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ON THE COVER
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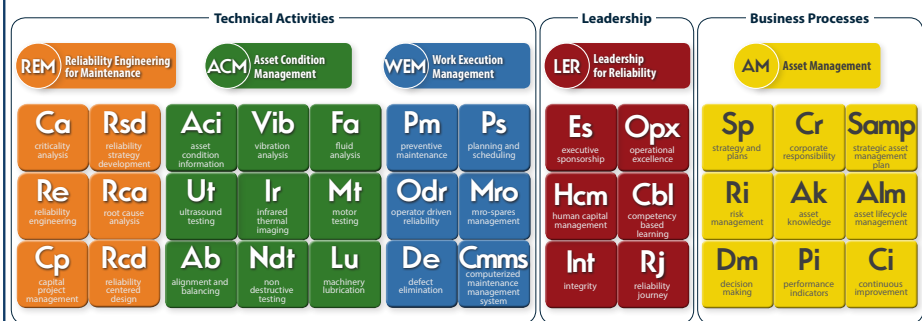


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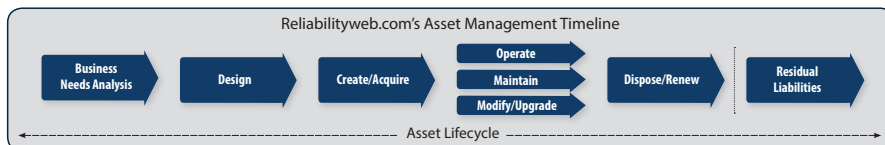
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Uptime® Elements



A Reliability Framework and Asset Management System™



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To subscribe to *Uptime* magazine, log on to
www.uptimemagazine.com
For subscription updates
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Uptime Magazine

8991 Daniels Center Drive, Fort Myers, FL 33912
1-888-575-1245 • 239-333-2500 • Fax: 309-423-7234
www.uptimemagazine.com

Uptime Magazine
is a founding member of



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Uptime® Magazine (ISSN 1557-0193) is published bimonthly by Reliabilityweb.com, 8991 Daniels Center Drive, Fort Myers, FL 33912, 888-575-1245. Uptime® Magazine is an independently produced publication of Reliabilityweb.com. The opinions expressed herein are not necessarily those of Reliabilityweb.com.

POSTMASTER: Send address changes to:
Uptime® Magazine, 8991 Daniels Center Drive, Fort Myers, FL 33912

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RELIABILITY IS INTENTIONAL

In case you were thinking that reliability was sometimes accidental.

The reliability of an asset is created when it is designed and then again when it is built, created, or fabricated. This is the design reliability level.

Then the design reliability level is realized or destroyed on installation. From there, you can only maintain whatever reliability got delivered – the operating reliability level. The operating reliability level could be much lower than the design reliability level, but it can never be better. To assure safety and reliability during the life of the asset, technically valid and economically feasible scheduled maintenance programs are developed with four objectives:

1. To realize the inherent safety and reliability levels of the asset;
2. To restore safety and reliability to their inherent levels when deterioration occurs;
3. To obtain the information necessary for design improvement of those items whose inherent reliability proves inadequate;
4. To accomplish these goals at a minimum total cost.

The physics of failure is not theoretical, nor is the reliability spend “variable.” There are knowable failure modes in context of consequences for a relatively small investment, and it is a valuable step to develop asset knowledge, defect elimination and cross-functional decision-making.

The asset will respond to physical conditions regardless of business decisions, so it is the best strategy to address these known risks with effective counters, measure them and improve them over time.

It helps when the culture thinks in this way or problem-solves in this way.

That is reliability leadership in action.

Most leaders underestimate how important it is to get the reliability culture right, leaving big influence in too few hands. The vision will be constrained by lack of diversity of input or view.

The best run organizations strive relentlessly to advance reliability and understand that attention to a unique and diverse cross-functional reliability leadership culture is the key to success. They use unique holistic approaches that include technology, culture and smart business to create good days where everything runs well, because nothing happens intentionally.



Other organizations should be encouraged to learn more by working with intentional reliability to:

- Reduce CO₂ footprint;
- Advance safety;
- Increase outcomes;
- Foster diverse leadership opportunities;
- Reduce typical costs;
- Many other benefits.

The variables are not simply the math and applied technologies. The trickiest part is around developing the leadership that creates the culture that delivers the performance, while also being effective and focusing locally and globally on aligned objectives.

Attention to a diverse reliability leadership culture is the key to success.

I am grateful for the opportunity to share this.

Terrence O'Hanlon, CMRP
About.me/reliability
CEO and Publisher
Reliabilityweb.com®
Uptime® Magazine
<http://reliability.rock>



IN THE NEWS

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Bentley Systems YII 2019 – October 21-24, 2019 – Singapore



Models of Excellence Workshop
Reliability Leadership Institute
October 8-10, 2019 – Fort Myers, FL



Maintenance Forum – Reliabilityweb.com
October 10, 2019 – Athens, Greece

CRL WORKSHOPS



Xcelerate19 Conference, November 12, 2019 – Fort Myers, FL



SABIC, October 27-30, 2019 – Saudi Arabia



Reliability Leadership Institute, November 11-15, 2019
Fort Myers, FL



Digitalization Roundtable – Bentley Systems
October 25, 2019 – Singapore



Asset Management Connect Roundtable
Reliabilityweb.com
October 28, 2019 – Emeryville, CA



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Lake Charles, LA - March 23-27

Houston, TX - March 30- April 3

Precision Maintenance Skills 2:

*Proper Bearing Installation & Maintenance for
Longer Equipment Life*

Lake Charles, LA - Dec 2-5

Baton Rouge, LA - Jan 20-23

Precision Maintenance Skills 3:

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Troubleshooting & Operations/Installation*

Decatur, AL - Jan 20-21

Lake Charles, LA - Feb 10-11

Baton Rouge, LA - Feb 13-14



FEATURED LEADER
UPTIME MAGAZINE Q&A WITH

LISA SEACAT DELUCA



INNOVATOR

When someone is named as one of the top “49 Female Entrepreneurs Who Are Reshaping the Business World” (*Entrepreneur Magazine*, 2019) and “World’s 50 Most Fascinating People in the World of Technology” (*Network*, 2014), you know you have someone that is changing the world. Meet Lisa Seacat DeLuca, Director & Distinguished Engineer at IBM. Lisa is leading the incubation and incorporation of the digital twin across IBM’s IoT offering suite and driving the digital transformation of IoT solutions.

Lisa’s innovation portfolio includes over 600 patent applications filed within the United States and abroad, of which, 400 have been granted, to date. The subject of her patent ideas range from areas such as cloud, mobile, IoT, social, security, cognitive, commerce and everything in between. Lisa is the most prolific female inventor in IBM history and the only one to ever reach the 100th Invention Plateau Award (an IBM internal patent award system).

Reliabilityweb.com and *Uptime* magazine are honored to have worked with Lisa over the last few years. We feel that is our reader’s time to meet this “golden child” of digital twin and discover how she is leading digital transformation.

Q. Your work is in the area of the Internet of Things (IoT), with a focus on digital twin technology. How is this technology affecting our lives and work today? How will it affect us in the future?

A. IoT is a really fun space to be working in these days because the adoption of IoT devices into most of our homes is only growing. We are consumers. We have experience with personal assistants, security cameras and wearables like Fitbits® that improve our everyday lives, put information at our fingertips and help us to be more aware of our health and wellness. It also means we have pain points and ideas for where this technology can go. These same smart, connected technologies and concepts we experience in our personal lives are making asset-intensive industries more intelligent. The growing adoption of IoT allows technicians, engineers, owners and operators to more effectively operate their businesses. And the future is automating further, which can be done through the help of artificial intelligence. I believe you can’t have AI without a digital twin. A digital twin is a digital representation of a physical thing. However, with the increased adoption of IoT, these digital twins come alive – now they can mimic all of the experiences of their physical asset counterparts. Digital twins are the source of truth, record and connectivity to actuate on a business need related to their physical assets.

Q. What can we do to embrace and better prepare for it?

A. Digital twins are not a new concept, the term has been around for over a decade. Most companies who haven’t embraced digital twins are just overwhelmed with where to begin. One way we can embrace and prepare for digital twins and the benefits of IoT is the digitization of our physical assets. Starting to put the bills of materials, parts lists, maintenance models and operational plans in a format that is easy to consume and build upon. One issue is there isn’t necessarily a single agreed upon format for many of these file types. So coming together as companies to create these standards will benefit us all.



Q. You have talked about how, as a young girl, you were always thinking of ways to enhance your life. How did you take that passion and turn it into a career?

A. I love problem-solving. Any time something takes a little too much time or feels more difficult than it should be, that's when the light bulb goes off that there may be a really valuable solution somewhere that others can benefit from as well.

Q. What led you to IBM®?

A. I got an internship when I was an undergrad at Carnegie Mellon University. Then, I got another internship the following summer with the IBM Extreme Blue program. I was impressed with the knowledge of my co-workers and the challenges we got to solve with technology that actually mattered to the world. I knew I wanted to join IBM full time.

Q. As the most prolific female inventor in IBM history and the only one to ever reach the 100th Invention Plateau Achievement Award (an IBM internal patent award system), you have over 600 patent applications filed with 400 granted. How do you stay creative and know what innovations to pursue?

A. Inventing is like any other skill, once you've done it enough, you start to get really good at recognizing when something might be patentable. I can see a product or pain point and turn it into a handful of ideas. As far as which ones to pursue, I typically align my inventions to the products I'm bringing to market that can create societal and economic value. That way, I know I'm adding value to IBM and protecting our competitive differentiation while future proofing our solutions.

Q. Named Innovator of the Year from Innovation & Tech Today magazine (2018) and one of MIT's 35 Innovators Under 35 (2015), what advice do you have for the younger generation following a similar path as yours?

A. Sometimes you have to give it some time before it becomes your passion. Keep playing with technologies and learning as much as you can based on your personal interests. You'd be surprised at how easy it is to overlap those learned skills with your day job, which will help you develop a unique skill set that sets you apart.

Q. To be an innovator, you need to be creative and sometimes, to be creative, you need to take risks. What gives you the courage and determination to move forward with your ideas?

A. As my father always said to me growing up, "You can't turn it down until it's offered." I live by those words, pushing for what I believe in and optimistically taking risks while being grounded by reality. Part of being prolific is having a lot of ideas in the works. Not all of them are going to work out, but the stronger ones typically find their way.

Q. Who influenced you the most and had the biggest impact on your career?

A. I've been really lucky with my IBM mentors. I give advice to my mentees to collect mentors because it's a great way to network and everyone has a different and unique perspective to share. However, the person who has had the biggest influence on my career is Ginni Rometty, IBM's CEO. She inspires me! She's a female in tech who grew up through IBM, serving as a reminder that I can do it too.

Q. What is your favorite invention you created? What is your favorite technology that someone else created? Why?

A. My favorite inventions of mine are absolutely the newly filed ones around digital twin. Bringing inventions to life through our new products is exciting. It takes about 18 months from filing until the inventions are searchable online, so stay tuned for some links. My favorite inventions from someone else are A/C, cars and refrigerators. Most inventions build off of some existing technology, so my favorite part of inventing is the collaborative nature of diverse thoughts sharing ideas for future generations to improve upon.



DIGITAL

TWIN:

**TRANSFORMING
ASSET OPERATIONS**

Lisa Seacat DeLuca

“Gartner estimates that there will be 20.4 billion IoT devices by 2020, creating more than 500 zettabytes per year in data”

As physical assets become increasingly software enabled and more complicated in their construction, a new model is required to operate them – a model that will not be fully possible without the creation of digital asset replicas. These replicas are called digital twins.

While there is a range of definitions for what digital twins are, the simple definition is “a digital representation of a physical asset.” This digital replica may include all of the components required to run and maintain that asset, from 3D computer-aided design (CAD) renderings to bills of materials and failure codes.

Digital twins are used by organizations to determine how their physical assets perform under certain conditions or how they monitor asset performance in real time. Powered with data from sensors attached to the physical assets, digital twins enable the creation of robust failure models. They help organizations understand asset criticality, right down to the individual parts each piece of equipment is made of, and then share that information across teams. As a result, digital twins become critical in transforming organizations and driving digitization initiatives end to end.

Many organizations want to create models that demonstrate how the various elements of the Internet of Things (IoT) will be brought into their operating reality and merged with existing ISO, Six Sigma and total quality management (TQM) aligned methods for ensuring reliability. To achieve this, they have to apply rigor to specific areas where they define the *what*, *when*, *how* and *why* of their IoT deployment. These decision points align with the Internet of Things knowledge domain that is found in the Uptime® Elements:



1. Source: The ready availability of digital twins will revolutionize the process of onboarding complex equipment. Onboarding is often a siloed process, rife with paperwork and prone to human error. When industrial equipment is purchased, maintenance plans must be built based on multiple conversations with original equipment manufacturers (OEMs). Materials lists must be created and entered into systems manually, and stocking occurs based on assumed part criticality and allocated budgets. With each stage managed by a different team, the process is plagued with inefficiencies and can take months to complete. For example, digitizing something as large and complicated as an entire oil refinery could take as long as five or six months. This assumes it would be based on physical blueprints and paper documents from its structure to its equipment inventory, processes and

failure modes. An initiative like this would completely dominate the time of plant engineers.

Digital twins can streamline this process to get the system up and running immediately. Rather than rely on slow, manual processes, the digital twin leverages existing digital replicas of the individual components that reside within the larger system. (These digital assets would have been created by the owners of the components during the development process.)



2. Connect: Many in the industry say that IoT sensors continue to drop in price every year. This is to encourage organizations to enable their enterprises with the IoT now. But, people often underestimate the various requirements that come with connecting their equipment, their enterprise and their industry. Additionally, there are many application programming interfaces (APIs) and other development approaches. And, many questions on issues, such as access, information flow and storage, must be answered before an organization can build a truly secure and purposeful digital nervous system. Every connection point creates a possible vector for a cyberattack. Therefore, each connection needs to be designed, developed and deployed to be secure; every single one. This is a lot of work without a platform that helps drive uniformity.

Digital twins that are used in operations with live data, as well as in collaborative development situations with manufacturers, operators and other third parties, require secure workspaces and communications. Otherwise, the integrity of the digital twins and the data they house cannot be maintained. Connectivity with asset sensors allows organizations to get closer to a full operating twin that mimics the experiences of the physical assets. But, it demands that the system is protected and facilitated as it's shared and updated by multiple parties.



3. Collect: Gartner estimates that there will be 20.4 billion IoT devices by 2020, creating more than 500 zettabytes per year in data. There is no doubt that companies are struggling with what data to collect, where to store it and how to make it usable.

Digital twins create a logical taxonomy of the data from the IoT, as well as the categorization and use of that data. The ability to shape the data set based on physical, digital and electromechanical attributes allows enterprises to manage their data requirements. Digital twins manage by exception and operating processes, such as anomaly detection, asset modifications and customizations. They *filter* the massive volumes of operating data that flows through the enterprise, limiting what needs to be captured, cleansed, stored, reused and actioned. By definition, the digital twin encompasses this collection phase, pulling in everything it knows to be true about the physical asset.



4. Analyze: As mentioned in data collection, data analysis is more effective based on volume of data. But it's less efficient based on the need to manage, merge and cleanse the volumes of data to create data sets that analysts and data

“The vision of the digital twin is to enable good decisions that deliver value to your physical and digital operations and support your ongoing industry transformation”

“DIGITAL TWIN: A digital representation of a physical asset”

scientists can use. By employing digital twins to categorize data and visualize and contextualize it, teams can compartmentalize their activities, create hypotheses and communicate results to nontechnical or nonanalytical peers. The addition of statistical analysis tools and models that execute a plethora of calculations on a rich model with multiple attributes makes it easier to predict failure, flow and feasibility. Modeling tools that enable the simulation of an issue or enhancement in a future state are already common in the virtual reality space, whereas digital twins allow physics to guide the analysis in a pseudo real-world sense. As such, whole production lines, factories, vehicles and systems can be tested before major investments or reductions in investments are made. This leads to the benefit artificial intelligence (AI) can bring to improving operations for physical assets. The digital twin holds the data that is collected and fed into the AI models to uncover key insights.

Do

5. Do: If done correctly, a digital twin allows owners and operators to perform simulation and what-if analysis on their physical assets. If the physical asset is IoT enabled and accepts commands to actuate on the asset, remote and autonomous operation becomes possible. By combining the IoT with AI for anomaly detection and prediction, you create the asset of the future.

The vision of the digital twin is to enable good decisions that deliver value to your physical and digital operations and support your ongoing industry transformation. While the digital twin will solve many issues, the achievement of its vision isn't possible unless you digitize your physical assets and their subassemblies. You must also work together to develop standards for how digital twin resources should be structured to achieve consistency across consumption technologies.

Regardless of the challenges, there is no question that even in the very physical, asset intensive industries (e.g., energy and utilities, oil and petroleum, manufacturing and industrial products), digital assets are becoming just as essential as physical ones. Digital twins are a revolutionary solution to help ensure that companies achieve efficiency and efficacy in their operations, and that they continue to bring value to their customers.



