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COURSE	WHO SHOULD ATTEND	YOU WILL LEARN HOW TO	DATES & LOCATION	DAYS/CEUs	COST
Maintenance Management Skills	Maintenance Managers and Supervisors, as well as Supervisors from Operations, Warehouse or Housekeeping areas	Lead a world-class maintenance department using planning and scheduling best practices to drive work execution, improve productivity, motivate staff, increase output and reduce waste.	Dec 4-6, 2018 (CHS) Jan 29-31, 2019 (CU) Apr 16-18, 2019 (OSU) Sept 24-26, 2019 (KU) Dec 3-5, 2019 (CHS)	3 consecutive days 2.1 CEUs	$1,895
Maintenance Planning and Scheduling	Planner/Schedulers, Maintenance Supervisors, Maintenance Managers, Operations Coordinators, Storeroom Managers and Purchasing Managers	Apply preventive and predictive maintenance practices. Calculate work measurement. Schedule and coordinate work. Handle common maintenance problems, delays and inefficiencies.	Feb 5-7, 2019 (CHS) June 18-20, 2019 (CHS) Aug 27-29, 2019 (CHS) Dec 10-12, 2019 (CHS)	4 consecutive days 2.8 CEUs	$2,495
Managing Planning and Scheduling	Lead and Senior Planners, Planning Department Managers, Maintenance Managers, Reliability Change Agents, Reliability Managers, Continuous Improvement Managers	Establish a proactive work management program or transform an existing program into an effective, results-producing department that positively impacts maintenance costs, plant reliability measures and morale.	May 7-9, 2019 (KU) July 23-25, 2019 (CHS) Sept 17-19, 2019 (CU) Nov 5-7, 2019 (OSU)	3 consecutive days 2.1 CEUs	$1,895
Materials Management	Materials Managers, Storeroom Managers, Planner/Schedulers, Maintenance Managers and Operations Managers	Apply sound storeroom operations principles. Manage inventory to optimize investment. Understand the role of purchasing. Implement effective work control processes.	Mar 5-7, 2019 (CHS) Oct 22-24, 2019 (CHS)	3 consecutive days 2.1 CEUs	$1,895
Planning for Shutdowns, Turnarounds and Outages	Members of the shutdown or outage teams, planners, plant engineers, maintenance engineers	Save time and money on your next shutdown by learning how to effectively plan for and manage such large projects. Learn processes and strategies for optimal resource allocation.	August 6-8, 2019 (CHS)	3 consecutive days 2.1 CEUs	$1,895
Predictive Maintenance Strategy	Plant engineers and managers, Maintenance, Industrial and Manufacturing Engineers, Maintenance Supervisors and Managers	Collect and analyze data to assess the actual operating condition. Use vibration monitoring, thermography and tribology to optimize plant operations.	Apr 2-4, 2019 (CHS) May 21-23, 2019 (OSU) July 30-Aug 1, 2019 (CU) Nov 5-7, 2019 (KU)	3 consecutive days 2.1 CEUs	$1,895
Reliability Engineering Excellence	Reliability Engineers, Maintenance Managers, Reliability Technicians, Plant Managers and Reliability Personnel	Learn how to build and sustain a Reliability Engineering program, investigate reliability tools and problem-solving methods and ways to optimize your reliability program.	Feb 26-28, 2019 (KU) Apr 30-May 2, 2019 (CU) June 18-20, 2019 (CHS) Oct 8-10, 2019 (OSU)	3 consecutive days 2.1 CEUs	$1,895
Reliability Excellence for Managers	General Managers, Plant Managers, Design Managers, Operations Managers and Maintenance Managers	Build a business case for Reliability Excellence, learn how leadership and culture impact a change initiative and build a plan to strengthen and stabilize the change for reliability. CMRP exam following Session Four.	SESSION 1 DATES: Mar 19-21, 2019 (CHS) Aug 27-29, 2019 (CHS)	12 days total (4, 3-day sessions) 8.4 CEUs	$7,495
Risk-Based Asset Management	Project Engineers, Reliability Engineers, Maintenance Managers, Operations Managers, and Engineering Technicians.	Learn to create a strategy for implementing a successful asset management program. Discover how to reduce risk and achieve the greatest asset utilization at the lowest total cost of ownership.	Feb 12-14, 2019 (OSU) Mar 26-28, 2019 (CU) Jun 11-13, 2019 (KU) Oct 1-3, 2019 (CHS)	3 consecutive days 2.1 CEUs	$1,895
Root Cause Analysis	Anyone responsible for problem solving and process improvement	Establish a culture of continuous improvement and create a proactive environment. Manage and be able to effectively use eight RCA tools to eliminate latent roots and stop recurring failures.	Mar 19-21, 2019 (OSU) May 14-16, 2019 (CHS) Aug 20-22, 2019 (KU) Oct 29-31, 2019 (CU)	3 consecutive days 2.1 CEUs	$1,895

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TRANSFORMING SAFETY TRAINING FOR TECHNICIANS

Eric Ayanegui

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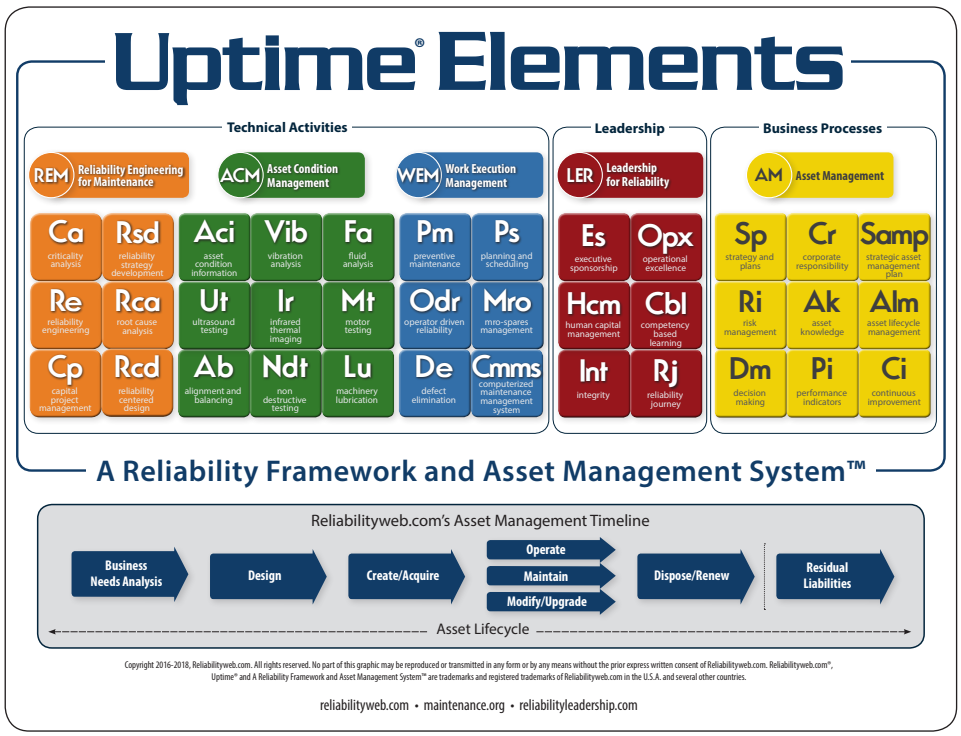
RELIABILITY PARTNERS

A powerful ecosystem of Reliability Partners who support the Uptime Elements Framework.



Uptime® Elements - A Reliability Framework and Asset Management System™ is in use at over 2,500 organizations around the work to engage and empower reliability culture.

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All Leadership Comes Down To This: Changing People's Behavior

Why is that so damn hard?

You just had a consultation with your long-time trusted doctor who tells you that your life will be significantly cut short unless you quit smoking, quit drinking, improve your eating habits and increase your exercise.

Could you change when it matters most?

Yes, you say?

Try again.

Yes?

You're probably deluding yourself.

You wouldn't change.

Don't believe it? You want odds? Here are the odds, the scientifically studied odds: nine to one. That's nine to one against you. How do you like those odds?

Think about that - in matters of life and death, it is a long shot that your efforts to change will be successful. Then I ask, how the heck will we ever unlock work performance potential in ourselves and our organizations through change?

No wonder over 70 percent of reliability change initiatives fail to generate sustainable business improvement!

Changing the behavior of people isn't just the biggest challenge in reliability and asset management. It's the most important challenge for all businesses trying to thrive in today's turbulent world.

Most organizations try to improve reliability performance by focusing on technical analysis and engineering techniques, however, behavior change happens by speaking to people's feelings. Through the work we do with Uptime® Elements — A Reliability Framework and Asset Management System™ leading to Certified Reliability Leader® status, people find ways to help others see the problems or solutions in ways that influence emotions, not just thought and technique.

Unfortunately, that kind of approach isn't taught in business schools, and it doesn't come naturally to the technocrats who run things — the engineers, accountants and managers who pride themselves on disciplined, analytical thinking.

As we approach the 3,000th Certified Reliability Leader, we are very proud of the change we are creating in the world. The people and organizations who embrace reliability leadership are rewarded with an empowered and engaged cross-functional high-performance culture.

The pages of *Uptime*® magazine are filled with great stories of reliability leaders, innovative technologies and powerful processes combining to advance asset performance. Read them, share them and discuss them. Someday, I hope we have the opportunity to learn from your story, too.

How do you support change as a leader?

I look forward to learning,

Terrence O'Hanlon, CMRP
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CEO and Publisher
Reliabilityweb.com®
Uptime® Magazine
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RELIABILITY

IN THE NEWS

SPECIAL GUEST TRAINING FOR RELIABILITY LEADERSHIP INSTITUTE IN 2019

Reliabilityweb.com is pleased to announce several special guest training events at the Reliability Leadership Institute during 2019. These trainings are designed to expand and extend Uptime Elements — A Reliability Framework and Asset Management System.

"I am thrilled to have an opportunity to work with and learn from reliability leaders like Ron Moore, Author of ***Making Common Sense Common Practice, Models for Operational Excellence*** and Ramesh Gulati, co-Author of ***10 Rights of Asset Management*** to extend the context we have created with the Uptime Elements and taking them to the next level," states Terrence O'Hanlon, CEO, who will be assisting Mr. Moore and Mr. Gulati to deliver the training workshops.

Ron Moore

TRAINING DATES:

- **Models for Operational Excellence**
  March 12-14, October 8-10
- **Reliability Strategy Development**
  June 4-6
- **Cause Mapping for Problem Solving and Root Cause Analysis**
  February 26-28, November 5-7
- **10 Rights of Asset Management with added feature: Asset Management for Executives**
  April 23-25
- **Transformer Management Essentials with one-day feature: Asset Management and Reliability Leadership**
  January 14-17
- **Lubrication Elements MLT Training and Certification Course**
  March 5-7, October 22-24
- **Certified Maintenance Manager (CMM)**
  April 9-12, August 20-23

Oman Gas was presented with the 2018's Asset Performance Award

Bentley Systems Year In Infrastructure Conference

Bentley Systems held their *Year in Infrastructure 2018* Conference and Awards, October 16-18, 2018 in London, United Kingdom. Reliabilityweb.com CEO, Terrence O'Hanlon, hosted a by-invitation Asset Performance Round Table featuring executives from asset intensive industries from around the world. The discussion centered around the challenges and solutions with digitalization related to asset performance and asset lifecycle information management.

MRO-Zone Bookstore Coming Soon: NEW RELEASES!

- **Risk-Based Asset Criticality Assessment Handbook: The Key to Interpreting Asset Risks** by Suzane Greeman
- **Asset Strategy Management ASMx: A Leader's Guide to Reliability Transformation in the Digital Age** by Jason Apps
- **Conversations in Maintenance Management** by Joel Levitt

Available mid-December 2018. Visit: **mro-zone.com**

HIGHLIGHTS

Robert Kegan, author of *Immunity to Change*, with Terrence O'Hanlon and Maura Abad, Reliabilityweb.com, at a recent facilitator workshop in Boston, Massachusetts

WIRAM gathering at Euromaintenance 4.0 in Antrwep, Belgium

Certified Reliability Leader Advanced Workshop – Fort Myers, Florida – November 5-9, 2018

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WEDNESDAY, DEC. 12

9:00am-9:30am
10:30am-11:00am
12:00pm-1:30pm
3:15pm-3:45pm

THURSDAY, DEC. 13

9:00am-10:00am
12:00pm-1:30pm

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Visit the AVEVA Asset Performance Learning Lab at IMC-2018 to experience hands-on demos of the latest in analytics, cloud, mobility and AR/VR solutions for asset maintenance and reliability while enjoying some light refreshments and charging your cellphone. Visitors may also register to win a Smart Home automation system.

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MAINTENANCE SAFETY CERTIFICATION:

TRANSFORMING SAFETY TRAINING FOR TECHNICIANS

Eric Ayanegui

"Safety must be much more than a subject we manage, it must be part of our corporate culture and a foundational part of everything we do as a company"

~ Scott Farmer, CEO, CINTAS

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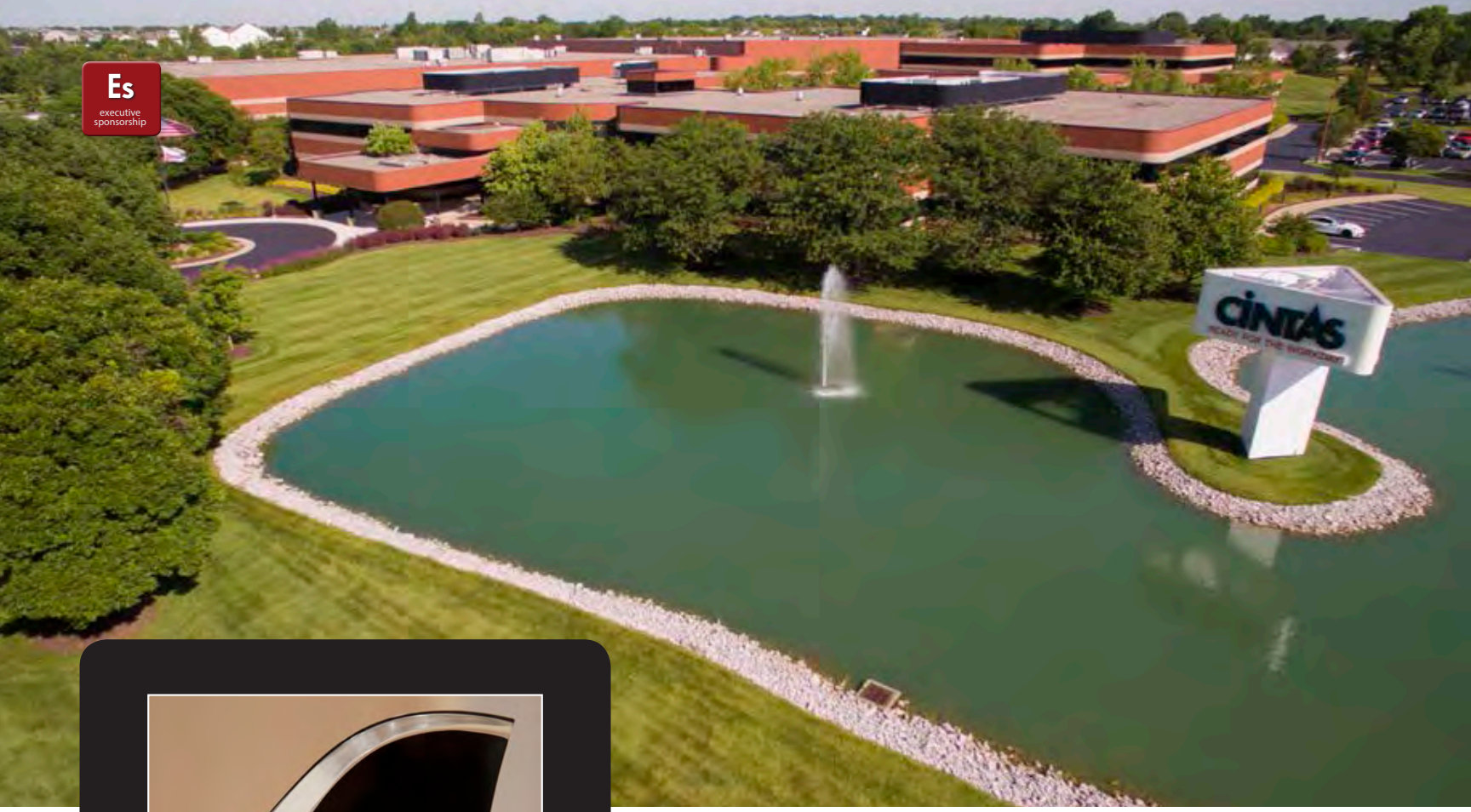

WINNER OF 2017 UPTIME AWARD FOR SAFETY IN MAINTENANCE

Cintas Corporation, which operates more than 400 facilities in North America, including six manufacturing companies and eight distribution centers, embarked on a mission to improve safety strategy, execution and results. This article follows the corporation's journey to make safety part of its culture and a foundational part to everything it does.

ABOUT THE COMPANY

Headquartered in Cincinnati, Ohio, Cintas is a publicly held Fortune 500 company, traded over the Nasdaq Global Select Market under the symbol CTAS, and a component of the Standard & Poor's 500 Index. The company provides more than one million businesses with a wide range of products and services to enhance their customers' image and help its customers keep their facilities and employees clean, safe and looking their best. Products and services include uniforms, floor care, restroom supplies, first aid and safety products, fire extinguishers and testing, and training and compliance courses.

BEGINNING THE SAFETY JOURNEY

In 2003, the company hired its first safety professional to help improve safety strategy, execution and results. Since that first hire, Cintas has worked diligently to achieve CEO Scott Farmer's vision that: *"Safety must be much more than a subject we manage, it must be part of our corporate culture and a foundational part of everything we do as a company."*

The company assembled a team of safety professionals, including outside executive level safety consultants, to develop and implement world-class safety solutions for Cintas's work environments to help reduce employee risk and improve safety processes.

To deliver its uniform rental service, Cintas operates more than 200 industrial laundry facilities and employs more than 1,000 maintenance technicians. Many of the company's safety programs and solutions affect these technicians as they work hard to maintain equipment in operating condition. Technicians attend mandatory regulatory safety training (e.g., lockout-tagout (LOTO), hazard communication (HAZCOM), electrical safety, etc.), as well as company required safety training (e.g., heat stress, ergonomics, safe lifting, etc.).

Many company resources are devoted to helping technicians understand the risks of their jobs and teaching them how to perform their jobs more safely.

INTRODUCING MAINTENANCE SAFETY CERTIFICATION

In 2011, Cintas improved its program by updating its maintenance training to utilize teaching methodologies that would help impart a higher level of knowledge and understanding of all aspects of on-the-job safety.

A maintenance safety certification development team was established. The team consisted of seasoned safety and engineering employees who reviewed safety topics and training programs affecting maintenance technicians, including safety manuals, checklists and other materials. The content was evaluated for relevance and importance. Once a list of safety topics was developed, the team drafted documents for the new maintenance safety certification.

