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for maintenance reliability and asset management professionals

How To Proactively Run What You Have Now

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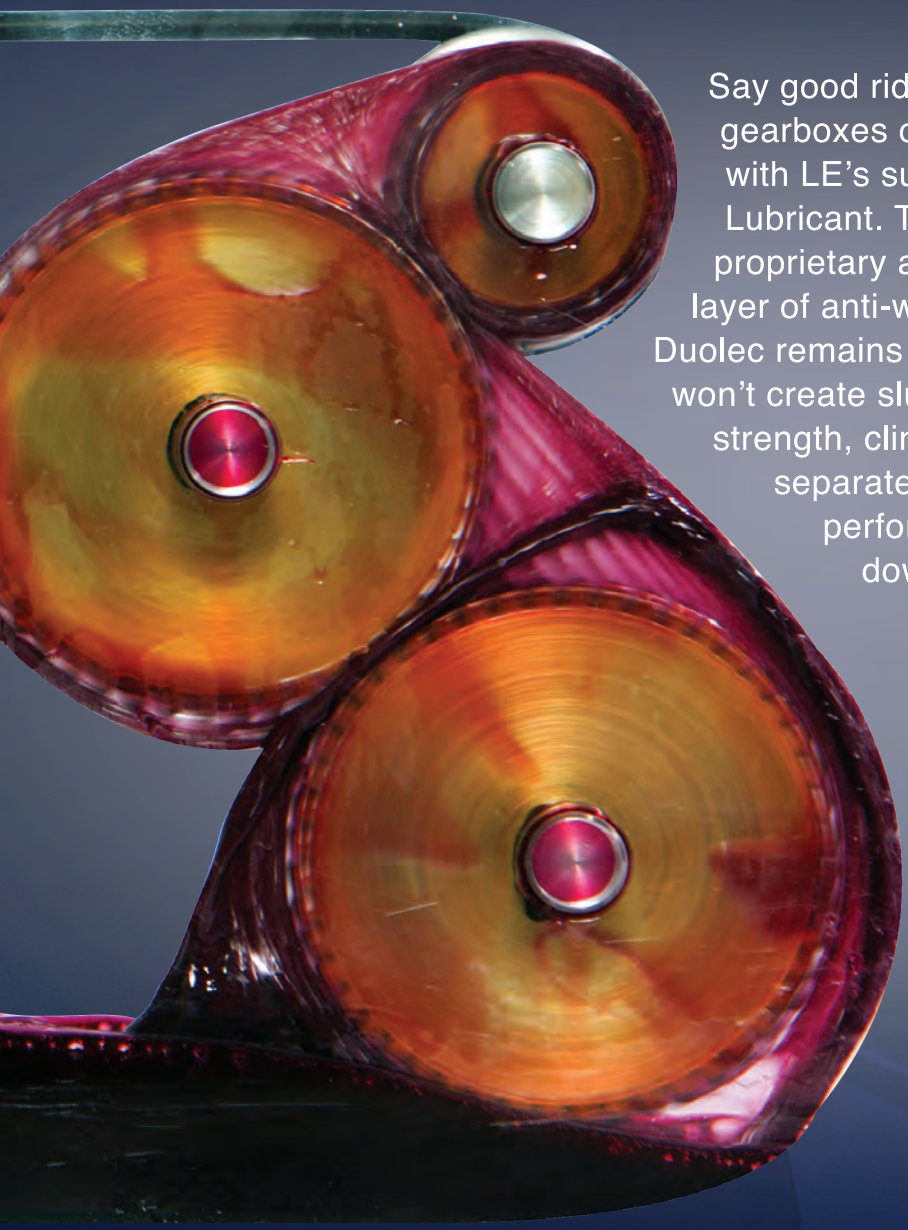

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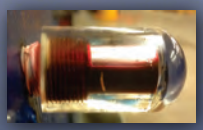

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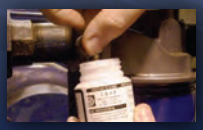

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ISO 55000: Creating an ISO 55000 Implementation Plan	Operations leaders who are implementing an ISO 55000 initiative, including middle managers from across the organization	Develop and draft an asset management policy for your organization, develop the strategic asset management plan, and create a project plan for individual asset management plans.	Jan 27-28, 2015 (CHS) Apr 21-22, 2015 (CHS) Jul 14-15, 2015 (CHS) Oct 20-21, 2015 (CHS)	2 consecutive days 1.4 CEUs	$1,495
Maintenance Planning and Scheduling	Planner/Schedulers, Maintenance Supervisors, Maintenance Managers, Operations Coordinators, Storeroom Managers and Purchasing Managers	Apply preventive and predictive maintenance practices. Calculate work measurement. Schedule and coordinate work. Handle common maintenance problems, delays and inefficiencies.	Feb 23-27, 2015 (CHS) Apr 20-24, 2015 (CHS) Jul 20-24, 2015 (CHS) Sep 14-18, 2015 (CHS) Nov 16-20, 2015 (CHS)	5 consecutive days 3.2 CEUs	$2,495
Management Skills for Maintenance Supervisors (DEVELOPED BY JOEL LEVITT)	Maintenance Managers and Supervisors, as well as Supervisors from Operations, Warehouse or Housekeeping areas	Lead a world-class maintenance department using planning and scheduling best practices to drive work execution, improve productivity, motivate staff, increase output and reduce waste.	Mar 17-19, 2015 (CHS) Aug 11-13, 2015 (CHS)	3 consecutive days 2.1 CEUs	$1,495
Materials Management	Materials Managers, Storeroom Managers, Planner/Schedulers, Maintenance Managers and Operations Managers	Apply sound storeroom operations principles. Manage inventory to optimize investment. Understand the role of purchasing. Implement effective work control processes.	Jun 9-11 2015 (CHS)	3 consecutive days 2.1 CEUs	$1,495
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Predictive Maintenance Technologies (DEVELOPED BY KEITH MOBLEY)	Plant engineers and managers, Maintenance, Industrial and Manufacturing Engineers, Maintenance Supervisors and Managers	Collect and analyze data to assess the actual operating condition. Use vibration monitoring, thermography and tribology to optimize plant operations.	Mar 10-12, 2015 (CHS) Nov 3-5, 2015 (CL)	3 consecutive days 2.1 CEUs	$1,495
Prosci® Change Management Programs	Executives and Senior Leaders; Managers and Supervisors; Project Teams; HR and Training Groups; Employees	Build internal competency in change management. Deploy change management throughout your organization. Become licensed to use Prosci's change management tools.	Contact us to schedule a private onsite class.	Sponsor: ½-day Coaching: 1-day Orientation: 1-day Certification: 3-day	Contact us for pricing
Reliability Engineering Excellence	Reliability Engineers, Maintenance Managers, Reliability Technicians, Plant Managers and Reliability Personnel	Learn how to build and sustain a Reliability Engineering program, investigate reliability tools and problem-solving methods and ways to optimize your reliability program.	May 12-14, 2015 (CL) Oct 6-8, 2015 (CHS)	3 consecutive days 2.1 CEUs	$1,495
Reliability Excellence for Managers	General Managers, Plant Managers, Design Managers, Operations Managers and Maintenance Managers	Build a business case for Reliability Excellence, learn how leadership and culture impact a change initiative and build a plan to strengthen and stabilize the change for reliability.	SESSION 1 DATES: Mar 10-12, 2015 (CHS) Aug 25-27, 2015 (CHS) (Sessions 2-4 dates are available on the website)	12 days total (4, 3-day sessions) 8.4 CEUs	$5,995
Risk-Based Asset Management	Project Engineers, Reliability Engineers, Maintenance Managers, Operations Managers, and Engineering Technicians.	Learn to create a strategy for implementing a successful asset management program. Discover how to reduce risk and achieve the greatest asset utilization at the lowest total cost of ownership.	Apr 14-16, 2015 (CL) Sep 15-17, 2015 (CHS)	3 consecutive days 2.1 CEUs	$1,495
Root Cause Analysis	Anyone responsible for problem solving and process improvement	Establish a culture of continuous improvement and create a proactive environment. Manage and be able to effectively use eight RCA tools to eliminate latent roots and stop recurring failures.	Feb 24-26, 2015 (CHS) Aug 18-20, 2015 (CL)	3 consecutive days 2.1 CEUs	$1,495

***LOCATION CODES:** (CHS) = Charleston, SC | (CL) = Clemson University in Greenville, SC | (UA) = University of Alabama

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YOU CANNOT OPEN UPTIME WITHOUT LEARNING SOMETHING

Welcome to 2015! We enjoyed a great holiday break, got some rest, did a little work and returned fully recharged. The Reliabilityweb.com team is back on company mission as you can see from the issue that follows. You cannot open Uptime without learning something!

It was a well-deserved break after the team hosted IMC-2014 the 29th International Maintenance Conference in Daytona Beach, Florida, featuring 1,200 reliability leaders and asset managers from 33 countries. Please make plans to attend IMC-2015 the 30th International Maintenance Conference held December 7-11, 2015 now back at the Hyatt Regency Coconut Point in Bonita Springs Florida.

Time was also taken to acknowledge and celebrate some of the team's accomplishments we achieved in 2014:

- We supported the launch of the Certified Reliability Leader (CRL) exam through the Association for Maintenance Professionals
- We published 29 Certified Reliability Leader Passports and the Certified Reliability Leader Travel Guide in English and Spanish (Print, Kindle and Audio versions)
- We published the world's first book on ISO 55000 Asset Management (The New Asset Management Handbook now in its 2nd edition)
- We delivered Certified Reliability Leader (CRL) and Uptime Elements workshops in Cincinnati Ohio, San Francisco California, Las Vegas Nevada, Atlanta Georgia, Bogota Colombia, Las Vegas Nevada, San Antonio Texas, Dallas Texas, New York City, New York, Cincinnati Ohio, New Smyrna Tennessee, Lima Peru, Bonita Springs Florida, Wichita Kansas, Kansas City Kansas, Topeka Kansas, Castlegar British Columbia, Akron Ohio, Monterrey Mexico, Phoenix Arizona, Montevideo Uruguay, Marysville Ohio, San Juan Puerto Rico, Austin Texas, London United Kingdom, Houston Texas, Daytona Beach Florida, Gwinnett County Georgia. (Try singing this to the melody of "I've Been Everywhere Man" by Johnny Cash!)
- We implemented and executed a process and procedures based management system

As this issue goes to press we are preparing to host the Asset Management Training Conference (AM-2015), the first of 5 focused training events at the Reliability Leadership Institute (RLI) in Fort Myers. The RLI Board of Advisors meeting will also take place to launch a new community of practice based on Uptime Elements – A Reliability Framework for Asset Performance.

As the eco-system for Uptime Elements continues to expand there has been an energetic response from the solution-provider community to work in alignment with Uptime Elements to join the new Mapped Services and Training (MSAT) Provider program (see News page for more details).

If that does not keep us busy enough we are in full swing with conference planning for RELIABILITY 2.0 Las Vegas (April 13-17, 2015) and Solutions 2.0 – Innovations in Asset Performance Houston (August 3-7, 2015).

So if reading this exhausts you, image how we feel! Actually the growing interest in reliability and asset management at all levels, including the executive level energizes us. We are grateful and thankful to have a chance to be of service.

You are invited to use Uptime Magazine as a printed or digital conference – and imagine each article as a presentation and each ad as an expo booth. Every page is created with thoughtfulness to ensure that you cannot open Uptime Magazine without learning something.

Warmest regards,

Terrence O'Hanlon, CMRP
CEO and Publisher
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IN THE NEWS

Certified Reliability Leader Travels to San Jose

The Certified Reliability Leader Workshop and Exam traveled to the Oracle Summit in San Jose January 26th. Terrence O'Hanlon, CEO and Publisher of Reliabilityweb.com and Uptime magazine, lead the one-day training event. The participants were guided through the Uptime Elements, which simply put, is a map by which to understand the interrelated nature of reliability throughout an organization.

In addition to the workshop, the Institute of Asset Management (IAM) USA hosted a Meet and Greet. Guest speakers included individuals from Bay Area Rapid Transit, Lawrence Livermore National Labs, Reliabilityweb.com and the University of Wisconsin.

Upcoming CRL Events:

February 2-6
Asset Management 2015
Training Conference – Ft Myers, FL

February 9-12
ARC Industry Forum – Orlando, FL

February 23-26
MARCON – Knoxville, TN

March 9-13
Asset Condition Management 2015
Training Conference – Ft Myers, FL

April 13-17
RELIABILITY 2.0 – Las Vegas, NV

Reliability Leadership Institute Introduces

Mapped Services and Training (MSAT) Providers Program!

Does your company provide products, services or training that support the Uptime® Element™ Framework?

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- Highlight mapped vendors in the Reliability Leadership Institute MSAT Directory
- Supply referrals of potential clients who require execution support for areas of the Uptime Elements
- Have a profound effect on business outcomes for organizations

Current MSAT Providers:

- Aladon Network
- Bentley
- Blue Sky Reliability
- People and Processes
- Uberlytics

For more information, contact Kaitie Sweet:
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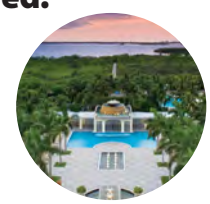
239.333.2500 ext 114

RLI RELIABILITY® LEADERSHIP INSTITUTE

IMC 2015 The 30th International Maintenance Conference

NEW "OLD" LOCATION! You asked, we listened!

The 30th International Maintenance Conference (IMC) has moved locations and will take place December 7-11, 2015 at the beautiful **Hyatt Regency Hotel and Resort in Bonita Springs, FL**. This location has been home to IMC in past years and is always a crowd favorite! Be sure to note this change when registering and making plans for this event. **We hope to see you there!**



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CERTIFIED RELIABILITY CRL LEADER ™

How To Proactively Run What You Have Now

by Paul Dufresne

5 Things to Improve Plant Reliability

Recently I had a conversation with the members of our leadership group concerning steps we need to take to improve the reliability posture of our business. I was charged with, of all the initiatives that are out there, the critical few we need to focus on to improve our competitive position for our business. With that in mind, I did some data mining and looked at our recent unplanned events and came to a not so unique conclusion. BASICS! We need to focus our attention on the basics of reliability. Our issue is that we need to improve our ability to address the basic fundamentals of reliability in order to improve our competitive position. It is plain and simple that we need a disciplined approach in applying some basic methodologies that will help us to improve. One common thread missing is engagement. We need to have engagement at every level in the organization.

Pareto Bad Actors – Focus on Chronic Failures

The first step in our journey was to identify and focus on our chronic failures. In any improvement initiative, you have to know where "ground zero" is so you can develop a path forward. For us, it was simple, Pareto your downtime events and use the "80/20" rule. For those that don't know the 80/20 rule, it is based on the Pareto principle named after Italian economist Vilfredo Pareto. It means that 80 percent of your failures are usually caused by 20 percent of your equipment. The application of the Pareto principle in problem solving and analysis can provide a great starting point with simple data analysis of process, plant failure and production data. This will provide an early insight into problem causes and effects without intense or complex analysis. We need to understand what our 20 percent is in order to focus our efforts on the critical few that will have the greatest impact on the business. Do you know what your top 20 percent are?

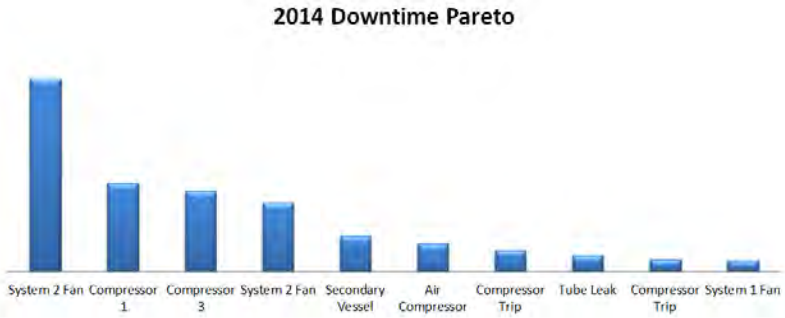

Figure 1: Pareto chart example

Apply RCFA and Measure Implementation of Recommendations

Once the Pareto analysis has been completed and we have identified our 20 percent, the next step was to conduct root cause failure analysis (RCFA). RCFA is a simple, yet disciplined process used to investigate, rectify and eliminate equipment failure, and it's most effective when directed at chronic failures. Your completed analysis is only as good as the person facilitating and the cross-functional team assigned to complete the engagement. Employee involvement is crucial in an effective RCFA analysis. You must have the right people on the team to complete the investigation and analysis. In order to understand and get the true value out of the RCFA, we must realize that most failures happen in three different layers. First are the physical component, human error and finally the latent root of the problem. The latter is always the true cause of the problem. Inevitably with most failures, there will always be some form of human error, whether someone failed to perform a task correctly, or missed a step in the process. Driving to the "true" root cause can be a challenge based on the dynamics of your operating culture. Again, the entire team has to be engaged and set the expectation that all failures are avoidable, and then work to foster a culture that takes root.

As the old saying goes, "what gets measured gets done," so it is true with RCFA recommendations. If you have experienced a repeat failure because you did not implement (in a timely manner) the recommendations of the analysis, then you understand what this adage means. Once the RCFA is completed and the recommendations are identified and prioritized, you must create an action log that has the task, as well as the owner responsible for ensuring the task recommendation is completed. Do not forget to put an expected date of completion beside the task as well. Once this is completed, set up a task review meeting to track progress. Include in your metrics the number of tasks completed, along with the number of open tasks awaiting completion, and add that to your weekly review meeting. Remember, if it is true that "what gets measured gets done," then you have created an avenue to improve the situation.

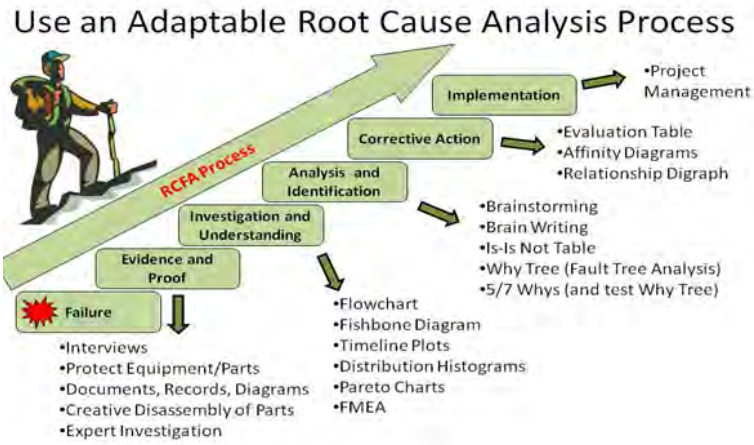

Figure 2: RCFA example

Visibility on the Health of Assets (P-F Curve)

John Moubray coined the phrase "P-F interval" which we know today as the "P-F curve". The simple way to describe the P-F curve is the point at which a potential failure (P) is identified before the functional failure (F) happens. The earlier you can identify the failure, the earlier you can take action. If your organization is not in a proactive maintenance state, or fully understand the value and impact of predictive maintenance (PdM) you now have the opportunity to make a dramatic impact on your business. The earliest indication that a problem is occurring will give you the ability to be proactive in your decisions and actions based on the condition of the equipment. The power of this information is crucial in allowing your work processes, such as gatekeeping, planning, scheduling, etc., to have the ability to work efficiently and have an effective impact on the organization. When the team understands the importance of the P-F curve and the impact it can have on an organization, this will help your team become proactive in their maintenance and reliability posture. The results can be a life less stressful, improved reliability, systems are working in harmony, and costs are lowering. Ultimately, the quality of life of all involved is improved. Is your team engaged and do they know the health of their assets? (see Figure 3)

Disciplined/Efficient Execution of Work Processes

Even in the most structured organizations, many work processes can be chaotic and disorganized. There is incomplete or outdated documentation, duplication of effort, or different people who carry out the process in a slightly different way. This is stressful for employees and costly for the organization. Although it wasn't the intention when the process first started, it evolves over time as small changes occur and work-arounds are developed. Sometimes, the work is pieced together out of necessity and no one gives any strategic thought or consideration on how this will affect the big picture. Because of our ability to adapt our thinking to compensate for what is an inefficient process, we simply make it work. How this impedes the operation and the opportunity to make improvements will be when we go looking for data to help us make the necessary critical decision on where to focus our

resources. If we follow the process and use our tools as they were designed, the vision of a more organized state becomes a reality. You then have an operation where employees have the tools they need and are empowered to execute flawlessly within the system, and cost savings are realized due to improved efficiency of the process and workflows. Ultimately, this will lead to having a profit center within your business. Is your team engaged and do they understand the importance of following the process? How efficient are your work processes? (see Figure 4)

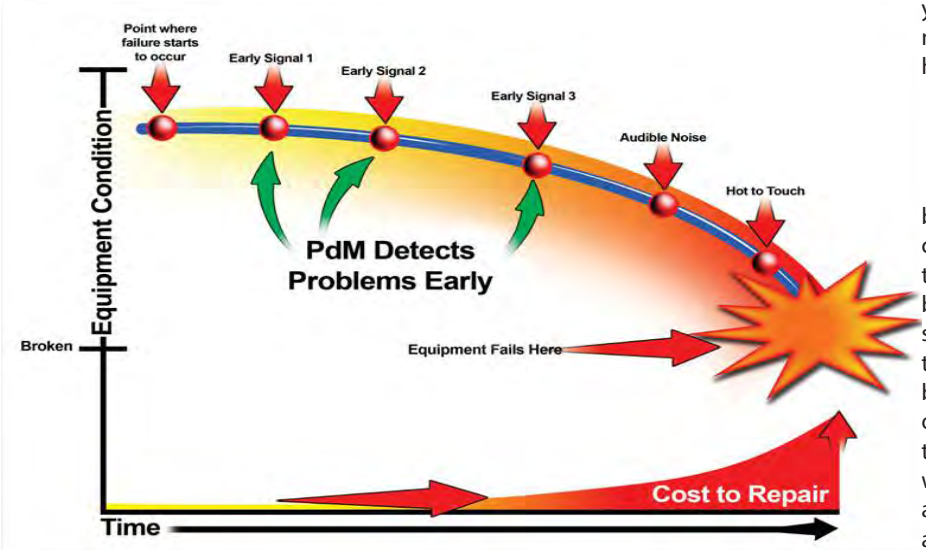

Figure 3: P-F curve

Courtesy of Allied Reliability

Behavior Focused Metrics

Why do we use metrics? The truth is we use metrics with the hope of driving positive outcomes and behaviors in our organizations. Unfortunately, we can get into metric overload if we have a laundry list of metrics that we report out on. One simple question to ask is, "what are the critical few metrics that would mean the most to your organization and add the greatest value?" For example, an effective way to monitor the impact of maintenance work on equipment reliability is to keep a list of all work done on an asset showing the dates that the maintenance was done, and recording what type of maintenance was performed. For each interaction with the equipment, record the work performed, the parts used or repaired, the failure evidence collected and observed, and the known causes of the maintenance work. When you see the same parts fail for the same reasons, you can conclude that the reliability was impacted due to the quality of the maintenance work performed.