Lisa Seacat DeLuca is a Director & Distinguished Engineer, leading the incubation and incorporation of the Digital Twin across IBM's IoT offering suite and driving the digital transformation of IoT solutions within IBM. Lisa is a TED speaker, and the most prolific female inventor in IBM history. Her innovation portfolio includes over 600 patent applications, of which 400 have been granted to date. www.ibm.com/iot

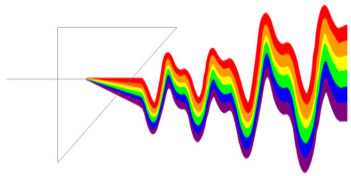
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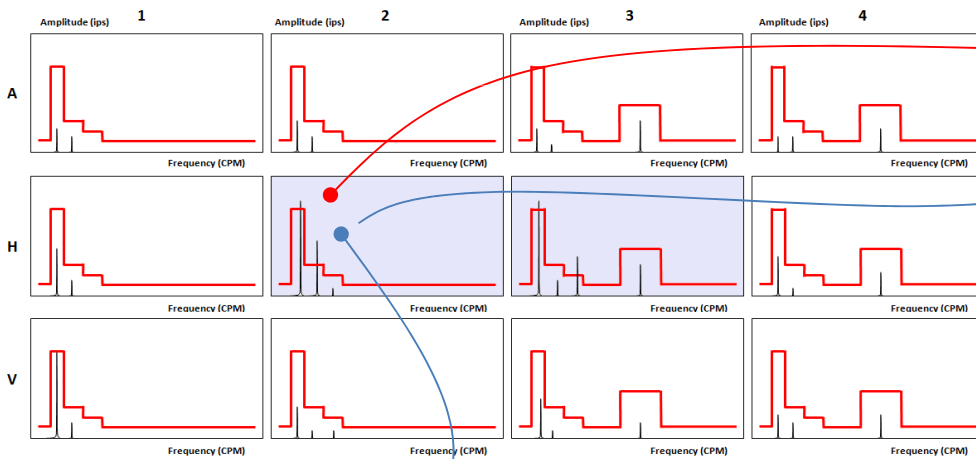
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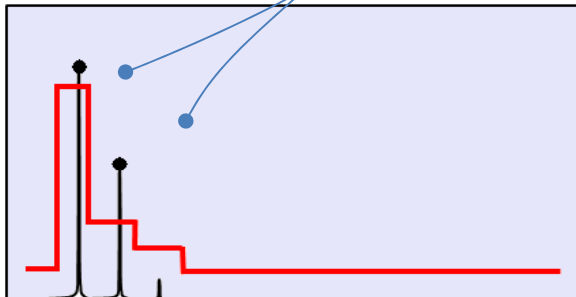
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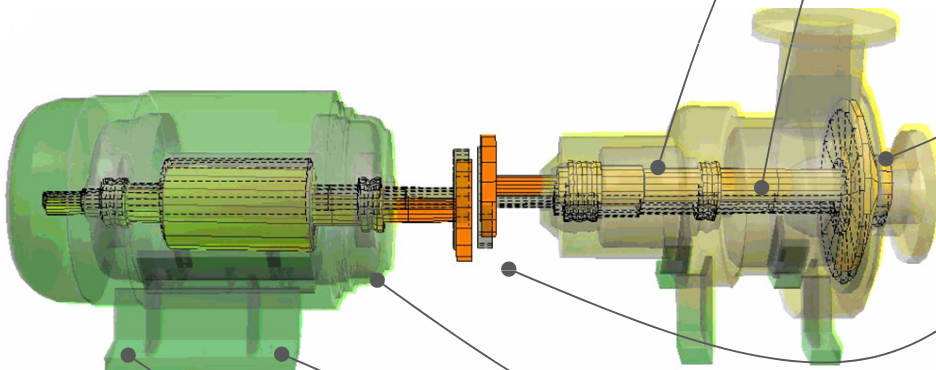


- **AMPLITUDE** Severity Alerts the Analyst
- **FREQUENCY** Spectrum Defines the Source
- **PHASE** Analysis Defines the Motions

Amplitude (ips)



Frequency (CPM)



1. Check for Unbalance / Eccentricity [H-V] @ Each Bearing
 Yes No
 [H₁-V₁] 90° +/- 30°
 [H₂-V₂] 90° +/- 30°
 [H₃-V₃] 90° +/- 30°
 [H₄-V₄] 90° +/- 30°
2. Check for Overhung Rotor Unbalance
 Yes No
 [A₃-A₄] 0° +/- 30°
3. Check for Bent Shaft
 Yes No
 [A₁-A₂] 180° +/- 30°
 [A₃-A₄] 180° +/- 30°
4. Check for Misalignment Across Coupling
 Yes No
 [A₂-A₃] 180° +/- 30°
 [H₂-H₃] 180° +/- 30°
 [V₂-V₃] 180° +/- 30°
5. Check for Cocked Bearings
 Yes No
 [A_{Top} - A_{Bottom}] 180° +/- 30°
 and/or
 Yes No
 [A_{Left} - A_{Right}] 180° +/- 30°
6. Check for Soft Foot (Mechanical Looseness)
 Yes No
 [V₁ - V₂] 180° +/- 30°



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A large offshore oil rig is silhouetted against a dramatic sunset sky. The sun is a bright, glowing orb positioned behind the rig's structure, creating a lens flare effect. The sky is filled with orange and red clouds, and the sea is visible in the foreground.

OPTIMIZING ASSET UTILIZATION: **LOOP'S CONTINUOUS IMPROVEMENT JOURNEY**

Brian J. Pertuit

In 2018, LOOP LLC received the Uptime Award for *Best Asset Condition Management Program*. It highlights a journey that began five years ago and led to many achievements along the way. Here's how the company re-invented industrial energy usage, applied science and technology to implement an effective asset conservation and improvement program.



Figure 1: A VLCC moored and connected to LOOP LLC's marine terminal in the Gulf of Mexico

The Start of the Journey

The Louisiana Offshore Oil Port (LOOP LLC) is the nation's largest privately owned crude oil terminal. Initially constructed in 1981 to import crude oil from around the globe, LOOP has grown to become a fully diversified crude oil trading and exchange hub. LOOP is the only facility of its kind in the world where shippers can off-load crude oil from very large crude carriers (VLCCs), load VLCCs, and purchase, sell, exchange, store, blend, or deliver crude oil.

In February 2018, LOOP's deepwater oil port became the first U.S. facility capable of fully loading a VLCC for crude export. Today, LOOP handles far more domestically produced crude oil than international varieties. In addition to its pumping and storage facilities, LOOP provides shore services for deepwater Gulf of Mexico production and operates pipelines. LOOP LLC's onshore facilities can store over 70 million barrels of crude in belowground caverns and aboveground storage tanks. Its unique pumping systems can transport crude at rates in excess of 100,000 barrels per hour on multiple, interconnected pipelines. After several decades of planning and successful execution, LOOP has now established the Clovelly Hub as a strategic component in the global crude oil marketplace.

LOOP is constantly seeking ways to remain market driven and operationally excellent. It enhances its strategies and tactical objectives annually for continued success in the ever-changing petroleum market. The safety of personnel, its environmental stewardship, the uptime or availability of assets, and energy consumption reduction all remain critical components of LOOP's business performance. Related key performance indicators (KPIs) and metrics, therefore, align with the company's vision for

success. It embeds proactive systems and programs into its culture. The company continues to plan its work and work its plans, taking note of lessons learned and corrective actions along the way and sharing them throughout all facilities. LOOP has made a habit of seeking opportunities for continuous improvement in all aspects of its business, with the help of its owners and strategic partners.

The Workings of the Asset Condition Management Program

Asset condition management is a key component of LOOP's success. For starters, the company strives to provide a reliable and safe facility where its employees, contractors and customers want to be. Its operator care and predictive and preventive maintenance programs are robust, thus field operators, reliability technicians and maintenance technicians are empowered as the first line of defense against asset failure. The Oil Movement Controllers (OMCs) in the control room are also asset stewards, responsible for alarm management. Additionally, engineers are designing reliability into the systems and eradicating failure out of the assets.

LOOP continues to utilize technology: vibration monitoring, ultrasound, thermography, oil analysis and other traditional asset condition monitoring components of a robust reliability-centered maintenance program. As technology changes, the company embraces condition monitoring advancement opportunities and remains prepared for major shifts in strategy. For example, LOOP is currently enhancing its platform for improved asset condition management by investing in a new enterprise asset management/enterprise resource planning (EAM/ERP) pre-integrated software solution to replace its computerized maintenance management system (CMMS) and financial systems with one application. This system will provide one truth in asset condition and work management status throughout the organization, including associated cost tracking, and will be the foundation for technological advances in true online condition monitoring well into the future. This investment into LOOP's future

Sun setting on the west side of one of LOOP's Marine Terminals (Photo courtesy of: Jason L. McMichael of LOOP LLC)

LOOP has made a habit of seeking opportunities for continuous improvement in all aspects of its business, with the help of its owners and strategic partners



Figure 2: LOOP LLC’s Clovelly Maintenance Crew, from left to right: Trent Rupert, Kerwin Matherne, Ryan Ford, Nat Pitre, Chase Orgeron, Terral Pitre, Anthony Pitre, Cody Pitre, Ricky Lee and Janson Thibodaux

is named Project Constellation, as it ties into the overarching technology strategy, which was developed after naming technology as one of the company’s five strategic focus areas in 2017.

LOOP continues to use KPIs to successfully manage what is important and must be measured. As always, data quality is important when it comes to metrics and KPIs, and so is relevance. The company continues to measure the things that should be managed, and where a cultural evolution has already taken place, eliminates data tracking that is no longer pertinent. This leaning out of its metrics and KPIs allows the organization more time to focus on current, relevant tactical objectives that are being embedded into its positive, proactive processes. This has been a recipe for success at LOOP for nearly 40 years.

The Journey’s Results

The results have been rewarding. LOOP achieved a record 99.75 percent uptime on its main oil line (MOL) assets in 2013, remains over 99 percent and has now exceeded 98 percent uptime for nearly a decade.

In 2013, LOOP established a five year goal to reduce its 2012 baseline energy consumption per barrel of crude oil transported by 15 percent. This goal was accomplished with three years to spare and has continued to decrease energy consumption to a current savings of over 30 percent compared to the company’s baseline. Though the organization has significantly reduced its energy consumption, it continuously strives to become even leaner as it realizes this is good for both business and the environment. LOOP appreciates Terrence O’Hanlon’s theory of the triple bottom line, and supports and encourages related initiatives throughout its facilities.

In 2018, LOOP handled over 940 million barrels of crude (over 37 billion gallons in total) at its Clovelly Hub in Galliano, LA, approximately 470 million barrels “in” and over 470 million barrels “out.” The company’s stewardship of these volumes includes adherence to strict standards for environmental releases. LOOP reports every drop of hazardous fluid that leaves containment and enters the water. Accordingly, it reported five environmental releases in 2018. However, the total volume released was only 0.02 ounce

es, or less than half a teaspoon. That ratio of throughput to release volume was a new record for LOOP and surpassed its prior year. However, its target is always goal zero for both safety and environmental incidents, so there is still room for improvement.

The company’s efforts have led to numerous recognitions over the years. LOOP has received three Uptime Awards in five years. The company won the Uptime Award for *Best Work Execution Management Program* in 2014, the 2016 Uptime Award for *Best Green Reliability Program* and the 2018 Uptime Award for *Best Asset Condition Management Program*.

After each Uptime Award, LOOP renewed its commitment to continuous improvement, vowing to not camp out at success or rest on its laurels. In recent years, the recommendations set forth in the American Petroleum Institute’s (API’s) RP1173 for a structured and integrated Pipeline Safety Management System (SMS) were implemented. This includes a Deming model style Plan-Do-Check-Act (or Adjust) component for all of its processes and programs, starting with risk assessments and mitigation evaluations at all operating facilities. There is synergy between RP1173 and ISO55000, so LOOP’s efforts are yielding a win-win for the company and its assets through a risk-based approach to asset management and safety.

The Uptime Award selection as the *Best Asset Condition Management Program* was based, in part, on LOOP’s continued uptime performance, risk-based asset management program and its asset management policy. This policy is signed by LOOP’s President and is embedded as a foreword to the organization’s *Maintenance Policies & Procedures Manual*, just as its safety policy is for its *Safety Manual*. These policies establish executive support and set the tone for asset, work



Figure 3: Kerwin Matherne of LOOP LLC and Avery Duet of Danos embody teamwork and collaboration, one of LOOP’s cultural pillars



Figure 4: The essential principles of LOOP's asset management policy

“ The Uptime Award selection as the Best Asset Condition Management Program was based, in part, on LOOP’s continued uptime performance, risk-based asset management program and its asset management policy



Figure 5: LOOP LLC receives its third Uptime Award in five years at the International Maintenance Conference in Bonita Springs, Florida, December 12, 2018. Pictured left to right for LOOP: Naresh Copeland, Brian Pertuit, Kerwin Matherne, Terry Coleman and Darren Fauchoux



Figure 6: Some members of the LOOP LLC leadership team after an August 2019 Safety & Environmental Roundtable

and safety management. Through threat assessments and risk management, the company is taking luck out of the equation for uptime and, more importantly, for safety and environmental incident prevention.

LOOP LLC is a joint venture of Marathon Pipeline LLC, Shell Oil Company, and Valero Terminating and Distribution Company. These owner representatives extended their support and shared best practices that have proactively improved LOOP's performance in safety, environmental stewardship and reliability. All LOOP employees, its owners and strategic partners take pride in the organization's continued stellar team performance and successes.

With an embedded, proactive culture, a clear focus on "getting it right" and a passion for continuous improvement, LOOP continues its journey toward operational excellence.



UPTIME AWARD WINNER:

2018 Best Asset Condition Management Program



Brian J. Pertuit, CMRP, is the Manager of Reliability & Loss Control for LOOP LLC. Mr. Pertuit has over 30 years in heavy equipment and the energy industry, in both the petroleum and power sectors. He began

his career in 1986 by serving in the U.S. Army as a tank mechanic specialist during overseas service and later worked in consulting engineering as a co-op student while attending the University of New Orleans, where he obtained a Bachelor of Science degree in Electrical Engineering in 1993.



Morgan B. Wolfe, CMRP, is the Sr. Vice President of Operations at LOOP LLC, where he also once served as the General Manager and has supported all of the asset condition management initiatives referenced in this article. Mr. Wolfe developed the Reliability Department at LOOP and his vision provided the genesis for many of LOOP's reliability initiatives. Mr. Wolfe is an executive owner in LOOP's Pipeline SMS program. He has over 40 years of experience in the oil and gas industry, and obtained a Bachelor of Science degree in Mechanical Engineering from Louisiana State University in 1979.



Chris A. Labat, CMRP, is the Vice President of Engineering & Technology at LOOP LLC, where he once served as the Reliability Superintendent. Mr. Labat supported the asset condition management initiatives and served as General Manager while LOOP reached many successful reliability milestones referenced in this article. Like Mr. Wolfe, Mr. Labat is an executive owner in LOOP's Pipeline SMS program. He has over 30 years of experience in the oil and gas industry, and obtained a Bachelor of Science degree in Mechanical Engineering from Louisiana State University in 1987.



The late **David A. Martin, CMRP,** (d. 2018) was LOOP's Reliability Planning Supervisor and the coauthor of two "Keeping It Simple" Maintenance and Reliability series books published by Reliabilityweb.com on the topics of Lubrication and Metrics & KPIs. Mr. Martin was a reliability champion, a loving husband, aspiring farmer and a blessing to all who knew him. LOOP LLC dedicates this article and its successes in asset management to the memory of its dear friend, David. Thanks to his legacy, LOOP always strives to perform "the right maintenance at the right time!"

Banetti

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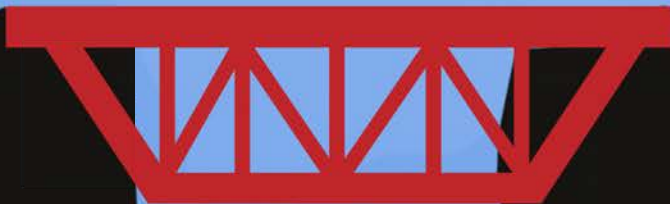
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REDISCOVERING ENGINEERING

Tools & Methodologies in the Digital Era

Alex Oliveira •

Since the beginning of time, human beings have survived and evolved through the use of tools. Tool usage is the basis for both ancient and modern engineering advances. With the advance of modern technologies, terms like artificial intelligence (AI), Industrial Internet of Things (IIoT) and Industry 4.0 are now more frequently used than robust engineering tools, like failure mode and effects analysis (FMEA) and root cause analysis (RCA).

In order to stay up-to-date, modern engineering needs to embrace the fast pace of the digital era, adapting its practices to keep up with a wave of technological breakthroughs with the advance of the Industry 4.0 revolution.

This article reviews some interesting and cost-effective examples of tools and methodologies rediscovered through the eyes of AI, analytics and business intelligence tools. By stimulating ideas, it can help your reliability and manufacturing excellence journeys to be faster, simpler and more sustainable.

FMECA – A New Way to Empower Your FMEA's through Analytics

Among a broad range of options, failure mode, effects and criticality analysis (FMECA) is a good choice, not just for design and qualification steps, but to empower maintenance strategy, asset management and facilities maintenance.¹ Criticality (the C in FMECA) gives a risk-based bonus that allows the failure modes to be prioritized. Note that the C is not asset criticality, but for criticality of the failure modes.

Although the FMECA concept is not new, business intelligence tools can boost FMECA and refresh its usage. Using analytics, it is possible to filter the data with assets, locations and operating units, calculating criticality parameters as failure effect probability, modal failure rate, failure mode criticality, and so on.