CERTIFICATION DOCUMENTS

The documents include a detailed list of questions and answers, divided by safety topic, for use by technicians to study and internalize. The same list is used by a certification panel to evaluate the technicians. The documents also include a series of complex troubleshooting scenarios for use during a Q&A section, as well as scenarios for use during a live demonstration section.

CERTIFICATION STRUCTURE

The maintenance safety certification process is based on other existing company certification processes, which include detailed study guides, study and review sessions and a certification panel consisting of leaders with knowledge of the certification subject.

The maintenance safety certification includes four sections:

1. **Study and Review Sessions**
   - Study guide
   - 8-10 weekly study and review sessions
2. **Certification Panel**
   - Panel session Q&A
   - Live demonstration
3. **Panel Discussion**
   - Discuss pass-fail and corrective action plan
4. **Recognition**
   - Certification award presentation

CINTAS SAFETY VISION

- Every Cintas location is injury-free
- Every partner is engaged in continuously improving safety
- Cintas is widely recognized as one of the world's leaders in safety and health performance

"Cintas has certified over 700 technicians, with about 87 percent passing on their first attempt"

STUDY AND REVIEW SESSIONS

Technicians are provided a detailed study guide and are included in a weekly review conference call. The call is directed by corporate safety and engineering employees, serving as an accountability method to help technicians keep pace with their study plan and remain on track for their certification. During the call, employees review and discuss material from the study guide to encourage a full and in-depth understanding of each point outlined. Technicians participate in eight to 10 weekly study and review sessions.

CERTIFICATION PANEL

The certification panel includes the plant's general manager, plant manager, human resources manager, corporate engineer, and corporate safety and health coordinator.

During the panel session, panel members randomly select and ask 50 questions from the study guide. The panel session is closed book; no notes or documents are allowed. Technicians must know detailed information from the study guide and be able to articulate detailed accurate responses. Technicians must respond to all questions correctly to pass.

After the 50 question section, the certification process includes a scenario section. Technicians are verbally presented with four scenarios randomly selected from a group of eight options based on real-life troubleshooting incidents, each with an elevated safety risk. The scenarios are based on these high-risk categories: LOTO, electrical safety, confined space and elevated work.

The scenarios presented include complex technical issues that require multiple safety precautions and procedures to be followed in order to safely

> "One key element for the success of the maintenance safety certification was executive support"

and successfully complete the repair. Technicians are expected to verbally describe, step-by-step and in detail, how they would proceed. The certification panel is provided with documented detailed steps that include all safety requirements of the scenario. As the technician verbalizes his or her response, the panel closely monitors responses and looks for all required safety cues.

At the conclusion of each scenario response, the certification panel asks the technician what could happen if the necessary safety steps were not followed. At this point, the panel is looking for the technician to internalize the consequences to his or her own safety and well-being and verbalize this understanding of personal safety responsibility.

Once the panel and scenario sessions are complete, the certification process changes venue from a conference room to the production floor. There, the certification panel verbally presents a demonstration scenario to the technician, who is expected to take this information and begin to troubleshoot. During this time, the certification panel observes all activity by the technician. Panel members evaluate if the technician follows all necessary safety requirements, completes necessary safety documentation, uses proper safety tools and follows appropriate safety protocols.

PANEL DISCUSSION

Once the demonstration section is complete, the certification panel reconvenes to review and discuss the technician's performance during all sections of the process to determine pass-fail for each section.

The technician is required to retest any failed section(s). If a technician fails a section, a customized and individual retraining plan is developed by the panel. This recertification plan may include review, study and recertification of failed sections and may also include escalating consequences, such as a revocation to perform certain tasks during the retraining period.

RECOGNITION

Once technicians successfully complete all sections of the certification, they are presented with a personalized maintenance safety certification award to emphasize this important professional development achievement.

In addition to the trophy presentation, each location is encouraged to plan a recognition event for the technicians to celebrate their achievement among their peers and other plant personnel, such as management and machine operators.

Cintas made the fundamental decision that successful completion of maintenance safety certification would become a condition for employment for its technicians. Therefore, collaboration with its human resources department was critical in the development and review of each element of the certification. Careful thought was given to ensure that the support and structure existed for technicians to be able to study and prepare for the certification while at work. Rules for pass-fail were carefully reviewed and rules and documentation for retraining plans were documented.

IMPLEMENTING A PILOT CERTIFICATION PROGRAM

In order to properly assess the effectiveness and employee impact of the maintenance safety certification process, Cintas chose to pilot this process across a limited number of selected locations. Locations were selected to ensure a broad spectrum of technicians were included in the pilot.

Based on observations and results from the pilot certifications, the process was slightly modified and rules were established. The process was improved to allow technicians to have a study guide that included complete and accurate answers from the outset. This eliminated technicians learning incorrect or incomplete information. The company also established a waiting period of six months before a technician is added to the certification list. This six-month period gives technicians who are new to the company the appropriate amount of time to learn and assimilate to Cintas. As with other company certification programs, it was established that technicians would be certified only one. Annual safety retraining would continue to be handled through the regular safety training calendar, including annual retraining on high risk topics like LOTO, electrical safety, confined space and elevated work.

During the pilot, the company also realized that most of the tenured technicians had not studied technical material for many years, some since high school, in the military, or vocational technical school. The maintenance safety certification process revived their test preparation and study habits. The

certification level of this program definitely elevated the level of preparedness necessary to have a positive outcome.

OBTAINING EXECUTIVE SUPPORT

One key element for the success of the maintenance safety certification was executive support. The certification development team counted on the support of a senior executive to serve as the executive sponsor of the project. This executive sponsor provided executive level input to ensure certification met expectations. In addition, the executive sponsor provided regular updates of the project and its importance to all other senior executives.

CONDUCTING THE FINAL ROLLOUT

Once the maintenance safety certification process was ready for company-wide rollout, appropriate marketing was done within the company to establish support and create buy-in. A video message was professionally created and shared with every management team member and technician. In the video, the executive sponsor introduced and described the certification's elements. The video also included a series of FAQs that the team had collected during the pilot certification. This approach made implementation and rollout easier since all company stakeholders understood the importance of the program.

RESULTS

Since the original certification rollout, Cintas has certified over 700 technicians, with about 87 percent passing on their first attempt, about 10 percent passing on the second attempt (testing on failed sections) and approximately three percent failing on the second attempt.

ADDITIONAL BENEFITS REALIZED

The maintenance safety certification became a transformational program in several ways. The program raised the profile and importance of safety training for technicians by elevating the training to certification level. This meant a higher degree of difficulty since deep understanding of the material was required. The program also changed the way technicians approached test preparation. Besides the required weekly study and review sessions, technicians would huddle as a team to study and quiz each other. Others would include family members in their preparation, often collaborating with loved ones to review flashcards and other certification content. This brought about an interesting dynamic that the company had not expected – family members and loved ones engaging in safety-related conversations with the technicians. These conversations often produced some very meaningful insights for the technicians because, suddenly, they were having to answer to their wife, son, or daughter about whether or not they follow LOTO or consistently wear personal protective equipment to guard against injury.

The certification process also became a transformational experience for members of management that participated on the certification panel. These management team members experienced high levels of excitement and pride as they witnessed their technicians correctly articulate answers to difficult safety questions, correctly address detailed responses to challenging

ELEMENTS OF THE MAINTENANCE SAFETY CERTIFICATION

- **STUDY SESSIONS**
  - Study guide
  - 8-10 weekly study and review sessions
- **CERTIFICATION PANEL**
  - Panel session Q&A
  - Live demonstration
- **PANEL DISCUSSION**
  - Discuss pass/fail and corrective action plan
- **RECOGNITION**
  - Certification award presentation

Es executive sponsorship

troubleshooting scenarios and show command of all detailed safety steps and requirements necessary during the tough demonstration section of the certification.

Most importantly, the maintenance safety certification became a transformational experience for the technicians. In the end, technicians obtained a significantly higher level of knowledge and understanding of the safety requirements of their jobs. They now know the "why" behind the importance of each safety element that impacts their job.

Upon successful completion of their certification, many were elated they were able to achieve success in obtaining certification. All the technicians experienced a sense of deep professional pride as they were presented with their certification trophies, often in front of the entire plant staff. Many technicians have expressed to company officials that this certification program was the most comprehensive and impactful safety program they had ever experienced. For many, this program is reassurance that the company cares deeply and sincerely about their safety.

Eric Ayanegui, *CRL, CPMM, is a technical leader at CINTAS Corporation, directing engineering, reliability, quality and safety initiatives in 210 industrial sites across North America and China. He is a founding member of CINTAS Corporate Safety team and a member of the CINTAS Corporate Executive faculty teaching reliability. Eric has over 20 years of experience in the industrial laundry industry. www.cintas.com*

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Good Practices
Safety Goggles
Hearing Protection
Informations
Warning
Evacuation Lane
Instructions
Joel Levitt

The safety of workers should be part of the mission of your organization. If it isn't, do something about it!

The fact is, shop safety in the U.S. and Europe has dramatically improved over the past few decades. Many unsafe acts accepted in the past are forbidden today. The idea of working without fall protection or lockout-tagout (LOTO) procedures is widely condemned by workers, management and supervision. Still, too many people get grievously hurt or even killed at work.

Many thinkers on this topic have identified core approaches. Some include behavior-based safety, a hazard and operability study (HAZOP) design for process safety, job safety analysis (JSA), and others.

This two-part series concentrates on:

- Risk management
- Conditions that are unsafe;
- Contributors to accidents;
- Specific safety for maintenance shops of all kinds.

Each group in an organization, from top management on down, contributes to make a shop safe. Along with that, each group is accountable for part of the safety situation. In fact, a safe shop depends on safety being discussed and being consistently applied at every level in the organization.

Part 1 discusses risk management and the tools to approach and manage any risk (hazardous, operational, financial, etc.). Most professionals know there is a relationship between reliability and safety. In Part 1, we will explore the reasons that reliable equipment is safe equipment. One way to look for hazards is to list all possible hazards. To that end, we provide a hazard list with mitigation. Finally, when looking for safety, we should think about all the conditions that can produce hazards and manage as many as we can.

One Lapse in Judgment Is All It Takes

The most common group to get injured are new hires. But, another big group are those who have 15 or 20 years on the job and have a momentary lapse in judgment.

That's why it's so important for organizations to keep reinforcing safe practices, so they are on everyone's minds when they go to work.

The Goal: Get people thinking and participating. Make safety fun, interesting and be sure to get people's attention.

Safety and Risk Management

Safety is part of the bigger topic of risk management. According to the book, *Managing Maintenance Shutdowns and Outages,* the three steps of risk management that are part of the planning process are risk identification, risk quantification and risk response. The first two, identification and quantification, are sometimes grouped together under risk analysis or risk assessment.

- **Risk identification:** Is there a risk here? Address both internal (those under the team's control) and external (outside world) risks.
- **Risk quantification:** How much money will the event cost the organization? How much time will it delay the completion? What is the likelihood of the risky event happening? How many people will get hurt and how hurt will they get?
- **Risk response:** What is the response? How costly is it to respond? How likely will the response eliminate the risk? Can the risk be transferred to someone else (e.g., fixed price contracts or buying insurance)? Does the response introduce any unanticipated risk?
- **Risk vigilance, once you are underway:** How do you organize your team so that when a risk becomes apparent, you find out and have enough time to respond? In addition to vigilance, this includes responding to changes in the character of the risk over the life span of the project.

Risk management, including risk identification, is best done as a team. This way, people from different backgrounds will see different potential hazards. Imagine the input of millwrights, riggers, operators, engineers, as well as safety people, to the risk equation. Hazards and accidents are two types of risks to be managed!

Reliability and Safety

Reliability and safety are directly related. Reliable equipment is safer equipment for four primary reasons:

REASON 1: Reliability reduces the need to put one's personnel into harm's way to fix the equipment. Many accidents are due to being in the wrong place at the wrong time. Those wrong places are on ladders, confined spaces, working hot and various other places maintenance personnel find themselves doing repairs. Reliability keeps people closer to safe areas more often.

REASON 2: The size and scope of the repair is smaller due to preventive maintenance (PM) making for safer repairs. People know that maintained equipment breaks down less often. This is because well maintained equipment has tightened bolts, is properly lubricated and is kept clean. Most failures are the direct result of breakdowns in these three activities of PM. Periodic, on-line or condition-based inspection is another important PM activity essential to safe repairs. This inspection detects defects, damage and deterioration before failure. The size and scale of repairs on problems detected before failure is smaller, lighter and easier to work on.

> "Accidents are five times more likely while working on breakdowns than they are while working on planned and scheduled corrective jobs"
>
> ~ ExxonMobil

TABLE 1 – THE HAZARDS TABLE		
SAFETY RISK	**HOW TO ELIMINATE IT**	**HOW TO MITIGATE IT**
Airborne contaminants	Eliminate contaminants	Respirators
Falls from heights	Do work at ground level	Guardrails, fall protection
Falling objects	Don't allow work below	Hard hats, temporary roofs, shelters, better procedures
Eye damage from particles, chemicals, flash	Find another way to work, isolate this work, use robots if feasible	Safety glasses, face shields
Entrapment and crushing	Don't allow work where people can get caught or crushed	Improved procedures, safety shoes, proper clothing, improve chocking and blocking
Slipping and tripping		Housekeeping, proper shoes, equipment laydown areas well organized, high visibility paint and tape, good lighting
Chemical ingestion, skin exposure, breathing	Eliminate hazardous chemicals	Proper personal protective equipment (PPE), better procedures, access and understanding safety data sheets (SDS)
Radioactive exposure	Eliminate radioactive substances	Clear areas and paths of gamma rays, protective clothing, lead barriers, wear dosimeters and limit exposure
Fire	Eliminate flammables	Procedures, watch people, pick less flammable chemicals
Electrocution	Lockout, do not allow work on or near energized circuits	Safe procedures, training, lockout
Explosion	Eliminate one or more of the components of the explosive mixture (there will always be a source of ignition)	Safe procedures, safety blanket gas, training
Asphyxiation	Do not allow entry into any dangerous areas	Gas monitors, gas alarms, air packs
Temperature stress	Do not schedule work during cold or hot times	Issue appropriate clothes, work time and temperature tables, cold vests, adequate cold water, shade, evening work

REASON 3: Hazards are eliminated or mitigated in the planning process. ExxonMobil studied its maintenance related accidents and found: "Accidents are five times more likely while working on breakdowns than they are while working on planned and scheduled corrective jobs."

High reliability also implies that maintenance planners have time to properly plan the job. One aspect of planning is considering all the hazards and then figuring out and describing a way to accomplish the work safely. The job plan an experienced planner develops reflects the safe way to do the job.

A planner should look at every job and see if any common hazards are present. Hazards include: Airborne contaminants; falls from heights; slipping and tripping; falling objects; eye damage caused by particles, chemicals or flash; chemical caused by ingestion, skin exposure, or breathing in; asphyxiation; radioactive exposure; fire; explosion; electrocution; entrapment and crushing; and temperature stress.

Every hazard identified is either eliminated, which is the best route, or mitigated, which is the second best option. The safest plants are those where the safety of workers is considered at every step in the job preparation process.

REASON 4: Planned jobs have fewer opportunities for the maintenance worker to improvise. Improvisation is statistically less safe than following a job plan with the correct tools and spares.

One of the building blocks of a reliable culture is adequate maintenance planning. Without planning, workers are forced to make do with what spares and tools they can find. To do their job, they may have to improvise to make things work. Improvisation might be great in the theater but can be deadly in maintenance.

Either you can plan and schedule your maintenance activity or your machines will! High reliability is part of a bigger picture of intentional maintenance. Intentional maintenance is where the maintenance effort determines its own schedule, not the breaking machines.

Reliability is the outcome of this intentional maintenance environment and is essential for a safe environment.

Specific Action Items Relating to Reliability

Mechanical integrity programs are difficult to measure directly. Management action items to transform the culture require minor modifications to the weekly and monthly key performance indicators (KPIs) used to run the plant or facility and award bonuses.

Some examples of specific action items are:

1. Ratio of emergent maintenance work to planned and scheduled maintenance work should be maintained above 80 percent planned and scheduled.

> An accident is almost never a truly accidental, random event, but rather the result of a cascade of events or causes that end up in damage or injury

2. PM performance above 95 percent. More than 95 percent of the PMs generated are completed in ±10 percent of the PM interval or 30-day PMs completed in between 27 and 33 days.
3. Schedule compliance above 85 percent. This means more than 85 percent of the jobs scheduled are completed sometime during the week they are scheduled.
4. Mean time between failures (MTBF) for major assets are on an improving trend.

Wider View: The Hazards Table

Table 1 is a reference hazards table that contains a list of all known hazards at most sites. In managing risk, there are four options:

- Accept it and do nothing;
- Remove or eliminate the risk;
- Mitigate the risk by reducing the severity or consequences;
- Transfer the risk, such as buying insurance, vendor contract, etc.

The hazards table also provides examples for eliminating the risk and mitigating the risk for each hazard.

When any of these hazards come into play, you have an accident. An accident is almost never a truly accidental, random event, but rather the result of a cascade of events or causes that end up in damage or injury.

Accidents and Quality

This section is a parallel conversation with quality. It turns out that eliminating the causes for accidents also addresses many of the causes of mistakes and quality problems.

What Causes Accidents?

The dictionary definition of an accident is: "An unfortunate incident that happens unexpectedly and unintentionally, typically resulting in damage or injury." There are many common causes for accidents in the workplace. Some accidents have overlapping causes and accountabilities.

Here is a list of some of them.