Figure 4: Basic workflow process

Remember, there are two types of metrics, leading and lagging. Having a right mix of metrics is critical to the success of any organization. A general rule of thumb is to have two leading metrics for each lagging metric. We hear a lot about leading and lagging metrics but what do they really mean? Lagging indicators or metrics are typically output oriented, easy to understand, but hard to improve or influence, while leading indicators or metrics are typically input oriented, hard to measure and easy to influence. Let's illustrate this with a simple example: For many, a personal goal is to lose weight. A clear lagging indicator that is easy to measure is you step on a scale and you have your answer. But how do you actually reach your goal? For weight loss, there are two "leading" indicators: 1. Calories taken in and 2. Calories burned. These two indicators are easy to influence, but very hard to measure. So having the right mix of leading and lagging metrics in place can assist you in achieving your goals. However, if you focus on only lagging metrics, it's like looking over your shoulder. You only see where you have been, not where you are going.

Conclusion, Don't Overload the Wagon!

At this point, you may be asking yourself, "this sounds great but how do I start?" It's simple, start with a vision! Pull together a cross-functional team of people within your organization that have the same desire and drive to accomplish the mission. Focus on the basics first, follow the process and realize this is a marathon, not a sprint. You will have ups and downs, and highs and lows as you go through this journey. Keep your eye on the prize and make sure you bring the team along with you, avoiding marching perilously alone on your journey toward reliability excellence. Remember, the sustaining effort will take three times the length of time you think it will. Start small, celebrate your successes and remember to have fun along the way. With leadership support, the vision of a better state and engagement by all on the team focusing fundamentals and getting them right the first time, you will be successful in your journey.

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Uptime® Awards 2014

Best Maintenance Reliability Programs

PolyOne Corporation
LOOP LLC
Metropolitan Sewer District of Greater Cincinnati
Hibbing Taconite Company: Managed by Cliffs
Marathon Oil Corporation

Recognizing the Best of the Best!

Uptime Magazine congratulates the following outstanding programs for their commitment to and execution of high-quality Predictive Maintenance and Condition Monitoring Programs.

PolyOne Corporation

Uptime Awards
Best Emerging Maintenance Reliability Program

In 2011, PolyOne embarked on a journey to transform our operations through a program we termed the PolyOne reliability program (PRP). The goal of the program was to improve operational supply reliability to our customers through improved on time delivery and increased facility longevity while maintaining world-class safety standards. In addition, significant effort was placed on best practice sharing, increased operational equipment efficiency (OEE) and the reduction of maintenance related expenditures.

A strong business case was developed with executive leadership engagement that facilitated buy-in throughout our organization, which at the time consisted of 46 sites. Through extensive benchmarking and utilization of Lean Six Sigma skills and resources, we identified performance gaps and developed an implementation strategy to address them. The rollout plan, known as the "playbook," was in the form of waves, where a group of sites were brought together for one week of training and then returned back to begin the transformation at their respective locations. Sites took ownership and responsibility for their implementation plan and were supported by corporate to ensure consistency and speed of execution.

In 2013, PolyOne added over 30 additional sites through a series of acquisitions. With the PRP wave implementation strategy and related action plan, we have been able to quickly incorporate these new locations. We now have 55 sites implemented with three more waves planned within the next year that will result in the complete integration of our organization.

To read more about each company, download the Uptime Award Winners' stories at: **uptimeawards.com**

LOOP LLC

LOOP LLC is a crude oil pipeline and storage company with onshore and offshore facilities in southeastern Louisiana, connected to a significant portion of our nation's refineries. We can store over sixty million barrels of crude and transport in excess of one million barrels per day at rates up to one hundred thousand barrels per hour.

Since 2011, LOOP has created and followed a new vision of becoming "Market Driven and Operationally Excellent." After developing related strategies and tactical objectives, we've determined the two go hand in hand. The uptime or availability of assets is certainly one component of our business that touches both aspects of our vision. Our related, proactive asset and work management programs have changed our culture through the implementation of reliability centered maintenance best practices. Our Oracle OWAM CMMS system went live in 1999, and predictive technologies and condition-based monitoring initiatives have been phased in and enhanced since then.

The results have been rewarding, as we achieved 99.75 percent uptime on our main oil line assets in 2013 and have exceeded 98 percent for over five years. In 2013, we realized a four year low in ad hoc repair cost, which and are trending down in 2014. Less reactive repair work has allowed an increased focus on proactive work which has facilitated a work, order backlog reduction to four weeks for both onshore and offshore maintenance crews. Results are proving to be sustainable.

Work management guidance is documented and implemented through LOOP's Maintenance Policies and Procedures Manual. This manual includes high level and detailed roles and responsibilities of the organization, as well as instructions for our maintenance reliability processes. This guidance document also covers the regulatory requirements and details of our facility management of change process.

Maintenance planners & schedulers plan 100 percent of available maintenance manhours. Weekly and daily schedules are created with stakeholder input on priority, then distributed for review and execution. LOOP's preventive maintenance procedures address asset failure modes and defect detection. They provide guidance to the technicians for ensuring desired outcomes and repeatability. The reliability group is responsible for the execution of the predictive maintenance program. LOOP utilizes thermography, vibration, ultra-sound, oil analysis, PdMA electric motor testing and partial discharge among other technologies. KPIs and metrics are used for monitoring and managing asset health.

Uptime Awards

Best Work Execution Management Program

Our operator care program consists of a detailed operator checklist, which field operators use to note the device location, actual versus expected readings and a plan of action if expectations are not in tolerance.

LOOP stores some critical spare components in on-site warehouse facilities, and outsources the balance of off-site, climate controlled storage.

These proactive processes have assisted LOOP in becoming successful in our work and asset management programs. With an embedded culture and focus on "Getting it Right" and a passion for "Continuous Improvement," LOOP continues its journey towards operational excellence.

Metropolitan Sewer District of Greater Cincinnati

Best Asset Condition Management Program

The goal of the Metropolitan Sewer District of Greater Cincinnati (MSDGC) was to build a sustainable, low cost, in-house asset condition monitoring (ACM) program, keeping in line with the overall business goal of "providing reliable, sustainable infrastructure and high-quality, cost-effective utility services for collection and treatment of wastewater and storm water."

With this in mind, MSDGC built a two-tiered ACM program consisting of a centralized predictive maintenance (PdM) team with sophisticated tools and decentralized teams with affordable technologies. A PdM vendor and a subject matter expert provided training and support to get the program up and running.

The centralized ACM team employs ACM hardware and computer software for vibration, IR, ultrasound and MCA\MCE that is fully functional and capable of detailed diagnostic analysis leading to accurate identification of defects, affected parts and evolving conditions. This allows more precise repair planning which, in turn, reduces lifecycle repair costs, decreases downtime for operations and shortens active repair time for maintenance, and ultimately minimizes required capital investments by deferring expansion projects by increasing asset useful life. ACM team members are trained and certified to collection data and perform advanced. This capability provides MSDGC WWT with the ability to anticipate critical repairs with a high level of confidence, minimizing expensive plant outages or permit violations. This allows the scheduling and completion of economically efficient repairs at times determined by personnel - not the equipment.

The decentralized portion of the ACM program employs maintenance crew members at WWT plants equipped with low cost, easy-to-learn and easy-to-use vibration, ultrasonic and infrared thermography instruments. These instruments have proven useful in a wide variety of applications in confirming the presence or absence of defects and are relied upon to quickly confirm whether or not a repair has been completed satisfactorily, allowing for timely return of equipment to service.

The ACM program is sustained through a five year master plan that establishes the training, communication, budgets and processes used by the two-tiered approach. The plan is a living document used to sustain performance throughout each fiscal year and make further progress using an annual auditing/planning exercise. One key communication item contained in the plan, the Find of the Week email, supports a culture of proactive effort and focus on value by sharing maintenance successes and cost avoidance on a monthly basis. The ACM program also tracks and communicates the overall return on investment of asset condition monitoring activities. To date, MSDGC has seen a total cost avoidance of $961,131. This significant savings provides a compelling business case to upper management for continued program support.

In two years, MSDGC has moved from external ACM services to an effective internal ACM program that delivers results. With the two-tiered approach, a sustainable master planning process and consistent demonstration of added value, the ACM program is a key element of MSDGC's success and an opportunity to continue achieving increased benefits in the future.

Recognizing the Best of the Best!

PolyOne Corporation • LOOP LLC • Metropolitan Sewer District of Greater Cincinnati
Hibbing Taconite Company: Managed by Cliffs • Marathon Oil Corporation

Hibbing Taconite Company: Managed by Cliffs

Uptime Awards

Special Recognition Award for Environmental Sustainability

A mine's success is now tied heavily to its ability to abide by and go beyond environmental regulations. In a capital intensive industry such as mining, environmental impacts are present in every step of the process. Hibbing Taconite's reliability engineering program has found innovative ways to minimize the risk of impact to the environment and the communities that surround the mine.

The reliability engineering department at Hibbing Taconite Company has always maintained the vision that strong PM and PdM programs minimize environmental and economic risk and protect the safety of our workforce. This emphasis formed its roots in the lubrication program. The goal of the lubrication program has always been to keep our lubricants clean, cool, and dry. Embedded into this philosophy is that well-maintained lubricants, along with well-maintained machines, allow the lubricant to stay in the assets until the lubricant has reached its maximum use. To extend the life of lubricants, Hibbing Taconite has switched many of the mineral oil based lubricants to synthetic oil based lubricants. Minimizing the amount of lubricant handling from storage to machine to disposal minimizes the risk of spills and exposure to the environment. To minimize costs of synthetic lubricants, many of the synthetic lubricants are reprocessed and repurchased at a reduced price. Another intended benefit of switching from mineral oil to synthetic oil in applications was the lubricant's ability to decrease the amount of energy consumed to move the machines. This, in turn, results in reducing the carbon footprint of the site.

Economic return has been harvested from these efforts by our ability to keep assets in production for longer intervals, decreasing labor hours by extending preventive maintenance intervals, and decreasing overall energy consumption.

Environmental stewardship is not just a buzz word at Hibbing Taconite; it is a means to the future of the mine, a core value of Cliffs Natural Resources, and a way of life.

Marathon Oil Corporation

Uptime Awards

Special Recognition Award for Social Responsibility

Marathon Oil Corporation is an independent global energy company with three primary operating segments: North American Exploration and Production, International Exploration and Production and Oil Sands Mining. Marathon Oil's largest producer – Marathon Equatorial Guinea Production Limited (MEGPL) – is located in the West African nation of Equatorial Guinea, Africa. MEGPL's offshore condensate/natural gas production site, known as the "Alba Field," is one of the largest producers in the Gulf of Guinea.

From the Alba Field, condensate and natural gas are extracted from the offshore platforms and sent to the onshore gas plant for processing into various products, including propane and butane. In addition to the hydrocarbon production and extraction facilities, the industrial complex includes terminals and export facilities for liquid hydrocarbon products. It also includes a liquefied petroleum gas (LPG) plant, a methanol production facility and a liquefied natural gas (LNG) production facility.

Marathon established the Alba exploration and production area in early 2002. When the company entered Equatorial Guinea in 2002, we took a long-term view of our investment. Our intent was not only to develop the country's oil and gas resources, but to develop its people resources, as well. Today, we work with local communities, government ministries, non-governmental organizations (NGOs) and other stakeholders to address critical social issues in Equatorial Guinea. Our efforts are focused on strengthening transparency, national capacity, workforce development, public health and formal education. We have initiated and participated in social responsibility initiatives addressing critical health, social, education and other issues in Equatorial Guinea. Some of these programs include:

- Bioko Island Malaria Control Project (BIMCP), an innovative and successful approach to eradicating malaria.
- Education, training and development of Equatoguineans to work in our facilities.
- Build new and refurbished school and clinic facilities for local communities.
- Provide scholarships for high-potential Equatoguinean nationals.
- Support Equatorial Guinea's participation in the Extractive Industries Transparency Initiative (EITI), an international organization which assesses levels of transparency around countries' oil, gas and mineral resources.

Align Your Ultrasound Team

Create a World Class Ultrasound Program

by Allan Rienstra

There are many things we can accomplish individually. Creating a world class ultrasound program is not one of them. It requires a team; and teams function best when they have balance and a common vision. Deciding who will make up the team roster requires thoughtful consideration. With the selection process completed, getting everyone on the same page is the essential first step.

The Same Page

Here are five questions that map out your first ultrasound team planning meeting. These questions identify your purpose and cultivate unifying debate. Prepare for your first team meeting by distributing the questions to each team member, leaving adequate spacing for note-taking.

1. What do we hope to accomplish?
2. What are we attempting to change?
3. Who do we need on our side?
4. What are our primary pain points?
5. How will we measure success?

Let's start at the beginning:

1. What do we hope to accomplish?

"World Class" ultrasound programs provide a better understanding about the health of our factory. We are better equipped to predict failures and plan the maintenance solution. Maintenance is planned so it doesn't interrupt production. That translates to better uptime stats and a stronger bottom line. Now we have EVERYONE'S attention.

Ultrasound offers compelling applications that promote energy cost savings and environmental sustainability. Steam system surveys ensure efficiency from the boiler room to point of use. Compressed air leak surveys help cap the cost of one of the most misused utilities in modern manufacturing.

Question one defines the real reason for embarking on a world class ultrasound program: To get a greater understanding about the health of your factory while reducing energy waste and improving product quality.

2. What are we attempting to change?

Seek change when change makes us better. Confront the ways we act, react, and interact with each other. An ultrasound program breeds a culture of awareness that infects everyone involved. The infection spreads beyond the team members and to all levels. I've seen it happen. So what are we attempting to change by starting an ultrasound program? "Culture."

The Culture of Reactive Maintenance

When we do things on the spur of the moment as a response to a sudden and unexpected change, we are in reactive mode. A reactive culture prevents us from doing meaningful work. If the entire day is spent responding to interruptions, when do you get time to start something new? When do you get to be creative and take initiative? How can you offer real value to your company if all your creative energy is zapped by reactive requests? How can you go home feeling fulfilled and satisfied by your work?

The Culture of Scheduled Maintenance

To eliminate many of the problems that cause reactive interruptions, companies turn to Scheduled Maintenance or PMs. PMs can be visual inspections, lubrication tasks, changing or cleaning filters, or tightening or realigning a belt drive. They are routinely scheduled based on either a calendar or time in service. The question to ask: "Is a time-based schedule the best solution for the given task?" When the answer is "NO," chances are its condition can be monitored with ultrasound.

3. Who do we need on our side?

This question accomplishes two things. It identifies the stakeholders and defines their roles and expectations. Who are the Stakeholders?

Upper management, middle management, front liners, and your ultrasound supplier all have astake in your success. Successful implementation gives an equal voice to each stakeholder. Upper management is normally concerned about how much the program can save. Middle management is a go-between voice for the front liners and upper management. Front liners carry the heavy load and need to know how things work, and the supplier has the wisdom and experience to guide the entire team.

Figure 1 - The relationship between Supplier and Customer is integral to your program`s long-term success.

4. What are our primary pain points?

Identifying your early pain points is a good starting place. Create a list of the small day-to-day problems that continually erode productivity and profitability. There are things that bite you hard every hour of every day and cost you more money in the long run. The problem is that most of those problems are now almost invisible to the business. They are just considered the cost of doing business. Some examples:

- Compressed air leaks
- Steam leaks
- Defective steam traps
- Inspection of electrical systems
- Over-lubricated bearings

This list represents five huge daily drains on resources. Targeting each of these will yield almost immediate justification for additional investment in Ultrasound and Condition Monitoring.

5. How will we measure success?

To give meaning to a measurement requires a benchmark for comparison. What do I need to give meaning to this single static measurement? History. Virtually every ultrasonic application is trendable. Air leaks can be measured in energy consumption. Bearings can be measured in grease used and failed bearings.

What is critically important for your ultrasound program is what you do with the success you generate. All significant wins must be documented. Go one step further. Captivate your colleagues (and your boss) and infect them with your cultural change by creating posters celebrating your savings. Place the posters in prominent locations (on the wall outside your boss's office or in the cafeteria) where your successful world class ultrasound program can be celebrated.

Allan Rienstra has over 20 years of experience leading SDT's team of implementation specialists. SDT creates world class results-oriented ultrasound programs all over the globe. Email: allan@sdthearmore.com Phone: 905-377-1313 Mobile: 905-373-2342

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HEAR SDT MORE

Understanding Criticality:

Myths and Pitfalls to **Avoid**

*Understanding criticality and where it fits in your reliability engineering plans is, well, **critical** to the success of your asset management program. But there are some commonly held myths and misperceptions about criticality. These top myths and pitfalls often prevent organizations from performing a comprehensive criticality analysis.*

by Tacoma Zach

Simply stated, criticality refers to the relative importance of an asset or system to the mission of an organization.

Here are seven myths and pitfalls to avoid in understanding criticality in your operation.

1 We know what's most critical already, so we don't need to do a criticality analysis.

This is probably the most common objection to conducting a criticality analysis. Too often, operations personnel declare unwaveringly that they "know what is critical." Usually, this is mostly true approximately 80 percent of the time, based on independent criticality studies conducted at a sampling of facilities.

Or, too often, criticality rankings are really just numbers plucked out of the air, based on a good hunch. This finger in the wind approach leads to real-life examples, like a kitchen appliance in the break room having the same criticality ranking as a key piece of process equipment in a refinery. Inevitably, a proper criticality analysis finds something highly critical has been overlooked, or resources are being misdirected to non-critical assets.

It is also important to ask **who** in your facility *knows* what is critical. How is their knowledge being preserved? What happens when they leave or get injured? A criticality analysis will integrate, document and preserve vital institutional knowledge so your organization is less people-dependent.

Are you relying on a hunch or assumption that your organization truly understands the criticality of its systems?

2 We just did a HAZOP/FMEA so we don't need another analysis. We've got all the information we need.

Congratulations! These studies take a lot of hard work. However, they have different aims and deliver different information than a criticality analysis.

A failure mode and effects analysis (FMEA) starts at the asset level and focuses on asset performance, the ways an asset can fail and the effects of failure on its performance. FMEA does not tell you how important an asset is to the mission of your facility. Here's the bad news: If you completed an FMEA without having a criticality analysis, you may have just wasted resources. FMEA is a resource-intensive and time-consuming effort. A system level criticality analysis prior to the FMEA will help you target your resources only toward assets critical to sustaining your operation.

Similarly, a hazard and operability (HAZOP) study does not help you identify your most important assets. A HAZOP is focused on process safety engineering design to identify inherent hazardous designs for safe operation and functionality. A HAZOP can tell you when the wrong valve is in use, but not how important that valve is.

In contrast to both FMEA and HAZOP, a criticality analysis starts with the big picture, evaluates the importance of systems and assets to the mission of the organization and considers the consequences of failure to overall mission objectives. The criticality rankings then direct further reliability engineering activities, such as FMEA, reliability centered maintenance (RCM), or capital project management.

> *Is a safety hazard being mistaken for a critical asset? Are you wasting valuable resources on non-critical assets?*

3 A criticality analysis is a very expensive and time-consuming effort. We're not sure it's worth the effort.

Like anything else in operations, a criticality analysis can be easily done inefficiently and cost way too much. However, an effective criticality analysis can be accomplished with far less time and cost than you may anticipate. There are several keys to making this possible.

Firstly, an effective criticality analysis starts at the system level instead of the asset level. In a typical operation or facility, the ratio of systems to assets is 10:1. So, starting at the system level dramatically reduces the workload. As critical systems are identified, the analysis is taken down to the asset level in those systems. Systems that are found to be insignificant to the overall mission of the operation can be analyzed later.

Secondly, world-class software tools are available that will help you calculate criticality rankings based on all the relationships of your systems and assets in relation to your mission parameters. It is possible to conduct a criticality analysis with a spreadsheet or even pen and paper, but why would you? The costs of doing it this way really are prohibitive.

Finally, simply ensuring that you have the right personnel participating in the study will dramatically improve your efficiency and the quality of your analysis. You need the right internal subject matter experts, including maintenance experts, reliability experts, operations leaders and someone who can proficiently manage your data. It is also very important to engage competent and experienced facilitators with field experience.

A criticality analysis will inform and influence many of your other reliability initiatives. Truly understanding the criticality of your assets allows for mitigating risk, directs further reliability engineering efforts, fine-tunes asset condition management, improves work execution management and lays the foundation for aligning all activities toward the mission of your organization.

> *Has the perceived short-term cost of a criticality analysis prevented you from taking advantage of all the long-term benefits it will bring?*

4 An expensive asset is definitely a critical asset. (Something inexpensive can't be that critical.)

Have you ever been sidelined by a faulty spark plug? A $5 part can make you late for work or miss your plane. However, it is doubtful a rip in your expensive leather upholstery ever kept your car from getting you where you needed to go.

It is very easy to think that if an asset is expensive, it must be critical and deserves lots of attention. While expensive items certainly should be looked after well, as the alternative is costly, they are not automatically critical.

Conversely, it is often assumed that an inexpensive part is unimportant. It is not uncommon for a small part or cheap system (e.g., a seal water system) to have the largest effect on the overall mission.

> *Are you paying undue attention to expensive assets or overlooking something important?*

5 If something is in poor condition, then it is critical.

Confusing condition with criticality is an easy and common mistake – we all speak of things being in critical condition all the time, meaning doing poorly. The condition of an asset does not correlate with its criticality to the function or mission of the system. To be sure, the condition of an asset affects the likelihood of its failure, but it does not change its importance to your operation.

Criticality analysis is different from condition assessment, which falls in the domain of asset condition management. Criticality analysis, combined with condition assessment and management, is powerful for directing work planning and execution.

> *Are you distracted by the condition of assets that are not critical to your operation?*

6 If it ain't broke, fix it.

Sometimes, the assumption is made that a critical asset must be the subject of aggressive preventive maintenance, whether it needs it or not. In fact, a critical asset may just need monitoring or critical spares to be stored.

