a predictive diagnostic tool and significantly improved the reliability of their machines, including motors, pumps, fans, gearboxes, conveyors and multiple pieces of equipment too numerous to mention. Identifying or predicting a failure before it happens provides opportunities for lower costs, planned repairs and minimal loss of production or output.

Although permanently monitoring the vibration of a machine provides a critical piece of information about its condition, a temperature measurement can be easily integrated into your reliability program at the same time to provide a second critical piece of information for trending purposes. There are many complementary technologies in reliability and quite often, vibration monitoring and temperature go hand-in-hand with each other. If we trend the vibration amplitude of a bearing, wouldn't it be nice to also trend the temperature of the bearing? This can be easily accomplished with a dual output sensor that provides a vibration output in acceleration (g's) and a temperature output in centigrade (C) or kelvin (K). Providing a sensor that will output both acceleration and temperature requires a three wire technology.

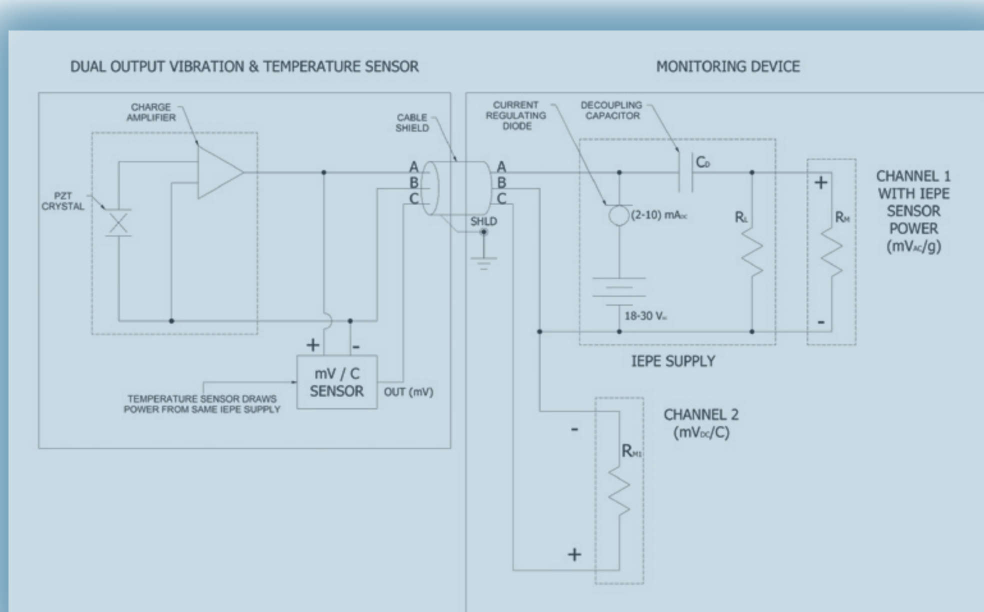


Figure 1: Dual output circuit for vibration and temperature (centigrade)

The temperature trend will actually be a measure of the temperature inside the accelerometer. These dual output models incorporate a small integrated circuit inside the accelerometer that detects the internal temperature of the accelerometer. Although this is not the absolute temperature of the bearing, it is a relative temperature of the bearing casing the accelerometer is mounted on and can be trended over time or alarmed for changes in the bearing temperature. Wear and tear or problems with lubrication will often cause high vibration and high temperature in the bearing. There should be relatively good correlation between the overall vibration trend