Management

- Unrealistic expectations, pushing too hard
- Not enough money or time to do the job correctly
- Mentality to cut costs regardless of consequences
- Mentality to ignore advice of maintenance, engineering and reliability professionals
- Poor planning
- Not demanding safety be discussed and dealt with at every stage of an activity
- Acceptance of temporary repairs with no plans to remediate
- Interruptions from managers

Processes and procedures

- No risk management
- No hazard identification
- Boiler plate LOTO to try out
- Ineffective hazard permitting (i.e., hot work)
- Lack of a permit to work system, when needed
- Inadequate PPE for level of hazard
- Different rules for management when they are in the shop
- Adherence to rules optional

Supervision

- No instruction
- Bad instruction (i.e., didn't communicate)
- Incorrect instruction
- Absent supervision
- Bad supervision
- Improper scope, no scope, wrong scope
- Bad communication between trades or shifts
- No wiring schematics
- Supervisor not standing for safety

Engineering

- No drawings
- Drawings wrong
- No as-built drawings
- No operations and maintenance (O&M) manual
- Equipment operated beyond design capacity
- Equipment being used for something it was not designed to do
- Bad design for use
- Designed with difficult access
- Badly designed equipment piping, wiring, or foundation
- No testing, no commissioning
- Old equipment at end of life cycle with multiple unfolding failure modes

Operations

- No standard operating procedures (SOP)
- Lots of short cuts and tribal knowledge needed to operate

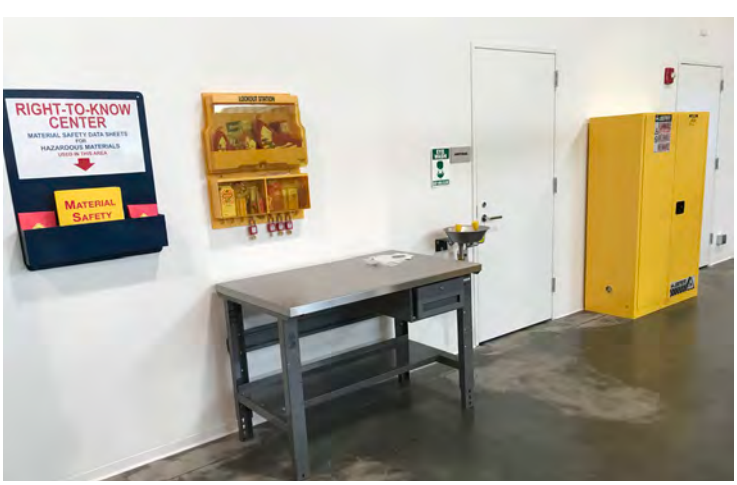

Figure 1: Examples of items that mitigate hazards (left to right): Material and safety data sheets and books on how to handle hazardous materials and what to do if exposed to chemicals, lockout station with locks and tags to reduce the chance people will forget and eye wash station to reduce potential damage

Figure 2: A flammable cabinet minimizes, but does not eliminate, the risk of fire and reduces the potential impact

Conditions of people who can contribute to accidents

- People untrained (i.e., ignorance)
- Trained people without experience (i.e., new graduates)
- Trained people without confidence
- Anger at company (i.e., sabotage)
- Low morale, don't want to do the work
- Bad attitude (rare by itself, usually accompanies another cause)
- People who don't have the capability (e.g., intelligence, strength, flexibility, endurance, visual and auditory acuity)
- People feeling frustrated and making mistakes, such as not being able to locate things
- People are drugged, legally or illegally
- People are drunk, hung over
- People are preoccupied by things outside of work
- People are preoccupied by things at work (e.g., personal conflict, layoff, merger, etc.)
- People are tired from long hours or moonlighting
- People dehydrated, low blood sugar
- People off their normal prescription medications or adding new medications
- People currently sick or not completely healed
- Injury not healed yet

Tools

- Wrong tools
- Broken tools
- Cheap tools
- Inadequate capacity of tools
- Improvised tools
- No tools
- Don't know how to use tools available
- Lack of PPE

Materials (e.g., parts, disposables, consumables, free issue, etc.)

- No material, lack of enough material
- Wrong material, but right part numbers
- Wrong material, wrong part numbers
- Slightly wrong material (i.e., make it fit or adapted to work)
- Cheap materials

Working conditions

- Bad lighting, such as too dark, wrong color for work
- Need for magnification
- Slippery
- Bad air, smells, chemicals
- Dusty
- Bad or inadequate work platforms
- Too hot or too cold
- High humidity
- Full sun
- Rain, snow, sand or dust storm
- Lightning, storms
- Graveyard shift
- Working at heights with fear of heights
- Other environmental factors

In Part 2, we descend from the 10,000-foot level of safety and start looking at specifics. These include techniques of job safety analysis (JSA), a look at specific nd statistics, and finally, shop inspections. Our goal is that everyone returns home in the same state that they arrived at work in.

Joel Levitt, *CRL, CPMM, is the President of Laser Focused Training. Mr. Levitt has 30 years of experience in many facets of maintenance, including process control design, source equipment inspector, electrician, field service technician, maritime operations and property management. He is a leading trainer of maintenance professionals and has trained more than 17,000 maintenance leaders from 3,000 organizations in 25 countries in over 500 sessions.*
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Taking Notice of the Telltale Signs

Tim Rice

Hindsight is the ability to understand an event or situation only after it has happened. How many times have you witnessed an asset failure and realized during the root cause analysis (RCA) investigation that there were indicators that a catastrophic failure was about to occur? Have we, as maintenance reliability practitioners, become desensitized in their ability to recognize the telltale signs of a failing asset? Is this being accepted as the new normal?

The RCA for an asset failure reveals obvious and not so obvious indicators that these events are likely to occur, with most of these indicators being well in advance to the event occurring. These indicators have signals, ranging from weak to strong. We accept these anomalies because they don't cause problems immediately or they haven't noticed that they caused problems in the past. They normalize them and accept them. They have become complacent. But, complacency has no place when talking about improving asset reliability. So, how can you remove the complacency around these leading indicators?

> "…Complacency has no place when talking about improving asset reliability"

To reverse this, organizations need to create a sense of unease, and not just when a major failure occurs, and not be complacent with the health of their assets.

Chronic unease is having discomfort and concern about the management of risks. It is a healthy dose of skepticism about decisions and inherent risks that remain. Simplified, it is the gut feeling that occurs when you are not quite confident in your decisions and your assessment of what is going on. It is the opposite of complacency.

Nothing ever happens out of the blue. There are always warning signs that people choose to ignore, either consciously or unconsciously. Once you start listening to what is happening around you, you will be surprised at just how much those little signs will tell you.

If the production team announces in a morning meeting that it broke the previous production record in the last 24 hours, what would you think? Initially, you might think, "Wow, that's great!" If you were to add a healthy dose of skepticism, you would think about how they managed to do this. What would come to mind?

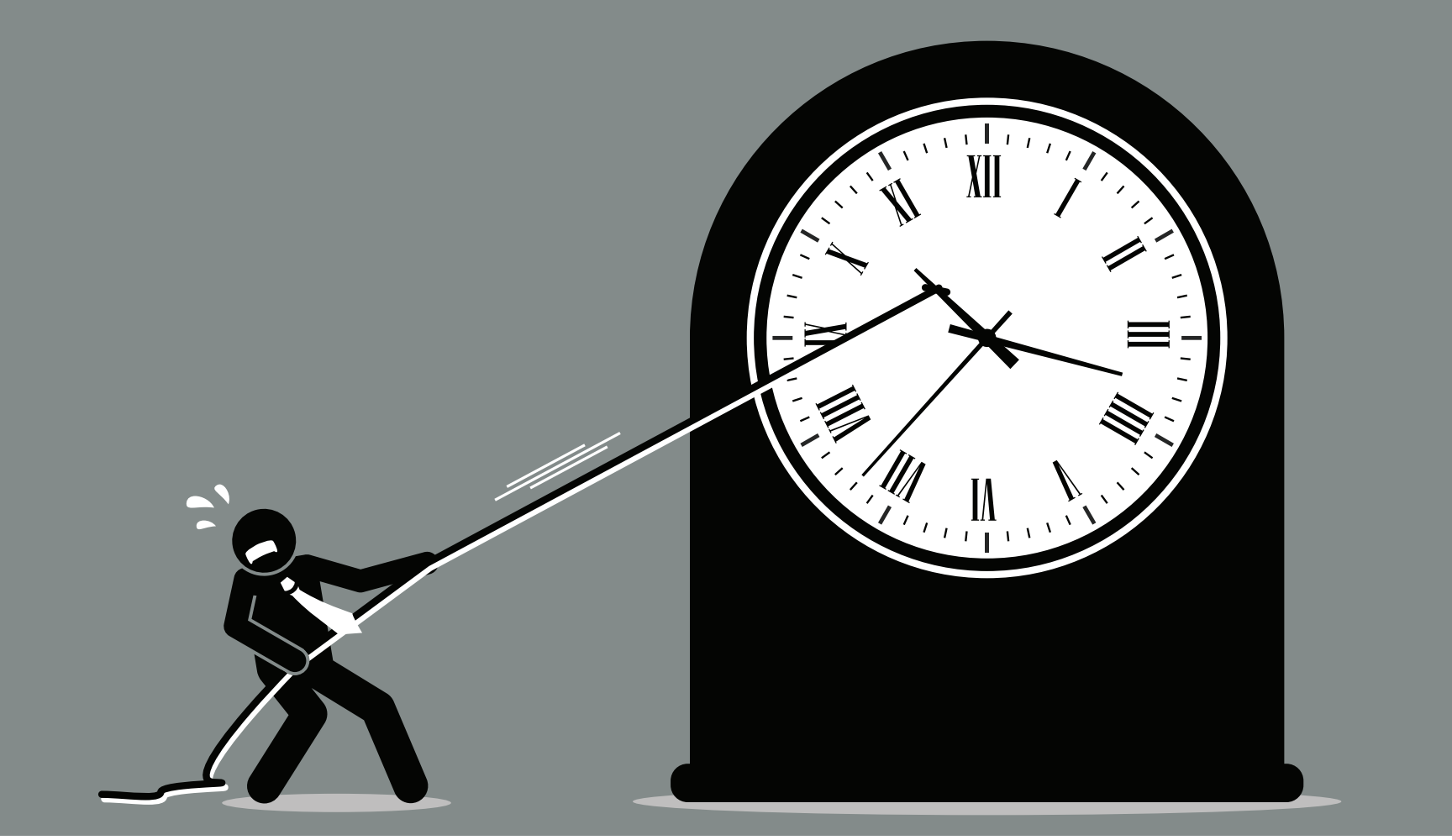
Did they operate the equipment within the guidelines of the operating strategy?

Did they place excessive stress on the system?

If they did place stress on the system, how has this affected the health of the equipment and its longevity?

Does this mean early equipment failures can be expected because of how they operated the equipment?

How comfortable do you feel now? Perhaps you are feeling a little uneasy about the health of your assets.



If you take a step back, prevention is the best cure. This can happen as early as the concept and design stage of a project, upon review and identification of a poorly performing asset, or when an asset has failed and potentially caused secondary damage.

> When prevention isn't possible, early detection and rigorous RCA processes are essential

Reliability advocates use risk assessment processes and tools to identify and mitigate potential failure modes before they occur. Identifying asset expectations and performance standards, what would cause them not to be met and what needs to be done to prevent them or mitigate their consequences if they did occur should be done at the design stage and utilized to help develop operating and maintenance procedures. A key aspect of this is identifying the level of risk the company is willing to take. This will help in understanding what is accepted as normal and what is identified as a deviance from the norm.

When prevention isn't possible, early detection and rigorous RCA processes are essential.

Early detection through condition monitoring and predictive analytics are ways for managing some of the failure modes you are not able to eliminate or ones you have not yet identified and thought were possible. If identified early enough, it will save a lot of heartache. Unfortunately, it's easy to fall into a trap where you think you did a great job identifying an issue early, but then you didn't investigate any further to determine its root causes. Unlike an event where you didn't identify an issue early on and it resulted in a catastrophic failure, you do not have to have a catastrophic failure in order to do an RCA. An RCA can be done when an asset or system is no longer able to meet its performance standard or is trending toward not meeting its performance standard.

For example, the onset of failure for a pinion bearing on a ball mill was identified through vibration analysis and confirmed with oil analysis. The issue was identified early so it could be planned and scheduled with little impact on the maintenance and production teams. However, there was no follow-up as to how this bearing got to be in this condition. Without a doubt, there would have been a lot of management noise and an RCA carried out to identify the root causes and actions taken to prevent reoccurrence if there was no early indication from vibration or oil analysis and the bearing catastrophically failed.

RCA identifies what you missed and what you need to do to prevent the undesirable event from happening again. It also can help identify other gaps and deviations that you were previously blind to. For example, an RCA investigation found that the flow and pressure instruments on a hydraulic system were routed incorrectly and reported to the wrong locations. They were not a cause for the failure, however, they are a deviance from the norm. They may result in a failure or not detect the onset of a failure later on, so it would make sense to fix them now.

Reliability-centered maintenance (RCM), failure mode and effects analysis (FMEA) and RCA are all tools reliability practitioners must work toward mastering. They provide the methodology for identifying what is holding a company back from achieving its desired level of reliability. Reliability practitioners need to utilize the reliability tools they have for identifying and managing risks.

A few more things need to happen. To regain control, reliability practitioners need to identify the things in their plants that have deviated from what was previously determined as normal. If no determination has been previously done, identify what is an acceptable standard for the business that can be classified as normal and what is not.

Reliability practitioners need to listen closer to the weak signals and that gut feeling that says something isn't quite right. Take action and look to validate or veto your gut feeling.

People tend to accept what they are willing to walk past. Summon the courage to slow down, take a step back and completely understand what is going on before quickly fixing the issue, pressing the reset button, giving the folks a pat on the back, returning to full production and forgetting anything ever happened. This is the hardest step. Companies have production targets to meet and to slow things down by being the skeptic will not sit well with a lot of people.

It is also difficult to do with limited resources, making it impossible to do an RCA for every event or when you feel uneasy. Pick your battles, but grasp every opportunity you get.

It's no good wondering, "If given the option to go back in time, what could I have done to prevent these events from happening?" Time travel is not possible yet, so take the time now before it's replaced with hindsight.

Tim Rice *has 12 years working in the reliability realm, with a majority of that time in mining and processing with Rio Tinto's Iron Ore Operations in Western Australia, and their Copper Operations in Utah. Tim's interests are in driving a whole of life asset management thought process and how reliability thinking can drive gains for all industries.*

WONDERING HOW TO ALIGN YOUR RELIABILITY PROGRAM WITH YOUR CMMS?

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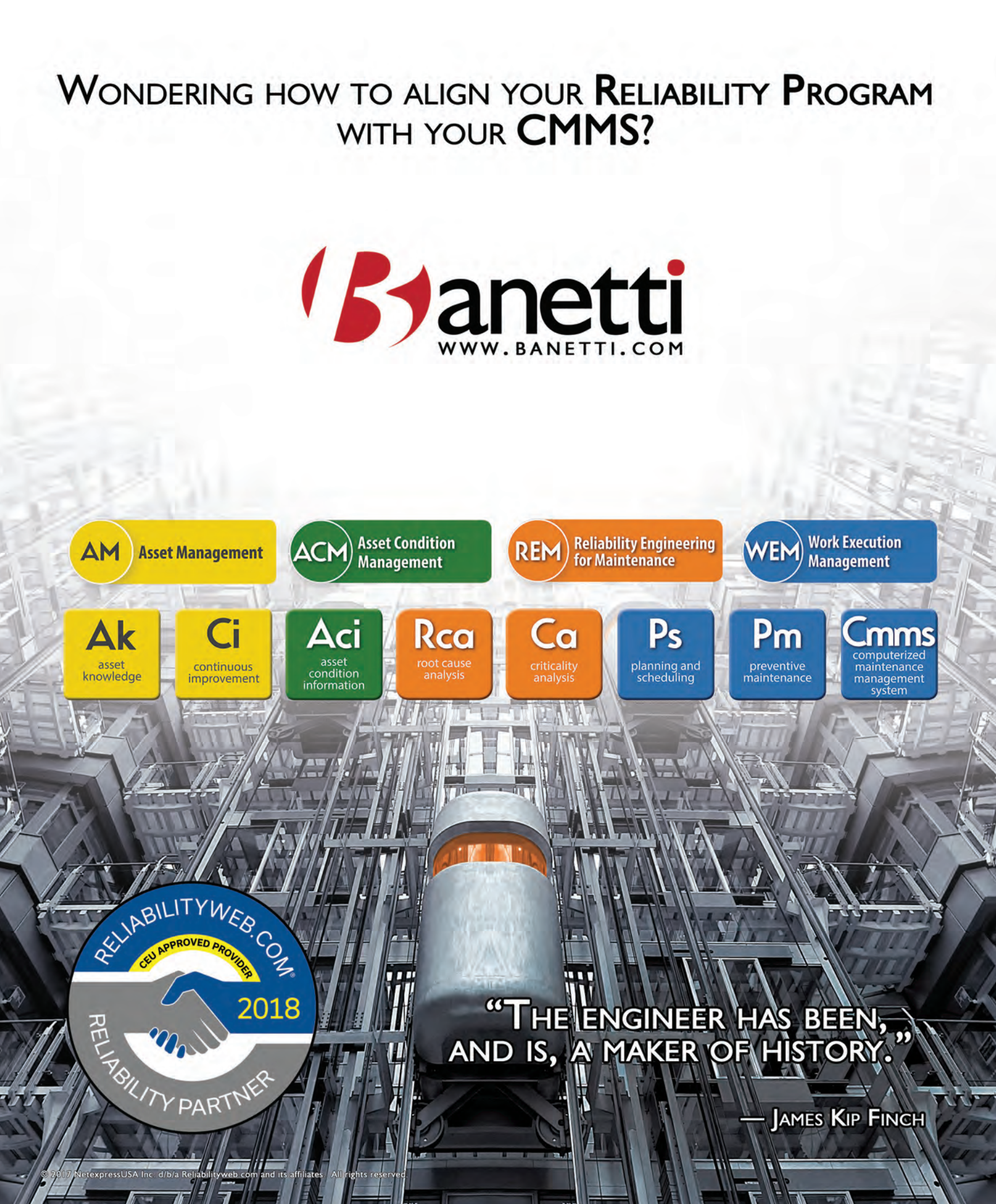

WHY ONLINE OIL QUALITY MONITORING IS A BEST PRACTICE FOR RELIABILITY PROGRAMS

Stephen Steen

Fluid monitoring programs have long been a challenge within the reliability and operations community. For example, oil samples provide a significant amount of value in diagnosing root causes, the presence of contaminants and the measurement of oil quality. Yet, for these programs to be implemented properly, the samples must be taken at intervals more frequently than assets or personnel are available. This leads to a reliability program lacking the information required to meet reliability targets. Best in class reliability programs have found success addressing this challenge by implementing online fluid or oil monitoring programs.

What Is Online Oil Quality Monitoring?

Online oil quality monitoring provides real-time monitoring of oil condition. Online oil monitoring systems have come a long way in recent years. Early systems relied on dielectric sensors and chip detectors to provide oil health and wear debris monitoring capabilities. Viscometers, water in oil, optical particle counters, inductive coil wear debris monitors and other sensor technologies were later introduced, proving some insights into general oil quality. However, they were not sensitive enough to many of the oil health properties that reliability programs were looking for.

These sensors helped establish the value of online oil quality monitoring, but more recent sensor technologies have improved sensitivity, range of detection and correlation with oil lab samples currently relied upon for decision-making. Modern inductive coil sensors are now twice as sensitive as the previous generation's sensors, allowing for a wear debris detection size roughly twice as small for the same bore diameter. The latest oil quality sensors, using an impedance spectroscopy technique, are now capable of correlating or directly measuring multiple critical aspects of the oil, such as overall health, oxidation, total base number (TBN), contaminants (e.g., water, soot), etc. These sensors are often bundled together as single offerings and/or packaged with other technologies, such as vibration, smart Industrial Internet of Things (IIoT) devices, data science, etc.