Fixing something that doesn't need fixing actually increases the likelihood that it will fail by introducing infant mortality. Criticality ranking determines how much attention a system or asset gets, not whether it needs fixing. Determining if an asset should be fixed depends on what constitutes failure and whether it has failed by this definition.

For example, a critical pump might be running smoothly. Its criticality determines paying a lot of appropriate attention to it. But we don't need to fix anything pre-emptively. It is a poor maintenance plan if, as a matter of routine, pump rebuilds occur every six months regardless of whether they are needed, all in the name of preventive maintenance.

> *Are you fixing things that aren't broken?*

7 Phew. We finished our criticality analysis. We can check that box.

Well, not exactly. Criticality is relatively static, unlike condition, which can change from day-to-day or even minute-to-minute. While condition monitoring needs to be ongoing, you do not need to review your criticality rankings daily or weekly.

However, although we just said criticality does not change day to day, it will change. You can't just "set it and forget it."

It is important to update your criticality analysis to reflect fundamental changes in mission objectives, regulation (including permits), sensitivity to safety or environmental issues, economic downturn, commodity prices, commercial terms and contractual terms, and even in some cases SOP and security policy rules.

Best practice is to review your criticality rankings every six months, but no longer than 24 months. Fortunately, revisiting criticality is far more efficient and accomplished in far less time than the initial analysis.

> *Did you set it and forget it? Do you need to update your criticality analysis?*

It is said that the best time to plant an orange tree is 10 years ago. The second best time is today. If you haven't completed a criticality analysis for your facility, the right time to do it is now. It can be done efficiently and will deliver tangible value to all the elements of your asset management program. If you avoid these pitfalls, you will get even better results.

***Tacoma Zach**, P.Eng., of Ontario and Alberta, Canada, is a Certified Reliability Leader™ and CEO of Uberlytics, experts in criticality analysis. With over two decades in operations under his belt Tacoma now helps organizations discover what's most critical to their mission and uses that information to optimize their asset management. His first book, "Criticality Analysis Made Simple" was recently published by Reliabilityweb.com. Find it at mro-zone.com. www.uberlytics.com*

Using Effective EAM to Improve Asset Utilization & Reduce Costs

by James Mourafetis and Uday Kamat

For businesses that rely on heavy assets, an effective enterprise asset management (EAM) program could hold the key to addressing the common challenges of increasing asset utilization rates and overall operational performance while holding the line on costs.

By focusing on people and operational improvement, such an EAM program can significantly improve asset utilization rates while reducing long-term capital costs. That attention to people and operations is an essential element of EAM success, however, strategies centered alone on capital investments in facilities and fleet logistics typically fall short of the significant benefits an effective EAM effort can produce.

EAM encompasses the whole life, optimal management of the physical assets of an organization to maximize value. It applies to the design, construction, commissioning, operations, maintenance, and the decommissioning and replacement of equipment and facilities.

Capital-intensive businesses in industries, such as rail, mass transit, utilities, oil and gas, mining, petrochemicals and airlines, are among those that stand to benefit from a thorough EAM approach. The railroad industry offers numerous examples of the potential value EAM can deliver.

Class I railroads, for example, typically see locomotive utilization rates in the 25 to 35 percent range. Like their counterparts in other heavy asset reliant industries, when railroad assets like locomotives are off-line, they aren't generating revenue. Meanwhile, that locomotive off-line time forces railroads to maintain larger fleets, increasing their capital costs.

EAM's Potential Benefits

EAM can benefit railroads' performance in three areas:

- **Productivity—**The typical railroad faces a 65 to 70 percent operating ratio, which means the cost to operate is 65 to 70 percent of revenue. So, railroads that optimize workforce efficiency can handle five to 10 percent year-on-year growth while bending the cost curve.

- **Reliability—**Fleet maintenance improvements can boost asset utilization rates and extend the life of rolling stock, allowing railroads to reduce the size and frequency of investments in their fleets.

- **Safety—**Improved fleet maintenance can lower accident rates and increase public safety.

An effective EAM initiative must combine a top-down approach, defining the initiative's strategies and goals with a bottom-up aspect focused on gaining workforce input and buy-in that can ease implementation of the strategy.

The Steps to EAM Success

For railroads, the key to EAM success is a simultaneous focus on both strategy and implementation as executives follow a four-step process. Those four steps include:

Identify assets and measures.

Executives must first answer three essential questions about the asset:

- *Utilization—How often is the asset in use?*
- *Reliability—How well does the asset work?*
- *Unit cost—How much does it cost to use the asset?*

It's also necessary to determine an asset performance index (API); for example, the percentage of time a locomotive is actually pulling railcars. Examining the locomotive's API against the various factors contributing to time not spent pulling railcars provides a detailed picture of the asset's current utilization and potential areas for improvement.

Create an asset vision for the future.

The railroad can use benchmarks from other heavy asset industries to set realistic targets, allowing for differences in systems and approaches between industries. Meanwhile, executives should assemble cross-functional teams to redesign workflows and achieve the desired improvements. Such collaboration will ensure buy-in from shop floor personnel who will be directly affected by process changes and maximize the chances for the EAM initiative's success.

Develop work streams to align and prioritize actions.

To maximize asset utilization, it's necessary to identify factors contributing to time loss buckets and target improvements to reduce losses. A top-level work plan should be established for each work stream that clearly defines its current and future state and measures the unit cost impact of planned improvements. Along the way, value is created by linking project deliverables to API improvements. The chain of command should look something like this:

- Champions assigned for each work stream lead reviews with project teams and periodically present project performance to an asset management team.
- The asset management team reports to an asset committee charged with devising strategies to remove work stream roadblocks.
- A senior management steering committee oversees governance over the initiative and reports progress quarterly to the chief operating officer.

Deliver productivity results through EAM integration and value analysis/value engineering.

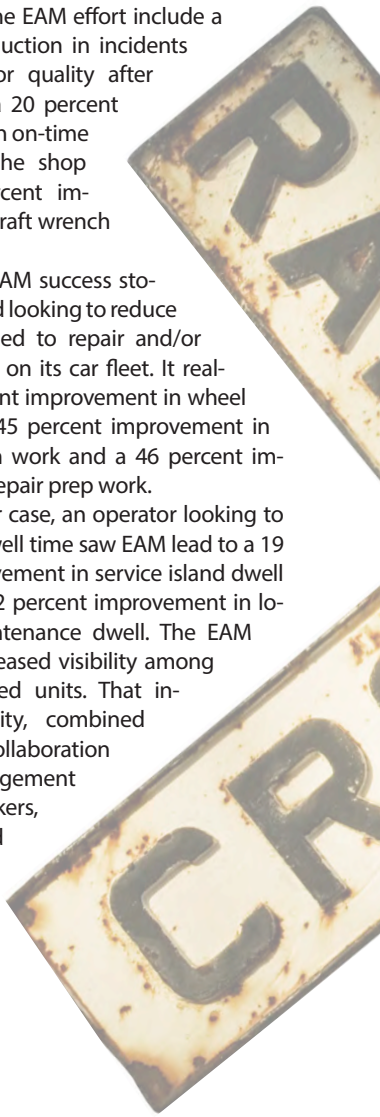
The first task in this stage is identifying what matters through on-site analysis. The next is developing capable processes by organizing repair and testing processes in a systematic manner. Site improvement councils should be created to develop and install the success factors critical to driving continuous improvement, while a quality council should be formed to eliminate defects. Detailed road maps and timelines aligned with specific targets will help achieve the desired short-term results of improved workforce efficiency and asset utilization, along with the long-term goals of reducing capital investments. Finally, integrating EAM to achieve sustainability and employing value engineering over the long-term can lock in the improvements.

EAM Benefits Delivered

The benefits Class I railroads can realize by employing a successful EAM initiative can be significant. One railroad, for example, set a long-term goal of improving its asset performance by 25 percent over a 15-year timeline, with every one percent improvement in the railroad's API equivalent to a one percent improvement in asset uptime. After engaging in the sort of EAM process described in the previous steps, the railroad is on course to reduce locomotive mechanical operating costs through a fleet reduction of 25 percent. Shop-level performance improvements produced by the EAM effort include a 30 percent reduction in incidents related to poor quality after shop release, a 20 percent improvement in on-time release from the shop and a 15 percent improvement in craft wrench time.

Another EAM success story saw a railroad looking to reduce the time needed to repair and/or replace wheels on its car fleet. It realized a 46 percent improvement in wheel repair time, a 45 percent improvement in documentation work and a 46 percent improvement in repair prep work.

In another case, an operator looking to reduce yard dwell time saw EAM lead to a 19 percent improvement in service island dwell time and a 12.2 percent improvement in locomotive maintenance dwell. The EAM effort also increased visibility among previously siloed units. That increased visibility, combined with the collaboration among management and shop workers, has improved morale and enabled sustained efficiency improvements.



A Coordinated EAM Approach Delivers the Greatest Benefit

The greatest improvements in asset utilization result from changes at the shop level and the involvement of employees working there.

Workflow process changes determined exclusively at an organization's highest level and handed down to the shop floor inevitably produce unsatisfactory results. Instead, the best EAM outcomes result from involving both craftspeople in the shop and their local management, as well as upper management. Such coordinated efforts not only maximize the chances of achieving desired short-term results, but also provide for the sort of long-term, high-level support that will help ensure the improvements' sustainability.

For any heavy asset business that traditionally takes a long-term view of its capital assets, an effective EAM initiative can produce clear and valuable benefits. These immediate gains in productivity and asset utilization can lead to long-term savings in operating costs and capital expenditures.

Figure 1: Assessments by time loss category

Road fleet time lost from not pulling railcars, including time loss due to reliability vs. utilization performance

Time bucket breakdown—sample week

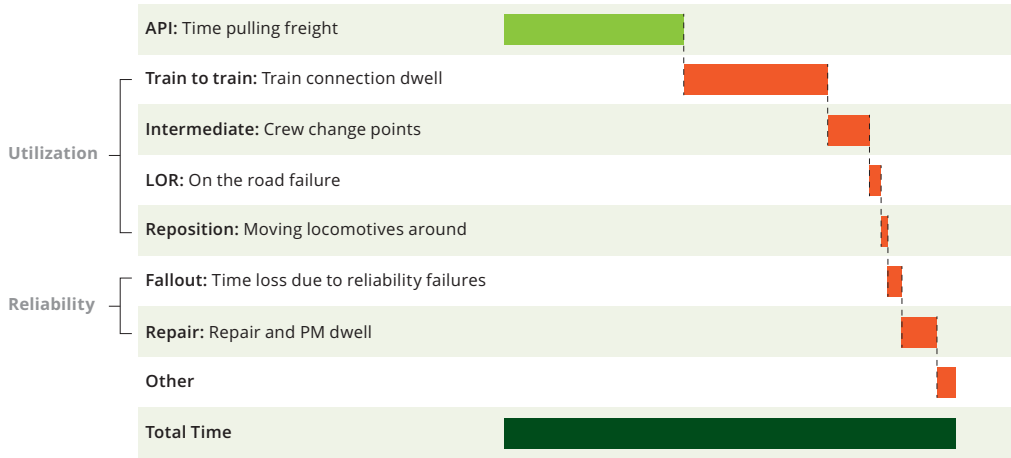
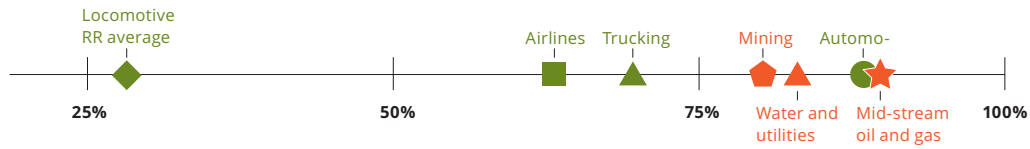


Figure 2: Utilization by Class I railroads compared with other heavy-asset industries

Heavy-asset industries by utilization percent



Asset performance comparison

Stable, reliable performances through process improvement

Real-time asset knowledge
- Location
- Condition
- Performance

Rapid deployment systems

Targeted maintenance

Infrastructure

Automation

__James Mourafetis__ is a Senior Vice President with Argo and leads its railroad and public transportation practice worldwide. He specializes in enterprise asset management. www.argoconsulting.com

__Uday Kamat__ is a Vice President with Argo and specializes in deployment of asset management tools at Class 1 railroads to improve safety, reliability and availability. www.argoconsulting.com

Is Your Plant Reliable? It's Good for Personal and Process Safety

by Ron Moore

Do you believe in safety?

There is always a unanimous and resounding "Yes!" when this question is asked, particularly from executives. If you, particularly you executives, believe in safety, then you must believe in reliability and, more importantly, have the appropriate policies, systems, practices and measures to support reliability. You must walk the talk about safety.

Compelling data from operating plants has been provided to demonstrate that "a reliable plant is a safe plant, is a cost-effective plant, is an environmentally friendly plant." The reverse was also demonstrated, that is, an unreliable plant is less safe, more costly and less environmentally friendly- Several of the figures in this article support this position.

When a plant is reliable, there are fewer failures and process upsets, resulting in higher production capability as measured by asset utilization (AU) or overall equipment effectiveness (OEE). This reduces the exposure to the risk of injury. See Figure 1.

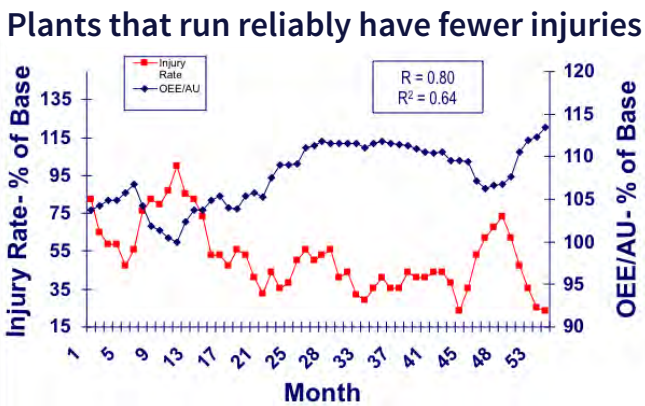


Figure 1: Production capability (OEE) versus injury rate

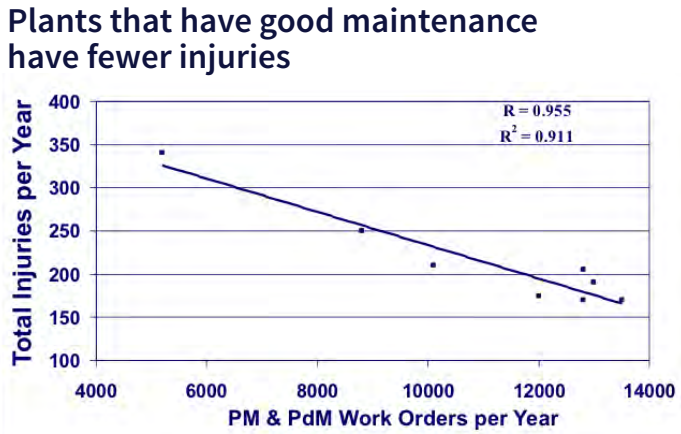


Figure 2: Injuries versus PM/PdM work orders per year

The more disciplined your maintenance, the fewer injuries you have

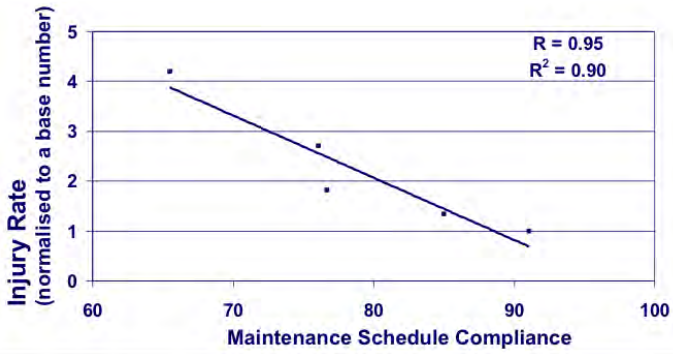


Figure 3: Injury rate versus maintenance schedule compliance

When plant equipment is cared for by doing preventive maintenance (PM) in a disciplined way, and when equipment is routinely monitored to detect problems early and those problems are managed by proper planning of the work, there are fewer injuries. See Figures 2 and 3.

On the contrary, reactive behavior that results in excess corrective work increases injuries. See Figure 4.

The more reactive and corrective work you do, the greater the risk of injury

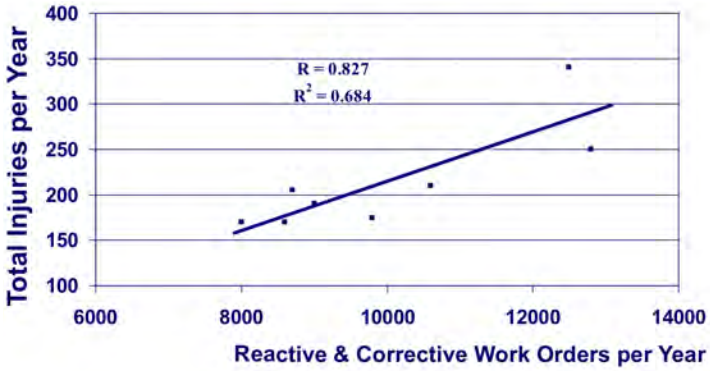


Figure 4: Injuries versus reactive and corrective work orders per year

With a highly reliable plant, costs are lower. With higher production capacity (i.e., OEE) and lower costs, there are fewer process disruptions, and systems and equipment don't fail as often. See Figure 5.

And, is the more reliable you are, the lower your costs

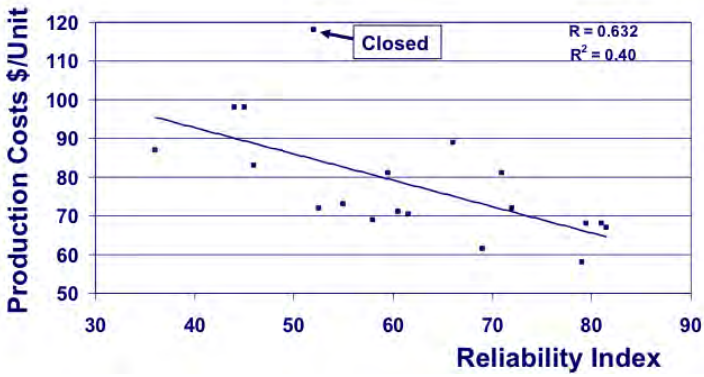


Figure 5: Production unit costs versus reliability index

And as reliability improves, environmental performance improves. See Figure 6.

And, the better your plant operates, the fewer environmental incidents you have

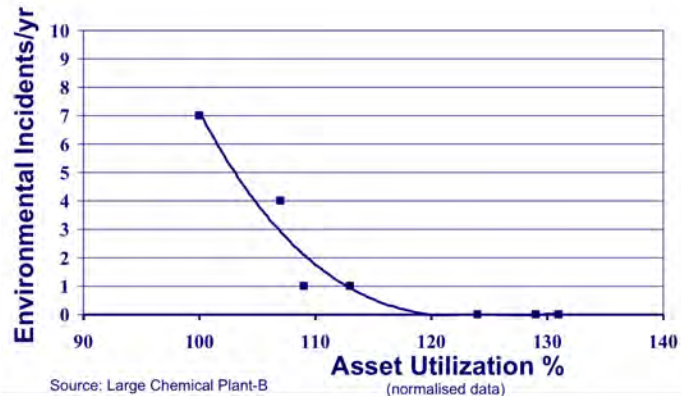


Figure 6: Environmental incidents versus asset utilization

The data shown is exemplary of a much larger data set, all of which is consistent. It is compelling!

How do you get reliability? You take a holistic and comprehensive approach to defect elimination in ***all*** processes, that is, design, procurement, stores, installation and start-up, operation and maintenance. Working together toward a common purpose results in a plant that is reliable, safe, cost effective and environmentally friendly. Reliable plants maximize benefits – production capability, on time delivery, quality, lower costs, higher gross profits that finance future investments in business and product development and, of course, growth in customer satisfaction, market share, earnings per share and share price. And reliable plants minimize risks of injury, production loss, higher costs and major accidents. Cost management through improved processes and defect and waste elimination are critical to your success.

Incidentally, doing better maintenance will provide some improvement, but if that's all you do, you'll only be performing work that you shouldn't be doing at all more efficiently. You do not get reliability by doing good maintenance, but you must have good maintenance to have reliability. Therefore, it's critical to eliminate the defects in all areas. This approach is illustrated in Figure 7.

The Reliability Process
(note where most defects occur)

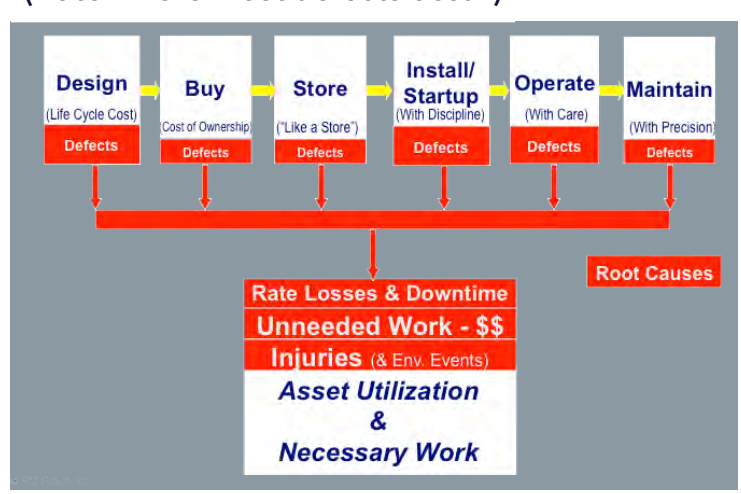


Figure 7: The reliability process

Is a Safe Plant Also Reliable, Cost Effective and Environmentally Friendly?

As the figures demonstrate, a reliable plant is a safe plant, but is a safe plant a reliable plant? Notwithstanding all this data, there are operations that have excellent safety performance, as demonstrated by their injury rate, and yet:

1. In one operation, a chemical plant went out of business. It is often said in total jest that if you don't want to hurt anyone, close the plant. This operation did, but obviously not because of a desire to eliminate injuries. They weren't making money in spite of a reasonable market for their products, in both market demand and price.
2. Another operation, a large oil refinery, had a major accident that killed several people and injured many others, resulting in hundreds of millions of dollars in damages. They had recently received an award for safety performance when the accident occurred.
3. In another operation, an offshore drilling rig, also had recently received an award for safety performance, but soon thereafter had a major accident that killed several people, injured many others and created an environmental disaster resulting in billions of dollars in damages.