Calculations can be automated with equations fed by queries on auto loops with analytics resources. Thus, years of information in your computer-

ized maintenance management system (CMMS) are available for practical use — far beyond spreadsheets manually fed by CMMS database downloads — just by using digital tools to harvest data from maintenance databases. Through analytics, you can upgrade your old FMEAs into powerful FMECAs.

“...Interesting and cost-effective examples of tools and methodologies rediscovered through the eyes of AI, analytics and business intelligence tools”

The challenge of new machinery without available maintenance history can be overcome by using internal benchmark data from the CMMS's global database of other manufacturing units. This is made available by integrating graphical resources and mathematical capabilities that any common business intelligence tools can now provide. Besides, with analytics' fast learning curve, all these accomplishments can be done without major effort using internal labor resources (e.g., automation engineers, reliability engineers, etc.).

Modern RCA Utilization

In any industrial sector, root cause analysis RCA² is a mandatory step for all companies seeking improvement to their processes. For some highly regulated sectors, such as pharmaceutical and biotechnology, root cause analysis (RCA) is more than improvement, it is a compliance requirement.



For chemical industries or environments where process safety is a must, RCA effectively avoids the recurrence of issues, assuring people’s safety. The list of examples is huge when underlining the importance of RCA for any industrial players. It is, in fact, the most cost-effective way to avoid recurrent failures and, consequently, reducing maintenance costs. Thus, a good RCA program with a robust set of tools should be part of an organization’s strategy, included in its training and development plans, be part of its control strategies, and made compulsory for any business that pursues excellence for its processes.

Cross-functional teams, along with knowledgeable facilitators, enable the accurate identification of root and contributing causes, as well as ease the design of action plans to effectively mitigate or eliminate risks. When investigating failures, rare are the cases when just one root cause is found. Normally, several root causes or, at the minimum, a root cause along with its contributing causes are a common place at RCAs. In this context, it is important to remember that failures not addressed will result in bigger successive breaks and, consequently, high costs of reactive maintenance, downtime impact and potential regulatory threats to manufacturing processes.

However, with modern digital resources, available both on the equipment (e.g., a digital control system {DCS}) and in industrial network systems (e.g., inside a standard enterprise resource planning {ERP} system), an effective data collection with proactive usage through analytics tools can ease the investigation process. Audit trails of programmable logic controllers (PLCs) and DCSs are becoming more evolved each day, feeding investigations with traceable process information. CMMS work orders register fill gaps during RCA processes. Even surveillance systems have opportunities with registers to add information to RCA inquiries. The point is to use technology to empower your old ways to collect and process data for RCA purposes.

Investigating teams can use data from such digital sources to conduct more robust analysis, thus detailing failure investigations with distinct and rich perspectives over the failure scenario. These data can be used to provide inputs to RCA dedicated software or even to traditional tools, like fault tree analysis (FTA), Ishikawa diagram, etc. The combination of smart data with cross-functional teams provides better results and savings through more failure modes captured, less recurrence, and faster and more effectively deployed action plans.

“Through analytics, you can upgrade your old FMEAs into powerful FMECAs”

Reliability Methodologies from Design to Maintenance & Operations

Good engineering methods, aligning modern and digital resources, can consistently improve and sustain efficient manufacturing processes. This learning was an important breakthrough for high-speed trains and aerospace manufacturers years ago. They have been using robust methodologies to assess and advance their products and installations.

Among a big variety of options, one of the best is the reliability, availability, maintainability and safety (RAMS) methodology due to its robustness and low-cost implementation. RAMS can be deployed with very low investment by means of just some engineering equations³ and through the usage of analytics resources to systematically automate calculations.

$$R = e^{-\lambda t} \quad A_I = \frac{MTBF}{MTBF + MTTR} \quad M = 1 - e^{-\mu t}$$

Figure 1: Reliability, inherent availability and maintainability equations

This approach, initially just for design and concentrated on specific niches like railway industry,⁴ is nowadays spreading to other sectors as well. The railway industry is one of the pioneers using RAMS and it has

AUTOMATION & HISTORIAN SYSTEMS



CMMS SYSTEMS



ANALYTICS



**PROFITS
\$\$\$**

Figure 2: IIoT utilization leveraging gains and savings

progressively achieved impressive results, producing faster and safer high-speed trains every year.

Widely recognized as a key tool for the design phase, RAMS also can be deployed during any stage of the asset’s lifecycle. Its expansion to maintenance programs has resulted in excellence for such manufacturers that is challenging archetypes and improving the reliability of operations and maintenance.⁵

Methodologies like RAMS can effectively contribute to the conversion of some intangible benefits of reliability into tangible gains, adding numbers to assumptions and insights about the asset’s health and equip-

“Widely recognized as a key tool for the design phase, RAMS also can be deployed during any stage of the asset’s lifecycle”

ment’s performance. RAMS and other asset management methods create the opportunities for cost savings by anticipating downtime caused by evolving failure modes in equipment and more effective decision-making capabilities for industrial investments.

Analytics to Speed up DDM Deployment

Data-driven maintenance (DDM) is a powerful method for maintenance cost reduction once it preconizes the use of data to drive maintenance decisions instead of relying on time-based inspections. Hence, besides a powerful ally of predictive techniques, it allows manufacturing processes improvements⁶ since decisions based on data and not just on insights are obviously more reliable.

Unfortunately, many companies do not benefit yet from their current maintenance history as they could because they are not aligning their approach in a database way. Through the application of AI algorithms, thousands of maintenance registers in a CMMS, like work orders, can be analyzed and, using pattern recognition, create many asset improvement opportunities in a similar way. Such an approach is being applied in operational optimization.

The way work orders are recorded and stored in the CMMS, the keywords used, the work duration, and many other parameters can be leveraged to boost maintenance savings when they are processed by AI algorithms, with the eyes of Industry 4.0. Such rich databases of asset information from your maintenance data can facilitate the redesign of systems and installations and revolutionize the way you maintain and even operate your equipment.

Conclusion

Although the IIoT is rapidly evolving and spreading, there still may be a long way yet to go until appropriate levels of AI and machine learning are accessible, reliable and cost-effective enough for all industrial processes, mainly in more conservative and regulated industries.

However, the fast pace by which new technologies are growing and multiplying their applications to reduce costs, facilitate human adaptability and improve reliability, the much-anticipated benefits of Industry 4.0 may be closer than you think.

In this context, traditional engineering methodologies, supplemented by modern technologies and tools, such as analytics and business intelligence resources, must work together to speed up reliability, maintenance and operational excellence journeys inside the new digital arena.

With a risk-based approach, good control strategies and synergy between modern technologies and good traditional engineering methods, the Industry 4.0 crusade will continue its accelerated development curve, bringing breakthroughs that will change our lives and boost our evolution.

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Combining Mechanical Integrity and RCM for Time, Cost Savings



For owner-operators of oil, gas and chemical companies, mechanical integrity (MI) and reliability-centered maintenance (RCM) are pivotal components of any comprehensive asset management (AM) program. However, most companies tend to treat MI and RCM as separate programs, utilizing different tools for each – where MI is administered by the engineering organization and RCM is administered under maintenance. Yet, with the advancement of technology in this area, there is now a far more cost-effective approach. The truth is, MI and RCM both fall under the larger umbrella of asset management. These days, both can be efficiently managed with one software tool, improving transparency and efficiency, while significantly reducing costs overall.

The Evolution of MI and RCM

In the U.S., MI and RCM evolved separately for many reasons. MI is driven mostly by American Petroleum Institute (API) standards, while RCM originated in the aerospace sector and the base standards come under the Society of Automotive Engineers (SAE). AM standards are relatively new and were driven by the International Organization for Standardization (ISO).

Malcolm Werner, Dave Maguire and Richard Fish

While MI was driven by safety and legal liability requirements, RCM was driven more by business needs to improve production certainty and reduce maintenance costs. Most maintenance organizations in the U.S. are still highly reactive due to a fear that vital work would fall behind immediate needs. Many maintenance groups' preventive maintenance for critical equipment has lower schedule compliance.

The Challenge

By keeping MI and RCM separated, companies might be foregoing the full potential of their asset management program. Take, for example, the factoring of complex asset types. Assets have long been divided into *fixed* or *static* equipment and *rotating* equipment, which often put control valves, instrumentation, electrical and other assets in limbo. Tanks, some piping and structures that are not specifically covered by standards could be missed either in inspection or maintenance plans. Piping is rarely listed in the asset registry unless care is specifically required by standards.

When adding new equipment to an RCM program, some equipment is assumed to be tracked under an engineering inspection program. While a critical system can include vessels, exchangers, piping, tanks, etc., failure mode and effects analysis (FMEA) and care plans are rarely entered into the computerized maintenance management system (CMMS) for planning, scheduling, or compliance tracking by the maintenance organization.

MI can address the inspection planning of all asset types. Care plans are tracked in engineering databases or specialized software and, with the right product, can be seamlessly connected to a company's CMMS for planning, scheduling and compliance tracking.

The Solution: One Software for Both

Changes are occurring that will encourage the integration of MI and RCM programs and benefit the care of all assets.

Most companies now recognize that operational excellence requires all stakeholders in the facility to be on the same team driving performance for the betterment of safety and financial success. More and more, finance/accounting, engineering, inspection, procurement, operations, maintenance and other organizations within the facility are working together to improve and sustain the business.

The ISO55000 asset management standard is educating all about what assets make up a business and how all stakeholders need to be held accountable for them. The Industrial Internet of Things (IIoT) and the Digital 4.0 revolution are providing tools that make information sharing and performance tracking easier for all.

Specifically, there are now software and digital data systems that enable tracking of all assets, helping a company manage both MI and RCM from one software platform.

The Benefits

Managing all facets of a company's asset management program with one software facilitates immediate cost and time savings benefits to owner-operators. By combining both services into one program, the operator will experience substantial cost savings in program maintenance, training and software updates. Having all data, for all asset types, for both integrity

and maintenance in one digital database results in heightened transparency and readily accessible actionable intelligence. Digitizing and streamlining processes into one program improves efficiency, security and reliability. Moreover is the added benefit to end users, who no longer have to learn and maintain functional knowledge of many different software programs. As an added bonus, selecting a software that connects to the company's existing CMMS helps complete the loop for work order management.



By keeping MI and RCM separated, companies might be foregoing the full potential of their asset management program



Selecting the Right Software

Modern day inspection data management software (IDMS) has evolved to include a wide range of features and functionality that can address the requirements of both MI and RCM. At its core, a comprehensive IDMS software already addresses MI, so it's important to find one that can also support the specific requirements of RCM. When looking for software capabilities to address RCM specifically, consider its four components: reactive, interval, condition-based maintenance (CBM) and proactive. The right software should:

- **Reactive:** Allow for the management of the reactive component by enabling a user to manage small, noncritical items that are either unlikely to fail or may be redundant (i.e., run to failure);
- **Interval (preventative maintenance):** Monitor equipment that is subject to wear or has known failure patterns and maintain it on specific frequencies or intervals;
- **CBM:** Allow for equipment with random failure patterns or ones not normally subjected to wear to be assessed on risk and managed accordingly;
- **Proactive:** Retain inspection results, such as root cause failure analysis and FMEA, with appropriate maintenance and further inspection scheduling, all managed within the software.

From there, to ensure both RCM and MI are being supported, seek an IDMS that has the following features:

- **All asset types from a single platform** – Includes rotating and fixed/static equipment, as well as tubes, piping, offshore structures, valves, etc.;
- **Configurable risk-based inspection (RBI)** – Supports inspection planning based on RBI methodology, allowing owner-operators to



Managing all facets of a company's asset management program with one software facilitates immediate cost and time savings benefits to owner-operators



prioritize critical assets over noncritical; Ideally, seek a software that allows the company to configure its own RBI model according to its unique needs;

- **General trending** – For specific measurement trending;
- **Scheduling** – Planning inspections with the ability to retain photos and attach inspection documents; Further aids in equipment management and simple data retrieval;
- **Seamless adherence to all major regulatory standards** – Includes ISO and API to facilitate regulatory compliance in the case of an audit
- **Flexibility** – Accommodates the various components of RCM while also providing an efficient solution for equipment management; Helps keep costs at a minimum;
- **Key performance indicators (KPIs)** – Allows the operator to produce management reports on equipment failure frequencies, operational availability and maintenance scheduling;
- **Integrity operating windows (IOW)** – Allows for monitoring of specific equipment variables that have a direct impact on equipment performance (e.g., for rotating equipment, if vibration monitoring is tied into the DSC, the IOW can track preset, high vibration alarms).

Conclusion

The evolution of technology delivered by the IIoT has resulted in more options than ever before for the asset management needs of oil, gas and chemical companies. There is no need to continue running RCM and MI as separate programs when both can be supported by one software, delivering tangible time and cost-saving benefits.



Malcolm J. Werner, P.E., CRL, CMRP, MIAM, is a registered professional mechanical engineer at Jacobs. He has more than 50 years' experience with equipment design, operation and maintenance. Most of his career has been in assessing O&M performance and designing and implementing improvement programs. His passion is helping people implement best practices.



Dave Maguire is an asset integrity specialist with Metegrity Inc. He has spent over 10 years implementing the Visions Asset Integrity Management (AIM) software and instructing/supporting clients with AIM and inspection systems. Dave worked with Shell Canada for 30 years in inspection, corrosion, major projects and process operations. www.metegrity.com



Richard Fish is an API consultant with Metegrity Inc., and is a 10-year veteran implementing the Visions AIM software and assisting clients with asset integrity management. Richard's background includes 30 years with Shell Canada in API inspection coordination, maintenance and process operations. www.metegrity.com



Fluid (Oil) Analysis Program Manager

Account: Hydr Molding Equip Name: Hyd 21 Comp Name: Pump Labr Mtr: Application: Industrial Equip Type: Molding Machine Comp Type: Hydraulic Vane Labr Brand: Equip Mtr: Equip Model: Comp Model: Labr Grade: ISO 46 Equip SerNo: 84700 Comp SerNo: 84700-1

MECHANICAL ADVISORIES

- Perform proper DIAGNOSTIC checks.
- Check SEALS for leakage or engagement.

MECHANICAL ADVISORIES

- CONSIDER INSPECTING FOR ABNORMAL WEAR IN THE FOLLOWING AREAS:
 - VANES
 - BEARINGS
 - IM SHING

Observation and Monitoring

- If present wear exceeds trend or ALARMING, suggesting close monitoring, or possibly maintenance action
- Lubricant from Source: Pump Housing, Vanes, Bearings, Rotor, Shaft
- Lubricant Origin: Source, Vanes, Pump Housing or Rotor, Caps on applicable
- Abnormalities are noted at MINOR level
- Particulate Count is MODERATELY HIGH
- Lubricant or Possible Silicon Seal Material

Labr Maintenance

- Change Inbr and Bush system
- Change Filter

Notes

- Performing Analytical Photography on this sample may help clarify the data, and subsequent decision making

	11/11/06	09/04/06	06/22/06	11/11/06	09/04/06	06/22/06	11/11/06	09/04/06	06/22/06
Pc	18	18	12	178.00	171	151.2	88.8	88.8	
CF	1	1	1						
Mt	1	1	0						
AD	2	1	2						
Nt	2	2	2						
Pt	0	0	0						
Ph	2	1	1						
Nt	1	1	0						
IS	20	20	14						
Nt	2	3	4						



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ENERGY INDUSTRY RISK ASSESSMENT

Current Practices and Elements

Gobind Khiani

As the North American oil and gas infrastructure ages, changes made to facilities during their lifetime may not have been transferred to the official recorded drawings of the facilities. Government regulations have also changed during the life of the facilities, rendering some system components non-compliant.

This article explains asset integrity management systems (AIMS) studies as a means of ensuring the integrity of operating assets in oil and gas through the application of a consistent and systematic process of assessment and improvement.

Why Risk Assessments Are Necessary

On May 1, 2016, a wildfire began outside the city of Fort McMurray, Alberta, Canada, and swept through the community, forcing the largest wildfire evacuation in the history of North America. Upward of 88,000 people were forced from their homes. The wildfire destroyed approximately

2,400 homes and buildings. Another 2,000 residents in three communities were displaced after their homes were declared unsafe for reoccupation due to contamination.

The fire continued to spread across northern Alberta into Saskatchewan, consuming forested areas and impacting Athabasca's oil sands operations. With an estimated damage cost of C\$9.9 billion, it was the costliest disaster in Canadian history.

The fire spread across approximately 590,000 hectares (1,500,000 acres) before it was declared under control on July 5, 2016. It continued to smolder until it was fully extinguished on August 2, 2017. It is suspected that the wildfire was caused by humans in a remote area 15 kilometers (9.3 mi) from Fort McMurray, but no official cause has been determined to date.

Since the fire, process hazards associated with operations and facilities in oil and gas are being identified systematically; risks are assessed and managed in accordance with good risk management practices; facilities and operations have been reviewed to ensure compliance with applicable legislation, engineering codes and regulatory requirements; and process

information (e.g., key drawings, data books, process flow diagrams, area classification drawings, calculations, etc.) have been made accurate and up-to-date.

Of particular interest are the older, existing facilities, which have continued to operate over an extended time period. (This article is not intended as a guide for the assessment of new facilities on the planning table.)