Challenges with Off-Line Oil Sampling

Oil quality and wear debris are typically not static, consistent, or slow changing within assets. Changes typically revolve around events, especially when transitioning from healthy to non-healthy states. Wear debris is lost in bursts over a period of time and is quickly filtered out by the filtration system. Whether or not the fault is detected, depends on when a sample is taken (see Figure 1). Contamination events or changes in oil properties, such as water contamination or additive dropouts, also occur in time periods much shorter than standard oil sampling frequencies. This often results in undetected fault

> "Online oil monitoring systems have come a long way in recent years"

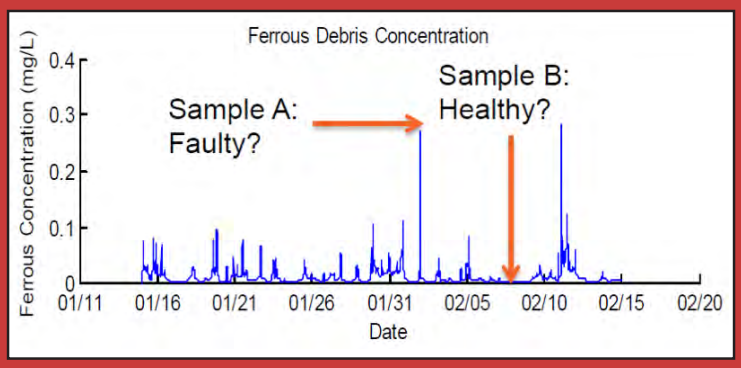

Figure 1: Example of wear debris measurements over time vs manual sampling

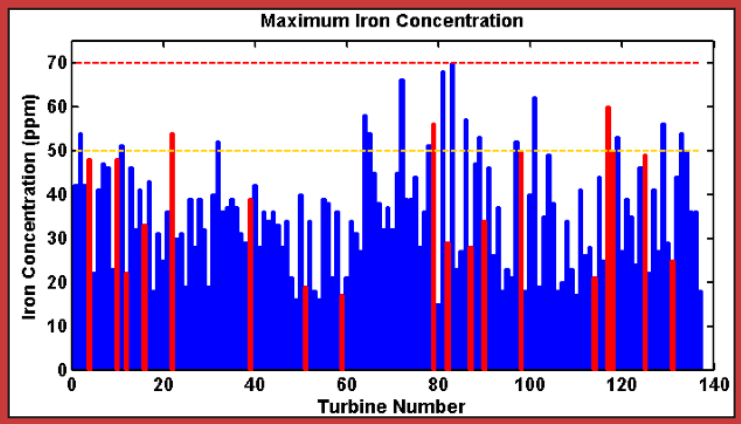

Figure 2: Maximum iron concentration with recommended warning (yellow line) and alarm (red line) limits

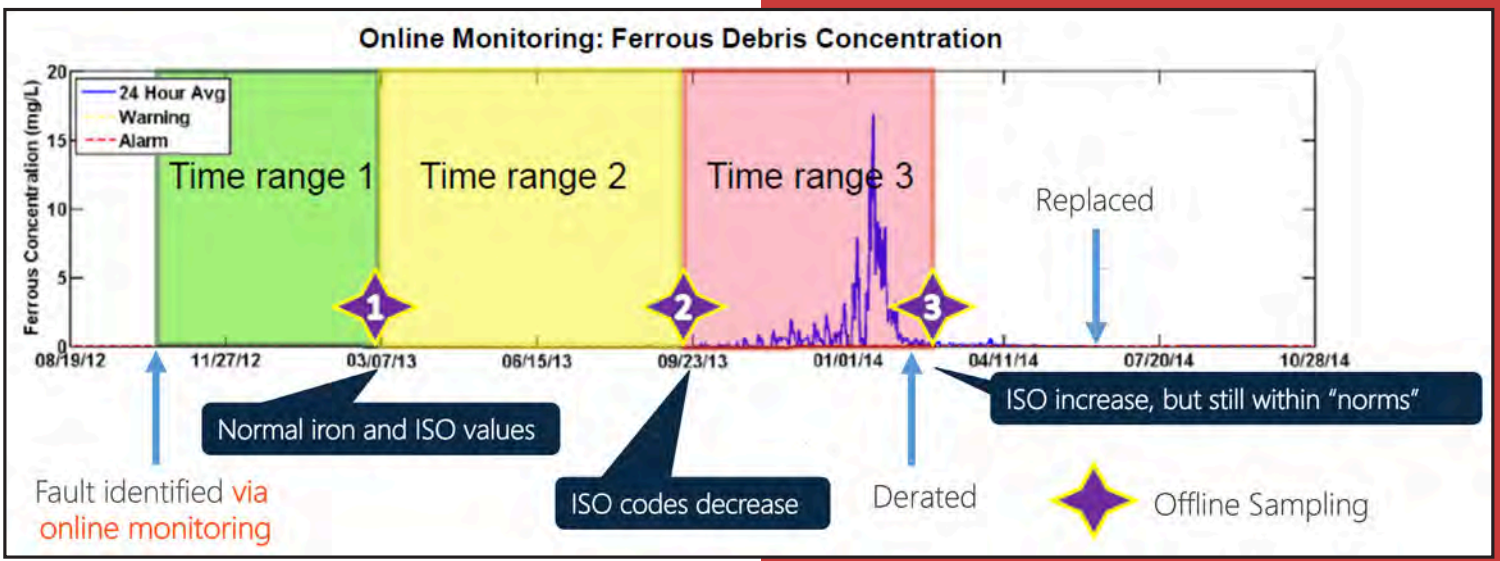

Figure 3: Wear debris timeline of a bearing raceway axial crack fault within an industrial gearbox

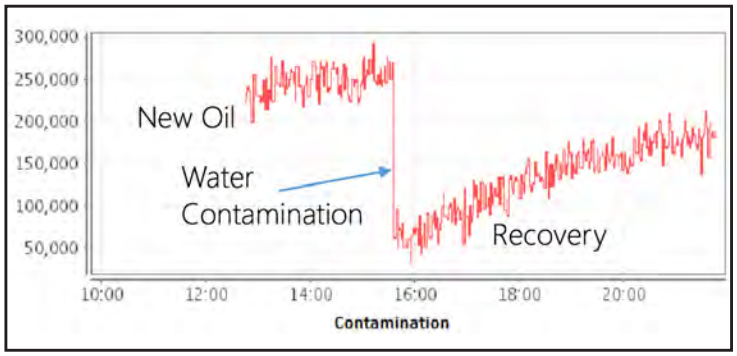

Figure 4: Water contamination event

conditions, causing further damage that, in many cases, cannot be reversed and may lead to catastrophic failure.

Where Is the Wear?

Wear debris is one of the best indicators of asset health. A study commissioned on a fleet of 137 industrial gearboxes examined the previous two to four years of oil samples, along with fault history. Figure 2 summarizes the findings with iron concentrations color coded by known healthy (in blue) and faulty (in red) gearboxes. Using traditional approaches, one would expect to find higher iron concentrations within faulty gearboxes. However, the study showed a lack of utility from these samples for determining asset health.

Online debris monitoring has proven itself as a perfect solution. During a 14-month timeline, as shown in Figure 3, periodic oil samples taken for analysis indicated no significant findings. In fact, the reported oil cleanliness actually exhibited improvement, based on International Organization for Standardization (ISO) cleanliness codes, as concentration levels reported by the online debris monitor increased. It is important to note that although the peak debris concentrations were increasing, the momentary concentrations remained highly variable.

Online monitoring of metallic wear debris enables these events to be observed and tracked in real time, allowing for adjustments in operation to prevent catastrophic failure and extend operating life until a repair or replacement can occur. Online wear debris monitors provide the additional benefit of allowing the analyst to correlate wear debris data with operational data to pinpoint the cause of fault progression, as identified by debris concentration spikes. In the Figure 3 use case, the asset was derated until maintenance could be performed.

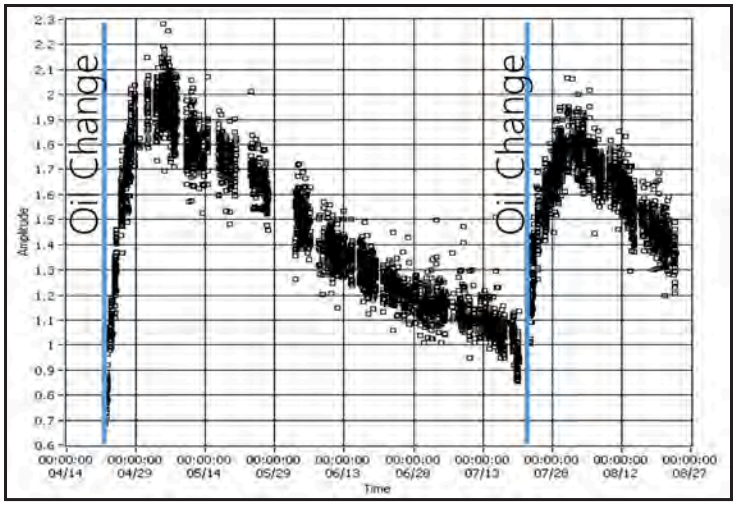

Figure 5: Overall oil quality

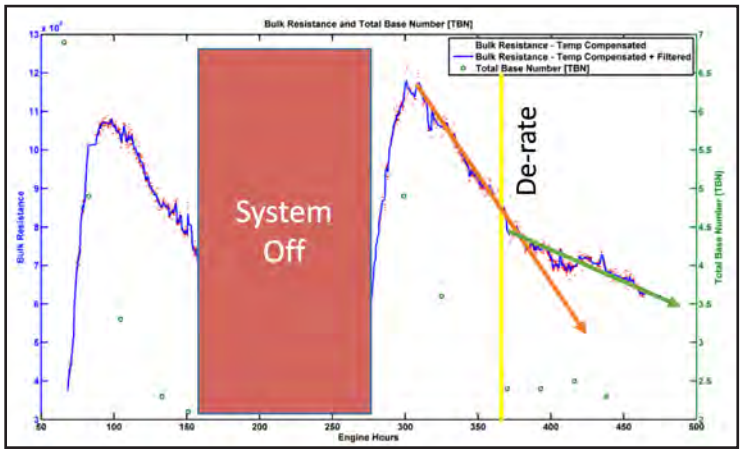

Figure 6: Oil life extension example

Oil Heath

Most of the value from oil samples is centered on oil health itself. Key properties and contaminant levels, such as oxidation, TBN, total acid number (TAN), additive packages, viscosity, water, fuel, soot, etc., are all used to judge the remaining useful life (RUL) and identify preventative and life extending actions. Just as with wear debris, many of these are event driven. Events, such as water and fuel contamination, happen within minutes and can be missed hours later, as shown in Figure 4.

Decision-making between oil changes, bleed and feed, top offs, etc., is often difficult because trending of the oil's critical properties and RUL estimation are not available. With online oil quality monitoring, many aspects of the oil can be trended and RUL estimated. In Figure 5, online oil monitoring allows for oil change optimization based on actual oil quality measurements, as compared to traditional time-based changes. With traditional time-based oil changes, oil is almost always exchanged too early or too late. Real-time monitoring allows for optimized oil change intervals for each asset.

Utilizing this data, RUL can be estimated and life extension actions can be optimized based on operational needs. In Figure 6, the asset was derated as a way to extend oil life by almost 100 operating hours. Actions, such as a bleed and feed, can be measured and overall oil life extended through many tools available to reliability teams.

Conclusion

Periodic off-line oil analysis provides significant value within reliability programs, but often it is not a sufficient tool on its own for meeting the program's reliability goals. Online oil quality monitoring systems have proven to be critical, cost saving tools, providing the data necessary to make optimal maintenance decisions.

Many industries, such as energy, mining, rail, marine, etc., have all started adopting an online oil monitoring program and it is expected such programs will become standard practice over the next few years. With new sensor technologies, the payback period for investment is usually less than one year, making them one of the best investments for any reliability team looking to adopt the latest best practices.

Stephen Steen *is VP of Industrial IoT for Poseidon Systems, LLC. He has diverse experience in reliability technologies, such as CM, PHM, ML, AI, and fluid analysis spanning automotive, ag, heavy equipment, and energy. Stephen's current role is focused on working with customers with adopting state of the art IoT fluid solutions.*
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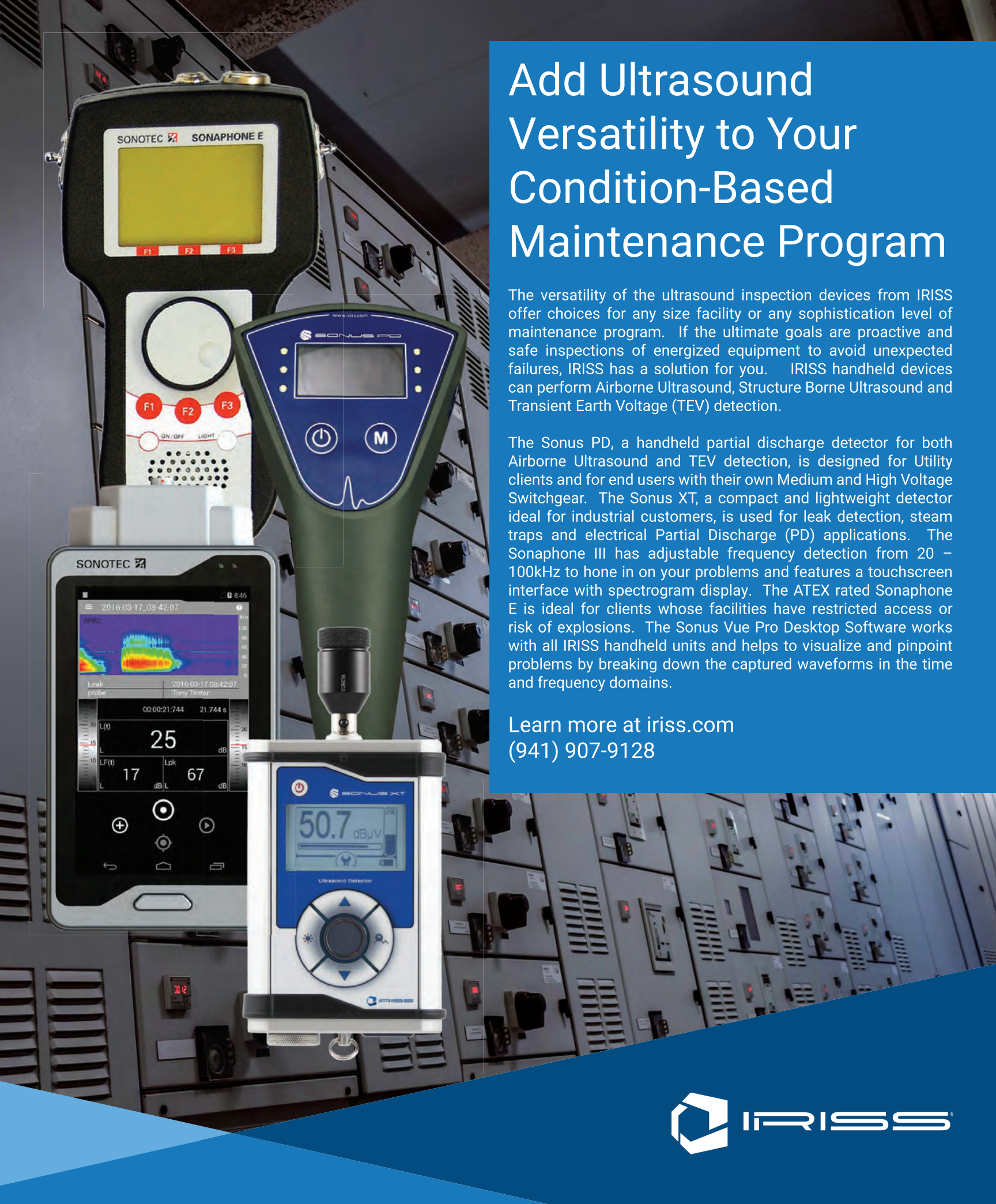

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IS IT TIME TO EVALUATE YOUR REVERSE LOGISTICS PRACTICES?

Tom DeVroy

Reverse logistics is becoming an integral part of operations for manufacturers, distributors and service providers so they can minimize lost revenue when moving products, parts and subcomponents back into inventory. Recent Statista research shows that returned goods cost $246.3 billion per year in North America and span customers, service organizations, supply chains, receiving departments, and even repair depot operations or subcontractors. For organizations to minimize this lost revenue, they must assess their approach to reverse logistics.

Here are three common reverse logistics scenarios. If any of these ring true for your organization, then it may be time to evaluate whether your reverse logistics strategy is costing you time, money and customer satisfaction.

Recent Statista research shows that returned goods cost $246.3 billion per year in North America

1. Do you deploy technicians and support assets in the field?

The field service process alone includes multiple reverse logistics steps. The technician pulls a component out of a repairable piece of equipment at the customer's site and replaces it with a part out of truck inventory. In a situation where the technician does not have a spare part, an inventory order needs to be placed. The field technician must have complete visibility as to whether the part is under warranty or if the customer is entitled to special pricing as a result of a contractual commitment.

Without an integrated end to end service platform, you are relying on a technician to communicate with separate field services, reverse logistics, warranty management, contracts and installed base systems to get the answers he or she needs.

Obviously, some type of communication between field service and reverse logistics software is necessary, if only to prevent losing track of parts or components pulled from equipment in the field. But in these situations, there needs to be a seamless way to track whether or not the part is going to be repaired, who owns the item as it enters the reverse logistics process and whether the part or repair is billable. Then, the part must be tied with a return material authorization (RMA) through the original field service order.

Regardless of whether an environment is focused entirely on reverse logistics or in the field, companies should expect their software platform to handle knowledge transfer. A technician in the field should be able to access tutorials on various repair processes, which, in turn, makes those with less experience more productive while increasing first-time fix rate. Reverse logistics software can now embed in the workflow detailed videos designed to walk a worker on the repair bench through the workflow. The result is increased productivity and putting knowledge into the hands of technicians where and when they need it.