So, what happened in these cases? If, as the figures demonstrate, a reliable plant is a safe plant, as well as a cost effective and environmentally friendly plant, is the reverse true? That is, is a safe plant a reliable plant, cost effective and environmentally friendly? The previous examples demonstrate that this is not necessarily true. Why is this?

The Process Safety Pyramid

Andrew Hopkins, in his groundbreaking work, "Failure to Learn: The BP Texas City Refinery Disaster," posits that there is a difference between personal safety and process safety, though they have overlapping areas. He characterizes process safety with a process safety pyramid, shown in Figure 8.

His analysis indicates that you can have excellent personal safety, all the while risking your process safety. For example, frequently exceeding safe operating limits, ignoring or not understanding alarms, missing critical inspections and calibrations, poor operating instructions and training thereto and poor maintenance of critical equipment all lead to a much higher risk of a process safety breach, loss of containment and, ultimately, a major accident. He further suggests that personal safety events are driven by high frequency, low consequence activities, while process safety is driven by low frequency, high consequence activities. In relative terms, this is relatively true. Twisted ankles, burned fingers, or even lost limbs are more common than explosions that kill people, so the former are more frequent and less consequential.

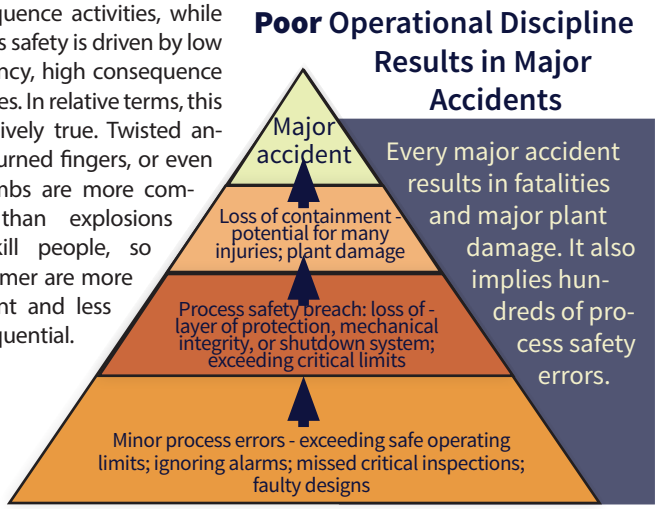


Figure 8: The process safety pyramid

The Reliability Pyramid

A similar figure, the reliability pyramid developed by Winston Ledet from operating plant data, is shown in Figure 9 and focuses on defect elimination. The more defects (i.e., imperfections in any area) you have, the more repairs you do, the more losses you have and the greater the risk of a major incident that results in injuries and higher costs.

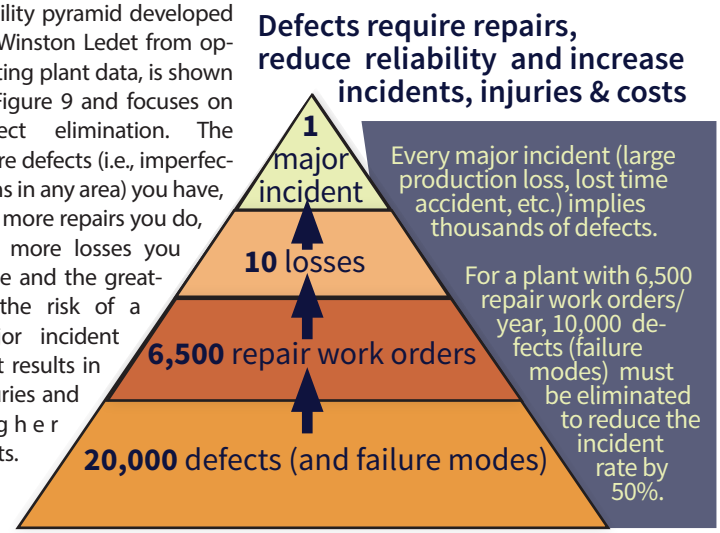


Figure 9: The reliability pyramid

The Original Safety Pyramid

The original safety pyramid, first posited by Herbert W. Heinrich in 1931, is shown in Figure 10 and suggests that unsafe acts of individuals create most accidents. Modern safety experts say that adhering to the Heinrich model can lead to an overemphasis on worker behavior and insufficient attention to system design and operating and maintenance practices. Heinrich is, however, credited with bringing attention to workplace safety and focusing on the human behavior element of safety, which is, in fact, a critical element. However, it is not sufficient.

All these safety pyramids have one thing in common. At the bottom are relatively minor acts, incidents, defects, or process variations that ultimately result in a major loss, injury, or even a catastrophe.

Personal safety appears to be influenced more by personal behavior, while process safety is influenced more by design, operating and maintenance practices, training and the like. However, there is considerable overlap, as suggested by Hopkins and shown in Figure 11 as the process and personal safety pyramids. And, in fact, each likely feeds into the other, that is, defects create minor process errors and vice versa, and personal behavior creates defects and minor process errors and vice versa. All the issues are interrelated.

Many modern safety experts are less enthused with the pyramid approach and subscribe more to the Swiss cheese model of accident causation, first proposed by James Reason. This model suggests that accidents and injuries, particularly the major ones, are more likely the result of having many holes in your systems and practices, like the layers of Swiss cheese, with each layer representing, for example, poor management, poor system design, poor training, poor decision making and so on. It is only

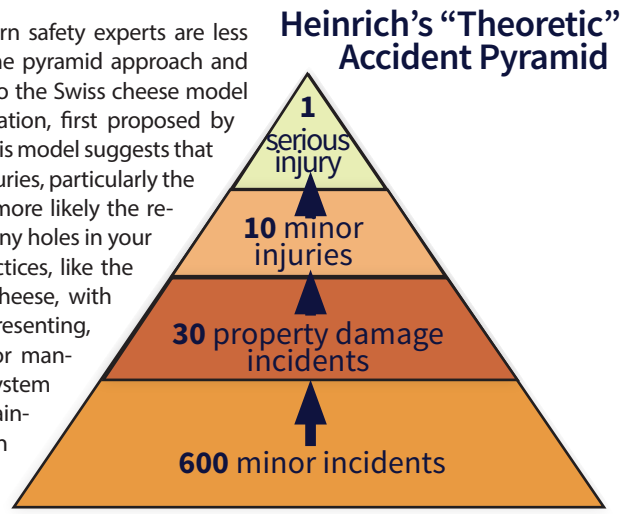


Figure 10: Heinrich's accident pyramid

when these holes line up that major incidents occur. Whether you subscribe to the pyramid model or the Swiss cheese model, it is the defects, process errors and behaviors that are at the root cause of these very undesirable events of injuries, costs and catastrophes. Therefore, they must be addressed through intense operational discipline.

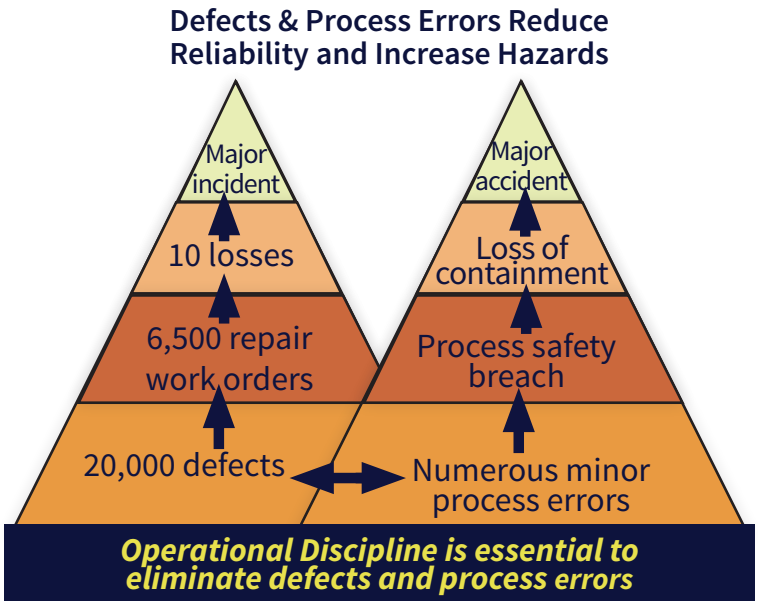


Figure 11: Process safety and personal safety pyramids

How to Manage All This

To minimize the risk of injury, incidents and major accidents, ***operational discipline is essential*** to encourage the appropriate behavior, eliminate the defects, minimize the process errors and foster the discipline in all practices that will reduce risk, including design, operation and maintenance.

Hopkins also suggests that focusing on slips, trips, falls and personal behavior, ***while cutting costs***, will likely expose the business to more hazards and much greater risk. Two messages are being heard: Behave safely by wearing your personal protective equipment, doing your lockout/tagout, holding the handrail, doing your permits to work and so on. But, we don't have enough money for people to do things right, like properly maintain the equipment, calibrate the instruments, add equipment to reduce hazards, train people in new procedures, eliminate spurious alarms, or do any number of things. It's a mixed message to the detriment of the company. People will try to follow the standard safety mantra, all the while seeing other things being done poorly. As demonstrated previously, you can get better personal safety performance, and still a) go out of business, or b) have a major catastrophe.

Granted, you must manage the business to make money or you won't have a business. But, this mixed message exposes the company to greater risk than it otherwise would. It is a delicate balance to manage. However, if you have operational discipline, apply the reliability process, engage the workforce in simple, routine improvement and show appreciation for the improvements, you will get better performance in ALL areas.

Leadership, Alignment and Cultural Change

Supporting this approach requires leadership, alignment and almost always, cultural change. Good leadership is the ability to inspire ordinary people to consistently perform at an extraordinary level, to look forward to coming to work every day. How? By putting employees into a business system that engages and aligns their personal interest with corporate interests. Give them work they like to do; challenge them to improve it; give them the tools to improve it; put them on an improvement team; teach them problem-solving methods; thank them and show your appreciation when they do a good job; send them to training, but when they return, make sure they use the training received. In other words, engage them. According to one study, engaged employees are three times more productive than others. According to another, eliminating the small, day-to-day problems has a much bigger impact on performance than focusing on the major problems. Think of hundreds of people routinely engaged in process improvement and defect elimination, and then think about what happens to costs, performance, and safety, both personal and process.

Alignment requires the repeated articulation of the strategy, goals and respective roles from the CEO to the shop floor. It also requires measures and systems that reinforce the strategy, goals and roles. It is really hard work. According to the studies, most organizations are not very well aligned. Most functions within a given organization operate within their silo, optimizing at the suboptimal level. Having everyone think at a systems level with regards to the impact their decisions will have on the business as a whole and aligned to a common corporate strategy, not just their department's, is essential.

Regarding cultural change, when asked, "Do people want to change?," many people will reply something to the effect of, "No, they do not; they're stuck in their old ways." Many will disagree with this view. People **do** want to change **if** given a compelling reason to change, **if** there's something in it for them (e.g., better pay, less hassle, more secure future, etc.) and, most importantly, **if** they participate in creating the changes and thus have ownership for them. It's up to the leadership of an organization to align the organization and facilitate change by applying these principles and to use safety as a compelling reason for change. Incidentally, cultural change isn't something you do once and it's done. It, too, is a continuing effort.

To this end, and given the data presented, organizations must have a policy for reliability, one that parallels, or is even integrated with, its safety policy. Consider the following safety policy, which mirrors that of many companies and to which additional words have been added in italics to address personal and plant safety:

- All injuries ***and failures*** are preventable.
- No task is so urgent that it cannot be done safely ***and reliably***.
- Management must provide a safe ***and reliable*** work environment.
- We are each responsible for preventing injuries ***and failures***.
- Everyone is empowered to stop unsafe ***and unreliable*** behavior.

Conclusion

Many companies have safety policies, but few, if any, have combined these policies to include reliability as a core value. Moreover, if CEOs of these companies truly believe that safety is a top priority, they would have policies for reliability, linking reliability and safety. If they truly believe in safety, they would give at least as much attention to reliability and operational discipline as they do to high-powered consulting companies. The truth is they do not and their commitment to a holistic view of safety is relatively weak. And as a result, the company and its people are at greater risk.

Getting both personal and process safety requires operational discipline – tenacious use of best practices in **all** areas.

Ron Moore *is Managing Partner of The RM Group, Inc., in Knoxville, TN. Ron is the author of "Making Common Sense Common Practice: Models for Manufacturing Excellence", now in its 4th Edition; "What Tool? When? A Management Guide for Selecting the Right Improvement Tools", now in its 2nd edition; and "Where Do We Start Our Improvement Program?", 1st edition, all available from MRO-Zone.com; as well as "Business Fables & Foibles" and "Our Transplant Journey: A Caregiver's Story", from Amazon.com. He has authored over 50 journal articles.*

A Sustainable & Effective Approach to Vibration Analysis

by Richard Bierman

The approach to vibration analysis is likely the most varied practice in the industry. This is partially due to the lack of standardization, combined with an explosion of new knowledge and technologies over the last two decades. Guidelines for creating a world-class vibration program will differ immensely depending on the source of information. When designing a new policy or optimizing an existing program, it is vital to have a good understanding of the shortcomings that can be found in almost every network in operation. A lack of buy-in, priority, provability, the uncertainty of diagnostics, false alarms, missed opportunities, time and dedication, improper settings and lack of resources are common reasons for a less than fully successful vibration program. In short, the issue is not one thing that's 100 percent wrong, but rather 100 things that are one percent wrong. At the Chevron Phillips Chemical Company's (CPChem's) Sweeny complex, a small amount of unique improvements made a significant difference in the program's success.

The first and one of the most valuable tools is the use of trend-based narrowband envelope alarming. Traditionally, plants used overall velocity to determine the condition of rotating equipment. Unfortunately, overall vibration could be affected by different situations, such as process conditions, machine load or location, mounting specifics and resonances unrelated to the machine itself. The alerting of an increase in overall vibration is an ineffective way to monitor machinery conditions. Spectra, time waveform, orbit plots, phase and other types of data have greatly improved the ability to identify the source and severity of the vibration instead of just the amplitude. Analyzing all this data takes a significant amount of time and when reacting to a possible fault condition, or trying to monitor thousands of components found at most facilities, there is much less time than there is data.

In short, the issue is not one thing that's 100 percent wrong, but rather 100 things that are one percent wrong.

With narrowband envelope alarms applied to the spectra, CPChem's Sweeny facility can focus its efforts on reviewing data that has deviated from its previous condition, regardless of amplitude. The trended alarms are customized for each collection point based off a trend of its various running condition signatures. These variances allow elevation and dissention of specific frequencies, such as those caused by changes in process, accelerometer placement and even ambient temperature. More so, the alarms can be set to more stringent bandwidth and amplitude levels, giving the analyst an extremely early warning of the first leading indicator.

The software used makes setting the narrowband alarms easier than setting up overalls, so as conditions change and no fault is found, they easily can be arranged to allow for a recurrence of that condition. At the same time, when a fault condition is discovered, the narrowband alarms can be set to flag any leading indicators found in the historical data. Constant updates to the signature alarms ensure the same situation never repeats itself. When specific frequencies breach the envelope alarm, the analyst is directed to the exact frequency of concern, reducing the amount of time it takes to diagnose the issue. The longer the alarms are in service, the more accurate and reliable they become.

With accurate alarms set to catch leading indicators, the majority of CPChem's vibration issues are detected and resolved before a mechanical fault occurs and without the need to shut the machine down. The alarms also allow more time to plan in situations that require a shutdown, reducing the frequency in which the data needs to be collected and the amount of points from which the data needs to be collected. Any machine that is outside of its normal running condition is added to an exception route. The exception route is collected more frequently and additional points are collected on that machine, giving better details of the situation. With less data to analyze, more focus can be put on the items that need it. With the use of trend-based narrowband envelope alarms, data collection has been reduced by over 80 percent and machinery saves have increased immensely.

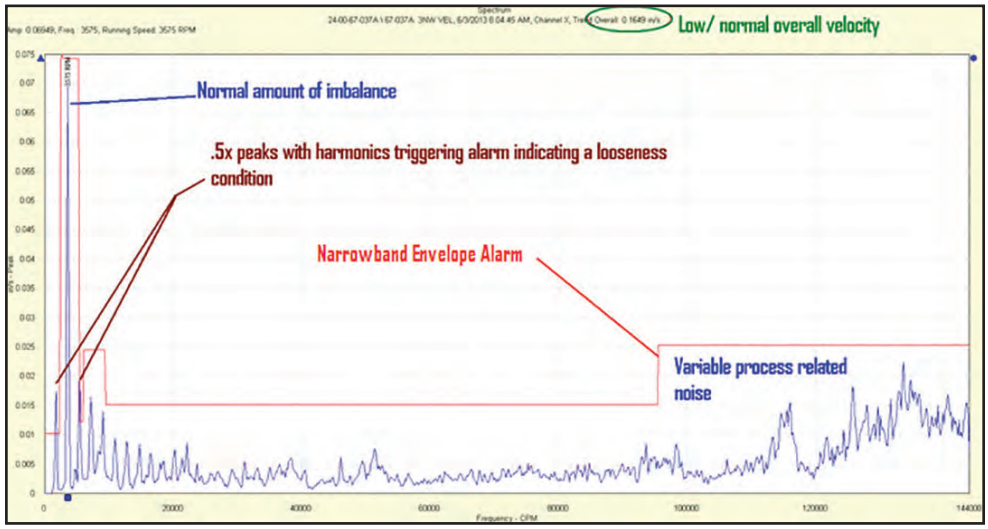


Figure 1: Narrowband envelope alarms trigger alerts for higher amplitudes at specific frequencies and allow higher amplitudes at others. Each alarm is customizable to specific points, allowing for variances in accelerometer placement and non-fault related conditions.

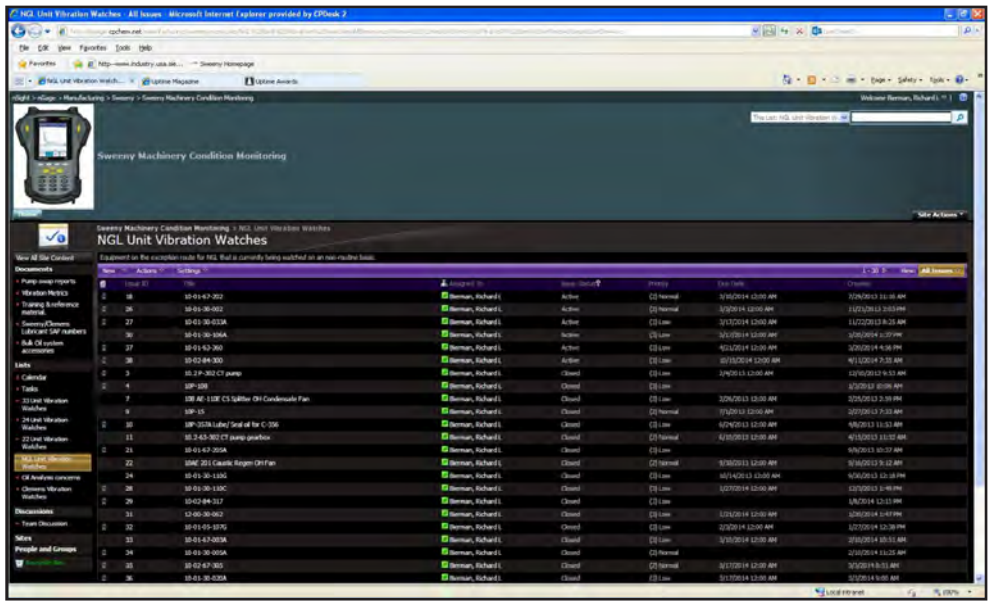
Guidelines for creating a world-class vibration program will differ immensely depending on the source of information.

Having such a powerful, predictive tool is not the only reason why CPChem has had such great success. Communication is the key to any successful program, whether it's reliability, safety, management, or productivity. The Sweeny complex uses a web-based platform to share data found by the analyst with the specific group affected. When the analyst finds a concern, a report is posted with recommendations in the vibration watch list for the specific area of responsibility. E-mail notifications are automatically sent to the subscribers for that section and the analyst can set up alert notifications to whomever else may need the information. This serves many purposes. Not only does it provide documented proof of vital communications, it also keeps a historical record of each machine in question. This constantly growing database of vibration reports provides an accurate account of machinery issues and makes it simple to find reoccurring problems, once again ensuring the same situation won't repeat itself.

Another essential benefit of this type of platform is that it builds enthusiasm for the program. At the Sweeny complex, the unit operators collect the vibration data. Prior to this, the data was uploaded and never seen again by the operators. Now operators are aware of what is being looked at and why. The reports include what was detected in the initial data, what was done to correct the issue and the results of the data afterwards. When a corrective action is executed, the team that performs the action can see the results of their efforts. No longer are they "collecting data for no reason" or "data that no one looks at." Rather, they are finding issues and resolving them. Combined with the reduced workload regarding the collection process, the team no longer dreads collecting data and likes knowing that what they are doing has proven value.

The data also shows that something as simple as adding grease to a motor or making minor process changes makes a difference in the performance of the equipment. Vibration analysis directs the frequency of preventive maintenance (PM) activities, process rates and much more than just mechanical maintenance. The exposure created by the company's communication platform has generated an interest in every depart-

Figure 2: Web-based communication platform for sharing data within the company



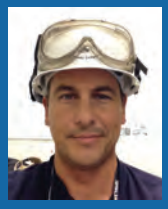
The success of the program stems from the collaboration of all the teams working together.

ment, which is proven by its consistent growth of new subscribers, including those from Corporate and other CPChem facilities.

This article covers only a few key points of the vibration program, which is part of a more elaborate reliability department and predictive maintenance system. The most important aspect for a successful vibration program is buy-in and support, not only from the leadership team, but everyone involved. Management at the Sweeny complex has always had a focus on reliability and continuous improvement. Accountability and consistency are equally important views shared by the team. The drive to create the program stems from the top. The success of the program stems from the collaboration of all the teams working together. Gaining this type of support does not happen by the direction of any single individual. The management and supervision at CPChem is just as much a part of the group as the technicians and production crew. Communication of goals and objectives allows everyone to work together to achieve them.