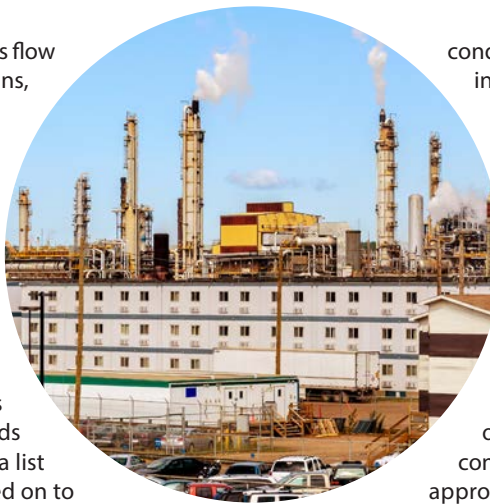
Forward-thinking companies have decided to review facilities, correct any deficiencies and record drawings to ensure these recorded drawings reflect the actual facility. They have also decided to perform a process hazards analysis (PHA) on the facilities to identify potential hazards and/or operability problems. The PHAs produce a list of recommendations that are required to be acted on to resolve the issues.

PHA studies indicate that significant deficiencies exist at older facilities and repairs and/or modifications are required. Significant costs are associated with the drawing updates, PHA processes and resolution of recommendations.

The Purpose of AIMS

Asset integrity management systems (AIMS) studies are being focused on major facilities. Facilities subject to AIMS projects typically include compressor stations, gas plants, batteries and others.

The AIMS studies are directed by the operations engineering group, which provides guidance to facilities and operations personnel as required, obtains the required levels of cost estimation for expenditure authorization, and ensures quality of asset review.



conducted as part of AIMS projects are useful for ensuring compliance.

The execution of AIMS studies should be a corporate responsibility and delegated to the applicable operations group. Associated responsibilities include scheduling and conducting HAZOPs, advising management on risk and tracking the resolution of recommendations.

HAZOPs are conducted by teams of qualified people that collectively possess process knowledge, subject matter expertise and relevant work experience. Membership on a HAZOP team normally includes a facilitator, engineers, operations staff, and engineering, procurement and construction management companies (EPCMs). Where appropriate, training is provided to ensure the competence of individual team members by the AIMS manager.

EPCM firms often support AIMS projects by providing the resources needed to complete specific tasks (e.g., field inspections, updating process and instrumentation diagrams (P&IDs), completing calculations, etc.). The qualifications of these firms and individuals are established to the satisfaction of the operating company when contracts are signed. The operations engineer and the oil and gas AIMS manager supervise the activities of the EPCMs.

The steps involved in implementing the AIMS work process include:

- Identifying facilities to be evaluated under the AIMS work process;
- Establishing an annual schedules for AIMS projects using risk-based criteria to prioritize sites (e.g., based on horsepower, materials handled, type of facility, setting, etc.);
- Obtaining business unit (BU) leadership approval for annual schedules and budgets;
- Individual AIMS projects:
 - Prepare/update as-built drawings for selected sites;
 - Prepare/update P&IDs, site plans and area classification drawings;
 - Verify the sizing of pressure safety valves (PSVs), control valves, vents and drains;
 - Verify material and energy balances;
 - Review shutdown keys;
 - Conduct HAZOPs;
 - Evaluate report findings, review recommendations and categorize them using the operating company risk matrix (i.e., impacts and likelihood);
 - Prepare and distribute HAZOP reports;
 - Discuss deficiency rectification actions required of the operating company and EPCM;
 - Sign off on action items after the operating company's internal review;
 - Prepare rectification drawing package for tender to qualified contractors;
 - Obtain competitive pricing and select contractor to complete HAZOP recommendations;
 - Monitor and report the status of deficiency rectification actions to appropriate asset team leads;
 - Verify that deficiency rectification actions have been completed;
 - Modify drawings and documents as necessary to reflect as-built;
 - Return critical documents and drawings to the company's document system.

“ The execution of AIMS studies should be a corporate responsibility and delegated to the applicable operations group ”

Engineering consultants may be engaged for the purpose of reviewing and developing process documentation (e.g., process flow diagrams, material and energy balances, as-built drawings, piping and instrumentation drawings, site plans, etc.) to ensure alignment with field conditions.

Consultants are typically used to lead and participate in hazard and operability studies (HAZOPs), verify engineering calculations, and control scheduling and execution of required modifications in association with operations personnel.

Lead operators, engineering, construction coordinators and area facilities engineers should participate in HAZOPs, ensuring completion of deficiency rectification actions as assigned and supporting the oil and gas AIMS manager in the purchasing of equipment for the construction management team.

Experimental Procedure Methods

Oil and gas companies should be committed to safeguarding all assets of the organization, maintaining the safety of operations and applying risk management throughout. In Alberta, there are requirements for complying with various engineering codes, occupational health and safety legislation, recommended practices, and standards. Assessments

- Conducting an annual look back to review overall adequacy, suitability and effectiveness of the AIMS program with the oil and gas leadership team;
- Updating AIMS schedules annually, and incorporating appropriate re-validation of location-specific HAZOPs every five to 10 years.

Training

Personnel supervising and conducting AIMS studies and HAZOPs should be competent based on knowledge, education, training and relevant work experience. Where necessary and appropriate, specific training should be provided to ensure the competencies of individual team members.

Qualifications for EPCMs are evaluated for each AIMS project to ensure competence based on knowledge, education, training and relevant work experience. At a minimum, EPCMs should have documented environment, health and safety (EHS) training, general liability insurance, a quality assurance (QA) manual and an agreement with the owner company. The personnel from each EPCM must have adequate professional qualifications so that a meaningful and accountable review can take place. The senior process engineer should be a professional engineer with an appropriate engineering degree and at least 10 years working experience in the process engineering field. Other participants should have technical backgrounds in instrumentation and project management, with significant experience in their discipline.

Project Schedules

Schedules for conducting AIMS studies should be reviewed from a company-wide perspective. They should be prepared annually by the operations group responsible for the AIMS program, in conjunction with the particular area manager. Schedules should be prepared with consideration of several factors, including, but not limited to:

- Risks associated with specific facilities (e.g., oil vs. gas, installed horsepower, setting, size of workforce, type of operations, etc.);
- Length of time since previous assessment (revalidation of HAZOP);
- Operations impact;
- Approved capital maintenance budgets;
- Availability of resources.

Schedules prepared by the AIMS manager are presented to the area leadership team for review and approval at an appropriate time for consideration during preparation of budgets.

Documentation and Record Keeping Requirements

All phases of AIMS projects require adequate documentation. These studies are typically broken down into three phases:

Phase 1 – As-Built Drawings: Documentation of the as-built set of drawings is extremely important as it is the basis for the HAZOP. The as-built set of drawings represents the actual site conditions existing at the time of the HAZOP.

Phase 2 – Process Calculations and HAZOP: The engineering calculations for heat and material balance, control valves, and PSVs are essential in determining the safe operation of the facility. The HAZOP is a structured review of the operability of each major segment or node of the facility in question. All possible failure modes are reviewed and recommendations made for correction of those items that pose a major risk to the facility or safety of the operating staff or public.

Phase 3 – HAZOP Recommendations: Recommendations represent the output from the HAZOP and identify those items that may pose a risk to the operability and safety of the facility in question. They must be documented so that a structured follow-up can be done.

The status of individual deficiency rectification actions versus pre-defined project milestones is tracked on a weekly basis to ensure a timely completion of the rectification process.

Four copies of AIMS-related documents (e.g., HAZOP assessment reports) are required of each EPCM. These documents are distributed to the operations engineer; drawing control; the area facilities engineer; and field operations.

Upon project completion, documents and records related to the project are sent to the field location and uploaded into corporate document control, where they are maintained for the life of the facility. Documents and records are updated when appropriate.

Performance Measurement

The following indicators can be used to monitor the performance of the AIMS process:

- Percent completion of AIMS studies in accordance with established schedules;
- Establishment of rectification plans for extreme/high-risk deficiencies within six months;
- Correction of extreme/high-risk deficiencies within one year;
- Percent completion of deficiency rectification actions according to schedules established in location-specific HAZOPs;
- Costs vs. budget.

Reviews should be conducted by the AIMS manager every five years to verify that the AIMS work process is being carried out as planned and is meeting desired performance objectives. Review reports should be provided to the operations engineering advisory team lead.

Updates on the performance of the AIMS work process and the status of its implementation should be provided annually to the leadership team. The focus of these discussions is to ensure the ongoing suitability, adequacy and effectiveness of the program.

Costs

A recent review of approximately 35 AIMS projects identified 800 items that required immediate attention and a further 800 items that could be handled on an as required basis. This could be considered typical of older facilities and indicates the necessity to review facilities on a regular schedule.

AIMS projects for gas compression sites up to a maximum size of 13,000 horsepower typically require expenditures in the order of several millions dollars over a 12 to 18 month period, from the initiation of the HAZOP through the completion of deficiency rectification. Large oil batteries may cost more. In practice, the resources required to complete each AIMS project varies based on a number of factors, including the size and complexity of the facility or operation, the nature and extent of the deficiencies found, and other factors.



Gobind Khiani, MEng., PEng., is a Consulting Fellow in Piping/Pipelines with O&G, Pipelines and LNG (namely Enbridge Inc.). He has an Honorary Fellowship in the field of Mechanical Engineering and has shared his knowledge by publishing several technical articles. Currently, he is an active member of API, CNS, ASME, ISO and CSA.

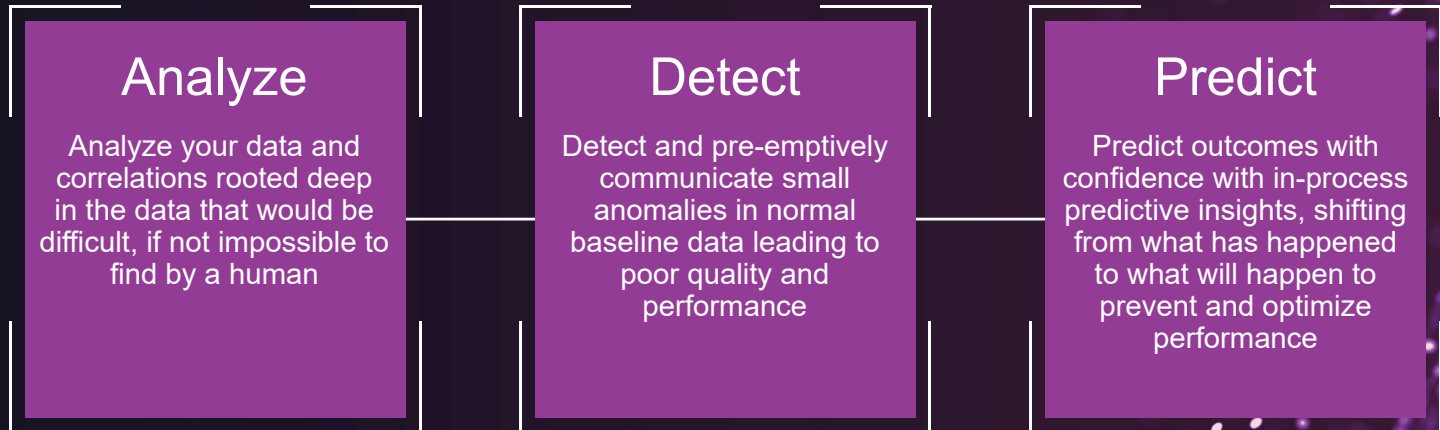
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What You Can Do If Your

RELIABILITY PROGRAM

Isn't Meeting Performance Goals

IT'S A TYPICAL STORY. You implement a computerized maintenance management system (CMMS) or either an enterprise asset management (EAM) or enterprise resource planning (ERP) system with all the bells and whistles, but it doesn't deliver a return on investment (ROI).



The system and associated work execution management (WEM) process was meant to improve the performance of assets, but failures keep occurring at a cost to your business. So, you decide to upgrade the system. It's a significant investment – perhaps you consolidate disparate systems into one single system, or maybe the cost comes with moving to the Cloud. Still, performance doesn't improve.

In all this, one thing is missing. Fundamentally, the performance you get from your assets will depend on how you care for them, given the operating environment they are in.

How you care for assets is dictated by the reliability strategies you have in place – that is, the maintenance plans and related content within the EAM system. It doesn't matter how much you spend on the system; if your master data is lacking, you simply won't get anywhere. In other words, there's no point investing in a Ferrari and expecting performance improvements, but then running it on diesel fuel. The Ferrari just can't do its thing.

Using APM Is a Stepping-Stone, Not a Solution

When organizations find that their investment in WEM and EAM systems don't improve performance, they often turn to the latest technology to help. Enter asset performance management (APM), which monitors asset condition and health in a bid to prevent unplanned, in-service failures by detecting degradation and allowing a planned intervention to occur.

On the surface, APM appears to tick the right boxes. And it does, but only in the sense that it protects you from unplanned, in-service failures. The APM approach takes a backward look at performance and provides some security against catastrophic failure.

While it helps to detect an impending failure by monitoring asset degradation, APM doesn't do anything to address the cause of degradation. It won't help determine how to change the strategy to prevent degradation in the first place or extend the asset life as much as possible.

“How you care for assets is dictated by the reliability strategies you have in place”

Again, a reliability strategy is the forward look – it's designing the appropriate reliability strategy to deliver the performance you require from the assets. And, what's clear, is if you want to get any return from an EAM system or an APM program, it must be combined with an effective reliability strategy. In fact, it all starts with strategy. A reliability strategy develops the content that an EAM system needs to be effective and delivers performance that an APM can then monitor and provide some protection around.

A Single Strategy Session Won't Work

Recognizing the value of strategy, some organizations conduct a formal strategy setting project for some of their assets. While this may be a valuable exercise, generally it is conducted as a finite project with a start and end date. Furthermore, it is typically time-consuming to complete and implement.

Then, once the reliability strategy is implemented, it deteriorates over time. Why? People with good intent, but using no formal review or justification process, change the strategy for the worse. Or, perhaps operating conditions change, yet the strategy is static. Either way, the strategy is no longer aligned to performance goals and you lose control. Failures occur, costs skyrocket and risk increases irrespective of the cloud-based EAM system or APM solution.

The Missing Piece of the Puzzle

What's missing is asset strategy management (ASM). ASM is a key pillar of an asset management system. It sits alongside EAM and APM, supporting them and enabling them to generate the returns they promise.

With ASM, you build, deploy and govern a reliability strategy with a focus on delivering performance goals at minimum cost and acceptable risk. The reliability strategies are deployed using a digitally connected data set to drive rapid, efficient and effective reliability strategy management over time. It ensures that optimal strategies are deployed on all assets, always.

Strategy no longer deteriorates, meaning the EAM system and WEM process are achieving the performance improvements they promised. APM supports risk management by detecting impending failures and also collects data to support further refinement and evolution of the reliability strategies via the ASM process.

In an organization that has implemented ASM, the WEM process has a direct connection to reliability strategy decision-making:

- All like assets are connected and improvements are leveraged across the entire organization;
- All decisions follow the appropriate workflow of review, approval and justification.

ASM provides both a forward-looking performance focus, as well as embedding root cause analysis (RCA) to prevent recurrence should a failure still happen.

Performance starts with strategy. Your reliability strategy is an asset and ASM protects, manages and improves that asset over time.



Jason Apps is the CEO of ARMS Reliability, a leading global provider of asset management solutions to some of the world's largest resource, power and utility companies. Jason has over 20 years of experience in reliability and maintenance engineering. www.armsreliability.com

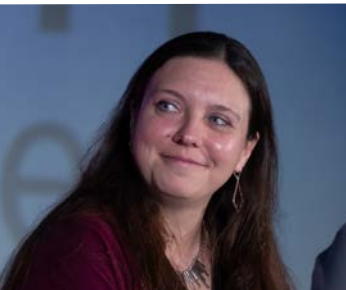
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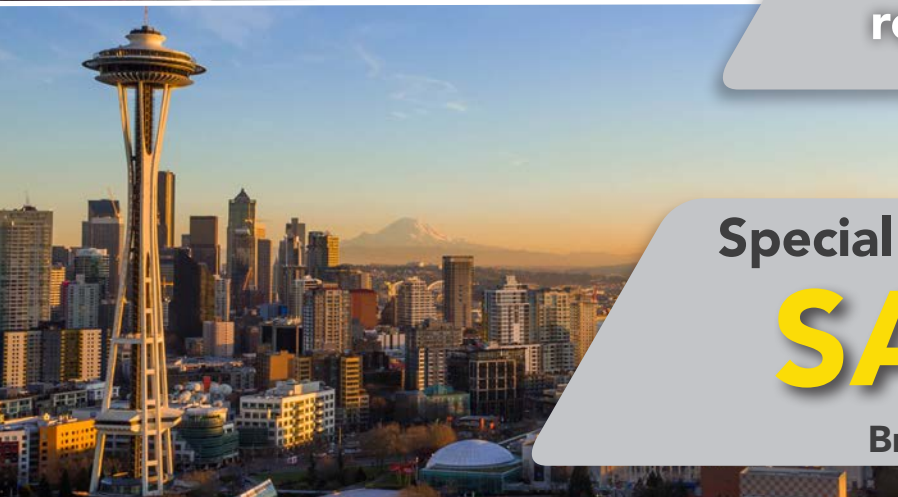
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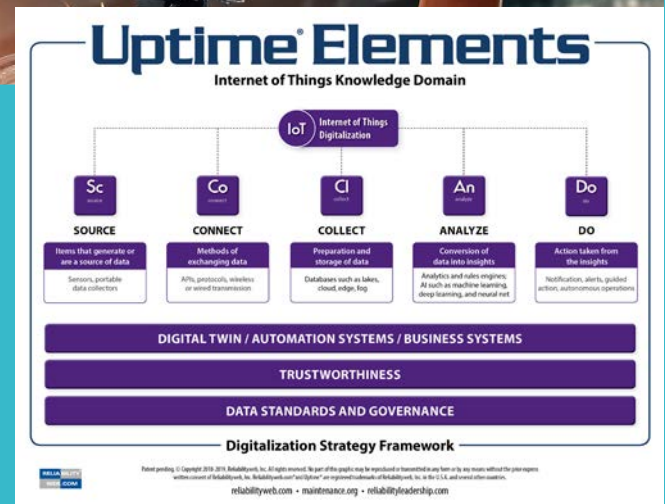
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WHO WILL BENEFIT FROM
MAINTENANCE

4.0

ADOPTION?