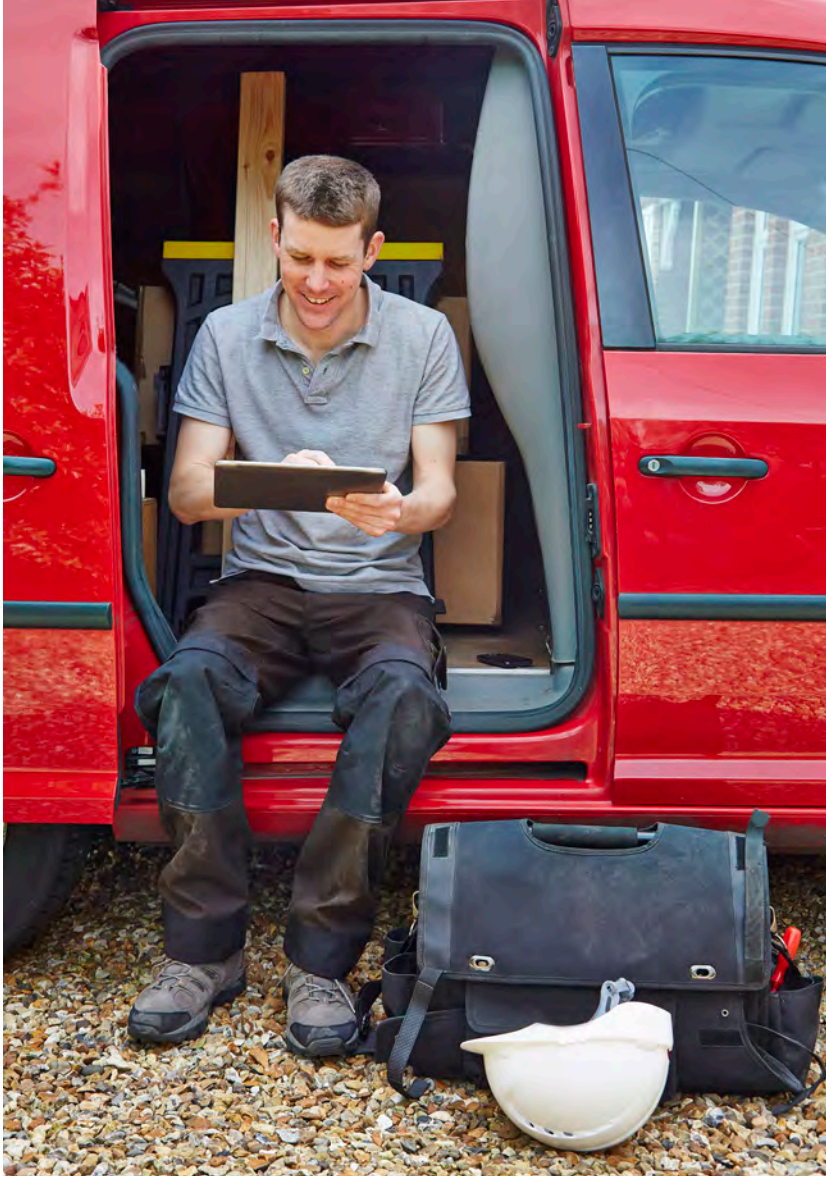
2. Do you rely on an intricate supply chain?

In most organizations, the reverse logistics process can be delineated by new products and after use returns. In an after use environment, the reverse logistics process involves multiple stakeholders. This means that a software product used to manage this value chain must encompass all, not some, of these stakeholders. Here's why:

The customer service department generally authorizes the service and repair work through the call center or, increasingly, digital customer portals, chatbots, or even social media.

If a replacement part is due for shipment, the customer service representative checks inventory availability and may have to contact purchasing. If the product replacement requires a build order, the customer service representative may have to involve manufacturing or supply chain departments. If the defect is being received for repair, logistics needs to be engaged to receive the defect and route it for repair. Each of these stakeholders has a role to play and each has its own specific process to follow. This gets even more complicated when there is a field service component to the reverse logistics process.

Throughout this process, there is a set of rules that must be followed. These rules cover everything, such as the asset or product itself, which parts are sent to which repair facility or depot, whether the part is covered by warranty or contract entitlement and whether a customer has a replacement for the part in inventory or you need to ship one, to name a few. Clear communication, starting with the task of defining processes to ensuring the correct business process is followed, perhaps with a configured workflow, is very difficult without some enterprise reverse logistics and repair software. Check yours out.



3. Are you outsourcing elements of your field service operations?

Combining reverse logistics with field service is challenging enough when relying on your own employees. But, more and more organizations outsource field service work to subcontractors for specific tasks or in peak demand times. Subcontractors introduce several new logistical steps into a reverse logistics process. Reverse logistics software needs to account for multiple subcontractor types and reimbursement policies in order to manage the complex situations caused by subcontracting.

First, in order to delegate tasks to subcontractors, you need to establish their availability given time constraints and ensure they have the parts and expertise needed for the job. The contractor must provide a not-to-exceed cost figure, receive a purchase order and perform the work.

But what if the subcontractor removes a part from a customer's equipment for return? This is where things can get very, very complicated. If part A is replaced with part B, what happens to part A? The subcontractor may send an invoice and want to get paid for the part used out of its inventory. Depending on the arrangement, the subcontractor may get paid for the new part only when you receive the returned original part. Or, if you have a strong relationship and have built trust over the years, the subcontractor may be paid once a material return is authorized or when shipping confirmation is

received by the contractors. All of this can change by individual subcontractor, customer, product line, or geography.

If the work and part are covered by a warranty, the subcontractor bills the vendor for the part. But, if the part and work is out of warranty and the subcontractor owns the relationship with the customer as an independent service provider, you, as the reverse logistics organization, may only get back parts if there is a core credit involved.

LOOKING BACK TO GO FORWARD

It's clear that reverse logistics operations span a complex network of players, parts and, in some cases, organizations. If you are encountering these common challenges on a regular basis, it might be time to reassess your approach to reverse logistics as a discipline.

The next step is to see how enterprise software can alleviate reverse logistics pain points. The right solution should be able to help your organization handle large supply networks and reduce costs.

Tom DeVroy *is Senior Product Evangelist, North America for IFS. Tom has over 30 years of experience in high-tech service operations, including working with hardware, software and consulting firms, as well as premier global service organizations like Ericsson, DHL, Xerox, and Ingenico. www.ifsworld.com/us/*

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Using Quantitative Fault Tree Analysis Based on Method of Cut Sets to PREDICT FAILURE

"…Fault tree analysis (FTA) is being widely used in any type of study that requires quantifying frequency or probability"

Originally, the intent of fault tree analysis (FTA) was to assess equipment reliability in the space industry. Nowadays, FTA is being widely used in any type of study that requires quantifying frequency or probability, or just for deductive representation of events that, when triggered, result in an occurrence of a top event. This article summarizes FTA quantification using the method of cut sets (MOCUS) and describes the methods of Birnbaum, criticality and Fussell-Vesely.

Background

FTA can be developed as far down as the analyst requires. The analyst must have a logical mind and the ability to understand and visualize the logic structure and the interactions of operability, chemical, electrical, mechanical, structural, control systems, subsystems, etc. It is also essential to know the client's desire to perform an FTA, without falling into the trap of providing an excessive amount of details, which can be useless for the client.

The FTA should take the exact level of detail needed, which is normally the equipment level. The internal design of a piece of equipment has a very low chance of redesign and requires specific expertise to assess internal components. Therefore, exploring detailed components may not always be the best approach, especially during the initial engineering stages. Figure 1 shows a simple example of a general FTA and its Boolean equation.

According to the American Institute of Chemical Engineers Center for Chemical Process Safety (AIChE/CCPS), these assumptions should be considered during FTA development:

- All failures are binary, meaning two states: operating or failed;
- Instantaneous transition between each state, meaning no delays;
- Statistically independent events;
- Constant failure rate;
- Equipment after a repair is as good as old, meaning after a repair, the equipment will be exactly at the same state before the failure occurred; there is no renewal process.

$$P(Q) = P(A) + P(B) - P(A \cap B)$$

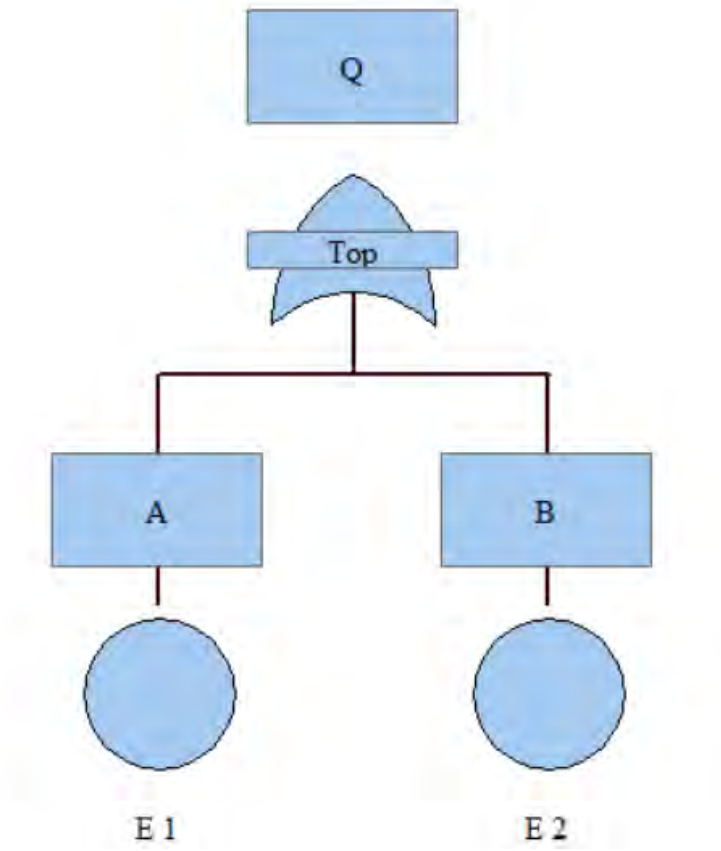

Figure 1: Simple FTA example

Birnbaum, Criticality and Fussell-Vesely Importance Measures

One of the desired outputs while performing an FTA is to identify event improvements that would maximize the performance of the system. The three importance measure methods typically used are Birnbaum, criticality and Fussell-Vesely. These methods allow for basic events identification with the highest importance measure value. The differences between the three are:

- Birnbaum is based on the top event probability variation between a scenario where a basic event has failed and another scenario where the same basic event has succeeded.
- Criticality is based on the probability that the top event is a result of the occurrence of a specific basic event.
- Fussell-Vesely is based on the probability that an event, not necessarily critical, has contributed to the top event's probability, based on MOCUS.

Method selection should consider the following:

- Birnbaum: Improvement efforts to increase availability are similar and can be applied to any basic event;
- Criticality: Improvement efforts can be applied only to the most basic critical events or when the objective is to prioritize maintenance efforts;
- Fussell-Vesely: When the objective is to minimize the contribution of each basic event.

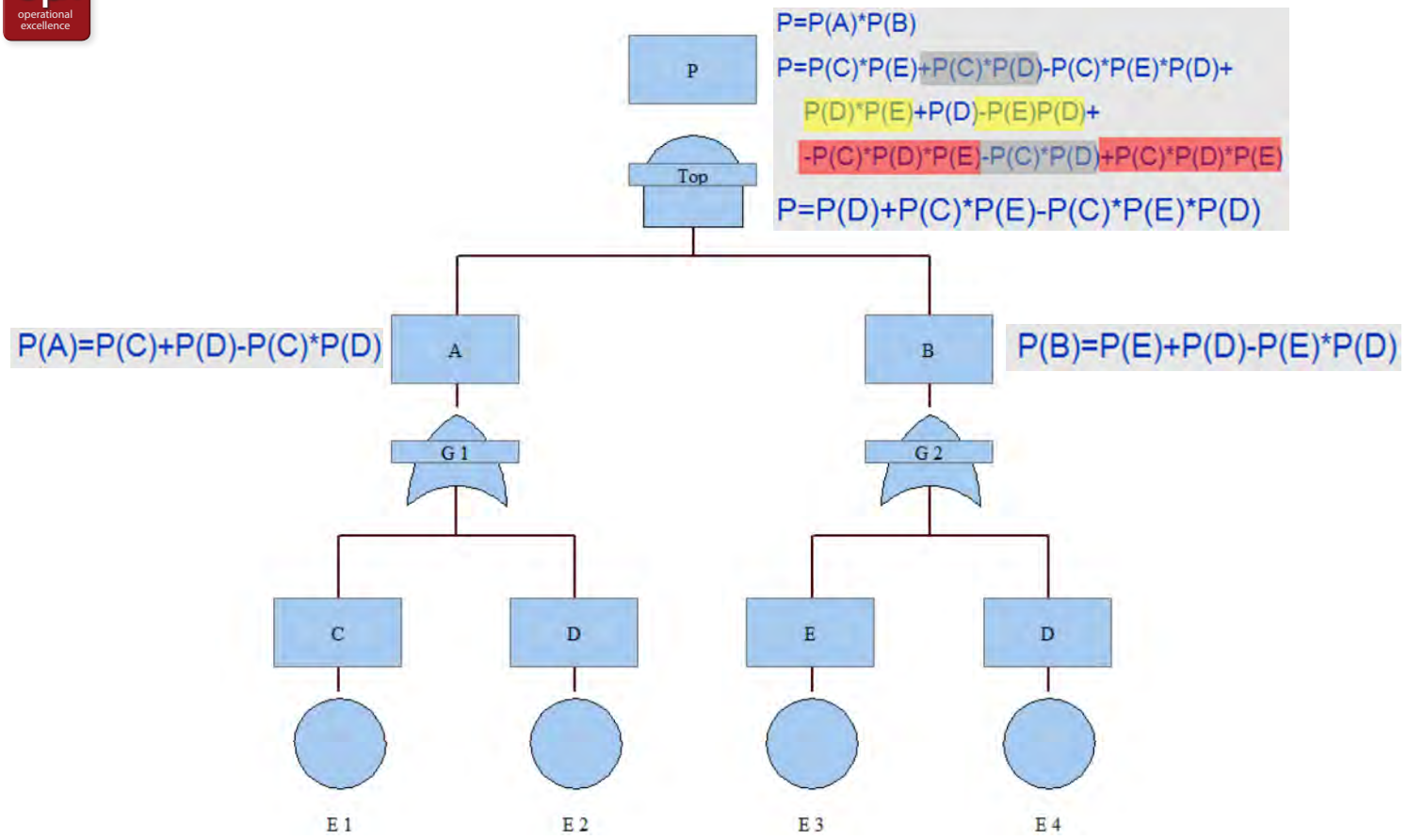

Figure 2: FTA example with cut sets

Cut Sets and Minimal Cut Sets

A cut set is a set of basic events whose occurrence would trigger a top event. A minimal cut set is a combination of basic events that trigger the top event. Minimal cut sets are used to calculate probabilities of events and, consequently, the top event's probability or frequency. The probability of the top event is calculated based on the probability of the Boolean sum of the minimal cut sets' probabilities. The cut sets for the previous Figure 1 are represented by {A} and {B}.

The following sections exemplify the cut sets and minimum cut sets calculation for the FTA provided in Figure 2, which includes the Boolean equation solution.

Definition of the Cut Sets

The top event P is triggered if the following combination of events occurs:

- C and E occur → {C, E}
- C and D occur → {C, D}
- D and E occur → {D, E}
- D and D occur → {D, D}
- C, D and E occur → {C, D, E}
- C, D, E and D occur → {C, D, E, D}

Using the correct representation of cut sets, Boolean simplification (numbers 4 and 6 in the following list) and super cut sets would look like this:

Combination		Cut Sets		Super Cut Sets		Minimum Cut Sets
1 {C, E}	→	{C, E}	→	{C, E}	→	{C, E}
2 {C, D}	→	{C, D}	→	{C, **D**}	→	{D}
3 {D, E}	→	{D, E}	→	{**D**, E}		
4 {**D**, **D**}	→	{**D**}	→	{**D**}		
5 {C, D, E}	→	{C, D, E}	→	{C, **D**, E}		
6 {C, **D**, E, **D**}	→	{C, **D**, E}	→			

Top Event Probability Based on Minimum Cut Sets

The top event probability is calculated as follows:

1. Combine basic events within minimal cut sets using an AND gate.
2. Combine minimal cut sets using an OR gate.

{D} → $P_{\{D\}} = 8.0E\text{-}01$

{C, E} → $P_{\{C,E\}} = P_{\{C\}} * P_{\{E\}} = 9.0E\text{-}01 * 7.0E\text{-}01$

Top Event → $P_{\{P\}} = P_{\{D\}} + P_{\{C,E\}} - (P_{\{D\}} * P_{\{C,E\}})$

Event Sensitivity

Event sensitivity using Birnbaum, criticality and Fussell-Vesely is used to evaluate the basic event criticality to the top event probability. This is performed following these tasks:

1. Calculate the top event frequency assuming the one basic event has completely failed (P=1).
2. Calculate the top event frequency assuming the one basic event is operating (P=0).

Table 1 – Event Sensitivity						
Basic Event	Probability	Top Event Probability Assuming Basic Event Completely Failed (P=1)	Top Event Probability Assuming Basic Event Is Operating (P=0)	Birnbaum Factor	Fussell-Vesely Factor	Event Sensitivity
D	8.0E-01	1.0E-00	6.30E-01	0.37	0.296	54.01%
C	9.0E-01	9.4E-01	8.00E-01	0.14	0.126	22.99%
E	7.0E-01	9.8E-01	8.00E-01	0.18	0.126	22.99%

3. Repeat task numbers 1 and 2 for each basic event.
4. Calculate the Birnbaum factor, which is obtained from the difference in results in task numbers 1 and 2.
5. Calculate the Fussell-Vesely factor, which is the product between the failure rate of the basic event and the Birnbaum factor.
6. Normalize the Fussell-Vesely factor to obtain the event's sensitivity.

Table 1 shows event sensitivity results considering the probability values displayed in the previous section.

The event sensitivity assessment shows that basic event D has the highest significance (54.01 percent) to the top event's occurrence, while basic events C and E have nearly half the significance (22.99 percent) when compared to event D and both C and E contribute equally to the top event's occurrence.

Cut Sets Criticality

Cut set criticality evaluates the influence of each cut set in the top event's probability. This is performed following these tasks:

1. Calculate the failure probability of each cut set.
2. Calculate the proportion between the failure probability of each cut set and the top event.

Table 2 shows the results for the cut set criticality.

Table 2 – Cut Set Criticality			
Minimal Cut Set	Probability of Failure of Minimal Cut Set	Top Event	Cut Set Criticality
{D}	8.0E-01	9.26E-01	86.39%
{C,E}	6.30E-01	9.26E-01	68.03%

The cut set's criticality assessment shows that the minimum cut set {D} has an 86.39 percent criticality, while the minimum cut set {C, E} is 68.03 percent.

Advantages of MOCUS

An FTA's top event can be calculated considering different methods, such as Boolean mathematics, Monte Carlo simulation, Markov chain, MOCUS, etc. Depending on the complexity of the FTA, Monte Carlo methods might take excessive amounts of effort to achieve convergence. Boolean math might become too complex to solve and Markov chain might not be adequate to consider all types of failures.

As demonstrated, MOCUS is a deterministic solution that requires less computer efforts to calculate the top event's probability or frequency, thus reducing error probability and taking less time to obtain the results.