The collection methods, analyzing techniques and site-wide communication have fed off the existing atmosphere already in place at the Sweeny complex. For Sweeny, a combined effort and receptive atmosphere have generated a truly sustainable, provably and effective method for a predictive maintenance program. Having a successful program using narrowband envelope alarms and sharing the information with the right groups give the program the recognition and attention it needs to maintain a high priority and sustain its success.

In conclusion, the shortcomings commonly found in other programs have been drastically offset at the CPChem Sweeny facility, not by doing one thing 100 percent better, but by several people doing several things one percent better.



Richard Bierman *is a Vibration Analyst for Chevron Phillips. Fifteen years of equipment monitoring experience has allowed Richard to understand the cause and effect of mechanical faults and how they relate to the vibration data, as well as recognize fault conditions not found in documents on the subject of typical vibration diagnostics. Mr. Bierman is also the SME for Lubrication Analysis and Program Optimization. www.cpchem.com*

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The Right Resources: Start Designing a Planning & Scheduling Program

by Kim Waterman

If you need to implement a new planning and scheduling program, you're probably discovering that the task can be rather daunting. You need the right resources, the right organizational support, the right data, the right business practices, the right amount of time, the right change management approach, and the list goes on. This high level generic stuff may seem like implementing planning and scheduling just isn't within your grasp. But there are ways to achieve an environment that will support a planning and scheduling program that works with what you already have in place and takes into account what your team is able to manage throughout implementation and beyond. If you take a closer look at what you already have, putting the final touches on a successful planning and scheduling program may not really be that big a beast to tackle.

Right Resourses

You already have them on staff; you just need to recognize it officially and maybe put a little more structure around what they're probably already doing. You already have the maintenance supervisor who assigns work to his or her crew. You have the crew lead who knows how long a particular job takes to complete based on how long it's taken the last umpteen times it's been completed. And you have that administrator who knows who's out sick, who's on vacation and when that big regulatory preventive maintenance (PM) is coming up that requires people from three different departments for a day and a half.

So leverage them.

There are countless studies full of funky math that will tell you that the average wrench time of any given maintenance technician is 35 percent of his or her day and that this figure will increase to 50 percent or more with the implementation of a planning and scheduling program. And that if you take one maintenance tech out of a crew of say 10 and designate this person as the planner/scheduler, the efficiencies this person achieves will increase the overall output of the crew to the point that the team is achieving the work of what would have previously been attributed to a crew of 15 people.

There's plenty of justification here for designating a resource – or resources – as planners and/or schedulers. All you have to do is figure out who that person, or those people, are.

Right Organizational Support

This one can be a bit trickier. If you don't have support from management to implement a planning and scheduling solution, you're fighting an uphill battle at best. You need at least one planning and scheduling champion within your organization who not only sees the value in implementing a program, but has the authority to help shape and enforce it.

How do you know if you have this person? If your enterprise asset management (EAM) implementation is meeting the needs of your user base (at

least for the most part), if that implementation is continually expanding and evolving both to keep up with technology and the changing needs of your organization, and/or if most of your users are working independently and comfortably with the EAM solution, chances are you have a champion already.

Planning and scheduling is generating a lot of buzz lately. It offers organizations already established with an EAM solution the ability to achieve greater efficiencies and cost savings while working with tools that are relatively low cost. It also allows organizations to stretch their dollars further while maintaining the same size workforce. It's pretty easy to pull together a compelling argument that will help you convince the higher-ups to at least let you pilot a planning and scheduling program. And it should be fairly easy to convince your existing EAM champion(s) that there's even greater return on investment (ROI) waiting to be achieved.

If you can't convince them to take the leap, convince them to speak with a planning and scheduling vendor. These vendors know the benefits of their business and can present convincing evidence to your organization's leadership.

Right Data

You know implementation isn't as simple as installation. You already know you need the right data in your system to get the data you want out of it. You have an EAM solution and it works. You did all the legwork to get your data in place. You know that in order to implement a planning and scheduling solution, you're either going to have the appropriate data already available in your system, or you're going to have to get it in there somehow. There's no way around it.

What data do you need? It depends on your business processes, your organizational goals and the data you have available. Your best bet is to conduct an internal readiness evaluation, or better still, get an independent expert to do it for you. This assessment should examine your business processes to determine what data is mandated, on what basis scheduling will be conducted, what resulting data output will make the planning and scheduling efforts meaningful, and the frequency(ies) with which your pending schedules will be reexamined.

Right Business Practices

What planning and scheduling methodology are you following? While the ultimate goal of all planning and scheduling methodologies is the same – to achieve greater organizational efficiency – the paths they follow to get there can be fairly different. How much backlog can you tolerate? How do you address break-ins that disrupt otherwise planned work? How far in advance do you schedule, to what percentage of your workload do you schedule each week and how often do you review your schedule with your team to ensure your goals are being met?

There are no right business practices and there are no wrong business practices. The best you have could be improved upon and the worst you have were implemented for reasons that seemed right at the time...to somebody.

Presumably, you'll be tracking your schedule in some kind of software, such as spreadsheet, project scheduling, or planning and scheduling. If you're willing to modify your business practices to meet the functionality of your software, the flexibility needs to exist within your organization, as well as a readiness to accept change, the people willing to participate in process redefinition and the time to do the work. Otherwise, you need software that offers you the functionality and flexibility to meet your process requirements with minimal customization.

Right Amount of Time

Yes, there'll be an investment of time. How much time you'll need is determined by a few factors:

- How many people are involved? If you're making decisions by committee, budget your time accordingly.
- What don't you have? If you have all your data and your business processes, and you know who's going to be involved and that your biggest time spend will be in designing and implementing the program, you're all set. If you don't have those things, add time.
- What's your weekly commitment? With your planning and scheduling program in place, will you have regular meetings to support it? (Tip: You should.) How many people will spend how much time each day and/or each week conducting planning and scheduling activities? How many people will review output metrics and how often?

It's not hard to come up with these estimates and figures, and it shouldn't be hard to stick to them with the right plan in place.

Right Change Management Approach

It's likely that the implementation of a planning and scheduling program will represent organizational change on some level.

In order to develop a change management approach that will help in your implementation, you need to figure out what the potential sticking points are and what you need to do to get around them. If you have to go through a union, you may want to alter your program approach to make the union change management process a little easier. If there are a number of resources very resistant to change, figure out why and an approach to addressing it. The "because I said so" approach can work when applied with the right pressure from the right spots in the team hierarchy, but working to achieve a willing buy-in will likely leave you with happier employees happily doing a better job in the long term.

CONCLUSION

These steps provide you with enough direction to at least get you started thinking about the things you can do to start pulling your planning and scheduling program together.

The implementation of planning and scheduling software should be one of the easiest steps to achieve in putting your planning and scheduling program in place. By the time a planning and scheduling vendor shows up to do the installation, you've already done 75 percent of the work.

Use this article to think of the different components of a planning and scheduling program that you already have in place in your organization. You're not starting from zero, you're just working to better organize what you already have.

__Kim Waterman__ is Solufy Information Technologies' Client Services Manager, providing pre- and post-sales services to Solufy's clients with their AKWIRE Visual Suite of Planning and Scheduling products for Maximo. Kim has been in IT for over 15 years, and first began working with Maximo Asset Management software in 2002 as a Technical Writer. From there, she transitioned into business analysis, functional implementation consulting, project management, support management, business development and marketing, and client services management. www.solufy.com

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Reliability means...

SAFETY

A typical refining facility will spend less than 10% of its time in transient operations. However, 50% of all process safety incidents occur during this time.

-Tame Your Transient Operations, Chemical Processing June 2010.

1/2

PROFITABILITY

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REPAIR COSTS

It costs approximately 50% more to repair a failed asset than if the problem had been addressed prior to failure.

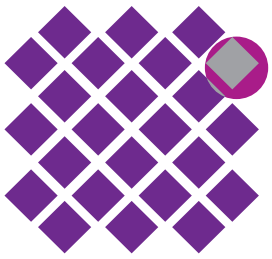
- U.S. National Response Center

$8.4 Million
PER YEAR

Every 1% gain in availability is worth $8.4 million of additional margin capture per year in a typical 200,000 bpd refinery.

- Doug White, Emerson Industry Expert – Based on Current Refinery Economics.

AVAILABILITY



5%
PRODUCTION CAPACITY LOST

Production capacity is lost to as much as 5% every year as a result of unplanned shutdowns.

- Asdza Nadleehe, "Engineering & Maintenance: Prevention Is Better Than Cure," Oil & Gas IQ, October 2011.

43%
DOWNTIME

As much as 43% of unplanned downtime is caused by equipment failure.

- Large Property Damage Losses in the Hydrocarbon-Chemical Industries, 17th Edition.

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Studies* show that companies reach the top-performing quartile when they have less than 3 percent unplanned downtime and maintenance costs less than 2 percent of plant replacement value (PRV). For example, a $1 billion top-performing plant spends $12 to $20 million per year on maintenance expense. By contrast, poor performers spend two to four times more per year.

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> **By reducing scheduled and unscheduled downtime, companies can reduce their maintenance spend by 50 percent or more.**
>
> *– Solomon Associates*

Emerson's success stories include Corbion, a global food and biochemical company. Corbion implemented standardized best practices of reliability over several years and reduced its global maintenance expense by one third while dramatically increasing availability. These actions enabled the company to capture millions of euros in increased profits and sustained increases in capacity and production.

**2013 Solomon RAM Study, Solomon Associates, LLC.*

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Photo by Matt Donnelly

Equipment Reliability Assessment

by Sampling Standard Information from Operations

Amtrak operates and maintains over 5,000 units of rolling stock that make up or support trains moving passengers mainly on the Northeast coast of the United States, while, also connecting the most populated regions. To improve business results, Amtrak tracks reliability performance of its locomotives and cars by analyzing standard information generated from its operations and maintenance.

Basic maintenance information contained in orders for repair work and preventive maintenance is managed with the help of a computerized system. The operations information contained in several types of production reports, including detailed documentation of individual incidents resulting in train delays, is also managed by the same computerized system.

Until recently, tracking the number and duration of train delays attributed to a specific system had been Amtrak's only approach for routinely assessing equipment reliability. Figure 1 shows a typical representation of reliability performance, as expressed by the number of incidents attributed to each system of Amtrak's HHP-8 locomotive fleet of 16 units between December 11, 2013 and March 12, 2014. The graph shows that the automatic train control (ATC) system was the highest contributor to work orders generated by delay incidents, with 29.9 percent of the total.

The graph intends to rank systems by reliability performance, with poorest performers on top. It suggests that resources and attention should be focused on the ATC system as an area with opportunities for improvement.

However, it has been known for some time that this kind of representation lacks two basic notions of performance measurement: reference and causation.

First, without a performance reference or base line, it is very difficult to qualify the actual performance level of any individual system. The inherent or achievable performance of any of those systems is missing in the analysis. Thus, the quantification of the potential improvement

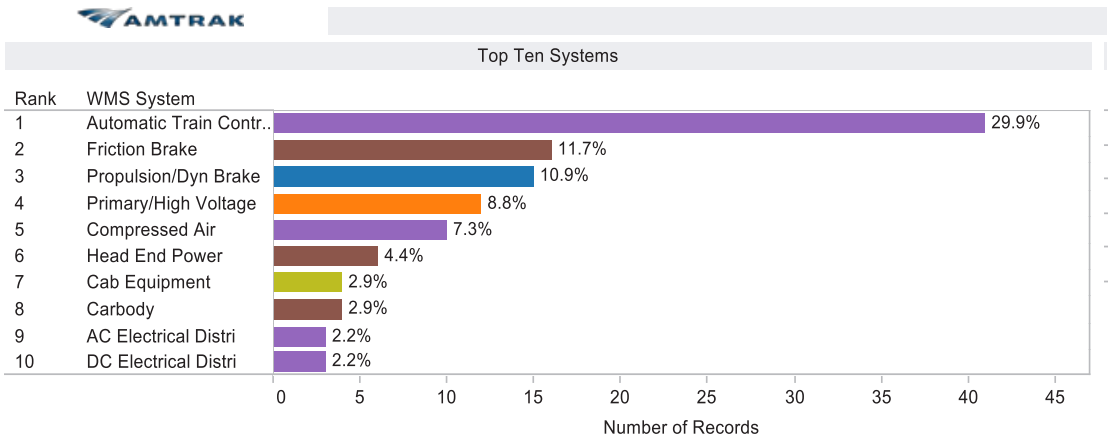

Figure 1: Contribution of HHP-8 locomotive systems to incident work orders

by Alex Gotera

opportunity, represented by the gap between current and achievable performance, is not there to allow clear quantification of goals for an improvement effort.

Secondly, without enough understanding of the causes for both achievable and current performances, it is very difficult to identify the areas that hold opportunities for improvement. The examination of the records represented in Figure 1 reveals that incidents associated with the ATC system contributed to 29.9 percent of delays. However, that number is not only comprised of what could be reasonably attributed to the system itself, but also includes effects of other systems' failures, debris damage, human error and other events.

The two shortcomings, in general, are due to the fact that standard operational data normally collected and analyzed through computerized systems is not intended to expediently produce performance reference and causation. This kind of data is intended to produce transaction records needed to run operations in an organized way. Using such data as crude input to performance assessment has been proven ineffective.

To overcome those two limitations of performance analyses, Amtrak considered five possible options:

- Judging the causes of all incidents;
- Benchmarking performance against a similar operation;
- Implementing a commercially available failure database system;
- Contracting the development of a formal reliability model of the operation;
- Judging the causes of a representative sample of all incidents.

The fifth option looked by far the most attractive in terms of cost effectiveness and budget. To test this perception, an initial exercise was designed and implemented to categorize the causes of all incidents associated with the complete rolling stock fleet.

The target data set consisted of incident work orders written for all rolling stock during the first 338 days of fiscal year 2012. The sample size was defined by a number of randomly chosen dates.

To select the random dates for the target data sample, a control database containing date, responsibility code, delay duration and region was used. The randomly chosen set of dates in the sample from the control database was continuously increased until the percentage of delay minutes per responsibility code and region was practically the same in the sample and the complete set. Very good representation was obtained by a sample size of 57 dates.

The causes of the 532 work orders in the target data set, written on the 57 chosen dates, were judged to fall within one of the following categories:

- Equipment failure;
- Nuisance trip;
- Debris damage;
- Operator error;
- Maintenance error;
- Inspection error;
- Other.

A fraction of the target data set is shown in Figure 2 (following page) as incident records, including judgment of cause category. Information related to each work order in the sample was scrutinized until a judgment was reached or, after 10 minutes, the category was labeled "undetermined."

As expected, the leading cause category was equipment failure, with 40 percent of the sample population, as shown in Figure 3. These failures occurred during train travel and no obvious indication of their imminence was observed during daily regulatory inspection before departure. Many incidents in this category are associated with failures of electric and electronic components and reflect the inherent reliability of the equipment. Very few opportunities for performance improvement are expected to be revealed by analyzing these incidents.

The second largest cause category was nuisance trip, with 11 percent of the sample. Typically, these incidents are very short shutdowns for no apparent reason that do not require any further intervention beyond restarting to resume travel. Practically all of these were associated with electronic compo-

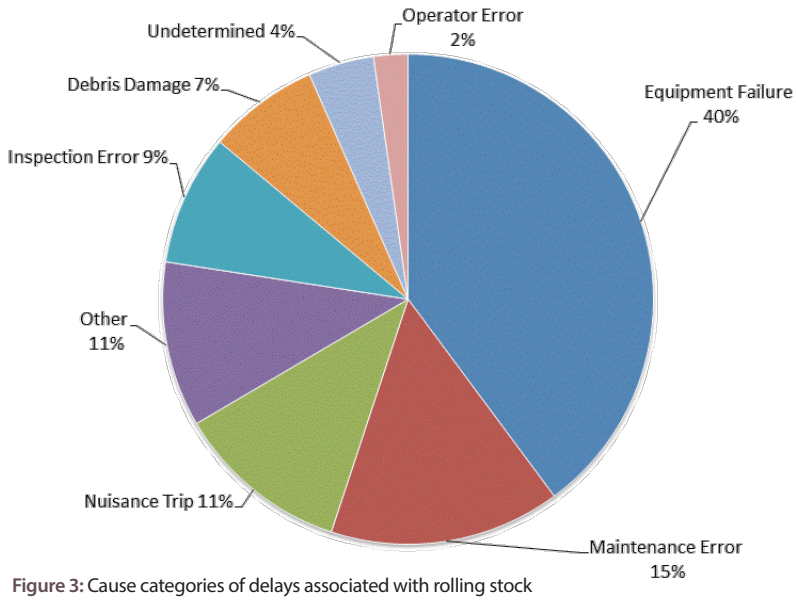

Figure 3: Cause categories of delays associated with rolling stock

Figure 2: Examples of incident work orders and cause category judgment

TRN_ DATE	Train No.	EQUIP #	INCIDENT #	EQUIP DLY	TOTAL DLY	PROB CODE	PROB DESC	WO #	Cause Category	Cause Sub-Category	Argument
10/2/11	0307	27	367738	0:30	0:30:00	LOAD	Loading Problems		Maintenance error	Maintenance error - Diagnosing issue	Repetitive loading issues, replacement of open fuses and contactors
10/2/11	0371	148	367565	0:08	0:08:00	EXSLP	Wheel Slip		Debris damage	Debris damage	P-42 loco lost traction due to frost and leaves
10/2/11	0637	904	367599	0:27	0:27:00	REVSR	Reverser Problems	2829873	Nuisance trip	Nuisance trip	Traction motor #4 recycled and good run
10/2/11	0669	905	367572	0:51	0:51:00	TLINE	480V Trainline Problems/ Short Loop		Expected failure	Expected failure	Pressure switch failure subject to some degree of randomness
10/2/11	0749	C2012	367619	0:17	0:17:00	DEAD	Engine Dead/ Shut Down	2829861	Debris damage	Debris damage	Engine part missing and replaced
10/6/11	0173	924	369298	1:04	1:04:00	MCBTR	MCB Tripping	2834590	Nuisance trip	Nuisance trip	On the move from BRP after reset engine
10/6/11	0230	713	369081	1:07	1:07:00	LOAD	Loading Problems	2834060	Nuisance trip	Nuisance trip	Back to business next day, no report on cause of problem

nents. Eliminating some of these trips require extensive investigation, while most of them are typically unavoidable.

Adding seven percent of debris damage to the latter two categories completes a set of 58 percent representing the causes of delay very unlikely to be significantly reduced unless design changes are introduced. This is the kind of performance reference that was missing until now.

Nearly 26 percent of delays was judged as being caused by some kind of human error, which in principle represent opportunities for improvement, typically through training. There were 35 delays, or seven percent, classified as the diagnosing issue subcategory within the maintenance errors category, which represents a significant improvement opportunity for the maintenance organization.

The results of this sampling exercise are in line with currently perceived opportunities for improvement at Amtrak and numerically express the causation of train delays that was missing until now.

For the majority of incident causes judged as equipment failure, it took relatively little time to check that a part was replaced or repaired and that the same failure had not recurred by the time of the analysis, making most judgments straightforward. Other incidents required significant time checking information to ensure reasonable level of confidence on the judgment. Only four percent of the sample delays was considered almost impossible to judge in 10 minutes, so these delays were left as unknown without investing any significant time in them or compromising the validity of the assessment.

This type of analysis has been adopted as the preferred option and is being applied to several questions and areas of performance. It allows for effective use of the high volume of standard operations data accumulated in Amtrak's computerized systems.

Sampling and judging performance records clearly show potential as a technique to fill voids of reference and causation. The exercise at Amtrak demonstrated the cost-effectiveness and the necessary accuracy of performance measurement achievable by expedited judgment of most of the incidents in the sample. This approach should work for any kind of performance analysis of equipment where extensive operations electronic data is available. The method of sampling and judging standard operational data to extract valuable conclusions from information not otherwise produced with data analysis in mind is both inexpensive and accessible.

Alex Gotera *is currently one of the Reliability Engineers in the RCM Team at Amtrak. For over thirty years, Alex has worked as analyst, consultant and plant engineer in several plants and projects in power, process, manufacturing, and transportation industries. He has formulated and coached reliability improvement projects using a comprehensive and sustainable approach to process improvement for several industrial operations. Alex is an active member of ASME and has a Master's degree in Mechanical Engineering. www.amtrak.com/home*

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As Advancements in Big Data, the Cloud and IoT Transform APM, Who Will Own the Data?

by Dan Miklovic

Without a doubt, advancing tech trends, like the Internet of Things (IoT), big data and cloud capabilities, are transforming the way we approach asset performance management (APM). The amount of process and equipment data available to aid in condition-based maintenance (CBM) activities and support reliability centered maintenance (RCM) programs is almost doubling annually, on track with overall big data growth rates. And as the Cloud and IoT provide more and more information about the current health and process conditions of the physical assets used to operate businesses, the better the decisions made about how to care for those assets.

But while this wealth of new information presents numerous benefits for advancing APM capabilities, it begs a question that has wide-ranging implications for businesses, from financial to legal to competitive and beyond—who actually owns this data?

This article explores how these advancements in technology are creating new operational dilemmas and why the question of data ownership will become increasingly important as time and APM capabilities move forward.

The Data Explosion and Migration to the Cloud

In APM, the transition from preventative maintenance (PM), centered on calendar-based service intervals, to predictive maintenance (PdM), based on actual run times or machine cycles, was the beginning of CBM and it was facilitated by increased data. The additional information associated with any given asset was one or two additional data points for the time or cycle count accrued. As CBM continued to evolve and additional data points were obtained through vibration monitoring and analysis, lubricant analysis and thermography data, additional information was accumulated on the most critical assets.

Combined with the advent of wireless and digital sensors, leading asset operators can now collect a magnitude of more information. In this realm, it is not uncommon to collect ambient information, such as temperature and humidity, operating information, such as operating pressures, temperatures, flows and pH for process equipment, as well as real-time vibration, load, speeds and feeds data. Consequently, instead of a few bytes of additional data for each asset, there may be dozens of additional data points being gathered every second.

The Cloud's Increased Computing Capacity

Whether it's customer buying trend data, pricing information, or APM intelligence, the data capture and analysis capabilities advanced by IoT and big data are outpacing the capacity of on-premise computing power.

Within APM, the natural evolution to this trend has been to move the analysis of APM data to the Cloud. While high capacity, in-memory computing architectures may change this scenario over time, for today, the vast majority of asset owners find that cloud-based analytics of CBM data is the most economical approach for extracting value from their data.