Deddy Lavid



Does Merriam-Webster’s definition of revolution as “a sudden, radical, or complete change” apply to Industry 4.0 – the industrial revolution of the 21st century? If so, consider that in every revolution, new elites emerge at the expense of old power centers. The position that the expected long-term benefits of Maintenance 4.0 (e.g., environment, efficiencies, etc.) will outweigh the costs is deceptively simple. This article explores whether the benefits of Maintenance 4.0 will be disproportionately spread and how this will impact the industrial sector.

What Is Maintenance 4.0?

Maintenance 4.0 is a subset of Industry 4.0 that covers maintenance reliability activities. These include preventive and predictive maintenance, machinery repairs and inspections. The default scenario is run to failure, whereby industrial equipment is used until it breaks down. During the period of downtime, repairs are scheduled and tools and parts are ordered. Searching for the root cause while production has unexpectedly halted adds additional pressure to repair crews and increases the likelihood of error or short-term fixes.

If big data is the oil of the Maintenance 4.0 revolution, then machine learning is the accelerant. With Maintenance 4.0, machine learning algorithms are applied to the data that is generated from sensors embedded within industrial plants. These algorithms are trained to detect anomalous patterns and then identify threats of evolving failure. The seismic difference between run to failure and machine learning predictive maintenance is the advanced warnings machine learning provides to repair technicians. Tasks ranging from understanding the problem to finding the best skilled repair crews are executed

before a shutdown occurs. The result? A significant reduction in unscheduled downtime and incremental revenue from increased yield rates.

The Good News: A Rising Tide Lifts All Boats

To some extent, it can be argued that humankind is the beneficiary of Maintenance 4.0. Although this may sound hyperbolic, there is validity to this concept.

According to a 2018 U.S. Congressional Report, U.S. Manufacturing in International Perspective, the top 13 global manufacturers generated \$9.1 trillion in manufacturing value added. Estimating that machine learning can reduce unscheduled downtime by five percent, then improvements in yield rates could add up to \$455 billion a year to these economies.

Although there are no guarantees, there are two trickle-down effects:

- The potential impact on the environment by more efficient use of industrial plants and a reduction in energy consumption and raw material wastage;
- Opportunities to address systemic issues, such as global food waste and hunger. McKinsey & Company views big data and predictive maintenance as catalysts for improving food efficiencies in emerging economies.

Will Robotics and Automation Level the Playing Field?

As background, it is important to start with the role of robotics and automation as driving forces for Industry 4.0 and Maintenance 4.0.

The 2016 United Nations Trade and Development Report states that in 1970, 27 percent of the workforce in developed countries (e.g., the U.S., Europe, Japan) were employed in man-

ufacturing. By 2011, this number had dropped to 13 percent. Conversely, the proportion in East Asia (e.g., China and South Korea) rose from 14 percent to 22 percent during this period. If the impact of automation outweighs the relative advantage of inexpensive labor costs, could manufacturing move closer to the end customer?



If big data is the oil of the Maintenance 4.0 revolution, then machine learning is the accelerant



A partial answer is found in a Deloitte research study on Industry 4.0. Almost half of the representatives from the Swiss manufacturing sector indicated that digital transformation will be able to slow down the trend toward relocating to low wage countries. Only eight percent of survey respondents completely disagreed.

Since the collapse of the Soviet Union, Eastern Europe has become a manufacturing hub for Northern and Western Europe. With sunk infrastructure costs and supportive governmental policies, this is unlikely to change.

However, the outlook for parts of Asia is less predictable. The 2017 United Nations Trade and Development Report ranks South Korea and Japan as the highest in robotics density in

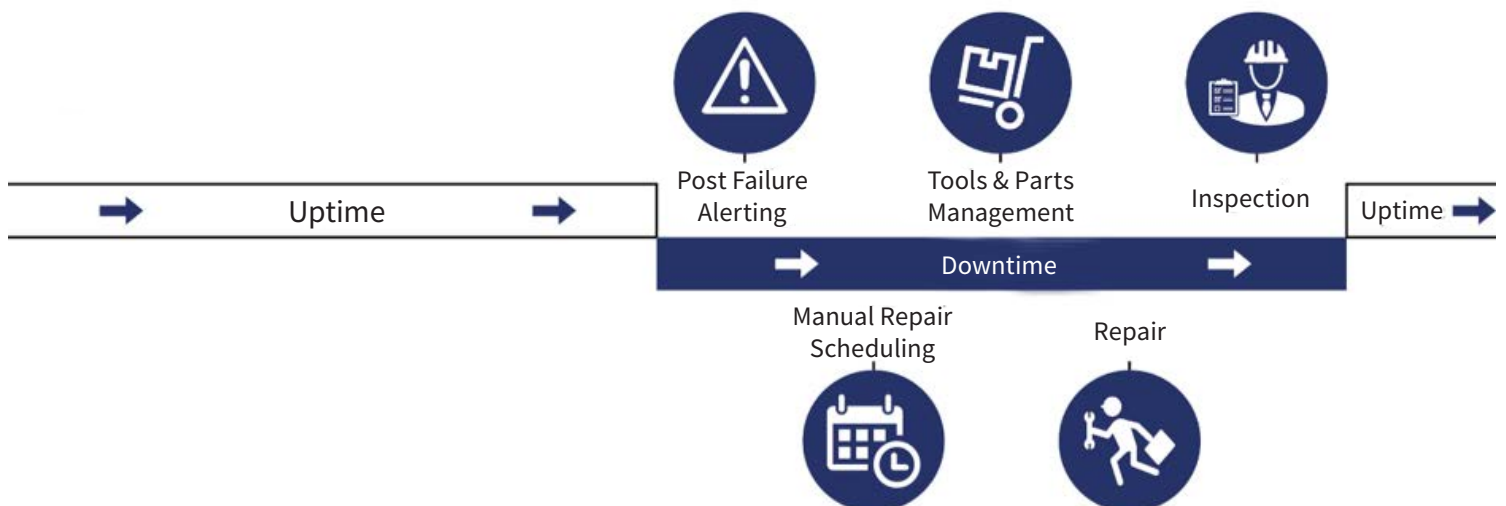


Figure 1: Reactive maintenance (Industry 3.0) Source: Presenso

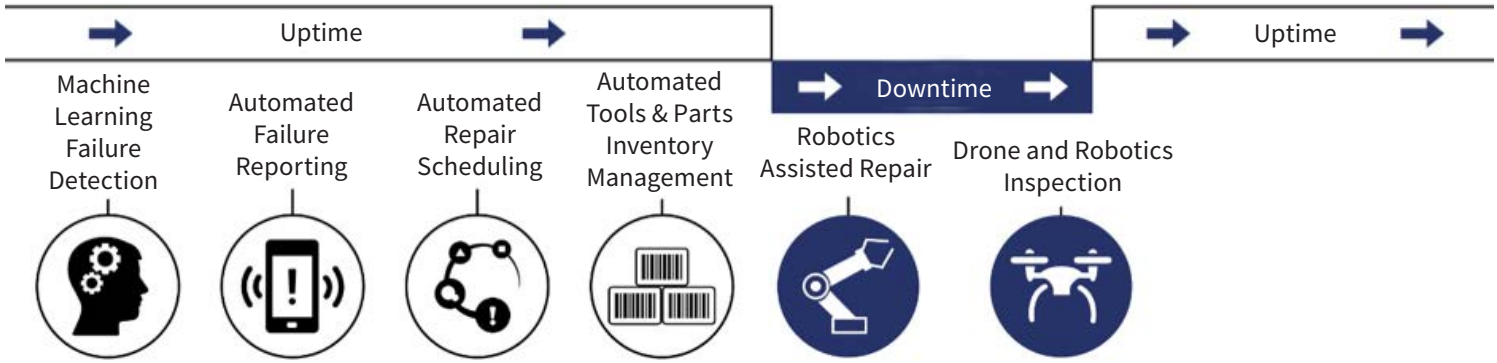


Figure 2: Automated machine learning-based failure prediction (Industry 4.0) Source: Presenso

manufacturing, followed by Sweden, Germany and the United States. China is now in catch-up mode, with only 49 robots per 10,000 humans, compared with a global average of 69.

Even if robotics parity between developing and mature economies is reached, the reality is that wage differentials will become less of consideration. In its Global Manufacturing Scorecard: How the U.S. Compares to 18 Other Nations, the Brookings Institution scores countries by their manufacturing environment based on numerous factors, including tax policies, business policies, infrastructure and innovation.

In the short-term, drastic changes in manufacturing are not expected. However, by adopting a zero-sum game approach, it is likely that automation and robotics remove an important

competitive advantage of low-cost manufacturing centers that are geographically far from the markets they serve.

Machine Learning and Big Data: The Untapped Resource of the Industrial Revolution

Deep within the exabytes of sensor data generated by industrial equipment are micropatterns that can be used to determine when a machine is likely to fail. Although this potential has been recognized by many industry observers, most industrial plants fail to use data effectively.

Why is this the case? First, there are technical barriers to accessing data. The World Economic Forum estimates that 85 percent of potential assets remain unconnected. More importantly, to understand the micropatterns within the big data requires the use of artificial intelligence (AI) and machine learning. Until recently, there were inadequate tools to access and analyze data in real time and provide actionable alerts of evolving failure.

Until recently, the machine learning discipline was primarily confined to academia. Today, the field is rapidly evolving so that vast amounts of data can be analyzed in real time. One significant development relates to the field of automated machine learning, whereby manual data science processes can be performed by self-learning algorithms.

Will advances in machine learning impact all manufacturers equally? Theoretically, the efficacy of a machine learning algorithm is not impacted by international borders and innovation can be shared rapidly. At the same time, insights from machine learning can be used to improve production processes and lower inefficiencies. In practice, the systemic application of machine learning to the manufacturing sector further narrows competitive advantages gained by plants in low labor cost countries.

Application to Operations and Maintenance

The confluence of robotics and machine learning has far-reaching consequences. As industrial nations are plagued by aging populations and skill set shortages, human labor can be replaced with artificial intelligence to detect evolving asset failures, and critical repair functions can be performed with partial or full robotics assistance.

These are not theoretical concepts and there are best practices emerging for multiple operations and maintenance use cases.

What is not yet apparent is the extent to which Maintenance 4.0 will change the manufacturing balance. Change is not expected overnight and there are multiple factors (e.g., Brexit, geopolitical turmoil, etc.) that are beyond the scope of this article. However, this industrial revolution may be consequential in ways that are unexpected for many and unwelcome for some.

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Deddy Lavid (Ben lulu) is a Cofounder of Presenso (acquired by SKF) and its Chief Technology Officer and VP of Data Science. Deddy is considered a leading expert in the application of automated

machine learning to industrial analytics. He has authored 12 machine learning patents and published extensively on big data and academic research topics. www.presenso.com

TABLE 1 – Country Rankings on Manufacturing Environment, 2018

COUNTRY	TOTAL SCORE OUT OF 100 POINTS
United Kingdom	78
Switzerland	78
United States	77
Japan	74
Canada	74
Netherlands	74
South Korea	73
Germany	72
Spain	72
France	70
Poland	69
Italy	62
China	61
Turkey	58
India	57
Russia	56
Mexico	56
Indonesia	53
Brazil	51

Source: Brookings Institution

Felix sure breathes more easily with his head out of the sand.



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INTELLIGENT TRANSFORMER MANAGEMENT



PM OPTIMIZATION:

Challenge and Transform Your PM Strategy

“ Many organizations are blindsided when asset failures occur, along with their unanticipated repair **costs and downtime** ”

Imagine it's that time to proactively schedule your annual physical exam with your doctor. During the appointment, after asking a series of questions about your habits and lifestyle, the doctor conducts the exam and gives you a clean bill of health. A few months later, however, you realize something is not quite right. You contact the doctor's office and make an appointment. After perform-

ing thorough medical tests, the doctor reveals you have a serious, life-threatening, medical condition. Blindsided by this diagnosis, racing thoughts overtake your mind. You start asking yourself, "How could this have happened? Why wasn't this identified during my annual physical? How did the doctor miss this?"

Similarly, many organizations are blindsided when asset failures occur, along with their

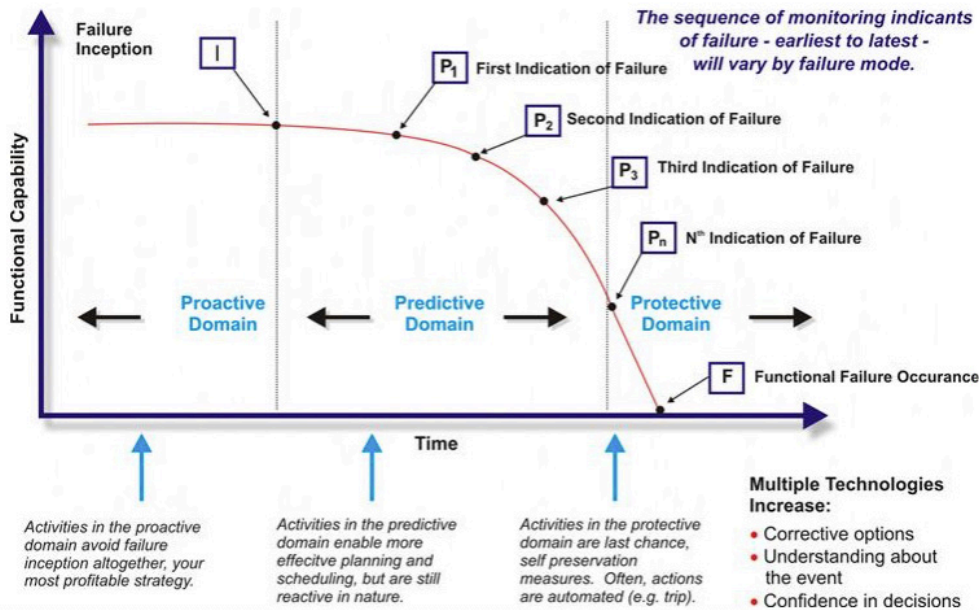


Figure 1: P-F interval approach (Source: Troyer, D. *Plant Reliability in Dollars & Sense Course Book*, page 330. Sigma Reliability Solutions, Tulsa, OK.)

unanticipated repair costs and downtime. These failures not only disrupt efficient and effective operations, but also significantly erode profit margins. The unplanned downtime can turn minutes into hours, hours into days and days into weeks. This results in missed productivity targets and, most importantly, an inability to meet customers' commitments.

Preventive Maintenance

The primary objective of maintenance is to provide the maximum availability and efficiency of company assets throughout their expected lifecycles at the lowest possible cost. Preventive maintenance (PM) is routine maintenance performed at set intervals to minimize the potential of unplanned downtime. This includes general upkeep of equipment through the replenishment of consumables, such as oil and lubrication, or the replacement of components subject to wear and tear.

Many organizations defer to original equipment manufacturer (OEM) recommendations as the basis of their PM strategy. These OEM "suggestions" are usually highly conservative and, in many cases, not based on operational and historical data. They are estimates based on the design and *recommended* operation of that equipment.

This "cut and paste" approach may actually have the opposite effect and may be giving organizations a false sense of security. They may be performing premature maintenance, which results in the commitment of time, money and resources that is truly not needed. They also may be performing intrusive maintenance, which has the potential for imparting maintenance

induced failures or infant mortality. If asset failures are experienced between scheduled maintenance intervals, a strictly time-based strategy may not be the right approach for many assets and certain failure patterns.

Challenge the PM Strategy

Many organizations conduct a daily schedule deviation meeting to verify that the scheduled PMs were performed (a good rule of thumb for PM compliance is +/- 10 percent of the due date) and/or determine why there were deviations to the schedule. Yet, some of these same organizations do not take the time to review and assess the effectiveness of their PMs. These are the organizations that have become complacent and unwilling to objectively poke holes in their strategies and strengthen them.

Organizations should implement formal review processes to periodically analyze and evaluate maintenance programs to ensure these are, in fact, achieving the primary objective of minimizing unanticipated asset failures. PM activities and procedures should be reviewed to ensure they are not only accurate, but also still relevant and scheduled at the proper frequency. This is paramount to ensuring that asset maintenance activities are value-added and cost-effective.

PM Optimization

PM optimization (PMO) is a structured, continuous improvement process with the objective of balancing maintenance costs and the risk of failure. PMO evaluates and refines existing PM activities to verify that they are truly adding value by identifying potential gaps in PM perfor-

mance and frequency. PMs may be eliminated or their set intervals revised to positively influence cost-effectiveness and asset reliability.

PMO is essentially a performance evaluation of PM tasks using historical data to assess whether the tasks eradicate failures as originally intended. The process also addresses whether the failure actually needs to be prevented and if there are better techniques to perform the same tasks now. This comprehensive approach may result in the elimination of redundant tasks, optimization of existing tasks, or the addition of tasks that were lacking from the original set. As a result, there should be no ambiguity in the PM program.