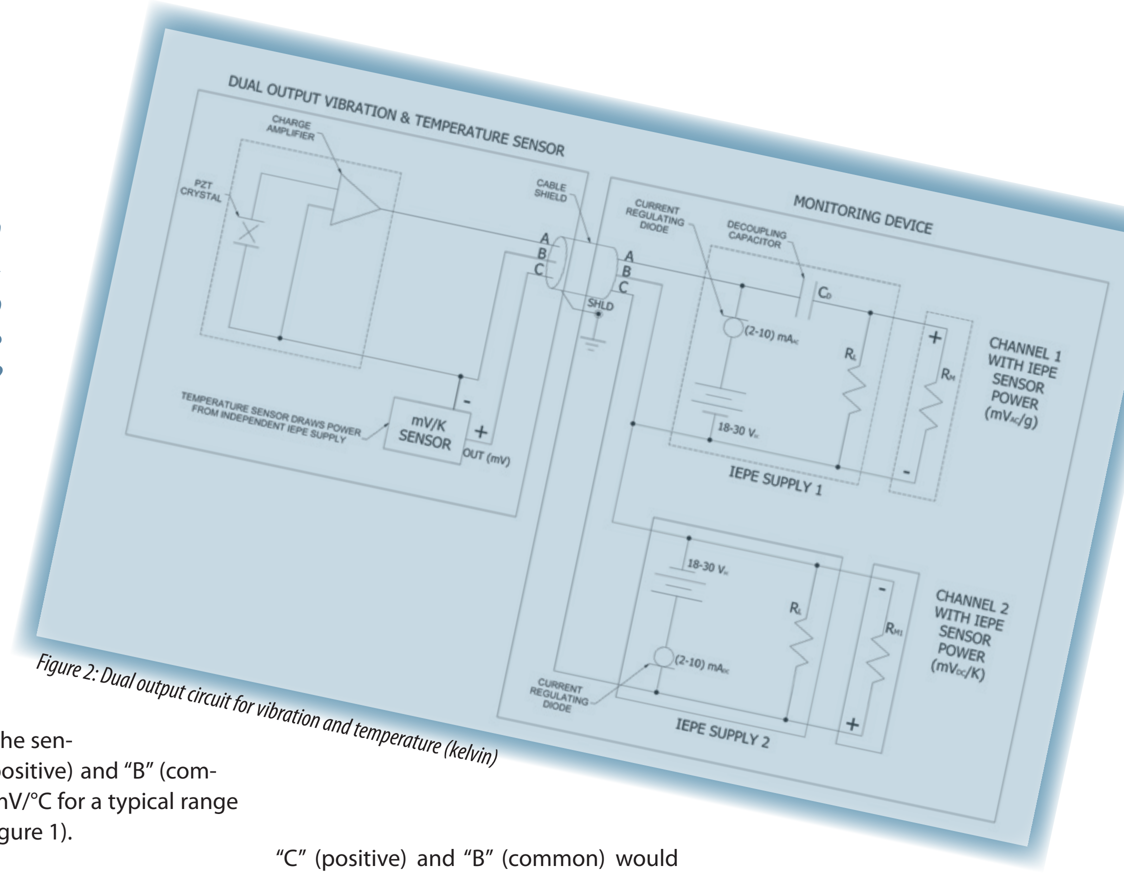


Figure 2: Dual output circuit for vibration and temperature (kelvin)

If we trend the vibration amplitude of a bearing, wouldn't it be nice to also trend the temperature of the bearing?

and the temperature trends providing supporting data on bearing condition and performance.

Centigrade Output:

In the case of a dual output sensor that provides a vibration output (mV/g) and temperature output in centigrade (10 mV/°C), pins "A" (positive) and "B" (common) would require the typical integrated electronic piezoelectric (IEPE) sensor power on the vibration side of the sensor to create the acceleration output. Pins "C" (positive) and "B" (common) would provide a DC voltage output at 10 mV/°C for a typical range of approximately 0 to 120 degrees centigrade (Figure 1).

Kelvin Output:

In the case of a dual output sensor that provides a vibration output (mV/g) and temperature output using the Kelvin scale (10 mV/K), pins "A" (positive) and "B" (common) would require the typical IEPE sensor power on the vibration side of the sensor to create the acceleration output. Pins "C" (positive) and "B" (common) would also require the IEPE sensor power, using a DC coupled input for the monitoring system on the temperature side of the sensor to create a DC voltage output of 10 mV/K (Figure 2) for a typical range of approximately -40 to 100 degrees centigrade. Centigrade? Yes, we won't be working on the Kelvin scale, but we will have a sensor capable of measuring a temperature that is less than zero °C, and because it is a powered circuit, avoid any impedance mismatch between the sensor output and monitoring system input. (An impedance mismatch could cause an error in the temperature measurement by creating a voltage drop much like you would experience if current was passing through a resistor.)

Kelvin to Centigrade Conversion:

If your application uses the dual output sensor with the Kelvin scale for temperature measurement, you may need a conversion from kelvin to centigrade for the monitoring system and correlation with bearing specifications or temperature limits.