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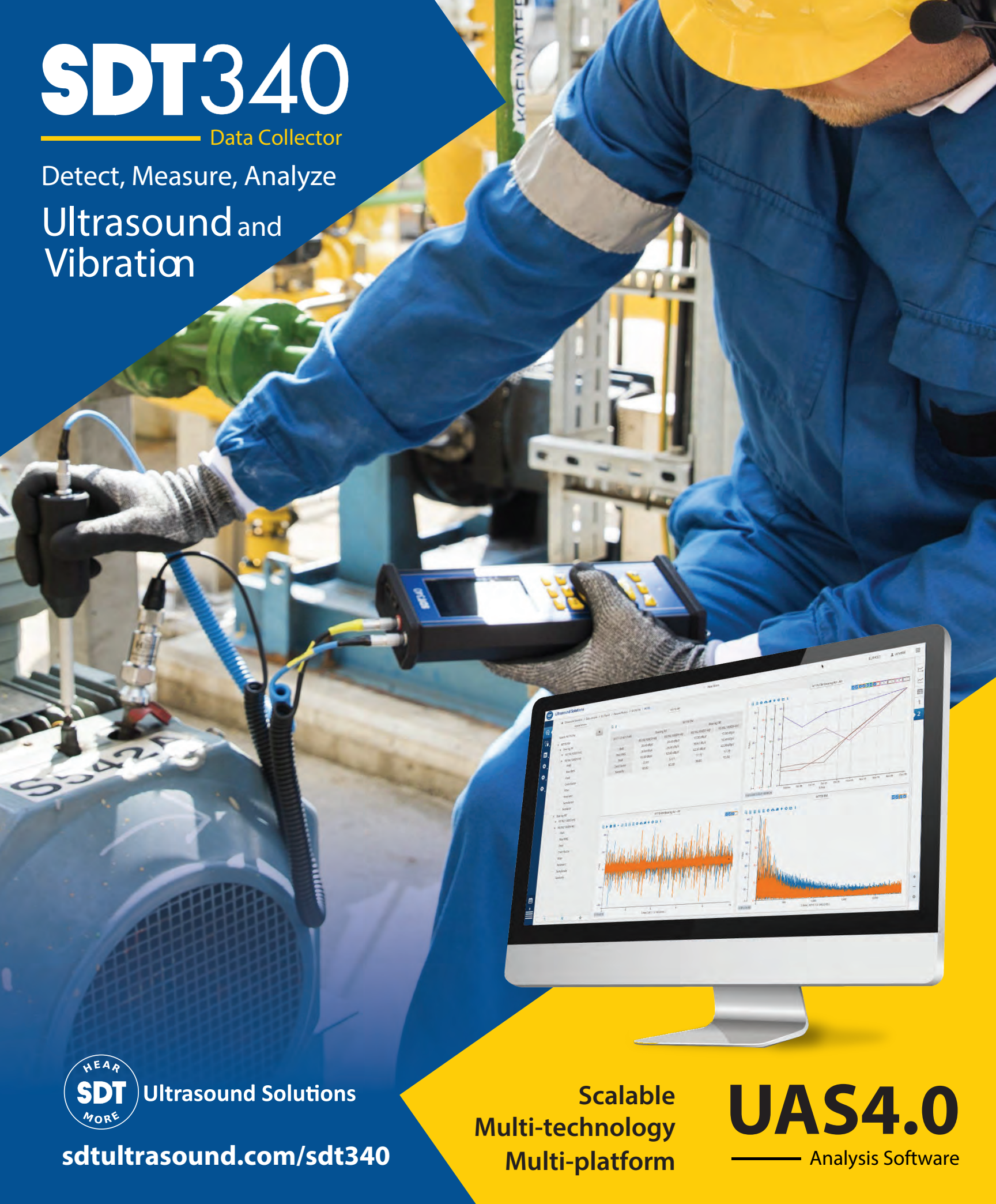

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ASSET STRATEGY MANAGEMENT:

THE MISSING PIECE IN THE ASSET MANAGEMENT PUZZLE

Jason Apps

When it comes to asset management, many organizations continue to be hampered by high costs, a high volume of unplanned failures and, ultimately, an unacceptable level of risk. The reason? There's a piece missing in their asset management puzzle.

That piece is called asset strategy management (ASM). It's a simple, but vital, component of any asset management or reliability focused organization.

The three questions you should ask to see if ASM would be of benefit to your organization are:

- Do you know if all the strategies in the enterprise asset management (EAM) system are currently being executed and at what set interval? If not, do you know what level of risk the organization is being exposed to?
- Do the strategies in the EAM system align to the agreed strategies or best in class strategies on all assets? If not, do you know what level of risk the organization is exposed to?
- Does the organization's maintenance plan cover all the basic equipment care fundamentals and statutory or regulatory requirements on all assets?

Answering "no" to one or more of these questions sends a clear signal that your organization would gain immediate value from implementing ASM.

Delivering High Reliability

Once an asset has been selected and installed, its ongoing reliability is determined by two things: how it is operated and how it is maintained.

Putting operations aside, how you maintain an asset directly impacts its performance. And, to decide how and when that maintenance is conducted,

"…An asset's performance all starts with a maintenance strategy"

you need a strategy. Hence, an asset's performance all starts with a maintenance strategy.

At the most basic level, there aren't many options for setting a strategy. You either decide to execute a task at a regular interval to prevent or predict a failure or you monitor the asset for specific failure mechanisms, with an alarm or alert triggered if remedial action is needed.

It sounds easy enough. Yet, many organizations will set a strategy in the first instance – upon installation of the asset – and leave it at that. There's no ongoing management of that strategy. The implication of this is that over time, the strategy may no longer be appropriate for how the asset is being

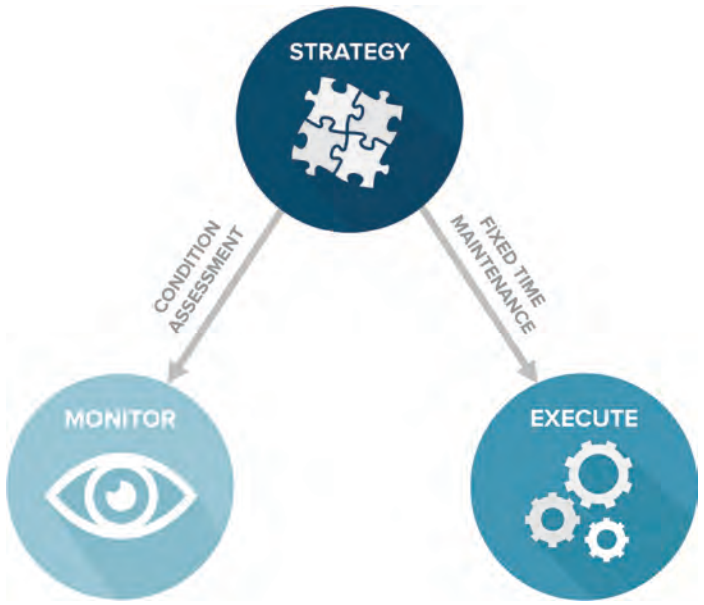

Figure 1: The two strategy options – fixed time maintenance or a predictive task/monitoring

used. Or, someone may change the strategy without proper review or justification. Think about it. If someone goes into the EAM system and changes an interval of one of your maintenance plans without any review – and it turns out to be an inappropriate change – imagine the risk to your business. Yet this happens on a daily basis in most organizations.

Since strategy is the single biggest driver of asset performance, it must be managed effectively over time to ensure it remains optimal for the life of the asset.

The Process to Realize Reliability

Enter ASM, a process that integrates with work execution management, but with a very different objective. Whereas work execution management is all about the efficient execution of work, ASM is all about making sure you are executing the right work all the time.

Many organizations have unsuccessfully tried to tackle ASM within their work management process. The reason this approach doesn't deliver results is that ASM and work management have very different objectives and, there-

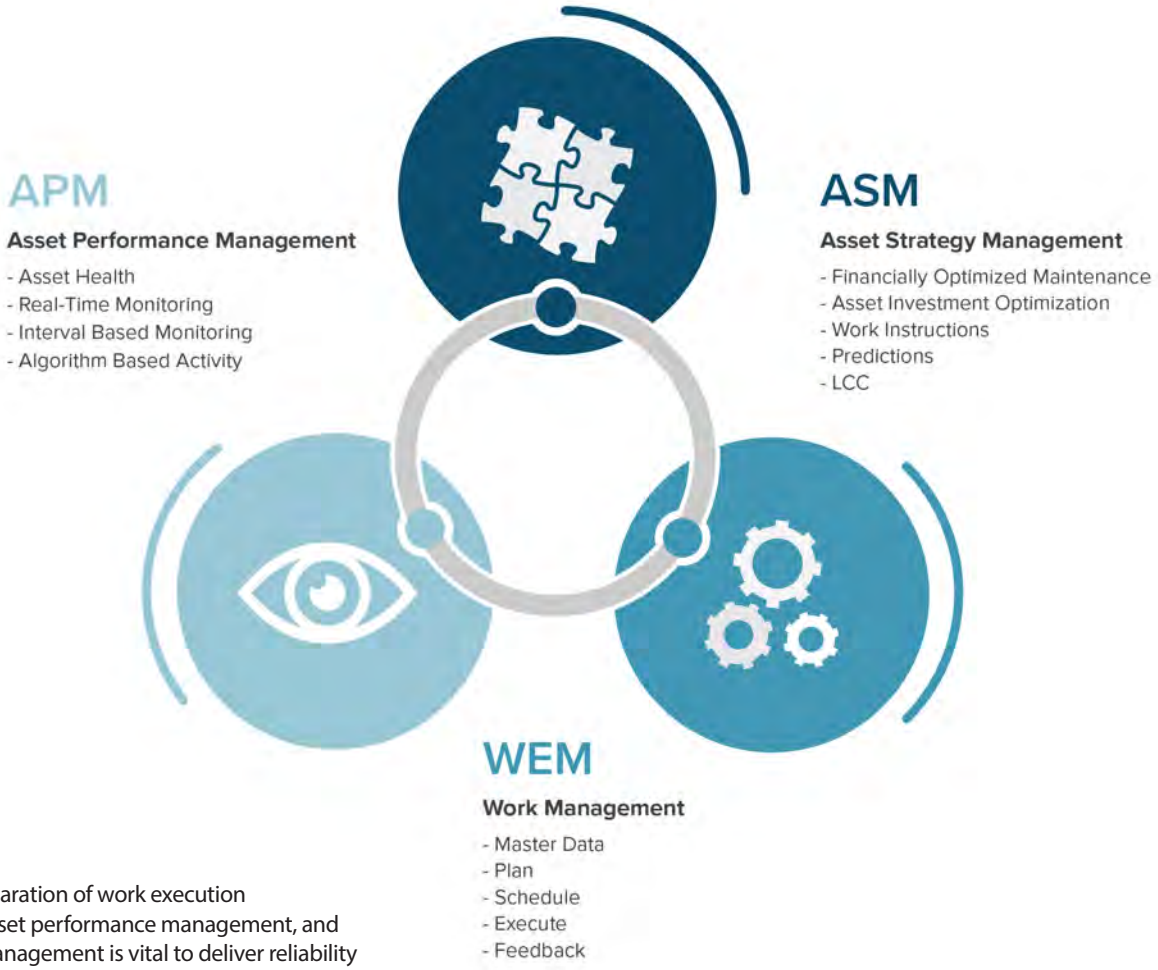

Figure 2: The separation of work execution management, asset performance management, and asset strategy management is vital to deliver reliability

fore, require entirely different triggers, resources, data and technical solutions to be effective.

Beyond delivering optimal performance and management of risk on an ongoing basis, ASM also delivers benefits that are currently out of reach for many organizations:

- A consolidated, standard, component-based maintenance strategy that drives consistency of strategy, but allows for local operating context;
- A consistent master data build for all plans and materials supporting execution;
- Identification of undesirable risk;
- Automatic detection of where to focus improvement initiatives;
- Rapid deployment of relevant strategy changes across the entire asset base.

Organizations typically see an immediate uplift in performance and reduction in costs upon implementing ASM. The clarity generated from an ASM program also can improve work management because the objective of the work management process becomes singular and clear, allowing the organization to do work more efficiently.

How Asset Performance Management Fits In

Some organizations may be familiar with asset performance management (APM), which is focused on maintaining asset health and condition. APM manages the ongoing performance of assets by monitoring current conditions or current performance data and alerting the organization when an intervention is required to prevent an impending failure.

Types of monitoring range from a periodic assessment by a technician to multi-parameter continuous monitoring devices. However, the intent is essentially the same: to understand the condition, determine if that condition is deteriorating and identify any impending failure so rectification can be scheduled into the workflow. And, in doing so, avoid that failure.

Recently, the cost of technologies that support online monitoring of asset operating parameters has fallen, leading to the adoption of online monitoring tools on a wider scale. As a result, APM is getting cheaper and easier to perform. That's good news for organizations, but it's important to remember that these monitoring tools don't take care of strategy.

ASM sits alongside APM to make sure that routine maintenance strategies and whole life asset strategies are best in class and aligned to the performance requirements of the plant. ASM uses a consolidated base of reliability master data that is deployed and connected across the entire asset base. Any updates to strategy follow a process to ensure that the change is effective (data-driven, where applicable) and the workflow is reviewed, approved and implemented. This may result, where applicable, in a single site-based change driving the update of the corporate reliability master data and the resulting change being deployed automatically across an entire asset base.

ASM also can help identify where it is cost-effective and practical to implement monitoring or APM. Hence, along with work management, you have a closed loop for reliability and maintenance.

Where Do You Start?

Most organizations already have a work management process in place. Ideally, this process has been refined to ensure that assets are maintained and repaired quickly to minimize downtime.

“Organizations typically see an immediate uplift in performance and reduction in costs upon implementing ASM”

However, if you’re serious about asset maintenance, then your next step is to implement an ASM plan. It’s the most effective way to deliver improvements, reduce costs and improve your existing work management processes.

Why? Because any reliability process must start with a strategy aligned to your performance goals. This strategy must be best in class and continually managed. It can’t be changed ad hoc without review and approval. By the same token, if effective local strategy changes are made, it is a waste not to electronically distribute that change to all relevant instances of that asset.

Implementing an ASM process puts the organization back in control of asset management and will continually drive the execution of best in class strategies across the entire asset base.

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***Jason Apps** is the CEO of ARMS Reliability. He has over 20 years’ experience in Reliability and Maintenance Engineering. ARMS Reliability is a leading global provider of asset management solutions to some of the world’s largest resource, power and utility companies.*
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Aci
asset condition information

HOW CUSHMAN & WAKEFIELD SERVICES IS LEADING ITS CUSTOMERS INTO THE

FUTURE OF RELIABILITY

Abhinav Khushraj

To reduce unplanned downtime for a leading Fortune 500 pharmaceutical client, Cushman & Wakefield (C&W) Services moved from a traditional route based condition monitoring program to a wireless and artificial intelligence (AI) based predictive maintenance (PdM) program. The shift in technology not only led to reduced unplanned downtime, but also a better utilization of resources and a deeper understanding of asset condition. Here's how C&W Services approached the challenges and arrived at solutions.

Background

C&W Services is an integrated facilities services and management company that serves more than 600 clients through the maintenance of more than 600 million square feet across North America. It transforms clients' maintenance practices from reactive to predictive.

One of its clients, a large pharmaceutical Fortune 500 company, had over 350 critical assets, including air handling units (AHU), chillers, exhaust fans, and compressors, spread across 40 buildings. C&W Services was using a manual walk-around program, where a handheld data logger collected data every 30 days and sent it to a third-party for analysis.

Challenges

While the walk-around program seemed promising initially, it had several challenges that made it difficult to achieve the reliability goals of the site. Among them:

1. **Unplanned Downtime:** Infrequent data collection led to failures happening between the monthly walk-around cycles. Even with a well-trained workforce, failures developed quickly and were difficult to catch in time, leading to unplanned downtime.
2. **Limitations of Resources:** Like many facilities, the pharmaceutical company had too many assets for manual data collection to be effective, requiring more people than were available. Readings were often taken by different people, which led to inconsistencies in data collection.
3. **Safety and Accessibility Concerns:** Some areas housing critical machinery posed dangers to the technicians collecting data. There were several assets, such as the AHUs, that were not readily accessible because they were behind metal structures and cages.
4. **Variable Operating Conditions:** The operating parameters of the AHUs were often modified to adapt to external weather conditions. These variable operating conditions led to inaccurate conclusions and an incomplete picture. For instance, different operating conditions made it impossible to trend over time.

All of these factors led to a catastrophic failure of a 200 hp AHU at the research facility. In addition to downtime, the pharmaceutical company incurred $30,000 in repair costs alone.

> "…**A catastrophic failure** of a 200 hp AHU…the pharmaceutical company incurred **$30,000 in repair costs alone"**

Goals

The catastrophic failure of the AHU and limitations posed by the walk-around program prompted C&W Services to evaluate wireless PdM solutions available on the market. Its team of reliability engineers set forth the following criteria:

1. **Continuous Monitoring of Critical Assets:** This allowed for more frequent data collection to avoid machine failures arising between data collection cycles. The team was looking for technology that would automate this and eliminate challenges around variable operating conditions, consistency of readings and manpower shortages.
2. **Access to Real-Time Data Insights:** With the advent of Industrial Internet of Things (IIoT) and machine learning capabilities, the team was looking for a system to help with anomaly detection capabilities and access to real-time data insights and diagnostics.
3. **Safety and Productivity of Personnel:** To eliminate hazards associated with a walk-around process and to reallocate manual labor to more productive activities, the team wanted to use wireless sensors for data collection.
4. **Ease of Installation:** It was necessary for the PdM system to be easy to deploy and quick to implement without the expense of wiring traditional sensors to equipment or undertaking any custom information technology (IT) projects.

The Solution

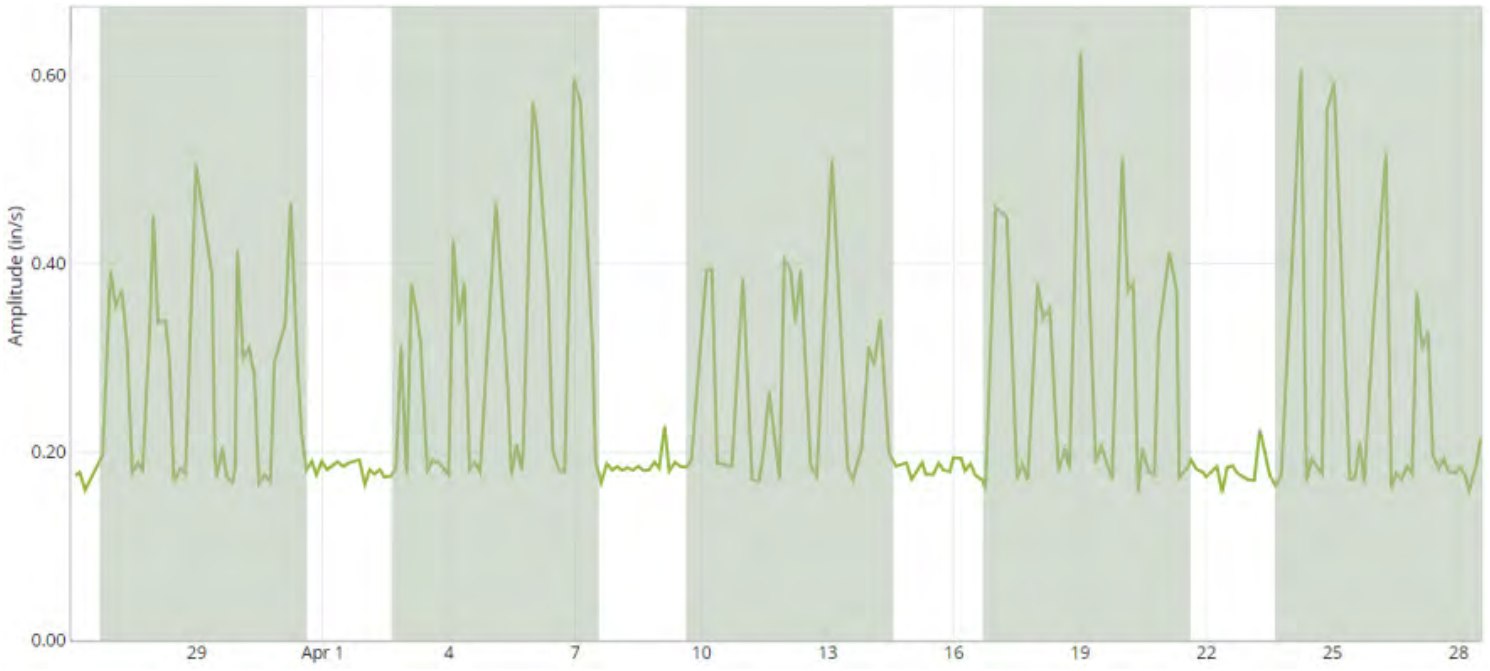
After a thorough evaluation, C&W Services selected Petasense, an IIoT predictive maintenance start-up to provide an Asset Reliability and Optimization (ARO) system to help monitor, analyze and predict the health of critical industrial equipment. The system includes wireless sensors, machine learning based analytics and Web and mobile dashboards.