Data-Driven Approach

An effective PMO process demands the evaluation of historical and real-time performance data on assets. Organizations can achieve maximum value with precise and consistent data derived from their computerized maintenance management system (CMMS). Granted, it is critical that organizations employ remediation exercises to ensure the information entered is accurate, consistent and complete. Otherwise, they will not reap the full benefits of the process.

An effective PMO process demands the evaluation of historical and real-time performance data on assets

Analyzing the performance data in context with the PMs currently being performed should be done while knowing the equipment's failure modes. If a PM does not apply to any failure modes, then it can be deemed redundant. Similarly, a task also can be considered redundant if it isn't feasible to perform due to equipment design or other factors. If the failure modes of a system are unknown, then a failure mode and effects analysis (FMEA) should be performed. FMEA is a methodology used to synthesize potential failure modes based on severity, expected frequency and likelihood of detection. This categorizes the different ways in which assets fail, along with their respective impact on the process.

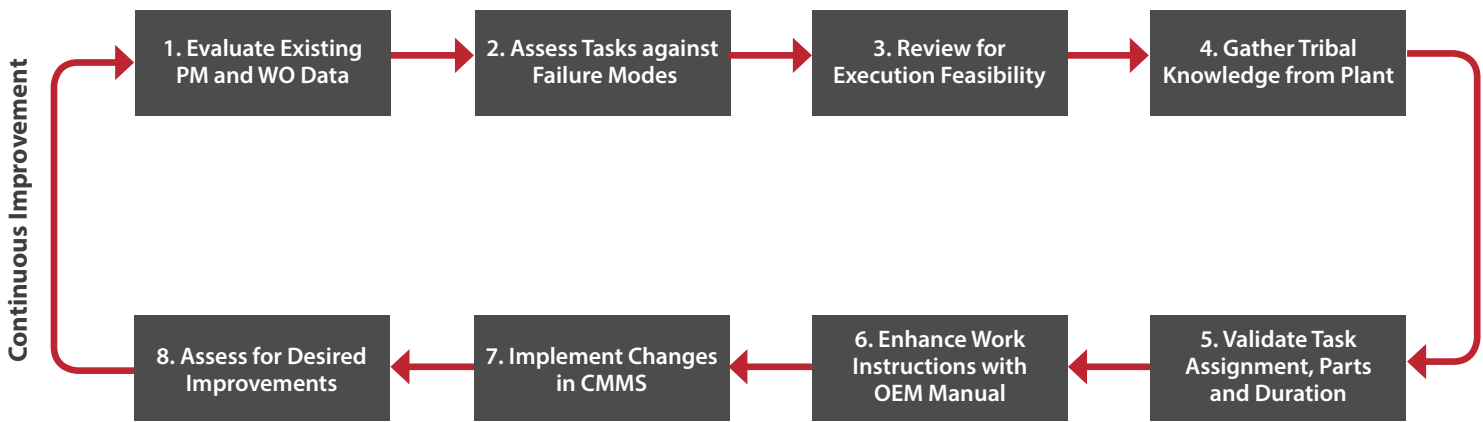


Figure 2: Formal PM tasks review process

There are varying opinions based on experience for optimizing the multitude of preventive and predictive tasks. Greasing, for example, can be condition-based or time-based, with intervals calculated using complex formulas. Cleaning tasks can be revised based on observations from plant personnel. In the absence of good data, a 6:1 ratio can be applied to most inspection tasks. This is sometimes called the golden ratio of maintenance or the John Day ratio. John Day, a manager of engineering and maintenance, proved this ratio at a certified world-class plant. In essence, his experience found that there should be one follow-up task for every seven inspections. Assuming an exponential distribution, this yields approximately 85 percent effectiveness.

Another approach is the P-F interval. Provided the data is available, the P-F interval can be used to challenge and revise PMs by illustrating deterioration over time. In Figure 1, the horizontal axis represents time, while the vertical axis represents condition. As an asset gradually deteriorates, it surpasses several points before total failure. "P" is the point on this curve when it is first possible to detect that a loss of function is imminent. "I" is the point of failure inception. A failure cannot be detected prior to "I," so all maintenance activities prior to this reside in the proactive domain. If a flaw remains undetected and unmitigated through P, the deterioration process accelerates until the asset experiences functional failure (F). The time range between P and F is referred to as the P-F interval.

The general rule of thumb is to inspect at 1/5 the P-F interval for critical equipment and 1/3 the interval for the balance of the plant. Again, assuming exponential distribution and, for example, a three month P-F interval, the effectiveness is:

- a. Yearly inspection < 1%;
- b. Six monthly = 13.5%;
- c. Quarterly = 36.8%;
- d. Monthly = 71.6%;
- e. Twice Monthly = 85% (correct for critical equipment – may warrant online monitoring if a sensor is available).

Mean time between failures (MTBF) and mean time to repair (MTTR) are other useful metrics to help establish PM frequencies. MTBF defines the average time an asset is operating between breakdowns or stoppages. The equation is:

$$MTBF = \frac{\Sigma(\text{Start of Downtime} - \text{Start of Uptime})}{\text{Number of Failures}}$$

This duration only includes operational time between failures and does not include repair time. MTTR is the average time it takes to troubleshoot and repair a failed component or asset and return it to operational condition. The equation is:

$$MTTR = \frac{\text{Total Downtime}}{\text{Number of Failures}}$$

It's also critical for organizations to supplement this data with the legacy knowledge of the operators and maintenance technicians. By engaging the individuals that operate and maintain the assets, they can validate the data, identify improvement opportunities, and provide a complete and accurate picture of what asset failures are occurring.

With this historical performance data, a formal PM tasks review process can be implemented, as shown in Figure 2. Starting with all

existing PMs, each PM should be screened to eliminate redundant tasks. Each PM should be reviewed to ensure that the executing work centers are accurate. With a final verification of work instructions against the OEM's procedure, the work orders should be enhanced to remove ambiguity. The finalized revisions, once implemented, should be routinely assessed to ensure the anticipated improvements are achieved.

Conclusion

The majority of organizations have recognized the need for a proactive PM strategy to increase the overall performance of their plants. However, once implemented, organizations must review, reassess and validate that the PMs are adding value and truly preventing unanticipated failures. Demanding continuous refinement, PMO ensures the right work is performed at the right frequency in the most cost-effective manner.

Mark Munion, CMRP, is a senior consultant at T.A. Cook, Inc. He is a Prosci® certified Change Management Practitioner with over 20 years of leadership and consulting experience across a diverse range of industries. Mark is dedicated to asset-intensive businesses in the refining and petrochemical industries, supporting clients with change management, maintenance optimization, STO optimization and OEE improvement. www.tacook.com

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Why Closed Oil Mist Lubrication Systems Are Worth Considering

Heinz Bloch

It is not uncommon to receive queries about “closed” plant-wide oil mist lubrication. Years ago, the writer of a question began his e-mail with a commendable statement that summarized what oil mist does: “Oil mist lubricates operating equipment, protects and preserves standby equipment, and provides superior lubrication to electric motors at little incremental cost.” But next, he inadvertently divulged an interesting confluence of partial recollections and misremembered anecdotes as he questioned: “Wouldn’t collecting the oil after it had made its once-through travel through a bearing (a) possibly require oil sampling and oil changes at times; (b) not protect/preserve standby equipment; and (c) require motors to continue to need inferior grease lubrication?”

Before answering this question, it should be pointed out that closed oil mist systems have been in successful use since the early 1980s. In any typical oil mist system—closed or open—a small volume of oil mist passes through the bearing. In a closed system and after the volume of oil has done its work, it is converted (actually, coalesced), collected, and manually pumped back into the oil supply header. Because this header has a slightly negative return slope, gravity assists as the oil flows through a fine filter. From the filter, it simply trickles back into its original supply tank or some other reservoir.

Figure 1 depicts a closed oil mist system with separate supply and oil mist return headers. This article, though, illustrates a slightly different system, namely one where the supply header doubles as an oil return header. However, in either system, a small (painted blue in figure) oil collecting tank is located near the outboard end of each drive motor, as shown in Figure 1. After wetting out and thus lightly coating or lubricating the var-

ious motor and pump bearings, the spent oil is carried off in its instrument-quality “carrier air” in the form of small atomized oil globules. These atomized oil globules and much larger drops of coalesced liquid oil are piped into the nearest small blue tank. Whenever a quart or liter of oil has accumulated, a plant operator strokes the small, built-in piston pump (visualize a bicycle tire pump). In single header systems, the oil is

pushed upward in a vertical pipe and into the slightly sloped supply header. After slowly flowing back and then leaving this sloped header, the oil reenters a vertical pipe and is led to a small oil reservoir inside an oil mist cabinet of the type and configuration shown in either Figure 1 or the midsize oil mist cabinet shown in Figure 2.

With regard to the positive displacement pumps built inside small, blue, collecting tanks, they may have to be stroked every three weeks. Depending on the number, style and size of the bearings in a specific pump set, it may take three to six weeks before a quart of oil is collected in one of the blue tanks.

When tracing the pipes in Figure 1, note that this version of a widely used closed oil mist system has an oil return header separate from the oil supply header. Oil and oil mist from the blue box are fed into one of two sloped headers. This would be the return header, with a pressure near or slightly below atmospheric. The header pressure, either slightly positive or negative, is produced by the small blower located at the top of the freestanding, stainless steel tank at the extreme left of Figure 1.

However, this blower, which is also shown on top of a similar stainless steel tank in Figure 2, serves two important purposes: (a) It develops a suction pressure below that in the oil mist supply header and, (b) Crinkled wire mesh, securely fastened near the periphery of the impeller discharge

“...It should be pointed out that closed oil mist systems have been in successful use since the early 1980s.”

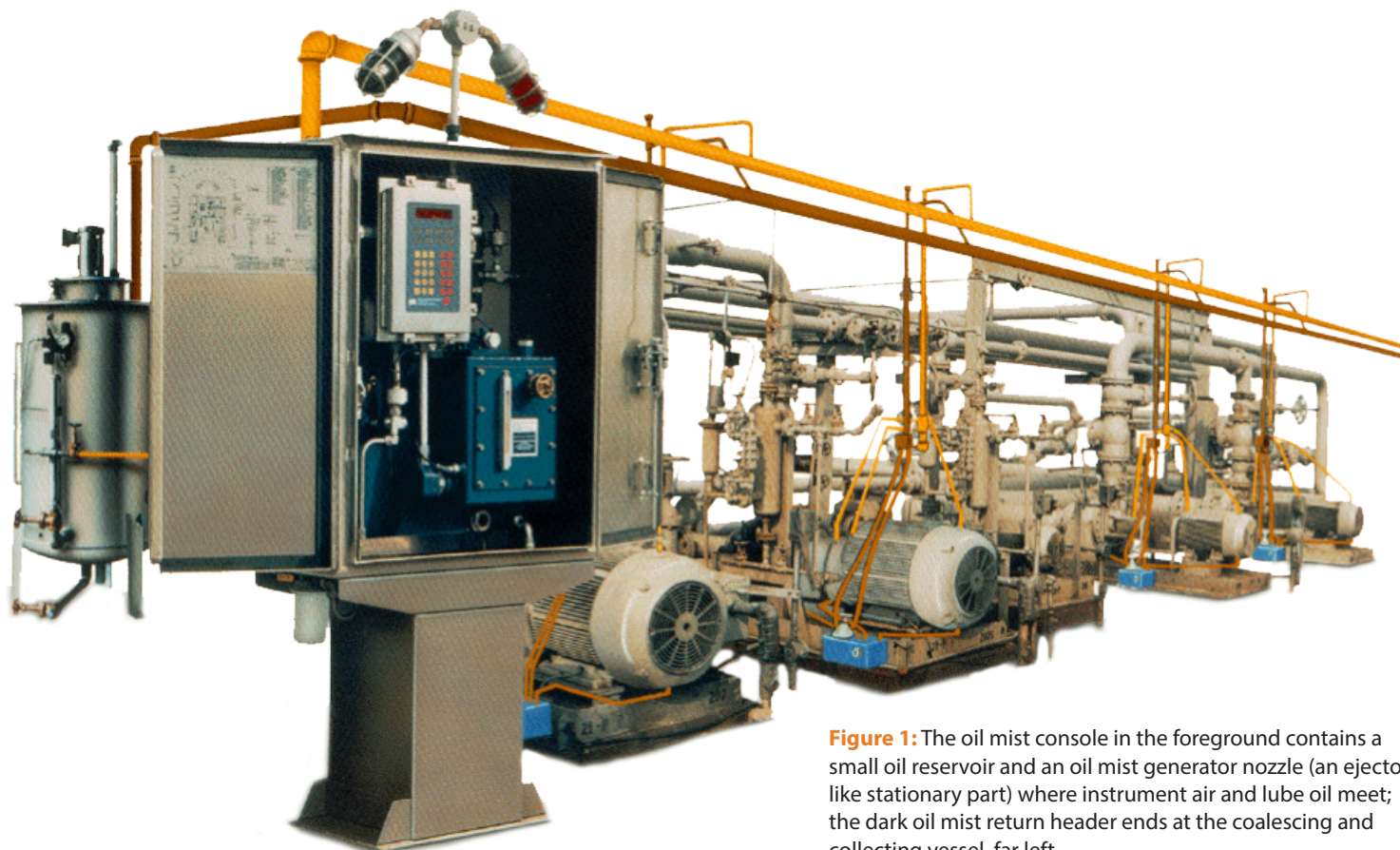


Figure 1: The oil mist console in the foreground contains a small oil reservoir and an oil mist generator nozzle (an ejector-like stationary part) where instrument air and lube oil meet; the dark oil mist return header ends at the coalescing and collecting vessel, far left

vaner, causes any remaining atomized oil droplets to coalesce. It then travels through a filter into the collecting tank and, from there, a fractional horsepower electric pump sends the clean oil into the oil mist cabinet's small reservoir for reuse.

Are Frequent Oil Sampling and Oil Changes Needed?

Returning back to the inquiry, the first part indicates uncertainty regarding the need to periodically change the oil and sampling of the oil. Oil changes are not necessary because the **oil is ultraclean**. The oil in the bearing housing sumps of conventionally lubricated process pumps is re-introduced to the bearings hundreds of times per hour without first being filtered. Quite obviously, reusing filtered oil from a collecting tank is much more desirable than reusing unfiltered oil from a small, possibly dust and water contaminated, traditionally lubricated bearing housing or oil sump.

The use of premium synthetic oils expands upon the answer. As previously noted, Figure 1 simulates an entire closed oil mist system with associated piping. Chances are that a reliability-focused fluid machinery owner would use a superior synthetic oil and, for peace of mind, would probably do so in closed loop oil mist systems as well. Analyzing a small oil sample once per year, these owner-users would likely find the oil well within the range of its original specification. It would then be pumped through a filter from the collecting vessel (far left in Figure 1 and to the right of Figure 2) into a small oil reservoir located inside the oil mist console depicted in the foreground of Figure 1. Premium synthetic oils in closed oil mist systems would probably be replaced after 10 years of circulation.

In contrast, more frequent oil replacement and recycling would be considered for certain, much less expensive, mineral oil formulations. Mineral oils tend to oxidize more readily when encountering an occasional hot bearing. Accordingly, these oils should be analyzed and recycled more frequently. The spent oil is sent to a waste oil recycling facility or mixed with the fuel used in boilers and furnaces. In neither case would the lube oil go to a landfill.

Is Standby Equipment Protected/Preserved?

In response to the second part of the question, the answer is based on six decades of well-established experience. Plant-wide oil mist supplies **are never turned off**. Thus, come rain or shine, an oil mist system serves to protect the nonrunning (i.e., standby) equipment as oil mist travels through the bearings and toward the bearing housing drain port. Without this preservation method, standby equipment will be exposed to an elevated risk of oil being wiped off due to vibration transmitted from the adjacent running equipment. Moreover, without this preservation method, the corrosion risks of bearings in nonrunning equipment are far greater. The rate of corrosion is a function of ingress and egress of air (i.e., the "breathing" action) of the affected bearing housings. This ingress-egress



Figure 2: A medium-sized oil mist console is shown on the left; an oil return tank with its associated blower is positioned on the right

Oil changes are not necessary because the oil is ultraclean

volume of ambient air is orders of magnitude greater with unprotected bearing housings, yet it cannot possibly occur in bearing housings filled with oil mist at about 0.1 to 0.25 psi over atmospheric pressure. Best in class companies can point to well over 40 years of success and experience with oil mist protection on many thousands of pumps and motors.

Do Motors Still Require Inferior Grease Lubrication?

With regard to the last part of the question, all motors with rolling element bearings will benefit from the application of pure oil mist. Close to 50,000 electric motors have been so lubricated over the past 40 years. Chapters in 10 or more books and dozens of papers have been written on the subject. The claim that motors would require inferior grease lubrication is factually incorrect. All motors with epoxy insulation and irradiation cross-linked polymeric cable terminations can be safely lubricated with oil mist. For owner-operators with plant-wide oil mist systems, **maintenance-intensive grease lubrication is truly a thing of the past.** And whenever electric motor lubrication by oil mist is included in cost justification calculations, payback will be considerably shorter than with grease lubrication.

Conclusion

If the three questions were indeed asked by an oil mist user, one would be inclined to assume that entrenched traditions are at work. Perhaps an uninformed staffer chose not to become familiarized with the very simple underlying scientific principles governing oil mist or words got mangled in translation.