Converting an output sensitivity of 10 mV/K requires compensation for the offset between scales where C = K - 273. If setting the temperature sensitivity of the monitoring system in C, apply 10 mV/°C as the engineering unit to scale the monitoring system in C and then subtract a 2.73 V DC or 273 degree offset from the output of the sensor to get the correct temperature value. The type of offset needed - voltage or temperature - will depend on the monitoring system's software or firmware design and setup.

> **EXAMPLE:** A temperature of 323K produces an output of 3.23V at a sensitivity of 10 mV/K
>
> (output voltage - offset voltage) / engineering unit = C
>
> (3.23 V - 2.73 V) / (10 mV/°C) = 50°C

Fahrenheit Conversion:

Although the dual output vibration and temperature sensors use the centigrade (C) or kelvin (K) temperature scale, it is possible to convert these units to the Fahrenheit (F) scale for the monitoring system.

Converting from C to F, where F = 1.8C + 32, would require an engineering unit of 5.556 mV/°F and an offset of +177 mV or + 32 degrees.

> **EXAMPLE:** A temperature of 50°C produces an output of 500 mV at a sensitivity of 10 mV/°C
>
> (output voltage + offset voltage) / engineering unit = F
>
> (500 mV + 177 mV) / (5.556 mV/°F) = 122°F

Converting from K to F, where F = 1.8K - 459.4, would require an engineering unit of 5.556 mV/°F and an offset of -2.55 V or - 459.4 degrees.

> **EXAMPLE:** A temperature of 323K produces an output of 3.23V at a sensitivity of 10 mV/K
>
> (output voltage - offset voltage) / engineering unit = F
>
> (3.23 V - 2.55 V) / (5.556 mV/°F) = 122°F

Summary:

Vibration monitoring relies on trended amplitude over time to determine the condition of the bearing and machine. Typical values for dual output sensors are 10 mV/g, 100 mV/g, and 500 mV/g. The vibration trend is not an absolute measurement due to small errors created by the sensitivity of the sensor, frequency response of the sensor and window filter used in the monitoring system. However, we understand and accept that if the amplitude of the trended vibration increases, the bearing or some part of the machine is experiencing a problem and will require the attention of the vibration analyst to identify the fault and the maintenance department to repair the machine.

> ***Remember, a dual output vibration and temperature measurement can be achieved at one location, with one sensor reducing the need for multiple connections, cables and monitoring devices. It can be used to provide efficiency and reliability for your condition monitoring program as an integrated technology preventing failures and increasing uptime.***

Although the dual output vibration and temperature sensor does not provide a direct contact measurement that a thermocouple or resistance temperature detector (RTD) might, it does come in a very durable and reliable stainless steel package that will survive the most severe industrial applications. Trending the temperature will also indicate if the operating condition of the machine is changing. An unexpected change in temperature should be an alert of a pending problem and it can be correlated with the vibration to assess the overall condition or criticality.

A thermocouple or RTD could be set up to monitor absolute bearing temperature, but the mechanical installation, electrical installation and power supply requirements are much more complicated when compared to a dual output vibration and temperature sensor. These complications with the thermocouple and RTD make dual output vibration and temperature sensors a much more cost-effective method for measuring temperature with a permanent vibration monitoring system.

Remember, a dual output vibration and temperature measurement can be achieved at one location, with one sensor reducing the need for multiple connections, cables and monitoring devices. It can be used to provide efficiency and reliability for your condition monitoring program as an integrated technology preventing failures and increasing uptime.

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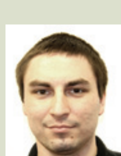