Vibration Motes

Wireless, battery-powered triaxial vibration sensors called motes were mounted on all critical rotating machinery, including AHUs, pumps, compressors, exhaust fans and chillers, to continuously monitor their health. These motes detect defects, like machine imbalance, shaft misalignment, structural looseness, pump cavitation and bearing wear. They connect wirelessly to the Cloud for advanced predictive analytics.

Predictive Analytics

The implementation included predictive analytics that use machine learning and multi-parametric analysis to make predictions about machine failure. By incorporating multiple parameters, such as temperature, pressure, current and ultrasound, a more robust prediction can be made. The IIoT predictive maintenance system provided a machine health score for each machine based on deviations from a multidimensional baseline, providing



real-time notifications when the score fell below an acceptable number. This enabled C&W Services to quickly identify problem equipment.

Web and Mobile Dashboards

The ARO system is accessible anytime, anywhere, through a Web or mobile app dashboard. It provides a role-based interface that is customized according to the role. For example, managers are shown only the most essential information, while engineers and analysts get highly interactive charts and rich analysis tools.

> "By implementing wireless PdM on the pharmaceutical company's critical equipment…achieve the goals of increased reliability, reduced failures and ensuring personnel safety"

Benefits

The benefits were evident soon after installation. C&W Services was able to catch a defect in an AHU that showed high vibration harmonics. An investigation determined looseness in the belts and shaft misalignment. The AHU was shut down and repaired without any unplanned downtime at a much lower cost than if it had failed.

On another AHU, the weekly vibration level was trending up, but when looking at real-time data in parallel with operational data, it was evident the cycling was due to normal workweek variations. C&W Services would not have been able to discover this with periodic readings, nor would it be able to derive a deeper understanding of asset operation cycles and the impact on maintenance.

By implementing wireless PdM on the pharmaceutical company's critical equipment, C&W Services was able to achieve the goals of increased reliability, reduced failures and ensuring personnel safety. Its team was better equipped to catch defects with real-time, actionable intelligence. This resulted in a substantial cost reduction associated with unnecessary reactive maintenance.

Another huge value driver was the ease of installation and implementation. According to David Auton, senior director of reliability engineering at C&W Services, "Any facility operator can easily deploy PdM, use it effectively, conduct waveform and data analysis, and derive meaningful insights without any formal training."

Conclusion

The AI-based predictive maintenance implementation helped C&W Services streamline data collection, improve uptime and reduce maintenance costs for a very important pharmaceutical client.

Predictive maintenance is currently one of the biggest uses for IIoT. With advances in wireless connectivity, cloud computing and artificial intelligence, along with lower sensor costs, there is a shift toward wireless condition monitoring. Facility managers have used traditional condition monitoring for decades, but are starting to recognize the benefits of applying wireless technology to bring more value to their clients.

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www.petasense.com

Mro
mro-spares management

IS YOUR MRO SPARE PARTS Improvement Program ISO55000 Compliant?

David Thompson

Under ISO55000, a company must demonstrate that it is managing its assets from project phase to end of life. However, at many companies, the creation of maintenance, repair and operating (MRO) spare parts master data is typically done very badly at the project phase and continues into the asset ownership phase. But, by developing an ISO55000 improvement program, companies can realize significant savings.

The ISO55000 asset management standard states that for assets, in particular spare parts, a company must:

- Demonstrate it is managing its data (e.g., cataloging, issue, returns, receipts, etc.);
- Have procedures in place (e.g., cataloging, initial spares purchasing, inventory management);
- Demonstrate risk-based decisions;
- Demonstrate continuous improvement.

Audits show that companies in almost every industrial sector have an ineffective MRO spare parts master data. to duplicate stock, loss of time trying to find spare parts, emergency purchases and excess stocking. The end result is excess costs.

Depending on how bad a company's MRO spare parts master data currently is, there is a potential for significant savings by developing an inventory reduction process. One such inventory reduction process is based on the following phases:

- Audit;
- Define Processes and Guides;
- Cleanse;
- Rationalize;
- Optimize;
- Measure Effectiveness.

PHASE 1: AUDIT

The first step for any inventory improvement program is understanding the company's issues. The scope of a complete inventory management audit should cover these areas:

- **MRO Best Practices** – A structured questionnaire is used to evaluate best practices in managing spare parts effectively;
- **MRO Written Procedures and Guides** – The documents developed to cover each phase of an item's life;
- **MRO Master Data Review** – Review of inconsistencies in short description that includes manufacturer and vendor part numbers and names, review of duplicates, etc.;
- **MRO Inventory Replenishment Control Parameters** – An evaluation of current reorder point (ROP), operational qualification (OQ), minimum-maximum, appropriate strategy used to replenish, etc.

The main focus for this article is activities related to spare parts master data.

A company's inventory data is mapped and imported to an auditor tool containing filters and queries to facilitate the master data review. A report details the findings, good and bad. Remember, poor cataloging represents potential savings.

Typical findings of MRO master data audits are:

- Short descriptions have inconsistent formatting;
- Qualifiers or modifiers are not identified;
- Manufacturers' names included in the short description for generic material;
- Lack of attribute data in the short description or inconsistent sequencing of the attribute data;

Short Description	Noun	Modifier
BUSHING,0126730281,KRONES INC	BUSHING	GENERAL
BUSHING,0900442761,KRONES INC	BUSHING	GENERAL
BUSHING,DRIVE,2012X1316KW,FENNER	BUSHING	DRIVE
BUSHING,0900989662,KRONES INC	BUSHING	GENERAL
BUSHING,00000001138,SIDEL	BUSHING	GENERAL
BUSHING,240568483,SIDEL	BUSHING	GENERAL
BUSHING,00000001846,SIDEL	BUSHING	GENERAL
BUSHING,0126738340,KRONES INC	BUSHING	GENERAL
BUSHING,0129900001,KRONES INC	BUSHING	GENERAL
BUSHING,0129900019,KRONES INC	BUSHING	GENERAL
BUSHING,0129900019,KRONES INC	BUSHING	GENERAL

Figure 1: Excess use of modifier general

Id	O-Ring Materials
1	BUNA-N
2	BUNA-N (NBR)
3	ELASTOMER/RUBBER
4	EPDM
5	EPDM DIS
6	EPDM PEROXIDE

Figure 2: Extract unique list of O-ring material

- Manufacturer part numbers (MPNs) have inconsistent formatting and often contain a mix of both vendors' and manufacturers' part numbers;
- Between 10 to 15 percent duplicate line items;
- Abbreviations are not used when they should be or they are inconsistent;
- Multiple suppliers for similar material;
- Standardized part names are not always used to name parts.

Figures 1 and 2 are two typical examples of poor cleansing delivered by a consultancy company.

Figure 1 shows that even after cleansing, one is unable to identify the type of bush and its size.

Figure 2 is an extract from the O-ring bearing material identified. There is no standardization of the material, resulting in 39 different variations.

PHASE 2: DEFINE PROCESSES AND GUIDES

ISO55000 states that a high-level strategic plan, known as a strategic asset management plan (SAMP), needs to be developed. The structure of the SAMP varies between consultants and the various maintenance associations. This is because ISO55000 is not prescriptive. For this article, the SAMP includes two elements relative to MRO spare parts:

- Initial MRO Spare Parts Planning (Project phase);
- MRO Spare Parts Management (Ownership phase).

> Remember, under ISO55000, you must demonstrate the management of data…

BUSHING TYPE GUIDE		
No	**Noun, Qualifier**	**Image**
1	**Bush, Plain Sleeve**	
2	**Bush, Flanged Sleeve**	
3	**Bush, Taper Lock**	
4	**Bush, Sure Grip**	
5	**Bush, Split Sleeved.**	
6	**BUSH, LOCKING. FLGE CLASSIC**	
7	**BUSH, LOCKING. FLGE EXPRESS**	
8	**Oilite & Glacier???** **Composite**	

Figure 3: Shaft bush type guide

Part Description	New Part Description
BEARING SELF ALIGNING 1212EKTN9/C3 SKF	BEARING, BALL. DRAC 60x110mm 1212 EKTN9/C3
BEARING SELF ALIGNING 1212ETN9 SKF	BEARING, BALL. DRAC 60x110mm 1212 ETN9
BEARING SELF ALIGNING 1212TV FAG	BEARING, BALL. DRSA 60x110mm 1212-TV
BEARING SELF ALIGNING 1213EKTN9/C3 SKF	BEARING, BALL. DRAC 65x120mm 1213 EKTN9/C3
BEARING SELF ALIGNING 1220K/C3 SKF	BEARING, BALL. DRAC 100x180mm 1220 K/C3
BEARING SELF ALIGNING 1310ETN9 SKF	BEARING, BALL. DRAC 50x110mm 1310 ETN9
BEARING SELF ALIGNING 1310-TVH FAG	BEARING, BALL. DRSA 50x110mm 1310-TVH
BEARING SELF ALIGNING 1312EKTN9 SKF	BEARING, BALL. DRAC 55x130mm 1312 EKTN9
BEARING TAPER ROLLER 15100S-15250X	BEARING, ROLLER. TPRD 1x2.5" 15100S-15250X

Figure 4: Before and after cleansing part descriptions

The main reason for poor cataloging is that the cataloging process is not documented in the project phase, which includes the computerized maintenance management system (CMMS) population.

Often, with cataloging by consultant or engineering contractors, the cataloging or the cleansing has been poor. Unless you document all the rules and build criteria, the cataloging will include inconsistencies.

Remember, under ISO55000, you must demonstrate the management of data and that means how the data is populated in the CMMS consistently.

Documentation can include:

- Guides and rules agreed and used during the cleansing;
- A list of all abbreviations;
- Type guides to cover the type of spares stocked and the agreed naming convention.

Figure 3 shows a typical type guide for shaft bushes.

PHASE 3: CLEANSE

The scope of cleansing the master data varies from company to company and is CMMS dependant. For example, users of one software solution may be able to describe their spare parts using up to 75 characters, while users of another are limited to 40 characters. This means users limited to fewer characters must use many more abbreviations to describe a spare part.

A tool for creating business applications may be an ideal solution when developed with standardized part descriptions and standardized template descriptions.

Another reason for duplicate line items is that manufacturers and vendors use different naming conventions. For example, to express a stainless steel part, they might use A2, 304, or SS. Any specification differences can make identifying duplicates difficult. Therefore, Phase 2 is essential. You must clearly identify your naming and specification standards.

Benefits of cleansed master data are the identification of potential duplicates, ease of finding spares, identification of standardization and rationalization opportunities, and inventory reduction.

Figure 4 shows a comparison of current part descriptions and the cleansed descriptions.

PHASE 4: RATIONALIZE

Rationalization is about reviewing your material and seeking inventory or cost reduction opportunities. Companies that have proceeded to the cleansing and rationalization phases have achieved a 60 to 70 percent reduction in line items for some material by:

- Standardizing part descriptions and MPNs;
- Removing duplicates;
- Standardizing material specification;
- Reducing the number of manufacturers;
- Removing stock that is not fit for purpose (i.e., wrong specification).

Rationalization covers several tactics, including:

- Assigning classifications for ABC, HML and XYZ approaches and demand classes;
- Identifying original parts manufacturers (OPMs) and advanced parts manufacturers (APMs);
- Standardization and reducing the number of manufacturers stocked;
- Reducing stocking locations;
- Conducting root cause analysis (RCA) for A items;
- Conducting spend analysis.

Id	Noun	AIV	RT	TS	%_Effect	% Element	ABC
1	Bearings	6800	6800	29945	0.23	4	A
2	Connectors	4500	11300	29945	0.38	8	A
3	Shaft	4200	15500	29945	0.52	12	A
4	Bolt	3520	19020	29945	0.64	16	A
5	Screw	3120	22140	29945	0.74	20	A
6	Bush	2120	24260	29945	0.81	24	A
7	Pipe	1500	25760	29945	0.86	28	B

Figure 5: Assigning ABC to a data set

New Noun	No of Mfgs
BEARING	31
VALVE	27
SWITCH	24
FILTER	16
SENSOR	16
LAMP	15
RELAY	14
CONNECTOR	13

Figure 6: Shows 31 manufacturers of bearings

Noun	Mfg	Count
BEARING	SKF	81
BEARING	RHP	25
BEARING	INA	22
BEARING	FAG	21
BEARING	COOPER	10
BEARING	NSK	9
BEARING	HEPCO	6

Figure 7: Number of line items by bearing manufacturer

Figure 5 shows what a query looks like after assigning ABC to a data set based on annual issue value (AIV).

Figures 6 and 7 show an analysis of manufacturers' parts stocked and forms the basis for a rationalization study.

Further cost savings are likely by proceeding to Phase 5, MRO optimization.

PHASE 5: OPTIMIZE

Optimization supports ISO55000 by making decisions based on risk. A stock out risk is set for each spare part based on the item's criticality. Opportunities for reducing inventory are identified by determining the optimum ROP and OQ and then the most appropriate replenishment strategy.

Optimum ROPs and stocking levels are determined by:

- Assigning a service level to each spare part based on its criticality;
- Identifying the true lead time that includes company plus supplier;
- Determining the average demand rate;
- Calculating existing and optimum metrics;
- Identifying reduction opportunities;
- Challenging the stocking of slow moving parts.

The three main replenishment strategies are:

- ROP: a fixed ROP and OQ;
- Min-max: a variable OQ to bring the stock level to a maximum;
- Constant vendor delivery: based on just-in-time (JIT) concepts.

Potential cost savings can be identified by looking for them. Prioritization is based on the differential financial value between the current average stock level and optimum average stock level.

Figure 8 is from a case study where the optimum values are not appropriate. The options, then, are to either: (a) increase one or more control parameters, for example OQ, so they are not the optimum values or (b) move to a different replenishment strategy.

In this example, the first option (a) was considered the most suitable choice. Figure 8 shows current performance, the optimized performance and the proposed performance. The proposed performance delivers 44 percent

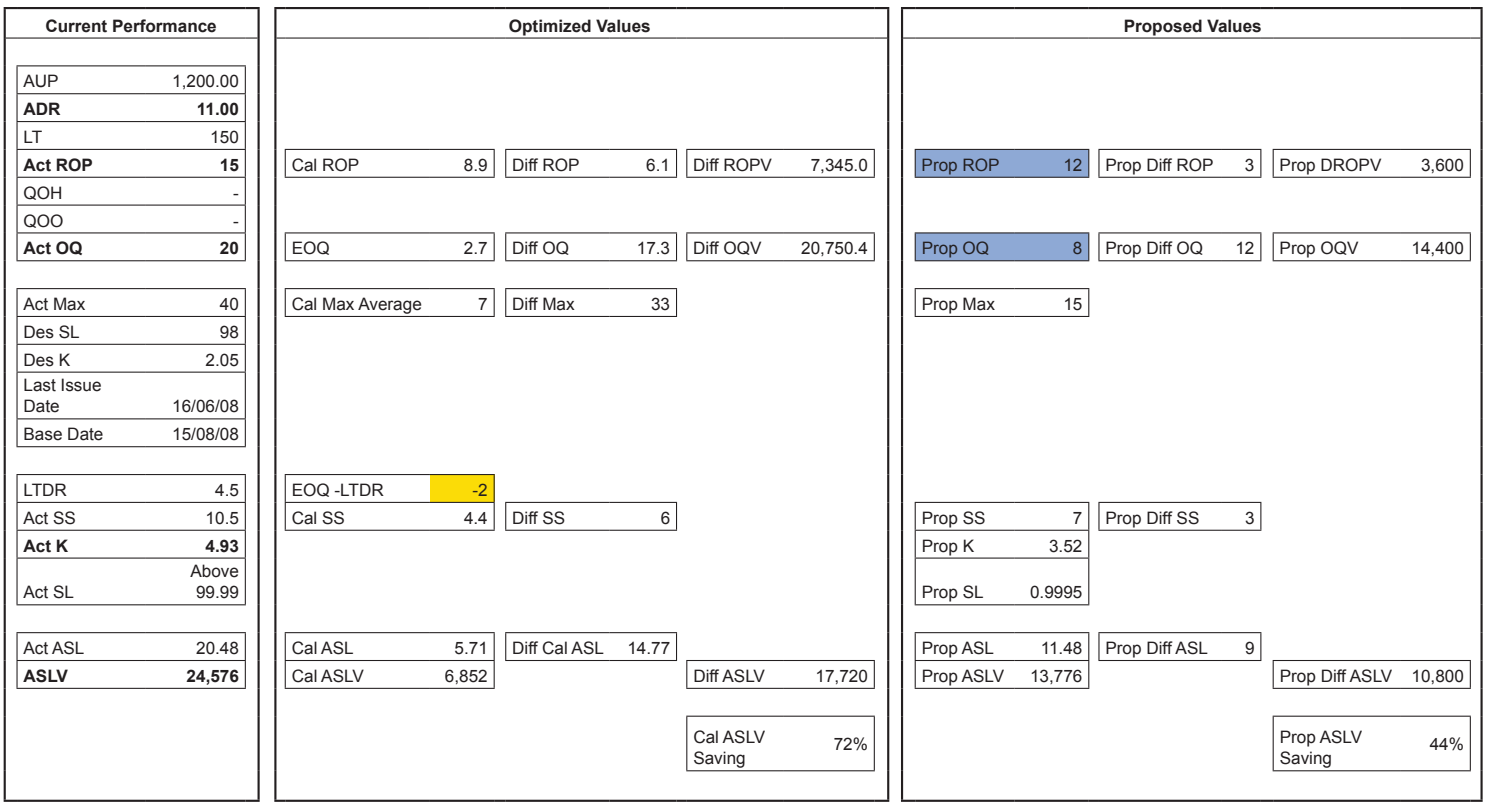


Figure 8: Optimization analysis

savings. If the company was to implement the optimized parameters, it would introduce a higher risk of a stock out.