Whatever the case may be, **trustworthy answers are available.** Seek out oil mist experts, read oil mist papers written by experts in oil mist technology, or attend conferences, seminars, or lectures that address oil mist lubrication.

Sadly, one such oil mist lubrication expert, Don Ehlert, succumbed to cancer in October 2019. He had ably assisted in compiling material for a book on optimized equipment lubrication, oil mist technology and storage preservation. Scheduled for release in late 2019, *Optimized Equipment Lubrication, Oil Mist Technology, and Storage Preservation Best Practices* (Reliabilityweb.com) will include highlights of his many decades of practical expertise with plant-wide oil mist systems. His knowledge of the subject was unmatched, and he will be missed by many, both in the U.S. and in countries around the world. The book will be dedicated to his memory.



Heinz Bloch began his professional career in 1962, which included long-term assignments as Exxon Chemical's Regional Machinery Specialist for the U.S. He has authored or cowritten over 750 publications, among them 21 comprehensive books on practical machinery management, failure analysis, failure avoidance, compressors, steam turbines, pumps, oil mist lubrication and optimized lubrication for industry. Mr. Bloch holds B.S. and M.S. degrees (cum laude) in Mechanical Engineering from the Newark College of Engineering. He is an ASME Life Fellow and was awarded lifetime registration as a Professional Engineer in New Jersey.



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ANOTHER

NOTRE DAME INCIDENT?

Exploring awareness as a safety
behavior to increase productivity



Juan Garcia

On April 15, 2019, the world watched as the Notre Dame Cathedral in Paris, France, burned. Immediately, the news media broadcasted everywhere, and after hours and days of continuous investigations, it was learned that some of the possible causes of the fire were ashes or sparks from people smoking and/or hot work being performing by one of the renovation companies working on the roof of the cathedral. The fire consumed the 13th century masterpiece's oak roof in a matter of minutes.

It is evident that a lack of safety was at the heart of the suspected causes. For many years, safety has been the love-hate element in the work execution field for both work crews and management. While management openly expresses during meetings and report outs to have safety as the first thing in their daily operations, they resent acknowledging conflicts in implementing an effective safety culture in their daily operations. Often, they justify conflicts in their operations organization with reasons like, employees have busy work schedules, there's not enough bandwidth, or there's a lack of resources to delegate a few minutes or hours to do more on improving daily work controls.

As with the Notre Dame Cathedral, some of the engineering applications to restore the standard operating condition of an asset could easily date back to past centuries. For example, a cable splicer performs the same operation that has been invariably repeated since it was created in the late 1800s. The engineer warms up the dielectric oil and melts the lead, passing the melting pot up and down the ladders. Hot metal pours down on the cable splicer chamber a few inches away from the cable slicer's body. The cable slicer handles the still hot malleable lead with a piece of natural fiber rag covering his hands to isolate a 480V secondary cable from the energized grid. Working while surrounded by countless hazards is perhaps one of the riskiest professions, but also requires immense skill and safety measures.

A walk-around the operations of just about any facility almost always reveals a propagation of unsafe conditions, as well as unsafe acts performed by some of the crew members. The working areas are crowded, creating a high potential for serious injuries and near misses. A good number of unsafe conditions exist from past jobs performed in an area or objects of all natures are left behind. Other unsafe conditions and acts are



Figure 1: 480V secondary cables and transformer (Courtesy of www.impactaconsulting.com)



Figure 2: Journeyman replacing 480V secondary cables (Courtesy of www.impactaconsulting.com)

the result of a lack of knowledge among the crews in implementing safety control measures.

Incorrectly implemented or a complete lack of safety measures is an accident waiting to happen. The low complexity of the job or just plain luck is most likely why more injuries do not happen daily.

Not long ago, a contractor crew member got electrocuted inside a vault on a primary and secondary cable cutting operation to replace an end-of-life transformer. Following the incident, corporate requested to have active supervision from both ends of the de-energizing operation, one at the cutting switch and one at the vault, communicating via cell phones when the power was shut down and went back up.

When questioned, most crew members are aware of existing safety threats. They either are not aware of them or do not care too much about them. Transformers not properly locked out or tagged out are a typical example. When the crew lead was asked what was inside the transformer, a straight answer was not forthcoming. It appeared this crew was more inclined to do mechanical repairs than electrical repairs on high voltage equipment. The lack of knowledge of the surrounding conditions in the presence of existing, unidentified hazards was the perfect recipe for another Notre Dame incident.

“For many years, safety has been the love-hate element in the work execution field for both work crews and management”

Fixed mind-sets contribute unfavorably toward the safety of labor and the preservation of the asset. A common attitude is: “We have been doing this operation this way for more than a century now. If some engineer comes and tells us how to do it differently, we would listen. But, for the most part, this job has not changed since the old days.” How does one argue with such a fixed mind-set? The standard operating procedure (SOP) to replace the piece of equipment may not have changed much since the late 1800s, but, and this is a very strong but, the surrounding conditions and the people performing the jobs have invariably changed.

Without a doubt, a complacent state of mind is part of the problem when disconnecting safety as a separate animal from the core steps of the

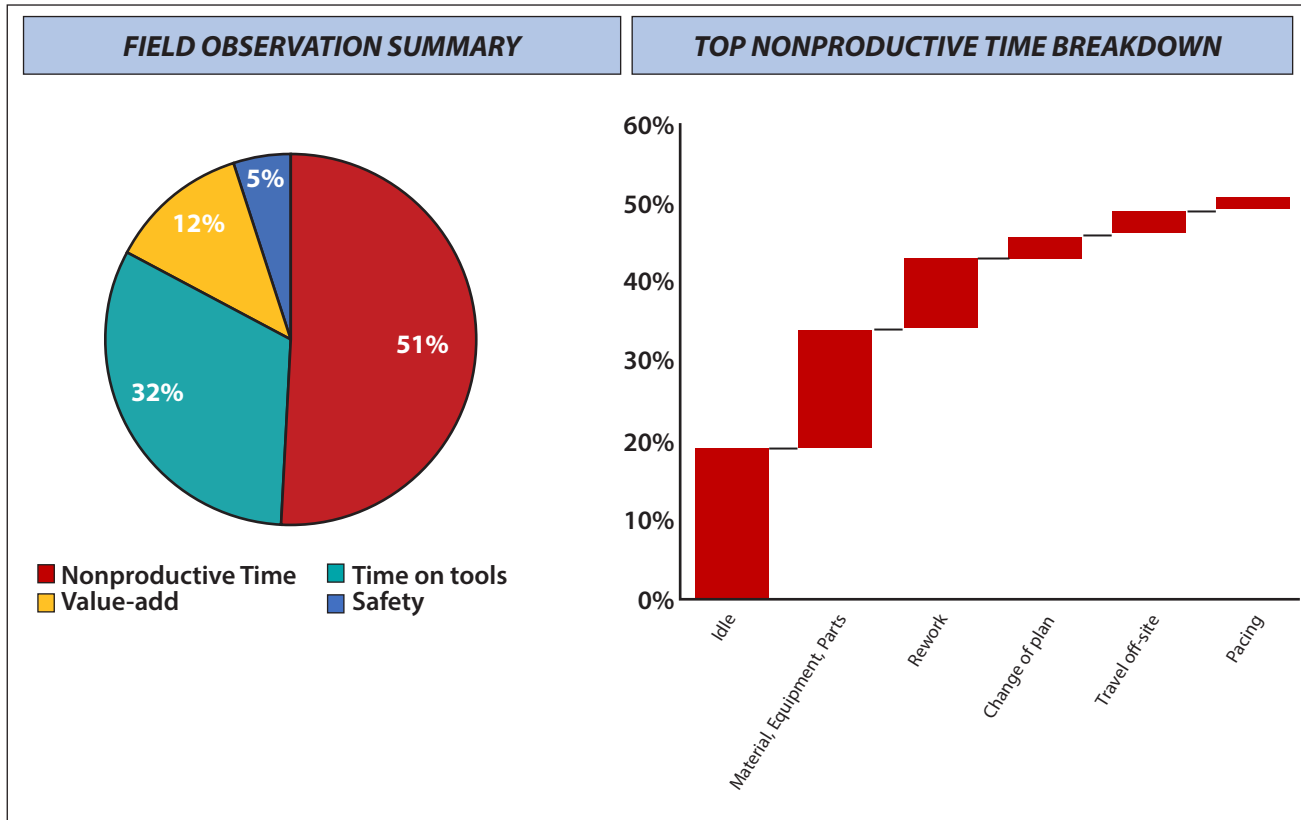


Figure 3: Productivity analysis sample (Courtesy of www.impactaconsulting.com)

operation. For example, fulfilling a mandatory OSHA requirement, such as the job hazard analysis, and later throwing the form inside a truck, not consciously thinking about the always changing hazardous working conditions. Like in the Notre Dame Cathedral incident, each repair operation was, in isolation, a low complexity and highly repetitive exercise. Erecting scaffolds have been done a million times by skillful crews. Some contractor companies even specialize in erecting scaffolds only for historical buildings. Yet, the fixed mentality that tells the brain that things are the same way now as they were before blocks the awareness required from an individual in identifying and assessing changes inside and outside their areas of control.

“Incorrectly implemented or a complete lack of safety measures is an accident waiting to happen”

What makes it worse is the ripple effect of the teachings from more experienced technicians that filter down to journeymen and apprentices. The new hazards – for instance smoking while fixing a roof or leaving objects behind between maintenance jobs – become part of the “new normal” day. This new generation of professionals are learning every day from the new normal daily practices.

In one analysis, in almost every operation, crews struggled to get the job done as it was originally planned. Fifty-one percent of the time, crews spent performing their low complexity, highly repetitive jobs were on non-

productive time (NPT) steps. Nine percent of the NPT observed during this analysis responded to rework. Rework refers to errors and omissions done by the crew while performing a job, forcing to repeat SOP tasks more than once. Frequently observed common reasons for rework is systemic and behavioral problems, such as poor planning and complacency. Traveling back and forth moving and chasing materials, tools and support equipment more than reasonably expected added 15 percent of their wasted time. Since the only time supervisors were present was when the power had to be shut off and brought back on, the junior crew members were either idle or simply waiting for new directions, which added 27 percent to delays in a normal day.

In summary, another Notre Dame Cathedral incident is possible. In fact, it has been in almost every company’s field level operation, away from the eyes of active supervision and leadership. Such incidents are closer to the fixed mentality of the many crew leads and frontline influencers when they say, “This is the way it has always been,” and closer still to one’s human nature that becomes complacent with the ever-changing work conditions and completely tolerable of the “new normal” day.



Juan Garcia is a well-versed professional with post graduate education in engineering and business management. Juan has worked in the Americas for Fortune 500 corporations as an external advisor in organizational change management and program and project management for more than 17 years.
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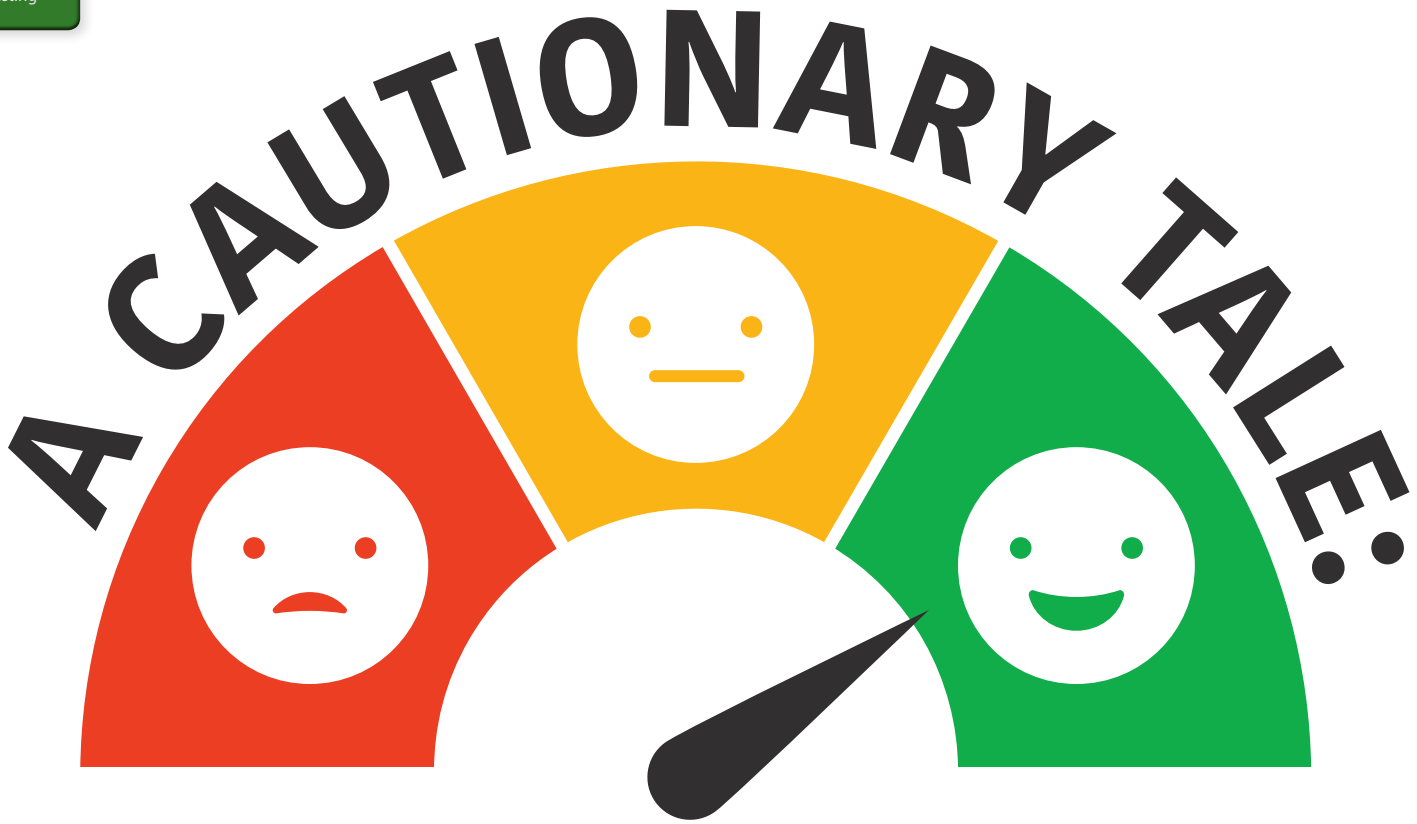
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The Story of One Family-Owned Company Putting the **CUSTOMER AHEAD OF REVENUE**

Mike Boyer

A family-owned motor repair business in Pennsylvania has been selling industrial motors, controls, gearboxes and all related services since 1981. Its vision has always been to grow beyond a geographic service area, but it was not willing to compromise on its commitment to quality.

When it comes to new technology, the company and its maintenance managers don't have the strongest reputation as early adopters, especially when it forces them to change tried-and-true practices connected to critical process equipment.

So, when the industry started throwing out terms like the Industrial Internet of Things and Industry 4.0, the company was skeptical.

Its on-site vibration analysis and repair group has consistently been the company's most profitable division. These are the people who get the call at 2 a.m. on a Sunday morning and don't stop until the process has been restored.

If the family business was going to jump into wireless monitoring, it had to offer advantages for its customers and its bottom line. With seven maintenance technicians driving to customer sites, demonstrating cost savings on manual data collection would be simple, but the company was looking for more than that.

As wireless technology matured, the basic questions of signal reliability, battery life and the high price point were addressed.

“ If it was going to **grow the business**, it needed to start looking at itself as early adopters ”

Indeed, the cost of sending technicians to physically take handheld measurements was becoming harder for the company to justify. In addition, the job of uploading sensor data from the field to a central database for analysis was slowing workers down.

So, the company started doing some research.

Finding the Best Tools

The wireless monitoring system that would work for the company would need to have:

- Wireless operation for signal transfer and power;
- Transmission range beyond the line of sight indoors;
- Support for a range of inputs;
- Minimal impact on existing plant infrastructure;

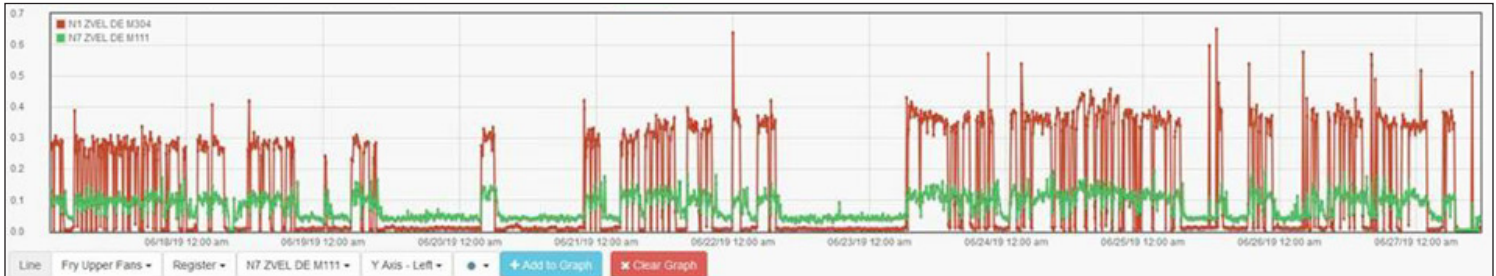


Figure 1: Connected data software dashboard shows the vibration level between the problem fan and another that is operating within normal conditions

- Scalability to meet customers’ needs today and in the future;
- Cloud-connected data management tools to send alarms to the company’s technicians and/or plant personnel for immediate intervention.