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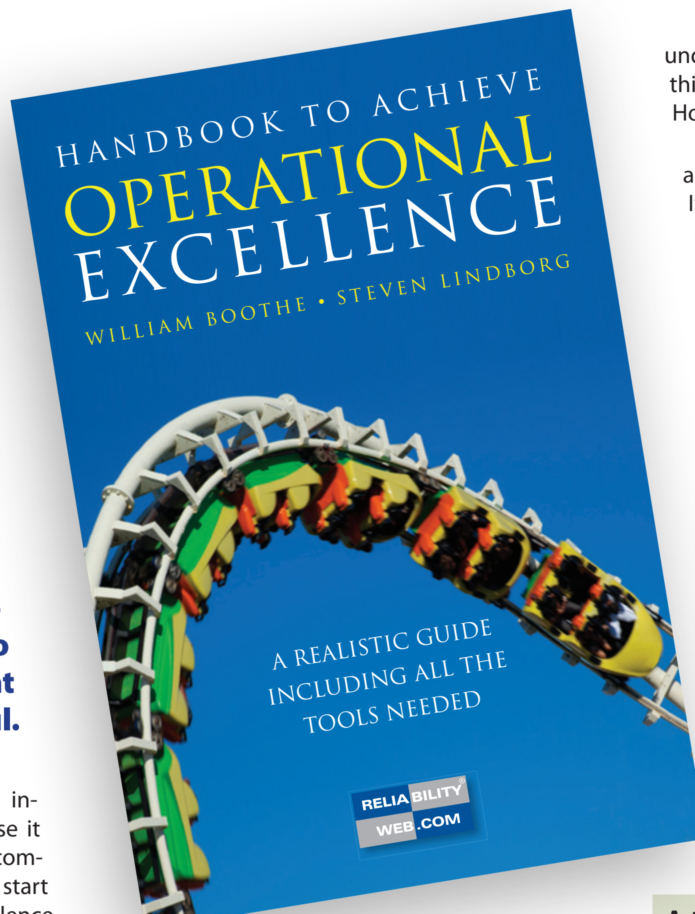
Handbook to Achieve Operational Excellence

Authors: William Boothe and Steven Lindborg • Reviewed by: Ricky Smith

When I read the first page of Handbook to Achieve Operational Excellence by William Boothe and Steven Lindborg, it pulled me in because of the initial statements about enterprise-wide management and alignment. These are serious topics that are well laid out in this book. Most companies either do not understand these two topics or they do not want to be successful.



I am very impressed with all the information in this book and will use it myself to help others. I highly recommend that any manager wanting to start on the journey to operational excellence or maintenance excellence read this book. You don't have to be an executive to gain knowledge from this book and add value to your company. Using it in your sphere of influence may start a revolution to success for you and your company.

I know the topics in *Handbook to Achieve Operational Excellence* are not new to most people, however, the importance of the first chapter, "Values, Mission and Vision" says it all. When the authors wrote about values, mission and vision, I thought it was great because it was easy to understand and apply. I have not heard people speak to these concepts in years. These guys talk about how to hold each other accountable and be sincere in the journey. You cannot be successful without identifying and agreeing on your values, mission and vision for any type of process or program; without them, execution will fail.

I love the statement on the first page of "Setting Top Level Goals". I quote, "When a ship misses a harbor, rarely is it the fault of the harbor." Companies who set top level goals have a very high probability for being successful and sustaining the change. This process is illustrated in the book in simple terms that are easy to understand. The authors point out that everything must be aligned from the top down. How true this is.

When I was reading the chapter on "Roles and Responsibilities," ideas started flowing. It's about time someone provided a simple method for defining roles and responsibilities and tying them into a RACI chart. Great work explaining this process and laying it out so anyone can apply it.

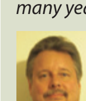
I also loved Chapter 11, "Motivating Your Employees." It provides simple concepts, a great approach and is easy to understand so anyone can follow the process and make a difference with motivating people.

Thank you William and Steven for your contributions to operational excellence! I believe this one book can make a difference to companies where jobs are at stake.

If you have ever read the book, *Good to Great*, then you will love this book. Buy it quickly before they run out! Thanks again to the authors for their contributions to the realm of operational excellence.

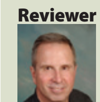
Authors

William A. Boothe was a consultant working with under-performing organizations to assist them in achieving operational excellence. For several years, he was the president of the largest lighting manufacturing company in the world. What he has contributed to this handbook is many years of experience "on the firing line."



Steven Lindborg has over 25 years of experience in manufacturing. He has been a senior manager for several global companies and is currently working as a consultant.

Reviewer



Ricky Smith, CMRP, CPMM, is the Senior Technical Advisor for GPAllied. Ricky has over 30 years experience in the field and is a well-known published author. www.gpallied.com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