Aggregation in the Cloud

Today, traditional CBM application providers, enterprise asset management (EAM) providers and equipment providers all offer on-demand, cloud-based APM/CBM solutions that assist asset owners in optimizing their maintenance activities. In doing so, many of these providers have realized that better decisions can be made if they aggregate the data from all the asset owners into a single database. Rather than trying to make a maintenance recommendation based on the data from a single piece of equipment in one factory and its historical performance, they can take all the data from all their subscribers and aggregate it to produce a far better model of over-

As companies move more and more data to the Cloud and allow third parties to use that data to make asset performance recommendations, provide asset care services, or even sell capacity instead of requiring the purchase of capital goods, who will own all this data?

all equipment performance. While this presents an exciting advancement in data analysis and decision-making, this deviation from the traditional data ownership model can lead to new concerns.

The IoT Is Enabling OEMs to Join the Aggregation Bandwagon

While some manufacturers of production equipment—notably heavy construction and industrial equipment manufacturers—have been equipping their mobile equipment with a rich array of onboard sensing technology to provide better diagnostic capabilities as a service for some time, the IoT has enabled any equipment manufacturer to do the same at an extremely low cost. Control system providers routinely offer the original equipment manufacturers (OEMs) who use their platforms the functionality to collect, aggregate and analyze performance data from their machinery at very affordable price points. Who better to make service recommendations about proper maintenance intervals on a piece of equipment than the company that manufactured it? Even more so considering the manufacturer has performance data from virtually every machine it has delivered.

New Business Models Are Emerging

As OEMs gain better insight into the performance and maintenance needs of the equipment they manufacture, they are beginning to expand beyond simply selling maintenance recommendations as a value-added service. With enhanced knowledge about the equipment, they are now in a position to actually provide asset care services for the equipment they sell. This lifts the requirements burden from manufacturers to have a highly trained maintenance staff to support the dozens of different brands and types of assets they operate. Since the OEM can focus on its equipment, it can offer a highly skilled workforce at a competitive price point.

For some time now, large OEMs have gone a step further and sold capacity instead of capital. For example, a top aircraft engine supplier bills the airlines for the use of their jet engines and provides all the parts and service as part of the deal.

The IoT and cloud analytics are also enabling even small OEMs to pursue the same capacity instead of capital paradigm. This trend of OEMs large and small moving into a role with increased intelligence and influence holds numerous benefits for APM, but also has broad implications for the business environment at large.

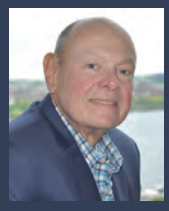
Who Will Own the Data?

That's the big question. The changes wrought by the IoT and cloud analytics give rise to a problem few companies have even begun to address. As companies move more and more data to the Cloud and allow third parties to use that data to make asset performance recommendations, provide asset care services, or even sell capacity instead of requiring the purchase of capital goods, who will own all this data?

In most situations, maintenance or operations departments have contracted with either an OEM or a cloud-based CBM analytics provider to provide CBM inputs into their EAM platform or computerized maintenance management system (CMMS). In some cases, the providers are aggregating the asset owner's data, while in other instances, it is kept separate. Unless IT has been part of the process, it is rare that data ownership issues are even addressed in the service agreements. This may ultimately prove to be a problem for many companies. In the event of an accident, will the information about the process and equipment be shared with the other litigants if there is a legal issue? Will regulatory bodies get ready access to asset and operational data in the event of a potential violation? Will competitors be able to glean insight into processes if they can access performance data?

All of these are valid questions and the answers clearly depend on who owns the data. In a scenario where a company is just shipping data off to an analytics engine with no aggregation and can control what gets sent and when, then they probably can make a case for owning the data. But what about when the OEM is in control and a company's data is aggregated with others? Or when the OEM sells a company capacity? In these cases, the answer is not so clear.

As APM evolves, the data ownership question will likely emerge as one of the biggest challenges companies will have to deal with. Before companies go too far down the path of leveraging all that rich CBM data coming from the IoT, they need to spend some time thinking about how they will deal with the central question of APM data ownership.



Dan Miklovic *joined LNS Research in May of 2014 and is now a Principal Analyst with his primary focus being research and development in the Asset and Energy Management practices. Dan has over 40 years of experience in manufacturing IT, R&D, engineering, and sales across several industries. Dan holds a BS in Electrical Engineering from the University of Missouri, as well as an MS in Management from the University of Southern California. www.lnsresearch.com*

Maintenance Triage:

Identifying Sick and Injured Assets to Improve Population Health

by Will McGinnis

Attempting to contextualize generally obscure statistical predictions about machines is an all too common practice. While statistics and predictive analytics are not new concepts, they have not yet been applied deeply enough to mechanical processes to be embedded in the vernacular. With a focus on the actionability of analysis, similes help to convey the messages. This article presents one of them.

Machines As Patients

In terms of failure, the primary difference between biological and mechanical systems is, for the most part, that small variations strengthen the biological and weaken the mechanical. A biological system dropped into an environment for which it is ill suited will eventually adapt to it, while the mechanical will simply fail. Despite this fundamental difference, they can be approached the same on the doctor's table.

Sickness

People and machines both get sick. The chronic propensity to fail can be seen in both terminally ill patients and mis-sized or improperly maintained machinery. Both cases are characterized by a likelihood of future failure that is independent of short-term variation in environment, behavior or process.

Injury

Likewise, both people and machines can be injured. With a person, this could be a broken arm. In most cases, it is a single, unexpected event that is unlikely to be repeated unless the environment consistently reproduces those events (e.g., a professional skateboarder). The mechanical equivalent would be an operator's error. A broken part due to operator error is not necessarily an indication of a long-term misapplication of the machine, but rather an isolated event caused by outside factors. The only ways to avoid injuries are to change the environment or improve the process (e.g., quit skateboarding or train more to fall less).

Sickness vs. Injury

With these similes, it can be pretty simple to visualize and understand the cases of mechanical failure. Sickness is environmentally independent and chronic, while injuries are heavily influenced by the environment and are acute. A machine can be both sick and injured, or just one of the two.

Measurements for both machine sickness (HealthScore) and injury (Warnings) can be seen in Table 1.

Table 1: Measurements for machine sickness and injury

Asset ID	Warning	HealthScore
001	1	97
002	0	24
003	1	54
004	0	99

There are four assets with the four boundary cases of condition:

1. Total Health (004)
2. Injured, but well (001)
3. Intact, but sick (002)
4. Sick and Injured (003)

The goal is a machine with both a high HealthScore and no warnings (predicted injuries). The opposite of this ideal is a sick and injured machine, with both a low HealthScore, indicating chronic risk of failure, and a warning, indicating imminent likelihood of injury.

In between these two extremes are machines with a warning, but a high HealthScore, indicating an environmental risk but no systemic misapplication, and machines with no warning but low HealthScore, indicating a systemic misapplication that is being well accounted for by the environment (i.e., users and maintainers). These are both interesting cases because they can be easily rationalized as good results, but while they are far better than sick and injured, they can be greatly improved by changing the environment or system, respectively.

Figure 1 shows an example of how a population of assets might look visualized in this way.

Plants As Populations

After establishing this idea of machines as patients (i.e., biological-esque entities), the natural extension is to look at a plant as a population of such entities. Scholar Nassim Taleb describes all things as being along a scale from fragile to anti-fragile.

If something is fragile, then a small, random variation makes it weaker. Conversely, if something is anti-fragile, then small, random variations make it stronger. Right in the middle of the two is robust or resilient, where variations do not affect the item.

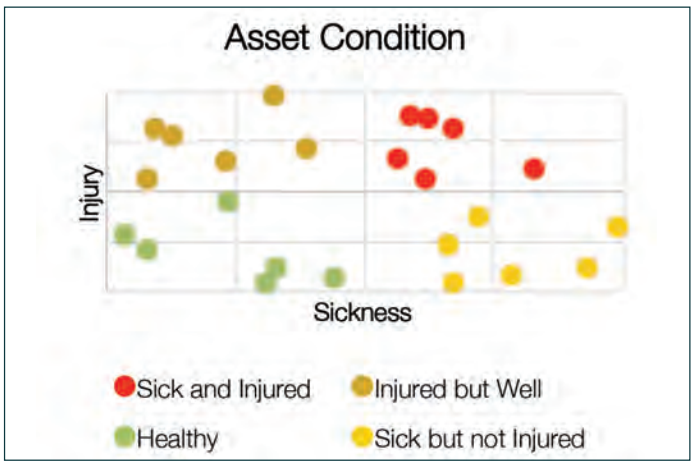
Individual machines are generally fragile by this definition. Likewise, individual people are, in many cases, fragile. A population of people, however, can be extremely anti-fragile, adapting over time to changes in the environment and gradually improving quality and longevity of life. The goal of a plant should be a population of machines that resembles a population of people or animals more so than a house of cards, where a collection of fragile items is more fragile than its constituent parts.

Selection

The first key concept that contributes to the anti-fragility of biologic populations is selection. Those animals or bacteria that are least fit for the environment do not continue on into the next generation. Likewise, to increase the anti-fragility of a plant, the fitness (health) of the machines needs to not only be tracked, but used to inform the replacement of machines. Machines that are chronically unfit (unhealthy) must be replaced with machines that are less predisposed to this condition. Where the machines themselves cannot be changed to be more fit for the environment, the environment must be changed.

Continuous, iterative improvement of both the conditions surrounding the machines in a plant and the fitness of the machines to that environment are critical in building the capacity for the plant to not only withstand unexpected variations, but to benefit from them.

Figure 1: Health injury plot



Compartmentalization

The other critical contribution to a population's anti-fragility is compartmentalization. The lower the effect that one failure has on other members of the population, the more anti-fragile that population will be.

Taleb uses the examples of airlines and banks. If a plane accidentally crashes somewhere in the world, other planes are no more likely to crash because of it. In fact, the aviation industry will learn from the accident and improve its processes so future planes will be less likely to crash, the very definition of anti-fragility. A bank, on the other hand, is more likely to collapse if one of its peers collapses. The financial crisis of 2007 is testament to this fact; the interconnectedness of the global economies (lack of compartmentalization) makes the population of banks fragile.

For a plant, this means the goal should be to minimize the impact of failures on downstream processes as much as possible.

Having described the idea of a plant as a population of entities with individual variations in health and injury, what can you actually do in your plant?

You want to have less downtime, lower maintenance costs and fewer accidents, and make more money. In a world of certain variation, you want your plant to have lower risk and to better weather storms. To do this, you must follow these steps:

1. Compartmentalize failures,
2. Predict machine injuries,
3. Replace sick machines,
4. Repeat.

It is an iterative process that reflects the constantly changing environment in which workers and their machines operate. By focusing on Steps 2 and 3, you can leverage preexisting data sources in your plant and use the power of predictive analytics to predict acute failures and quantify long-term machine health.

In closing, here is one more simile. If your plant is a population of sick and injured patients, how are you maintaining it? With predictive analytics, you have a means by which you can perform triage in order to build continuous improvement.

***Will McGinnis** is a Mechanical Engineer from Auburn University working at Predikto Analytics. At Predikto, he uses advanced machine learning techniques to leverage pre-existing data in asset intensive industries to predict failures, identify bad actors, and impact bottom lines. www.predikto.com*

Chasing the Checkered Flag

What the Process Industry Can Learn from Formula 1 Racing about Remote Reliability and Performance Monitoring

by Mike Boudreaux

For the past three years, the top teams in the world have gathered at a 5.5 kilometer track in Austin, Texas, on a Sunday in November to race for 56 laps at speeds pushing 200 mph. The Formula 1 United States Grand Prix showcases precision, high performance and innovative vehicles driven by best-in-class drivers. In an industry where hundredths of a second can mean the difference between winning and losing, race teams are looking for any advantage they can get. They use every tool at their disposal to design, tune and maintain Formula 1 (F1) cars in the pursuit of excellence. For these teams, remote monitoring is an important means for achieving gains in performance and reliability.

The Road to Remote Monitoring

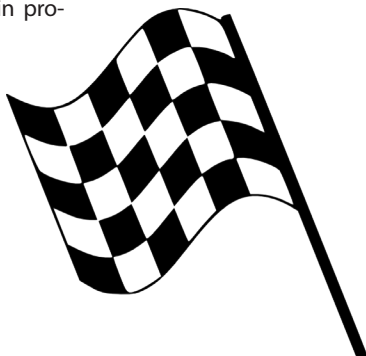
Years ago, F1 cars were designed by instinct, experience and history. Once the car got to the track, the driver communicated information about the car's performance based on the feel of the car and what could be seen. The crew relied on their senses, too. They watched the car accelerate and turn and brake, looking and listening for problems. Often, by the time they spotted a problem, it was too late to make a change. Other times, although they identified a problem early enough, they didn't have the right spare parts to fix it.

These days, teams design new cars every few years. They use cutting-edge technology to develop incredibly complex machines, constantly tweaking the formula. The driver is supported by engineers on the track, stationed locally and at team headquarters. An F1 car has hundreds of sensors on it, which are used for control of the vehicle, as well as monitoring its performance. Sensors measure the pressure and temperature of the tires, the engine temperature and oil pressure, among other key performance indicators. And performance data is collected from numerous points on the vehicle for analysis.

Data Driven Decision-Making

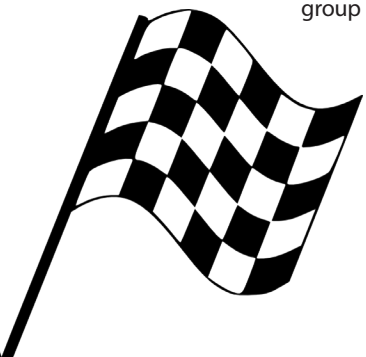
Similar to how process operators use distributed control systems to control their processes, drivers use the control unit in the car to make operational adjustments to adjust to changing track, environmental and equipment conditions. The driver changes gears approximately 3,500 times during a race, keeps radio contact with the crew team, checks fuel level, deploys the kinetic energy recovery system and selects tire adaptation. The driver can preset the wing to accommodate race conditions and view useful information on lap times, speed and gear, as well as change brake settings and activate the pit lane speed limiter as needed.

There is a separate monitoring unit called the team data acquisition system (TDAS), which is similar to a monitoring system deployed in process control. The TDAS pulls data from the control unit and collects unique sensor data as well. This data is transmitted wirelessly back to the



team so race engineers can perform remote analysis to enable better and faster decisions about how they set up and configure the car.

The three-day F1 format more fully illustrates the role technology plays in enabling the collaboration and fast, accurate decision-making needed to win races. The first day is dedicated to practice. The qualifying race to determine position is on the second the day. And the third day is the race itself. Teams use the practice day to identify how well their car is performing and what adjustments need to be made. A driver's engineering team is in an enclosure on the track, closely collaborating with the driver. In a trailer near the track, another group of engineers is using a suite of software tools to analyze engine performance, chassis performance and other aspects of how the car is performing on the track.



Their systems receive data from high performance computing systems that collect it from the wireless systems on the car. Data is also sent wirelessly via satellite to the team's headquarters where additional computers store the data for use in simulations, trending and future design. Before any changes are made to the car on the track, the team will run the simulation multiple times at headquarters to ensure they're making the right decision.

Enabling Technology Is Available and Cost-Effective

In addition to Formula 1 racing, industries, such as energy, transportation, military and commercial aviation, routinely use integrated operations. A wide variety of technology enablers currently available have made adoption of integrated operations increasingly common. New sensor technologies are available that are less intrusive and more cost-effective, including corrosion, ultrasonic, acoustic and infrared. Wireless technologies, such as WirelessHART and 4G networks, have enabled easier collection of data. Access to and reliability of the Internet have become ubiquitous. Collaboration tools, such as video conferencing and social media, make it easier to make informed decisions, no matter where members of the team are located. Advances in display technologies and high fidelity process simulation have made virtual training a reality. The increase in the ability of devices to

> A wide variety of technology enablers currently available have made adoption of integrated operations increasingly common.

Figure1: Remote monitoring - Formula 1 and process industry

communicate about themselves, the ability of pervasive sensing to capture a whole new level of site operations data and the use of big data for analytics promise even better monitoring for increased reliability.

Applying Remote Monitoring to Process Problems

What's happening in the racing industry today is also taking hold in the process industry. Traditionally, the process industry has been a conservative one. It hasn't pushed the limits of technology in the same way as the racing industry. However, just like a race team can't make money if the car isn't performing well on the track, a company can't be competitive with unexpected outages or underperforming production.

Common challenges preventing reliability and performance improvements include a lack of specialized resources, inability of organizations to change their work practices and increasing complexity of technology. For example, powerful technologies may be deployed with a vision for success, but the organization doesn't realize the expected value because of its inability to adapt. The problem may be a lack of organizational awareness, training, experience, or leadership. In addition, leaders are often too busy fighting fires to spend the time needed to drive true change.

As operations become more remote, these challenges are exaggerated. The early adopters of remote monitoring solutions are found in industries with 4D operations, meaning those located in dull, dirty, dangerous and distant environments. The mining industry provides an excellent example; gold and diamond mines are located near the Arctic Circle, hundreds of kilometers from the nearest large city. Conditions in these mines are inhospitable to say the least.

With the growing trend of people wanting to work where they live, attracting experienced, skilled subject matter experts to go to these isolated locations is nearly impossible. If a company does find someone who is willing, the logistics

can pose safety and economic problems. For example, oil companies operating in Northern Alberta have seen cost impacts of housing one employee in Fort McMurray to be $200,000 more than what it would cost to employ the person in Calgary.

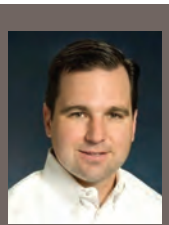
When the ultimate goal is to improve reliability and performance in far-flung operations, remote monitoring is often the best option. Remote monitoring of reliability and performance in process automation assets, as well as production assets, is increasing. End users are monitoring the condition of critical assets, such as turbines, blowers, cooling towers and heat exchangers. They are also remotely monitoring control systems, instrumentation and valves. And new sensing technologies are enabling remote monitoring of site safety, energy use and the environment. Professionals can analyze the data generated through remote monitoring and provide early warnings of pending failures, no matter where they are located. When a problem is identified, local operations personnel have time to plan, schedule the maintenance, and ensure the right parts and maintenance equipment are available.

The ability to leverage data from remote monitoring for collaboration among subject matter experts is available to companies of all sizes. Large-scale companies can leverage internal experts from across the globe for faster, more accurate decision-making. For companies without the scale to have subject matter experts in a range of technologies, leveraging third-party process experts makes sense. These process experts, just like the race engineers in the trailer or at headquarters, have a depth of knowledge and experience that can be applied to a problem anywhere in the world.

The Future Is Here

In the Formula 1 racing world, teams are harnessing the latest technologies in wireless and remote monitoring, coupled with high-skilled subject matter experts, to make better, faster decisions and optimize performance for a three-day race. The stakes and the payoff in reliability and performance improvements for implementing remote monitoring capability in the process industry are even greater. Some process companies may see remote monitoring capabilities as a vision for the future. But the fact is, the future is here for the process industry. The technology and expertise exist today and adoption is gaining momentum.

For companies chasing the checkered flag to success, the time to deploy remote monitoring capabilities is now.



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Get Ready for Forecasting!

The 7 Steps for Success with Prognostics

by Moritz von Plate, Frank Kirschnick and Julia Heggemann

Why Care about Prognostics in the First Place?

Whether a conscious effort or an implicit way of making decisions, making prognoses is a daily routine when operating equipment. For example, by scheduling the next planned maintenance in two months, you expect your equipment to be available until then. Likewise, by accepting a customer's order on a tight delivery schedule, you assume your plant will not fail you.

These are implicit prognoses usually based on experience. They are also likely supported by predictive diagnostic insight into the current condition of the equipment and fleet-wide averages derived from original equipment manufacturer (OEM) specifications or mean time between failures (MTBF) analyses.

Have you considered improving such implicit prognoses with prognostics?

- Prognostics is based on rigorous data analytics, transparently supporting decisions thus far largely based on experience.
- Prognostics provides relevant and significant time horizons with explicit risk profiles. This is a step change in comparison to the much less specific and shorter horizons achievable with predictive diagnostics.
- Prognostics is calculated for the individual asset based on its unique data, thereby increasing the prognostic accuracy as compared with traditional methods of fleet averages.

The insights gained from prognostics are used to improve operation and maintenance strategies. Remaining useful life (RUL) can be managed and expanded, helping to improve the cost structure of your operations. In addition, downtime for maintenance can be reduced and unscheduled downtime can be especially minimized.

Here is how to prepare for prognostics.

Step 1 : Selecting the Equipment

The first step is to select the equipment for which you would like to obtain prognostic information. Ideally, you should start with an equipment type that:

- ✓ Is truly critical for continuous plant operations;
- ✓ Involves considerable costs and effort in case of malfunction or failure;
- ✓ Generates condition and process data that is being recorded and available for further quantitative processing.

Step 2 : Specifying the Malfunctions

Typically, the list of possible malfunctions for any type of technical equipment is long. It ranges from a steady loss of efficiency and leakages to a complete failure or outage. Even though the equipment keeps running for most of these malfunctions, it is not fully functional or is running below its potential power.

Accordingly, the second step is to specify the **top 10 malfunctions** of the equipment type selected. These could be malfunctions that you have always managed to avoid, possibly almost literally at all cost. You also could have observed them over the last five to 10 years. Whatever the case may be, be sure to consider the true root cause of the malfunction at hand and how you typically detect it in the data.

Step 3 : Reviewing the Data

After having specified the top priority malfunctions and their related data, you can move on to exporting a data history from the historian. The length of the data history needed for prognostics varies depending on the prognostic horizon demanded and the type of malfunction. As a rule of thumb, three to five years is considered ideal.

To make sense of the data, you can now visualize it over time and try to detect patterns that explain malfunctions. Since many data patterns are hard to identify, applying advanced stochastic methods probably will be required.

Questions that can help you accomplish this step include: Can I formulate data diagnostic rules that would be helpful for detection *before* the malfunction occurs? What alarm thresholds, limits and benchmarks would I have to apply for detection?

Make sure you verify what you observe in the data is reasonable by involving engineers from the plant.