The company’s service team tested several industrial wireless systems advertised for predictive maintenance and condition monitoring. Some of these products used Bluetooth® or Wi-Fi™ to send data, including temperature, vibration and current, back to a gateway controller.

Bluetooth worked well to collect data, but required signal enhancers to reach all areas the company needed to monitor. It also meant a company technician had to be on-site, regardless of the actual process conditions.

Although Wi-Fi had a greater transmission range, it was more sensitive to interference and often required the support of a corporate IT department.

After many hours of discussions and all the hardware demos the company’s team could endure, it chose a global industrial automation firm.

Working with them, the family business defined wireless condition monitoring test kits at a list price under \$5,000 to collect vibration and temperature from four remote assets.

The setup could be deployed in a couple of hours, convincing the motor repair company to invest in six kits that included:

- A gateway or wireless controller;
- 4 nodes or field devices;
- 4 vibration sensors;
- Access to a tool for storage, visualization and definition of condition-based alerts.

Utilizing Its Wireless Monitoring Services

The first customer where the family business put its new wireless monitoring services to the test was a commercial printer. The motor repair company received an e-mail notification of a high vibration level on a critical fan. It informed the printer’s on-site personnel and continued to monitor the situation remotely. The printer’s personnel made plans to follow the shutdown procedure at the next shift change.

Vibration levels continued to increase as input was gathered from the crew on location. Before the system was restarted, a maintenance technician manually inspected the bearing, but found nothing wrong.

Even though it was unsure a real issue existed, the motor repair company asked its customer to perform a complete physical inspection. Only then did they find serious damage.

With the system installed and the 24-7 remote monitoring services, the commercial printer saved \$70,000 in repair and downtime costs in this one event.

This is a great example of wireless technology empowering the company’s motor repair team to add value to customers without making the trip to their site.

The family company had the experience needed to interpret the real-time information coming in and recommend the best way to intervene.

However, it was critical that this action plan was routed to the right people.

The motor repair firm could have taken care of the printer’s maintenance work under a regular, time-based contract, but the technicians on the ground were in the best position to act. Stepping into this “first responder” role ensured that the family business was recognized as the expert that could be trusted. However, this role did not result in the same revenue.

It was becoming clear that the company’s motor repair experience was an asset the family business was not set up to charge for. If it was going to grow the business, it needed to start looking at itself as early adopters. Not as early adopters of wireless data collection, but by turning remote service into a revenue stream.



Figure 2: Damaged fan

Risks and Rewards

The family-owned company was willing to take some risks with the repair and replace revenue because it believed that any demonstrated operational improvements would solidify a successful business relationship.

It went from getting emergency calls from technicians in panic mode to being asked to participate in operational efficiency planning meetings with senior leaders. This happened with customers the family business had been selling motors to for years.

For one customer, the motor repair company’s predictive monitoring and proactive maintenance resulted in no critical failures in over two years. Previously, the family business could count on at least \$200K for that customer’s annual service contract. But now, the company puts customers over revenue. Certainly, the family business still makes money, but not if it waits for customers to call them the next time they need a new motor.

Where Is the Family Business Now?

Today, the family-owned motor repair company has come to understand that remote asset monitoring technology is both the best and worst thing to happen. Every system it installs makes it harder to put the genie back in the bottle. The company now has over 20 customer locations where it monitors the condition of assets remotely. This is in place of its manual inspection process with handheld data collection performed on a scheduled basis.

In cases where the company remotely monitors assets, it has consistently reduced the average customer spend on repairs by tens of thousands of dollars. On one hand, it is great that the family business gets to be the problem solvers that find ways to save its customers money. On the other hand, the more success the company has preventing unplanned shutdowns, the smaller its repair invoices get.

You've probably heard the cautionary tale of how a major camera film company didn't want to commercialize the digital camera technology it invented because it represented too much of a threat to its profitable film sales and processing. Other companies that weren't even recognized as competitors at the time saw this opportunity to give consumers what they really wanted at a lower cost and they prevailed. The major film company ended up filing for bankruptcy protection. Even though it had the technology that would meet the needs of consumers right in its hands, the company didn't adapt its business model.

Revenue Model to be Determined

As history has proven over and over, market share will go to the forward-thinkers that make the hard choices now while they are still on top.

For service companies looking at the future of their business, the need for change is a certainty. The business model, however, is far less defined.

For the family-owned motor repair company, establishing business relationships has been a positive next move.

What Is Known to Be True

Service companies must keep up and define a new way to replace lost revenue generated in a run to failure world or risk being left behind. Those that accept this reality and begin experimenting with new ways to monetize their services rooted in remote monitoring and predictive maintenance technology will be ready to grow with their customers instead of being mired in the business logistics to keep up.



Mike Boyer is Vice President of Sales of Motor Technology and has more than 24 years of experience in predictive and preventive maintenance. Mike has achieved great success as a Certified Level II Vibration Specialist by identifying early defects in his customers' rotating equipment, thus preventing unplanned downtime.
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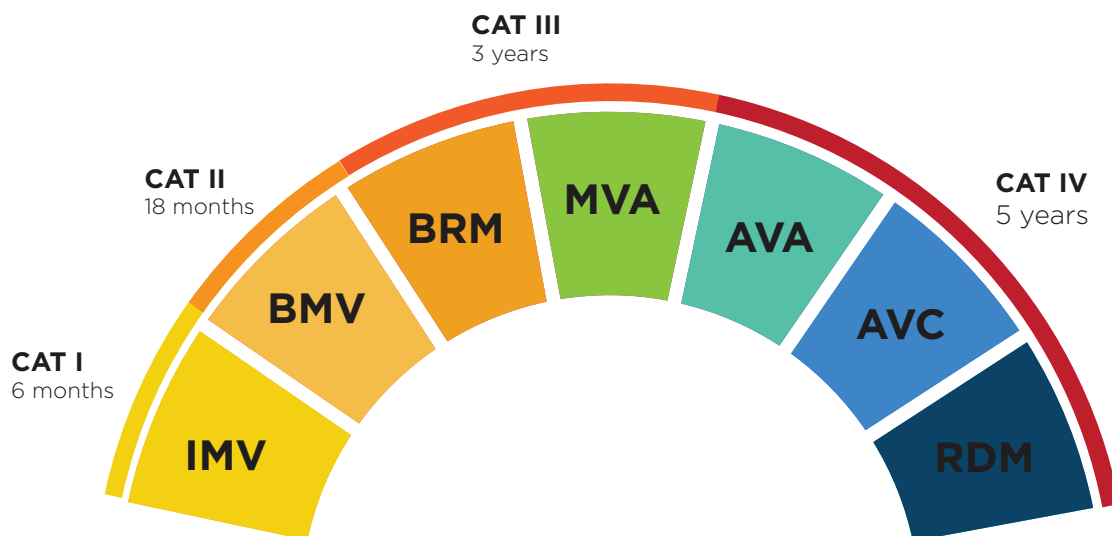
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Women in Reliability and Asset Management

(WIRAM) offers women working in the reliability and asset management fields a professional peer group while providing the opportunity to expand their network and enhance their leadership skills in a local group setting. WIRAM members can also take advantage of face-to-face roundtable meetings at industry events, access thought leaders and experts, and provide mentorship to STEM students.

WIRAM Advocates are a group of corporate members who are committed to the aim of engaging and empowering women as leaders who advance reliability and asset management in their organizations and the world. These include executive sponsors, asset managers and reliability leaders.



Aqitas Solutions is a leading provider of enterprise asset management (EAM) and Internet of Things (IoT) solutions that optimize asset intensive industries. The company works strategically and collaboratively with top, globally recognized EAM and IoT platform solution providers to heighten business value and bring bottom-line benefits to their clients.

Becoming a WIRAM Advocate

Aqitas' support for WIRAM stems from a dramatic increase in our own hiring efforts to bring women onto our team, as well as the changing landscape of the workforce. Aqitas recognized a growing need within this industry to support and appreciate the accomplishments and future impact that women have in this field. Since becoming a WIRAM Advocate in 2019, our support and advocacy for the group's efforts continue to grow. The maintenance workforce is changing with increased diversity of technicians with different skill sets, heightening the need for a supportive community within reliability and asset management for women and, more importantly, by women. WIRAM's ability to inspire its members through empowering, intellectual presentations and gatherings is essential in helping promote a successful and vibrant community of reliability. Aqitas is proud to be an official advocate of the WIRAM group and continually seeks opportunities to contribute to its ongoing growth and success.

As Maddy Hawkins, Director of IoT Sales at Aqitas, stated, "WIRAM creates a networking environment that was sorely lacking in our industry of reliability and asset management. As an active participant since the group was first introduced, I have seen it grow stronger every year."

How Aqitas Solutions Is Promoting Diversity

Being a part of the WIRAM group has encouraged Aqitas to embrace diversity in all aspects of its business operations. The company holds employees to a high standard of mutual respect internally, as well as working with customers. The relationship between Aqitas' leadership and its employees is one bolstered by positive reinforcement to inspire confidence and bring success to every project. Being an advocate for WIRAM has raised an important priority to promote and celebrate diversity at Aqitas, so the company is regularly exploring ways to support employees and improve diversity efforts in order to foster a strong, welcoming work environment.

www.aqitas-solutions.com



Fiix is a Toronto-based maintenance and asset management platform provider that's simplifying the journey to modern maintenance. We're mixing innovative technology with a focus on partnering with customers to make buying, implementing and using maintenance software easier than ever.

Becoming a WIRAM Advocate

In our own industry and the industry that we serve, we recognize the need for more diverse and inclusive practices. That's why we decided to become an advocate of WIRAM.

WIRAM is a change agent in the asset and reliability space. It is committed to building a more equitable world by giving underrepresented voices an opportunity to be heard in a predominantly male field. The work WIRAM does is so important and we are excited to be part of this equity-seeking movement as one of the first five official advocates. Together, we can amplify our impact to make positive change in our industry.

How Fiix Is Promoting Diversity

Fiix is committed to cultivating and preserving a culture of diversity, inclusion and respect. Our goal is to create a workplace that is representative of our community, where people feel a sense of belonging.

We started our diversity, inclusion and belonging (DIB) programming by gathering metrics and data through the use of an optional self-identification survey. This helps us better understand who our people are and where and how we can improve. The results of this survey guide our annual DIB programming, where we host monthly campaigns and events for major holidays and celebrations.

We believe that celebration must be coupled with education, which is why we introduced Crescendo, the diversity and inclusion education tool for Slack. Each week, every employee receives a



new piece of content exploring different topics, such as privilege, unconscious bias, and race, just to name a few. We complement this content with a monthly lunchtime meetup where employees gather to discuss a topic identified by Crescendo and the ways in which the content can be applied in the workplace.

Introduced recently are our Employee Resource Groups (ERG), which are employee-led groups formed around common interests, issues and/or a common bond or background. ERG members create a positive work environment at Fiix by actively contributing to our core values and efforts specific to inclusion, such as recruitment and retention. All of Fiix's ERGs are open to any employee.

Lastly, we measure whether all of this is working through anonymous pulse surveys. This information tracks whether employees feel like they are included at work and their voices are heard.

www.fiixsoftware.com



Interloc Solutions, an IBM® Maximo® enterprise asset management (EAM) and Mobile Informer software and services reliability certified consulting organization, has been a leader in delivering innovative services and solutions for over 16 years. Interloc is one of the largest Maximo system integrators in North America. Along with our worldwide, award-winning mobile program based on our Mobile Informer mobility solution for Maximo, Interloc's reliable EAM solutions significantly enhance the mobile workforce's capabilities and dramatically improve operational efficiencies across our clients' enterprises.

Becoming a WIRAM Advocate

WIRAM has held critical importance to Interloc since 2015 when we recognized its need and became a founding sponsor. The organization's objectives tightly align with Interloc's diversity principles.

How Interloc Solutions Is Promoting Diversity

Interloc is passionate about providing a dynamic and challenging environment to all employees. We embrace and value all perspectives and experiences and recognize what a diverse organization brings to bear. Contributions from a diverse population are broader and more comprehensive, allowing us to achieve greater success internally and externally. Interloc Solutions' Executive Vice President of Business Development and Marketing, Gretchen Gallagher, says gender diversity brings a more complete perspective to the reliability and asset management industry.

www.interlocsolutions.com



The Prometheus Group is a leading global provider of comprehensive and intuitive plant maintenance operations and optimization software, with a broad platform of solutions addressing the unique idiosyncrasies and requirements of heavy asset operators. The company's interconnected platform allows changes to be communicated in real time across an organization, improving manpower efficiency and driving production uptime.

Becoming a WIRAM Advocate

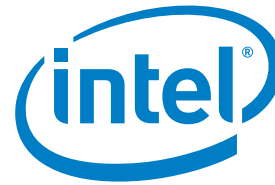
We are a WIRAM advocate because we've seen the growth of women in our customer base and the value they are bringing. Their stories are very inspiring and we want to support them in every way we can. The growth of women in the maintenance reliability space and the organizations that support them and help them grow are phenomenal.

How Prometheus Group Is Promoting Diversity

The Prometheus Group is dedicated to making our customers more productive and efficient by streamlining and making their work intuitive. To that end, we support every customer out there, making their jobs easier, helping them to learn and nurturing our relationships with them. We want to help women share their inspirational stories. We are adding a women's event to our annual user conference so they can share these stories. As a company, we are becoming more diverse, developing and adding women in leadership roles and throughout the company.



www.prometheusgroup.com



Intel is known for the chips inside computers, but the majority of the business is focused on redefining what it means to be an innovator by expanding who has access to technology skills and experiences. Ensuring that the next generation of innovators is empowered, diverse and inclusive enables us to harness the full power of technology to create the best future possible for everyone.

Becoming a WIRAM Advocate

In a recent study initiated to understand the impact of technology on today's workforce, we found our sampling group in manufacturing consisted of mostly white males. This is indicative of the situation in manufacturing, where certainly we see more and more women in important roles, but it's still not enough. WIRAM is a rich source of women leadership, mentors, education, best practices and a body of knowledge that will empower members with the tools they need to be successful as women engineers. That's why Intel will continue to support this important institution.

How Intel Is Promoting Diversity

For Intel, diversity is a journey and a lifestyle. Intel hired a Chief Diversity Officer, Barbara Whye, to set the strategy to help us achieve our diversity goals, along with policies designed to reach these goals.

In 2015, Intel announced plans to achieve full representation of underrepresented minorities and women in our U.S. workforce by 2020. Setting the course for our definition of full representation of women and underrepresented minorities, we reached our goal in October 2018, two years ahead of schedule. By 2018, representation of women increased by 8.5 percent, which makes up 26.8 percent of Intel's workforce. Out of all women at Intel, 19.4 percent are in leadership roles. This commitment and focus are shaping the future of technology, both here at Intel and around the world.

Recognizing that diversity and inclusion are critical to success is just one step. It's action and efforts that lift goals into reality. Intel believes a diverse workforce creates a solid foundation for building an inclusive culture, fueling innovation and delivering a positive impact to employees, partners and customers. Diverse ways of thinking make the impossible possible.

www.intel.com



Caterpillar Asset Intelligence provides digital services and solutions to customers. The portfolio of solutions ranges from collecting the data to predicting and avoiding equipment failures, reducing fuel and energy consumption, and maintenance optimization. These innovative technology and service offerings complement the Caterpillar products and technologies that are focused on providing the highest level of uptime and the lowest lifecycle cost.

Becoming a WIRAM Advocate

WIRAM adds to the multiple initiatives that Caterpillar already has in place. Caterpillar values the opportunity to grow and support women within our industry to promote increased business results through diversity and inclusion, equal representation and women in leadership. WIRAM provides Caterpillar the opportunity to share the stories of high performing women within our team that help drive Caterpillar's strategy and reliability footprint in the industrial and asset management space.

How Caterpillar Is Promoting Diversity

At Caterpillar, we believe each person is unique and valued, and are committed to ensuring that our workplace is diverse and representative of the many customers we serve around the globe. Different perspectives help us achieve our best work and come together to form a high performing Caterpillar team that makes positive changes in the communities where we live and work.

www.catassetintel.com



Accenture is a leading global professional services company, providing a broad range of services and solutions in strategy, consulting, digital, technology and operations. Combining unmatched experience and specialized skills across more than 40 industries and all business functions, Accenture works at the intersection of business and technology to help clients improve their performance and create sustainable value for their stakeholders.

Becoming a WIRAM Advocate

At Accenture, we believe the future workforce is an equal one and have set bold goals to accelerate gender equality.

How Accenture Is Promoting Diversity

Our focus is to unleash innovation by fostering an inclusive and diverse workforce. To drive a culture of equality, three components are essential:

- 1. Empowering Environment + Purpose + Autonomy:** Training and development opportunities, greater flexibility and commitment to work-life balance are the most powerful drivers of an innovation mind-set. Employees are empowered by a shared sense of purpose, paired with autonomy, which helps them reach their individual potential.
- 2. Bold Leadership + Experimentation + Resources:** Culture starts at the top. Setting and publishing diversity targets, holding the leadership team accountable and measuring progress are critical steps. Leaders must give employees the resources they need to innovate and the freedom to fail.
- 3. Comprehensive Action + Inspiration + Collaboration:** Forward-looking policies and practices are important, but they also must be evenly accessible to ensure that individuals or groups don't feel singled out or held back. When employees are inspired by those inside and outside the organization, their commitment to living the company's core values, and for collaborating with one another, grows.

www.accenture.com

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