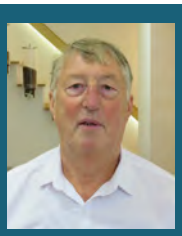
PHASE 6: MEASURE EFFECTIVENESS

This phase would include activities such as:

- Reporting performance using key performance indicators (KPIs);
- Monitoring usage in line with predictions;
- Monitoring stock balance and taking action— the balance is always above safety stock or there are stockouts;
- Conduct spend analysis.

Summary

A structured approach to inventory reduction can deliver significant results and help companies make their MRO spare parts program ISO55000 compliant.



David Thompson *has over 50 years of experience in maintenance, reliability and spare parts management. David's experience is in several industries, including steel, mining, utilities, general manufacturing, food & beverage, and oil & gas, which has expanded into over 36 countries. www.ramsoftuk.com*

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Opx
operational excellence

Critical Factors to Achieve World-Class Manufacturing Reliability

Dale Emanuel and Jorge Mastellari

The benefits of maintaining a facility with world-class reliability are enormous and should not be underestimated. Major advantages associated with excellent reliability are higher utilization of the asset, lower maintenance costs, fewer overall people required to run the facility, better safety performance and better energy efficiency.

What World-Class Means

Many perceive world-class reliability performance as a panacea, as plant operations always seem to be in flux with other priorities getting in the way or integrated asset upgrade plans suffer significant delays at manufacturing facilities.

Becoming top quartile, U.S. best, or world-class is not just about a robust capital investment program. It requires a relentless commitment to maintenance and asset care excellence. First and foremost, a fully engaged plant requires matrix participation from engineering, design, operations, maintenance and the reliability leadership team. This allows for complete utilization of the asset by maintaining close to maximum capacity. It also keeps maintenance costs consistent, sustainable and, generally, better than the average.

Figure 1: Problem-solving meeting with a reliability action team using a visual tracking board

Critical Factors

Maintenance organizations in world-class facilities are always focused on preventive and predictive activities instead of high priority break-in type work.

Maintenance organizations within reliable facilities are very good at planning and scheduling activities because they are not continually fighting equipment failures. Programs around precision maintenance and equipment specific care plans tend to have excellent results. A crucial and direct side effect of world-class reliability is a consistent safety track record. Additionally, when a facility is reliable, it requires much less energy to operate because it is always in a stable state, avoiding continuous shutdowns and rate cut situations that impact the uninterrupted functioning of the asset.

> Employees need results-driven, consistent leadership to make lasting operational changes

A number of requirements must be met before a facility can become world-class. The four critical ones are:

1. A results-driven, high-energy and consistent management team

Employees need results-driven, consistent leadership to make lasting operational changes. When the management team is changing frequently, it is a sign that the facility is not a candidate for exceptional reliability. A facility needs a management team that is high-energy, focused and, most of all, visible to the workforce – these are by far the most effective. The management team should be committed to daily performance discussions with frontline teams. The more visual the communication, the better. For example, the leader standard work routine, which uses a visual board to formalize weekly maintenance walks, has proved successful in creating discussions about better pump care and overall root cause analysis.

2. A reliability culture in place from the top of the organization to the bottom

A reliability culture starts with facilitating the right forums. These forums discuss key topics, such as reliability imperatives, training and engaging in daily problem-solving. Each member of the reliability leadership team has to take an active role in following this script, spreading the reliability message and clearly assigning the reliability-centric roles, responsibilities and expectations. Until this reliability culture is in place, not even the most advanced and expensive reliability tools will be helpful. A reliability culture is where reliability is everyone's responsibility and all decisions are made with reliability as a key consideration. For example, consider how a true safety culture works within a manufacturing facility. Safety becomes everyone's responsibility, where all decisions involve a safety review. From the top of the organization to the bottom, everyone is focused on safety. The same holds true with reliability. Everyone in the organization must become personally responsible for reliability and all decisions should include a reliability review. Reliability culture is the most elusive, yet most important pillar for achieving world-class reliability. This pillar is why most manufacturing facilities fall short.

3. A playbook for reliability and maintenance programs

Only after a strong management team and a reliability culture are in place can established and efficient reliability and maintenance programs be put into place. A playbook to deploy the reliability program is a must. This playbook is not a thick book full of step-by-step procedures, but rather an easy to follow, visual manual that allows every member of the reliability team to understand both the short- and long-term plays. This helps drive preventive maintenance, predictive maintenance, root cause failure analysis and key performance indicators, tracks action items and provides leadership for continuous improvement.

Figure 2: Daily maintenance department accountability meeting using visual metrics board

4. Utilization of digitization and Internet of Things (IoT) tools

Top quartile teams are starting to integrate digitization and IoT tools, such as sensors, radio-frequency identification (RFID), enhanced reality, geolocation and operator mobility tools, to improve reliability programs. While many organizations are in the initial piloting phase, several large operators have started company-wide programs to utilize digitization tools that go from equipment monitoring to proximity analysis for scheduling efficiency. For example, by using enhanced reality with mobility platforms, technicians and maintenance crews are able to execute more accurate and comprehensive repairs and overhauls of pumps, turbines and valves as part of their daily reliability routines.

For a reliability program to advance into a next generation phase, realistically, one must have all these components in place. Never underestimate the importance of having good tools and systems to manage and drive better performance. More importantly, never underestimate the need to have a reliability culture in place to make sure the tools are used to their highest potential.

Dale Emanuel *is an experienced executive with more than 40 years of experience in the refining and petrochemical industries throughout the US, Europe, Middle East and Asia. At the end of 2016, Dale retired as the CEO and President of a worldwide energy consulting firm, HSB Solomon Associates.*

Jorge Mastellari, *Sr. Vice President, coleads Argo's Private Equity practice. He manages projects with major international corporations in the USA, Europe, Canada, and Latin America. Jorge's consulting experience includes projects in the medical equipment, manufacturing, transportation and logistics, consumer products, and paper and packaging sectors. www.argoconsulting.com*

2019

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LEADERSHIP DEVELOPMENT PLAN

World-class organizations recognize that success is achieved through leadership; however, they also realize that results are only delivered through engagement and empowerment of everyone in the workforce. Leadership does not come from one person; it comes from everyone. This is especially true for reliability.

CONFERENCES

May 6-10, Seattle, WA

The RELIABILITY Conference™

Co-located with Maintenance 4.0 Digitalization Forum, TRC is designed for those who lead, manage and contribute to a reliability and asset management program. Reliability leaders, asset condition management experts, asset and maintenance managers will deliver information you can put to use immediately.

August 6-8, Orlando, FL

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MaximoWorld includes a diverse ecosystem of business thought leaders, asset management experts, implementation service providers, digital pioneers, data scientists, support teams, analysts and mobility specialists with one common connection: IBM® Maximo® and Enterprise Asset Management. Discover new ideas and approaches for your asset management or IoT journey.

December 9-12, Marco Island, FL

IMC The International Maintenance Conference

IMC is acknowledged as the leading maintenance, reliability and asset management conference in the world. Experience a community of practice and knowledge that is moving beyond "why reliability?" towards effective actions that align to the business process.

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TRAINING

To advance reliability and asset management further through competency-based learning, the **Reliability Leadership Institute® (Fort Myers, FL)** also offers other powerful learning experiences:

LER

Models for Operational Excellence

March 12-14, October 8-10

Presented by Ron Moore, Author of *Making Common Sense Common Practice* and *What Tool? When? A Management Guide,* and Terrence O'Hanlon, Reliabilityweb.com and Uptime Magazine

REM

Reliability Strategy Development

June 4-6

Presented by Jason Ballentine, ARMS Reliability and Terrence O'Hanlon, Reliabilityweb.com and Uptime Magazine

REM

Cause Mapping for Problem Solving and Root Cause Analysis

February 26-28, November 5-7

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AM

10 Rights of Asset Management

April 23-25

Presented by Ramesh Gulati and Terrence O'Hanlon, Co-authors of *10 Rights of Asset Management*, with added feature: **Asset Management for Executives**

ACM

Transformer Management Essentials

January 14-17

Presented by Chuck Baker, SD Myers with one-day feature: **Asset Management and Reliability Leadership** by Terrence O'Hanlon, Reliabilityweb.com and Uptime Magazine

ACM

Lubrication Elements MLT Training and Certification Course

March 5-7, October 22-24

Presented by Mark Barnes, Des-Case

WEM

Certified Maintenance Manager (CMM)

April 9-12, August 20-23

Based in Uptime Elements Work Execution Management (WEM) domain to gain updated skills in managing preventive maintenance, planning & scheduling, CMMS/EAM, MRO spare parts, operator driven reliability and defect elimination.

Dates and locations subject to change.

AM

Q&A

BRANDY AVERY, CRL

Sr. Director • IFM Deployment Transitions and Corrigo Migrations

With over 20 years of IFM, Project, and Global Program Management experience, Brandy leads the IFM Deployment team, which is responsible for coordinating major transitions for new and expanded real estate portfolios for North American and global clients in JLL's Corporate Solutions business. Her team has transitioned more than 40,000 sites for clients totaling over 400 million square feet.

Brandy provides leadership, ensuring client requirements are understood and delivered with JLL best practices. She has a passion for process and standards, contributing to the IFM QMS and ISO9001:2015 Quality certification, and ensuring her team applies them with rigor.

Q. Can you explain the concept of integrated facility management (IFM)?

By definition, integrated facility management is the integrated management of multiple and interdisciplinary technologies, personnel, systems and processes. The goal behind facility management (FM) is to promote a safe, efficient and collaborative environment to meet and fulfill the key objectives and mission of an organization. Historically, this has meant that our work was primarily focused on the buildings themselves. In today's world, as owners and occupiers see the strategic value facilities can bring to their guests and employees, the scope has expanded to not only include the facility, but the end user experience as well.

Q. How does reliability and asset management relate to IFM?

This fits the JLL IFM model encompassing buildings and asset management (hard services) and workplace and people (soft services). It also relates to ISO55001 asset management and ISO41001 facility management and how these standards can work together and not compete with each other. ISO55001 defines an asset as "anything that brings value to an organization" and is obviously very broad. ISO41001, while narrowing in on facility assets, is broader when it comes to adding soft service delivery.

I view asset management as a very critical element of FM. When it comes to reliability, the experts in asset management will say there is a

big difference between "managing assets" and "asset management," with the latter being more strategic and focused on delivering the expected outcomes. Reliability and asset management enable the FM mission by providing safe, secure, reliable, healthy and productive places to learn, live, work and play.

Q. How does leadership play a role in the effectiveness of IFM, that is, leadership from both the client and JLL?

Leadership is crucial to the effectiveness of IFM. In today's work, IFM programs are often tied to some of our clients' most strategic goals, specifically ones around talent attraction and retention. The most successful relationships are built on trust. Given the pace of change, we need to be able to move quickly to adapt to new situations with ease, together. A strong partnership at the leadership level paves the way for strong teams across the organization.

It is so important that leadership be aligned with clients on how existing IFM agreements support their core objectives (i.e., the AIM). It is equally important that our employees understand why the work they do is so critical to achieving that AIM. The more they buy into the "why," the more successful the outcomes.

Q. How are artificial intelligence (AI) and the Internet of Things (IoT) being applied to IFM?

Global IoT surveys reveal that FM professionals are most aware of the potential of the Internet of Things in relation to building automation, energy management, maintenance, security and physical access, and safety. Since IoT technologies are creating access to vast amounts of real-time data that connected devices generate, IFM teams have more information to make better workplace decisions.

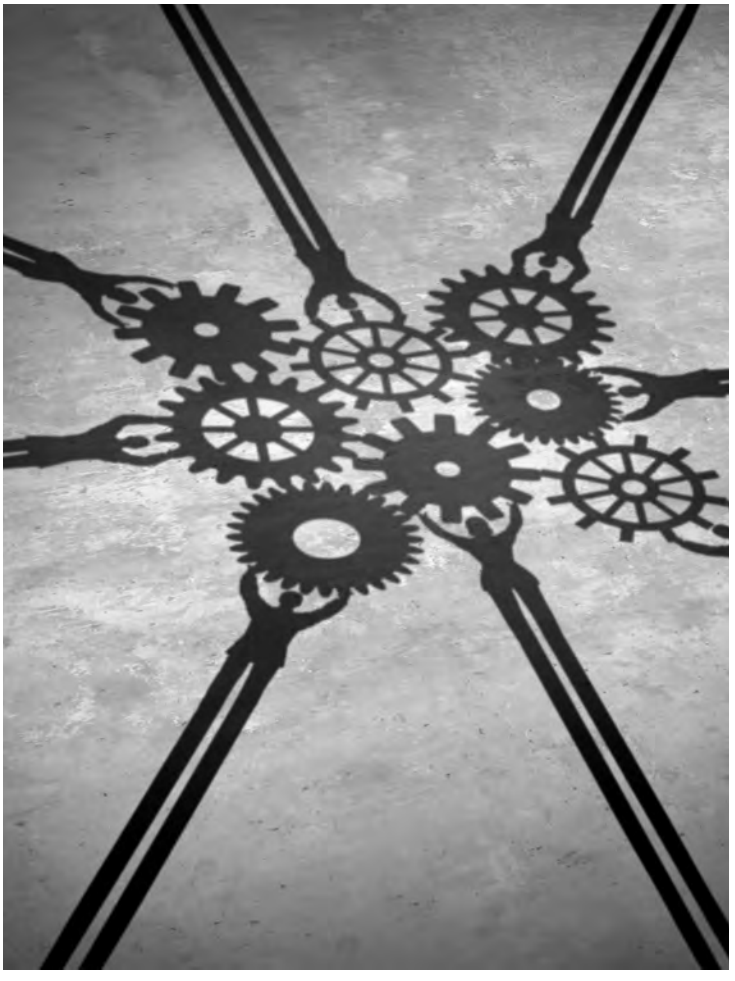
While FMs intuitively understand the benefits of reduced maintenance costs and energy savings, there is additional opportunity to expand the IFM focus beyond buildings and assets to encompass the people inside, leveraging AI and IoT to improve the human experience in the workplace. For example, the ability to use data from an intelligent lighting system can show how many, how often and how long employees are using particular work spaces, providing valuable insights for space planning and workplace strategy. The IoT can also power workplace tools and amenities. Digital signage, wayfinding tools, wireless audio/visual systems and other connected devices can go a long way toward creating a more engaging and empowering experience for employees and helping end users feel engaged and fulfilled at work and, ultimately, happier and more productive.

Q. Where do you see IFM in five years?

I believe there will be a continued focus on the human experience and there is no doubt that owners will continue to invest in building automation, AI and IoT. While there will still be a mix of old and new technology, I expect that client expectations will be higher and it will be critical that FMs use the data collected to improve budgeting, planning and forecasting, and to identify new productivity and cost savings. Having a strategy for collecting, storing and using data will be an important part of IoT activation, planning and operations.

Q. You have over 20 years of experience in IFM. When you first transitioned into your current role, was there a colleague or mentor you worked with? How did this person prepare you?

In my current role as IFM director of deployment, the transition to JLL was one of the first and most critical client experiences. Joy Naseath, senior director, IFM operational excellence, has been a strong mentor and role model. Joy's approach to everything is client first and empowering and supporting others to succeed for the benefit of JLL and its clients. I have known Joy for many years, from many accounts and, most recently, as part of the IFM service line platform. With each account, she has won over the most challenging of clients with her transparency and ability to bring vision and measurable outcomes to the table. Those around her experience her innate ability to pull people together and create a wave of energy



to solve problems or improve service delivery processes and measurements for our accounts. She has been a huge source of support through the transformation of the IFM deployment team, first by pursuing the creation of baseline processes and tools that did not previously exist, then promoting collaboration, consistent delivery and empowering the team to own the deliverables for each transition.

Q. Within your organization, is there an individual that you would consider a leader? Why? What qualities does this person possess?

Maureen Ehrenberg, FRICS, CRE, and president of global integrated facilities management at JLL, is a visionary at the forefront of change in the industry. It is her vision and passion that inspires me to want to make a difference for our clients and how we deliver service.

Q. What has been the biggest challenge you have faced in recent years?

The pace of change. While we tend to think on a linear scale, technology continues to drive change at an exponential rate. This may require business processes to evolve quickly, requiring more focus on strategy and collaboration instead of just execution.

Q. What advice do you have for women or the next generation who choose technical careers? Do you have any strategies to share for advancement in this industry?

Stay current on technology advancements in your industry. Don't be afraid to take risks based on facts and data and act early. If you wait until you're 100 percent confident, you may never get anything done. Experiment more, plan less, but understand the risks and have a mitigation plan in place.

Q. What book would you recommend? What is on your reading list?

The Belief Economy: How to Give a Damn, Stop Selling, and Create Buy-In by David Baldwin; *Generations: This History of America's Future, 1584 to 2069* by William Strauss and Neil Howe; and *Beyond the Fads: How Leaders Drive Change with Results* by Ronald N. Ashkenas.

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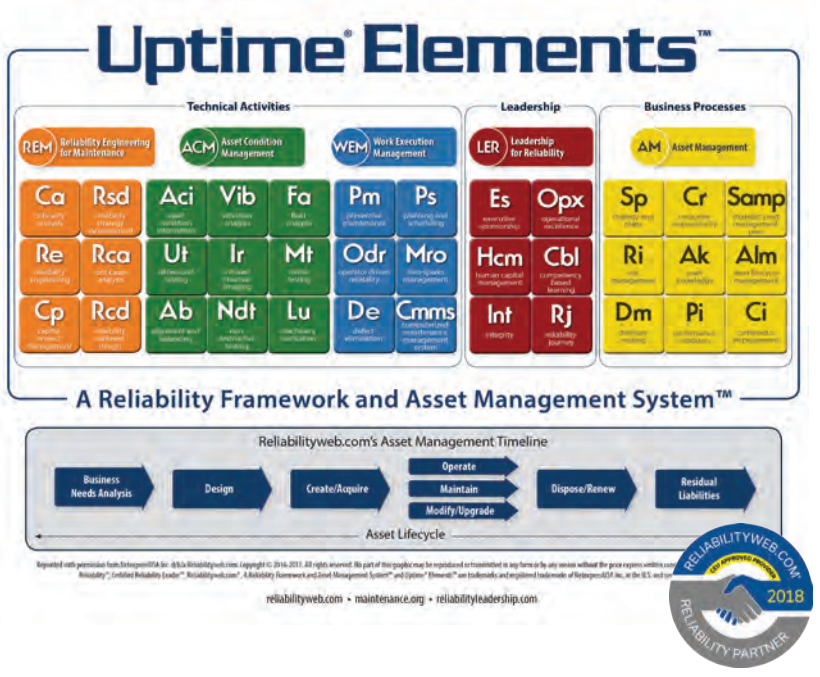

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