Step 4 : Formulating the Parameters and Correlating Malfunctions

In this step, correlations of data to particular malfunctions must be specified. At this point, make sure to carefully distinguish between direct and indirect causal relationship. You may formulate useful condition parameters that reflect your diagnostic rules of thumb involving arithmetic or logical functions. During this process, consider the period of data observation and make sure to observe contingencies and dependencies on other rules. Furthermore, a set of value ranges has to be determined for the parameters formulated.

Halfway Prognostics Checklist ☑

- **Do you know your equipment?**
  - ☐ Did you select the truly critical equipment in Step 1? [Y/N]
  - ☐ Did you find consensus on the top 10 malfunctions in Step 2? [Y/N]
  - ☐ Have you been able to specify these malfunctions in Step 2? [Y/N]
- **Do you own the right data?**
  - ☐ Have you been able to download and review the data in Step 3? [Y/N]
  - ☐ Does it cover a sufficient time frame? [Y/N]
  - ☐ Do you have data related to all malfunctions from Step 2? [Y/N]
- **Do you master diagnostics?**
  - ☐ Did you find consensus on parameters in Step 4? [Y/N]
  - ☐ Can you compute these parameters with the given data? [Y/N]
  - ☐ Do the parameters relate to at least one of the malfunctions? [Y/N]

If you answered "Yes" (Y) to all these questions, you are ready for the next steps that go beyond current insights to obtain foresight on equipment condition.

Step 5 : Computing RUL

Step 5 consists of several computational operations that require advanced knowledge of data analytics. To be explicit, in this step, the condition and process data, as well as the complementary malfunction and parameter specifications, need to be fed into a stochastic model. Highly specialized software vendors or online service providers support this step and can provide an end-to-end solution. The following computations should be accomplished during Step 5:

- Projection of equipment condition over an explicit prognostic time horizon.
- Application of diagnostic rules at different future time stages.
- Inference of malfunction likelihoods based on prognostic and diagnostic results.
- Obtaining a set of malfunction-specific RUL distributions.
- Consolidation of the result to a total RUL distribution for the equipment.
- Conversion of the distribution to a meaningful illustration for maintenance planning.

Step 6 : Validating Results

In this step, it is crucial that you ensure the plausibility of the results. For example, a check can be done by conducting a retrospective analysis. This allows you to validate the results with empirical observations from the past. Additionally, it is useful to continuously monitor the prognostic results and ascertain their plausibility.

Step 7 : Utilizing the Foresight

To best use your results, you can now analyze how your current reliability management processes can be leveraged using the insights from prognostics. As a result, the newly gained transparent information about future risk profiles will help you improve your operations and maintenance. For example, you can bundle maintenance work into clusters, thereby reducing your downtime. You can also increase the efficiency of your maintenance scheduling by making use of longer visibility into the future and selectively migrating from preventive or reactive to truly condition-based schedules.

Some useful questions that can assist you at this stage are:

- How can I adjust my maintenance schedule so I trigger the maintenance when the equipment condition really warrants it?
- How can I use the insight from prognostics to prevent my equipment from wearing out more quickly than necessary?
- Would it help to adjust the operation strategy of the equipment so the RUL can be prolonged while keeping operations running smoothly?

Reaping the Benefits from Your Prognostic Efforts

After applying the seven steps, you will immediately gain new understanding of your equipment and probably come across opportunities to technically optimize your condition monitoring. After gaining some experience in handling prognostics, you soon will be able to convert most of your unscheduled downtime into scheduled maintenance. In the mid to long run, prognostics enables you to create commercially optimal condition-based maintenance schedules.

Case Study

How Prognostic Analysis Was Used to Prolong RUL at a Hydroelectric Power Plant

A Swiss power producer was concerned about the remaining useful life (RUL) of the aging equipment in one of its hydroelectric plants. Applying the prognostic methodology described in this article, historical vibration, temperature measurements and process data were used to prognosticate the condition of various critical assets.

During the data analysis, statistically significant trends in the condition data for one of three generators were identified. This prompted an in-depth examination, which revealed a notable increase in vibration displacement of the generator's bearing over time. A subsequent scenario analysis established a dependency between the development of the vibration displacement and the power level at which the generator is run.

This alerted the operator to adjust the current operations strategy. It turned out that operating that generator below a specific threshold would significantly prolong its RUL. Since the lost output of this generator could be switched to the other two healthy generators, this strategy could be accomplished without a drop in overall power production. Thus, while still allowing the generator to operate at a considerable capacity, this simple adjustment helped increase the RUL of a mission critical component and, thereby, the entire plant.

In addition, the operator now has advanced knowledge of when a replacement is likely to become necessary. Based on this newly acquired insight, maintenance scheduling for all plant equipment was improved. Operations are now more reliable and predictable, with a notable positive impact on the maintenance budget.

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Frank Kirschnick *is the founder and CTO of Cassantec, a company specializing in prognostics for industrial assets. During years of research, he developed a prognostic data analytics solution that builds the foundation of Cassantec´s technology. Frank has 20 years of industry and consulting experience with large industrial asset operators and manufacturers. He holds a PhD in Engineering Economic Systems from Stanford University and a Master's in Computer Science from Technical University, Munich. www.cassantec.com/management*

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Separate Yourself from the Pack: FOLLOW-UP

by George Mahoney

"You know what we like about you, kid … you write things down. You may not know anything, but at least you follow-up on what we tell you."

Even though it is only my first month on the job, a little piece of me dies. Apparently from the above quote, the mechanics that I am supervising think I don't know anything. Worse yet, they only like me because I follow-up on their "demands."

I am **THEIR** boss … Shouldn't it be the other way around?

Fast forward 15 years …

I now realize that the backhanded compliment given to me by an ornery mechanic was the best advice I had ever gotten. The people you work with don't care how smart or how talented you are. They only care about you doing what they asked you to do or you doing what you said you were going to do. To keep it simple, they care if you **Follow-Up**.

Think of the people you work with who are the most successful. This doesn't mean the ones with the best title or the highest salary, but rather those who accomplish the most and, at the same time, earn the respect of the people around them. Watch how these people operate and you're sure to see that each and every one of them follows up.

How do you know if you are a person who follows up? Ask yourself the following set of questions. If you answer "No" to two or more, you have some work to do. Roles have been added to some of the questions to help you in determining where to focus your attention.

- ❑ YES ❑ NO Do you walk down maintenance jobs after they are completed to see how the execution went? (Maintenance Supervisor)
- ❑ YES ❑ NO Do you talk to the mechanics after the job execution to get their thoughts on your job plan? (Maintenance Planner)
- ❑ YES ❑ NO Does your boss ever have to forward you old e-mails he sent you as a reminder to complete old action items? (Maintenance Engineer)
- ❑ YES ❑ NO Do you talk to the customer after a job is complete to see how he or she liked the service? (Mechanic/Facility Manager)
- ❑ YES ❑ NO Do you run metrics one year after your Six Sigma project is complete to see if it is still working? (Continuous Improvement Leader)
- ❑ YES ❑ NO Do you continue to check failure history for equipment you completed a root cause analysis (RCA) on two years ago? (Reliability Engineer)
- ❑ YES ❑ NO Do you check to see if your lean maintenance initiative has made progress before starting your green maintenance initiative? (Maintenance Manager)
- ❑ YES ❑ NO Do you give people special assignments and then never reach out to them to see how it went? (Maintenance Manager)
- ❑ YES ❑ NO Can you walk through the plant floor without hearing mechanics and operators say, "Whatever happened to that thing I asked you about?"

TIPS:

If you believe you need some help after reading the preceding questions, fear not. Here is a list of simple tips to help you follow-up. These tips do not take any special talent or skill. They just require focus and a strong will.

1 Make a List

It doesn't matter how good your memory is, you can't remember everything. This is especially true in today's world, where companies are trying to save money by making people assume multiple jobs. Create an official "Follow-Up List" where requests will sit until they are addressed. Keep this list with you at all times because you never know when you will get a new request.

2 Give Yourself a Short Deadline

Setting a short-term target will force you to take action. You have a better chance of getting something done if you give yourself two days as opposed to two weeks.

3 Say "No"

If you take on too many requests, you have no shot of getting anything done in a timely manner (See Tip #2). You're probably thinking, "Doesn't saying 'Yes' all the time make me a team player?" No, it doesn't. It makes you the guy who doesn't follow-up on anything.

4 Focus on Your List

There are a lot of people who are constantly looking for new assignments, without making any attempt to complete the ones they already have. Some of those people do not have the self-discipline to focus on the task at hand. Others are simply trying to use multiple job assignments as a means to advance their career. Either way, focus on finishing the assignments you have now, before taking on new ones.

5 Don't Fear Failure

Many people dread following up on a job assignment they completed. After all, what if the requester didn't think their actions were up to par? Unfortunately, getting feedback is the only way to grow. You need to check your ego at the door and acknowledge that you are not perfect. After you complete a job, ask the requester for feedback on your execution. Use every bit of feedback as a means to continuously improve your work. Your colleagues will thank you for it.

To keep it simple, they care if you **Follow-Up**.

__George Mahoney__ currently acts as the Reliability Excellence Lead for Merck in North and Latin America. In addition, he serves a mentor, sponsor and instructor for Merck Six Sigma. He is an expert at making lean methodologies and continuous improvement a part of everyday life for an organization. From the shop floor, to the executive board meeting, George will find a way to eliminate non-value added work so you can focus on what is important without distraction.

Asset Management & Servitization

by Rejeesh Gopalan and Sajit Kumar

Servitization has strong potential to influence the way asset management functions would be carried out in the future.

Manufacturing has gone through myriad transformations over the last few decades and it is predicted that this trend is going to continue with more rigor. The road map for the future of the manufacturing industry, also referred to as the fourth industrial revolution, indicates a total revamp of the manufacturing business model through disruptive transformations. One area that has been emphasized a lot in this regard is the way manufacturing companies would manage their service offerings. Organizations have already started moving away from a pure product offering focus to what is known as servitization, a business model integrating product and services in an optimal mix.

IBM, rebranding itself as a service company as opposed to a pure computer manufacturer, and Syngenta, which now offers a wider range of business solutions to its farming customers rather than just supplying seeds and fertilizers, have clearly reinforced this trend. Servitization has strong potential to influence the way asset management functions would be carried out in the future. This is largely due to the existence of its inherent synergies with asset management functions. Fundamentally, two aspects of the servitization-related transformation of asset management are worth discussing. These are the evolving asset management model in the context of servitization and a parallel advancement in technology developments to support the servitization philosophy.

Evolution of a New Asset Management Business Model with Servitization

Servitization will be more profound and will influence multiple elements of the manufacturing value chain. Manufacturing organizations, in the pursuit of servitization, will move from a pure, capital expenditure-based transactional model to a revenue, expense-based relationship model. Servitization is causing the fine divide of services and product offerings to fade off to form an integrated offering intended to deliver value to the customers. Manufacturers will have to help customers define and acquire value instead of just selling them products. They just cannot afford to sell features of a product that doesn't address the desired functional value anymore. So, what does all this mean for asset management functions?

With servitization, asset management as a domain is expected to go much beyond the traditional concept of maintenance and optimization of a company's own assets. For a manufacturer, as the focus of organization shifts more towards total cost of ownership, the enterprise asset management (EAM) system as a function would be responsible for keeping track of performance, even for equipment that is already sold, throughout its lifecycle. This paradigm shift in the way products are being servitized will result in organizations beginning to view asset lifecycle management as a service provided by the original equipment manufacturer (OEM). For example, Caterpillar may no longer be interested in selling earth moving equipment, but would be interested in providing the service of earth moving using equipment owned and maintained by Caterpillar.

So, what does all this mean for asset management functions?

Traditionally, asset management for a manufacturing organization had been more inward looking, dealing with programs and functions purely in the context of products. It had little deliberation on the business process or the final business value to which the products were associated. However, with increased focus on creating service-based value differentiators, the purview of asset management will change. It will be pushed further to deliver to the context, which means the goals now will be closer to the realizable business goals of the customer. Asset management will demonstrate a clear move from just being a cost centric model targeted to reducing equipment breakdowns to one related to reducing business risks and improving value creation. This will allow manufacturers to engage in evaluating dimensions of such value, adding activities targeted to the ultimate profit for the company. If reliable business operations are what is required from equipment being sold, then manufacturers will have to channelize their energies to ensure uptime of the equipment. Services, such as annual maintenance contracts that included packages for routine maintenance and repairs, would be replaced with more focused programs, such as predictive maintenance, to ensure corrective actions are performed judiciously. The responsibility and upkeep of the system would shift hands. The onus will be with manufacturing firms to design the right maintenance programs and align the supporting systems, such as the IT infrastructure and the principle software packages governing the customer's processes for optimal performance.

The Technology Enablers for Servitization

In the pursuit of servitization of asset management, the contribution of a parallel advancement of technology will be predominant. Without it, the asset management transformation will be incomplete. The asset management stream has certainly been influenced by digitization and this will definitely have a remarkable impact on the way the day-to-day asset management functions are carried out. A caveat to this is, while these advancements are happening at a faster rate, there will be premium costs to avail technological enhancements. Further aggravating the problem is that fast-changing technology comes with even faster and higher depreciation rates of such high capital investments. This can make these transformations less favorable among early adopters.

However, the concept of servitization, which emphasizes converting the upfront capital expenditure to a continuous operational or revenue, expense-based pricing, will be a savior for customers.

This has a potential to attract customers of manufacturers to leverage the latest technologies, while ensuring their funds are invested at their best bets and where their capabilities actually reside.

In the context of servitization, there are some predominant technological interventions that hold the potential to catapult asset management functions to newer heights. These are enabling cloud-based asset management; analytics; and smart asset monitoring systems.

[1] Opening Up for a Cloud-Based Model

Who understands the nerves of the equipment better than the manufacturer? And who better than the manufacturer knows the best design applicable for a maintenance program? If the answer is a resounding "NONE," then you will certainly appreciate the role of a manufacturer in maintaining the assets at the customer's facility. The Cloud model can bridge the infrastructural gaps to align with the asset management's requirements in the context of the customer's business requirements. With the advent of the Cloud, the servitization of the asset management process would be further streamlined by packaging the chosen service with cloud-based enabled EAM information technology. Consolidated programs also can be hosted and accessed by the customers, wherein they would pay a lump sum for engaging the service of the manufacturers. This do-it-yourself kind of maintenance, whereas the in-house maintenance team would be guided with maintenance methods or directions from a geographically remote manufacturing location, would be a realizable option using cloud-based technologies. The Cloud would also enable manufacturing companies to support common maintenance tasks for its manufactured equipment operating at different customer locations. It will enable faster relaying of a service manual or a video log (vlog) in an effective manner. This social media, coupled with cloud-based technology, will further boost the connectivity between manufacturer and customer to create a comprehensive asset knowledge bank.

[2] Data Analytics – Big Data

In the past, there had been a conscious effort by companies to gather operational information, however, this exercise lacked objectivity in terms of analyzing the information and drawing meaningful conclusions from it. This information seldom moved up the value chain and fell short of its actual objective of reviving and optimizing the maintenance program or aligning with the business goals. Also, the expertise to perform such high-end analysis and program revival techniques was limited among the customer base, given the limited understanding of actual asset potential. Manufacturing organizations, by virtue of being connected to the end customers and the affordability of high-end analytical tools, such as big data, can fill this gap a great deal. Access to real-time and historical data can be sliced and diced and extrapolated against multiple business scenarios being observed at different clients' facilities and different processes. This can then help in formulating a robust asset management program. While servitization would partially or completely shift the capital cost of expensive instrumentation controls associated to the equipment operating in the customer's premise, it will present manufacturers with an opportunity to monitor the vital parameters and a chance to reconfigure or reprogram a maintenance operation designed for the equipment. And what do manufacturers get in return? A constant source of revenue through a pay and use model that could include well-informed consultant services being offered to customers, an extended contract and, more importantly, customer loyalty.

[3] Smart Monitoring for Intelligent Assets

Assets are getting smarter. The instrumentation controls tethered to these assets further help in relaying meaningful information on asset performance, operations and health. This information has become essential in channelizing maintenance programs and, more importantly, providing feedback on how these assets are faring on operational parameters in the context of a business process. With close proximity of manufacturers to their customers and their business processes as an inherent nature of a servitized business framework, assets would naturally lose their generality. Manufacturers could receive quick feedback on the operational equipment in the context of business processes. The resultant outcome is a cease of mass production of general equipment to open up for specific, custom and to context equipment designs. Remote monitoring technologies will play a vital role in creating a robust platform to feed important operational information of equipment back to the manufacturer while being cost effective. This will be of great relevance to manufacturer's producing high value capital equipment, enabling them to analyze performance of the equipment and feed the R&D department with useful design inputs like never before. Such real-time operational data will be invaluable in the designing process of equipment and help in cutting the overall manufacturing cycle time.

The Way Forward

The transformation envisioned by servitization and its relation with asset management is real. The change in mind-set to encourage a move to a revenue, expense-based model of servitization is going to place asset management into an altogether new perspective. Manufacturers will strive to deliver services that will directly address the business process needs, rather than simply packaging a product. While servitization of asset management talks volumes about a transformation in the asset management business process, the success will largely depend upon the convergence of technology for enabling the implementation of the servitization framework. Companies of the future would follow a pay and use model that includes process implementation and technological support with virtually no implementation cost component involved. While this would shift customers from a capital investment model to a revenue, expense-based model, it will entrust manufacturers to constantly innovate in the pursuit of delivering the best value to the customer.

A competitive market of this kind with minimal exit barriers for the customer is waiting for you to explore.

Are you up for servitization and are you ready for the challenge?

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Where Do You **Draw the Line** with Warranties?

Raise the bar and boost your bottom line with improved warranty management

by Michael Currie

Warranty terms, conditions, triggers and limits on heavy equipment are difficult to track.

If a single instrument gauge fails, would a warranty even cross your mind? What about a submersible pump? A critical gas turbine engine? Many industrial organizations spend little time pursuing warranties unless the assets involved are particularly visible or high priced. Unfortunately, taking this ad hoc approach is more costly than you think.

Warranty costs can add up. Every unrecovered asset expense has a negative impact on the bottom line. But it's not just repair or replacement costs at stake. Failing to consistently pursue and track warranties represents a lost opportunity to optimize purchasing and engineering decisions, which ultimately impact operational risk and production uptime.

Warranties usually get overlooked if there is no easy way to access and manage the details. Warranty contracts range from long and complex to brief and vague, and the terms, conditions, triggers and limits may not be readily understood. Additionally, if the contracts are not electronically accessible and searchable, there is little motivation to search through scores of paper records.

Fast-paced industrial maintenance environments require quick and effective decisions and actions. Any business process that is perceived as inefficient, nonessential, or adding little value will be pushed aside unless there is a compelling reason to do otherwise.

Fortunately, warranty process improvements are simple and relatively inexpensive to implement, plus they deliver a rapid return on investment. Modest gains can be made through simple procedural changes, but for maximum business benefits, consider implementing best-practice warranty management processes supported by a warranty management and tracking system that is fully integrated with your enterprise resource planning (ERP) system. The visibility and automation provided by such systems reduce the administrative burden, speed the recovery of warranty costs and help to improve operational reliability and effectiveness.

Real-World Approaches Yield Valuable Rewards

Organizations that upgrade their warranty processes realize solid and sustainable business benefits. The following snapshots are of three companies that had different business drivers for implementing process efficiencies and are now enjoying ongoing benefits.

The cost and reliability incentive:

A heavy equipment supplier reduced its failure rates by 40 percent and increased warranty recoveries by more than $12 million per year by merging the warranty group into maintenance engineering and tracking warranties across equipment categories using modern reporting software.

Prior to introducing these changes, the supplier's warranty processes were paper-based and uncoordinated. There was very little insight into systemic problems across specific asset groups and no means of sharing the information between those who were trying to solve reliability problems and those who were trying to recover costs for warranty repairs.

The insurance rate incentive:

When a marine transportation enterprise implemented a warranty management system, payback was immediate due to insurance rate savings earned by digitizing the maintenance and warranty records. The insurer had encouraged the change to a uniform, electronic process because it knew the company's costs and repeat failures would be reduced, as would its insurance claims. The insurer's rate incentives were significant enough to pay for the system's implementation.

Until then, the company used several different paper and stand-alone software processes to track work and recover warranty claims from suppliers. This contributed to poor cost and equipment reliability metrics compared to industry peers.

The process simplification incentive:

A major energy company reduced its risks by aligning all suppliers on a single warranty standard as a condition of doing business. It was a coordinated effort by the purchasing group that didn't require any systematic support. The company achieved sizable savings on claims and administration because the new process was consistent.

Before the warranty standardization mandate, the energy company had to track and manage widely divergent warranty terms, conditions and processes, hindering the ability to recover costs on a timely and efficient basis.

Warranty Management Financial Benefits

- Recover warranted costs
- Reduce claims processing costs
- Redirect repair costs
- Reduce future maintenance costs
- Achieve maintenance budget targets
- Reduce asset lifecycle costs
- Improve vendor negotiations
- Improve purchasing decisions

Multiple Challenges Threaten Financial Recovery

Big dollars are potentially involved in warranty claims. Approximately two percent of capital costs and up to five percent of maintenance, repair and operations (MRO) material costs may be warrantable. Capturing those dollars can be cumbersome if the processes and information are not properly managed.

- Complex industrial assets may have multiple types of warranties within the same asset hierarchy.
- Suppliers often record the warranty start date as the date of sale for MRO materials, while operators tend to track the install date.
- Warranty qualification may depend on specific use conditions or processes, such as routine oil changes.
- Warranty enhancements or extensions may be offered by contractors for major components installed by them.
- Mobile fleet components that are within a component exchange program may be eligible for prorated warranties if they fail earlier than the benchmark term.

Warranty Claims Typically Represent

3-5% of capital spending
8-20% of repair costs

Remedies Are at Your Fingertips

Any one of the following strategies represents a step up from typical warranty practices. Implementing all the recommendations will deliver holistic business benefits.

- Treat warranties as receivables. Get organized and know what you have coming to you, and request compensation in an efficient and accurate manner.
- Don't rely on paper-based systems or supplier records. Set up your own records and utilize modern solutions to track recoverable cash.
- Align warranty efforts with engineering troubleshooting. Share warranty performance information (e.g., assets with high infant mortality) with engineering and purchasing personnel so they can improve design and selection decisions.
- Use warranties as a way to improve supplier services and communication. Share with vendors any information that can drive product quality improvements and leverage the information in supplier negotiations and selection.

Each of these remedies can be implemented and optimized with the support of a comprehensive warranty management system, especially those with a warranty tracker that integrates with and extends the value of ERP-based warranty processes. These types of warranty management systems automate vendor claims for warrantable repairs and facilitates cooperation and communication with other departments, as well as the various suppliers.

Choosing a Warranty Management System

When choosing a warranty management system, look for one that allows all warranties to be tracked, including new and rebuilt assets (e.g., equipment, parts and subassemblies), as well as contract labor. It should provide an understanding of the various terms, conditions and required service processes for warranty eligibility; when the warranty clock begins (e.g., the purchase, installation, or in-service date); which assets qualify for an extended or prorated warranty; and whether a warranty's coverage includes parts and/or labor for repair, rebuilds and/or replacements. It should leverage this knowledge base to automatically and accurately generate warranty claims, which can be reviewed and processed with a click of a button.

Equally important is the human touch, which is needed to ensure warranty process success. It is necessary to designate one or more owners to establish and enforce a consistent warranty approach. The owners will be responsible for warranty notification and claims, including how the claims will be prioritized, reported and reconciled.

Conclusion

Whether it's through people, process or technology, the effort to improve warranty recoveries is one of the best ways to make an immediate bottom-line impact. Long-term, organizations enjoy productivity gains because they have a better understanding of their physical assets, and they improve both internal and external relationships because all sides benefit from an active and transparent approach to this asset management best practice.

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IS YOUR COMPANY FIT FOR DEPLOYMENT?

by Trent Phillips

One of the top priorities of any military organization is keeping soldiers fit for deployment upon demand. This usually involves exercises to maintain and increase job skill, physical abilities, overall health and mental capabilities. Troops are encouraged and required to participate in activities that achieve these readiness goals. Why should your organization and position be any different? What are you and your organization doing to ensure fitness for job deployment each day? Are your employees trained to function like F Troop or SEAL Team Six?

American companies spend billions of dollars each year on employee learning activities. Even with this huge investment, the majority of companies still lack the required skills for success. This proves that just spending large amounts of money will not solve a problem. It can be argued that employees are a company's greatest assets. Therefore, investment must be continually made to maintain and grow human capital. But the investment must be done in a way that secures the greatest return for stakeholders. Human capital affects every aspect of a company and is directly tied to the successes and failures experienced. Lack of employee development or misguided training activities could be one of the contributing reasons for failure within your corporation.

It seems that most companies track employee learning and development in dollars. This form of tracking may show the associated costs of these activities, but does little to show the returns on the investment. Instead, learning activities should be developed and focused on:

- **Training:** Focused and evaluated against the employee's current job function. Do not overlook critical craft and technical skills, such as proper use of tools (e.g., measuring devices, etc.), understanding procedures, precision maintenance practices, appropriate safety, etc. This will ensure the employee can operate and maintain equipment in the most efficient and safe manner possible.
- **Education:** Focused and evaluated against job positions and responsibilities that the employee may be assigned in the future.
- **Development:** Activities that encourage and prepare the employee for greater job responsibilities, growth and advanced skills that are aligned with mutual strategic goals.

Job responsibilities should be clearly defined. By doing so, an employee can be evaluated and focused training can be developed or sought externally to produce competency and confidence. To achieve the greatest return on investment, each of the following areas should be looked at:

- Obtaining results and not just on delivery of materials or entirely on money spent.
- Alignment with clear and strategic goals, like increased production, improved safety, better maintenance reliability, etc. Otherwise, the results will be difficult to measure and obtain.
- Ensuring employees fully understand why the training is being provided and how it is linked to strategic company goals.
- Focusing on resolving identified knowledge gaps within the organization. Employee development is expensive and the investment should be maximized. Therefore, it is critical that assessments be completed to determine what knowledge is lacking within the organization and how this lack of knowledge impacts the strategic goals of the corporation.
- Employee involvement to help determine what knowledge, skills and abilities are learned.
- Ensuring employees are encouraged to participate in the learning experience.
- Training to be conducted in a safe, supportive and respectful environment.
- Employee development as a building process that is linked to an employee's past training and work experiences.
- Methods utilized to verify employee understanding of the subject matter conveyed. This should include skills verification activities, testing, etc. Most people learn from doing, therefore, development activities should be reinforced with practice during and after the learning experience has been completed.
- A manner to provide feedback is included. This will allow opportunities for improvement to be understood and implemented.
- Recognition of the trainer. Someone can be knowledgeable in a subject matter, but lack the skills required to convey that knowledge to others in a meaningful way. It is critical for the trainer to have professional knowledge in the subject(s) being taught, have the dedication and ability to transfer this knowledge, be recognized as a leader in the area and understand the strategic goals of the training exercise.

Human capital is one of the greatest expenses within a company. Companies that effectively train employees are more likely to retain them and receive the greatest return on investment. Skills development is one of the primary reasons employees are either attracted to an employer or decide to seek other opportunities. Employees typically have greater job satisfaction when their employer makes routine investments in them. Management is rewarded with increased performance, a happier workforce, improved safety, lower risks, easier goal achievement, competitive advantages, lower costs and increased profits. The workforce is rewarded with improved job satisfaction, greater skills, higher self-esteem and employment stability.

Basically, as the saying goes, "if you don't use it, you lose it."

Human capital development should not stop at formal training. Coaching, mentoring, networking and appraisals should be provided. This helps to build relationships, reinforce training and generate feedback for both the employee and employer. The coach should provide guidance, feedback and reassurance of skills. The mentor should provide advice and support. Appraisals allow for development, evaluation and resolution of issues. Employee interaction at seminars, professional groups and with other employees should be encouraged as well. This allows for networking, knowledge transference and development to occur.

Employee development is a shared responsibility between employee and employer. An individual's willingness to be fit is just as critical. How can an individual maintain job readiness when he or she does not read books, refuses training when available, does not maintain or increase his or her skills, or challenge himself or herself? Employers can provide an employee the opportunity to learn, but cannot make the person do so if he or she is unwilling.

Basically, as the saying goes, "if you don't use it, you lose it." This means you have to work to maintain the skills you have already acquired. Life and our employers constantly expect us to do more with less and this will never change. Usually, it is not about how much you do, but ensuring that what you do is done correctly and the desired results obtained. Guaranteeing results requires constant usage of current skills and development of new ones. Every employee is responsible for constantly seeking learning opportunities that help them maintain and grow skills. Otherwise, you will most likely become obsolete to your employer.

Sometimes, management only asks half of the questions that should be asked and answered before investing in employee development. For instance, most companies struggle with the question:

Q: What will happen if we invest in this person and he/she leaves?

This is a valid question, but it always should be accompanied by the flip side question:

Q: What will happen if we don't invest in this person and he/she stays?

Always remember two key points. First, an employer that makes continual investments in its human capital (employees) will most likely retain them and receive the most return on investment. Second, an untrained employee is an unfit employee for the job demanded of the individual! The employee will be unable to perform in a safe, consistent and effective manner. It is difficult to hold employees accountable when they have not been properly prepared to perform what is being asked of them.

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Invariance of Vector Factors in the Direct Solution for **Two-Plane Field Balancing** with the Orientation of the **Overhung Rigid Rotor**

by José A. Méndez-Adriani

This article examines the invariant character of the vector factors in the direct static/couple solution for the two-plane field balancing with the orientation of the overhung rigid rotor. The aim of the article is to establish the correct application of the formulas involved to a practical case, which also has been particularized for the fixed scale convention.

In particular, the deduction of the direct two-plane static/couple solution is presented according to the convention for phase measurement of the rotating angular scale with the fixed reference mark [3][1]. The development of the standard solution for the two-plane balancing of a symmetric rigid rotor using complex vectors and based on the modern method of influence coefficients was done for the phase convention of the fixed angular scale with the rotating reference mark [4]. For the verification, it was necessary to express the direct static/couple solution for the two-plane field balancing of an overhung rigid rotor according to the convention for phase measurement of the fixed angular scale with the rotating reference mark [6].

Demonstration

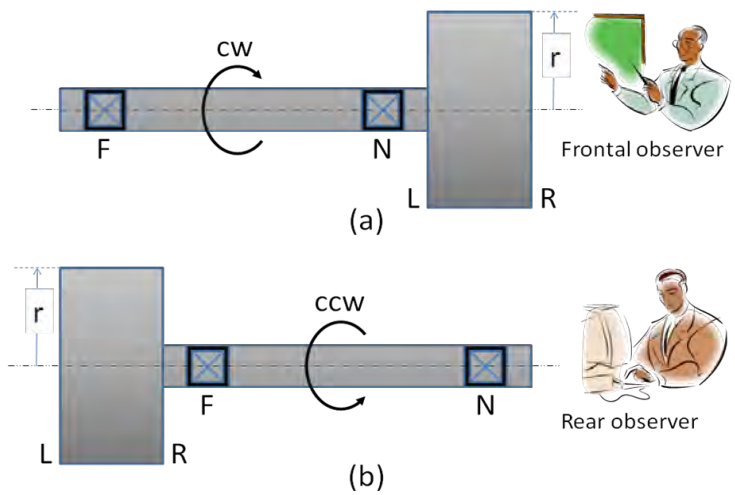
An overhung rotor has its balance correction planes located outside of the supporting bearings as shown in Figure 1.

Figure 1(a) illustrates an overhung rigid rotor as a disk with equal radii r to attach trial and correction weights in the left balancing plane *L* and in the right balancing plane *R*, whose shaft is rotating in the clockwise direction and supported on the near bearing *N* and on the far bearing *F*, which are localized toward the left side as seen by a frontal observer. Figure 1(b) shows the same overhung rigid rotor rotating in the counterclockwise direction, with an interchange of the relative position of planes and bearings now localized toward the right side, as seen by a rear observer.

With reference to Figure 1(a), in the coordinate system associated with the convention of the rotating scale, whose angles are measured in a sense

[1] Numbers in brackets indicate references at the end of the article.

Figure 1: Overhung rotor supported on bearings



opposite to the rotation of the rotor, the vibration of the near bearing is represented by the vector $\vec{N}$ and the vibration of the far bearing is represented by the vector $\vec{F}$.

For the second run of the balancing procedure, $\vec{N}_2$ is the vibration of the near bearing and $\vec{F}_2$ is the vibration of the far bearing when a quasi-static trial weight $\vec{W}_{TEL}$ is added to the left plane in the direct solution to produce the effects $\vec{Q}$ and $\vec{q}\,\vec{Q}$, which is expressed as [3, 6]:

$$\begin{aligned} \vec{N}_2 - \vec{N} &= \vec{Q} \\ \vec{F}_2 - \vec{F} &= \vec{q}\vec{Q} \end{aligned} \tag{1}$$

For the third run, $\vec{N}_3$ is the vibration of the near bearing and $\vec{F}_3$ is the vibration of the far bearing when a pair of trial weights, $\vec{W}_{TR}$ & $-\vec{W}_{TR}$, forming a couple are added to produce the effects, $\vec{v}\,\vec{V}$ and $\vec{V}$, given by the following expressions [3, 6]:

$$\begin{aligned} \vec{N}_3 - \vec{N} &= \vec{v}\,\vec{V} \\ \vec{F}_3 - \vec{F} &= \vec{V} \end{aligned} \tag{2}$$

The direct static/couple solution, using the convention for phase measurement of the rotating angular scale with the fixed reference mark, gives the quasi-static correction weight in the left balancing plane and the right correction weight to form a couple in the right and left balancing planes, respectively as [6]:

$$\begin{aligned} -\vec{W}_{EL} &= \left[\frac{\left(\vec{v}\,\vec{V}\right)\vec{F} - \vec{V}\,\vec{N}}{\vec{Q}\vec{V} - \left(\vec{q}\vec{Q}\right)\left(\vec{v}\vec{V}\right)}\right]\vec{W}_{TEL} \\ -\vec{W}_{R} &= \left[\frac{\left(\vec{q}\vec{Q}\right)\vec{N} - \vec{Q}\vec{F}}{\vec{Q}\vec{V} - \left(\vec{q}\vec{Q}\right)\left(\vec{v}\vec{V}\right)}\right]\vec{W}_{TR} \;\;\&\;\; \vec{W}_{R} \end{aligned} \tag{3}$$

The phasor, $\vec{N} = Ne^{ia_N} = (N, a_N)$, which is also expressed in polar coordinates, where $N = |\vec{N}|$ is the modulus and a_N is the angle, being e the base of the natural logarithms and $i = \sqrt{-1}$ the imaginary unit, as a tensor of rank one over the complex field, is a mathematical object whose magnitude is invariant under coordinate transformations [1].

In the coordinate system associated with the convention of the fixed scale, whose angles are measured in the same sense of the rotation of the rotor, the angle of the complex vector representing the vibration of the near bearing is calculated employing the following conversion formula [1]:

$$a'_N = 360° - a_N = -a_N \tag{4}$$

Therefore, in the coordinate system associated with the convention of the fixed scale, the vibration of the near bearing is represented by the complex vector:

$$\vec{N}' = Ne^{ia'_N} \tag{5}$$

Taking the complex conjugate of the preceding equation in this coordinate system, the conjugate complex vector representing the vibration of the near bearing is found for the phase convention of the fixed angular scale with the rotating reference mark as [6]:

$$\overline{\vec{N}}' = Ne^{-ia'_N} \tag{6}$$

Following a similar development for each one of the terms in equation (3), or by expressing equation (3) in this coordinate system and taking the complex conjugate, you have that:

$$\begin{aligned} -\overline{\vec{W}}'_{EL} &= \left[\frac{\left(\overline{\vec{v}}'\overline{\vec{V}}'\right)\overline{\vec{F}}' - \overline{\vec{V}}'\overline{\vec{N}}'}{\overline{\vec{Q}}'\overline{\vec{V}}' - \left(\overline{\vec{q}}'\overline{\vec{Q}}'\right)\left(\overline{\vec{v}}'\overline{\vec{V}}'\right)}\right]\overline{\vec{W}}'_{TEL} \\ -\overline{\vec{W}}'_{R} &= \left[\frac{\left(\overline{\vec{q}}'\overline{\vec{Q}}'\right)\overline{\vec{N}}' - \overline{\vec{Q}}'\overline{\vec{F}}'}{\overline{\vec{Q}}'\overline{\vec{V}}' - \left(\overline{\vec{q}}'\overline{\vec{Q}}'\right)\left(\overline{\vec{v}}'\overline{\vec{V}}'\right)}\right]\overline{\vec{W}}'_{TR} \;\;\&\;\; \overline{\vec{W}}'_{R} \end{aligned} \tag{7}$$

Taking again the complex conjugate of the previous equation, in the new and direct solution, the quasi-static correction weight in the left balancing plane (*L*) and the right correction weight forming a couple in the right and left balancing planes (*R* and *L*), respectively, for the fixed scale convention, are given by [6]:

$$\begin{aligned} -\vec{W}'_{EL} &= \overline{\overline{\vec{V}}}'_{E}\,\vec{W}'_{TEL} \\ -\vec{W}'_{R} &= \overline{\overline{\vec{V}}}'_{C}\,\vec{W}'_{TR} \;\;\&\;\; \vec{W}'_{R} \end{aligned} \tag{8}$$

In the associated coordinate system, $\vec{W}'_{TEL}$ is the quasi-static trial weight in the left plane and $\vec{W}'_{TR}$ is the right trial weight.

The conjugate of the quasi-static vector factor $\overline{\vec{V}}'_{E}$ and the conjugate of the couple vector factor $\overline{\vec{V}}'_{C}$ in this coordinate system are defined as [6]:

$$\begin{aligned} \overline{\vec{V}}'_{E} &= \left[\frac{\left(\overline{\vec{v}}'\overline{\vec{V}}'\right)\overline{\vec{F}}' - \overline{\vec{V}}'\overline{\vec{N}}'}{\overline{\vec{Q}}'\overline{\vec{V}}' - \left(\overline{\vec{q}}'\overline{\vec{Q}}'\right)\left(\overline{\vec{v}}'\overline{\vec{V}}'\right)}\right] \\ \overline{\vec{V}}'_{C} &= \left[\frac{\left(\overline{\vec{q}}'\overline{\vec{Q}}'\right)\overline{\vec{N}}' - \overline{\vec{Q}}'\overline{\vec{F}}'}{\overline{\vec{Q}}'\overline{\vec{V}}' - \left(\overline{\vec{q}}'\overline{\vec{Q}}'\right)\left(\overline{\vec{v}}'\overline{\vec{V}}'\right)}\right] \end{aligned} \tag{9}$$

With reference to Figure 1(b) in the coordinate system associated with the convention of the fixed scale, whose angles are measured in the same sense of the rotation of the rotor, the vibration of the near bearing is represented by the vector $\overline{\vec{N}}'$ and the vibration of the far bearing is represented by the vector $\overline{\vec{F}}'$.

For the second run of the balancing procedure, $\overline{\vec{N}}_2'$ is the vibration of the near bearing and $\overline{\vec{F}}_2'$ is the vibration of the far bearing when a quasi-static trial weight, $\vec{W}_{TER}'$, is added to the right plane in the direct solution to produce the effects $\overline{\vec{Q}}'$ and $\overline{\vec{q}}'\overline{\vec{Q}}'$, which is expressed as:

$$\begin{aligned} \overline{\vec{N}}_2' - \overline{\vec{N}}' &= \overline{\vec{Q}}' \\ \overline{\vec{F}}_2' - \overline{\vec{F}}' &= \overline{\vec{q}}'\overline{\vec{Q}}' \end{aligned} \tag{10}$$

At this point, it is necessary to explain that the quasi-static trial weight has to be added to the right plane to avoid a high level of cross effect [2, 5].

For the third run, $\overline{\vec{N}}_3'$ is the vibration of the near bearing and $\overline{\vec{F}}_3'$ is the vibration of the far bearing when a pair of trial weights, $\vec{W}_{TL}$ & $-\vec{W}_{TL}$, to form a couple are added to produce the effects, $\overline{\vec{v}}'\overline{\vec{V}}'$ and $\overline{\vec{V}}'$, given by the following expressions:

$$\begin{aligned} \overline{\vec{N}}_3' - \overline{\vec{N}}' &= \overline{\vec{v}}'\overline{\vec{V}}' \\ \overline{\vec{F}}_3' - \overline{\vec{F}}' &= \overline{\vec{V}}' \end{aligned} \tag{11}$$

However, the values would be entered in equations (9), as follows:

$$\begin{aligned} \overline{\vec{V}}_E' &= \left[\frac{\left(\overline{\vec{F}}_3' - \overline{\vec{F}}'\right)\overline{\vec{N}}' - \left(\overline{\vec{N}}_3' - \overline{\vec{N}}'\right)\overline{\vec{F}}'}{\left(\overline{\vec{F}}_2' - \overline{\vec{F}}'\right)\left(\overline{\vec{N}}_3' - \overline{\vec{N}}'\right) - \left(\overline{\vec{N}}_2' - \overline{\vec{N}}'\right)\left(\overline{\vec{F}}_3' - \overline{\vec{F}}'\right)} \right] \\ &= \left[\frac{\overline{\vec{V}}'\overline{\vec{N}}' - \left(\overline{\vec{v}}'\overline{\vec{V}}'\right)\overline{\vec{F}}'}{\left(\overline{\vec{q}}'\overline{\vec{Q}}'\right)\left(\overline{\vec{v}}'\overline{\vec{V}}'\right) - \overline{\vec{Q}}'\overline{\vec{V}}'} \right] \\ \overline{\vec{V}}_C' &= \left[\frac{\left(\overline{\vec{N}}_2' - \overline{\vec{N}}'\right)\overline{\vec{F}}' - \left(\overline{\vec{F}}_2' - \overline{\vec{F}}'\right)\overline{\vec{N}}'}{\left(\overline{\vec{F}}_2' - \overline{\vec{F}}'\right)\left(\overline{\vec{N}}_3' - \overline{\vec{N}}'\right) - \left(\overline{\vec{N}}_2' - \overline{\vec{N}}'\right)\left(\overline{\vec{F}}_3' - \overline{\vec{F}}'\right)} \right] \\ &= \left[\frac{\overline{\vec{Q}}'\overline{\vec{F}}' - \left(\overline{\vec{q}}'\overline{\vec{Q}}'\right)\overline{\vec{N}}'}{\left(\overline{\vec{q}}'\overline{\vec{Q}}'\right)\left(\overline{\vec{v}}'\overline{\vec{V}}'\right) - \overline{\vec{Q}}'\overline{\vec{V}}'} \right] \end{aligned} \tag{12}$$

The results demonstrate the fact that a different orientation of the overhung rotor does not change the values of the vector factors.

Nevertheless, in the new and direct solution, the quasi-static correction weight in the right balancing plane (*R*) and the left correction weight to form a couple in the left and right balancing planes (*L* and *R*), respectively, for the fixed scale convention are given by:

$$\begin{aligned} -\vec{W}_{ER}' &= \overline{\overline{\vec{V}}}_E' \vec{W}_{TER}' \\ -\vec{W}_L' &= \overline{\overline{\vec{V}}}_C' \vec{W}_{TL}' \quad \& \quad \vec{W}_L' \end{aligned} \tag{13}$$

With reference to Figure 1(a), a comparison of the standard solution, which was obtained by the addition of a left trial weight, $\vec{W}_{TL}'$, for the second run and the addition of a right trial weight, $\vec{W}_{TR}'$, for the third run [4], with the static/couple direct solution, which was obtained by the addition of a left quasi-static trial weight, $\vec{W}_{TEL}'$, for the second run and the addition of a pair of trial weights, $\vec{W}_{TR}'$ & $-\vec{W}_{TR}'$, in the right and left planes (*R* and *L*), respectively, to form a couple for the third run [6]; it can be seen that the corresponding effects in such formulas come from the same differences at the same points of measurement *N* and *F*. Then, it is possible to utilize the standard solution to find the static/couple direct solution, employing a pair of trial weights to form a couple during the third run, assuming that the left correction weight, $-\vec{W}_L'$, is interpreted as the left quasi-static correction weight, $-\vec{W}_{EL}'$, and that in addition to the right correction weight, $-\vec{W}_R'$, an opposite left correction weight of equal magnitude, $\vec{W}_R'$, also must be added.

Conclusion

The invariance of the vector factors in the direct solution for the two-plane field balancing with the orientation of the overhung rigid rotor has been demonstrated for the fixed scale convention.

The correct application of the formulas involved to a practical case also has been established.

The standard solution for the two-plane field balancing of a general rigid rotor developed for the fixed scale convention could be used as the direct static/couple solution for the fixed scale convention to balance an overhung rigid rotor since the effects come from the same points of measurement.

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